DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

PAWPAW - HANCOCK FOLIO

MARYLAND - WEST VIRGINIA - PENNSYLVANIA

BY

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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds—(1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

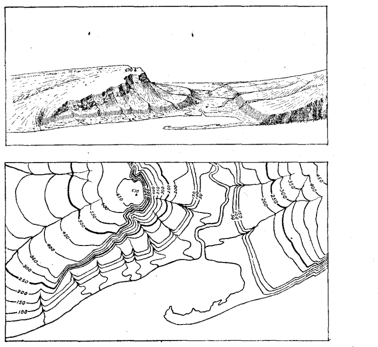

FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land and, by means of structure sections, their underground relations, so far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits of these are called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the kinds of deposit named may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which rocks were made is divided into *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by the name of the time interval in which it was formed.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. Where two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent Pleistocene	Q	Brownish yellow.
	Tertiary	Pliocene Miocene Oligocene Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		TR	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Є	Brick-red.
	Algonkian		A	Brownish red.
	Archean		AR	Gray-brown.

SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterward partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

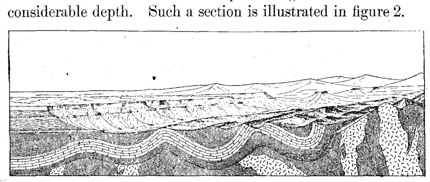

FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

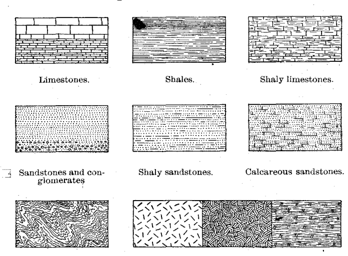

FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction of the intersection of a bed with a horizontal plane is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in figure 4.

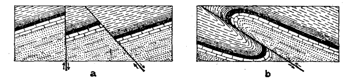

FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists were metamorphosed, they were disturbed by eruptive activity, and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

The intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

GEORGE OTIS SMITH,
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May, 1909.

DESCRIPTION OF THE PAWPAW AND HANCOCK QUADRANGLES.

By G. W. Stose and C. K. Swartz.[a]

INTRODUCTION.

LOCATION AND AREA.

The Pawpaw and Hancock quadrangles embrace parts of eastern West Virginia, western Maryland, and southern Pennsylvania between parallels 39° 30′ and 39° 45′ and meridians 78° and 78° 30′, and contain 460 square miles. (See fig. 1.)

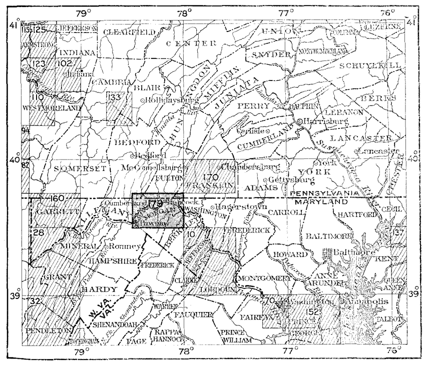

FIGURE 1.—Index map of the vicinity of the Pawpaw and Hancock quadrangles.

The location of the Pawpaw and Hancock quadrangles is shown by the darker ruling. Published folios describing other quadrangles are indicated by lighter ruling, as follows: Nos. 10, Harpers Ferry; 28, Piedmont; 32, Franklin; 70, Washington; 82, Masontown-Uniontown; 94, Brownsville-Connellsville; 102, Indiana; 110, Latrobe; 115, Kittanning; 123, Elders Ridge; 125, Rural Valley; 133, Ebensburg; 137, Dover; 152, Patuxent; 160, Accident-Grantsville; 170, Mercersburg-Chambersburg.

Parts of eight counties are included in the area, Morgan, Berkeley, and Hampshire in West Virginia, Washington and Allegany in Maryland, and Bedford, Fulton, and Franklin in Pennsylvania. Hancock, Md., is the largest town in the area, Pawpaw, Great Cacapon, and Berkeley Springs, W. Va., being next in importance.

THE APPALACHIAN PROVINCE.

The Pawpaw and Hancock quadrangles form part of the Appalachian geographic and geologic province, which extends from the Atlantic Coastal Plain to the Mississippi lowlands and from central Alabama to Canada. This region has had throughout its extent a similar history, which is recorded in its rocks and its topographic features. Only a part of this history can be interpreted from so small an area as the Pawpaw and Hancock quadrangles, and it is therefore desirable to consider the area in its relation to the entire province.

The Appalachian province is composed of three well-marked divisions, each of which shows similar sedimentary deposits, geologic structure, and topography. The western division is named the Appalachian Plateau; the middle the Appalachian Valley and valley ridges; the eastern the Appalachian Mountains and Piedmont Plateau. (See fig. 2.) These divisions extend nearly the length of the province from northeast to southwest, but the following description applies more directly to the portion south of the State of New York.

Appalachian Valley.—The central division, the Appalachian Valley, is the best-defined and most uniform of the three. In its southern portion it coincides with the belt of closely folded and faulted rocks forming the Coosa Valley of Alabama and Georgia and the valley of eastern Tennessee and Virginia, where it varies in width from 40 to 125 miles. Throughout its central and northern portions the eastern side is marked by great valleys ranging in width from 8 to 13 miles, among them being the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and southern Pennsylvania, the Lebanon Valley of eastern Pennsylvania, and the Kittatinny Valley of New Jersey. The western side of this portion of the Appalachian Valley is a succession of narrow valleys separated by parallel ridges, known as the Appalachian Valley ridges. This central division is sharply delimited on the southeast by the Appalachian Mountains and on the northwest by the Appalachian Plateau.

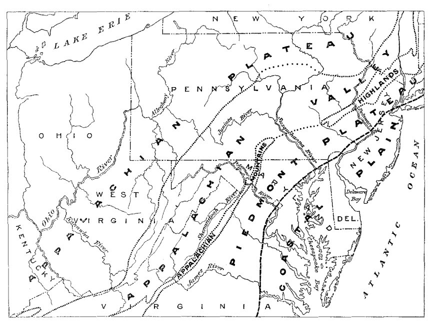

FIGURE 2.—Map of the northern part of the Appalachian province, showing its physiographic divisions and its relation to the Coastal Plain.

The Pawpaw and Hancock quadrangles are situated in the Appalachian Valley division at the narrowest part of Maryland.

The rocks of the Appalachian Valley are almost wholly sedimentary, consisting of limestone, shale, and sandstone. The strata when deposited were nearly horizontal, but they are now inclined at various angles and their outcrops at the surface form narrow belts of different kinds of rocks. The surface relief varies with the outcrops of rocks of different hardness and solubility. In the southern portion of the valley, where large amounts of calcareous rock are exposed by the erosion of anticlinal folds, the surface is more readily worn down by streams and is lower and less varied than in the adjacent regions on the east and west. In the western part of the northern portion of the valley, however, sharp ridges and narrow valleys of great length follow the narrow belts of upturned hard and soft rocks respectively.

Appalachian Mountains and Piedmont Plateau.—The eastern division of the province embraces the Appalachian Mountains and the Piedmont Plateau. The Appalachian Mountains are made up of many ranges and ridges, which under various local names extend from southern New York to central Alabama. Chief among these are South Mountain in Pennsylvania, Blue Ridge and Catoctin Mountain in Maryland and Virginia, the Great Smoky Mountains in Tennessee and North Carolina, and the Cohutta Mountains in Georgia. The Piedmont Plateau is a vast upland that lies at the eastern foot of the Appalachian Mountains. It stretches southward from New York to Alabama and merges eastward into the Coastal Plain, which borders the Atlantic Ocean. The mountains and the plateau grade into each other with no sharp boundary. The same rocks and the same structures appear in each, and the form of the surface varies largely in accordance with the ability of the different streams to wear down the rocks. Most of the rocks of this division are more or less crystalline, being either sediments that have been changed to slates, quartzites, or schists by varying degrees of metamorphism, or igneous rocks, such as granite, diabase, and gneiss, which have solidified from a molten condition.

Appalachian Plateau.—The western division of the Appalachian province includes, in addition to the Cumberland Plateau of Tennessee and Georgia and the Allegheny Plateau of Pennsylvania, Maryland, Virginia, and West Virginia, the lowlands of central Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite but may be arbitrarily regarded as a line coinciding with the eastern boundary of the Mississippi embayment as far up as Cairo, and then crossing the States of Illinois, Indiana, and Ohio. Its eastern border is sharply defined in most places along the Appalachian Valley by the Allegheny Front and the Cumberland escarpment.

The rocks of this division are almost entirely of sedimentary origin and are only gently folded. The surface, which is dependent on the character and attitude of the rocks, is that of a plateau in various stages of dissection. In the southern half of the province portions of the plateau are of wide extent and nearly flat, but it is more commonly intersected by numerous valleys and ravines, which leave small elevated flat-topped remnants. In West Virginia and in portions of Pennsylvania the plateau is so largely dissected that the irregularly rounded knobs and ridges that remain bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion, and the surface is now comparatively low and level or rolling.

Altitude.—The Appalachian province attains its greatest elevation in North Carolina, where the Appalachian Mountains have a maximum altitude of 6712 feet. The range descends southward from this culminating point until its height becomes less than 1000 feet at its southern end in Alabama, and northward to 3500 feet in Virginia and 1750 feet in Maryland and Pennsylvania. The plateau division west of the valley, beginning at its southern limit at an altitude of 500 feet, ascends to 2000 feet in Tennessee, and culminates in eastern Kentucky at about 4000 feet, whence it descends again to 2000 feet in central Pennsylvania.

The elevation of the floor of the Appalachian Valley is determined largely by the drainage basins of the trunk streams which cut through the mountain barriers on either side at irregular intervals, and it has therefore numerous culminating points on the watersheds between these streams. It rises from less than 500 feet in Alabama to 2700 feet on the Tennessee River-New River divide, at which point it begins a descent to 2200 feet in the New River valley. The elevation of the valley floor rises and falls over the divides and valleys of the James and Potomac rivers, reaching a minimum of 500 feet in the latter basin. It does not rise above 1000 feet in Pennsylvania. Throughout the length of the province the stream channels are cut 50 to 250 feet below this valley floor, and the valley ridges rise from 500 to 2000 feet above it.

Drainage.—The drainage of the province is in part eastward into the Atlantic Ocean, in part southward into the Gulf of Mexico, and in part westward into the Mississippi. All the western or Plateau division of the province, except small portions in Pennsylvania and in Alabama, is drained by streams flowing westward into the Ohio and thence into the Mississippi. The northern portion of the Appalachian Mountain division is drained eastward into the Atlantic, but south of New River all except the eastern slope is drained westward into the Ohio by tributaries of the Tennessee or southward into the Gulf by tributaries of the Coosa.

In general the streams of the Appalachian Valley flow for long distances in the lesser valleys along the outcrops of softer rocks parallel to the mountain ranges bounding the valley. These longitudinal streams empty into larger transverse rivers which cross one or the other of the mountain barriers. In the northern portion of the province Delaware, Susquehanna, Potomac, James, and Roanoke rivers pass through the Appalachian Mountains in narrow gaps and flow eastward to the sea. In the central portion of the province, in Kentucky and Virginia, the longitudinal streams form New River, which flows westward in a deep, narrow gorge through the Cumberland Plateau into the Ohio. From New River southward to the boundary of Georgia the valley of eastern Tennessee and Virginia is drained by tributaries of the Tennessee, which at Chattanooga leaves the broad valley and, entering a gorge through the plateau, runs westward to the Ohio. South of Tennessee River the streams flow directly to the Gulf of Mexico.

Rocks and general geologic history.—The rocks that appear at the surface of the Appalachian province comprise igneous and sedimentary rocks and crystalline rocks which, on account of their age and extensive alteration, are of unknown origin. The geologic history of the region is preserved in these formations, but at no one place is the entire record complete and only by combining the data from the various parts of the

[a] The Pawpaw and Hancock quadrangles were surveyed in cooperation with the State Geological Survey of Maryland. The Maryland portion of these areas was originally surveyed by George C. Martin of the Maryland Survey. The Silurian, Lower Devonian, and Carboniferous boundaries were later revised by George W. Stose, and the Middle and Upper Devonian boundaries were newly mapped by Charles K. Swartz, D. W. Ohern, and T. P. Maynard of the Maryland Survey in cooperation with the Federal Survey. The West Virginia portion of the quadrangles was surveyed by Stose and the Pennsylvania portion by Stose and Swartz. The text, except the chapter on the Middle and Upper Devonian by Charles K. Swartz, was written by George W. Stose. Fossils of the Lower Devonian and older rocks were determined by E. O. Ulrich, who contributed most of the discussion of the correlation for this portion.

This folio is one of several describing the quadrangles that lie between the Allegheny Plateau and the sea along the northern border of Maryland, to be published by the United States Geological Survey in cooperation with the State Geological Survey of Maryland. These folios will form an educational series to illustrate the geology of the middle Atlantic slope. One folio of this series has already been published, namely, Accident-Grantsville, No. 160.

province can the general occurrence of geologic events be determined.

The oldest rocks of the region consist chiefly of gneisses and schists which occur in the Appalachian Mountains and in the Piedmont Plateau. The original character of these rocks is obliterated by the extensive alteration which has taken place during the long ages since their formation, and it is generally impossible to determine whether they were a part of the cooled surface of an original molten mass or sediments laid down in the earliest seas. The great pressure and heat to which the rocks were subjected during periods of compression. while deeply buried in the earth have caused recrystallization of the mineral particles in new forms and associations, and have given the rocks a gneissoid or schistose structure. During this early period, while still deeply buried, these schists and gneisses were penetrated by great masses of molten rocks from below, which now occur at the surface as granites, diorites, and other crystalline igneous rocks. This basal complex is generally regarded as belonging to the Archean period.

After these once deep-seated rocks were brought to the surface in pre-Cambrian time by uplift and long-continued erosion, they were covered by lavas. Whether these ancient lavas represent a late portion of the Archean period or are of Algonkian age is not certain. They are separated from the overlying Cambrian strata by an unconformity, and fragments of the lavas form basal conglomerates in the Cambrian. These pre-Cambrian rocks are found both in the Appalachian Mountains and in the Piedmont Plateau. In general, the oldest rocks occur on the eastern side of the province and successively younger strata appear toward the west.

After a period of erosion a portion of the land was submerged beneath the sea, and sand, gravel, mud, and calcareous ooze were laid down upon the older rocks in the form of marine sediments. In these deposits, now hardened to sandstone, conglomerate, shale, and limestone, are to be seen fragments of waste from the igneous and metamorphic rocks of the adjacent land.

These strata do not represent continuous sheets of deposits throughout the province, for portions of the sea bottom were at times uplifted into land and the newly deposited sediments were exposed to erosion while other portions were still submerged. The sea in which these sediments were deposited was an inland body of water occupying the interior of the North American continent, and its eastern shore oscillated back and forth across the Appalachian province. The submergence began at least as early as the beginning of Cambrian time, and perhaps in Algonkian time, and continued with interruptions to the close of the Carboniferous period.

Several great cycles of sedimentation are recorded in the rocks of this region. The first deposits were conglomerates, sandstones, and shales, laid down in early Cambrian time along the eastern border of the interior sea as it encroached upon the sinking land. As the land was worn down and erosion became less active the sediments became finer, until in late Cambrian time very little mechanical detritus reached the sea and the deposits consisted for the most part of calcium carbonate. This condition continued into the Ordovician period without a marked break in the sedimentation, but the beginning of the Silurian period was marked by increased activity of the erosive agencies, and a considerable thickness of quartz sand and pebbles, equivalent in age to the Medina sandstone of New York, was laid down throughout the length of the province.

