Bedrock Geology of the Evitts Creek and Pattersons Creek Quadrangles, Maryland, Pennsylvania, and West Virginia

GEOLOGICAL SURVEY BULLETIN 1173

Prepared partly in cooperation with the Maryland Department of Geology, Mines, and Water Resources

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By WALLACE DE WITT, JR., *and* GEORGE W. COLTON

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A detailed discussion of the stratigraphy and structure of the area, and general descriptions of the geologic history and mineral resources

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

BEDROCK GEOLOGY OF THE EVITTS CREEK AND PATTERSONS CREEK QUADRANGLES, MARYLAND, PENNSYLVANIA, AND WEST VIRGINIA

By WALLACE DE WITT, JR., and GEORGE W. COLTON

ABSTRACT

The Evitts Creek and Pattersons Creek quadrangles occupy about 115 square miles of mountainous western Maryland and contiguous parts of Pennsylvania and West Virginia.

The exposed strata consist of about 8,000 feet of sedimentary rocks ranging in age from Late Ordovician to Late Devonian. The stratigraphic sequence is divided into 21 formations, several of which are subdivided into members. In ascending order the stratigraphic units are: the Juniata Formation of Ordovician age; Tuscarora Quartzite, Rose Hill Formation, Keefer Sandstone, Rochester Shale, McKenzie Formation, Bloomsburg Red Beds, Wills Creek Shale, and Tonoloway Limestone of Silurian age; Keyser Limestone of Silurian and Devonian(?) age; the Helderberg Group (Coeymans Limestone, New Scotland Limestone, and Mandata Formation), Oriskany Group (Shriver Chert and Ridgeley Sandstone), Needmore Shale, Marcellus Shale, Mahantango Formation, Harrell Shale (including the Burket Black Shale Member in the basal part), Woodmont Shale, and Chemung(?) Formation of Devonian age. The hard and resistant formations such as the Juniata Formation, Tuscarora Quartzite, and Ridgeley Sandstone commonly form the large hills and mountains in this region. The soft and easily eroded formations such as the Wills Creek Shale, Needmore Shale, Marcellus Shale, and Harrell Shale generally underlie lowlands and valleys.

The rocks of the Evitts Creek and the Pattersons Creek quadrangles were deposited in a shallow sea, a part of the Appalachian geosyncline, during the middle of the Paleozoic Era. Source areas east of the geosyncline supplied large amounts of mud, silt, and sand during the accumulation of the red beds of the Juniata Formation in the Late Ordovician and during the deposition of the Tuscarora Quartzite, Rose Hill Formation, and Keefer Sandstone during the Early and Middle Silurian. The volume of sand and silt decreased markedly at the close of Keefer time. Calcareous sediments accumulated in the area during much of the Middle and Late Silurian and the Early Devonian. A large and diverse fauna existed in the sea during Rochester time and early McKenzie time when the water was clear and shallow. During the accumulation of the upper part of the McKenzie Formation, the Bloomsburg Red Beds, and the Wills Creek Shale, the environment was unfavorable to many forms of marine life; however ostracodes existed in great numbers. During much of the Late Silurian the sea was smaller than at other times.

A shallow, well-aerated sea and an abundant food supply gave rise to a large fauna which produced the thick bioclastic limestones of the Keyser at the end of the Silurian and the beginning of the Devonian. Uplift of the source areas early in the Devonian began another westward transgression of clastic sediment. Coarse sand became the dominant type of sediment in the shallow sea during Ridgeley time. Despite the large volume of coarse-grained detritus carried into the sea, a large and diverse fauna lived in the shallow water. After the deposition of the Ridgeley Sandstone, a great volume of mud and silt accumulated in the slowly subsiding basin. At times the sea became slightly deeper and its circulation restricted. Black and brownish-black mud rich in organic matter, which accumulated in this euxinic environment, comprises much of the Needmore Shale, Marcellus Shale, and Burket Member of the Harrell Shale. However, throughout much of the Middle and Late Devonian, the shallow open sea sorted and winnowed the sediments into the great thickness of alternating beds of gray mud, silt, and fine sand that upon lithification formed the monotonous sequence of greenish-gray rocks of the Mahantango, Harrell, Woodmont, and Chemung(?) Formations.

The rocks in the Evitts Creek and Pattersons Creek quadrangles were folded and faulted by great compressive forces during the Appalachian orogeny near the end of the Paleozoic Era. Asymmetric anticlinal folds of large size, oversteepened and locally overturned to the northwest, dominate the structure in the northern part of the area. Faulting was also more intense in the northern part of the area where thrust faults offset the harder rocks on the flanks of anticlines and involve thick masses of softer rocks in the synclines. Locally, normal faults crossed some folds. The southern part of the area is dominantly synclinal; the amplitude of the folds decreases, and faulting occurred there on a small scale. A large part of the relative movement of the rocks during folding appears to have been absorbed in the thick sequence of incompetent shaly rocks above the Ridgeley Sandstone where many of the folds become progressively smaller.

Known mineral resources in the Evitts Creek and Pattersons Creek quadrangles are limited mainly to nonmetalliferous deposits, construction materials, and building stone. The quadrangles contain a considerable quantity of limestone. The largest amount of high-calcium rock is in the Keyser Limestone. Some beds of limestone in the Keyser are as much as 90 percent calcium carbonate. Silica in the form of chert nodules is the main contaminant. Some of the best quality Tonoloway Limestone may contain as much as 80 percent calcium carbonate. Silica, alumina, and magnesia are the main contaminants in the Tonoloway. Limestone, siltstone, sandstone, and quartzite are available in quantity for road metal and building stone. In the past, iron ore was mined, mainly from the Roberts ore bed in the Keefer Sandstone. However, the ore bed is too thin and lacks sufficient iron to be exploited economically at present. Although the Ridgeley Sandstone is an important source of glass sand at Berkeley Springs the sand in all the exposures of the Ridgeley examined in the mapped area, has too high a percent of impurities to be prepared for glass sand by existing methods. The Tuscarora Quartzite appears to be the best source of high-purity silica in the area. Only small amounts of clay and shale are available in the two quadrangles for making ceramic ware.

INTRODUCTION

The Evitts Creek and Pattersons Creek quadrangles cover an area of about 115 square miles in mountainous western Maryland and the contiguous parts of Pennsylvania and West Virginia (fig. 1). The

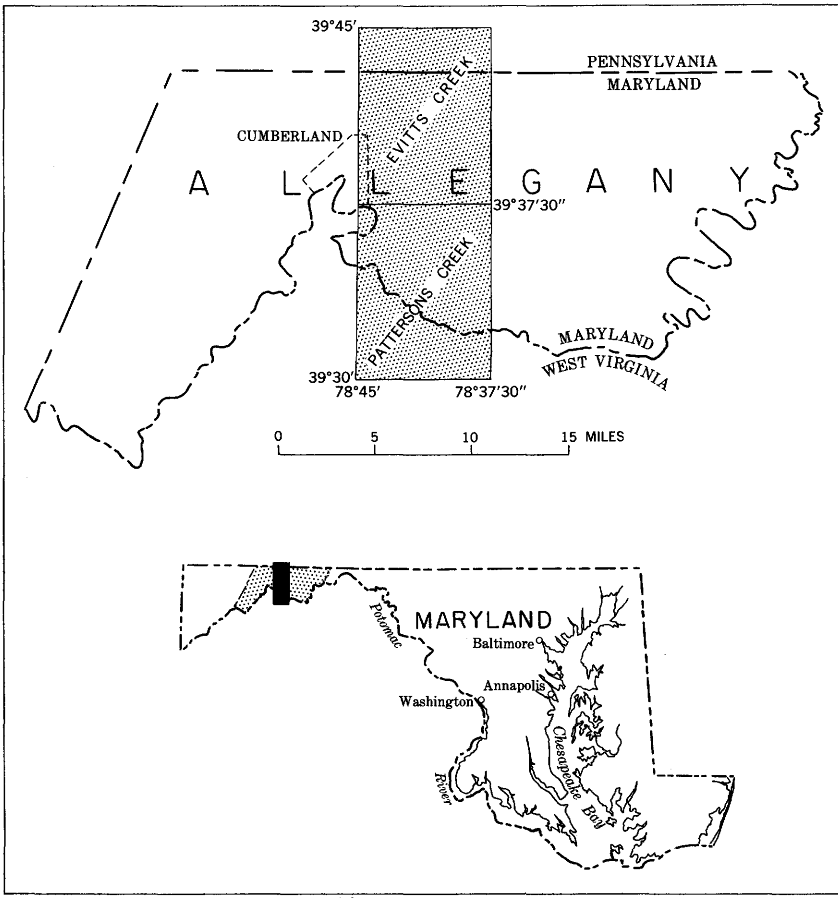

FIGURE 1.—Location of Evitts Creek and Pattersons Creek quadrangles, and Allegany County, Md.

area encompasses about 78 square miles in Allegany County, Md., including part of Cumberland, the county seat; 12 square miles in Bedford County, Pa.; 7 square miles in Hampshire County, W. Va.; and 18 square miles in Mineral County, W. Va.

Detailed reconnaissance mapping of the Evitts Creek quadrangle by H. L. Berryhill, Jr., and of the Pattersons Creek quadrangle by Colton was begun late in the summer of 1954 as part of a cooperative project between the U.S. Geological Survey and the Maryland Department of Geology, Mines, and Water Resources to revise the geologic map of Allegany County, Md. After Berryhill's reassignment the writers returned to the area and continued mapping in greater detail during parts of April and August of 1956 and again in April and October of 1957. Fieldwork consisted of tracing member and formation boundaries, determining the attitude of key beds, and measuring many stratigraphic sections with planetable and telescopic alidade or with steel tape. The elevations of key beds were determined by precise altimetry or by planetable survey. Fossil identifications were made in the field by the writers, unless otherwise stated in the text, and represent only the most abundant and most conspicuous forms at the localities listed.

The quadrangles are covered by a network of Federal, State, and county roads. U.S. Highway 40, the National Road, crosses the Evitts Creek quadrangle in a northeasterly direction from Cumberland, Md., to Martin Mountain, and U.S. Highway 220 from Cumberland, Md., to Bedford, Pa., crosses the western side of the Evitts Creek quadrangle. Uhl Highway, Maryland Highway 51, roughly follows the course of the North Branch of the Potomac River across the Pattersons Creek quadrangle. Many secondary roads, several of which are hard surfaced, give access to much of the area, except some of the higher hills and mountain ridges. The Western Maryland Railway crosses the Pattersons Creek quadrangle along the northern bank of the North Branch of the Potomac River. The main tracks of the Baltimore & Ohio Railway follow approximately the same route along the south bank of the river. Both the Pennsylvania and the Baltimore & Ohio Railroads follow the valley of Wills Creek in the northwestern corner of the Evitts Creek quadrangle. The now-abandoned Chesapeake and Ohio Canal closely follows the North Branch of the Potomac River across the Pattersons Creek quadrangle. Of great economic importance to the region in the last century, the canal has long been outmoded. Today the weed-choked bed, brush-covered tow path, and ruined locks mark the course of this once-busy waterway along the southern boundary of Allegany County.

PREVIOUS INVESTIGATIONS

In 1840 J. T. Ducatel, State Geologist of Maryland, made a reconnaissance study of Allegany County, Md. In his report to the legislature, Ducatel (1841) described the water gap through Wills Mountain at Cumberland and noted that compressive forces seemed to have moved the gray sandstone (Tuscarora Quartzite) into a vertical position at the west end of the gap. A cross section accompanying this report shows some of the rocks along the National Road, now U.S. Highway 40, in the area of the Evitts Creek quadrangle east of Cumberland.

During the 1840's, H. D. Rogers in Pennsylvania and W. B. Rogers in Virginia established the general stratigraphic sequence and named many of the stratigraphic units in the central part of the Appalachians. Although their studies did not deal directly with the area around Cumberland, Md., the principles they formulated greatly advanced the understanding of the geology of this general region and facilitated later investigation in western Maryland.

In 1861, P. T. Tyson, State Agricultural Chemist, prepared the first geologic map of Allegany County, Md., correctly interpreted the anticlinal structure of several large mountains near Cumberland, determined the stratigraphic sequence for the area, and suggested correlations between the rocks of western Maryland and strata in parts of Pennsylvania and New York.

James Hall visited the Cumberland area several times in the middle of the 19th century and collected extensively from the Silurian and Devonian rocks of Allegany County. Studies of the faunas from these rocks enabled Hall (1857, 1861, 1867, 1874) to make regional correlations in much of the Appalachian area.

J. J. Stevenson (1882) mapped the geology of Bedford and Fulton Counties, Pa., including a small strip of Bedford County that is in the northern part of the Evitts Creek quadrangle. Although his report was concerned largely with the mineral resources of the area, Stevenson described the stratigraphy and structure of the two counties in considerable detail; however, adequate base maps were not available, and he was not able to show the geology on a topographic base. Stevenson described and named several large folds in Pennsylvania that were later traced across the contiguous part of Maryland by other geologists.

In a detailed study of the geology of Allegany County, Md., C. C. O'Harra (1900) amplified the stratigraphic succession recognized by Tyson by further subdividing the sequence and by introducing additional formation names. O'Harra's report contains a rather extensive bibliography, but most of the references deal with the coal fields in the western part of the county. O'Harra carefully studied and described the structure of the area, but he did not delineate the axes of folds on his geologic map. In discussing the structure of Allegany County, O'Harra stated (1900, p. 153–154):

> Faulting is rare and the amount of vertical movement is never great. Only the more thinly bedded strata present instances of faulting worthy of note, and none of the observed faults have more than a local extent.

During the early decades of the 20th century, a group of geologists from the Johns Hopkins University under the direction of C. K. Swartz made detailed and thorough studies of the paleontology and stratigraphy of several systems of Paleozoic rocks in western Maryland. Cooperating with the group either in the field or laboratory were R. S. Bassler, J. M. Clarke, E. M. Kindle, E. O. Ulrich, Charles Schuchert, and G. W. Stose.

E. M. Kindle (1912) showed that the Onondaga fauna was present in western Maryland, although the fossils occurred in a soft shale and not in the cherty limestone which is typical of the Onondaga in New York. In 1913, C. K. Swartz (1913a, b) and his associates reported on their study of the Devonian System. Many sections were described in detail; however, the greater contributions from the study were the systematic paleontology of the Devonian formations of western Maryland and the improved correlations of these strata with rocks of similar age in other parts of the country. A planimetric geologic map accompanying the report shows the outcrop of the Devonian rocks in greater detail than on O'Harra's geologic map of Allegany County, but many of the important structural features of Allegany County are not delineated. C. K. Swartz and his associates next studied the Silurian System of Maryland, and in 1923 the Maryland Geological Survey published the results of their study. The greatest contribution from the study was the very detailed systematic paleontology of the Silurian formations of western Maryland. Of special note was the description of the ostracodes by Ulrich and Bassler. This part of the report has become a classic in paleontologic literature. In the report many measured sections were described in great detail, several local names were introduced for parts of the Clinton Group in Maryland, and the Middle and Upper Silurian rocks were thoroughly zoned on the basis of their contained faunas. A planimetric map at a scale of 3 miles per inch accompanied the report. Although the outcrop of the Silurian rocks was carefully delineated, most structural features in the area were not indicated.

D. B. Reger (1924) mapped the geology of Mineral and Grant Counties, W. Va., and 3 years later J. L. Tilton (1927) mapped Hampshire County, W. Va. Parts of Mineral and Hampshire Counties lie in the Pattersons Creek quadrangle. The investigations by Reger and Tilton added to the general knowledge of the stratigraphy and structure of northern West Virginia.

F. M. Swartz (1935) studied in detail the relationship of the faunas in the Rochester Shale and the McKenzie Formation in the area between Cumberland, Md., and Lakemont, Pa. The report shows the difficulty of trying to separate these two units in southern Pennsylvania and western Maryland.

During the 1930's, Bradford Willard (1935a, b, c) in association with F. M. Swartz and A. B. Cleaves (1939) studied and revised the stratigraphy of the Devonian System in the eastern half of Pennsylvania. Their work extended beyond the borders of the state and included the area around Cumberland, Md. They demonstrated that parts of several of the formations of previous workers were temporally equivalent facies in the large Catskill delta and not individually superposed units, as had been previously believed. Willard subdivided several of the existing formations and introduced local names for the new members and formations.

H. P. Woodward reported on his study of the Silurian System of West Virginia in 1941 and on his study of the Devonian System in 1943. These two reports are important because they are syntheses of a great deal of stratigraphic information in a large part of the central Appalachians, including the Cumberland area. The reports are based in large part on the published county reports of the West Virginia Geological Survey, supplemented by Woodward's extensive field and laboratory work. They include generalized summaries of the stratigraphy, nomenclature, and paleontology of the Silurian and Devonian rocks of neighboring states.

W. E. Davies (1950) reported on the caves of Maryland. Three caves in the mapped area, including Twigg's Cave at Twiggtown—the largest cave in Maryland—are described in this paper.

ACKNOWLEDGMENTS

The writers acknowledge the detailed reconnaissance mapping in the Evitts Creek quadrangle by H. L. Berryhill, Jr., in the fall of 1954. Murray Levish and Harvey J. Hambleton assisted the writers for brief periods during the spring and fall of 1956. Wilbert H. Hass visited the area for several days during August 1956 and collected fossils from the Burket Member of the Harrell Shale for comparison with rocks in the lower part of the Upper Devonian sequence of central New York.

TOPOGRAPHY

The Evitts Creek and Pattersons Creek quadrangles lie in the western part of the Ridge and Valley province of the Appalachian highlands. The banks of the North Branch of the Potomac River near Green Spring, W. Va., at an altitude of about 530 feet above sea level are the lowest place in the mapped area. Several small knobs on the crest of Evitts Mountain in the northeastern part of the area exceed 2,350 feet above sea level and are the highest places in the two quadrangles. The maximum relief of the mapped area is slightly more than 1,800 feet. Evitts Mountain, Wills Mountain, and Warrior Mountain are the three most prominent ridges. These mountains rise conspicuously above the summits of Collier Mountain, Irons Mountain, Martin Mountain, Nicholas Ridge, Patterson Creek Ridge, Pine Ridge, and Shriver Ridge, within the mapped area.

The Evitts Creek and Pattersons Creek quadrangles are drained by the North Branch of the Potomac River, by Evitts Creek, Patterson Creek, and Wills Creek, and their tributaries. Most of the larger tributary streams flow across wide alluvial-covered valleys near their junction with the Potomac, in contrast to the smaller tributaries which commonly flow in narrow valleys and gullies devoid of flood-plain deposits. Many of the mountain ridges in the two quadrangles are separated by narrow valleys. At other places, broad valleys partly mantled with alluvium separate the ridges and uplands. The valley of the North Branch of the Potomac River is widest in the vicinity of North Branch Station and Evitts Creek, where the flood plain is about 0.75 mile wide. Locally, several smaller streams flow through wide valleys which are generally under cultivation and are the sites of small villages and towns. Short tributary streams such as Collier Run flow through narrow, steep-walled valleys for most of their length. The narrow valleys are commonly choked with large amounts of colluvium and are generally unsuited for cultivation. The northeast-southwest alinement of many of the larger streams in both quadrangles was produced as the streams followed the linear trend of the least resistant rocks in the stratigraphic sequence. Locally some streams, Rocky Gap Run for example, abandoned the softer and more easily eroded strata to cut across the hard and resistant rocks. The narrow gaps cut in the resistant strata by these streams contain some of the most spectacular outcrops in the area. Excellent exposures of the resistant sandstones and quartzites, which form the higher ridges in the mountainous district, are present along the rim of Rocky Gap and in the cliffs along the North Branch of the Potomac River between North Branch Station and Spring Gap.

STRATIGRAPHY

The exposed bedrock in the Evitts Creek and Pattersons Creek quadrangles (pls. 1 and 2) ranges from the Juniata Formation of Late Ordovician age to the Chemung(?) Formation of Late Devonian age. The total thickness of the exposed rocks is about 8,000 feet (pl. 3).

ORDOVICIAN SYSTEM

JUNIATA FORMATION

NAME AND EXTENT

Darton (in Darton and Taff, 1896, p. 2) gave the name Juniata to a sequence of predominantly red and purple rocks that underlies the Tuscarora Quartzite in Maryland and parts of adjacent States. The formation is typically exposed along the banks of the Juniata River in south-central Pennsylvania.

The Juniata Formation is exposed in the Evitts Creek quadrangle only on the western side of Evitts Mountain in a long narrow strip from the north edge of the quadrangle to a point about 4,000 feet south of the Pennsylvania State line. The uppermost beds of the Juniata probably crop out near stream level in the center of Rocky Gap. The floor and the lower part of the walls of the gap are covered with large float blocks of Tuscarora Quartzite, however, and the writers were unable to find the reddish-purple rocks of the Juniata exposed in the gap.

CHARACTER AND THICKNESS

In the Evitts Creek quadrangle the Juniata Formation is composed largely of grayish-red to dusky-red sandy mudrock and shale. Some grayish-red, dusky-purple, tan, light-pink, and medium-light-greenish-gray quartzitic sandstone and siltstone are present, particularly in the upper part of the formation. The sandstone in the Juniata is composed largely of fine to medium, subangular to subrounded quartz grains. Many sand grains are heavily stained by hematite which imparts the reddish color to the rock. Muscovite, chlorite, pyrite, decomposed feldspar, and ferruginous clay occur as accessory constituents in the sandstone. The sandstone ranges from hard vitreous quartzite to soft slabby-weathering argillaceous rock that contains many irregularly shaped fragments of silty shale and mudrock. Fluvial crossbedding is common in the coarser grained rocks in the Juniata Formation, particularly in the upper part. Reddish-gray or grayish-red silty micaceous mudrock and shale constitute most of the fine-grained rocks in the formation. They are relatively soft, and weather quickly to form dark-red sandy clay soil. Much of the surface underlain by the Juniata along the west flank of Evitts Mountain is covered by talus composed of blocks of red sandstone from the Juniata and white or light-gray quartzite from the Tuscarora. Consequently, few exposures of the softer rocks in the formation can be observed, though much of the upper part of the formation may be seen in the Narrows of Wills Creek about a mile west of Cumberland, Md.

The lower boundary of the Juniata is not exposed in the area. The upper part of the formation grades into the overlying Tuscarora Quartzite through an interval of 15 to 20 feet of reddish-gray sandy shale and interbedded pink to light-gray quartzite. The boundary is arbitrarily placed at the top of the youngest bed of red shale, above which the sequence is composed largely of gray, tan, and white quartzite.

About 450 feet of the Juniata crops out in the exposures along the west side of Evitts Mountain. By comparison with sections along strike in southern Pennsylvania, the writers estimate that the Juniata is about 900 to 950 feet thick in the mapped area.

AGE AND CORRELATION

The Juniata is the only Ordovician formation exposed in the mapped area. It is of Late Ordovician age and is equivalent to the Queenston Shale of western New York and to the Sequatchie Formation of southwestern Virginia and eastern Tennessee. No fossils were found in the Juniata Formation in the Evitts Creek and Pattersons Creek quadrangles.

SILURIAN SYSTEM

TUSCARORA QUARTZITE

NAME AND EXTENT

Darton (in Darton and Taff, 1896, p. 2; Darton, 1896, p. 2) gave the name Tuscarora to the massive sedimentary quartzite that forms the crest of many of the linear mountain ridges in the central Appalachian Mountains. The quartzite is typically exposed along Tuscarora Mountain in south-central Pennsylvania.

The Tuscarora Quartzite is well exposed on the crests of Wills Mountain and Evitts Mountain in the northern part of the mapped area (pl. 1). It plunges under the cover of younger rocks about a half a mile south of Rocky Gap. A small fault on the east limb of the mountain brings the upper beds of the Tuscarora a quarter of a mile farther south, where they are exposed in a small unnamed run 2,500 feet north of U.S. Highway 40.

CHARACTER AND THICKNESS

In the Evitts Creek and Pattersons Creek quadrangles, the Tuscarora is a massively bedded, light-gray to white quartzitic sandstone or sedimentary quartzite composed largely of angular to subround grains of medium to coarse vitreous quartz sand. At many places the angularity of the grains has been increased by overgrowths of secondary silica in optical continuity with the original quartz. Commonly the Tuscarora is tightly cemented by secondary silica to a dense tough rock that is highly resistant to weathering. Long-continued weathering eventually removes much of the cementing material, and the Tuscarora disaggregates into a clean white sand. Small well-rounded discoidal pebbles of gray, white, and light-pink quartz or quartzite 0.1 inch thick and 0.1 to 0.5 inch long are present in the middle and upper parts of the Tuscarora as isolated individuals or locally in thin beds.