The sea covered the region as far south as Virginia until the close of the Silurian, during which time the sediments became finer and finer until ultimately limestones were again deposited. Pure white sand and conglomerate equivalent in age to the Oriskany sandstone of New York were deposited in early Devonian time by reason of a third uplift of the land and were followed by a vast accumulation of mud and sand on the sinking bottom of the shallow sea. South of Virginia other conditions prevailed during Silurian and Devonian time, for in general only a few feet of Devonian black shale overlies the sandstone of early Silurian age. Vast land areas must have existed in this part of the province during the latter part of the Silurian period and most of the Devonian.

The Carboniferous period, although it began with marine deposits consisting for the most part of limestones, is characterized by brackish-water and marsh deposits, which indicate the existence of broad, shallow estuarine basins, in which were accumulated detrital material brought in by streams. With the sands and mud were occasionally buried layers of carbonaceous matter derived from dense growths of vegetation in the shallow waters of the bay or in marginal swamps. These have since been converted into the coal beds which comprise the great Carboniferous coal field of the Appalachians.

Sedimentation in the Appalachian province ceased almost entirely at the close of the Carboniferous period, at which time the region was uplifted and the area previously covered by the inland sea was drained and added permanently to the land. Estuarine deposits were locally laid down, however, in shallow basins on the eastern margin of the Piedmont Plateau during the Triassic period. In the ages since that time the region has been subjected to erosion, and no deposits except local stream gravels are left to record its history, which is preserved only in the topographic forms.

TOPOGRAPHY OF THE QUADRANGLES.

RELIEF.

The Pawpaw and Hancock quadrangles lie entirely within the Appalachian Valley division of the Appalachian province. The Appalachian Valley in this area, and generally throughout the northern Appalachian region, has an eastern or valley portion, known in Maryland and Pennsylvania as the Cumberland Valley and in West Virginia as the Shenandoah Valley, and a western or mountainous portion comprising the Appalachian Valley ridges. Only the extreme southeastern corner of the area included in these quadrangles is a part of the Shenandoah Valley, a wide limestone valley extending eastward to South Mountain. Throughout the rest of the area mountains, narrow valleys, and deeply dissected uplands alternate, the whole cut across by the deep winding gorge of the Potomac. The most prominent mountains are North, Third Hill, Short, Sleepy Creek, Cove, and Keefer mountains in the Hancock quadrangle, and Cacapon, Sideling Hill, Spring Gap, and Town Hill mountains in the Pawpaw quadrangle.

Cacapon Mountain.—Cacapon Mountain is the highest and most important mountain in the area, and serves as a dividing line between two varieties of mountainous topography. To the east is a low plateau, extensively dissected, with occasional higher ridges and mountains rising above it. To the west the general surface, originally a plateau, is now so deeply dissected and has so many ridges rising above it that it has a much more rugged and mountainous character.

Beginning as a small ridge at Sir Johns Run on the Potomac, Cacapon Mountain develops southward into a narrow precipitous mountain that rises rather abruptly to an elevation of 1800 feet. It broadens south of this point to a massive flat-topped mountain 2000 feet in elevation, with very precipitous slopes, and attains an altitude of 2270 feet at the southern border of the quadrangle. Great Cacapon River, which is graded nearly to the level of the Potomac, flows along the western base of the mountain, and its short lateral tributaries have cut deeply into the western side of the mountain forming several very rugged, densely wooded ravines—the most picturesque bit of mountain scenery in the area. Prospect Rock, where the Great Cacapon has undercut the mountain and formed steep bare cliffs, commands a superb view of the river gorge and the mountains to the west, and is the scenic point for visitors from the neighboring summer resorts. (See Pl. II.) Another and more easily accessible viewpoint is on the crest of the mountain where it is crossed by the Great Cacapon road, directly above the place where the Potomac undercuts the mountain and is deflected at right angles from its hitherto eastward course. (See Pl. I.) The eastern slope of the mountain, although steep, is free from deep ravines and foothills except near the southern border of the quadrangle, where moderately rugged ravines lie back of the Piney Ridge foothills.

East of Cacapon Mountain.—The topography of the region lying east of Cacapon Mountain and Tonoloway Ridge and north of the Potomac is as a rule less rugged than that to the west. The surface in general forms a rugged upland ranging from 700 to 1000 feet in elevation, into which is cut an intricate "trellis" drainage, and above which rise hills and mountains. The upland is composed in part of long straight hogback or structural ridges, such as Warm Spring, Horse, Pious, Highland, Cove, and Timber ridges, whose wide level summits are of about the same elevation. These higher ridges are composed of relatively hard strata. Elsewhere the upland is formed of level-topped ridges and hills of somewhat less altitude, formed on softer rocks. Pigskin, Coon, and many unnamed similar ridges, whose level tops do not ordinarily rise to heights greater than 700 feet, are of this class. The origin and history of these elevated level plains are discussed under the heading "Historical geology."

North Mountain, Ferrel Ridge, Moore Knob, Elbow Ridge, and several unnamed ridges and foothills are minor elevations above the upland level. Sleepy Creek Mountain, Third Hill, Short Mountain, Dickeys Mountain, Keefer Mountain, and Cove Mountain rise much higher above this upland, and form parts of mountain chains that extend far beyond the limits of the quadrangles.

West of Cacapon Mountain.—The higher ridges and mountains are so numerous in this part of the area that the plateau features are somewhat obscured. Between the high ridges, however, are many level-topped hills and terraces at 1000 to 1100 feet elevation which are the remnants of the plateau, and nearer the present drainage are other level stretches at 800 to 900 feet elevation that represent the lower plain. The latter are well shown at the brink of the Potomac gorge in Plate IV, and the higher upland plain appears as a cultivated shelf at the foot of Town Hill in the distance, hardly discernible in the photograph. Above this plain rise sharp straight ridges, such as Green and Tonoloway, composed of harder rocks, and Sideling Hill, Purslane Mountain, Spring Gap Mountain, Town Hill, Ragged Mountain, Gabriel Knob, and Polish Mountain, higher mountains which rise to heights of 1800 or 2000 feet. Most of the ridges in this part of the quadrangle are long, narrow, and straight, bearing N. 25°–30° E. This is true not only of the higher ridges, such as Green Ridge, Town Hill, Sideling Hill, and Tonoloway Ridge, but also of some of the lower ridges, such as Long, Bare, and Road ridges. This linear character is due to the fact that the folds of the rock strata are continuous across this part of the quadrangle, whereas in Cacapon Mountain and eastward the folds are shorter and terminate abruptly by pitching, which gives rise to curving outcrops and discontinuous rock ridges.

DRAINAGE.

The Potomac and its branches.—The entire drainage of the two quadrangles flows into Potomac River, which with its tributaries illustrates the "trellis" drainage characteristic of portions of the Appalachian province. The Potomac, the trunk stream, enters the area in the extreme southwest corner and passes out in the middle of the eastern margin, cutting across the structure of the rocks and the trend of the ridges for most of the way. Its general course was inherited from the channel of a "consequent" stream that flowed upon a tilted peneplain, which is represented by the dissected upland existing to-day, as is explained under the heading "Historical geology." The main tributaries are lateral branches joining the trunk stream nearly at right angles, which follow the trend of the rock structure and are called "subsequent" streams. These again have minor transverse tributaries, the longer ones mostly from the west, and they in turn have smaller branches parallel to the trend of the structure. Figure 3, a map of the streams of the Pawpaw-Hancock quadrangles, illustrates this trellis system of drainage.

The main tributaries of the Potomac, from west to east, on the Maryland side are Fifteenmile, Sideling Hill, Tonoloway, Great Tonoloway, and Licking creeks; on the south or West Virginia side, Little Cacapon River, Rockwell Run, Great Cacapon River, Sleepy Creek, and Back Creek, which are described below.

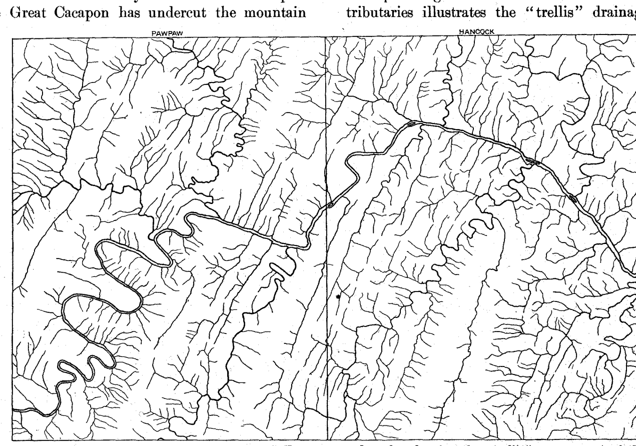

FIGURE 3.—Drainage map of the Pawpaw and Hancock quadrangles, showing the "trellis" arrangement of the streams.

Most of the streams directly tributary to the Potomac, the main stock of the trellis system, follow the direction of the strike of the rocks, and the shorter branches run at right angles to this course.

From Little Cacapon to Lineburg the Potomac flows in a structural valley and is therefore of the subsequent type. It is unusual for a stream intrenched in a deep-cut channel to have a winding course such as is this part of the Potomac, and its wide meanders are explained under the heading "Historical geology" as having been inherited from a previous drainage system. Along the meanders are many short tributaries, both transverse and parallel to the structure.

Between Sideling Hill Creek and Great Cacapon River the Potomac has several moderately long straight lateral tributaries on both sides. Those on the north have few branches, but those south of the river have been formed by the coalescence of several small streams into two main tributaries. East of Cacapon Mountain, Sir Johns, Warm Spring, and Dry runs are long straight streams in narrow lateral valleys with few tributaries. Other short lateral tributaries enter the Potomac from both sides as far as Sleepy Creek. Between this and Back Creek the minor tributaries are less regular because the rocks across which they flow are soft. Cherry Run, a relatively long stream that heads back of Short Mountain, has an irregular zigzag course diagonally across the trend of the structure.

Major tributaries from the north.—Fifteenmile Creek drains all the northwest quarter of the Pawpaw quadrangle. As explained under the heading "Historical geology," the lower part of its course, east of Green Ridge, was probably inherited from the consequent stream that flowed down the Schooley peneplain and was superposed across the structure. In this portion of its course it has several long straight branches of the subsequent type, and others that ramify in irregular fashion. The upper portion of the valley is of the subsequent type with long branches which flow from the west across the trend of the rock folds. Of these Bear Camp Branch, which drains the extreme northwest corner, is the longest.

The lower portion of Sideling Hill Creek and Bear Creek Fork forms a crooked meandering subsequent stream that lies close to the west foot of Sideling Hill and therefore has short tributaries on the east. To the west the main branches are longer, one of them now being the main stream. It has cut through Barnes Gap in Town Hill and apparently captured the drainage of a considerable area once drained by the antecedent of Fifteenmile Creek.

Little Tonoloway Creek is another major tributary whose lower portion is transverse to the rock structure and apparently follows the old course of the consequent trunk stream, as explained under the heading "Historical geology." East of Tonoloway Ridge it has long straight subsequent branches on both sides. Immediately west of the ridge it forks into two subsequent streams, all of whose important branches come from the west and drain the east slope of Sideling Hill.

The source of Great Tonoloway Creek is far beyond the north border of the area. It first enters the quadrangle in a small hook, where it cuts through Cove Ridge and drains a small area of the quadrangle west of the ridge. Below the point where it reenters the quadrangle it has few tributaries and therefore drains but little of the area.

The rock structure is not so regular in the eastern part of the area, and Licking Creek does not follow the trellis system so definitely. It is in a general way a crooked subsequent stream with irregular lateral branches. Its main tributary, Little Cove Creek, flows directly into it from the north, but the main stream, which is parallel to the structural ridges on the west side of Dickeys Mountain, cuts across them at the Pennsylvania boundary. This deflection of the stream across the structure rather than the continuation in a straight course past Warren Point to the Potomac is probably due to the tendency of major subsequent streams to locate near the upslope (west) side of major structural ridges. Thus the original stream on the sloping upland plain followed the west side of Dickeys Mountain to its end, around which it passed to the next structural ridge down the slope. Since then it has intrenched itself across the hook of the minor Elbow Ridge.

Major tributaries from the south.—Little Cacapon River drains a large region south of the quadrangles but passes through only $1\frac{1}{2}$ miles of the Pawpaw quadrangle, in which it has only a few short tributaries.

Rockwell Run is a single long stream with almost no lateral branches that drains the narrow basin between Sideling Hill and Purslane Mountain. It is parallel to the rock structure over most of its course but near its mouth turns west through a rocky gorge in the mountain and enters the Potomac in its meandering portion.

Great Cacapon River, which heads far beyond the southern limit of the Pawpaw quadrangle, is strictly a subsequent stream within the bounds of the quadrangle. It lies close against the west foot of Cacapon Mountain from which descend many short steep tributaries that have cut deep rocky ravines in the mountain side. In most of its course in the quadrangle it is closely confined on the west by Tonoloway Ridge. South of Ziler Ford, where it passes through a gap in the ridge, it has numerous transverse tributaries, chiefly from the west. Some of these probably once drained north along the west side of Tonoloway Ridge but have been reversed, as explained under the heading "Historical geology." Above Spring Ford the stream has a winding course, and its deeply intrenched meanders are unusually symmetrical and regular in form.

Sleepy Creek drains a large portion of the central southern part of the quadrangles. It is essentially a subsequent stream in this area, and follows closely the west foot of Sleepy Creek Mountain in its lower stretches. At several places it has been deflected from successive parallel courses farther out in the valley, each of which is in turn the continuation of a long longitudinal tributary, such as Mountain Run. These offsets in the main stream may be due to the more rapid development of tributary streams than of the trunk stream by the deflection of drainage from other sources. For example, Rock Gap Run and other streams west of Timber Ridge were probably at one time tributary to Sir Johns Run or Warm Spring Run, but were diverted by the greater activity of Sleepy Creek.

Meadow Branch, one of the main tributaries of Sleepy Creek, drains the basin inclosed by the Sleepy Creek, Third Hill, and Short mountains. Along the lower reaches of this stream, where it is actively cutting its bed in the hard sandstone of the mountain, it has a very steep grade, and this spot is one of the most picturesque in the region. (See Pl. VI.)

Back Creek, which drains the southeast corner of the area, is a deeply incised meandering stream, with its tributaries chiefly on the west. Its meanders have a peculiar crescent-shaped appearance, due to the preservation of the undercut cliffs of the harder strata on the east while the soft strata in the banks on the west have slumped down and lost their regular curved outline and steep character. Tilhance Creek, its main tributary, is throughout most of its course a subsequent stream flowing along the structural ridge culminating in Ferrel Ridge. Its transverse branches and lateral sub-branches of the trellis system drain all the area east of Third Hill Mountain.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.[a]

The rocks of the Pawpaw and Hancock quadrangles are all of sedimentary origin and are of Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Tertiary, and Quaternary ages. Cambrian and Ordovician rocks are exposed only in the small triangular tract in the southeast corner of the Hancock quadrangle and in Cacapon Mountain. The greater portion of the area is covered by Devonian rocks. Silurian and Carboniferous strata occur chiefly in narrow north and south anticlinal and synclinal bands. Unconsolidated gravels and alluvium along terraces and bottom lands of the streams are mapped only in the larger valleys. (See the areal geology maps.)

CAMBRIAN SYSTEM.