The Tuscarora Quartzite is medium bedded in the lower and upper parts and massively bedded in the middle part of the formation. The thickness of beds ranges from a few inches near the upper and lower boundaries of the formation to as much as 7 feet in the middle part of the Tuscarora in the exposure at Rocky Gap. Most beds are lenticular. Crossbedding is common, and many of the thinner beds in the upper part of the formation are ripple marked. Irregularly shaped fragments of dark-gray or dark-greenish-gray silty shale occur in the upper 20 to 30 feet of the Tuscarora in exposures along Wills Mountain north of Cumberland, Md.

The Tuscarora Quartzite is the most resistant rock in the Evitts Creek and Pattersons Creek quadrangles. It forms the highest mountain ridges and disintegrates slowly to produce great quantities of talus. Large blocks and slabs of quartzite commonly break away from the outcrops high on the mountain sides and gravitate into the adjacent valleys. The mantle of talus covers the adjacent softer formations and makes location of the boundaries of the Tuscarora Quartzite difficult.

The upper boundary of the Tuscarora is gradational into the overlying Rose Hill Formation through a transition zone 20 to 25 feet thick in which the thin-bedded light-gray quartzite of the Tuscarora grades into medium-olive-gray silty shale and medium-gray slabby-weathering sandstone of the Rose Hill. The upper boundary of the Tuscarora is arbitrarily located by the writers at the top of the youngest layer of quartzite above which the rocks are largely thin-bedded silty shale and sandstone.

The Tuscarora Quartzite is about 400 feet thick in the mapped area. The writers measured 412 feet of Tuscarora in the Narrows of Wills Creek west of Cumberland, in fairly close agreement with the thickness of 380 feet reported by Swartz (in Swartz, C. K., and others, 1923, p. 26). Nearby the Tuscarora is reported to be 400 to 600 feet thick in northern Bedford County, Pa. (Butts, 1945, p. 6), and 317 feet thick in central Grant County, W. Va. (Reger, 1924, p. 175).

AGE AND CORRELATION

The Tuscarora is of Early Silurian age. It is a correlative of the Albion Group of western New York (C. K. Swartz, and others, 1942) and of the Clinch Sandstone of southwestern Virginia and eastern Tennessee.

The Tuscarora Quartzite is relatively unfossiliferous in the mapped area. *Arthrophycus alleghaniensis* (Harlan) is present in some of the Tuscarora float in Rocky Gap; *Scolithus* cf. *S. verticalis* (Hall) and *Buthotrephis* occur in several of the massive beds of quartzite on the west side of Wills Mountain near Cooks Mills. The brachiopod *Stegerhynchus neglectum* (Hall) was reported to be present in layers of shale in the upper part of the Tuscarora in the vicinity of Cumberland, Md., (C. K. Swartz and others, 1923, p. 26). The writers were unable to find the fossil in the Tuscarora and concur with Woodward

(1941, p. 48) that the fossiliferous shale probably lies in the Rose Hill Formation and not in the Tuscarora.

ROSE HILL FORMATION

NAME AND EXTENT

Swartz (in C. K. Swartz, and others, 1923, p. 27–31) applied the name Rose Hill Formation to the rocks between the top of the Tuscarora Quartzite and the base of the Rochester Shale at Rose Hill in the southwestern part of Cumberland, Md. Swartz included the Keefer Sandstone in the lower part of his Rochester Shale. In this report the name Rose Hill Formation is adopted and includes the rocks between the top of the Tuscarora Quartzite and the base of the Keefer Sandstone.

Narrow belts of Rose Hill are present on the west side of Evitts Mountain and Wills Mountain where the rocks dip steeply. Outcrop belts of the formation are wider on the east sides of the two mountains, where the rocks have a more gentle dip. The Rose Hill underlies a wide area south of Rocky Gap. The south plunge of the Evitts Mountain anticline (pl. 1) carries the formation under the cover of younger rocks in the valley of Cabin Run about three-quarters of a mile south of U.S. Highway 40. A part of the Rose Hill is isolated in a small faulted syncline on the east side of Evitts Mountain northeast of Rocky Gap.

CHARACTER AND THICKNESS

The Rose Hill Formation is composed largely of olive-gray, medium-gray, and purplish-gray slightly silty or sandy mudrock and shale. Small amounts of pale-red, yellowish-brown, and pale-purple shale are interbedded in the formation, particularly in the middle and upper parts. The mudrock in the Rose Hill weathers into small sharp-edged blocks and chunks that are commonly coated by a film of dark-reddish-brown iron oxide. Many layers of light-gray to medium-gray and medium-greenish-gray sandstone are present in beds half an inch to 8 inches thick in most places, but some layers of sandstone are more than 3 feet thick. The beds of sandstone and siltstone are thickest and most numerous in the lower part of the formation. Most layers of sandstone and siltstone are lenticular and many are crossbedded. Oscillation ripple marks and interference ripple marks occur in the upper parts of some beds, and ramose fucoids are present on the bottoms of some beds. Small discoidal chips of light-gray, tan, or light-brown siltstone and very silty shale occur in small lenses in some of the thicker beds of sandstone.

A 5- to 20-foot sequence of hematitic coarse-grained quartz sandstone in beds from 6 inches to 3 feet thick is present from 145 to 175 feet above the base of the Rose Hill Formation. This sandstone is the Cresaptown Iron Sandstone of Swartz (in C. K. Swartz and others, 1923, p. 29). Its color ranges from pale red to dark purplish red, depending upon the amount of hematite present either in oolites or as the cementing material between the sand grains. The sandstone containing the greatest quantity of iron is the darkest red. Swartz' Cresaptown is composed of medium to coarse subrounded grains of quartz. Although this sandstone is a relatively resistant unit on the mountain sides, it is commonly covered by talus from the harder Tuscarora. Only a few scattered blocks of reddish sandstone indicate the position of the hematitic sandstone in the formation. In direct contrast, on the relatively flat land south of Rocky Gap at the south end of Evitts Mountain, the red sandstone is well exposed at many places. Hematitic sandstone can be seen on U.S. Highway 40 under a bridge across Elk Lick Run 900 feet west of Pleasant Grove Church, and at another place on Highway 40, 800 feet west of the junction of the highway with the road along Cabin Run. Massive red sandstone containing some oolites of hematite is exposed on the road along Cabin Run at the sharp turn where the road swings south parallel to the run about 500 feet south of U.S. Highway 40 (fig. 2).

Some lenticular beds of greenish-gray siltstone and a few beds of very dark gray argillaceous limestone 2 to 8 inches thick occur in the upper 75 feet of the Rose Hill Formation in close association with the Keefer Sandstone. Both the siltstone and the limestone weather light tan or light olive gray. In general the limestone contains fossils and the siltstone is barren; however, fossils are not abundant even in the more fossiliferous beds.

The upper boundary of the formation is nongradational and sharp. Silty olive-gray shale in the upper part of the Rose Hill is overlain by light greenish-gray to tan Keefer Sandstone, and the contact betweeen the two formations is clearly defined.

The Rose Hill Formation is about 540 to 570 feet thick in the mapped area. Accurate determination of the thickness of the Rose Hill is difficult because the formation is incompetent, and many small folds and faults are present in the shaly rocks. How great a thickness of beds may have been repeated by local structures cannot be determined unless the Rose Hill is well exposed.

AGE AND CORRELATION

The Rose Hill Formation is of Middle Silurian age. It is equivalent to most of the Clinton Group of western New York and to the upper one-half of the Red Mountain Group of eastern Tennessee and northwestern Georgia (C. K. Swartz and others, 1942).

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FIGURE 2.—Cresaptown Iron Sandstone of Swartz (1923) near Cabin Run; 53 inches of hematitic sandstone containing thin layers of oolitic hematite exposed on a county road 0.1 mile south of the mouth of Cabin Run, Evitts Creek quadrangle. This outcrop is on the flank of a small fold near the crest of the Evitts Mountain anticlinorium.

Fossils are scarce or absent in much of the Rose Hill Formation. Locally, however, some beds contain a great many fossils. The Rose Hill has been subdivided by Ulrich and Bassler (C. K. Swartz, and others, 1923, p. 364–367), largely on its ostracode fauna. The writers found fossils in the silty shale associated with the Cresaptown Iron Sandstone of Swartz, but not in the sandstone itself. In the field the senior writer identified the following fossils from the lower 200 feet of the Rose Hill:

Stegerhynchus neglectum (Hall)
Coelospira hemisphaerica (Sowerby)
Tentaculites sp.
Zygobolba anticostiensis Ulrich and Bassler
decora (Billings)
emaciata Ulrich and Bassler
Mastigobolbina lata (Hall)

The following fossils were found by the writers in the middle part of the formation:

Protochonetes novascoticus (Hall)
Stegerhynchus neglectum (Hall)
Coelospira hemisphaerica (Sowerby)
Tentaculites minutus Hall
Calymene cresapensis Prouty
Zygosella postica Ulrich and Bassler
Mastigobolbina lata (Hall)
Buthotrephis gracilis Hall

The upper 75 feet of the Rose Hill, which is more fossiliferous than the rest of the formation, (C. K. Swartz, 1923, p. 377) contains:

Parmorthis elegantula (Dalman)
Schellwienella sp.
Protochonetes novascoticus (Hall)
Stegerhynchus neglectum (Hall)
Coelospira sulcata Prouty
Atrypa cf. *A. reticularis* (Linné)
Tentaculites minutus Hall
Liocalymene clintoni (Vanuxem)
Bonnemaia rudis Ulrich and Bassler
Mastigobolbina typus Ulrich and Bassler

KEEFER SANDSTONE

NAME AND EXTENT

Ulrich (1911, p. 522, 591) proposed the name Kiefer Sandstone, and Stose (in Stose and Swartz, 1912, p. 5), who used the currently accepted spelling—Keefer, stated that the sandstone was well exposed near Warren Point, Pa., at the south end of Keefer Mountain about 35 miles east of Cumberland, Md. Butts (1918, p. 536) placed the Keefer in the top of his Clinton Formation in central Pennsylvania. In the present report the Keefer Sandstone is considered a separate formation because it is lithologically dissimilar to the rocks above and below. However, at many places the Keefer is too thin to be shown separately; consequently it is mapped with the underlying Rose Hill Formation on the accompanying geologic map of the Evitts Creek quadrangle.

The Keefer Sandstone forms a low hogback ridge near the foot of the east slopes of Evitts and Wills Mountains. South of Evitts Mountain in the vicinity of U.S. Highway 40, the Keefer forms a series of small ridges and knobs. The sandstone passes below drainage on Cabin Run about one-half mile south of Highway 40, but is exposed in a small fold along the Run about 1,000 feet to the southeast. The Keefer Sandstone is not exposed in the Pattersons Creek quadrangle but is present in the subsurface.

CHARACTER AND THICKNESS

Throughout much of the Evitts Creek quadrangle, the Keefer is composed of very fine to medium-grained quartz sandstone and medium- to coarse-grained quartz siltstone in lenticular beds 1 to 8 inches thick. Locally, however, the Keefer is massive, and individual beds are as much as 5 feet thick. In most places the formation is irregularly bedded. Where freshly exposed, the Keefer is light-gray or light greenish-gray and weathers light brownish gray, tan, or white, depending on the iron content of the beds. A network of ramose fucoidlike markings covers the upper and lower surfaces of many beds. Short vertical worm tubes about 0.1 inch in diameter and as much as 2 inches long penetrate the strata. Well-rounded quartz pebbles as much as 0.3 inch in diameter occur locally, either in small lenses or isolated in the sandstone or siltstone. Many beds of sandstone or siltstone contain small, irregularly shaped chips or chunks of light-gray or light greenish-gray silty shale or shaly siltstone that commonly weather sooner than the remainder of the bed and impart a ragged or "moth-eaten" look to the rock.

The Keefer is a hard and resistant unit which commonly forms small ridges and knobs. Slabs and blocks of tan, reddish-brown, and light-gray quartzitic sandstone litter the slopes of the small ridges. Locally in Pleasant Valley near the Pennsylvania State line, the Keefer is composed mainly of light-gray, massively bedded quartzitic sandstone that closely resembles the Tuscarora Quartzite. Here the Keefer appears to be more than 20 feet thick; however, the section is not completely exposed.

A bed of sandy hematite or hematitic sandstone 6 to 24 inches thick is present in the upper part of the Keefer. This bed, the Roberts iron ore of Swartz (in C. K. Swartz and others, 1923, p. 33), was mined on the flanks of Wills Mountain near Cumberland during the last century. The Roberts ore ranges in composition from a coarse-grained ferruginous sandstone containing a few hematite oolites to a bed of oolitic hematite containing quartz sand, small subangular to well-rounded quartz pebbles, and a few discoidal pebbles of yellowish-brown siltstone. Specular hematite, limonite, goethite(?), and pyrite occur as accessory minerals in the ore. According to Swartz (in C. K. Swartz and others, 1923, p. 33), the Roberts ore contained as much as 37 percent metallic iron. The ore occurs in layers as much as 8 inches thick that have wavy or irregular bedding surfaces. At some places the ore bed splits along thin laminae of dark-olive-brown silicified siltstone. Poorly preserved fossils are present in iron ore on Wills Mountain near the Maryland State line. The Roberts ore is a good key bed for field mapping because it imparts a red color to the thin sandy soil covering the Keefer Sandstone. The presence of oolitic hematite in the layers of reddish sandstone serves to differentiate the Keefer Sandstone from the nearby Bloomsburg Red Beds which are commonly similar in lithology to the Keefer but do not contain oolitic hematite.

In many places the upper boundary of the sandstone is not as clearly defined as the lower. Where the Roberts iron ore is thin or locally missing, thin slabby-weathering beds of siltstone in the top of the Keefer are interbedded in medium light-gray calcareous shale of the Rochester through an interval of about 1 to 1½ feet. The upper boundary of the Keefer is placed by the writers at the top of the siltstone sequence. Locally where the Rochester Shale rests directly on the Roberts iron ore the upper boundary of the Keefer is clearly defined.

The Keefer Sandstone is 10 to 25 feet thick in the Evitts Creek quadrangle. It is thickest in Pleasant Valley and thinnest near Cumberland. Swartz (in C. K. Swartz and others, 1923, p. 80) reports 22.5 feet of Keefer in an exposure on Cabin Run south of U.S. Highway 40. The complete thickness of the Keefer is difficult to determine except in artificial exposures, because in most outcrops the contacts of the sandstone with adjacent strata are obscured by float.

AGE AND CORRELATION

The Keefer Sandstone, of Middle Silurian age, is sparsely fossiliferous in the mapped area. Worm tubes, *Scolithus keeferi* Prouty, occur in some of the thicker layers of sandstone, and crinoid stems are present sparingly. *Stegerhynchus neglectum* (Hall), *Tentaculites* cf. *T. minutus* Hall, and *Hormotoma* were found by the writers in blocks of the Roberts ore on the east side of Wills Mountain in the valley of Pea Vine Run.

ROCHESTER SHALE

NAME AND EXTENT

Conrad (1839, p. 58, 63) first used the name Rochester, and in the same year Hall (1839, p. 289) described the Rochester Shale in its type area along the Genesee River at Rochester, Monroe, County, N.Y. In the Evitts Creek quadrangle, the Rochester Shale includes the rocks above the Keefer Sandstone and below the base of the "*Schellwienella*" *elegans* zone of the McKenzie Formation (F. M. Swartz 1935, p. 1180, 1181).

The outcrop of the Rochester Shale is coextensive with the outcrop of the McKenzie Formation. Because the Rochester Shale is lithologically indistinguishable from the McKenzie Formation and is thin, the two formations have been mapped together on the accompanying geologic maps.

CHARACTER AND THICKNESS

The Rochester Shale is a medium-gray calcareous shale containing many lenticular beds of very dark gray argillaceous limestone. The limestone, which ranges from very finely crystalline to coarsely crystalline, weathers light tan to light olive gray. Commonly slabs of fossiliferous limestone 1 to 6 inches thick weather from the shale and litter the slopes underlain by this soft formation.

Swartz (1935) placed the upper boundary of the Rochester Shale at the top of the *Drepanellina clarki* zone and the base of the "*Schellwienella*" *elegans* zone. Lithologically the rocks above and below the top of the Rochester are so nearly identical that separation is possible only by paleontological criteria.

The Rochester Shale is about 30 feet thick in the mapped area. Swartz (in F. M. Swartz 1935, p. 1174) reports 25.5 feet of Rochester Shale in a section at the south end of Rose Hill at Cumberland. The shale is 34.4 feet thick in an exposure on Cabin Run south of Highway 40 (C. K. Swartz, and others, 1923, p. 79–80).

AGE AND CORRELATION

The Rochester Shale of Maryland is Middle Silurian in age. It is equivalent to the Rochester Shale of New York, Pennsylvania, and West Virginia (C. K. Swartz and others, 1942). The Rochester Shale is one of the most fossiliferous Paleozoic formations in Maryland. Woodward (1941, p. 112) reports 70 genera and species from the Rochester Shale in the adjacent part of West Virginia. Most of these fossils are present in the Rochester of Maryland. The fauna of the Rochester Shale in Maryland has been designated the *Drepanellina clarki* fauna for this abundant and characteristic ostracode (C. K. Swartz and others, 1923, p. 386; F. M. Swartz 1935, p. 1179–1182). The following fossils from the Rochester were identified in the field by the writers:

Craniops squamiformis Hall
Parmorthis elegantula (Dalman)
"*Schellwienella*" *elegans* (Prouty)
Stegerhynchus neglectum (Hall)
Uncinulus sp.
Atrypa reticularis (Linné)
Eospirifer radiatus (Sowerby)
Howellella crispa (Hisinger)
Cleidophorus nitidus Prouty
Pterinea sp.
Hormotoma marylandica Prouty
Diaphorostoma niagarense Hall
Tentaculites niagarensis Hall
Calymene niagarensis Hall
Homalonotus sp.
Dalmanites limulurus (Green)
Drepanellina clarki Ulrich and Bassler
Dizygopleura sp.

McKENZIE FORMATION

NAME AND EXTENT

Ulrich (1911, p. 522, 545, 591, and chart 28) gave the name McKenzie to the rocks above his Clinton Group and below the Bloomsburg Red

Beds. The type exposure is in the vicinity of the McKenzie Station on the Baltimore & Ohio Railroad about 6½ miles south of Cumberland, Md.

The McKenzie Formation crops out in narrow belts along both flanks of Evitts Mountain and Wills Mountain. Two belts of McKenzie coalesce south of Highway 40 in the vicinity of Cabin Run. From Cabin Run, the McKenzie extends along the crest of the south plunging Evitts Mountain anticline to a point about 3,000 feet south of Hardinger Road where the formation dips under the cover of younger rocks.

CHARACTER AND THICKNESS

The McKenzie Formation is composed of medium-greenish-gray to medium-dark-gray calcareous shale and interbedded dark-gray argillaceous limestone. Small amounts of calcareous mudstone and calcareous siltstone are present, mostly in the middle and upper parts of the formation. The shale weathers light olive gray or tan. It is most calcareous in the lower and middle parts of the formation and becomes less calcareous and more silty in the upper part. Clastic limestone is common in the lower part of the McKenzie, but many of the beds in the upper part of the formation consist of fine-textured nonclastic limestone. Some beds, which have a granular appearance when broken, are composed largely of ostracodes in a matrix of finely crystalline limestone. The shells of the brachiopod "*Schellwienella*" *elegans* make up several layers of limestone 0.5 to 3 inches thick in the basal 6 feet of the McKenzie. The beds of limestone in the McKenzie are thin, commonly less than 6 inches thick; locally, however, some layers are more than 2 feet thick. Layers of intraformational conglomerate composed of angular chips of limestone cemented by fine-textured limestone occur in the lower half of the formation.

The McKenzie and the underlying Rochester are nonresistant and commonly underlie valleys between small ridges formed by the Keefer Sandstone and the Bloomsburg Red Beds. Float from these more resistant formations covers the McKenzie at most places.

The upper boundary is clearly defined. Greenish-gray shale in the upper part of the McKenzie is overlain conformably by medium-gray siltstone in the basal part of the Bloomsburg Red Beds. In many places the boundary between the two formations is obscured by float from the resistant Bloomsburg, but where visible, it is a 2-foot transition zone of interbedded gray shale and gray siltstone.

A completely exposed and undeformed section of the McKenzie was not available for measurement in the mapped area. The thickness of the formation calculated from planetable traverses in the Evitts Creek quadrangle ranges from 285 to 380 feet.

AGE AND CORRELATION

The McKenzie Formation is of Middle Silurian age. F. M. Swartz (1935, p. 1192) and Woodward (1941, p. 144) suggest that the McKenzie Formation and the Lockport Dolomite of New York are contemporaneous facies.

The McKenzie is not abundantly fossiliferous although some beds of limestone in the lower part of the formation are composed largely of shell fragments. The gastropods *Hormotoma marylandica* and *Hormotoma hopkinsi* are common in some of the thin beds of limestone in the middle part of the McKenzie. The senior writer found the following fossils in the upper part of the McKenzie in exposures along Hinkle Road and on Cabin Run:

Parmorthis elegantula (Dalman)	*Ctenodonta subreniformis* Prouty
Cupularostrum, sp.	*Tentaculites* sp.
Uncinulus sp.	?*Orthoceras mackenzicum* Prouty

BLOOMSBURG RED BEDS

NAME AND EXTENT

The name Bloomsburg Red Shale was given by White (1883, p. 106–109) to a sequence of red shale and red sandstone that crops out near Bloomsburg, Columbia County, Pa. These red rocks were named the Bloomsburg Red Beds by C. K. and F. M. Swartz (1931, p. 626). In the Evitts Creek and Pattersons Creek quadrangles, the Bloomsburg Red Beds separate the McKenzie Formation below from the Wills Creek Shale above.

The red beds are poorly exposed on the west flank of Wills Mountain, where the rocks dip steeply to the west; however, on the east side of the mountain where the dip is less steep, the resistant Bloomsburg forms a low ridge in Cumberland Valley between Wills Mountain and Shriver Ridge. Similarly the red beds are not well exposed along the west side of Evitts Mountain, but form a low hogback ridge in Pleasant Valley on the east side of the mountain. South of Highway 40 along the trend of the Evitts Mountain anticline, the Bloomsburg forms the crest of two low ridges which coalesce about 3,000 feet south of Hardinger Road.

CHARACTER AND THICKNESS

The Bloomsburg consists of several beds of greenish-gray and purplish-red sandstone and siltstone intercalated in purplish-gray, grayish-red, and medium-gray, slightly calcareous silty mudrock and shale. The mudrock breaks down into small, irregularly shaped chunks and chips, whereas the slightly softer shale weathers to a light-red sandy soil. Small spherical calcareous nodules about 0.5 inch in diameter are present in the lower part of the Bloomsburg at several places. Sandstone and siltstone occur in lenticular beds an inch to 3 feet thick . The coarser grained rocks are tightly cemented and very resistant to weathering. The upper and lower surfaces of the beds are undulatory and are commonly marked by a network of short branching worm tracks and fucoids. The thinner bedded siltstones weather to small slabs, whereas the thicker bedded siltstones and sandstones break out in nearly equidimensional blocks, particularly where jointing is closely spaced. Consequently, the outcrop of the Bloomsburg is generally littered with an accumulation of rectangular blocks of green and red sandstone and siltstone.

Several beds of medium-dark-gray fine- to medium-crystalline argillaceous limestone as much as 1.5 feet thick occur in the middle part of the Bloomsburg Red Beds. These beds are the Cedar Cliff Limestone of Swartz (in C. K. Swartz and others, 1923, p. 42). An intraformational conglomerate about 9 inches thick is present in the upper part of Swartz' Cedar Cliff Limestone in an exposure on U.S. Highway 40 (fig. 3). Because it is soluble and nonresistant, the limestone

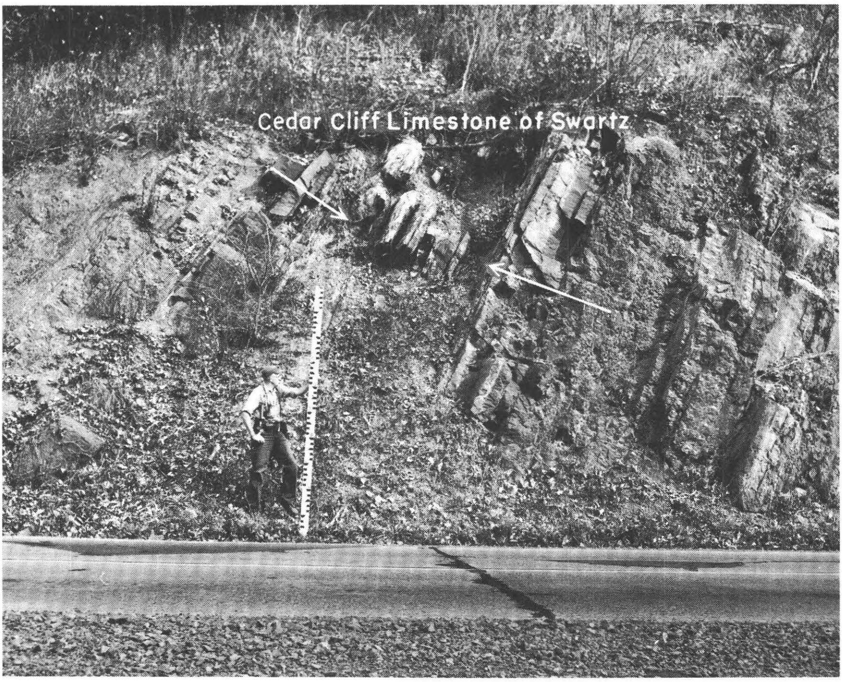

FIGURE 3.—Bloomsburg Red Beds along U.S. Highway 40; a complete exposure of the Bloomsburg about 0.75 mile west of Pleasant Grove Church on the north side of U.S. Highway 40. Purplish-red and greenish-gray quartzitic siltstone and sandstone form the ledge about 8 feet to the rodman's left. Cedar Cliff Limestone of Swartz (1923) crops out near the top of the bank behind the stadia rod. Thin-bedded argillaceous siltstone in the basal part of the Bloomsburg in extreme right of the photograph.

generally is not exposed, and the deeply weathered argillaceous residue resembles the weathered mudstone in the upper or lower part of the Bloomsburg. The different kinds of rock in the red-bed sequence are exposed on the north side of Highway 40 about 2,000 feet west of the junction of the road along Cabin Run with the main highway.

Section of the Bloomsburg Red Beds on U.S. Highway 40 about 2,000 feet west of Cabin Run (fig. 3).

		Thickness (feet)
Wills Creek Shale (total thickness not measured):		
Mudrock, light-dusky-yellow, calcareous		6.4
Bloomsburg Red Beds (43.6 ft. thick):		
Mudrock, grayish-red, massive; grades into bed above		2.3
Mudrock, olive-gray		.5
Mudrock, pale-grayish-red, slightly calcareous; contains some tan spots		3.75
Mudrock, olive-gray, calcareous, slightly silty		2.2
Shale and mudrock, grayish-red, slightly calcareous		2.75
Siltstone, grayish-red, argillaceous, irregularly bedded		1.2
Mudrock, purplish-red, chippy-weathering		1.65
Shale, light-greenish-gray, calcareous		1.1
Siltstone, light-gray, argillaceous, irregularly bedded		.55
Shale, light-gray, silty, slightly calcareous		.55
Sandstone, light-gray, fine-grained, argillaceous; in 0.1-ft beds; contains 0.2-ft, irregularly shaped calcareous nodules		.6
Shale, light-gray to light-greenish-gray, silty; contains 0.15 ft of light-gray siltstone near center of bed		1.5
Sandstone, purplish-red, fine-grained, quartzitic; weathers in 0.4- to 0.6-ft beds; greenish-gray vertical worm borings in upper part of unit		2.95
Mudrock, purplish-red		.52
Siltstone, purplish-red, slabby-weathering		.65
Shale, red		.3
Cedar Cliff Limestone of Swartz (in C. K. Swartz, and others, 1923):		
Limestone, medium-dark-gray, fine to medium crystalline, argillaceous; flow structure in upper part of bed, 0.75 ft bed of limestone-pebble conglomerate in base of unit	2.5	
Limestone, medium-dark-gray, finely crystalline, argillaceous; 0.6- to 1-ft beds, bedding surfaces irregular; *Leperditia* present	4.6	
		7.1
Shale, medium-gray, calcareous; partly covered		1.1
Sandstone, quartzitic, fine-grained; greenish-gray in upper part grades into basal 1.35 ft. which is purplish-red; worm tubes and fucoidal marks in bedding surfaces		3.45
Mudrock, purplish-red, silty; weathers into small chunks; scattered calcareous nodules 0.1 ft in diameter		1.35
Siltstone, purplish-red, massive; contains much fine-grained quartz sand; weathers in beds 0.3 to 0.6 ft thick; fucoidal marks abundant		3.95
Siltstone; upper 0.9 ft is purplish-red, basal 1.5 ft greenish-gray; quartzitic, massive; vertical worm tubes in upper part		2.4

Section of the Bloomsburg Red Beds on U.S. Highway 40 about 2,000 feet west of Cabin Run (fig. 3)—Continued

	Thickness (feet)
Bloomsburg Red Beds—Continued	
Siltstone, light-gray, argillaceous, nonresistant	0.83
Siltstone, medium-greenish-gray, slightly calcareous, slabby-weathering	.35
Total thickness of Bloomsburg Red Beds	43.6
McKenzie Formation (thickness not measured):	
Mudrock, light-greenish-gray, calcareous, slightly silty; contains 0.1- to 0.25-ft beds of dark-gray argillaceous limestone.	

The upper boundary of the formation is not as readily determined as the lower. Purplish-red mudrock in the upper part of the Bloomsburg interfingers with greenish-gray and dusky-yellow mudrock in the lower part of the Wills Creek Shale. The writers draw the boundary at the top of the uppermost bed of purplish-red mudrock.

In the Evitts Creek quadrangle the Bloomsburg is 25 to 50 feet thick. The red beds are about 27 feet thick in the valley of Pea Vine Run, 43.6 feet thick on Highway 40 west of Cabin Run, more than 27 feet thick on Hinkle Road where the upper part of the sequence is not exposed, and 42 feet thick on the road to Dickens west of Rocky Gap.

AGE AND CORRELATION

The Bloomsburg Red Beds in the mapped area are of Late Silurian age and constitute the lowest unit of the Upper Silurian Series in this part of the Appalachian Mountains. Part of the Bloomsburg Red Beds in the Evitts Creek quadrangle is equivalent to Reger's Williamsport Sandstone (Reger, 1924, p. 395–398). The rapid thickening of the red beds to the east and the presence of thick beds of red and purplish-red mudstone and shale in the Bloomsburg in the eastern part of the Evitts Creek quadrangle and to the east in the adjacent Flintstone quadrangle shows that in central Allegany County the Bloomsburg includes more strata than Reger's Williamsport Sandstone. The red beds in the Evitts Creek quadrangle are equivalent to a part of the thick Bloomsburg Red Bed sequence in eastern Pennsylvania, and may be partly equivalent to the red Vernon Shale of east-central New York.

The Bloomsburg Red Beds are almost unfossiliferous except for the Cedar Cliff Limestone of Swartz. The writers found a few poorly preserved *Leperditia* in the Cedar Cliff in the outcrop on Highway 40 west of Cabin Run. Small vertical worm borings and medium-sized fucoids are present in the red beds at some places.

WILLS CREEK SHALE

NAME AND EXTENT

The name Wills Creek was first used by Uhler (1905, p. 20–25) to designate a sequence of shale, mudrock, and limestone exposed in the banks of Wills Creek in the City of Cumberland, Md. As originally defined the Wills Creek included the thin Bloomsburg Red Beds in the basal part. Later Ulrich (1911, p. 522, 541, pl. 28) and C. K. and F. M. Swartz (1931, p. 622–660) excluded the red beds from the Wills Creek in Maryland and restricted the Wills Creek to the rocks between the top of the Bloomsburg Red Beds and the base of the Tonoloway Limestone.

The Wills Creek Shale underlies parts of Wills Creek Valley west of Wills Mountain, Cumberland Valley east of Wills Mountain, Pleasant Valley, and Murley Branch. Outcrops of the Wills Creek Shale on the flanks of Evitts Mountain converge to the south along the plunging anticlinal fold and merge about 0.6 mile north of Williams Road.

CHARACTER AND THICKNESS

The Wills Creek Shale is composed predominantly of dark-gray and medium-dark-gray calcareous mudrock and shale. The lower 150 feet of the Wills Creek contains many beds 1 to 3 feet thick of very dark gray calcareous mudrock interbedded with dark-gray to medium-gray calcareous shale and a few lenticular beds of dark-gray argillaceous limestone 4 inches to 1 foot thick. The middle part of the Wills Creek contains approximately equal parts of calcareous shale and calcareous mudrock. Argillaceous limestone is present in small amounts. The amount of limestone increases upward in the Wills Creek; the upper 100 feet of the formation is composed of nearly equal parts of argillaceous limestone and calcareous shale. Sedimentary features indicative of very shallow water deposition, such as desiccation cracks, rill marks, interference ripple marks, and rain-drop impressions, are present on the surface of many of the beds of limestone when freshly exposed by quarrying in borrow pits. Some of the limestone in the Wills Creek is thinly bedded, but in general most of the limestone in the middle and upper part of the formation is thick bedded. At many places the limestone beds grade vertically into the overlying beds of calcareous shale. Much of the Wills Creek Shale is dark gray on fresh exposure but readily weathers to a characteristic grayish yellow green. Several beds of grayish-black shale ranging from 1 to 4 feet in thickness are present in the upper part of the Wills Creek; the most noticeable is from 150 to 220 feet below the top of the formation. The black shale is not readily apparent in roadcuts; however, chips of blackish shale having light-greenish-gray rims litter the surface of the Wills Creek in plowed fields and pastures. Swartz (in C. K. Swartz and others, 1923, p. 40, 43) discusses several beds of sandstone that occur in the lower and upper parts of the Wills Creek Shale. These layers of sandstone, which consist of fine-grained quartz sand and much quartz silt, are tightly cemented by calcite. The well-rounded sand grains, many of which have a high degree of sphericity, suggest aeolian transportation. The layers of sandstone are commonly 2 to 6 inches thick; locally a bed may be as much as 3 feet thick. The beds of sandstone can be seen in exposures along roads and railroads but are not sufficiently resistant to stand out on hill slopes.

The Wills Creek Shale is one of the more poorly exposed units in the Evitts Creek quadrangle. Much of the area underlain by the Wills Creek is in permanent pasture or in woodlands where the outcrops are largely obscured. Most of the rocks in the Wills Creek Shale weather into small chunks and chips of soft yellowish-green and greenish-gray mudrock which gives little indication of the appearance of the unweathered rock.

The upper boundary of the Wills Creek Shale is not sharply defined. It is arbitrarily placed at the top of the stratigraphically youngest bed of yellowish-green-weathering shale or mudrock above which the sequence is composed of dark-gray laminar limestone that weathers into small dark-bluish-gray plates. In fresh exposures the beds of limestone in the upper part of the Wills Creek superficially resemble the beds of limestone in the lower part of the overlying Tonoloway Limestone, and the boundary between the two formations is difficult to locate. However, in weathered outcrops where the argillaceous nature of the Wills Creek Shale is readily apparent, the upper boundary of the formation can be recognized easily.

The Wills Creek is about 500 feet thick in the mapped area. The writers measured 484 feet of Wills Creek Shale along Rocky Gap Run. Swartz (in C. K. Swartz and others, 1923, p. 41) reported the Wills Creek to be 450 to 500 feet thick in Maryland.

AGE AND CORRELATION

The Wills Creek Shale is a part of the Upper Silurian Series. The Wills Creek Shale of the mapped area is equivalent to much of the Bloomsburg Red Beds of eastern Pennsylvania, and in a general way is a correlative of the Camillus Shale of western and central New York (C. K. Swartz and others, 1942).

The Wills Creek Shale is not abundantly fossiliferous. Locally some beds contain many ostracodes, generally *Leperditia*. Other fossils found by the writers in the Wills Creek include:

"Schellwienella" interstriata (Hall)
Cupularostrum litchfieldensis (Schuchert)
Uncinulus marylandicus Swartz
Hormotoma sp.
Herrmannina alta (Conrad)

TONOLOWAY LIMESTONE

NAME AND EXTENT

Ulrich (1911, pl. 28) proposed the name Tonoloway, and Stose and Swartz (1912, p. 7 and section) defined the Tonoloway Limestone as lying between the Wills Creek Shale and their Helderberg Limestone.

The Tonoloway Limestone crops out in a narrow belt in the valley of Wills Creek west of Wills Mountain. It underlies the lower part of the western slope of Shriver Ridge and a broad belt in Cumberland Valley. A narrow belt of Tonoloway crops out along the west side of the Evitts Mountain anticline to the north edge of the Pattersons Creek quadrangle, where it coalesces with a broader belt that lies along the west side of Irons Mountain and the west side of Martin Mountain. Much of the broad valley east of Twiggtown is underlain by the Tonoloway Limestone.

CHARACTER AND THICKNESS

The Tonoloway is composed largely of very dark gray laminated argillaceous limestone that ranges from subcrystalline to finely crystalline. A few beds of oolitic limestone and small amounts of medium dark-gray to medium-gray calcareous shale are interbedded in the formation. Quartz silt occurs abundantly in laminae in many layers of limestone, and fine- to medium-grained calcareous quartz sand is present in a few places. In fresh exposures the Tonoloway appears massive in beds as much as 6 feet thick, but it rapidly weathers into plates of light bluish-gray limestone 0.25 to 2 inches thick. In weathered outcrops the limestone is distinctly and uniformly laminated. The alternation of light and dark laminae in the layers of limestone gives the weathered Tonoloway a characteristic and unmistakable banded appearance. Hill slopes underlain by weathered Tonoloway Limestone are commonly littered with small plates of resistant light-gray or light bluish-gray limestone which break with a metallic sound when struck with a hammer.

The Tonoloway is well exposed in quarries along the western flank of Shriver Ridge in Cumberland and in the cliffs along the Baltimore & Ohio Railroad near Pinto Station, 6 miles south of Cumberland in the adjacent Cresaptown quadrangle; many sedimentary features can be seen there that are not visible in most outcrops. Ripple marks of small amplitude and beds of limestone pebble conglomerate are mainly in the lower part of the formation. Desiccation cracks similar to those in the Wills Creek Shale are present in some of the shalier beds in the middle part of the Tonoloway. Locally some layers of the limestone are crowded with ostracodes. Scattered nodules of very dark gray chert occur in the middle and upper parts of the Tonoloway. In addition to considerable argillaceous matter, some beds contain much quartz silt and fine quartz sand. Locally these beds grade laterally into very calcareous sandstone or siltstone.

In the Evitts Creek quadrangle the Tonoloway can be divided into three parts. The lower 200 to 250 feet and the upper 200 feet contain much argillaceous material in the limestone as well as a considerable amount of interbedded calcareous shale. The middle 100 feet of the Tonoloway is relatively pure dark-gray to grayish-black limestone. This part of the formation was quarried for limestone in Cumberland Valley west of Shriver Ridge.

The upper boundary of the Tonoloway Limestone is well marked. Laminar, finely crystalline limestone in the upper part of the Tonoloway changes abruptly to thick-bedded clastic limestone in the basal part of the Keyser. The contact between the two formations is arbitrarily placed at the base of the oldest bed of coarsely crystalline clastic limestone above which the laminated Tonoloway-type limestone is not present. Keyser fossils are abundant in the beds a short distance above this layer of clastic limestone, and nodules of dark-gray chert are common.

The Tonoloway is about 550 to 600 feet thick in the Evitts Creek and Pattersons Creek quadrangles. The thickness is difficult to determine in most places because the formation is tightly folded and beds are duplicated. The thickness of the Tonoloway calculated by the writers closely approximated the 600-foot thickness determined by Swartz (in C. K. Swartz and others, 1923, p. 46).

AGE AND CORRELATION

The Tonoloway Limestone is of Late Silurian age and is a part of the Upper Silurian Series. It correlates with the upper part of the Bloomsburg Red Beds, the Poxino Island Shale, and the Bossardville Limestone in northeastern Pennsylvania and the adjacent part of New Jersey (C. K. Swartz and others, 1942). The Tonoloway appears to be equivalent to the lower part of the Bass Island Group of northwestern Ohio, southeastern Michigan, and southwestern Ontario, and to the Hancock Limestone of southwestern Virginia and northeastern Tennessee (C. K. Swartz and others, 1942).

The Tonoloway is only sparingly fossiliferous throughout much of its thickness; locally, however, some layers are composed largely of fossils. Ostracodes are abundant in the Tonoloway, and brachiopods, gastropods, and cephalopods are present. Swartz (in C. K. Swartz and others, 1923, p. 216–231) and Woodward (1941, p. 249–253) give extensive lists of the fossils in the various parts of the Tonoloway Limestone in Maryland and the adjacent part of West Virginia.

SILURIAN AND DEVONIAN(?) SYSTEMS

KEYSER LIMESTONE

NAME AND EXTENT

The name Keyser Limestone was introduced by Ulrich (1911, p. 563, 590–591) for the basal formation of his Helderberg Group in the central part of the Appalachian valley. The limestone was named for the town of Keyser, W. Va., and the type exposure is in the now-abandoned quarry of the Standard Lime and Stone Co. along the Baltimore & Ohio railroad about 0.75 mile east of Keyser.

The Keyser Limestone crops out in places in Wills Creek Valley south of Cooks Mills, along the west flank of Shriver Ridge, on the west side of Evitts Mountain and Irons Mountain, along the east side of Pleasant Valley, and on Martin Mountain in both Maryland and Pennsylvania. It underlies large areas at the head of Murley Branch and forms much of the crest of Warrior Mountain. The middle and upper parts of the Keyser are well exposed in the abandoned Sensabaugh Quarry about 1 mile east of the hamlet of Evitts Creek. The lower part of the formation is exposed in a small quarry on U.S. Highway 40 about 1.5 miles east of Wolfe Mill and on the west side of the Baltimore & Ohio Railroad about 0.5 mile south of Cooks Mills.

CHARACTER AND THICKNESS

The Keyser is composed mainly of medium-gray to medium-dark-gray fine- to coarsely crystalline clastic limestone. Many beds are made up of whole shells and fragments and contain little cement. A few thin beds of medium-gray calcareous shale are present in the middle and upper parts of the formation in the southern part of the mapped area. Chert is common in the Keyser, particularly in the upper 50 to 60 feet of the formation; many nodules of very dark gray to grayish-black chert are from 0.1 to 0.3 foot thick and from 0.1 to 0.6 foot long. Small ellipsoidal nodules and ramose masses of dark chert 0.25 foot in diameter also occur in the basal 20 to 25 feet of the Keyser Limestone at the type locality. Stromatoporoidal biostromes are present at several horizons in the Keyser, the thickest being in the lower and middle parts of the formation in the Evitts Creek and Pattersons Creek quadrangles. The lower half of the Keyser contains massive beds as much as 10 feet thick composed largely of stromatoporoids and corals in a matrix of fragmented fossils. Many beds of argillaceous limestone 1 to 3 inches thick occur in the middle part of the Keyser. Beds of granular clastic limestone ranging from an inch to a foot in thickness form the upper part of the formation. In fresh exposures, mainly quarries and roadcuts, bedding can be easily distinguished, although many bedding planes are irregular and stylolitic bedding surfaces are common. The more massive Keyser Limestone weathers to large rubbly-surfaced blocks in which bedding can be seen with great difficulty, if at all. The thinner bedded limestone breaks into small chunks and nodular blocks of limestone gravel that litter the hill slopes underlain by the Keyser. At some places individual fossils weather free from the surrounding matrix, but in general the process of disintegration shatters the fossils, particularly the large stromatoporoids, corals, and ramose Bryozoa.

The thick-bedded Keyser is considerably more resistant to erosion than the underlying thin-bedded Tonoloway Limestone and calcareous Wills Creek Shale. Consequently the Keyser forms many small hills and ridges in the mapped area as well as some of the higher mountains in the two quadrangles. The Keyser forms low cliffs at many places along its outcrop on the flanks of ridges and mountains, which prevent use of these slopes for pasture and crop lands.

The upper boundary of the Keyser Limestone, the base of the Helderberg Group, is the top of a sequence of thin- to medium-bedded dark-gray limestone containing many nodules of dark-gray chert. This sequence of beds is abruptly overlain by the thick-bedded crinoidal Coeymans Limestone. In the mapped area the contact between the Keyser and the Coeymans is sharp and does not appear to be disconformable, although it has been shown to be disconformable in nearby Berkeley County, W. Va. (Woodward, 1943, p. 55).

The Keyser Limestone as defined above is about 300 feet thick. The writers measured 295 feet of Keyser at the Sensabaugh Quarry near Cumberland and 285 feet at the type exposure east of Keyser, W. Va.

AGE AND CORRELATION

At present the age of the Keyser is in doubt. It has been assigned to the Early Devonian (C. K. Swartz and others, 1913a, p. 85; Swartz, F. M., 1929, p. 27) and to the Late Silurian (F. M. Swartz in Willard, Swartz, and Cleaves, 1939, table 13; Cooper, and others, 1942). Various aspects of the problem of the age of the Keyser Limestone in relation to the limestones of the Helderberg Group and in relation to the boundary between the Silurian and the Devonian Systems in different parts of the Appalachian region have been discussed by Swartz (in Willard, Swartz, and Cleaves, 1939, p. 47–50) and by Woodward (1943, p. 60–67). J. M. Berdan (oral communication, 1961) points out that the lower part of the Keyser is definitely Silurian, whereas the upper part may be either Silurian or Devonian. Because of the uncertainty as to the age of the Keyser, the limestone is classified as Silurian and Devonian(?) in this paper. The Keyser Limestone of the Evitts Creek and Pattersons Creek quadrangles is equivalent in age to the Decker Sandstone and the Rondout and Manlius Limestones of eastern Pennsylvania, and is equivalent to the Wilbur, Rosendale, Cobleskill, Rondout, and Manlius Limestones in the vicinity of Kingston, N.Y. (F. M. Swartz, in Willard, Swartz, and Cleaves, 1939, table 13).

The Keyser Limestone contains two distinct faunal zones: the "*Chonetes*" *jerseyensis* zone about 100 to 110 feet thick in the lower part and the *Favosites helderbergiae* var. *praecedens* zone about 175 to 200 feet thick in the upper part of the formation. Both zones contain an abundant fauna (C. K. Swartz and others, 1913a, p. 124–132; Woodward, 1943, p. 58–62). F. M. Swartz traced these two main zones and several subzones widely across parts of Maryland, Pennsylvania, West Virginia, and Virginia (F. M. Swartz, 1929, p. 31–37; in Willard, Swartz, and Cleaves, 1939, p. 41–47). The present writers found the following fossils in the Keyser Limestone in the Sensabaugh Quarry near Cumberland, Md.:

"*Chonetes*" *jerseyensis* zone:

Stromatopora constellata Hall
Aulopora sp.
Eridotrypa sp.
Craniops ovata Hall
Rhipidomelloides? sp.
Leptaena "*rhomboidalis*" (Wilckens)
Schellwienella sp.
"*Chonetes*" *jerseyensis* Weller
Cupularostrum giganteum (Maynard)
C. litchfieldensis (Schuchert)
Uncinulus nucleolatus (Hall)
Atrypa reticularis (Linné)
Howellella vanuxemi (Hall)
Merista typa (Hall)
Nucleospira sp.
Whitfieldella sp.
Tentaculites gyracanthus (Eaton)
Leperditia sp.
Kloedenella? sp.

Favosites helderbergiae var. *praecedens* zone:

"*Zaphrentis*" *keyserensis* Swartz
Favosites helderbergiae var. *praecedens* Schuchert
Cladopora sp.
Aulopora sp.
"*Dalmanella*" sp.
Schuchertella prolifica Schuchert
Cupularostrum altiplicatum (Hall)
Uncinulus keyserensis Swartz
Howellella vanuxemi (Hall)
Meristella sp.
Whitfieldella sp.
Tentaculites gyracanthus (Eaton)
Leperditia sp.

DEVONIAN SYSTEM

HELDERBERG GROUP

NAME AND EXTENT

The name Helderberg was given by Conrad (1839, p. 58, 62) to the group of limestones and calcareous shales that form the Helderberg

Mountains of southeastern New York. O'Harra (O'Harra and others, 1900, p. 94) recognized equivalents of the group in Allegany County, Md., and gave the name Helderberg Limestone to a stratigraphic unit that included the Tonoloway and Keyser Limestones as well as the Helderberg Group of this paper. Swartz (C. K. Swartz and others, 1913a, p. 82, 84–90) considered the Keyser Limestone to be the basal unit of the Helderberg in Maryland and excluded the Tonoloway from his Helderberg Formation. Later F. M. Swartz (in Willard, Swartz, and Cleaves, 1939, p. 50 and table 13) concluded that the Keyser was of Silurian age and excluded it from the Helderberg Group which, in the vicinity of Cumberland, Md., he restricted to the Coeymans and New Scotland Limestones and the Mandata Formation. His usage of the Helderberg Group in western Maryland is followed in this paper.

The Helderberg Group is exposed in the valley of Wills Creek south of Cooks Mills, along the west flank of Shriver Ridge, on the west sides of Evitts Mountain and Irons Mountain, along both sides of Martin Mountain, in the head of Murley Branch southeast of Twiggtown, and along the flanks and crest of Warrior Mountain.

CHARACTER AND THICKNESS

The Helderberg Group is largely limestone in this area. Chert is an important constituent of the group and locally makes up as much as 40 percent of the New Scotland Limestone. Shale is sparingly present except in the Mandata Formation which is a calcareous shale.