Only the uppermost Cambrian formation (Conococheague limestone) is exposed at the surface in the Hancock quadrangle. The Elbrook, Waynesboro, and Tomstown formations of Shenandoah Valley and the underlying sandstones, shales, and quartzites that compose South Mountain to the east probably underlie the Conococheague but have not been exposed by erosion in the area. The Conococheague limestone is part of the Shenandoah group, which comprises all of the limestones and interbedded shales including the Tomstown at the base and the Chambersburg at the top.

CONOCOCHEAGUE LIMESTONE.

Character and distribution.—A small triangular portion of a narrow body of Conococheague limestone occupies the southeast corner of the Hancock quadrangle. It is brought to the surface by the erosion of an anticline, and the basal sandy, conglomeratic layers are not exposed in the area but appear on another anticline farther east. The lowest beds seen at the axis of the fold in the quadrangle are bright-yellow to reddish sandy rocks, the product of leaching finely siliceous limestone. Above this are banded highly siliceous limestones which weather to hard shale fragments that cover the slopes and form ridges. Next above is dark pitted limestone with siliceous partings followed by light oolitic limestone. The basal beds exposed a short distance east of the quadrangle are very sandy limestone conglomerates which weather to coarse porous sandstone with large pits out of which limestone pebbles have been dissolved. The thickness in the Hancock exposures is approximately 1250 feet. The best measurement obtained in the Mercersburg-Chambersburg area to the northeast gave a total of 1635 feet.

Correlation.—Except *Cryptozoon proliferum*, which occurs rather generally in the lower portion of the formation, no fossils were found in the Conococheague limestone in the Hancock quadrangle, although at the type locality on Conococheague Creek in the Chambersburg quadrangle several species of trilobites and a brachiopod were collected in the lower beds. These fossils are all of Upper Cambrian (Saratogan) species, and the formation has been definitely assigned to that age.

ORDOVICIAN SYSTEM.

The Ordovician strata exposed in the quadrangles comprise a few areas of the Juniata formation, Martinsburg shale, and Beekmantown limestone. The Stones River and Chambersburg limestones, which normally occur between the Beekmantown and Martinsburg formations, are cut out by faulting along the eastern foot of North Mountain and are not known to occur in the Pawpaw and Hancock quadrangles.

BEEKMANTOWN LIMESTONE.

Character and distribution.—Only one narrow body of Beekmantown limestone occurs in the area, in the extreme southeast corner of the Hancock quadrangle, east of North Mountain. It is here poorly exposed and is much sheared at its western border where it is faulted against the Martinsburg shale, so that its character can not be determined with satisfaction. Its outcrops are chiefly light-gray magnesian limestone, with some cherty shaly beds and purer fine-grained limestones. As it is bounded on both sides by faults its thickness and stratigraphic relations can not be determined in this area. In the Mercersburg quadrangle, adjoining the Hancock quadrangle on the northeast, where the Beekmantown limestone has a thickness of about 2300 feet, it is underlain by the Conococheague limestone and overlain by the Stones River and Chambersburg limestones, which occur normally between it and the Martinsburg shale but are here cut out by faulting. It is in general a comparatively pure limestone, in part minutely laminated by impurities and in part smooth, even grained, and light pink. Near the base are siliceous banded beds similar to those of the Conococheague with coarse "edgewise" limestone conglomerates, which have been separated as the Stonehenge limestone member. This member occurs in the area immediately east of the Hancock quadrangle, where its base is locally composed of porous sandstone. It was not seen in the Hancock quadrangle, being there apparently cut out by faulting.

Correlation. — The lithologic character of the limestone corresponds in general with that of the Beekmantown in the Mercersburg quadrangle, and the few poorly preserved gastropods found in it here establish its correlation with that formation. A rather large fauna, including gastropods, ostracods, trilobites, and a few brachiopods, has been collected from the Beekmantown limestone in adjacent areas and these are listed in the Mercersburg-Chambersburg folio, No. 170. They prove the approximate identity of this formation with the Beekmantown of New York.

MARTINSBURG SHALE.

Character and distribution.—The Martinsburg shale occurs only in a narrow area one-fourth mile wide along the eastern foot of North Mountain. As exposed in the roads and fields it is a soft buff sandy shale, in places fissile but generally breaking to small blocky fragments. Its thickness can not here be determined, because it is bounded by a fault on the valley side and is probably itself more or less squeezed out and faulted. In the adjacent Mercersburg quadrangle, where it has a thickness of about 2000 feet, the lower part of the formation is a black fissile shale with hard black calcareous layers at the base. The upper portion is sandy and calcareous, with locally hard siliceous beds, and grades upward into ferruginous sandstones referred to the Juniata formation.

Correlation.—No fossils have been found in the Martinsburg shale in the Hancock quadrangle, but at Martinsburg, the type locality, a few miles eastward, and in the adjacent Mercersburg quadrangle a graptolite and trilobite fauna including *Corynoides calycularis*, *Glyptograptus* sp. nov., *Climacograptus spinifer*, *C.* cf. *hughesi*, *Trinucleus concentricus?*, and *Triarthrus becki* was obtained from the basal beds. The same graptolite zone was observed just south of the quadrangle on the east side of North Mountain. In the sandy beds in the upper part of the formation occur *Dalmanella multisecta*, *Plectambonites sericeus*, *Zygospira modesta* var., and *Calymene callicephalus*.

According to Ulrich, these fossils determine the lower part of the formation to be equivalent to the Trenton of the New York section, and the upper part to correspond with the Utica and the Lorraine of the New York section.

JUNIATA FORMATION.

Character and distribution.—The Juniata formation is a series of soft red sandstones and shales between the sandy beds at the top of the Martinsburg and the hard quartzose sandstone of the Tuscarora. Because of its close association with the hard Tuscarora it generally occupies the steep slopes of mountains. Its only known outcrops in the area are on the east slope of North Mountain in the southeast corner of the Hancock quadrangle and in some of the deeper gorges on the western slope of Cacapon Mountain in the Pawpaw quadrangle. On Cacapon Mountain it is concealed by the sandstone débris

[a] The determination of formational units and the adoption of new names for use in this folio are the result of agreement between the United States Geological Survey and the Maryland Geological Survey.

from the overlying Tuscarora, and on North Mountain the rocks are steeply overturned to the southeast by the intense folding and faulting to which this area has been subjected and are slickensided in many places. The best exposure is on the road crossing the mountain near the southern boundary, where the formation consists of coarse reddish sandstones with minor red shales which contain large shale pebbles and which become coarser and darker red toward the base of the formation. At the base is a heavy bed of cross-bedded white sandstone and quartz conglomerate, which is apparently local, for it does not appear at the road through the gap at Hedgesville, just beyond the eastern border of the quadrangle, nor is it general in the Mercersburg quadrangle. In the excavation back of the Mount Clifton Hotel at Hedgesville the soft red and brown sandstones and yellow shale of the Juniata are faulted against a thin remnant of the Oriskany. The thickness of the Juniata represented in the outcrops on North Mountain is only about 200 feet, but the total thickness of the formation in the Mercersburg quadrangle is 400 to 450 feet.

Correlation.—No fossils have been found in this formation in the Hancock quadrangle or in the adjacent areas. Its age is determined in part by its relation to other fossiliferous formations and in part by its representative elsewhere in the Appalachian Valley. In the Pennsylvania Geological Survey reports this formation and the overlying Tuscarora sandstone, which together form prominent ridges, have been generally called the Medina and Oneida sandstones. In lower Virginia and Tennessee the terms Clinch and Bays sandstones have generally been applied respectively to a corresponding upper white sandstone and lower red sediments. Large collections or fossils made from the Bays sandstone in Tennessee and Virginia by Ulrich and others show that it is of late Ordovician age. Similar though somewhat older Upper Ordovician fossils were obtained from sandstones in the transition zone between the Martinsburg and the red sandstone mapped as Juniata in the adjoining Mercersburg quadrangle. The formation is named from Juniata River in central Pennsylvania, where similar red rocks underlie the white Tuscarora sandstone, but Ulrich has recently discovered faunal and stratigraphic data tending to show that the typical Juniata formation is younger, being the equivalent of the lower or red Medina, whereas the red beds in Maryland, Virginia, and Tennessee appear to correspond more nearly with the beds in New York formerly called Oswego sandstone. The term Juniata, used in the Mercersburg-Chambersburg folio, will, however, be tentatively continued in this report.

SILURIAN SYSTEM.

The Silurian system in this area comprises a cycle of sedimentation beginning with the Tuscarora sandstone, followed by shale and sandstones of the Clinton formation, and ending with the McKenzie, Wills Creek, and Tonoloway calcareous formations. The latter sediments represent the late Silurian deposits composing the Cayuga group of New York. The Rochester is represented by thin fossiliferous calcareous beds in the upper part of the Clinton.

TUSCARORA SANDSTONE.

Character and thickness.—The Tuscarora sandstone is one of the principal mountain-making rocks in the Pawpaw-Hancock region. It is a resistant white quartzose sandstone, in places quartzite, occurring both in thin and in massive beds. On narrow monoclinal ridges like North Mountain, Cove Mountain in the northeast corner of the Hancock quadrangle, and Tuscarora Mountain beyond the north border, its rocky white ledges form the crest and its débris covers the outer slope. The general character of the formation may be best observed in the quarry of the Silica Sand Co., east of Great Cacapon, on the road over Cacapon Mountain. The sandstone is milk white, generally fine grained, very compact and massive, and somewhat irregularly bedded in layers from 6 inches to 2 feet thick. A few thin drab shale beds occur interbedded with the sandstone. The massive character of the strata is best exhibited in the cliffs at Edes Fort where Great Cacapon River cuts through a small fold on the flank of Cacapon Mountain. (See Pl. VII.)

On North Mountain the sandstone is not so thick as elsewhere, being not more than 200 feet thick near the south border of the quadrangle and diminishing northward to small exposures of less than 100 feet. Distributed faulting may account for this condition, as the rocks are strongly overturned and faulted along two distinct adjacent planes. At the gap at Hedgesville, just east of the quadrangle limits, the Tuscarora and overlying formations are entirely cut out by faulting and the red Juniata sandstone rests against the Oriskany sandstone. On Cacapon Mountain the formation is estimated to be about 250 feet thick; on Cove and Tuscarora mountains, in the Mercersburg quadrangle, measurements showed a thickness of 270 feet.

Distribution and surface form.—The Tuscarora sandstone occurs in four areas in the Pawpaw and Hancock quadrangles, the largest and most important of which is in Cacapon Mountain, where an anticline of large proportions brings to the surface the steeply dipping sandstone beds. The Tuscarora sandstone dips with the slope on both flanks, and deep trenching by streams on the west side gives rise to very rocky and picturesque ravines, densely forested and overgrown with underbrush. The flat crest of the mountain is capped by a thin cover of shales and sandstones of the Clinton formation, but the sharp crest of the northern part of the ridge is composed of the Tuscarora. From the flat-lying sandstone ledges forming Prospect Rock a splendid view may be had to the west. (See Pl. II.) The Cacapon Mountain area of the sandstone crosses the Berkeley Springs road and ends near the east border of the Pawpaw quadrangle, where the sandstone passes beneath the Clinton shale, but is again exposed in this anticline for a short distance on the bank of the Potomac south of Sir Johns Run in the Hancock quadrangle.

Dickeys Mountain, in the northeastern part of the Hancock quadrangle, is the plunging end of an anticline of Tuscarora sandstone which extends into the quadrangle about a mile. The outcrop divides toward the north, and the eastern limb forms Tuscarora Mountain, a single narrow straight ridge many miles in length. The other occurrences of the formation in the area are on the south end of Cove Mountain, in the extreme northeast corner of the Hancock quadrangle, and on North Mountain, where the sandstone forms the narrow crest of the ridge for about 3 miles across the southeast corner of the quadrangle.

Correlation.—No fossils except the transversely ribbed plant or trail-like markings, called *Arthrophycus harlani*, have been found in the Tuscarora sandstone of this area. Its name is taken from Tuscarora Mountain, of which Dickeys Mountain is the southern end. Together with the underlying red strata it is continuously exposed in this ridge and in other similar sandstone ridges across Pennsylvania, where they have been described in the reports of the Pennsylvania Geological Survey as the Medina and Oneida sandstones. The Tuscarora sandstone is unquestionably directly continuous with the typical Medina sandstone of New York which is also characterized by *Arthrophycus harlani*. In lower Virginia and Tennessee the corresponding white sandstone is named the Clinch.

CLINTON SHALE.

Character and thickness.—The Clinton shale, which directly overlies the Tuscarora sandstone and flanks the mountains composed of that formation, is primarily a fine fissile clay shale of drab color, in places reddish or yellow, with thin rusty sandstone layers and locally thin beds of hematite iron ore. In the eastern part of the Hancock quadrangle heavy beds of ferruginous sandstone in the upper part of the formation make high ridges and mountains. Occurring as it does in many places in the area in minor synclines on the flanks of anticlines of massive sandstone, the soft shale of the formation is there closely plicated, particularly on the steeper western sides of the folds.

The inclosed thin sandy layers are more or less porous, owing to the solution of calcareous grains and are generally stained yellow or brown by iron. The formation is very fossiliferous, the calcareous sandy layers especially being crowded with minute crustaceans. Toward the top are thin-bedded slabby sandstones, which weather to blocks, on whose surfaces are numerous trails, markings resembling fucoids, mud flows, and other impressions. They contain pebbles of red shale and have a slickened coating of bright-red iron oxide, which in places is a workable bed of iron ore. On both sides of Dickeys Mountain and on the west slope of Cove Mountain in the northeast corner of the Hancock quadrangle a massive quartzitic bed of ferruginous sandstone is strongly developed at or close to the top of the formation and continues into the Mercersburg quadrangle. Locally it is a workable ore of iron, although generally it is too siliceous. A bed of iron ore of small extent in the Clinton formerly mined above the village of Sir Johns Run is probably at one of these horizons. The top of the formation is well defined by the ridge-making *Scolithus*-bearing white sandstone at the base of the Cayuga group named the Keefer sandstone member of the McKenzie formation. This bed was formerly regarded by the writer as the topmost bed of the Clinton shale, but fossils recently found in it prove its alliance with the Cayuga group.

On account of the general lack of exposures on the débris-covered mountain slopes and the general plicated character of the shale, the thickness of the Clinton can not readily be determined. It is about 550 feet thick on the north end of Cacapon Mountain and on Dickeys Mountain. On Cove Mountain it apparently has the same thickness that it possesses in the adjacent Mercersburg quadrangle, where 750 feet were measured. On North Mountain the formation is faulted on the west and no determination of its thickness was made.

Distribution and surface form.—The largest area of Clinton in the quadrangle is that about Cacapon Mountain. The bands of steeply inclined strata on both sides of the mountain unite at the east boundary of the Pawpaw quadrangle and form the whole north end of the mountain. The Clinton shale crosses Sir Johns Run and ends in the unnamed high mountain in the angle of the Potomac east of Roundtop. On the west side of Cacapon Mountain the beds dip steeply and are closely folded. This condition is finely shown on the map by the fluted appearance of the narrow outcrop of the Keefer sandstone member of the overlying McKenzie formation. On the east side of the mountain the dip of the beds is less steep and more uniform, and the boundary lines are simpler. The higher flat tops of Cacapon Mountain representing the crest of the massive anticline are also thinly covered by the shales and thin sandstones of the Clinton. The formation in this area contains no prominent sandstones to compare with the hard ferruginous quartzite of the eastern mountains.

The next most important area of Clinton is on the west slope of Cove Mountain. The shales are poorly exposed in this area because of the waste from the Tuscarora sandstone at the crest of the mountain. The hard quartzitic red sandstone at the top of the formation forms prominent ledges and benches on the steep mountain slope at various places. It swings to the east around the southward-plunging end of the anticline, where the dips are gentle, and passes out of the quadrangle in a prominent ridge.