The upper boundary of the group, the top of the Mandata Formation, is clearly marked. Medium-dark-gray shale in the top of the Mandata is overlain by dark-gray siliceous shale and bedded chert in the basal part of the Shriver Chert. The contact between the Mandata and the Shriver appears to be conformable at the few places where it is exposed in western Maryland.

The group is 60 to 70 feet thick in the Evitts Creek and Pattersons Creek quadrangles. For convenience, on the accompanying geologic maps of the two quadrangles, the Keyser Limestone and the Helderberg Group are not divided.

AGE AND CORRELATION

The Helderberg Group is of Early Devonian age (Cooper and others, 1942). The Helderberg of the mapped area correlates with the Coeymans, New Scotland, and Becraft Limestones and possibly with the Alsen Limestone in the vicinity of Kingston, N.Y., near the south end of the Helderberg Mountains (F. M. Swartz, in Willard, Swartz, and Cleaves, 1939, table 13). The correlation of the group is based largely on paleontological data because the formations of the group cannot be traced continuously between Maryland and New York.

The strata of the Helderberg Group are commonly fossiliferous. The Coeymans Limestone is characterized by the brachiopod *Gypidula coeymanensis*, and the New Scotland Limestone contains the guide fossils "*Eospirifer*" *macropleurus* and *Kozlowskiellina perlamellosa.*

COEYMANS LIMESTONE

NAME AND EXTENT

Clarke and Schuchert (1899, p. 876–877) introduced the name Coeymans for the limestone that had been previously called the Lower Pentamerus Limestone in the Helderberg Mountains of New York. The name was applied to strata in Maryland by Swartz (in C. K. Swartz and others, 1913a, p. 86).

The Coeymans Limestone appears to have the same lateral extent as the group in the mapped area.

CHARACTER AND THICKNESS

The Coeymans is a medium-dark-gray, coarsely crystalline limestone in beds 4 to 7 feet thick. Locally it weathers into layers 6 inches to 2 feet thick. Small amounts of quartz silt in the limestone impart a gritty feeling to the weathered rock, and segments of crinoid stems commonly weather in relief on the bedding surfaces. Some nodules of dark-gray to dark-brownish-gray chert are present in the Coeymans at the Sensabaugh Quarry. The presence of the nodular chert and the absence of the guide fossil *Gypidula coeymanensis* at this locality make it difficult to distinguish the Coeymans from the upper beds of the Keyser.

The upper boundary of the Coeymans is conformable. The massive Coeymans is abruptly overlain by light-gray limestone and light-colored chert in the basal beds of the New Scotland Limestone.

The Coeymans is 7 to 10.5 feet thick in the area. The writers measured 10 and 10.4 feet of Coeymans Limestone in the Sensabaugh Quarry. The limestone appears to be thinner in the vicinity of Big Knob where about 7 feet of crinoidal limestone crops out on the west face of the knob.

AGE AND CORRELATION

The Coeymans Limestone is of Early Devonian age (Cooper, and others, 1942). The Coeymans of the mapped area is the correlative of the Coeymans Limestone of the Helderberg Mountains of southeastern New York. It is equivalent to the Olive Hill Formation of Western Tennessee (F. M. Swartz, 1929, p. 40).

Although the Coeymans is generally fossiliferous, the fossils commonly do not weather free and are difficult to collect from the massive strata. The writers found the following fossils in the Coeymans at the Sensabaugh Quarry east of Cumberland:

Leptostrophia sp.
Schellwienella sp.
Uncinulus sp.
Atrypa "reticularis" (Linné)
Kozlowskiellina cf. *K. perlamellosa* (Hall)
Nucleospira sp.
Platyceras? sp.

NEW SCOTLAND LIMESTONE

NAME AND EXTENT

The New Scotland Limestone was named by Clarke and Schuchert (1899, p. 876–877) for exposures of the limestone in the vicinity of the village of New Scotland, Albany County, N.Y. In the Evitts Creek and Pattersons Creek quadrangles, the New Scotland Limestone has the same lateral extent as the other formations of the Helderberg Group.

CHARACTER AND THICKNESS

The New Scotland is a medium-light-gray, fine- and medium-textured fossiliferous cherty limestone in beds 2 inches to 1 foot thick. Nodular-bedded white, pink, tan, and light-gray chert is abundant and locally makes up as much as 40 percent of beds in the lower part of the formation. In fresh exposures the limestone is readily seen, but in weathered outcrops only the chert is observed. Hill slopes underlain by the New Scotland are commonly covered by slabs of massive chert as much as 8 inches thick, 2 to 3 feet wide, and 3 to 4 feet long embedded in a gravel of small angular blocks of chert. Such hill slopes are rarely cleared for cultivation because of the large amount of residual chert. At places where the New Scotland is steeply inclined, solution has produced small sink holes 10 to 30 feet long and 6 to 10 feet deep in the limestone. The alinement of these sink holes on the New Scotland facilitates tracing the formation across covered intervals. Chert from the New Scotland Limestone and from the Shriver Chert becomes mixed on many of the broad hilltops of the mapped area. Discrimination between the two types of chert is difficult in the absence of guide fossils, but, in general, the chert from the New Scotland is light colored and tends to remain hard, whereas chert from the Shriver is darker colored and weathers more into a soft porous mass.

The boundary between the New Scotland Limestone and the overlying Mandata Formation is gradational through an interval of 6 to 9 inches in which lenticular beds of medium-gray limestone are intercalated in medium-gray calcareous shale. The writers draw the contact at the top of the youngest bed of limestone.

The New Scotland Limestone is about 25 feet thick in the mapped area. The writers measured 23.8 feet of New Scotland Limestone in the Sensabaugh Quarry east of Cumberland. Swartz (in C. K. Swartz and others, 1913a, p. 168–175) reports thicknesses ranging from 25 to 30 feet in the vicinity of Cumberland. The thickness determined by the writers agrees closely with the 20- to 25-foot thickness of New Scotland reported by Woodward (1943, p. 85) in western Maryland and northeastern West Virginia.

AGE AND CORRELATION

The New Scotland Limestone in the Evitts Creek and Pattersons Creek quadrangles is of Early Devonian age (F. M. Swartz, 1929, p. 27). On the basis of its stratigraphic position and faunal content, it appears to be correlative with the New Scotland Limestone of the type area in eastern New York.

The New Scotland contains many fossils. Recovery of fossils from the formation is difficult, however, because weathering dissolves the fossils in the limestone, and the fossils in the chert are commonly destroyed when the chert disintegrates into small chips and blocks. The writers found the following in the New Scotland Limestone in the mapped area:

Favosites helderbergiae Hall
Orbiculoidea cf. *O. discus* (Hall)
Rhipidomelloides oblata (Hall)
Leptaena? sp.
Leptostrophia sp.
Schellwienella woolworthana (Hall)
Chonetes? sp.
?*Cupularostrum altiplicatum* (Hall)
Costellirostra singularis (Vanuxem)
Atrypa reticularis (Linné)
Howellella cycloptera (Hall)
Kozlowskiellina perlamellosa (Hall)
"*Eospirifer*" *macropleurus* (Conrad)
Meristella sp.
Trematospira multistriata (Hall)
Actinopteria? sp.
Platyceras? sp.
Tentaculites sp.
Phacops logani Hall
Crinoid plates

MANDATA FORMATION

NAME AND EXTENT

The name Mandata was proposed by F. M. Swartz (1938, p. 1923) for beds of shale and chert above the New Scotland Limestone in central Pennsylvania. In the Evitts Creek and Pattersons Creek quadrangles the Mandata, which is composed almost entirely of shale, lies above the New Scotland Limestone and below the Shriver Chert.

The areal extent of the Mandata Formation appears to be the same as that of the other formations in the group. The writers found no complete exposure of the formation in either quadrangle, although the Mandata is partly exposed at the top of the high wall of the Sensabaugh Quarry. The formation is well exposed in an abandoned quarry of the Standard Lime and Stone Co. east of Keyser, W. Va., in the

Keyser quadrangle, and along the Western Maryland Railway at Corriganville, Md., in the Cumberland quadrangle.

CHARACTER AND THICKNESS

In the mapped area the Mandata is a medium-gray to medium-light-gray slightly calcareous shale which weathers rapidly to a dusky-yellow clay. Because the Mandata Formation is a soft unit between two more resistant formations—the New Scotland Limestone below and the Shriver Chert above—it is generally obscured by float from these formations. Consequently, the Mandata is seen only in manmade excavations.

The upper boundary of the formation is clearly defined. The basal cherty beds of the Shriver abruptly overlie the gray shale of the Mandata.

The Mandata Formation is about 20 feet thick in the Evitts Creek and Pattersons Creek quadrangles. The writers were unable to measure a complete thickness of the formation in the exposure at the Sensabaugh Quarry. They measured 18.6 feet of Mandata at the now-abandoned quarry of the Standard Lime and Stone Co. near Keyser, W. Va.

AGE AND CORRELATION

The Mandata Formation is of Early Devonian age. As yet the stratigraphic relationship of the Mandata with contiguous rocks has not been satisfactorily worked out, and the relationship of the Mandata with the Helderberg Group of New York is uncertain. According to F. M. Swartz (in Willard, Swartz, and Cleaves, 1939, p. 68–69) the lower part of the Mandata Formation contains a New Scotland fauna and is equivalent in age to the New Scotland Limestone of New York, whereas the upper part of the Mandata may be considerably younger than the New Scotland of New York.

The writers did not find fossils in the Mandata Formation in the Evitts Creek and Pattersons Creek quadrangles. C. K. Swartz (in Swartz and others, 1913a, p. 89) reported the following fossils in the rocks which make up the Mandata Formation at Twenty-first Bridge near Keyser, W. Va.:

Platyorthis planiconvexa (Hall)
Rhipidomelloides oblata (Hall)
Leptaena "rhomboidalis" (Wilckens)
Schellwienella woolworthana (Hall)
Anoplia helderbergiae Rowe
"Eospirifer" macropleurus (Conrad)
Meristella arcuata (Hall)
?*Ambocoelia umbonata* (Conrad)
Trematospira multistriata (Hall)

ORISKANY GROUP

NAME AND EXTENT

The name Oriskany was first applied by Vanuxem (1839, p. 273) to the fossiliferous white sandstone that crops out at Oriskany Falls, Oneida County, N.Y. Hall (1857, p. 63) first used the name Oriskany for the sandstone at Cumberland that is lithologically and faunally similar to the Oriskany Sandstone of New York. Swartz (in C. K. Swartz and others, 1913a, p. 91) divided the Oriskany Formation into the Shriver Chert Member below and the Ridgeley Sandstone Member above. In the present report the Oriskany is recognized as a group containing two formations—the Shriver Chert below and the Ridgeley Sandstone above.

The Oriskany Group, which is unusually resistant to weathering, covers large areas on the crests and flanks of many of the mountains and ridges in the Evitts Creek and Pattersons Creek quadrangles. Pine Ridge, Collier Mountain, and Patterson Creek Ridge are entirely underlain by the Oriskany. Most of Irons Mountain and Martin Mountain, much of the east flank of Shriver Ridge, and large areas on both flanks of Warrior Mountain are underlain by the Oriskany Group.

CHARACTER AND THICKNESS

The Oriskany Group is composed of two types of rock. The lower formation, the Shriver Chert, consists largely of thin- to medium-bedded, very calcareous gray siltstone, siliceous siltstone, and thin beds, layers, and nodules of very dark gray to grayish-black chert. The upper formation, the Ridgeley Sandstone, consists largely of medium- to thick-bedded, fine to very coarse grained, medium-gray to light-gray sandstone.

The boundaries of the Oriskany Group are very sharply defined. The Oriskany is abruptly overlain by the Needmore Shale. The contact is knife sharp in many places.

In the Evitts Creek and Pattersons Creek quadrangles the Oriskany Group is about 330 feet to 350 feet thick.

AGE AND CORRELATION

The Oriskany Group is of late Early Devonian age. The lithologic similarity between the Ridgeley Sandstone of the Oriskany Group in the central Appalachians and the Oriskany Sandstone at its type area in New York, the general similarity of the faunas, and the presence of the guide fossil *Costispirifer arenosus* in both areas indicate that the Oriskany of Maryland is closely equivalent to the Oriskany of New York.

The Oriskany Group, especially the upper part of the Ridgeley Sandstone, is very fossiliferous. Brachiopods are common and are characteristically very large and heavily ribbed. Crinoids, pelecypods, gastropods, ostracodes and a few trilobites and corals are present in the fauna.

SHRIVER CHERT

NAME AND EXTENT

Early workers (O'Harra, 1900, p. 96; Schuchert, 1903, p. 422) realized that the Oriskany included two lithologically distinct units. Swartz (in C. K. Swartz and others, 1913a, p. 91–92) proposed the name Shriver Chert Member for the lower part of the Oriskany. The Shriver was named for exposures on Shriver Ridge in the vicinity of Cumberland, about 0.7 mile west of the west edge of the Evitts Creek quadrangle.

The Shriver Chert underlies much of the east flank of Shriver Ridge; a narrow belt along the lower part of the west flank of Evitts Mountain; much of the crest of Irons Mountain, Nicholas Ridge, and Collier Mountain; and part of the west flank of Martin Mountain. The chert is well exposed along the Western Maryland Railway across the south end of Nicholas Ridge where all but the lower 20 to 30 feet of the formation crops out. The Shriver is fairly well exposed on Williams Road about 0.2 mile east of Mount Hermon Church and on U.S. Highway 40 near the crest of Martin Mountain.

CHARACTER AND THICKNESS

The Shriver consists largely of siltstone, chert, and shale. Much very dark gray to grayish-black chert occurs in the lower half of the unit in thin beds and in layers of small- to medium-sized discoidal and ovoid nodules. The lower half of the Shriver also contains some dark-gray calcareous irregularly fissile shale in stringers and thin partings between beds of siltstone. The upper half of the Shriver consists largely of medium-dark-gray medium- to thick-bedded, very calcareous siliceous siltstone. Some beds of siltstone near the top of the Shriver contain as much as 30 percent calcium carbonate. Little chert is present in the upper part of the formation. Three or four very thin beds of soft limonitic shale are present in the upper part of the Shriver.

Weathering of the Shriver removes calcium carbonate from the siltstone, devitrifies the chert, accentuates bedding planes by softening the beds and stringers of shale, and changes the color of the rock from dark gray to yellow, tan, and brown. Continued weathering breaks down the Shriver into rectangular blocks of siltstone and chert and produces a porous gravelly light-yellowish-brown or orange-brown soil containing small blocks of very light yellowish-gray chert.

The Shriver Chert grades into the overlying Ridgeley Sandstone through a 12-foot interval of alternating beds of very calcareous cherty siltstone and fine to very coarse grained fossiliferous sandstone. The boundary between the Shriver and the Ridgeley is arbitrarily placed at the base of the lowest bed of sandstone.

In the mapped area the Shriver Chert is about 160 to 170 feet thick. It is 164 feet thick in the Sensabaugh Quarry. The thickness of the Shriver was not measured in the Pattersons Creek quadrangle because of the lack of complete exposure.

AGE AND CORRELATION

The Shriver Chert is late Early Devonian in age. Correlation of the Shriver with other rock units in the Appalachian area is uncertain. The Shriver Chert of Maryland is thought by some (C. K. Swartz and others, 1913a, p. 122) to be equivalent to the lower part of the Oriskany Sandstone in New York. Others (Cooper and others, 1942) believe that the Shriver of Pennsylvania, Maryland, and West Virginia is older than the Oriskany Sandstone at the type area in eastern New York. Woodward (1942, p. 32, 35–36) included the Shriver at Cumberland, Md., in the upper part of his Helderberg Group, and applied the names Port Ewen Limestone and Port Jervis Limestone to the lower and upper parts, respectively, of the Shriver Chert of this report. The present writers believe that there is insufficient evidence to justify extending the names Port Ewen and Port Jervis from their type localities in southeastern New York to the central Appalachian area.

RIDGELEY SANDSTONE

NAME AND EXTENT

The name Ridgeley Sandstone Member was proposed by Swartz (in C. K. Swartz and others, 1913a, p. 92) to designate the very fossiliferous beds of sandstone in the upper part of his Oriskany Formation—the Oriskany Group in this report—in Allegany County, Md., and the adjacent part of West Virginia. The type locality was designated as Knobly Mountain in the vicinity of Ridgely, Mineral County, W. Va. The name is spelled Ridgeley in the U.S. Postal Guide, and this spelling has been accepted by later workers in accord with the recommendations of the U.S. Board of Geographic Names. The name Ridgeley has been applied to similar-appearing rocks that occur at the same stratigraphic position in Pennsylvania and West Virginia.

The Ridgeley Sandstone underlies large areas of the ridges and mountains in the Evitts Creek and Pattersons Creek quadrangles.

It underlies Pine Ridge; Patterson Creek Ridge; most of Collier Mountain, Nicholas Ridge, and Irons Mountain; large areas along the east flank of Shriver Ridge; much of Martin Mountain; and large areas on both flanks of Warrior Mountain. The Ridgeley is completely exposed along the Western Maryland Railway near the south end of Nicholas Ridge.

CHARACTER AND THICKNESS

The Ridgeley consists largely of medium-dark-gray to light-bluish-gray calcareous quartz sandstone. The beds of sandstone generally range in thickness from a fraction of an inch to 8 feet, but the average is from 2 to 3 feet. The Ridgeley is composed largely of fine-grained to medium-grained quartz sand, although quartz grains are present from silt-sized particles to oblong pebbles as much as three-fifths of an inch in length. Pebbles in thin stringers and beds of conglomerate are intercalated in thicker beds of sandstone in the lower and upper parts of the formation. The sandstone is commonly very fossiliferous. Some 1- to 5-inch lenticular beds of very soft earthy hematitic shale are present in the Ridgeley. Cementing material in the formation consists of both calcium carbonate and silica. In areas where calcium carbonate cement predominates, the Ridgeley weathers rapidly to orange-brown sand. In areas where silica cement predominates, the Ridgeley weathers slowly into medium-sized to large angular blocks of gray to tan sandstone.

Both boundaries of the Ridgeley Sandstone are sharply defined where the rocks are well exposed, as they are along the Western Maryland Railway near the south end of Nicholas Ridge. However, the boundaries are visible in few other places in the mapped area. The contact between the Ridgeley Sandstone and the overlying Needmore Shale is knife sharp. Soft dark-brownish-gray shale in the lower part of the Needmore abruptly overlies coarse-grained sandstone in the upper part of the Ridgeley. This boundary, which is marked in some places in the vicinity of the mapped area by a thin lenticular bed of lean hematite ore in the base of the Needmore Shale, was thought to be unconformable by some earlier workers (Darton, 1892; C. K. Swartz and others, 1913a, p. 95). The present writers did not find evidence in the Evitts Creek and Pattersons Creek quadrangles to show that the contact represents more than an abrupt change in the type of sediment deposited.

In the Evitts Creek and Pattersons Creek quadrangles, the Ridgeley Sandstone ranges in thickness from 144 to 175 feet. Along the Western Maryland Railway tracks across the southern part of Nicholas Ridge the Ridgeley is 144 feet thick; in the Sensabaugh Quarry the Ridgeley is 164 feet thick.

AGE AND CORRELATION

The Ridgeley Sandstone in the central Appalachian area is approximately equivalent to the Oriskany Sandstone at its type area near Oriskany Falls, Oneida County, N.Y. *Costispirifer arenosus* (Conrad), long considered to be a reliable guide fossil of the Oriskany Sandstone in New York, is present in the Ridgeley Sandstone in Pennsylvania, Maryland, and West Virginia.

The Ridgeley Sandstone, especially the upper part of the formation, is extremely fossiliferous. Many gastropods, corals, crinoids, pelecypods, and trilobites occur in the formation, but the fauna consists largely of medium-sized to large heavy-shelled brachiopods. Among the diagnostic brachiopods are: *Costispirifer arenosus*, *Acrospirifer murchisoni*, *Rensselaeria circularis*, *R. marylandica*, and *Hipparionyx proximus*.

NEEDMORE SHALE

NAME AND EXTENT

The Needmore Shale, a name herein adopted, was named by Willard (in Willard, Swartz, and Cleaves, 1939, p. 149) for exposures of the shale in the area between Needmore and Warfordsburg, Fulton County, Pa.

In the mapped area it occurs in narrow belts that parallel the flanks of many mountains and ridges held up by the Oriskany Group. The Needmore is not resistant to weathering; it underlies topographically lower ground than the much more resistant rocks of the stratigraphically lower Oriskany Group. The lower 70 feet of the Needmore is well exposed along the Western Maryland Railway near the south end of Nicholas Ridge, but the upper part of the formation is covered. The upper part of the Needmore is well exposed along the same railroad about 0.4 mile southeast of Spring Gap.

CHARACTER AND THICKNESS

The Needmore consists largely of soft calcareous medium-dark-brownish-gray and greenish-gray shale and mudrock and of soft, slightly calcareous very fissile brownish-black shale. The proportions of gray shale and black shale vary from place to place. At most places the middle third of the formation consists largely of black shale, whereas the lower and upper parts consist largely of lighter colored shale and mudrock. Many thin lenticular beds of resistant dark-gray argillaceous limestone and numerous layers of dark-gray to medium dark-gray argillaceous limestone nodules and concretions occur in the upper third of the Needmore. The nodules and concretions range in thickness from 1 to 10 inches and in diameter from 2 inches to 5 feet.

The gray shale and mudrock of the Needmore weathers rapidly into very small light olive-gray to light-tan chips, and black shale weathers rapidly into very thin grayish-white chips and flakes.

The upper boundary of the Needmore Shale is well defined at the few places where it is exposed. Medium-gray shale in the upper part of the Needmore is sharply overlain by black shale in the basal part of the Marcellus. In the southern part of the Pattersons Creek quadrangle, the base of a bed of siltstone about 8 inches thick in the bottom of the Marcellus Shale marks the contact of the Needmore with the Marcellus. The two formations are soft incompetent rocks that are commonly poorly exposed and complexly infolded at many places. In the absence of well-exposed sections, the boundary between the formations cannot be delineated accurately; consequently, on the accompanying geologic maps the Needmore Shale and the Marcellus Shale are not divided.

The writers found no exposures in the Evitts Creek and Pattersons Creek quadrangles where the thickness of the Needmore Shale could be measured accurately. In most places, the formation is either covered by soil or float from the adjacent Ridgeley Sandstone, or it is contorted by numerous small sharp folds. The Needmore is probably about 150 feet thick in this area. The most nearly complete exposure examined by the writers is along Williams Road near Mount Hermon Church. The lower part of the Needmore is repeated by faulting in this outcrop and the beds near the top of the formation are poorly exposed, but the outcrop width indicates an apparent thickness of approximately 150 feet.

AGE AND CORRELATION

The Needmore Shale is early Middle Devonian in age according to Willard (in Willard, Swartz, and Cleaves, 1939, p. 134) and Woodward (1943, p. 253, 254). Cooper and others (1942, p. 1732–1733 and chart), however, briefly discuss the possibility that the Onondaga—and the equivalent Needmore—are Early Devonian in age. Since the work of Kindle (1912), most geologists are agreed that the Needmore Shale in south-central Pennsylvania, western Maryland, and northern West Virginia is equivalent to the Onondaga Limestone at its type area in Onondaga County, N.Y.

Fossils are abundant in the calcareous rocks of the Needmore and scarce in the beds of dark-gray and black shale. The fauna consists mainly of brachiopods and trilobites. The brachiopods *Coelospira acutiplicata* and *Eodevonaria arcuata*, the ostracode *Favulella favulosa*, and the trilobite *Phacops cristata* are diagnostic of the Needmore.

The writers identified the following fossils in the Needmore from outcrops on Christie Road and Williams Road:

Orbiculoidea lodiensis (Vanuxem)
Chonetes mucronatus Hall
Anoplia? sp.
Anoplotheca acutiplicata (Conrad)
Naticopsis? sp.
Coleolus? sp.
Agoniatites vanuxemi (Hall)
Bactrites? *aciculum* Hall
Phacops cristata Hall

MARCELLUS SHALE

NAME AND EXTENT

The name Marcellus was proposed by Hall (1839, p. 295) to designate a sequence of black shale overlying the Onodaga Limestone near the town of Marcellus, N.Y. The name Marcellus has been applied by geologists in Pennsylvania, Maryland, and West Virginia to beds of black shale approximately equivalent in age to the Marcellus in New York. These rocks have been called the Marcellus Formation in Pennsylvania (Willard, 1939, p. 163–164, 166), the Marcellus Shale in West Viriginia (Woodward, 1942, p. 253–254, 311), and the Marcellus Member of the Romney Formation in Maryland (C. K. Swartz, and others, 1913b, p. 49–50; Cloos and others, 1951, p. 87; Amsden and others, 1954, p. 76–77). The name Marcellus Shale is recognized by the U.S. Geological Survey (Wilmarth, 1938, p. 1286–1296), and is so used in this paper.

The Marcellus, like the Needmore Shale, extends in narrow belts along the sides of valleys between the mountains and ridges formed by the more resistant rocks of the Oriskany and Helderberg Groups. The Marcellus is completely exposed along the Baltimore & Ohio Railroad, 0.65 mile south of Bethel Tabernacle, and most of the formation well exposed along the Western Maryland Railway between Nicholas Ridge and Collier Mountain. The Marcellus is present in exposures along Williams Road a few yards east of Mount Hermon Church, but, at this locality, the upper third of the formation is very poorly exposed.

CHARACTER AND THICKNESS

The Marcellus is composed of two different types of rocks. The lower and upper parts of the formation consist of nonresistant black and olive-black nonpetroliferous noncalcareous shale. At some places, several layers of hard dark-gray argillaceous limestone nodules and septaria 1.5 to 15 inches thick and 4 inches to 4 feet in diameter are interbedded in the black shale in the lower part of the Marcellus. The middle third of the Marcellus, which is lithologically similar to the upper part of the Needmore Shale, consists largely of nonresistant medium-olive-gray calcareous mudrock and irregularly fissile shale. Many layers of medium-dark-gray argillaceous limestone nodules and beds of resistant nodular to massively bedded medium-gray argillaceous limestone from a few inches to about 2 feet thick are present in the middle part of the formation. A resistant bed of laminated dark-gray siltstone about 8 inches thick occurs at the base of the Marcellus in some exposures in the southern part of the Pattersons Creek quadrangle and the northern part of the contiguous Hanging Rock 15-minute quadrange.

The Marcellus readily weathers into very small buff to grayish-white chips and forms an infertile clayey soil.

The upper boundary of the Marcellus is sharply marked at most places where the rock is well exposed. It is visible however, at only a few places. In the Evitts Creek quadrangle, black shale in the upper part of the Marcellus is overlain by dark to very dark gray shale in the lower part of the Mahantango. In the Pattersons Creek quadrangle the lower part of the Mahantango contains some beds of siltstone, and the base of the lowest siltstone is picked as the contact between the Marcellus Shale and the Mahantango Formation. Former geologists working in Allegany County, Md., designated the highest occurrence of *Leiorhynchus limitare* as the top of the Marcellus. The top of the Marcellus so delimited is about 250 feet above the contact that the present writers drew by using lithologic criteria.

The Marcellus Shale is about 227 to 255 feet thick in the mapped area. It is 250 feet thick along the Baltimore & Ohio Railroad southwest of Bethel Tabernacle, and about 255 feet thick along Williams Road east of Mount Hermon Church.

AGE AND CORRELATION

The Marcellus Shale is early Middle Devonian in age. In lithology and in faunal content the Marcellus in the study area is very similar to the Marcellus at its type locality in east-central New York.

The fauna of the Marcellus Shale is sparse. The brachiopod *Leiorhynchus limitare* and the pteropod *Styliolina fissurella* are the most abundant fossils. Other small brachiopods, a few pelecypods, gastropods, and cephalopods have been reported from the formation (C. K. Swartz and others, 1913b, p. 105–108; Woodward, 1943, p. 327). Different criteria have been used by several geologists to delimit the lower and upper boundaries of the Marcellus. For this reason, some of the fossils reported as belonging to the Marcellus may have been collected from contiguous parts of either the Needmore Shale below or the Mahantango Formation above.

MAHANTANGO FORMATION

NAME AND EXTENT

Willard (1935a, p. 205) proposed the name Mahantango Formation to designate the rocks in central Pennsylvania that extend from the top of the Marcellus Shale to the base of the so-called Portage; the type area of the formation is the North Branch of Mahantango Creek in Snyder County, Pa. Later Willard (1935b, pl. 95) showed that the Mahantango in the vicinity of its type area is overlain by the Burket Member of his Rush Formation. The Burket Member of the Rush Formation of Willard seems to be equivalent to the Burket Shale Member of the Harrell Shale of this report. Willard (1935c) traced the Mahantango southwestward from central Pennsylvania to the vicinity of Cumberland, Md. In the Evitts Creek and Pattersons Creek quadrangles the present writers include in the Mahantango Formation all rocks between the top of the Marcellus Shale and the base of the Harrell Shale. In western Maryland the rocks of the Mahantango have been called the Hamilton Member of the Romney Formation (C. K. Swartz and others, 1913b, p. 50; Cloos and others, 1951, p. 88; Amsden and others, 1954, p. 76). In adjacent parts of northeastern West Virginia, rocks equivalent to the Mahantango Formation have been named the Hamilton Series (Reger, 1924, p. 308; Tilton, 1927, p. 309) and the Hamilton Formation (Woodward, 1942, p. 330–336). The writers doubt the advisability of restricting the name Hamilton to the rocks above the Marcellus Shale in Maryland, because in New York the Marcellus Shale is considered a formation in the Hamilton Group. Consequently they propose to adopt Willard's name Mahantango Formation (Willard, 1935a, p. 205) for the rocks above the Marcellus Shale and below the Harrell Shale.

The Mahantango Formation occupies narrow belts along both sides and part of the center of the valley of Evitts Creek. A wider belt of the Mahantango extends from the southwest corner of the Pattersons Creek quadrangle northeastward to a point near the head of Mill Run not far from the north edge of the quadrangle, and southward along the west flank of Warrior Mountain and the east side of the quadrangle to the south edge of the Pattersons Creek quadrangle.

CHARACTER AND THICKNESS

The Mahantango is roughly divisible into two parts—a lower part composed largely of shale and an upper part composed largely of mudrock, siltstone, and sandstone. The lower part of the Mahantango, about 450 feet thick, consists mainly of homogeneous nonresistant slightly calcareous medium-gray to very dark gray shale and mudrock. South of the North Branch of the Potomac River many beds of resistant fossiliferous medium light-gray to light-tan siltstone, from a fraction of an inch to 17 inches thick, are present near the bottom of the formation. In most places north of the Potomac River the siltstones are fewer in number, thinner, less resistant to weathering, and less fossiliferous. The lower part of the Mahantango rapidly weathers into very small ash-colored chips and flakes of shale, and eventually forms a very light gray to orange-tan clay soil.

The upper part of the Mahantango Formation, approximately 600 feet thick, consists largely of dark-gray, slightly calcareous, very silty mudrock and medium-gray even-bedded to irregularly bedded, very coarse grained siltstone and very fine grained sandstone (fig. 4). Beds of siltstone and sandstone comprise about 20 percent of the upper part of the Mahantango and generally range in thickness from 2 inches to 4 feet. A 30- to 55-foot sequence composed almost entirely of medium- to thick-bedded siltstone and sandstone occurs from 13 feet to 60 feet below the top of the formation (fig. 5). In many exposures in the southern part of the Pattersons Creek quadrangle, the uppermost bed of this siltstone sequence contains a great number of brachiopods, bryozoa, and corals, and many *Taonurus caudagalli*. The resistant sequence of siltstone and sandstone forms a sharp ridge near the upper contact of the Mahantango throughout much of the mapped area. A similar but thinner sequence of siltstone near the middle of the formation forms another ridge near the center of the outcrop belt of the Mahantango. Both ridges are shown on the accompanying maps. Many layers of spherical to ovoid nodules of ferruginous limestone from 2 to 7 inches thick and from 4 inches to 1 foot in diameter are imbedded in a sequence of very silty mudrock, about 25 feet thick, just below the upper sequence of ridge-forming siltstone and sandstone.

The very silty mudrock in the upper 600 feet of the Mahantango weathers spheroidally in most exposures. (See fig. 4). The spheres are as much as 6 feet in diameter. Continued weathering causes the spheres to disintegrate into small irregularly prismoidal, slightly curved chips, and the color of the rock changes from dark gray to medium dark reddish brown. Prolonged weathering of the Mahantango rocks produces a clayey, moderately fertile soil.

In most places where the rocks are well exposed, the upper contact of the Mahantango is sharply defined. The gray shale, mudrock, siltstone, and sandstone in the upper part of the Mahantango are abruptly overlain by very dark gray and grayish-black shale of the lower part of the Harrell Shale. The upper boundary of the Mahantango Formation is well exposed along Maryland Highway 51 about 0.6 mile east of Old Mount Tabor Church, along the Western Maryland Railway 0.8 mile southeast of Old Mount Tabor Church, and on U.S. Highway 40 about 0.35 mile west of Wolfe Mill.

At the top of the Mahantango in parts of the central Appalachians, Willard (1939, p. 164) and Woodward (1943, p. 332, 334) have reported a disconformity which may represent either a period of erosion or a period of nondeposition at the end of Mahantango time.

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The present writers found no conclusive evidence of such a disconformity at the top of the Mahantango Formation in the Evitts Creek and Pattersons Creek quadrangles.

The thickness of the formation can be measured accurately at only a few places in the mapped area. The Mahantango is about 1,030 feet thick along Williams Road in the vicinity of Mount Hermon Church. A thickness of 1,350 feet was determined by plane table and alidade along the Western Maryland Railway about 0.65 mile south of Old Mount Tabor Church; however, in these exposures much of the lower part of the formation is covered, and the apparent thickness may be excessive owing to repetition of beds by folding in the covered interval.

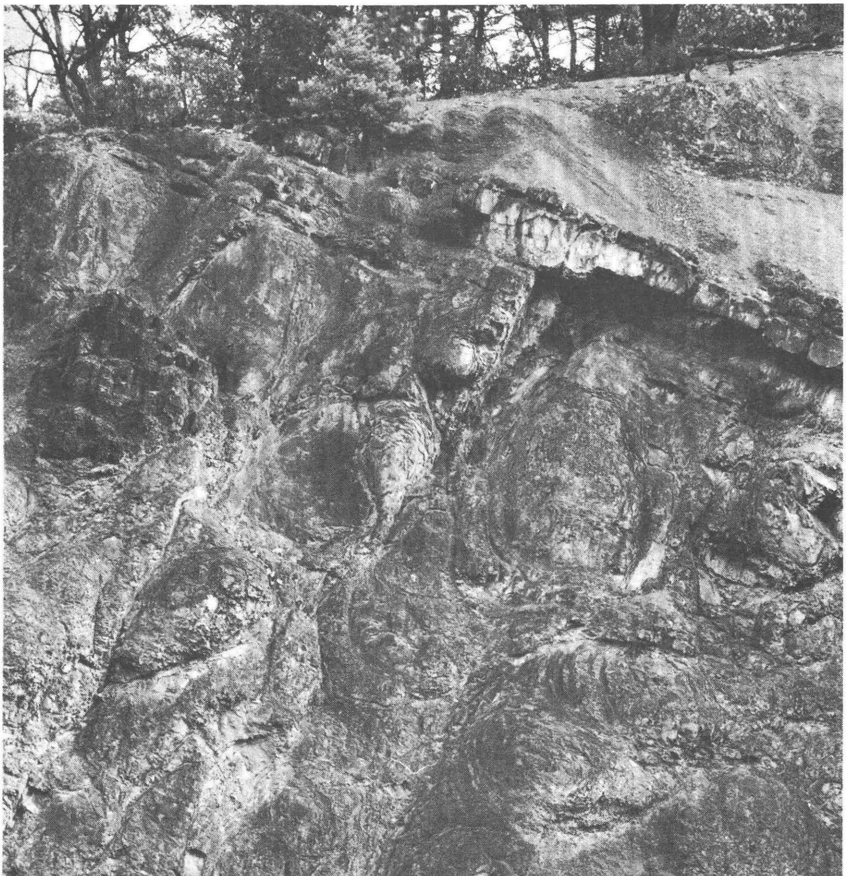

FIGURE 4.—Spheroidal weathering in the Mahantango Formation; silty mudrock and thin-bedded siltstone in the middle of the Mahantango Formation exposed in a cut along the Western Maryland Railway about 0.7 mile east of Spring Gap, Md., showing typical development of spheroidal weathering in the silty mudrock. Individual spheres are about 6 feet in diameter.

FIGURE 5.—Contrast in weathering between massive siltstone and silty mudrock in the Mahantango Formation; basal part of the sequence of massive siltstone in the upper part of the Mahantango exposed in a cut along the Western Maryland Railway about 0.9 mile east of Spring Gap, Md. Calcareous nodules about 0.4 foot in diameter in the lower 1.5 feet of the siltstone are rarely observed in natural outcrops. The siltstone weathers in slabs, whereas the mudrock weathers typically in small irregular-shaped blocks and chips.

AGE AND CORRELATION

The Mahantango Formation is Middle Devonian in age. It is underlain by the Marcellus Shale of early Middle Devonian age, and is overlain by the Harrell Shale of early Late Devonian age. In the central Appalachians the rocks, which are called Mahantango in this report, have long been correlated with the post-Marcellus rocks of the Hamilton Group in New York (C. K. Swartz and others, 1913b, p. 43–46, 50–51). The faunal and lithologic similarities between the Mahantango Formation in the mapped area and the upper part of the Hamilton Group at its type area in central New York are striking.

The lower part of the Mahantango is sparsely fossiliferous in most places. In some exposures in the southern half of the Pattersons Creek quadrangle, however, the brachiopods *Leiorhynchus limitare* and *L. laura* occur in profusion in the basal part of the formation. The upper part of the formation is very fossiliferous. Brachiopods are the most common forms, but pelecypods, gastropods, and cephalopods are common in some exposures. "*Spirifer*" *tullius*, *Pustulina pustulosa*, the coral *Stereoelasma rectum*, and the imprint of *Taonurus* *caudigalli* are extremely common near the top of the Mahantango.

Hass (written comm., 1957) identified the following conodonts from the upper 25 feet of the Mahantango Formation along Highway 40 about 0.4 mile west of Wolfe Mill:

Bryantodus typicus Ulrich and Bassler
Hindeodella sp.
Ligonodina sp.
Neoprioniodus sp.
Ozarkodina sp.
Polygnathus pennata Hinde

HARRELL SHALE, INCLUDING THE BURKET BLACK SHALE MEMBER

NAME AND EXTENT

The name Harrell was proposed by Butts (1918, p. 523, 536) to designate a sequence of interbedded silty gray, very dark gray, and grayish-black to black shale in the vicinity of Harrell, Blair County, Pa. At the type locality the Harrell overlies the Hamilton Group and underlies the rocks that are here included in the Woodmont Shale. As originally defined by Butts (1918, p. 523, 536), the Harrell contains some beds of gray shale and siltstone in the upper part that the present writers place in the lower part of their Woodmont. Butts recognized a member—the Burket Black Shale Member—in the basal part of his Harrell Shale in the western part of the Hollidaysburg quadrangle. The writers follow Butts' usage of the name Burket by considering the Burket as a member of the Harrell Shale. The Burket, which is a black shale facies of the Harrell, is present only in the northwestern part of the mapped area. It interfingers to the east with lighter colored shale of the Harrell and cannot be positively identified east of the Evitts Creek quadrangle, or east of the center of the Pattersons Creek quadrangle. The Burket is chiefly equivalent to part of the Harrell Shale.

The Harrell Shale underlies areas along the sides and a small area in the center of the southern part of the valley of Evitts Creek. One outcrop extends along the west side of Irons Mountain southward almost to Plum Run. Another outcrop of the Harrell extends from the southwest corner of the Pattersons Creek quadrangle northeastward to the vicinity of Olivers Grove Church on Walnut Ridge, where the trend is reversed and the outcrop swings southward in an irregular line to the south edge of the quadrangle about 0.6 mile west of Green Spring Run.

Most of the Harrell Shale is well exposed along U.S. Route 40 about 0.35 mile west of Wolfe Mill; the lower part is covered by the highway. The formation is completely exposed along Maryland Route 51 0.8 mile east of Mount Tabor Church, and well exposed along the Western Maryland Railway 0.9 mile southeast of Spring Gap. At the last-mentioned exposure, however, the contact between the Harrell and the Woodmont Shale is concealed.

CHARACTER AND THICKNESS

The Harrell is composed largely of homogeneous well-laminated platy-weathering, slightly calcareous, very dark gray shale and some fissile grayish-black to black shale. Some fissile medium-gray shale, and very thin beds and laminae of light-gray siltstone are present in the formation. Beds of gray shale and siltstone increase in thickness and number eastward across the mapped area; conversely, the percentage of very dark gray to black shale decreases eastward. In the central part of the mapped area, fissile black shale is restricted to a few thin beds in the lower half of the formation. In the northwestern part of the mapped area, however, the Burket Member forms the lower half of the formation, and consists largely of grayish-black to black shale. A few limestone nodules and septaria 3 to 8 inches thick and 6 to 18 inches long are present in the Harrell. They are most common in the Burket Member.

The Harrell weathers to chips and plates of medium-gray shale. Because it is less resistant to weathering than the adjacent rocks, the Harrell in many places underlies a narrow linear valley between ridges formed by the upper part of the Mahantango and the lower part of the Woodmont.

Although the upper part of the Harrell Shale is gradational into the overlying Woodmont Shale in many places, at some places the boundary is sharp. The contact between the two formations is arbitrarily placed at the base of the lowest discrete bed of siltstone above a thick homogeneous sequence of very dark gray and grayish-black shale. Above this bed the shale is lighter colored and contains numerous thin to moderately thick layers of light-gray siltstone. In many exposures one or several thin beds of siltstone containing a great number of *Styliolina fissurella* (Hall) are present in the basal part of the Woodmont. The base of the lowest *Styliolina*-bearing siltstone is a convenient boundary between the Harrell Shale and the Woodmont Shale. The contact descends to progressively lower stratigraphic positions eastward across the mapped quadrangles as the beds of dark shale at the top of the Harrell grade laterally into beds of lighter colored shale and siltstone in the lower part of the Woodmont. The contact between the Harrell and the Woodmont Shales is well exposed along Maryland Route 51, 0.6 mile east of Old Mount Tabor Church.

In the Evitts Creek and Pattersons Creek quadrangles, the Harrell Shale ranges from about 100 to 165 feet in thickness. It thins gradually from the northwest part of the mapped area to the southeast as beds of medium-gray shale and siltstone of the Woodmont descend to successively lower stratigraphic positions. The Burket Member also thins from northwest to southeast as the black shale grades laterally into the dark-gray and very dark gray shale that comprises the rest of the Harrell Shale.

The Burket Member is about 45 feet thick along U.S. Route 40 at a locality 0.35 mile west of Wolfe Mill and only 37 inches thick along the Western Maryland Railway 0.9 mile southeast of Spring Gap. The writers were unable to recognize the Burket Member in exposures on Maryland Route 51, 0.6 mile east of Mount Tabor Church, where the Harrell is well exposed.

The Harrell Shale is moderately fossiliferous, but the fauna is restricted in the size of the individuals and in the number of species present. The Burket Member of the Harrell contains very few fossils. The writers found only a few *Lingula spatulata* (Vanuxem), *Styliolina fissurella* (Hall), and some conodonts in the member. Pteropods, small pelecypods, and small cephalopods are the most common fossils in the Harrell. The following forms are present in most exposures of the formation:

Paracardium doris Hall
Buchiola retrostriata (von Buch)
Pterochaenia fragilis (Hall)
Styliolina fissurella (Hall)
Tornoceras uniangulare (Conrad)
Bactrites? *aciculum* (Hall)

A few worm trails, a few specimens of the brachiopod *Lingula spatulata*, and several conularids are also present in the Harrell Shale.

AGE AND CORRELATION

Hass (written comms., 1957, 1958) identified the following conodonts from the basal 0.2 foot of the Burket Member of the Harrell Shale along Highway 40 about 0.4 mile west of Wolfe Mill:

Ancyrodella cf. *A. rotundiloba* Bryant
Bryantodus radiatus (Hinde)
  typicus Ulrich and Bassler
  sp.
Hibbardella sp.
Hindeodella sp.
Icriodus sp.
Ligonodina sp.
Neoprioniodus alatus (Hinde)
Ozarkodina sp.
Polygnathellus colligata? (Bryant)
Polygnathus cristata? (Bryant)
  ordinata Bryant
  pennata Hinde
Prioniodina sp.

In 1958, Hass (written communication) wrote concerning the age of the Burket Member of the Harrell Shale and its possible correlative in the Upper Devonian rocks of New York:

> In New York the above listed conodonts range throughout much of the pre-Sonyea Upper Devonian interval. I cannot make a more precise correlation

with the New York section because certain key conodont species were not recognized in the material herein reported on.

A 0.3-foot bed of dark-gray siltstone about 60 feet above the base of the Harrell Shale along Maryland 51 about 0.85 mile east of Mount Tabor Church yielded the following conodonts (Hass, written comm., 1957):

Ancyrodella sp.	*Icriodus* sp.
Hibbardella sp.	*Polygnathus pennata* Hinde

Although the number of conodonts found at this locality was small, the forms are similar to those in the basal part of the Burket Member near Cumberland and indicate an early Late Devonian age assignment for the Harrell Shale.

WOODMONT SHALE

NAME AND EXTENT

Swartz (in C. K. Swartz and others, 1913b, p. 411–412) proposed the name Woodmont Shale Member of the Jennings Formation to designate the rocks that overlie the Harrell Shale of this report and underlie his Parkhead Sandstone Member in the vicinity of Woodmont Station (Woodmont Club on recent maps), Washington County, Md. The outcrops along the Western Maryland Railroad half a mile east of Woodmont Station were designated as the type exposure. In the present report the name is redefined as the Woodmont Shale. As redefined in this report, the Woodmont Shale extends from the top of the Harrell Shale to the base of the Chemung(?) Formation. In the Evitts Creek and Pattersons Creek quadrangles, the writers include in the Woodmont a zone of more than 600 feet of rocks that were formerly identified as Parkhead by Swartz (in C. K. Swartz, and others, 1913b, p. 348, 411–417, 517). The rocks in this biostratigraphic zone are included in the Woodmont Shale because they are lithologically indistinguishable from the Woodmont. They are a part of a thick sequence of sandy siltstone, silty sandstone, and intercalated shale which can be separated from the rest of the sequence only by their contained fossils. Rocks of similar lithology and of approximately the same age as the Woodmont were named the Brallier Shale in south-central Pennsylvania by Butts (1918, p. 523, 532, 536), and the Brallier Member of the Fort Littleton Formation by Willard (1939, p. 201). Woodward (1943, p. 412–426) recently applied the name Brallier Shale to similar-appearing rocks in northeastern West Virginia. The present writers feel that the term Woodmont is more appropriate because it has priority over the name Brallier.

The Woodmont Shale crops out in two areas in the Evitts Creek and Patterson Creek quadrangles. One occupies much of the valley of Evitts Creek from the vicinity of Dickens southward to the North Branch of the Potomac, and southward along the west edge of the Pattersons Creek quadrangle to the vicinity of Plum Run. The other area—roughly triangular in shape—extends from Olivers Grove Church to the southern boundary of the Pattersons Creek quadrangle.

CHARACTER AND THICKNESS

The Woodmont is a monotonous sequence of alternating layers of silty gray shale and siltstone or very fine grained sandstone. The shale in the Woodmont ranges from dark gray and dark olive gray in the lower part of the formation to medium dark greenish gray in the middle and upper parts. Most of the shale is fissile or platy, but some beds near the middle of the Woodmont are irregularly bedded and are more accurately described as shaly mudrock. Some grayish-black and brownish-black shale is interbedded with gray shale and light-gray siltstone in the exposures along Williams Road about 1,160 feet stratigraphically above the base of the Woodmont. The shale and mudrock weather rapidly into very small smooth light-greenish-gray to buff chips and shoepeg-shaped fragments. Siltstone, which forms about 30 percent of the Woodmont, occurs in layers ranging from laminae a fraction of an inch thick to beds as much as 5 feet thick. It is medium light greenish gray to medium light brownish gray when fresh and light greenish gray or buff when weathered. Many layers of siltstone show no internal bedding except small-scale crossbedding in the upper half inch. Other layers of siltstone are faintly but uniformly laminated. Small ripple markings occur on the surface of some beds.

The contact between the Woodmont Shale and the younger Chemung(?) Formation is not exposed in the Evitts Creek and Pattersons Creek quadrangles. Fragments of fossiliferous medium- to coarse-grained conglomeratic sandstone, tentatively assigned to the Chemung(?) Formation, are present in the mapped area near the crest of the ridge along the Mineral County-Hampshire County line near the south edge of the Pattersons Creek quadrangle. The contact between the Woodmont Shale and the Chemung(?) Formation probably is present in a covered interval about 60 feet below the crest of the ridge.

The complete thickness of the Woodmont Shale was not measured within the mapped area. The full thickness of the formation, however, was measured along the road that extends from the valley of Green Spring Run northwestward to the ridge crest in the vicinity of the Mineral-Hampshire County line near the north boundary of the Hanging Rock quadrangle. At this place the Woodmont is approximately 2,450 feet thick.