Around the south end of Dickeys Mountain the red quartzitic sandstone also makes a prominent ridge with a barren rocky crest, called Keefer Mountain. The line of knobs and hills formed by this hard bed, which skirts the eastern slope of Tuscarora Mountain north of the quadrangle as far as Cove Gap in the Mercersburg quadrangle, is a continuation of Keefer Mountain.

Owing to the overturned dips and faulting of the massive Tuscarora sandstone on North Mountain, the shale and red sandstones of the Clinton lie well up on the western slope of the Mountain and form the crest of some of the saddles.

Correlation.—Fossils are abundant in the shale and thin calcareous sandstone beds of the Clinton in this and adjacent areas. Certain calcareous sandstone beds within the formation are largely composed of the small horseshoe-shaped valves of ostracods belonging to species of *Beyrichia* and *Bollia*. The fossils of the greater part of the Clinton in this region are of species usually found in the Appalachian facies of the formation. In the Pawpaw-Hancock area the following fossils were collected from outcrops in Sir Johns Run and identified by Ulrich, a greater variety having been collected in the adjacent Mercersburg quadrangle and listed in folio No. 170:

Dalmanella elegantula var.	Camarotœchia neglecta.
Stropheodonta corrugata.	Tentaculites n. sp.
Stropheodonta prisca.	Conularia niagarensis.
Chonetes sp. undet.	Bollia lata.
Atrypa ? gibbosa.	Beyrichia, 2 species.
Anoplotheca hemispherica.	Calymene clintoni.
Whitfieldella intermedia.	

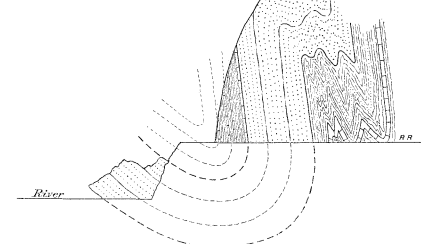

FIGURE 4.—Section on the Baltimore & Ohio Railroad east of Great Cacapon.

The thin limestone at the right contains a Rochester fauna and underlies the Keefer sandstone member of the McKenzie formation at the left.

The red sandstones in the formation contain no fossils other than numerous trails and other undetermined markings on their surfaces. A crystalline crinoidal limestone bed directly below the Keefer sandstone member of the overlying McKenzie formation exposed in the Baltimore & Ohio Railroad cut 1½ miles east of Great Cacapon (see fig. 4) contained the following fossils, identified by Ulrich:

Dalmanella elegantula.	Calymene blumenbachi.
Leptæna rhomboidalis.	Dalmanites limulurus.
Spirifer radiatus.	Beyrichia granulosa.
Spirifer eudora.	Beyrichia, 2 large undescribed species.
Camarotœchia cf. indianensis.	Kloedenia n. sp.
Anoplotheca hemispherica.	
Platyostoma niagarensis.	

These faunas are correlated by Ulrich with the Clinton of central and eastern New York. The latter fauna, observed in the Pawpaw and Hancock quadrangles only in a limestone forming the uppermost few feet of the formation at Great Cacapon, contains characteristic elements of the Rochester fauna of western New York, and the bed is regarded as the thin eastern representative of the Rochester shale. In the Cumberland area in western Maryland the zone containing the Rochester fauna is much thicker and its species prevail in the upper 30 feet of calcareous shale and limestone of the Clinton formation. Prouty,[a] who recently studied the fauna and stratigraphy of the mid-Silurian strata of Maryland, included in the Niagara not only the beds containing the Rochester fauna but the overlying beds here named the McKenzie, which contain a fauna distinct from the Rochester but with some similar forms, principally small ostracods.

The crystalline limestone containing the Rochester fauna was not found in the eastern part of the Pawpaw-Hancock area and apparently thins out in that direction. There a massive ferruginous sandstone, the rock that caps Keefer Mountain, occurs at the top, and it is possible that these siliceous iron-bearing rocks represent the beds containing the Rochester fauna in the west and indicate near-shore and probably land conditions.

The general lithologic character and stratigraphic position of the formation as well as the faunal contents are the same as those of the Clinton of east-central New York, where an iron-bearing shale and sandstone directly overlying the Medina sandstone have in their upper portion calcareous beds containing the Rochester fauna. The name Clinton is therefore applied to this formation. This name has also been used in the reports of the Maryland and Pennsylvania Geological Surveys, although calcareous beds at the top of the formation or at the base of the overlying McKenzie formation were separated as Niagara.

In the Franklin and Monterey folios the same belt of strata as it occurs 70 to 80 miles to the southwest is described. There the Tuscarora sandstone is overlain by about 300 feet of flaggy red sandstone, called the Cacapon sandstone. This is overlain in turn by 400 to 500 feet of iron-bearing fossiliferous shale with some intercalated limestone beds, capped by a persistent hard ridge-making sandstone or quartzite. The assemblage above the Cacapon is called the Rockwood formation, the description of which corresponds closely with that of the Clinton in this area, except that the capping quartzite member may prove to be the sandstone which in western Maryland sections underlies the beds carrying the Rochester fauna and not the Keefer sandstone, which is now made the basal member of the succeeding McKenzie formation. The Cacapon sandstone is probably a local sandy deposit at the base of the Clinton not represented in the Pawpaw-Hancock area.

CAYUGA GROUP.

Character and thickness. — The Cayuga group, composed chiefly of limestones and shales, lies between the Clinton shale and the Helderberg limestone. Soft shales apparently comprise the bulk of the strata, but limestones are an important element, and in places are of commercial value as cement rock. The limestones are especially conspicuous in the upper part of the group, and form massive outcrops in fresh stream exposures that are not very readily distinguishable from the more massive limestones of the Helderberg. A heavy white sandstone near the middle of the group is locally important, and a tough, thick-bedded red argillaceous sandstone is present in the lower shales throughout both quadrangles. A quartzitic sandstone forms the base. This group has been divided into the following formations and members, which will be described in detail. They are arranged in the order of their deposition.

- Tonoloway limestone.
- Wills Creek shale.
  - Bloomsburg red sandstone member.
- McKenzie formation.
  - Keefer sandstone member.

The best section of the Cayuga group in the area is along the Baltimore & Ohio Railroad track east of Grasshopper Run, where the following section was measured by E. O. Ulrich and the writer:

Section of Cayuga group at Baltimore & Ohio Railroad cut east of Grasshopper Run, W. Va.

	Ft.	in.
Crystalline, crinoidal, massive, and lamellar limestones (Helderberg).		
Tonoloway limestone, 400 feet:		
Finely lamellar limestone interbedded with shale	6	
Finely lamellar limestone weathering shaly	85	
Shaly limestone, more shaly below	58	
Massive thinly lamellar limestone, fine grained, slightly argillaceous. Thick coral reef of *Stromatopora* and thin seams of crystalline limestone filled with ostracods, small brachiopods, and *Tentaculites gyracanthus* near base. Three of the ostracods are diagnostic of this zone but are undescribed species	143	
Magnesian limestone	2	
Massive laminated limestone, *Tentaculites gyracanthus* and large *Leperditia*	60	
Very thin bedded limestone interbedded with thin shales	14	
Massive and thinly laminated limestones, some arenaceous. Contains ostracods and shells—*Hormotoma* (small species), *Rhynchonella? lamellata*, *R. litchfieldensis?*, *R. hydraulica?*, and *Leperditia altoides*	32	
Wills Creek shale, 445 feet:		
Greenish sandstone, fine grained, in thick and thin plates	7	6
Massive laminated magnesian limestone, weathering thin bedded, with argillaceous beds weathering yellow. Fine oolite with *Leperditia* near the base	45	
Greenish shale and shaly limestone with thicker limestone beds in middle and at base. *Stromatopora* and ostracods at base. *Kloedenella clarkei* and *Leperditia alta?*	50	
Shale and shaly limestone	60	
Greenish impure calcareous sandstone with some rounded quartz grains	4	
Shaly limestone and limy shale with thin sandy beds	15	
Crumbly greenish shale with very thin sandy layers containing *Leperditia*. Purplish shale and sandstone at base	100	
Crumbly greenish shale and sandstone containing casts of salt crystals, *Leperditia*, and a small *Spirifer*	15	
Red sandstone	1	6
Gray shale with casts of salt crystals and *Leperditia*, some red shale, and a few thicker limestone beds	80	
Red sandy shale and yellow shale	15	
Bloomsburg red sandstone member, 52 feet:		
Massive bedded, jointed red sandstone	10	
Hackly jointed red sandy shale	7	
Red jointed sandstone	5	
Alternating red shale and sandstone	30	
McKenzie formation, 170 feet:		
Blue shale with a few thin limestones containing *Kloedenella*	25	
Gray subcrystalline limestone crowded with *Kloedenella* and rhynchonelloid shells	35	
Covered (in near-by section seen to have dark shale near base and thin conglomeratic fossiliferous limestone beds above)	70	
Keefer sandstone member:		
White quartzitic sandstone with *Scolithus* tubes, and interbedded hard black shale containing eurypterids	40	
Total Cayuga group	1015	
Clinton shale:		
Fossiliferous drab shale.		

[a] Prouty, Wm. F., The Meso-Silurian deposits of Maryland: Am. Jour. Sci., 4th ser., vol. 26, 1908, pp. 563–574.

Along the Baltimore & Ohio Railroad at Potomac, Md., west of Cumberland, the Cayuga group, as recently measured by Ulrich, is 1383 feet thick, the McKenzie formation 330 feet, Wills Creek shale 447 feet, and Tonoloway limestone 606 feet. The division line between the Tonoloway and Wills Creek is somewhat arbitrary, as the finely lamellar limestones that appear shaly at the surface may be massive in fresh exposure. It is placed 84 feet above a 2-foot bed of sandstone in the Potomac section, while in the Grasshopper Run section it is 162 feet above a similar 4-foot sandstone. The rocks at Potomac, however, appear to be more calcareous and the limestones to be more massively bedded, and the greater measured thickness of limestone is probably due to this fact.

McKENZIE FORMATION.

Character and thickness.—The McKenzie formation is the alternating series of shale and thin limestone, formerly regarded by some geologists as Niagara, with a basal white quartzite member named Keefer, directly overlying the Clinton. Although the formation appears in most outcrops to be composed chiefly of shale, the alternation with the shale of thin limestone beds is exceptionally well shown in the fresh cut of the Western Maryland Railway opposite Great Cacapon. (See Pl. XII.) The section here, although the beds are closely folded and the basal member of the formation is not exposed, is approximately as follows:

Section of McKenzie formation, Western Maryland Railway cut opposite Great Cacapon, W. Va.

	Feet.
Blocky red sandstone (Bloomsburg member of Wills Creek shale).	
Shale, red at top, green below	10
Green to yellow and red shale, soft and weathers to fine fragments; somewhat crumpled	80±
Contorted interbedded olive to drab fissile shale and beds 1 to 2 inches thick of fossiliferous gray subcrystalline limestone. Limestones thicker and more numerous in lower portion	70±
White sandstone, Keefer member (not exposed here)	40
	200±

Near the mouth of Grasshopper Run, where the structure is a simple monocline, a thickness of 170 feet was determined, but a large portion of the section was not well enough exposed for the determination of details.

Section of McKenzie formation, mouth of Grasshopper Run, W. Va.

	Feet.
Red sandstone (Bloomsburg member of Wills Creek shale).	
Chiefly olive to bluish clay shale, with few thin limestones	25
Largely thin fossiliferous gray to blue subcrystalline limestone beds with olive fissile clay shale	35
Largely concealed; dark to black shale near base and thin slabby conglomeratic limestone composed of minute fossils toward the top	70
Keefer sandstone member, composed of two hard sandstone beds with thin hard black shale between	40
	170

Small outcrops of the fossiliferous limestone of the formation are not uncommon, but in general it is not seen because the shale of the formation slumps down and covers it and the limestone when weathered closely resembles the shale. The greenish to gray fissile shale and yellow clayey shale are not unlike that of the Wills Creek.

The limits of the formation are invariably well defined in the Pawpaw-Hancock area by the Keefer sandstone member at the base and above by the red jointed sandstone and argillite (Bloomsburg member) of the overlying formation.

The Keefer sandstone member, composed of two sandstones separated by black shale, is excellently exposed at Warren Point, the south end of Keefer Mountain, where the lower sandstone is 15 feet thick, the upper 25 feet and very massive at the top, with 15 feet of shale, chiefly covered, between, making 55 feet for the thickness of the member. The sandstone is composed of white quartz and is both massive and thin-bedded. The bedding surfaces, which are usually stained red or rusty, are rough and pitted with numerous worm or *Scolithus* tubes, which have short length across the bedding.

At Lock 53 on the canal, 6 miles above Hancock, a new road cut has freshly exposed the Keefer member and the following detailed section was measured:

Section of Keefer sandstone member at Lock 53, Chesapeake & Ohio Canal, Md.

	Feet.
Soft gray to yellow shale, overlying the sandstone.	
Hard white to gray sandstone, thick bedded above, thin bedded to shaly below	14
Hard black fissile shale	1
Hard sandstone with rough surfaces, stained yellow and red	10
Hard black shale, sandy at top and pitted by rust-stained worm tubes; contains abundant fragments of a eurypterid closely allied to *Hughmilleria socialis*	6
Irregular bedded sandstone	7
Drab to pink shale with thin sandy beds at top (Clinton.)	
	38

In the Cumberland area to the west the Keefer sandstone member is not recognizable at the base of the formation, and the limestone and shales of the Clinton pass into those of the Cayuga without marked lithologic break, a faunal change only being observed.

Distribution and surface form.—The McKenzie formation occurs as a narrow strip surrounding the anticlinal areas of Clinton shale, and the Keefer sandstone member at its base is a still narrower band on its inner margin. The Keefer sandstone member, owing to its resistant character, is the most prominent feature of the formation, and is readily recognized throughout the area because it usually forms low hills with rocky ledges of soft shale in smooth lowlands. Some of the ledges have a dikelike appearance. (See Pl. V.)

Near the southern border of the Pawpaw quadrangle on the west side of the Cacapon Mountain anticline, where the dips are steep, its closeness to the Tuscarora sandstone makes its outcrops inconspicuous. Northward, toward Rock Ford, minor folds carry it farther from the mountain, and its hard sandstone beds make rocky fluted ledges in the stream gorges and its isolated synclinal remnants cap sharp ridges. The plications are too numerous to be shown in complete form on the scale of the map, but the intricacy of the folding is suggested by the flutings of the Keefer member that are shown. The formation follows a rather straight course to Great Cacapon. It crosses the Potomac but appears only in crumpled outcrop beneath a gentle arch of the Bloomsburg red sandstone member in the river bluff. After swinging back to the West Virginia side around a low fluted syncline it again continues its northward course in a wider belt of soft rocks fringed by the hard sandstone bed.

The fluting of the thin Keefer sandstone member is best illustrated in this part of the area. On the narrow neck of land between the parallel courses of Great Cacapon River at the big bend where the power plant is located the bottoms of three sharp synclines of the Keefer sandstone are barely preserved. These synclines descend northward, forming rocky ledges on the banks of the stream, and at Fluted Rocks present a very picturesque and instructive series of minor folds. (See Pls. X, XI, and XIV.)

At the north end of the Cacapon Mountain anticline two narrow prongs of the Keefer sandstone extend into Maryland at the canal level. South of the river it rises with the slope and caps the prominent knob just east of Roundtop. Farther south on the east limb of the anticline its dikelike outcrops form the ridge east of Sir Johns Run station, which terminates at the Sir Johns Run road in picturesque ledges locally known as the "Devils Nose." South of this point the Keefer sandstone does not make ridges or prominent ledges until near the southern border of the quadrangle, where the rocks dip more gently and produce a series of hogback ridges, called Piney Ridge, which flank Cacapon Mountain.