AGE AND CORRELATION

The Woodmont Shale is early Late Devonian in age. Cooper and others (1942, chart 4) show that the Woodmont and the Parkhead of Stose and Swartz in western Maryland are equivalent to the rocks above the Geneseo Shale and below the Chemung Formation in the vicinity of Cayuga Lake in central New York, and to the rocks between the top of the Geneseo Shale and the base of the Angola Shale in western New York. Work in New York by the writers (de Witt and Colton, 1959) indicates that the contacts at the top of the Geneseo Shale and at the base of the Chemung should be redefined across much of the western half of New York. Consequently, the writers are reluctant to correlate the Woodmont Shale in the central Appalachians with units in New York.

The fauna of the lower part of the Woodmont Shale has been referred to as a Naples fauna (C. K. Swartz and others, 1913b, p. 411, 413; Willard, 1939, p. 239; Woodward, 1943, p. 373, 442; Butts, 1945, p. 11). It consists largely of small pelecypods and cephalopods. The present writers identified the following in the lower part of the Woodmont Shale at many outcrops in the mapped area:

Paracardium doris Hall
Buchiola retrostriata (von Buch)
  specicosa (Hall)
Pterochaenia fragilis (Hall)
Styliolina fissurella (Hall)
Probeloceras lutheri (Clarke)
Tornoceras uniangulare (Conrad)
Bactrites? *aciculum* (Hall)
Pteridichnites biseriatus Clark and Swartz

The worm trail (?) *Pteridichites biseriatus*, which occurs in profusion, is diagnostic of the Woodmont. Some brachiopods probably characteristic of the Parkhead Sandstone Member were reported (C. K. Swartz and others, 1913b, p. 517) from the upper part of the present Woodmont Shale exposed along the old Williams Road in the Evitts Creek quadrangle. Among the brachiopods are:

Tropidoleptus carinatus (Conrad)
Leiorhynchus? *congregatum* (Conrad)
mesacostale (Hall)
Tylothyris mesacostalis (Hall)
"*Spirifer*" *marcyi* var. *superstes* Clark and Swartz

As previosuly stated, the Parkhead Sandstone Member could not be differentiated from the Woodmont by lithologic criteria in the mapped area. Consequently the Woodmont as redefined in this report, contains a pelecypod and cephalopod fauna in the lower part and a brachiopod fauna in the upper part.

CHEMUNG(?) FORMATION

Although bedrock of the Chemung(?) Formation was not seen in the study area, many blocks of fine- to medium-grained conglomeratic sandstone were scattered along the crest of a broad ridge near the junction of the Mineral County-Hampshire County line and the southern border of the Pattersons Creek quadrangle. Most of the float blocks contain layers of small well-rounded spherical or discoidal pebbles of grayish-white quartz as much as a quarter of an inch in diameter. The blocks of sandstone are white on the surface and are internally stained reddish brown or orange brown by hematite and limonite. The bottoms of many of the blocks are marked by groove casts, lobate rill marks, and by forms resembling *Fucoides graphica* Hall. From the position of the float and its relation to outcrops of Woodmont Shale lower on the flanks of the ridge, the writers estimate that the beds containing the conglomerate are about 50 or 60 feet thick. They lie in the trough of a south-plunging syncline and are about 2,300 to 2,400 feet above the base of the Harrell Shale.

In the adjacent Cresaptown, Cumberland, and Flintstone quadrangles, the basal part of the Chemung Formation contains several beds of conglomeratic sandstone intercalated with layers of siltstone and sandstone that commonly have groove casts and similar scour marks on the bottom surface. These beds of conglomeratic sandstone are 2,000 to 2,400 feet above the base of the Harrell Shale and are generally associated with fossiliferous strata containing a *Cyrtospirifer disjunctus* fauna. The similar lithology and stratigraphic position of the basal conglomerate in the Chemung in neighboring quadrangles with the float blocks of conglomeratic sandstone on the ridge in the southern part of the Pattersons Creek quadrangle lead the writers to conclude that the upper 50 to 60 feet of this ridge is underlain by the Chemung(?) Formation.

NAME

James Hall (1839, p. 322–326) gave the name Chemung to a thick sequence of sandstone, siltstone, and shale that contains the *Cyrtospirifer disjunctus* fauna in outcrops along the Chemung River in Chemung Township, New York. For many years the name has been applied to similar-appearing fossiliferous strata in parts of New York, Pennsylvania, Maryland, Virginia, and West Virginia. The Chemung of western Maryland includes the rocks containing the *Cyrtospirifer disjunctus* fauna (C. K. Swartz, and others, 1913b, p. 418). It occurs above the rocks that contain an "Ithaca" fauna and below the generally barren red beds of the Catskill or Hampshire Formation. The Chemung has been variously defined as a member, formation, group, or series by different workers. In this paper it is considered a formation.

THICKNESS AND CORRELATION

The writers estimate that only the basal 50 to 60 feet of the Chemung(?) is present in the mapped area; the greater part of the formation has been removed by erosion. Woodward (1943, fig. 15) shows that the Chemung is about 2,500 feet thick in Mineral County, W. Va., and about 3,000 feet thick in Hampshire County, W. Va. In the western part of Bedford County, Pa., the formation is about 1,500 feet thick (Willard, 1939, fig. 93). The Chemung Formation in western Maryland is probably of middle Late Devonian age and is approximately equivalent to the Chemung Formation of central New York; however, precise correlation of the formation in the two states is not possible at present.

STRUCTURE

The Evitts Creek and Pattersons Creek quadrangles are in the western part of the Ridge and Valley province of the folded Appalachian mountains. During a period of orogeny near the close of the Paleozoic Era, compressive forces from the east folded the bedrock into many anticlines and synclines. Locally the strata were sheared and faulted. The more competent rocks, the Tuscarora Quartzite and Ridgeley Sandstone, were able to transmit much of the deforming stress and were folded into a series of large, broad folds. Incompetent strata—the Rose Hill Formation, Tonoloway Limestone, Marcellus Shale, and Mahantango Formation, for example—were unable to transmit much of the compressive forces and consequently were compressed into numerous small, closely spaced folds. Shears, drag folds, and faults formed in the softer and more easily deformed rocks.

The westward movement of the rocks in response to the orogenic forces is shown by the oversteepened and locally overturned west limbs of anticlines and east limbs of synclines, by the east dip of most thrust faults, and by fracture cleavage inclined to the east in beds of siltstone in the Wills Creek Shale and Mahantango Formation and in beds of shaly limestone in the Needmore Shale.

Folding was the dominant mode of adjustment to the deforming stresses in the area, although many large folds were thrust faulted. In general the folds are parallel, but locally small folds in the less competent formations are disharmonic, especially in the Tonoloway Limestone. Disharmonic folds are few and are generally on the over-steepened limbs of larger folds. Much of the stress applied to the incompetent beds was taken up by bedding-plane slippage, drag folding, and local thrust faulting.

FOLDS

Folds in the area range from anticlines several thousand feet in amplitude to minute crumplings of less than an inch. At many places, particularly in the Devonian rocks, relatively thin-bedded brittle layers of siltstone or sandstone intercalated in a thicker sequence of shale slipped along bedding planes and fractured in a shingle structure (Cloos and others, 1951, p. 157).

In general the largest and most complex folds are in the northern part of the Evitts Creek quadrangle, which contains parts of three anticlinoria and two synclinoria (pl. 4). Competent units form large open folds having a structural relief of about 7,000 feet. The intensity of folding and structural relief decreases to the south, and in the southern part of the Pattersons Creek quadrangle the beds are gently folded. Anticlinoria, which are conspicuous in the Evitts Creek quadrangle, decrease in size and disappear in zones of small folds in the southern half of the Pattersons Creek quadrangle (pl. 4). Structural relief of large folds south of the Potomac River is less than 3,000 feet. Folds and faults die out vertically in the thick sequence of shaly rock that crops out at many places in the quadrangle.

The anticlinoria plunge to the southwest at low angles from a culmination in central Pennsylvania into a depression in northern West Virginia. Most individual folds plunge to the southwest, although some folds plunge sharply to the northeast (fig. 6).

The relative amount and thickness of competent and incompetent rocks in the stratigraphic sequence and the manner in which these rocks deform seem to be the factors that controlled the complexity and size of folds. The older rocks, exposed mainly in the Evitts Creek quadrangle, consist of thick competent formations intercalated in less competent units of about equal thickness. These strata formed large folds which have the greatest structural relief in the area. In the Pattersons Creek quadrangle the competent strata are covered by a homogeneous sequence of younger, relatively incompetent shaly rocks as much as 4,000 feet thick. The shaly rocks were deformed by small-scale folding, shearing, and crumpling and by the formation of bedding thrusts and slaty cleavage. The decrease in size and relief of folds southward across the two quadrangles and the simplification of large-scale structures clearly show that the sequence of shaly rocks absorbed by many small adjustments the forces that produced the large folds in the older competent units in the northern part of the two quadrangles.

Many names have been given to the folds in the area. Folds in Blair County, Pa., named by Platt (1881) and folds in Bedford and Fulton Counties, Pa., named by Stevenson (1885) were extended into Allegany County, Md., and into Mineral and Hampshire Counties, W. Va., by earlier workers (O'Harra, and others 1900; Reger, 1924; Tilton, and others 1927). Reger (1924, p. 101) points out many of the difficulties involved in trying to match the structures named by

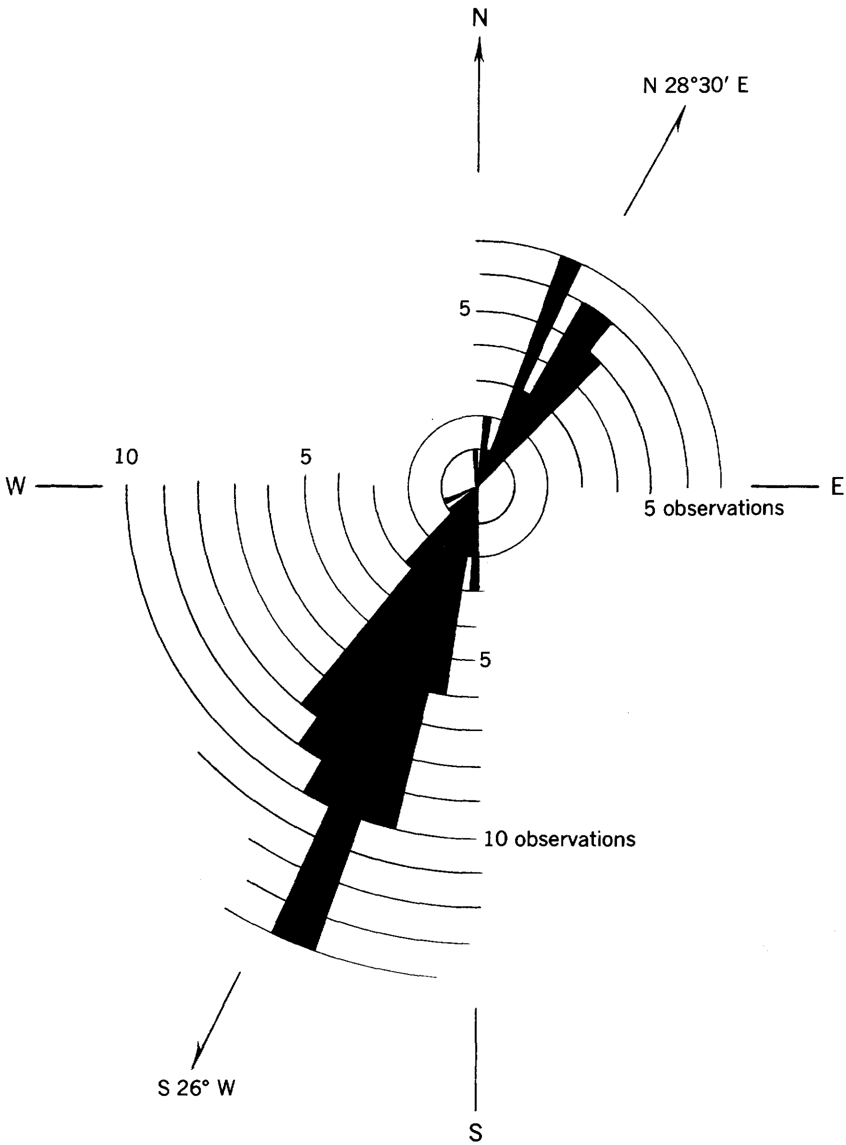

FIGURE 6.—Diagram showing the strike of crests of anticlines and troughs of synclines in the Evitts Creek and Pattersons Creek quadrangles determined by stereographic projection (Phillips, 1954, p. 12–14). The average strike in the northeast quadrant is N. 28° 30′ E., and the average plunge of the folds is 5°. In the southwest quadrant the average strike is S. 26° W., and the average plunge of the folds is 7° 10′.

Platt and Stevenson in Pennsylvania with the folds in Mineral County, W. Va. The present investigation shows that the earlier workers were not always successful in tracing the fold axes from Pennsylvania to West Virginia, and that in some places anticlinal axes have been extended across intervening synclines. Where possible, the writers use the names of folds proposed by O'Harra (pl. 4).

WILLS MOUNTAIN ANTICLINORIUM

The Wills Mountain anticlinorium includes the Wills Mountain anticline, Shriver Ridge terrace, Pine Ridge anticline, and the Pine Ridge Road syncline. The Wills Mountain anticline (O'Harra and others, 1900, p. 148) is a large anticline in the Tuscarora Quartzite in the northwestern part of the Evitts Creek quadrangle. The fold is nearly symmetric in the Hyndman quadrangle north of the mapped area in Pennsylvania and becomes progressively asymmetric to the south in Maryland. In the Evitts Creek quadrangle, beds of resistant Tuscarora Quartzite dip 45° west to vertical on the west limb and 12° to 47° east on the east limb of the anticline. The asymmetry of the fold can be seen in the water gap of Wills Creek at the Narrows west of Cumberland on U.S. Highway 40. The gentle dip on the east flank of the Wills Mountain anticline is modified by a low terrace along Shriver Ridge south of Pea Vine Run. The axis of the terrace is so poorly defined that it could not be shown on plate 4, except arbitrarily. Dips of 1° to 3° in the Ridgeley Sandstone southwest of Zion Church indicate the presence of a terrace along the east side of the anticlinorium. The belt of low dips departs from Shriver Ridge north of Pea Vine Run and extends northward along the broad outcrop of Wills Creek Shale and Tonoloway Limestone into Cumberland Valley in the Hyndman quadrangle to the north. The Pine Ridge anticline is a short asymmetric fold in the Ridgeley Sandstone and Shriver Chert along the west side of Evitts Creek valley south of Gordon Lake. The fold is steepest on the west side where the Shriver Chert is locally overturned. Dips of 25° to 35° are common on the east flank. The fold dies out to the south in the Needmore and Marcellus Shales. The Pine Ridge Road syncline, so called because the trough of the syncline underlies Pine Ridge Road along the west side of Pine Ridge, is a narrow syncline containing infolded Needmore Shale and Marcellus Shale. In the few exposures in the syncline, the shale appears to be almost vertical, but the surfaces observed may be cleavage and not bedding. The syncline cannot be traced far south of the south end of Pine Ridge.

EVITTS CREEK SYNCLINORIUM

The Evitts Creek synclinorium includes the Eastman Road and Evitts Creek synclines, the Wolfe Mill anticline, several small unnamed folds, and the McNamee Hill fault and associated faults. The synclinorium, which underlies the valley of Evitts Creek, is narrowest in the northern part of the Evitts Creek quadrangle where only the Eastman Road syncline is present. The synclinorium widens to the south where part of it occupies the northwestern part of the Pattersons Creek quadrangle. In the southeastern part of the Cresaptown quadrangle the Evitts Creek synclinorium coalesces on the east with the Mill Run synclinorium as the intervening anticlinorium plunges out. The Eastman Road syncline, so named because the trough underlies Eastman Road, north of Hillcrest Memorial Park, is a narrow, tightly folded trough. Steep dips on the east side of the syncline range from 50° to vertical, whereas gentle dips on the west flank of the syncline range from 20° to 50°. South of Pine Ridge the west side of the syncline is broken by the faults of the McNamee Hill fault system. The name Wolfe Mill anticline designates a local fold in Middle and Upper Devonian rocks. The rocks dip most steeply on the west flank of the fold; locally, along Miller Road 0.25 mile north of Wolfe Mill, the beds are overturned and faulted. Dips of 65° to vertical are not uncommon along the west side of the anticline. The rocks dip from 40° to 70° to the east on the less steeply inclined limb of the fold. The crest of the Wolfe Mill anticline is difficult to trace because of alluvium along Evitts Creek. The anticline disappears to the north between Dickens and Hazen; to the south it plunges out in the vicinity of South Cumberland. The Evitts Creek syncline (O'Harra and others, 1900, p. 147) was traced from the vicinity of Hazen south along the east side of Evitts Creek for about 7.5 miles. The trough crosses U.S. Highway 40 about 0.5 mile east of Wolfe Mill, crosses Williams Road 0.6 mile west of Mount Hermon Church, underlies the hamlet of Evitts Creek, and leaves the west side of the Pattersons Creek quadrangle about a mile west of Davis Church. Dips along the west side of the syncline are gentle, 20° to 60°, whereas dips ranging from 75° to vertical are not uncommon along the east side of the fold.

EVITTS MOUNTAIN ANTICLINORIUM

The Evitts Mountain anticlinorium occupies a large part of the Evitts Creek quadrangle where it includes the Evitts Mountain and Big Knob anticlines, the Wildcat Hollow syncline, the Rocky Gap fault and several unnamed structures. Southward the Evitts Mountain anticlinorium coalesces with the Tussey Mountain anticlinorium as the intervening Martin Mountain synclinorium rises and disappears near the boundary of the Evitts Creek and Pattersons Creek quadrangles. In the Pattersons Creek quadrangle the dominantly anticlinorial structure between Irons Mountain on the west and Martin Mountain on the east is divided into two parts by the Collier Run syncline—the southernmost extension of the Martin Mountain synclinorium. Structures west of the Collier Run syncline are more closely related to the Evitts Mountain anticlinorium and will be discussed here. Structures east of the syncline are more closely related to the Tussey Mountain anticlinorium and will be discussed under that heading.

The Evitts Mountain anticline (O'Harra and others, 1900, p. 145), one of the largest folds in the area, trends S. 25° W. across the northern half of Evitts Creek quadrangle and plunges out near the mouth of Cabin Run. North of Rocky Gap dips of 20° to 50° are common on the gentle east flank of the fold. The west flank of the fold is steeper, and north of Rocky Gap the beds are locally overturned. Small folds are superimposed on the Evitts Mountain anticline, especially south of Rocky Gap in the incompetent Rose Hill Formation. Folding and local thrust faulting modified the east limb of the Evitts Mountain anticline at the east end of Rocky Gap. The basal beds of the Rose Hill Formation are exposed in a sharp anticline of small amplitude at stream level on Elk Lick Run along U.S. Highway 40 between Pleasant Grove Church and the mouth of Cabin Run.

The Keefer Sandstone is brought above drainage along Cabin Run by another fold on the east side of the anticlinorium. This unnamed fold increases in size to the south and becomes the dominant structure along the Evitts Mountain anticlinorium south of Hardinger Road. The crest of the anticline crosses Williams Road about 0.5 mile east of Mount Hermon Church and plunges out southeast of the village of Evitts Creek. The name Irons Mountain anticline is used here to designate a large fold in the Ridgeley Sandstone along the crest of Irons Mountain in the northern part of the Pattersons Creek quadrangle. The fold is present in the northwestern part of the quadrangle and trends S. 13° W. to the Potomac River where it plunges to the south at 12°. The fold is not apparent in outcrops in West Virginia south of the river. The name Moores Hollow syncline is here given to two small en echelon synclines separated by a low col. The troughs underlie Moores Hollow, between the Irons Mountain anticline on the west and Nicholas Ridge anticline on the east. The southern and deeper of the synclines contains a small amount of infolded Needmore Shale, whereas along the sides of the northern syncline the shale has been eroded away and the Ridgeley Sandstone is exposed at several places.

The Nicholas Ridge anticline is a large fold that separates the small Moores Hollow syncline from the larger Wildcat Hollow and Collier Run synclines north of the Potomac River. South of the river, it separates the Evitts Creek syncline from the Collier Run syncline. The Nicholas Ridge anticline rises in the Pattersons Creek quadrangle on the east flank of Irons Mountain about 1.25 miles south of Williams Road. Near its northern end the fold is poorly defined; however, to the south where the Ridgeley Sandstone is well exposed, the anticline is clearly marked. It forms a saddle near the Maryland-West Virginia boundary where the Potomac River has cut a gap across the ridge. The part of the fold in Maryland plunges to the south at 4°, that in West Virginia plunges to the north at 13°. The Ridgeley Sandstone forms the arch of the Nicholas Ridge fold south and west of the village of Pattersons Creek, and extends southwestward to the vicinity of Plum Run near the west edge of the Pattersons Creek quadrangle where it plunges out. The Nicholas Ridge anticline is more nearly symmetrical than the Evitts Mountain and Irons Mountain anticlines. The Ridgeley Sandstone dips 48° on the west flank and 43° on the east flank of the anticline in Rocky Run southwest of the village of Pattersons Creek.

The Wildcat Hollow syncline is a small syncline in the rocks of the Oriskany Group on the east side of the Evitts Mountain anticlinorium. It appears as a small downwarp at the north end of Irons Mountain near Mount Fairview Church and plunges to the southwest along Wildcat Hollow. The syncline, which is narrow and oversteepened on the east limb, coalesces with the Collier Run syncline south of Wildcat Hollow where the intervening Big Knob anticline dies out.

The Big Knob anticline is a short fold in Lower Devonian rocks on the east side of the Evitts Mountain anticlinorium near the southern boundary of the Evitts Creek quadrangle. It underlies Big Knob and the ridge south of the knob. The anticline separates the Wildcat Hollow syncline from the Collier Run syncline, the westernmost unit of the Martin Mountain synclinorium. The Ridgeley Sandstone, which crops out on the fold throughout much of its length, plunges 3° S. 34° W. on the nose of the fold at the mouth of Wildcat Hollow. The anticline disappears a short distance to the south where the Wildcat Hollow syncline coalesces with the Collier Run syncline.

MARTIN MOUNTAIN SYNCLINORIUM

The Martin Mountain synclinorium, which is named for Martin Mountain in the northeastern part of the Evitts Creek quadrangle, is a canoe-shaped, dominantly synclinal structure between the Evitts

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Mountain and Tussey Mountain anticlinoria. It encompasses the northern part of Collier Run syncline, the Bush Ridge and Breakneck Hill anticlines, the Martin Mountain and Twiggtown faults, and several unnamed folds. The synclinorium rises to the northeast and disappears as the Evitts Mountain and Tussey Mountain anticlinoria coalesce about 3 miles northeast of the mapped area near Beans Cove in Pennsylvania. It disappears to the southwest as the same two anticlinoria coalesce near the south edge of the Evitts Creek quadrangle.

The Collier Run syncline (O'Harra and others, 1900, p. 144), the principal fold in the Martin Mountain synclinorium, is present on Martin Mountain in the vicinity of U.S. Highway 40 and extends along the west flank of the mountain to the headwater of Collier Run south of Breakneck Road. The fold is one of the longer synclines in the area and can be traced continuously along Collier Run to the Potomac River and farther south along the valley of Patterson Creek to the west edge of the Pattersons Creek quadrangle near Plum Run. We do not recognize the Martin Mountain synclinorium in the Pattersons Creek quadrangle because the Collier Run scyncline, the main fold of the synclinorium, is but one of several (pl. 2, section *A–A′*) in the much larger anticlinorial feature formed by the merging of the Evitts Mountain and Tussey Mountain anticlinoria.

The writers apply the name Bush Ridge anticline to a fold that forms the crest of Collier Mountain in the vicinity of Mount Collier Church and the crest of Bush Ridge for several miles north of Williams Road. The fold reaches its maximum amplitude near the telephone line about a mile north of Mount Collier Church where the Shriver Chert is exposed in the core of the anticline. The fold decreases in amplitude to the north and dies out north of a deep hollow, known locally as Carr Hollow, about 1¼ miles south of Breakneck Road.

The name Breakneck Hill anticline is used here to designate an anticline in the vicinity of Breakneck Hill that separates the Collier Run syncline on the west from another long syncline on the east. The anticline rises en echelon to the northern part of the Bush Ridge anticline in the vicinity of Carr Hollow and extends about 2.5 miles northeast before it plunges out on the east flank of Martin Mountain, about 0.5 mile south of U.S. Highway 40. Limestone of the Helderberg Group and older formations crops out along the crest of the Breakneck Hill anticline north of Breakneck Road. The Ridgeley Sandstone is present on the west flank of the fold along Martin Mountain.

The structure of the Martin Mountain synclinorium is complicated by faulting in the vicinity of the U.S. Highway 40 and by a small anticline in the Lower Devonian rocks north of the highway. This anticline is bounded on the east by the faulted limb of the Collier Run syncline and on the west by the Martin Mountain fault, but we were unable to trace it to the northeast because of the scarcity of outcrops.

The name Brice Hollow syncline is applied here to the long syncline that underlies the valley of Brice Hollow Run from the Potomac River north to the vicinity of Williams Road, where the trough of the syncline passes beneath the Twiggtown fault. The syncline reappears northward on the flank of Bush Ridge east of Mount Collier Church and extends north of Breakneck Road, where it is narrow and contains infolded rocks of the Keyser Limestone and Helderberg and Oriskany Groups. Only that part of the Brice Hollow syncline north of the Twiggtown fault is here considered to be a part of the Martin Mountain synclinorium. The southern part appears to be a small downfold in the southern extension of the Tussey Mountain anticlinorium.

TUSSEY MOUNTAIN ANTICLINORIUM

In the Evitts Creek and Pattersons Creek quadrangles, the Tussey Mountain anticlinorium—a modification of the Tussey Mountain anticline of O'Harra and others (1900, p. 142)—is a complex structural high. It is divided into two fingers throughout its extent in the Evitts Creek and Pattersons Creek quadrangles by a northeast-projecting finger of the Mill Run synclinorium. The western finger, separated from the Evitts Mountain anticlinorium only by the narrow Collier Run syncline, is dominated by the Patterson Creek Ridge, Collier Mountain, and Murley Branch anticlines. The eastern finger is dominated by the Warrior Mountain anticline. The two fingers of the anticlinorium—as well as the southern extension of the Evitts Mountain anticlinorium—decrease in size to the southwest as the constituent anticlines plunge to the southwest. The western finger appears to extend for some distance southwest of the Pattersons Creek quadrangle along the fold axes shown by Reger (1924, map 111) as his Evitts Mountain and Tussey Mountain anticlines and the Bear Cove syncline. The eastern finger disappears within the east-central part of the Pattersons Creek quadrangle.

The Murley Branch anticline extends southwest along the valley of Murley Branch and the crest of Martin Mountain to the Potomac River, where it plunges out at about 4°. Throughout most of its extent in the Pattersons Creek quadrangle the Murley Branch anticline is exposed in rocks of the Oriskany Group. In the Evitts Creek quadrangle, the resistant Oriskany rocks have been breached, and rocks as old as the Wills Creek Shale are exposed on the crest of the anticline.

The Patterson Creek Ridge anticline is a nearly symmetrical fold that rises in the vicinity of Fort Ashby, W.Va., in the southeast corner of the Cresaptown quadrangle, extends northeastward along the crest of Patterson Creek Ridge, and forms a gentle saddle at the Potomac

River. In Maryland the anticline continues northeastward along the crest of Collier Mountain. About 1.3 miles south of the north edge of the Pattersons Creek quadrangle the anticline coalesces with the Collier Mountain anticline across a low col as the intervening Spring Gap syncline flattens out. The Ridgeley Sandstone crops out along the entire length of the Patterson Creek Ridge anticline. In most places the beds on the west flank dip a few degrees more steeply than the beds on the east flank. Along the Western Maryland Railway west of Spring Gap, where the Ridgeley is well exposed, the anticline plunges at 2° to the southwest into the saddle through which the Potomac River has cut a gap.

The name Collier Mountain anticline (O'Harra and others, 1900, p. 144) designates a fold in the Oriskany Group that extends from the northern part of Collier Mountain southwestward along the crest and east flank of the mountain to the Potomac River. The anticline plunges abruptly in the vicinity of the river, then rises southwestward on the east flank of Patterson Creek Ridge. The Collier Mountain anticline is nearly symmetrical throughout most of its length. The northern end of the Collier Mountain anticline dies out against the west flank of the Bush Ridge anticline.

The north end of the Walnut Ridge syncline—the Big Spring Run syncline of O'Harra and others (1900, p. 144)—separates the Murley Branch anticline from the Warrior Mountain anticline. The Warrior Mountain anticline is a large fold in Lower Devonian rocks and forms the eastern arm of the Tussey Mountain anticlinorium. Recent work in Allegany County by Berryhill and others (1956) shows that the Warrior Mountain anticline originated as a small fold on the east side of Tussey Mountain near the Pennsylvania State line north of the village of Flintstone, Md., about 5 miles north of Rush, Md. The Warrior Mountain anticline trends S. 20° W. across the Flintstone quadrangle and reaches its greatest size in the northeastern corner of the Pattersons Creek quadrangle. From there the competent Ridgeley Sandstone plunges below cover of the soft Devonian shales in the valley of Mill Run near Maryland Highway 51, and the crest of the anticline is lost among several small folds in the Marcellus Shale and Mahantango Formation between Mill Run and the Potomac River. A small anticline of low amplitude parallel to and slightly offset from the Warrior Mountain anticline crosses the Potomac River 0.1 mile west of the mouth of Round Bottom Hollow. This small fold may be a continuation of the Warrior Mountain anticline; because of insufficient exposures, the folds cannot be traced across the area between Mill Run and the Potomac River. Several small folds are present along the west flank of the Warrior Mountain anticline in the southern part of the Evitts Creek quadrangle and the northern part of the Pattersons Creek quadrangle.

The name Spring Gap syncline designates the small syncline that separates the Patterson Creek Ridge anticline from the Collier Mountain anticline in the vicinity of Spring Gap. The trough is on the east side of Patterson Creek Ridge south of the Dans Run Road, and its axial trace crosses the Potomac River at Spring Gap. In Maryland the syncline follows a shallow valley between the two spurs of Collier Mountain and spoons out about 3 miles north of the Potomac River.

The Mount Tabor Church anticline is a low fold about 2 miles long on the east side of the southern extension of the Tussey Mountain anticlinorium. It lies east of the companion Martin Spring Branch syncline (O'Harra and others, 1900, p. 144) and west of the southern part of Brice Hollow syncline. The fold becomes apparent in the valley of Brice Hollow Run about three-fourths of a mile north of Mount Tabor Church where the resistant Ridgeley Sandstone rises above weak Devonian shales. East of Spring Gap, the sandstone forms a low ridge trending S. 22° W. to the Potomac River. Across the river the anticline is represented by a low arch of Ridgeley Sandstone on the Baltimore & Ohio Railroad and Dans Run Road. The fold plunges under cover of younger Devonian rocks about 0.5 mile south of the road. A small anticline west of Seedars Road and parallel to the Patterson Creek fold may be a part of the Mount Tabor anticline, but we were not able to trace it north and tie it into the Mount Tabor fold.

The Twiggtown syncline is a small trough, about a mile long, on the west flank of the Tussey Mountain anticlinorium. It appears to be oversteepened on the east limb, although outcrops are sparse in the syncline. The exposed Needmore and Marcellus Shales are tightly infolded and sheared. The Twiggtown syncline is separated from the Brice Hollow syncline on the west by a low faulted anticline. Apparently the fault carried the Twiggtown trough westward about 0.25 mile toward the Brice Hollow syncline. The Twiggtown syncline spoons out about 0.5 mile north of Williams Road and disappears about the same distance south of Williams Road.

For reasons stated earlier, that part of the Brice Hollow syncline south of the Twiggtown fault is included in the Tussey Mountain anticlinorium. This part of the syncline extends southwest as a narrow downfold to the vicinity of the Potomac River, half a mile southeast of Spring Gap. Here it plunges rapidly and cannot be traced south of the river. Throughout its extent in the Pattersons Creek quadrangle the trough of the Brice Hollow syncline contains infolded Marcellus and Needmore Shales.

MILL RUN SYNCLINORIUM

The Mill Run synclinorium, here so named because it underlies the valley of Mill Run south of Oliver Beltz Road, includes several small anticlines and synclines in the Middle and Upper Devonian rocks of this dominantly synclinal area. This structure was named the Big Spring Run syncline by O'Harra and others (1900, p. 144) but, because the name "Big Spring Run" does not appear on the topographic maps and the location of the run is uncertain, the name Mill Run is here given to the synclinorium, which interdigitates with elements of the Tussey Mountain anticlinorium and becomes wider and deeper to the south as the Tussey Mountain anticlinorium plunges out. In general the folds in the synclinorium decrease in amplitude and increase in number upward through the thick sequence of siltstone and shale above the competent Ridgeley Sandstone. Complex small-scale thrust faults are common in the Needmore and Marcellus Shales but less common in the younger Mahantango Formation and Woodmont Shale.

The most prominent fold in the synclinorium is the Walnut Ridge syncline, so named because it underlies Walnut Ridge in the Pattersons Creek quadrangle. The trough of this syncline was traced with little difficulty south from Oliver Beltz Road along Mill Run and Walnut Ridge to the Potomac River. South of Maryland Highway 51, several small anticlines and synclines are present on both sides of the Walnut Ridge syncline, and south of the Potomac River the Walnut Ridge syncline cannot be differentiated from other synclines in this part of the synclinorium.

Two large synclines are present in the eastern part of the Mill Run synclinorium south of the Potomac—the Clearville syncline of Tilton and others (1927, p. 117) and the Green Spring Ridge syncline. The Clearville syncline is a broad trough along the Mineral-Hampshire County line in the south-central part of the Pattersons Creek quadrangle. The syncline, which is broadest near the head of Corduroy Hollow, spoons out to the north and does not reach the Potomac River. Reger's (1924) geologic map of Mineral County shows his Big Spring Run syncline, which is the same as Tilton's Clearville syncline, departing from the Mineral County-Hampshire County line and swinging northwest to cross the Potomac midway between Wagoner at the mouth of Round Bottom Hollow and the mouth of Dans Run. Tilton (1927) drew the axis of his Clearville syncline about half a mile east of Reger's Big Spring Run syncline and showed that it crossed the Potomac at the mouth of Round Bottom Hollow. A low anticline near the mouth of Round Bottom Hollow separates the northern part of Tilton's Clearville syncline from the easternmost of the two anticlines near the mouth of Dans Run and indicates that the structure as mapped by Reger is incorrect. The Green Spring Ridge syncline, which appears to be the southern part of the Clearville syncline of Stevenson (1882, p. 30–32) and the Polish Mountain syncline of O'Harra and others (1900, p. 141), underlies the village of Green Spring, W. Va., as well as Green Spring Ridge. The trough of the syncline crosses the Potomac River at Green Spring, trends S. 30° W. along Green Spring Ridge, and crosses the south boundary of the Pattersons Creek quadrangle about a mile southwest of the mouth of Corduroy Hollow.

Several small folds in the Needmore and Marcellus Shales are present in the valley of Green Spring Run; however, lack of exposures prevents their accurate delineation. In general the Mill Run synclinorium is characterized by many short, closely spaced folds in contrast to the larger and longer folds in other synclinoria in the area. Two small folds are present in the western part of the synclinorium in the vicinity of the Potomac River about 1.1 miles southeast of Spring Gap. Many small, closely spaced folds, some of which are oversteepened to the west, are present in the southwest part of the mapped area near Myers Run.

The crest of White Horse Mountain, a part of Tilton's (1927, p. 114) Broad Top anticline, is present adjacent to the southeast corner of the mapped area, and the Ridgeley Sandstone on the west flank of the fold crops out in the southeastern corner of the mapped area. It is apparent that Tilton's Broad Top anticline in the area immediately adjacent to the southeast corner of the Pattersons Creek quadrangle is a complex structural high composed of several anticlines and synclines (Tilton, 1927, Map III; Berryhill and others, 1956). Inasmuch as the present study included only a very small part of this anticlinorial structure, it has not been redefined.

FAULTS

The writers found that faults were more common in the Evitts Creek and Pattersons Creek quadrangles than had been previously recognized (O'Harra and others, 1900, p. 153). In general the more competent rocks are faulted, and the less competent strata are sheared and tightly folded. Faults in the Tuscarora Quartzite or in the Ridgeley Sandstone are generally readily observed and may be traced for considerable distances. On the other hand, faults in incompetent units such as the Rose Hill Formation, the Tonoloway Limestone, or the Woodmont Shale cannot be easily seen, nor can they be traced far from a single outcrop.

Faulting was most widespread in the Evitts Creek quadrangle where resistant ridge-forming rocks were displaced, and hard competent rocks were thrust on softer strata. Numerous exposures in parts of the quadrangle facilitated tracing the faults; in other parts of the quadrangle, the rocks are not well exposed, and faults, if present, cannot be seen. In these places, faulting can be determined generally by the abrupt thickening or thinning of stratigraphic units and by the presence or absence of keybeds—for example, the fault planes of the McNamee Hill faults northeast of Cumberland cannot be seen; however, the appearance of four ridges of resistant siltstone where normally only two are present and the increased width of the outcrop of the Mahantango Formation without a corresponding decrease in the dip of the beds clearly indicate that the strata are repeated by faults.

Faulting is much less evident in the Pattersons Creek quadrangle, than in the Evitts Creek quadrangle, for several reasons. A thick sequence of shaly Middle and Upper Devonian rocks, largely devoid of readily identifiable key beds, is at the surface in much of the quadrangle. The soft rocks do not form extensive outcrops and are covered by colluvium or by alluvium at many places in the area. Faults decrease in displacement upward in the thick sequence of shaly rocks and merge into local zones of sheared and folded strata. Beds in the lower part of the sequence above the Ridgeley Sandstone may be offset by more than a hundred feet, whereas vertical movement along the same fault in the middle of the Woodmont Shale may be almost imperceptible. Most of the deformation in these rocks was by folding and small-scale shearing. Because it took place parallel to or at a low angle to the bedding, displacement along most faults is small and inconspicuous; however, the total movement in the sequence of Middle and Upper Devonian rocks must have been considerable because these rocks absorbed the forces that faulted the older rocks below.

Faults are commonly associated with small folds of low amplitude and with shear zones in the thicker sequences of incompetent shaly rocks in both quadrangles. The shale and mudrock were folded and wrinkled, whereas intercalated beds of siltstone, sandstone, or limestone were faulted. Faults in the shaly rocks commonly formed low on the flanks of anticlines or in the troughs of the adjacent synclines where the pressure developed during folding was most easily relieved by movement outward and upward from the bottom of the trough. Beds were shortened along the limbs of the anticline by wedging, thrusting, and telescoping of the thin competent rocks, and by shearing and flowage of the soft incompetent rocks along planes closely parallel to the bedding. Movement was taken up by thrusting and flowage of material into the crest of the fold, which thickened the section at the crest in relation to the faulted limb of the fold. Continued movement of material led to disharmonic folding. If the displacement was considerable, the fault might behead the fold near the crest, slice across the adjacent syncline, and move into the next anticline to the west. Gair (1950, p. 871–876) showed the relation of faults to folds in the less competent and more easily deformed rocks in Allegany and Washington Counties, Md.

Most of the thrust faults in the area dip to the east, but several thrusts along the west side of the Evitts Mountain anticlinorium dip steeply to the west (pl. 1, sec. *A–A′* and *B–B′*). They apparently formed as the Evitts Creek synclinorium was squeezed between the adjacent anticlinoria. Pressure on the east limb of the synclinorium was released, in part, by thrusting older rocks eastward and upward over younger strata. Some movement also took place nearly parallel to the axis of the synclinorium, but the displacement in this direction was small. The west-dipping thrust faults are generally steeply inclined and have small stratigraphic displacement. Faults of similar origin and dip are probably present north of Breakneck Road in the Martin Mountain synclinorium, but the field evidence is inconclusive because of inadequate exposures.

Wills Creek fault.—The Wills Creek fault is a high-angle east-dipping thrust fault in the Middle Silurian rocks on the west side of Wills Mountain near Cooks Mills. The south end of the fault is in the Rose Hill Formation near the State line, and the displacement along the fault increases to the north as younger strata are covered by the plate. The fault is obscured by alluvium in the valley of Wills Creek near the mills. About 2.5 miles to the north, the Rose Hill Formation is thrust on the Wills Creek Shale, and approximately 500 feet of beds has been cut out. The writers did not attempt to trace the fault north along the flank of Wills Mountain far beyond Cooks Mills, and its extent into Pennsylvania is not known.

McNamee Hill fault system.—The NcNamee Hill faults are a series of thrusts in the Marcellus Shale and Mahantango Formation on the west side of the Eastman Road syncline north of Cumberland. As mentioned previously, the writers did not observe the fault planes in the McNamee Hill system because of the cover of vegetation and alluvium. The presence and size of the faults were determined largely from the abnormal thickness of the Mahantango Formation and the repetition of the lower sequence of ridge-forming siltstone in the formation. Faulting took place in the basal part of the Mahantango below the lower massive siltstone sequence, and at some places involved the upper part of the Marcellus Shale. (See pl. 1.) The greatest displacement was along the Mc-

Namee Hill fault on the west side of McNamee Hill. Faults on the east side of the hill are interpreted as higher angle branch faults rising from the lower thrust. The McNamee Hill thrust departs from a bedding-plane fault in the lower part of the Mahantango Formation west of Union Grove Cemetery and increases in displacement to the south. In the vicinity of McNamee Hill proper, the fault appears to cut out the upper and middle parts of the Marcellus Shale as well as the lower part of the Mahantango. Slivers rising from the main fault repeat the lower ridge-forming siltstone sequence in the middle of the Mahantango Formation twice near Cumberland.

Wolfe Mill fault.—The Wolfe Mill fault is a local zone of shearing and small-scale thrusting on the west flank of the Wolfe Mill anticline near Miller Road north of the Wolfe Mill. Rocks in the upper part of the Mahantango Formation and in the Harrell Shale are involved. Locally the beds are overturned and the thickness of the Burket Member of the Harrell Shale is greatly reduced. Displacement along the fault appears to be small. The upper siltstone zone in the Mahantango Formation has been thrust westward over the soft shale in the top of the Mahantango and the black shale in the Harrell Shale.

Christie Road fault.—The Christie Road fault crosses Christie Road about 0.1 mile west of the junction of Christie and Hardinger Roads on the west flank of the Evitts Mountain anticline. It has been traced from the vicinity of U.S. Highway 40 to a telephone line crossing Christie Road about 1.7 miles north of Mount Hermon Church. The fault, which dips west at 80° to 85°, has a maximum stratigraphic displacement of about 180 feet. Along Christie Road the full thickness of the Ridgeley Sandstone is repeated. To the south the fault is lost in the poorly exposed and easily deformed Needmore and Marcellus Shales north of Mount Hermon Church. To the north the fault disappears in incompetent Tonoloway Limestone near U.S. Highway 40.

At least three more high-angle thrust faults of small stratigraphic displacement are present in the Upper Silurian and Lower Devonian rocks on the west side of the Evitts Mountain anticline in the Evitts Creek quadrangle. The lower part of the Needmore Shale is repeated by faulting in the vicinity of Mount Hermon Church on Williams Road. Thickening in the outcrop of the Ridgeley Sandstone in the hollow about 0.4 mile north of the church suggests that the fault may extend north and involve the Ridgeley. Offset ridges of Upper Silurian and Lower Devonian rocks in the vicinity of Hazen near the Pennsylvania State line and about 1.5 miles north of Hazen are interpreted as faults similar to the Christie Road fault. In the fault at Hazen, the Shriver Chert in the plate overrode the middle part of the Ridgeley Sandstone in the sole block. The stratigraphic displacement is about 100 to 125 feet. The writers were unable to observe the fault plane in the poor exposures near Hazen, but they assume that it dips steeply to the west as does the Christie Road fault and other faults along the west flank of the Evitts Mountain anticline.

A fault is suggested by the thinning in the Rose Hill Formation north of Rocky Gap on the west side of Evitts Mountain. The formation in this area is thinner than normal, and a fault may have cut out as much as 150 feet of the Rose Hill north of the State line.

Rocky Gap fault.—The Rocky Gap fault is a small thrust on the east side of the Evitts Mountain anticline near the east end of Rocky Gap. The stratigraphic displacement of the fault is about 150 feet near the Gap. The fault breaks the Tuscarora Quartzite about 0.5 mile south of the State line and extends S. 30° W. along the east flank of Evitts Mountain. It disappears in a broad area underlain by the Rose Hill Formation at the south end of the mountain. The resistant Tuscarora Quartzite failed by faulting, whereas the weaker rocks of the Rose Hill absorbed much of the stress by slippage along bedding planes and by shearing.

Twiggtown fault.—The Twiggtown fault is a thrust on which the small unnamed anticline on the west side of the Twiggtown syncline has been moved westward across the eastern limb of the Brice Hollow syncline in the vicinity of Williams Road. The fault is not well exposed. The fact that locally the Ridgeley Sandstone is overturned to the southeast suggests drag along an east-dipping fault plane. Restriction of the north end of the Brice Hollow syncline by a belt of Ridgeley Sandstone that strikes due north is also suggestive of faulting. The Twiggtown fault is interpreted as a low-angle thrust on the east side of an oversteepened anticline. It is a part of the complex structure formed when the Martin Mountain synclinorium was squeezed between the Evitts Mountain and Tussey Mountain anticlinoria. The Twiggtown syncline is also cut by a normal fault which strikes about N. 65° W. and is downthrown on the south side. Whether or not the normal fault cuts the Twiggtown fault is unknown.

Martin Mountain fault.—The thickness of the Ridgeley Sandstone is nearly doubled by faulting along the west side of Martin Mountain north of Breakneck Road. The fault forms in the Collier Run syncline near Breakneck Road, crosses U.S. Highway 40 about 0.4 mile west of the mountain crest, and leaves the Evitts Creek quadrangle in the vicinity of the Maryland State line. The Martin Mountain fault (pl. 1) is interpreted as a thrust from the east. Displacement along the fault seems to be greatest in the vicinity of U.S. Highway 40 and decreases north and south of the highway. The faulting is associated with a low terrace that constricts the west side of the Collier Run syncline near Breakneck Road. The syncline does not seem to be faulted south of Breakneck Road, but outcrops are scarce and the southern end of the fault cannot be located with certainty.

The Ridgeley Sandstone is probably faulted along U.S. Highway 40 at the crest of Martin Mountain, but we were unable to locate the fault. Local thickening of the Shriver Chert and Ridgeley Sandstone in exposures along the north side of U.S. Highway 40 east of the crest of Martin Mountain and abrupt change in dip from 80° SE. to 37° SE. in the exposure at the mountain crest suggest that a fault crosses the highway near the top of the mountain. These data strongly suggest the presence of one or more local high-angle faults. However, the bedding in the weathered Shriver east of the mountain top, although poorly exposed, indicates that at least part of the apparent thickening may be infolding and not faulting.

Local faults of small displacement are present at many places in the mapped area. Several small faults can be seen along the Western Maryland Railway and the Baltimore & Ohio Railroad in the central part of the Pattersons Creek quadrangle. These small faults are most numerous in the interbedded siltstone and shale of Early and Middle Devonian age. They are associated wth local zones of complicated folding and shearing. Because of the impossibility of tracing the small faults in the covered areas between stream valleys and the abruptness with which the thrusts disappear by passing into bedding-plane slippage, the writers did not attempt to show them on the accompanying geologic maps.

GEOLOGIC HISTORY

The bedrocks of the Evitts Creek and Pattersons Creek quadrangles are sedimentary rocks of Paleozoic age that accumulated in a long narrow, slowly subsiding trough, the Appalachian geosyncline. During the Paleozoic Era the trough extended from the Maritime Provinces of Canada southwest across much of the Eastern United States. Large parts of the geosyncline were inundated by a shallow epicontinental sea that covered much of the central part of the United States as well as the Appalachian region. Borderlands on the east side of the geosyncline were the source of much terrigenous detritus that was carried by water and by wind into the epicontinental sea. The Appalachian geosyncline subsided slowly throughout much of the Paleozoic Era, apparently at a nearly uniform rate. Various kinds of sediment were trapped in the sinking trough. At times, when the elevated borderlands were being rapidly eroded, the rate of sedimentation exceeded the rate of subsidence of the geosyncline and detritus filled the trough. As the strand line of the epicontinental sea migrated westward across the geosyncline, subaerially deposited sediments succeeded marine sediments. At other times when the borderlands were worn down to low hills, only small amounts of fine-grained clastic sediments, colloidal suspensions, and chemicals in solution were carried into the epicontinental sea. The rate of subsidence of the geosyncline then exceeded the rate of sedimentation. The epicontinental sea deepened and, as the strand line moved eastward, marine sediments succeeded subaerially deposited sediments.

The abundance of fossiliferous rocks in the Evitts Creek and Pattersons Creek quadrangles indicates that this part of the Appalachian geosyncline was a marine sedimentary basin throughout much of mid-Paleozoic time. In general the evidence suggests that the water was shallow, ranging in depth from a few inches to several hundred feet. Gray, brown, and black calcareous and noncalcareous mud, silt, and sand accumulated on the sea floor. At times of more rapid sedimentation when the surface of the basin was above sea level, the subaerially deposited sediments consisted of tan, purplish-gray, and red mud, silt, sand, and small pebbles.