Northward along this same general anticlinal fold in the valley of Tonoloway Creek, 2 miles west of Hancock, Md., the massive ledges of the Keefer sandstone member are exposed by erosion in a small area, just enough to make a marked rocky island over which the road abruptly climbs in the midst of a wide lowland. The area of the McKenzie formation that surrounds this small outcrop of quartzite runs north into Pennsylvania $1\frac{1}{2}$ miles, and unusually good exposures of both the shale and limestone of the formation occur along the small branch of the Tonoloway.

In the narrow belts of the formation encircling Dickeys Mountain and on the west slope of Cove Mountain in the northeast corner of the quadrangle the shale and limestone of the formation are largely covered by detrital material from the sandstones above. The Keefer sandstone member, however, is very prominent and somewhat thicker than toward the west. It makes rocky ledges on the flanks of Keefer and Dickeys mountains, and at Warren Point the plunging fluted beds descend to the creek level and form low rock arches on the south bank of the stream. It produces a broken line of hills where the gently dipping formation swings east around the south end of Cove Mountain.

The McKenzie formation was not observed on North Mountain, for it is cut out by faulting, the Oriskany on the west being in contact with the Clinton and Tuscarora on the east.

Correlation.—The thin limestones in the McKenzie formation are quite fossiliferous, although the number of species obtained from them is usually small. Farther west, in the vicinity of Cumberland, fossils are somewhat more varied and better preserved. A notable feature of the fauna is the total absence of species of *Leperditia*, which appear immediately in the overlying Wills Creek. Ulrich has identified the following fossils collected at Grasshopper Run and in Tonoloway Valley:

Small ostracods (*Kloedenia* n. sp., several species of *Kloedenella*, and *Beyrichia moodeyi*), a rhynchonelloid brachiopod (related to *Uncinulus mutabilis*), and *Bythotrephis* cf. *gracilis*.

A more complete collection by Ulrich and the writer from the Western Maryland Railway cut opposite Great Cacapon furnished the following:

- Dalmanella postelegantula.
- Trematospira n. sp. (near T. camura and T. perforata).
- Whitfieldella n. sp. (near W. nitida).
- Spirifer n. sp. (near S. sulcatus).
- Spirifer cf. eriensis.
- Rhynchonella formosa.
- Rhynchonella cf. vellicata.
- Rhynchonella n. sp. (very finely plicated).
- Uncinulus cf. pyramidatus.
- Ctenodonta n. sp.
- Cleidophorus cf. Nucula sinuosa Simpson.
- Prothyris n. sp. and other pelecypods.
- Coleolus sp. undet.
- Othoceras, 2 species undet.
- Beyrichia moodeyi.
- Kloedenia cf. sussexensis.
- Two undescribed species of Kloedenella and prenuntial varieties of K. pennsylvanica, K. turgida, and K. clarkei.

Except the short *Scolithus* tubes, fossils are very rare in the Keefer sandstone member. At only one place in the area, Lock No. 53, on the Chesapeake & Ohio Canal, at the western edge of the Hancock quadrangle, were any other organic remains found. Here the black shale in the midst of the member is finely exposed in a road cut recently made at the crossing of the Western Maryland Railway, and from it were obtained fragments of a eurypterid crustacean determined by Ulrich as closely allied to *Hughmilleria socialis*.

These faunas are referred by Ulrich to the Salina formation of the Cayuga group of New York. The *Hughmilleria* from the Keefer member is much like *Hughmilleria socialis*, which occurs in the Pittsford shale of the reports on west-central New York. It is closely allied also to *Hughmilleria shawangunk* found in the thick Shawangunk conglomerate of southeastern New York, also generally regarded as of Salina age, which suggests that they may represent the same horizon, but it can not be positively asserted that the Keefer is the southwestward feather edge of the thick Shawangunk, for they have not been traced into one another. It is known, however, that the Keefer, which is absent farther west, attains a thickness of more than 50 feet in the eastern part of the Hancock quadrangle and continues with equal prominence throughout the Mercersburg quadrangle, to the northeast.

The fossiliferous limestone of the McKenzie formation overlying the recognized Clinton has heretofore been regarded by many geologists as the representative of the Rochester shale and Lockport limestone of New York, and the name Niagara has therefore been applied to it. As previously explained, the characteristic Rochester fauna has been found in this area in only a few feet of limestone beneath the Keefer sandstone, and the inclusion of the McKenzie strata in the Niagara was due to their calcareous character and stratigraphic position, to the fact that the fauna somewhat resembles the Rochester fauna, and to the confusion of the Keefer member with a lower sandstone of the Clinton beneath the bed containing the Rochester fauna in the Cumberland area.

The formation may be correlated approximately with the lower part of the Salina formation of the Cayuga group of New York. Since it is not the equivalent of any previously recognized formational unit, a new name has been given to it, taken from McKenzie station on the Baltimore & Ohio Railroad west of Cumberland, where the formation is well exposed. The Keefer sandstone member is named from Keefer Mountain in the Hancock quadrangle, at the south end of which along Licking Creek the sandstones are finely exposed. The formation has been observed and identified by Ulrich by its fossils and stratigraphic position as far north as central Pennsylvania.

WILLS CREEK SHALE.

Character and thickness.—The middle formation of the Cayuga group is chiefly a gray calcareous papery shale with thin, finely laminated limestones in the upper part and a heavy bed of tough argillaceous red sandstone at the base. The latter is distinguished as the Bloomsburg red sandstone member.

The section of the Cayuga group on the Baltimore & Ohio Railroad east of Grasshopper Run given above presents the details of the formation in general and shows its thickness in this region to be 445 feet.

The Bloomsburg sandstone member varies in thickness and character from place to place. It is excellently exposed in the Western Maryland Railway cut east of Tonoloway Ridge, where the following details are shown:

Section of Bloomsburg red sandstone member, Western Maryland Railway cut east of Tonoloway Ridge.

	Feet.
Compact argillite or mud rock, green to gray in color, in part finely laminated.	
Green and red massive-bedded argillite; weathers crumbly and shaly	40
Bloomsburg red sandstone member, 80 feet:	
Jointed argillaceous sandstone, red and green banded and mottled	20
Jointed red argillaceous sandstone in massive beds	20
Red and yellow shale	3
Jointed argillaceous sandstone, chiefly red, weathering to blocks	15
Argillite, red and sandy above, green to bluish below	22
Drab shale with thin fossiliferous limestone (McKenzie).	

The red argillites at the base are regarded as transition beds of the Bloomsburg member because they resemble the beds of that member more than they do those of the underlying McKenzie shale. The red and green argillite above the sandstone has one bed with peculiar knotty segregations which are joined to the surface of the bed by diagonal markings like filled channels, the whole resembling burrows. (See Pl. XVIII.)

The Bloomsburg red sandstone member is so tough and resistant that its outcrops are a conspicuous feature throughout the area, and notwithstanding its thinness it has been separately mapped. In Tonoloway Valley 2 miles west of Hancock it has been quarried in large slabs for foundation stones.

Above the Bloomsburg member the formation is chiefly light-drab shale, calcareous, firm, and platy in fresh exposure, but soft and clayey where weathered. It is from certain of these thin calcareous-argillaceous beds that natural cement has been made at Roundtop, Md., and elsewhere in the western part of the State. The section of the cement beds at the Roundtop Cement Co.'s openings shown in figure 5 was measured by G. C. Martin. Most of the cement beds are beautifully marked by sun cracks and fine ripple marks (Pl. XVI); others contain clay pebbles and show mud flows, various trails, and curious markings on their surfaces. Pseudomorphs of salt crystals were also found in these shales at several places.

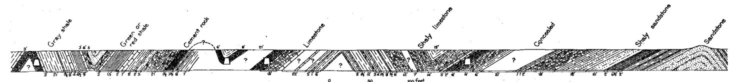

FIGURE 5.—Section of cement rock and associated beds of the Wills Creek formation along the Chesapeake & Ohio Canal at Roundtop station, Md. Measured by G. C. Martin.
The cement rock is the layer in which the tunnels are located.

A thin hard white sandstone occurs near the top of the formation throughout the Hancock quadrangle, although it was not observed in the Pawpaw quadrangle. In both Maryland and Pennsylvania just west of Hancock it forms a line of hills covered with blocky white sandstone fragments from the slopes of Roundtop to the northern edge of the quadrangle, winding in conformity with the structure and repeated by folding. A similar hard sandstone occurs in the eastern portion of the quadrangle, the beds being particularly thick and resistant in the vicinity of Pecktonville and in the Ferrel Ridge anticline. In the latter area a 20-foot layer of soft brown sandstone, probably calcareous when fresh, is overlain by 7 feet of hard sandstone, the lower part of which is pure white and quartzitic. Above this lies a 5-foot layer of soft, yellowish sandstone with flat clay pebbles, which in turn is overlain by red and yellow sandy shale with soft yellow sandstone beds.

The limestones of the formation in general contain magnesium and other impurities and have the composition of water limes, which are capable of being burned into natural cement and have been used for this purpose.

The top of the formation, in clear-cut sections like that at Grasshopper Run, is placed at a platy sandstone below which the beds are distinctly more shaly than those above. It is 162 feet above the hard white sandstone previously described. The upper sandstone is not generally noticeable on the surface where the rocks are weathered, and in mapping the line is drawn where limestone outcrops practically cease and shale predominates.

Distribution and surface form.—The Wills Creek shale occupies probably a larger area in these quadrangles than any of the formations previously described. On both sides of Cacapon Mountain it forms a narrow belt fringed with the still narrower strip of the Bloomsburg red sandstone member. The latter, especially on the west, expands to considerable width at intervals, due to intricate folding, and these areas, as represented on the map, include small masses of shales of both the Wills Creek and McKenzie formations that are closely infolded and are not distinguishable on the scale of the maps.

This formation is similar to the McKenzie formation in that its soft shales and limestones are rarely exposed, but the outcrop of the formation is conspicuous because of the features produced by the sandstone member. The sandstone caps small hills, and although it does not make rocky ledges its outcrops are generally barren and stony because it does not disintegrate readily and its soils are infertile. On the west side of Cacapon Mountain its barren red ledges are especially conspicuous on Cedar Hill near Harland Ford and along the road north of Rock Ford. On the banks of the Potomac opposite Great Cacapon it forms a conspicuous broad arch that can be seen from passing trains, and makes an area of hills and rough barren country northeast in Maryland to the point where it pitches under at the edge of the Pawpaw quadrangle. A better-exposed arch composed of this sandstone, classic in textbooks on geology, is at the old cement works at the east base of Roundtop. (See Pl. XVII.)

The belt of Wills Creek shale expands northward, inclosing the synclinal area forming Roundtop and exposing the basal red sandstone member again around the center of uplift on Tonoloway Creek. The close folding or fluting of the beds is well shown by the arches and troughs of the sandstone along Tonoloway Creek and the Baltimore pike, and produces a relatively broad area of wooded stony land with rough topography at the fluted plunging ends and on the western side of this anticline. In this broad area of soft, easily eroded Wills Creek shale, the white sandstone bed of the formation, which is here strongly developed, makes rocky ridges and knobs. The roads paralleling the east slope of Tonoloway Ridge follow its outcrop for the most part.

The Bloomsburg red sandstone member does not show conspicuously in the straight narrow belt of Wills Creek shale on the eastern side of Cacapon Mountain, but its plunging folds make rough country again around the north end of this uplift southwest of Hancock.

Near the Dickeys Mountain anticline the Wills Creek shale displays the usual characteristics. The barren outcrops of the red sandstone at the base form low hills and conspicuous monoclinal ledges on the south side of Licking Creek, and the soft shales and limestones produce gentle slopes and rolling country. The formation is faulted out at the north on the slopes of Cove Mountain, but attains unusual width at the point of the southward-plunging anticline where the dips are very gentle to the south. The basal red beds are not so sandy and resistant as elsewhere in the quadrangle, but make a low ridge of sterile red sandy soil. The hard white sandstone bed in the midst of the formation makes a decidedly hilly tract north of Lanes Run. The beds dip to the south and west in common with the outward slope of the ridge, making the roads that descend it steep and rocky.

In the Ferrel Ridge anticline the Wills Creek shale occupies nearly all the area within the inclosing ridges. The low sandstone hills forming the center of the uplift are composed of the white sandstone of the formation with red and yellow shale and softer sandstone on the flanks. A faulted arm of the anticline makes a secondary ridge southwest of Tomahawk on which the ledges of blocky sandstone stand above the surface. The shale occupies the lowland next to the outer ridges and the interior valley. On North Mountain the Wills Creek shale is not known to occur and is probably faulted out.

Correlation.—Fossils are not plentiful in the Wills Creek shale of this area, but those that do occur are conclusive as to age. The red and green sandstone and mud rocks at the base are barren of fossil remains and their general character resembles the barren red gypsiferous shale of the Salina of New York. The pseudomorphs of salt crystals here also indicate somewhat similar conditions of sedimentation to the salt beds of that formation. The calcareous shale and thin limestone beds contain chiefly ostracods—*Leperditia alta, Leperditia* sp. undet., *Kloedenella* cf. *clarkei* and undescribed species of *Primitia, Ulrichia*, and *Kloedenia*—and a few undetermined pelecypods. Ulrich states that "so far as known the fauna of the Wills Creek is intermediate in character between that of the underlying McKenzie and the overlying Tonoloway, the presence of species of *Leperditia* suggesting the latter formation while some of the smaller ostracods are closely allied to species abundantly preserved in the McKenzie. No exactly corresponding marine fauna is known in America, and eurypterids have not been found in the Wills Creek. Nevertheless this formation is assigned to the age of the Salina of New York on the assumption that it represents shallow marine conditions prevailing in the Appalachian Valley region while more confined saltpan conditions existed in western New York."

In the recent Maryland Survey reports the term Salina has been used for this and the next overlying formation, and in earlier reports of the Maryland Survey and of the United States Geological Survey for adjacent areas they were included with all associated limestones under the heading Lewistown limestone. In the Pennsylvania Survey report on Fulton and Bedford counties about 150 feet of red shale and sandstone were provisionally referred to the Salina, but were combined with the Clinton and Niagara of that report under the title Formation No. V. A fine-grained gritty red sandstone about 20 feet thick, mentioned as forming Red or Rocky Ridge in Bedford County, is undoubtedly the same as the basal member of the formation mapped in the Pawpaw and Hancock quadrangles. In later State reports I. C. White gave the name Bloomsburg red shale to sandy red shale and sandstone at this horizon. In Huntingdon County these beds were reported to be 270 feet thick and farther north, near the center of the State, 400 feet thick. Although the red sandstone is much thinner in Maryland, it is believed to be the same lithologic member as that described by White, and the name Bloomsburg red sandstone member is employed in this report.

The name Wills Creek for this middle shale formation of the Cayuga group is selected because the formation is well exposed on the banks of Wills Creek in Cumberland, Md., where the cement beds have been quarried and burned for cement. Uhler[a] had previously applied the name rather indefinitely to the rocks outcropping at this place.

TONOLOWAY LIMESTONE.

Character and thickness.—The Tonoloway limestone is the upper calcareous portion of the Cayuga group. It is composed throughout of finely laminated, fine-grained limestone, light-gray to dove in color with shaly beds alternating with harder and more massive layers. Where freshly exposed the formation appears massive, but in the ordinary outcrops beds of platy to shaly limestones are only occasionally seen. The minutely lamellar character, which is brought out finely by weathering, is very characteristic of the formation. The surfaces of some of the beds are finely ripple-marked, checkered by sun cracks, and marked by mud flows, rain prints, and various trails. Other surfaces are very rough and have a black carbonaceous coating, and in some of the lower beds show local deep basins and rounded domes that on close examination prove to be large forms of *Cryptozoon*. The top of the formation, which is in general somewhat more shaly than the lower part, is placed at the base of more massive-bedded limestones, generally darker gray or blue and less platy and shaly than those below, that weather to a nodular or "cobbly" appearance and are more fossiliferous than the underlying formation. The lower limit of the formation is arbitrarily placed at a thin sandstone, below which the beds appear more shaly in the fresh section and on weathering form soft shales at the surface.

The detailed section of the Cayuga group at Grasshopper Run in the Hancock quadrangle shows the formation to be 400 feet thick. At Potomac, Md., west of Cumberland, it measured 606 feet and the beds appear more massive in the freshly cut section, indicating a thickening of the calcareous strata to the west. As previously stated, the base of the formation at Potomac is placed lower with respect to a certain sandstone bed than it is to a similar bed in the Grasshopper Run section, but the identity of these two sandstone beds is not established. The boundary, moreover, is a lithologic line and not strictly stratigraphic.

Distribution and surface form.—The distribution of the Tonoloway limestone is similar to that of the next succeeding formation. It occurs as a narrow band on the lower slope of the Helderberg-Oriskany ridges and in adjacent parallel valleys, and, as it contains no hard siliceous beds, it forms gentle slopes with rich deep soil that is generally cultivated.

Beginning on the west, the Tonoloway limestone occupies much of the bottom land of Cacapon River from Ziler Ford to Rock Ford. In the stream cliffs about Ziler Ford the massive character of the beds in fresh exposure is well shown. North of Rock Ford it forms the lower eastern slope of Tonoloway Ridge, both south of the Potomac and north to the edge of the quadrangle. In the local syncline of Roundtop Mountain it forms an elongated area surrounding the higher formations in the center of the basin and several thin flat-lying remnants on the hills to the northeast.

On the east side of the Cacapon Mountain anticline the Tonoloway limestone forms the lower western slope of Warm Spring Ridge to the Potomac. North of the river it spreads out in the gentle folds west of Cove Ridge and forms wide fertile limestone valleys. It is exposed again on the inner slopes of Elbow Ridge, on the flanks of Dickeys Mountain anticline, and on the inner slopes of the elliptical line of ridges terminating at the north in Ferrel Ridge. Its western band in the latter area is very narrow because of the steepness of the dip, but the eastern band is much wider and is indented by the stream gorges. A fault also exposes a band of the formation diagonally across the uplift.

The Tonoloway limestone is not seen in the North Mountain uplift, as it is faulted out there, but in the region west of Cove Mountain it is extensively exposed below the Helderberg outcrops, usually at the base of slopes and in stream valleys.

Correlation.—Ulrich has furnished the following lists of fossils and a statement of their correlation:

As a whole, the Tonoloway limestone of this region is very sparingly fossiliferous. Some layers, however, are crowded with organic remains, while here and there a *Stromatopora* reef may be encountered. Such a reef was noted 280 feet beneath the top of the formation in the Grasshopper Run section. The fossils usually seen are ostracods, species of *Leperditia*, *Kloedenia*, and *Kloedenella* being especially abundant. Locally the ostracods are associated with numerous *Tentaculites gyracanthus*, while several small brachiopods and a few slender branching Bryozoa occur more rarely. Farther west, between Cumberland, Md., and Keyser, W. Va., where the beds are better exposed and have been more carefully searched, a larger fauna has been found. There, as in the vicinity of Hancock, the respective faunas of the lower and upper portions are largely distinct. This will be apparent from the following two partial lists of species:

Partial list of fossils from the lower portion of the Tonoloway limestone.

Stromatopora sp. undet.	Hormotoma sp. undet. (resembles H. gracilis).
Favosites globuliformis.	Tentaculites gyracanthus.
Fistuliporella, thinly lamellose species.	Calymene camerata.
Cyphotrypa, new lamellate species.	Leperditia alta.
Orthopora n. sp. (cf. O. regularis).	Leperditia altoides (?)
Schuchertella hydraulica var.	Beyrichia n. sp. (resembles Entomis flabellifer and E. oblonga).
Meristella bella?	Kloedenia n. sp.
Whitfieldella nucleolata.	Bollia (? Halliella) n. sp. (reticulated surface, loop obsolete).
Rhynchospira globosa.	Kloedenella clarkei.
Rhynchonella litchfieldensis.	Kloedenella halli.
Rhynchonella hydraulica?	Kloedenella (? Tetradella) cf. hieroglyphica (Krause).
Rhynchonella? lamellata.	

Fossils from the upper 50 feet of the Tonoloway limestone.

Stropheodonta bipartita.	Primitia humilis ?
Spirifer corallinensis.	Kloedenella clarkei.
Spirifer eriensis.	Kloedenella (? Tetradella) hieroglyphica.
Tentaculites gyracanthus.	Octonaria n. sp.
Kloedenia cf. nearpassi.	Bythocypris cf. concinna.
Kloedenia sussexensis var.	
Halliella ? cf. seminulum.	

Comparison of these faunas with the New York section leaves little doubt concerning the late Cayuga age of the formation. Most of the diagnostic species above listed occur in the Schoharie Valley sections in New York between the base of the Cobleskill and the top of the "Tentaculite," or typical Manlius, limestone. A considerable part of these species, it is true, passes upward in the Maryland sections into the Helderberg limestone. Noting their presence in the latter but disregarding the composition of the Tonoloway fauna, especially of its lower beds whose fossils are most like the Cobleskill, geologists who have studied the sections in the Potomac Valley have generally drawn the base of the formation which they correlated with the Cobleskill and Manlius rocks above the top of the Tonoloway. Recent field studies seem to establish that the typical Manlius limestone of New York is older than the base of the rocks here referred to the Helderberg limestone. The Manlius and Cobleskill therefore seem to be in general correlatable with the Tonoloway, although the fauna indicates that Tonoloway sedimentation in Maryland in part preceded that of the Manlius and Cobleskill in New York.

From the above discussion it is evident that the Tonoloway limestone does not agree exactly with any named formational unit in New York. The Bossardville limestone of central and northeastern Pennsylvania may correspond to the upper part of the formation, but it is thought by Ulrich more likely to be somewhat younger. Under the circumstances the new name Tonoloway is proposed, from Tonoloway Ridge in the Pawpaw and Hancock quadrangles, the lower slopes of which are composed of the formation and furnish a good exposure of it in the stream cliff west of Rock Ford.

DEVONIAN SYSTEM.

Under Devonian system in this folio are described the Helderberg limestone, the Oriskany sandstone, the Romney shale, the Jennings formation, and the Catskill formation. Heretofore in the United States Geological Survey reports the Helderberg has been regarded as Silurian, but it is now the consensus of opinion that it properly belongs in the Devonian, and the formation will henceforth be so treated. The Romney shale comprises representatives of the Marcellus shale, the Hamilton formation and the Onondaga limestone of New York, while the Jennings is the equivalent of the Genesee, Portage, and Chemung formations. The Catskill, as in central New York, is an estuarine or fresh-water facies of the upper part of the Chemung, and as such is a distinct lithologic formation.

LOWER DEVONIAN.

HELDERBERG LIMESTONE.

Character and thickness.—The Helderberg in general is a series of thick-bedded dark-blue limestones and shaly limestones with numerous cherts in its upper part, lying between the more shaly limestone of the Tonoloway below and the siliceous Oriskany above. In this area it is readily distinguished from the Tonoloway by its more massive and generally crystalline character, darker color, more numerous fossils, and especially its tendency to become nodular or cobbly upon weathering instead of platy and finely lamellar. Good complete sections in this area are rare. Probably the best section is that along the Western Maryland Railway opposite Great Cacapon, which was measured by Ulrich and the writer as follows:

Section of Helderberg limestone, Western Maryland Railway cut opposite Great Cacapon, W. Va.

Bed.		Ft.	in.
	Yellow shale with chert containing lower Oriskany fossils.		
27.	Residual clay after limestone filled with white blocky chert, with numerous fossils of New Scotland type	12	
26.	Hard blue-gray mottled and fine black-specked limestone, full of fossil fragments (fauna perhaps Coeymans)	8	6
25.	Somewhat lamellar limestone with argillaceous and purer fossiliferous subcrystalline bands	6	
24.	Coarsely cobbly to irregular lamellar impure limestone, with purer fossiliferous bands. Bryozoa and Brachiopoda abundant, especially in a crinoidal layer at the top	26	
23.	Very shaly, platy limestone full of *Tentaculites* and other fossils	3	
22.	Shaly cobbly limestone, solid when fresh	7	
21.	Very shaly cobbly limestone, with many fenestellids and other Bryozoa	2	6
20.	Dark gray-blue limestone, coarsely cobbly and fossiliferous in lower part	10	
19.	Cobbly limestone with surface full of Bryozoa and *Tentaculites*	2	
18.	Cobbly limestone containing shells and reef of *Stromatopora*	2	
17.	Coarsely cobbly argillaceous limestone	3	
16.	Cobbly limestone; numerous fossils in middle	14	
15.	Rather shaly cobbly limestone; shells abundant	12	
14.	Massive cobbly limestone	4	
13.	More shaly limestone, breaking into irregular laminæ	6	
12.	Single layer finely cobbly limestone; fossils less abundant; basal part bored by worm tubes	24	
11.	Somewhat clayey, finely cobbly limestone; poor fossils	2	8
10.	Slabby crinoidal limestone	1	
9.	Finely cobbly limestone, massive when fresh, but breaks up on weathering into irregular pieces and cobble. Small reef of *Stromatopora* and *Favosites* near top and a thicker one near base	21	
8.	Subcrystalline limestone banded with thin clayey seams. Contains fossil fragments	5	
7.	Subcrystalline limestone irregularly bedded with thin clayey seams and containing large crinoid columns	5	
6.	Thick-bedded subcrystalline limestone	7	
5.	Finely cobbly limestone with some *Favosites*, massive Bryozoa, and rhynchonelloid shells	6	6
4.	Thin slabby and shaly limestone, argillite in part, not very fossiliferous except a seam with Ostracoda	4	
3.	Very massive finely cobbly limestone, breaking into hackly cobbles. Fossils scattered; lower 10 feet full of *Rhynchonella litchfieldensis* and *Rhynchospira globosa*	70	
2.	Very massive finely lamellar and shaly limestone. Numerous *Chonetes jerseyensis*	16	6
1.	Crystalline limestone, slightly conglomeratic, with clayey limestone pebbles	1	6
	Shaly limestone of the Tonoloway, poorly exposed.		
		282	2

Fairly good sections occur in the gaps in the ridges of Oriskany sandstone around the Ferrel Ridge anticline, and the following detailed section was measured at Tomahawk:

Section of Helderberg limestone, Tomahawk, W. Va.

	Feet.
Compact gray subcrystalline limestone with interbedded black flint; contains Oriskany shells.	
Largely concealed. Some dark, fine-grained limestone beds exposed. Contains Becraft fauna	90
Calcareous sandstone with shale below	13
Thick-bedded massive limestone, with large *Spirifer macropleura* and numerous shells of New Scotland fauna	79
Banded light-gray calcareous sandstone	10
Thick-bedded coarse limestone, with wavy parting, weathering cobbly and containing Bryozoa and shells of Coeymans type	22
Largely concealed. Shale at base, dense limestone above, and loose fragments of a 2-foot bed of coarse sandstone 20 feet below the top	84
Chiefly cobbly limestone with some thin-bedded and shaly limestones	32
Shale with 6-inch bed of black chert	6
Massive coarse granular limestone with *Favosites*	2
Massive cobbly limestone with numerous *Favosites* in lower part	25
Dark siliceous limestone	1
Crystalline, rough bedded limestone, coarse grained above, with *Favosites* and crinoid stems	16
Finely laminated barren drab limestone with darker limestone at contact (probably Tonoloway).	
	380±

On Licking Creek, one-fourth mile west of the bridge near Warren Point, in the Hancock quadrangle, the upper 162 feet of the section is well exposed and was carefully measured by R. B. Rowe. The total thickness of the formation there is estimated to be about 350 feet. The partial section as measured by Rowe is as follows:

Partial section of Helderberg limestone on Licking Creek, near Warren Point, Md.

	Feet.
Fossiliferous sandstone (base of Oriskany).	
Light-gray limestone free from chert, containing numerous brachiopods of Becraft fauna	25
Light-gray limestone with numerous bands of black chert	20
Pure light-gray fossiliferous limestone, little chert	25
Mostly black chert in nodular layers, with some limestone near top	17
Covered	40 ?
Light-gray fossiliferous limestone with numerous layers of white chert at bottom and black chert at top. New Scotland fauna	25
Light-gray, almost quartzitic sandstone locally forming rocky ridges; weathers to coarse, porous, gritty sandstone marked by large crinoid columns	10
Covered. Fragments containing *Gypidula* cf. *coeymansensis*.	
Massive gray limestones containing *Gypidula galeata* and other fossils of the Coeymans fauna.	

[a] Uhler, P. R., Trans. Maryland Acad. Sci., vol. 2, 1905, pp. 19-26.

Marked differences are observed in the detailed sections. In the western part of the area, typified by the Great Cacapon section, the formation is composed chiefly of thick-bedded fossiliferous limestone, most of which weathers nodular, and a subordinate amount of shale or shaly limestone containing chert near the top. This same general sequence is observed also in the Cumberland area farther west, where the total thickness is somewhat greater than at Great Cacapon. Eastward a heavy calcareous sandstone is found locally near the base of the shaly beds containing the chert, the top of the formation in the western sections, and a thick series of limestones with a little chert is developed above this sandstone. The thickness correspondingly increases from 280 feet to about 380 feet. The sandstone, which is calcareous and quartzitic when fresh, weathers to a coarse-grained porous rock marked by molds of fossils, in particular large columns of crinoids. Its outcrop forms ridges in places, of which Elbow Ridge is the most prominent, and large ledges of the rock occur on the crest of Moore Knob. The low hills north of Moore Knob also have large blocks of the sandstone and numerous fragments of chert on their surfaces. Beyond this restricted area the sandstone is not a ridge maker but is seen in rock exposures and in weathered fragments to the south. Usually it can be readily recognized by its porous character, dark rusty color, and large molds of crinoid columns. This sandstone was seen as far south as the southern border of the quadrangle on the road from Tomahawk to Jones's Spring. The sandstones recorded in the upper part and near the middle of the formation in the Tomahawk section are peculiar to this vicinity and suggest nearness to the eastern shore of the ancient sea.

Besides numerous shells in the limestones of this formation, corals and similar fossils occur in great numbers and in places form large *Stromatopora* and *Favosites* reefs. Some of the dark coralline beds have a fetid odor when struck. The thicker beds are quarried for building stone in places, chiefly around Hancock, where they are also locally burned for field lime. In the western outskirts of Hancock a well-bedded, rough-surfaced, dark slabby limestone is quarried for flagging and building stone. On Cove Ridge, 2½ miles north of Hancock, a thick bed of very pure even-grained drab limestone, which would undoubtedly make an excellent grade of lime, is quarried for foundation stones. The formation yields the most fruitful soil in the area, but since it usually forms the slopes of the adjacent sandstone ridges the soil is filled with chert and sandstone fragments.