The geologic history of the Evitts Creek and Pattersons Creek quadrangles, which can be deciphered from the exposed bedrock, extends from the Late Ordovician to the Late Devonian. Lower Paleozoic rocks are not exposed, and upper Paleozoic rocks have been removed by erosion. Consequently, the geologic history of the mapped quadrangles in the early and late Paleozoic must be deduced from studies in nearby areas where the lower and upper parts of the Paleozoic sequence are exposed.

During the Late Ordovician a large mass of red beds, comprising the Queenston delta, filled much of the northern part of the Appalachian geosyncline. In the mapped area the red, purple, green, and gray mud and sand that make up the Juniata Formation were probably deposited on a flood plain or on the braided distributaries of a delta where the sediments were alternately covered by water and exposed to the air. Torrential cross lamination and ripplemarks in many beds of sandstone indicate that the sediments were transported by vigorous currents. The absence of a marine fauna suggests that the sediments were deposited in a nonmarine environment.

The intertonguing of red mudrock and siltstone of the Juniata with light-pinkish-gray and white sandstone of the Tuscarora and the general increase in the size of sand grains near the formation boundary indicate a change in the environment of deposition at the close of the Ordovician. The Early Silurian sea transgressed eastward over the slowly subsiding Queenston delta and spread a blanket of clean quartz sand across the Evitts Creek and Pattersons Creek quadrangles. The sand accumulated in a high-energy, shallow-water environment in which sediments were actively winnowed and sorted by waves and currents. The effectiveness of the sorting agents is shown by high-angle crossbedding and current ripplemarks in many of the thicker beds of sandstone, the presence of lenses of small quartz pebbles, and the absence of marine life, excepting the trail *Arthrophycus* and the seaweed *Buthotrephis*. Waves, currents, and the wind were probably all involved in winnowing and sorting the quartzose sediment along the eastern shore of the transgressing epicontinental sea. The absence of pebbles and a slight decrease in the grain size of the sand in the upper part of the Tuscarora indicate a decrease in the ability of waves and currents to transport sediment, probably as a result of the deepening of the epicontinental sea.

Subsidence continued and by early Middle Silurian time the sea covered the Evitts Creek and Pattersons Creek quadrangles. The high-energy environment of deposition of the Early Silurian changed to low energy in the Middle Silurian. Clay and silt accumulated in a shallow sea near or at effective wave base. Beds of well-sorted siltstone intercalated with layers of silty mudrock show that at times waves or currents winnowed the silt and removed the finer grained mud, whereas at other times waves were not vigorous enough to stir and sort the sediment on the sea floor. The coarse-grained Cresaptown sandstone of Swartz accumulated during a brief return to a high-energy depositionary environment. Some hematite accumulated in the Cresaptown in the form of oolites. The oolites may have formed in a manner similar to the formation of oolites of calcium carbonate (Newell and Rigby, 1957, p. 55). The presence of the oolites and the coarse-grained sand in the Cresaptown both indicate an increase in the activity of waves and currents, probably resulting from a temporary shoaling of the epicontinental sea. Beds of fine-textured limestone intercalated in the shale and mudrock in the upper part of the Rose Hill indicate a return to a low-energy environment of deposition as the sea continued to deepen slowly throughout much of Rose Hill time.

The Keefer was deposited in the Evitts Creek and Pattersons Creek quadrangles during another influx of coarse-grained sediment and shoaling of the sea. It accumulated in a high-energy marine environment along the eastern side of the epicontinental sea where waves and currents sorted and winnowed the sandy stream-borne detritus. The rapid lateral and vertical change in grain size from silt to medium and coarse sand and the many current ripple marks, worm borings, and trails of invertebrates suggest the accumulation of sediments in shallow water. Many fossils, both shattered and unbroken, oolites of hematite, and small pebbles of siltstone associated with the Roberts iron ore bed in the top of the Keefer also seem indicative of a shallow-water, high-energy environment. In much of the area the Keefer is finer grained, thinner bedded, and considerably more fossiliferous than the Tuscarora Quartzite; this difference may indicate that the Keefer Sandstone may have been deposited in slightly deeper water than the Tuscarora.

The environment of deposition returned to one of low energy at the close of Keefer time. Deposition of quartz silt and sand ceased abruptly, and layers of shells alternating with layers of calcareous mud accumulated. The source area of the insoluble clastic sediment lay far to the east and was apparently tectonically quiescent, because only the finer grained detritus was carried into the mapped area. Remains of an abundant and varied marine fauna indicate that the epicontinental sea was clear and well aerated in Rochester time. Currents and waves swept the sea bottom from time to time and winnowed the fine calcareous mud away from the accumulating sea shells to form beds of whole and fragmented shells.

Calcareous and noncalcareous mud intercalated with beds of sea shells continued to accumulate in the shallow sea. The fauna in the Middle Silurian sea changed from a normal marine fauna containing brachiopods, gastropods, corals, cephalopods, ostracodes, and trilobites to a more restricted fauna dominated by ostracodes. Most benthonic invertebrates died out. The change of environment in the marine basin may have resulted from an increase in the amount of mud carried into the sea and from restricted circulation and consequent stagnation of the sea. In parts of New York, Ohio, and Pennsylvania to the north and west, large reefs formed in the clear sea and were barriers that restricted the circulation in the eastern part of the marine basin. The argillaceous limestone and calcareous shale of the McKenzie Formation seem to have accumulated behind the reefs as a back-reef deposit. Such deposits commonly have a more restricted fauna than reef and fore-reef deposits.

During the Middle Silurian, erosion of uplifted source areas to the east provided large quantities of red mud, silt, and sand that formed a delta on the eastern side of the epicontinental sea in central Pennsylvania. This delta, the Bloomsburg delta, expanded rapidly to the west in Pennsylvania and more slowly southwest along the shore of the sea. Presently, bright-colored clastic sediments spread into western Maryland and temporarily interrupted deposition of calcareous sediments. The red beds accumulated largely in a high-energy environment in which waves and currents were active. Cross-bedding, current ripplemarks, trails and borings, and the dominant red color of the sediment suggest rapid deposition in shallow water. Locally, drab calcareous mud accumulated in the more protected places where currents were less active. The few scattered ostracode tests in the mud show that marine life existed in the epicontinental sea even in the unfavorable environment along the fringe of the muddy Bloomsburg delta. Red beds accumulated for a short time in the mapped area until the volume of red clastics decreased, and a shift to a low-energy reducing environment brought about the deposition of dark-gray calcareous mud.

Calcareous mud of the Wills Creek accumulated along the margin of the shallow marine basin, in estuaries, in lagoons, and on broad flats bordering the sea. Dessication cracks, rain drop or hail impressions, and rill marks indicate that at times the sediment was exposed to the air before lithification. Beds of black shale show that organic-rich mud was deposited in an euxinic environment at other times. The association of dessicated mud and black mud strongly suggests accumulation on a low coastal plain along which lagoons and estuaries alternate with mud flats. Drying and cracking of some partly lithified mud on these flats produced many small sharp-edged fragments which, when swept into layers by the sea, formed the beds of edgewise intraformational conglomerate or breccia. Although the sea in Wills Creek time was decidedly unfavorable to most forms of life, ostracodes lived in the lagoons, and eurypterids existed in the estuaries.

Increased amounts of calcareous sediment accumulated in western Maryland during the Late Silurian. Quiescent source areas, a greater distance from the eastern shore of the sea, and a low-energy depositional environment probably led to the decrease in the amount of noncalcareous mud that was carried into the mapped area. Quartz silt and fine sand present in the Tonoloway may have been blown into the epicontinental sea by winds. The thin laminae of terrigenous sediment in the Tonoloway indicate that the sediment was stirred and sorted by waves and by currents from time to time. The general absence of raindrop impressions in the area and a large increase in the kinds and numbers of fossils in Upper Silurian rocks suggest that most of the sediment accumulated in a marine environment. The large number of ostracodes in the fauna, however, indicates that the sea was probably not of normal salinity.

The open shallow epicontinental sea covered the area during the Late Silurian and much of the Early Devonian. Marine invertebrates throve in the clear, nutriment-rich water, and thick beds of bioclastic limestone were deposited. The source of terrigenous sediment was far to the east, and only small amounts of noncalcareous mud were transported to western Maryland during the accumulation of the Keyser, Coeymans, and New Scotland Limestones. Coralline, bryozoal, and stromotoporoidal biostromes grew in the shallow sea, particularly during Keyser time, and thick beds of coquinoid limestone accumulated at many places where waves and currents swept away the finer grained calcareous sediment.

A stable shelf environment persisted with little change in western Maryland throughout much of the Late Silurian and Early Devonian. To the east, however, tectonic activity elevated the borderland. Large amounts of soluble silica were precipitated in the marine basin to form the bedded chert in the New Scotland Limestone of western Maryland. In general the epicontinental sea was open, clear, and well aerated during the deposition of the Keyser, Coeymans, and New Scotland, in contrast to the restricted hypersaline sea of the Wills Creek and Tonoloway. By analogy with modern seas, the Keyser, Coeymans, and New Scotland Limestones accumulated in shallow, well-aerated water not much more than 100 feet deep.

In response to continuing tectonic activity in the source areas, a great influx of noncalcareous mud and clay from the rising borderland swept into the epicontinental sea at the beginning of Mandata time.

As the borderlands continued to rise in the Early Devonian, increasingly large amounts of mud, quartz silt, and free silica were transported into the marine basin. Silica precipitated on the sea floor to form the nodules of dark-gray, slightly calcareous chert that characterizes the Shriver in western Maryland. The sea shoaled as the load of terrigenous sediment increased, but when the varying influx of clastic debris was least, beds of impure silty calcareous sediment accumulated. The sequence of silty shale and argillaceous silty limestone in the lower and middle part of the Shriver gives way to beds of calcareous siltstone and sandstone in the upper part of the formation. The change in character of the sediment indicates a shift to a high-energy environment as the shoreline of the epicontinental sea advanced into western Maryland from the east. Fossils become considerably more common in the upper part of the Shriver because the increasingly active waves and currents swept away the finer grained sediment and produced an environment more favorable to marine organisms.

The maximum regression of the epicontinental sea in the Early Devonian is marked by the spread of coarse-grained quartzose sediment across the mapped area during Ridgeley time. Near-shore deposits of sand and gravel accumulated in western Maryland as waves and currents energetically stirred, sorted and winnowed the finer grained components from the sediment. Large-scale cross lamination,

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lenses of "wheat grain" conglomerate, and lenticular beds of coquinite composed of thick-shelled invertebrates show that the Ridgeley was deposited in a high-energy environment similar to the environment in which the Tuscarora Quartzite accumulated.

Deposition of the Ridgeley Sandstone was terminated by the abrupt decrease in the supply of coarse detritus, and the epicontinental sea flooded eastward across the Appalachian geosyncline. During much of the Middle Devonian, calcareous and noncalcareous mud, silt, and finely macerated carbonaceous matter accumulated in a low-energy environment in the mapped area. Apparently at times the sea was too deep for waves and currents to stir and winnow the bottom sediments effectively. The environment ranged from euxinic to moderately well aerated, depending upon the effectiveness of circulation in the marine basin. Black, brownish-black, and grayish-black organic mud accumulated in the euxinic environment which was best developed during Marcellus time. The fauna in areas where black sediment accumulated is composed largely of small thin-shelled pelagic forms. The gray calcareous and noncalcareous mud and silty mud of the Needmore and of the lower part of the Mahantango were deposited in a better aerated sea that was populated by a larger fauna containing both pelagic and bottom-dwelling forms.

During the Middle Devonian, tectonic activity again elevated the borderland along the eastern side of the geosyncline, and large quantities of sediment were carried into the sea. A large complex delta, the Catskill delta, began to grow in east-central Pennsylvania. It was not made by a single river but was formed by the coalescing deposits of many streams and rivers. The delta sediments spread westward and began to displace the epicontinental sea from the geosyncline. Because the Evitts Creek and Pattersons Creek quadrangles lay well southwest of the center of accumulation, they were little affected at first by the influx of clastic sediments. In time, however, the deltaic sediments spread into western Maryland and modified the sedimentary history of the two quadrangles.

As the carrying and sorting power of waves and longshore currents increased in the shallowing sea, coarse quartzose silt from the growing Catskill delta in Pennsylvania was transported into western Maryland during Mahantango time. Large amounts of silt accumulated and the finer sediments were carried farther to the south and west. A large and diverse marine fauna lived in the shoaling sea.

At the close of the Middle Devonian, deposition of silt and sand of the Mahantango ceased, and black, brownish-black, and very dark gray organic-rich mud accumulated in the shallow sea that covered western Maryland. The dark-colored sediments comprise the Harrell Shale.

They accumulated in a low-energy environment which may have been caused by a decrease in circulation of the marine currents, by a shift in the location of the distributaries that carried sediment into the sea, or by a combination of these factors.

Clastics from the spreading Catskill delta continued to fill the shallowing marine basin during the Late Devonian, and the environment of deposition changed gradually from low to high energy. The shift is shown by the succession of strata and faunas in the Harrell Shale and the Woodmont Shale. The Harrell is composed largely of dark shale containing only a few thin discrete layers of siltstone. The fauna is largely restricted to small fragile-shelled pelagic forms. The dark color of the rock, small fauna, and the dominance of fine-grained sediment are characteristic of a low-energy environment in which sediment accumulated below effective wave base. In contrast, the lower part of the overlying Woodmont is composed largely of medium-gray shale and intercalated siltstone. It contains little very dark gray shale. Although fauna is sparse at most places, pteropods are exteremely abundant locally. Apparently these rocks were deposited in relatively quiet water, but waves and currents were able to sort and stir the sediment from time to time. The upper part of the Woodmont contains thick beds of ripplemarked and crossbedded siltstone intercalated with beds of nearly silt-free shale. The fauna in the upper part of the Woodmont is large and contains many thick-shelled forms characteristic of a shallow-water environment. The more abundant fauna indicates that the sea was clear and well aerated, and contained a large amount of nutriment and dissolved minerals. The Chemung(?) Formation, only the basal part of which remains in the mapped area, contains many thick layers of quartzose sandy siltstone and silty sandstone, which at many places occupy channels cut in the underlying strata. Layers of pebble conglomerate and a fauna including many thick-shelled bottom-dwelling forms in the lower part of the Chemung(?) Formation suggest deposition in shallow water near the strand line of the Catskill delta in a high-energy environment of deposition.

Although all Paleozoic rocks younger than the lower part of the Chemung(?) Formation have been carried from the mapped area by subsequent erosion, a study of the rest of Allegany County by Berryhill, Johnston, and the present writers shows that at least 7,000 feet of Upper Devonian, Carboniferous, and Permian rocks were deposited on the youngest rocks now exposed in the Pattersons Creek quadrangle. These strata consisted of gray and red shale, siltstone, and sandstone comprising the middle and upper parts of the Chemung(?) Formation; red beds of the Hampshire Formation of Late

Devonian age; and sandstone, siltstone, shale, and small amounts of limestone, claystone, and coal of the Mississippian, Pennsylvanian, and Permian Systems. Most of these rocks accumulated near the strand line of the epicontinental sea as marine shelf deposits, littoral, estuarine, and fluviatile deposits.

During the Appalachian revolution, a period of orogenic activity that began late in the Paleozoic Era and continued into the early part of the following Mesozoic Era, the rocks in the Appalachian geosyncline were folded and faulted. The geosynclinal rocks were uplifted, and the geologic history of the Evitts Creek and Pattersons Creek quadrangles since the close of the Appalachian revolution has been largely a story of subaerial erosion accelerated at times by renewed uplift. The more rapid erosion of the softer rocks left the more resistant rocks standing as ridges and mountains.

ECONOMIC GEOLOGY

Chert, limestone, shale, siltstone, and sandstone are being quarried at present from the bedrock of the mapped area. In the past, iron was mined from the Silurian rocks in the vicinity of Cumberland. but the discovery of large quantities of higher grade ore in the Lake Superior district has long since brought a halt to iron mining in Allegany County.

LIMESTONE

In the mapped area and vicinity, limestone has been quarried from the Wills Creek Shale, the Tonoloway Limestone, the Keyser Limestone, and the Coeymans Limestone for chemical limestone, agricultural limestone, cement, and building stone. The purest limestone, containing as much as 90 percent calcium carbonate, was quarried from the Keyser (Reger, 1924, p. 678). The main impurities are silica and alumina. The presence of nodular chert scattered throughout the Keyser assures that some silica will be present in any large quantity of rock quarried from the formation. The middle 100 to 150 feet of the Tonoloway Limestone in the vicinity of Cumberland contains limestone that is only slightly less pure than the limestone in the Keyser. The calcium carbonate content of these beds ranges from 70 to 85 percent (Reger, 1924, p. 678). The main impurity again is silica although some of the rock contains an appreciable amount of dolomite. In the 19th century, argillaceous limestone was quarried from the Wills Creek Shale near Cumberland for the manufacture of natural cement. The introduction of portland cement ruined the natural cement industry and the quarries were abandoned. Limestone from the Keyser and the Tonoloway has been burned for quicklime and ground for agricultural lime at several places in the area. A fairly large quantity of the thicker bedded Tonoloway Limestone and some of the more even-bedded Keyser Limestone has been quarried for dimension stone. At present most of the output of the quarries is crushed and sized stone for road metal, railroad ballast, concrete aggregate, and filler for black-topping highways.

At present, little use is being made of the abundant resources of limestone in the area. A quarry that was opened about 1960 in the Keyser Limestone on the west flank of Irons Mountain about 0.9 mile east of the village of Evitts Creek is probably the only active one in the mapped area. The Sensabaugh Quarry on the west side of Irons Mountain, about 0.2 mile north of the active quarry east of the hamlet of Evitts Creek, is the largest abandoned quarry in the area. Small quarries were located along Highway 40 about a mile west of Pleasant Grove Church, east and west of Yonkers on Highway 40, along Pea Vine Run about 0.5 mile west of Zion Park Cemetery, in the vicinity of Centenary Church near the Maryland State line on Highway 220, and on Murley Branch not far from the eastern edge of the Evitts Creek quadrangle boundary.

About 1905 the Casparis Stone Co. built a large processing plant and opened a quarry on the west flank of Patterson Creek Ridge about 1.3 miles south of the village of Pattersons Creek (Reger, 1924, p. 663). Stone for railroad ballast was the desired product. Residents of the area report that only a few carloads of stone were shipped before the operation was abandoned. Reger (1924, p. 663) stated that the quarry contained 25 feet of Helderberg Limestone in the lower part. An analysis of the quarry stone showed 38 percent calcium carbonate and 53 percent silica (Reger, 1924, p. 678). The writers examined the quarry and concluded that it cut through the basal part of the Ridgeley Sandstone and into the upper beds of the Shriver Chert. In the quarry of the Casparis Stone Co. and in outcrops along the Western Maryland Railway near the south end of Nicholas Ridge the upper part of the Shriver Chert is composed of a homogenous dark-gray very calcareous siltstone and fine-grained sandstone similar in appearance to limestone when freshly exposed. Limestones of the Helderberg Group are neither exposed on Patterson Creek Ridge in the vicinity of the Casparis Stone Co. quarry nor along the ridge above the quarry, although the geologic map of Mineral County (Reger, 1924) shows a belt of Helderberg Limestone along the crest of the ridge.

SHALE AND CLAY

Shale that is more or less self-cementing upon compaction is well suited for surfacing the lightly traveled unpaved secondary roads in the two quadrangles. Such material has been obtained from the

Rose Hill Formation, Needmore Shale, Marcellus Shale, Mahantango Formation, and Harrell Shale in the mapped area. Some shale possesses sufficient plasticity when ground to be used in the manufacture of ceramics. Tilton (1927, p. 124–125) reported that shale from the Marcellus, Mahantango, and McKenzie are suitable for making tile and brick. Brick was made from shale in the Rose Hill at Cumberland (Reger, 1924, p. 716), and O'Harra and others (1900, p. 184) stated that brick was being manufactured from shale obtained from the upper part of the Woodmont at South Cumberland.

Small amounts of clay are present in the alluvium along the North Branch of the Potomac River and along the lower parts of Evitts Creek and Patterson Creek. Much of the clay is impure because of intermixed sand and rock fragments. As long as an adequate supply of clay and shale remains in the coal fields of Allegany and Garret Counties, a short distance west of Cumberland, it seems doubtful that the meager amounts of sandy clay in the mapped area will be exploited.

SILTSTONE AND CHERT

Siltstone for fill and surfacing roads has been excavated from small borrow pits and quarries in the Rose Hill Formation, Shriver Chert, Mahantango Formation, and Woodmont Shale in several places within the two quadrangles. Chert and siltstone from the Shriver and chert from the New Scotland Limestone are used extensively for surfacing gravel roads in the central part of Allegany County. A large quarry has been opened in the Shriver Chert on the west flank of Irons Mountain midway between the hamlet of Evitts Creek and Davis Church. The Shriver Chert and the New Scotland Limestone have been obtained for road metal from quarries on Williams Road 0.25 mile east of Twiggtown and on U.S. Highway 40 about 1 mile west of Pleasant Grove Church.

Small amounts of siltstone from the Woodmont Shale have been quarried for flagstone and for dimension stone. The purplish-red and grayish-green siltstones in the Bloomsburg Red Beds have recently been used for dimension stone in retaining walls and foundations in the vicinity of Cumberland.

SANDSTONE AND QUARTZITE

Locally quartzite from the Tuscarora and sandstone from the Ridgeley have been used for dimension stone. The rocks have also been used for road metal, railroad ballast, and aggregate for concrete. A large quantity of crushed quartzite from a quarry on the west side of Wills Mountain, about 1 mile north of the Narrows in the neighboring Cumberland quadrangle, has been produced from the Tuscarora. To the north in Blair County, Pa., the Tuscarora has long been quarried as ganister for the manufacture of refractory brick (Butts, 1945, p. 18). Tests may show that the Tuscarora of the Evitts Creek quadrangle can also be used to make refractory brick.

The Ridgeley Sandstone is the main source of silica for the manufacture of glass in the central part of the Appalachian Mountains. In the vicinity of Berkeley Springs, W. Va., about 35 miles east of the mapped area, the Ridgeley Sandstone is mined and quarried for glass sand. The sandstone quarried near Berkeley Springs contains as much as 98.8 percent silica. It contains very little iron or other impurities and is easily crushed for processing. In all the exposures of the Ridgeley examined by the writers in the Evitts Creek and Pattersons Creek quadrangles, it contained too much calcium carbonate and iron oxide and was too hard to be successfully exploited by present methods.

IRON ORE

Prior to the discovery of the large deposits of high-grade iron ore in the Lake Superior district, iron was mined extensively from small deposits of lean ore in the Appalachian Mountains. In the vicinity of Cumberland, iron was obtained from Swartz' Cresaptown Iron Sandstone, the Roberts ore at the top of the Keefer Sandstone, the iron-rich beds in the Helderberg Group, and from a bed that occurs in some places at the contact between the Ridgeley Sandstone and the Needmore Shale. The Roberts ore, which contains as much as 37.4 percent iron (C. K. Swartz and others, 1923, p. 33), was extensively mined along the east side of Wills Mountain north and south of Cumberland. Numerous prospect pits can be seen along the outcrop of the Keefer Sandstone on the west flank of Wills Mountain south of Cooks Mills and on the west side of Evitts Mountain between the Maryland State line and the north boundary of the Evitts Creek quadrangle. The Cresaptown Iron Sandstone of Swartz, which surficially resembles the Roberts ore, locally contains as much as 70 percent silica (C. K. Swartz and others, 1923, p. 29) and was at best a very low grade ore. Modern blast furnaces using the less expensively processed Lake Superior iron ores forced the closing of the older and less efficient furnaces in the Appalachian region and led to the abandonment of the iron smelting industry in Allegany County.

OIL AND GAS

The exposed bedrock in the Evitts Creek and Pattersons Creek quadrangles does not appear to contain appreciable quantities of petroleum. Rocks of the Oriskany Group and the Tuscarora Quartzite, which contain oil and gas in other parts of the Appalachian Mountains, crop out in many places in the mapped area. It is very doubtful if these rocks contain commercial concentrations of petroleum close to their outcrop. In the more deeply buried rocks, the Trenton Limestone of Middle Ordovician age and the Gatesburg Formation of Late Cambrian age may contain some oil or gas in the mapped area. The Trenton Limestone has produced oil in southwest Virginia and contained several shows of gas in a deep test well in Wood County, W. Va. The sandy Gatesburg Formation contains gas and salt water in central Pennsylvania. Assuming that the stratigraphic sequence is normal and not faulted, in the mapped area the top of the Trenton Limestone is 2,100 to 2,300 feet below the base of the Juniata Formation, and the top of the Gatesburg Formation should be about 5,400 feet below the base of the Juniata Formation. These older rocks are closest to the surface in the Evitts Mountain and Wills Mountain anticlines in the northern part of the area. Wells properly located on the east flanks of the anticlines could best test the petroleum potential of the deeper formations.

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INDEX

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