Distribution and surface form.—The Helderberg limestone outcrops in narrow bands on opposite sides of the Cacapon anticline, around the southern end of Dickeys Mountain anticline, on the west and south sides of Cove Mountain monocline, and encircling the Ferrel Ridge anticline. In all occurrences it occupies the inner slope of Oriskany ridges, that is, the side toward the axis of the anticlinal fold.

The upper part of the steep eastern slope of Tonoloway Ridge is composed of this formation, forming a relatively straight narrow band entirely across the quadrangles. Its exposures are largely covered by chert from its upper beds and sandstone from the overlying Oriskany. A remnant of the limestone is preserved in the subsidiary Roundtop syncline on the surface of the Cacapon anticlinal fold, southwest of Hancock. A similar narrow band of the limestone forms the upper western slope of Warm Spring Ridge, the highly fossiliferous chert at the top of the formation outcropping near the crest of the ridge. North of the Potomac the formation continues to outcrop on the upper western slopes of Cove Ridge to the border of the quadrangle, where it is offset into the valley by a fault and caps a low hill. The narrow strip of Helderberg on the sides of the Dickeys Mountain anticline flares out into a wide curved belt at the southern end under the influence of low dips. A calcareous sandstone of the formation here thickens locally to a heavy ridge-making bed and forms the crest of Elbow Ridge, while the Oriskany becomes calcareous and forms the outer slopes of the ridge.

East of Coon Ridge the Helderberg occupies a relatively broad anticlinal area bounded by nearly parallel faults which converge northward and cut out the formation. The sandstone bed in the formation forms rocky ledges on the upper slopes of Moore Knob beneath the capping of the Oriskany and at a few places along the belt of Helderberg to the north. South of Lanes Run the Helderberg area swings sharply to the east along the steep northern slope of the Oriskany sandstone ridge about Indian Springs. Although not so shown on the map it extends across the river west of Cherry Run.

The inner westward slope of Ferrel Ridge and of the two lines of disconnected sandstone ridges running south from its curved ends to the limit of the quadrangle are composed of Helderberg limestone. The western strip is very narrow and straight because of the steep dips, but on the eastern side low dips and accessory folding and faulting produce a wider and more irregular strip. On North Mountain the Helderberg is faulted out.

Faunal zones.—A systematic collection and study of the fauna of the Helderberg from this and adjacent areas has not been completed, but the following provisional lists of fossils and notes on the faunal zones of the Helderberg are contributed by Ulrich.

In the Potomac Valley, between North Mountain on the east and Keyser, W. Va., on the west, the Helderberg formation presents four broadly conceived faunal zones. The three upper zones—those containing the Coeymans, New Scotland, and Becraft faunas—are well known as formations of the Helderberg group in New York and New Jersey. The lowest faunal zone is the most persistent and also the most important zone of the formation as developed in areas near the Potomac in West Virginia, Maryland, and southern Pennsylvania. This zone is excellently exposed both in fresh quarry cuts and in weathered outcrops at Keyser, W. Va. It is partly represented in New York by certain beds which have hitherto been erroneously identified with the "Tentaculite" or Manlius limestone, but no appropriate name has been applied to it.

At no single locality are all these four zones fully developed and at most places one or another is entirely absent. The lower third or so of the lowest zone at Keyser seems altogether wanting east of Hancock, while the Becraft fauna is unknown west of that town. The Coeymans fauna, though generally recognizable, is irregular in its occurrence and possibly locally absent. It may be absent, for instance, in the Great Cacapon section, though it is probably represented in the 8½-foot bed near the top (bed 26 in the section). The New Scotland fauna is perhaps everywhere present, but the zone containing it varies greatly in thickness. At Great Cacapon, where the zone forms the top of the formation, it is but 12 feet thick; at Tomahawk and near Warren Point, in the eastern part of the area, the zone is 60 to 90 feet thick; between Cumberland and Keyser its thickness varies between 25 and 65 feet. As has been stated the lower zone at Keyser also varies from place to place, but so far as known in Maryland its thickness seems never to fall under 100 feet. At Tomahawk about 150 feet of beds are referred to it, at Great Cacapon 262 feet, at the Devils Backbone, near Cumberland, about 280 feet, and in the Keyser quarries about 290 feet. Finally, it should be stated that no beds were observed in Maryland corresponding to the Port Ewen limestone, the uppermost formation of the Helderberg group in New York.

Although each of the three upper zones is practically indivisible on faunal grounds, the relatively thick zone at the base of the formation may be divided into at least three subzones. These are easily distinguished by fossils confined to the several subdivisions or by diagnostic associations of species. The lowest of these subzones is commonly absent, but is well developed in the vicinity of Hancock and Great Cacapon, where it comprises beds 1 to 4, aggregating about 92 feet of limestone. To the west it is well exposed at the base of the Helderberg in the railroad cut at Potomac, Md., and in the quarry at Keyser, W. Va. A fauna including *Cyphotrypa rotundata*, *Schuchertella deckerensis*, *Chonetes jerseyensis*, *Spirifer eriensis*, *Rhynchonella litchfieldensis*, and *Leperditia gigantea*, or any four of these species, may be confidently accepted as indicating this subzone.

The second of these subzones, though generally present, varies greatly in thickness. At Potomac only its uppermost part was recognized, but at other localities between Hancock and Keyser lower beds are intercalated which bring the total thickness of the subzone from 50 feet up to nearly 100 feet. The top consists of a very persistent and usually massive bed that is recognized at once, especially in the sections west of the Hancock quadrangle, by the abundant valves of a small variety of *Gypidula galeata* that it contains. The lower beds also contain widely recognizable fossil horizons. One of these lies from 30 to 50 feet beneath the *Gypidula* bed and is notable for its abundant remains of numerous cystids and crinoids that have been seen only in this part of the section. Though highly fossiliferous chiefly to the west of Cumberland the cystid bed has been noted to the east also as far as Hancock. *Camarocrinus stellatus* is confined to a layer between the cystid and *Gypidula* beds. In the vicinity of Great Cacapon a small *Stromatopora* and *Favosites* reef holds a similar position and helps in locating the more important adjacent fossil horizons.

Although more subzones were indicated in the field it seems inadvisable in the present state of our knowledge to attempt a further subdivision of the remainder of the zone. However, there are at least three and probably four fossil horizons above the *Gypidula* bed that may be said to be generally recognizable. The lowest of these lies directly above the *Gypidula* bed and is usually a shaly limestone containing many Bryozoa of which a species of *Petalotrypa* is the best for purposes of identifying the bed. Large specimens of *Chonetes jerseyensis*, though unknown in the underlying subzone, are not infrequently found in this bed. The corresponding horizon in the Great Cacapon section was not positively recognized, but it is thought to belong between the base of bed 13 and the top of bed 16.

The *Petalotrypa* bed is everywhere succeeded by a more or less well developed *Stromatopora* reef which usually forms a single massive ledge. Over this reef is a third widely distinguishable horizon, in places shaly, that commonly contains such diagnostic fossils as *Beachia* n. sp., *Rensselaeria mutabilis* var., and a new variety of *Spirifer vanuxemi*. A late mutation of *Tentaculites gyracanthus* occurs very plentifully and as it seems to be confined to this bed and the genus is rare or absent in the other subzones, it is of considerable value in correlating the beds of the Helderberg limestone in Maryland. Locally this *Tentaculites* bed includes or is followed by another *Stromatopora* bed.

Finally, a still higher bed, containing few fossils except a late form of *Leperditia alta*, appears in the vicinity of Cumberland and at Keyser. This bed has not been recognized in the Great Cacapon section, in which, moreover, the upper part of the zone—the beds above the main *Stromatopora* reef—is thinner than in the more western sections mentioned. In view of these facts it seems probable that shallowing and partial withdrawal of the sea took place before the more extensive withdrawals and temporary land conditions indicated by physical criteria at the end of the lower faunal zone and again at the end of the zone containing the Coeymans fauna.

Comparisons with formations in New York and New Jersey are appended to each of the following lists of partially identified fossils collected from the faunal zones of the Helderberg limestone in Maryland. The species thought to be diagnostic of the respective zones are distinguished by an asterisk.

Lowest fauna in the Helderberg limestone, procured chiefly from beds 1 to 4 of the section opposite Great Cacapon.

Diphyphyllum integumentum.
*Cyphotrypa n. sp.
Trematopora sp. undet.
Pholidops ovata ?
Stropheodonta bipartita.
*Schuchertella deckerensis.
*Chonetes jerseyensis.
Spirifer vanuxemi.
Spirifer eriensis.
Whitfieldella nucleolata.
Rhynchospira globosa.
Rhynchonella formosa.
Rhynchonella litchfieldensis.
Rhynchonella ? lamellata.
Uncinulus mutabilis.
Tentaculites gyracanthus.
Leperditia altoides.
*Leperditia gigantea.
*Beyrichia n. sp.
Kloedenia barretti.
Kloedenia sussexensis.
Kloedenella clarkei.

This fauna is regarded as indicating the time of the lower and middle beds of the Decker limestone in the Delaware Valley in northwestern New Jersey and northeastern Pennsylvania. Locally, as at Potomac, Md., a higher coral zone is developed that is thought to correspond to the upper coral-bearing beds of the Decker limestone as described by Weller in New Jersey. This upper subdivision is marked by *Cladopora rectilineata*, the slender branching coralla of which occur in great abundance at Potomac. It is of sufficient interest to repeat here that the coral zone at this locality is followed almost immediately by the *Gypidula* bed.

Second fauna of the Helderberg limestone, represented in beds 5 to 25 of the section opposite Great Cacapon.

Stromatopora sp. undet.
Favosites helderbergiæ.
Favosites helderbergiæ præcedens.
*Striatopora sp. undet.
Cladopora rectilineata.
*Cladopora multiseriata.
*Aulopora schohariæ.
*Aulopora n. sp. (very slender).
*Vermipora cf. serpuloides.
Diphyphyllum integumentum.
*Prismatophyllum sp. undet.
*17 cystids of the genera Pseudocrinites, Sphærocystites, Jækelocystis, Tetracystis, and Lepocrinus.
*5 or 6 genera of crinoids.
*Numerous Bryozoa, most of them undescribed and characteristic of this zone, representing the following genera: Ceramopora, Fistuliporella, Eridotrypa, Cyphotrypa, Lioclema, Stromatotrypa, Petalotrypa, Fenestella, Semicoscinium, Orthopora.
Pholidops ovata.
Dalmanella concinna.
Rhipidomella oblata var. emarginata.
Uncinulus pyramidatus.
Uncinulus nucleolatus.
* Gypidula galeata var.
*Mytilarca sp. undet.
*Amphicœlia ? n. sp.
*Grammysia n. sp.
Conularia pyramidalis.
Tentaculites gyracanthus var.
Dalmanella cf. postelegantula.
*Orthostrophia cf. strophomenoides.
Strophonella geniculata.
Schuchertella deformis.
*Schuchertella cf. woolworthana.
*Chonetes jerseyensis.
Leptæna rhomboidalis.
*Spirifer vanuxemi var.
Spirifer octocostatus.
Spirifer modestus.
*Merista typa.
Meristella lævis.
*Meristella cf. arcuata.
*Nucleospira cf. elegans.
Rhynchospira globosa.
Atrypa reticularis var.
*Rensselaeria mutabilis var.
*Beachia n. sp.
Rhynchonella formosa.
Rhynchonella litchfieldensis ?
Rhynchonella transversa ?
Rhynchonella ? lamellata.
Leperditia altoides.
Kloedenia kümmeli.
*Beyrichia n. sp.
Kloedenella clarkei.
Kloedenella pennsylvanica.
Kloedenella turgida.
Kloedenella hieroglyphica ?
*Octonaria n. sp.
Calymene camerata.

More than 100 species from this subzone are contained in the collections of the National Museum; and over two-thirds of these are strictly diagnostic. Taken as a whole the fauna is decidedly Helderbergian, most of the brachiopods, for instance, passing into the zones of the typical Coeymans and New Scotland faunas with so little change in character that it is difficult and often impracticable to distinguish them. On the other hand, most of the corals and ostracods, the trilobite, and a few of the brachiopods are more closely related to the preceding fauna and the Tonoloway fauna. This relation, together with the fact that the larger part of the fauna is confined to the lowest of the four Helderbergian zones recognized in Maryland, strongly suggests an older stage of the Helderberg group than is known or recognized in New York; and the truth of this suggestion is established by the occurrence of a typical Coeymans fauna above this lowest zone in Maryland. That this fauna is not the equivalent of the Cobleskill and Manlius faunas of New York, as has been supposed heretofore, is proved not only by its strong Helderbergian aspect but more positively by the presence in the lower Tonoloway, some 300 to 600 feet beneath the Helderberg in Maryland, of a fauna that agrees more closely with the typical Cobleskill and Manlius faunas.

Coeymans fauna from the Pawpaw-Hancock and adjacent areas.

Orthopora regularis.
Rhipidomella oblata.
Leptæna rhomboidalis (large var.).
Strophonella punctulifera.
Schuchertella woolworthana.
*Gypidula (Sieberalla) galeata (typical form).
Spirifer cyclopterus.
Meristella lævis.
Anoplotheca concava.
Atrypa reticularis.
Uncinulus nucleolata.
Uncinulus mutabilis.

Neither the Coeymans fauna nor the beds of this zone are as well developed in this region as in the Helderberg Mountains of New York. *Gypidula galeata*, which may almost always be found after a few minutes search, is the principal guide fossil. Although a smaller variety of the species is widely distributed in the underlying zone, the typical form of the species and the zone of which it is diagnostic can be at once distinguished by its associated fossils. A number of species, like *Spirifer cyclopterus*, *Strophonella punctulifera*, and *Schuchertella woolworthana*, are unknown beneath beds containing the Coeymans fauna; hence, the presence of any of these with *Gypidula galeata* may, according to present information, be regarded as positive evidence of the typical Coeymans fauna.

New Scotland fauna from the Pawpaw-Hancock and adjacent areas.

Corals.
*Edriocrinus pocilliformis.
*Monotrypa (Ptychonema) tabulatum.
*Dalmanella eminens.
*Dalmanella perelegans.
Dalmanella planiconvexa.
Rhipidomella oblata.
Leptæna rhomboidalis.
*Stropheodonta becki.
*Strophonella headleyana.
Strophonella punctulifera.
*Strophonella cavumbona.
Schuchertella woolworthana.
Spirifer cyclopterus.
*Spirifer macropleura.
Spirifer perlamellosus.
Spirifer concinnus (?).
Meristella subquadrata.
Meristella arcuata.
*Trematospira deweyi.
*Trematospira equistriata.
*Trematospira multistriata.
Nucleospira elegans.
Nucleospira ventricosa.
Atrypa reticulata.
*Atrypina imbricata.
Anoplotheca concava.
Anoplotheca flabellites.
*Camarotœchia altiplicata.
Uncinulus mutabilis.
Uncinulus vellicatus.
Eatonia medialis.
Eatonia peculiaris.
Eatonia singularis.
Rensselaeria mutabilis.
*Platyceras spirale.
Platyceras gebhardti.
Platyceras bisinuatum.
*Phacops logani.

In Maryland, as in New York, the zone of the New Scotland fauna is the most fossiliferous zone of the Helderberg. Though there are many other forms, and most of them characteristic of the zone, it is only the brachiopods that are very common. Fortunately there are enough of the latter that are either strictly confined to the New Scotland fauna or occur only rarely outside of it to render the identification of the zone exceptionally easy. Almost any of the species marked with the asterisk (*) may be relied on, and it is a poor outcrop indeed that does not quickly yield several of these. The cherty beds are especially prolific.

Becraft fauna from the Pawpaw-Hancock and adjacent areas.

Crania sp. undet.
Dalmanella planiconvexa.
*Rhipidomella assimilis.
Schuchertella woolworthana.
*Spirifer concinnus.
Spirifer cyclopterus.
*Cyrtina rostrata.
Meristella lata (?).
Meristella arcuata.
Nucleospira elegans.
Atrypa reticularis.
Anoplotheca flabellites.
Anoplotheca concava.
*Gypidula pseudogaleata.
Rhynchonella eminens.
Rhynchotreta (?) n. sp.
Plethorhyncha campbellana.
Eatonia medialis.
Eatonia peculiaris.
*Rensselaeria æquiradiata.
Rensselaeria æquiradiata var.
*Rensselaeria subglobosa.
*Phanerotrema labrosa.

Most of the species in this list were collected by Charles Schuchert in the vicinity of Cherry Run, in beds which are incorrectly included with the Oriskany on the geologic map. A few are added from collections made by R. B. Rowe, of the Maryland Geological Survey, from a light-gray limestone near the top of the zone near Warren Point, Pa. As usual, the greater part of the fauna is made up of species found abundantly also in the New Scotland fauna. However, the absence of such species as *Spirifer macropleura* and *S. perlamellosa* and the presence of such diagnostic forms as *Rhipidomella assimilis, Spirifer concinnus, Cyrtina rostrata, Gypidula pseudogaleata,* and *Rensselaeria æquiradiata* in beds overlying a fully and typically developed New Scotland fauna places the correlation of the upper beds of the formation in the vicinity of Tomahawk, Cherry Run, and Warren Point with the Becraft limestone of New York beyond all reasonable doubt.

Correlation.—The presence in this region of a representative of the Helderberg group of New York has long been known, but in earlier reports of the United States Geological Survey and of the Maryland Survey it was not differentiated as a separate formation but was included with the underlying calcareous formations under the name Lewistown. In 1901, Prosser,[a] reporting the results of studies made by him and his associates for the Maryland Geological Survey, later embodied in the State report,[b] recognized in the Maryland rocks the various faunal divisions of the Helderberg of New York. In the Pennsylvania State reports this limestone was early called the Lower Helderberg limestone, or Formation No. VI, and was later generally referred to as the Lewistown limestone, which embraced all the massive limestones beneath the Oriskany, including at the base a pure limestone in places distinguished as the Bossardville.

ORISKANY SANDSTONE.

Character and thickness.—The Oriskany sandstone, a conspicuous ridge-making quartzose formation overlying the limestones just described, is variable in composition in this area, but is in general a pure white to gray calcareous sandstone, with a minor amount of quartz conglomerate. Calcareous matter predominates in places, especially in the eastern areas, and forms a limestone that is burned for field lime; elsewhere, particularly in the western part of the area on Tonoloway and Warm Spring ridges, the sandstone is entirely free from lime at the surface, and is quarried for glass sand. A fine quartz pebble conglomerate is usually present at or near the top. In the eastern areas of the Pawpaw and Hancock quadrangles and farther west in the Flintstone quadrangle the pebbles are clean, well-rounded milk-white quartz of about one-fourth inch diameter, but in the vicinity of Hancock the conglomerate is an impure angular grit.

The Oriskany of Tonoloway Ridge is for the most part very massive, forming a nearly vertical wall of rock along the crest of the ridge, especially south of the Potomac. At the base, however, are thin shaly beds. The following section was measured along the Western Maryland Railway opposite Great Cacapon.

Section of Oriskany sandstone opposite Great Cacapon.

	Feet.
Black shale (Romney).	
Soft, porous, brown fossiliferous sandstone, some beds a fine dark vitreous quartz conglomerate. Very fossiliferous layer at the base	40
Massive beds, 10 to 20 feet thick, of white fossiliferous quartzose sandstone	85
Softer, thinner-bedded, fossiliferous sandstone, weathering yellowish	90
Hard quartzitic sandstone	2
Soft, thin-bedded yellowish sandstone, few fossils	45
Covered. Soft sandstone débris	140
Yellow, probably calcareous, fossiliferous shale with much chert, containing Oriskany fossils	15
Crystalline dark limestone containing Helderberg fossils.	
	417

The portion of the formation exposed on the south bank of the river is a very thin hard quartzitic ledge. Whether the formation was originally thinner at this point, whether it was partly squeezed out by intense folding, or whether the thinness is only apparent, due to the removal by erosion of the softer beds, could not be ascertained.

Throughout the Warm Spring Ridge the formation is composed of massive pure-white quartz sandstone, but being rather loosely cemented it is not so resistant and does not form so high a ridge as Tonoloway Ridge. Near the southern margin of the Pawpaw quadrangle a partial section was measured at Rock Gap as follows:

Section of Oriskany sandstone at Rock Gap.

	Feet.
Shale lowland (Romney).	
Very massive beds, 5 to 10 feet thick, of hard white to gray sandstone	40
Soft brown sandstone	51
Concealed	80
Soft gray sandstone with rust-stained surface, disintegrating to white sand	57
Covered; some soft sandstone and chert.	
	228+

Near the Potomac the Oriskany of this ridge is mined for glass sand, and the workable beds are well exposed in a number of open quarries. About 130 feet of rock is quarried at the northernmost pit, the Pennsylvania Glass Sand Co.'s mine, near Lovers Leap. The upper 20 feet is a hard quartzose layer, not suitable for the best grade of glass sand, but about 100 feet of rock below is pure white quarry rock, except where it is stained at the surface or along joint cracks. One 6-foot bed near the top is soft and clayey, but the quartz is pure white. The quarry rock is generally even grained and is sufficiently friable at the bottom of the quarry, 120 feet in depth, to be worked with pick, sledge, and shovel. This crumbly character apparently results from the leaching of the calcareous cement of the unaltered rock by percolating meteoric waters. At the base of the workable beds is a 20-foot layer of harder rock which can not be quarried profitably. The total thickness of the formation here is about 150 feet.

The sandstone thins rapidly north of the Pennsylvania mine, and entirely disappears within one-fourth mile of the end of the ridge, where the Romney shale and Helderberg limestone occur within a few feet of each other. In the railroad cut at the point of the ridge are exposed about 40 to 50 feet of white and black banded sandstone and fine conglomerate of angular black quartz pebbles in a dirty sand matrix between the overlying black Romney shale and underlying Helderberg limestone. North of the river, at the sand quarry back of Hancock, there are about 90 feet of coarse brown sandstone with the same fine conglomerate of angular black pebbles in impure sand matrix at the top. This local thinning is regarded by some geologists as due to overlap or unconformity, but as the top of the Helderberg is also absent at these points and the rocks are so closely compressed, the thinning of the formations is more probably due to faulting.

The following section of the Oriskany one-fourth mile east of the bridge near Warren Point was measured by R. B. Rowe.

Section of Oriskany sandstone near Warren Point.

	Feet.
Black and gray arenaceous and argillaceous shale with thin basal conglomerate (Romney).	
Coarse milk-white quartz conglomerate	1½
Blue arenaceous limestone with bands of fine conglomerate or grit at the top	12
Covered	10
Light-gray massive arenaceous limestone	8
Covered	2
Massive dark-gray limestone, with conglomerate bands at top	10
Covered	6
Conglomeratic dark-gray limestone with fine pebbles and coarse sandstone	3
	52½

Whether or not this is the full thickness of the Oriskany in this portion of the area the formation is evidently thinner here than in most places in the quadrangle, and it is so calcareous that it is not the ridge-forming element in Elbow Ridge, a locally heavy coarse sandstone in the Helderberg making the crest. The thinning in this direction is accompanied by a deposit of iron ore at the base of the formation, indicating that at the beginning of Oriskany time there was a land area here on the lowlands of which bog iron accumulated and was later covered by marine sediments.

In the hills north of Indian Springs, thick and highly fossiliferous calcareous sandstone again forms a prominent part of the Oriskany. Although the formation is so strongly calcareous that it is burned for lime south of the river, its chert and sandstone layers form Ferrel Ridge and the low ridges to the south. The following section was measured at the small stream gap in the eastern ridge at Tomahawk.

Section of Oriskany sandstone, Tomahawk, W. Va.

	Feet.
Flat valley (probably Romney shale).	
Massive calcareous white sandstone containing numerous specimens of *Spirifer arenosus.* Hard blue siliceous limestone with black flint below, very fossiliferous	45
Chiefly fossiliferous limestone with black flint	16
Hard granular sandstone with white quartz conglomerate at top	3
Concealed. Thick beds of limestone in part	41
Chiefly hard siliceous fossiliferous limestone, weathering to sandstone and chert	75
Siliceous gray limestone with interbedded black flint, and thin fossiliferous limestone	33
Concealed. Probably Helderberg.	
	213±

Distribution and surface form.—The Oriskany occurs in two narrow northeast-southwest bands crossing the Pawpaw and Hancock quadrangles and in five small isolated areas extending into the quadrangles. The narrow continuous outcrops, which are on opposite sides of the Cacapon Mountain anticline, compose Tonoloway and Warm Spring ridges. The crest and upper western slopes of Tonoloway Ridge, which is prominent throughout both quadrangles, are formed by Oriskany sandstone dipping steeply westward. This outcrop is straight and narrow except where Great Cacapon River cuts through the ridge near the southern border of the Pawpaw quadrangle. There the strata are doubled back in a fold and the ridge on the north side attains unusual width and height. The low arch of the southward-plunging anticline is exposed in the north bank of the river, but the fold immediately rises again south of the river and forms the ridge east of Spring Ford. The beds are more gently inclined in the Warm Spring Ridge, of which they form the crest and east slope. The pure white quartz sandstone in this ridge is less coherent than that in Tonoloway Ridge, as a result of which the formation is less resistant and has less relief, and it is thinned by faulting to only a few feet of coarse sandstone at Potomac River, where the ridge becomes low and narrow. The continuation of the Warm Spring Ridge north of the river is locally called Cove Ridge.

Between these long bands is a small narrow area of Oriskany on the west slope of Roundtop, preserved in the bottom of a minor syncline.

Around the Dickeys Mountain anticline the Oriskany forms a loop which extends into Maryland on the southern slope of Elbow Ridge. The formation here is composed largely of cherty limestone with thin conglomerate at the top, not much more than 50 feet thick in all. It is cut off on the west at Licking Creek by a fault. East of Keefer Mountain the narrow body of sandstone swings across Little Cove beyond the border of the quadrangle in low ridges that reenter the northeast corner, where the formation is cut out by the main Cove Mountain or Foltz fault. South of the Maryland State line a narrow outcrop reappears on the east side of the fault. Moore Knob is capped by a thin remnant of the formation, and a thin layer of chert and associated siliceous iron ore cover the surface along the same minor syncline to the north, suggesting the waning of the prominent ridge-making formation of the west in the immediate proximity of the shore line of the Oriskany interior sea.

The high semicircular hills north of Indian Springs are composed of massive beds of the Oriskany in a gently southward pitching minor syncline, which is cut off on the west by the Cove Mountain or Foltz fault. Not only is the ridge capped by the formation but its southern slope down to the Baltimore pike is covered by large fragments of the coarse sandstone, containing numerous casts of large characteristic shells.

In the southeastern part of the Hancock quadrangle the Oriskany forms a loop of narrow ridges that culminates at the north in the prominent knob called Ferrel Ridge. The formation is here quite calcareous and not so resistant as elsewhere, so that its low ridge is cut by many water gaps. A very narrow band is poorly exposed next to the fault on the west slope of North Mountain. Only the upper layer of coarse granular sandstone was seen at this place, but the lower calcareous beds are exposed farther north, beyond the limits of the quadrangle, where the formation is cut out by the fault in places.

Correlation.—The Oriskany sandstone is very fossiliferous in this area. In the sandstones of the Warm Spring and Tonoloway ridges the shells are generally preserved as interior casts, but since most of the fossils are large and of characteristic form they can be readily identified. In the eastern calcareous portion the fossils are beautifully preserved, and where the rock has been burned for lime, as, for example, near Tomahawk, the white calcined shells stand out in marked contrast with the less pure gray groundmass.

In the cherty calcareous shale at the base of the formation exposed in the Western Maryland Railway cut opposite Great Cacapon the following fossils, identified by E. O. Ulrich, were collected:

Pholidops terminalis.	Craterellina robusta.
Rhipidomella oblata.	Craterellina oblonga.
Stropheodonta becki.	Thlipsura multipunctata.
Leptæna rhomboidalis.	Bollia ungula.
Schuchertella sp.	Bollia americana.
Anoplotheca concava.	Kirbyia n. sp.
Spirifer cyclopterus.	Pachydomella sp. undet.
Spirifer nearpassi.	Bythocypris sp. undet.

These are correlated by Ulrich with the lower Oriskany of New York, which has generally been considered absent in this part of the Appalachian Valley. Schuchert[a] states that in the area included in the Pawpaw and Hancock quadrangles nothing has as yet been found comparable with the lower Oriskany of the Cumberland region, which is there a black shale with nodular chert, 90 feet thick. Its presence in soft strata that are generally poorly exposed may account for its not having been previously recognized. This is the only section in the area where the fauna was positively identified, and it is probably the easternmost occurrence of this faunal zone.

From the calcareous beds of the eastern portion of the area the following fossils have been identified by Ulrich:

Orbiculoidea sp. undet.	Leptocœlia flabellites.
Rhipidomella musculosa.	Meristella lata.
Hipparionyx proximus?	Camarotœchia barrandei.
Stropheodonta lincklaeni.	Rensselaeria ovoides.
Stropheodonta magnifica.	Megalanteris ovalis?
Chonetes cf. cumplanata.	Megambonia bellistriata.
Spirifer arenosus.	Avicula textilis var. arenaria.
Spirifer cumberlandiæ.	Platyceras gebhardti.
Spirifer hartleyi.	Platyostoma ventricosum.
Spirifer murchisoni (arrectus).	Tentaculites cf. elongatus.
Spirifer tribulis.	Bryozoa (several unpublished species).
Anoplia nucleata.	

In addition to these fossils, many of which occur also in the purer sandstones of the western area, well-preserved crinoids have been obtained by members of the Maryland Geological Survey from the sand quarries near Hancock.

[a] Prosser, C. S., Jour. Geology, vol. 9, 1901, p. 416.
[b] Maryland Geol. Survey, vol. 6, 1906, pp. 133–134.

[a] Schuchert, Charles, Lower Devonic and Ontaric formations of Maryland: Proc. U. S. Nat. Mus., vol. 26, 1903, pp. 413–424.

The fossils listed above are all characteristic of the upper Oriskany of New York. Since they occur directly overlying the Helderberg limestone, which contains undoubted New Scotland and Becraft faunas, the lower Oriskany is absent in the eastern part of the area. Unconformity and overlap are further indicated by the fact that the representative of the upper Oriskany is much thinner in the extreme eastern portion of the area than it is in the west. The topmost conglomeratic bed is present throughout the areas, however, although its character changes from place to place.

The Oriskany was called the Monterey sandstone in the earlier reports of the United States Geological Survey and of the Maryland Geological Survey, and has long been known to extend southward into Virginia and northward across Pennsylvania into New York, with very similar characters and faunas.

MIDDLE AND UPPER DEVONIAN.

By Charles K. Swartz.

ROMNEY SHALE.

General features.

Character and thickness.—The Romney shale directly overlies the Oriskany sandstone throughout the area, save where the original sequence is disturbed by faulting. It consists chiefly of shale but contains several heavy beds of sandstone. The shale is dark or nearly black when freshly exposed. On weathering the larger part of the shale of the upper beds becomes yellowish green with numerous reddish stains. Massive beds of sandstone occur in the upper part of the formation. This formation derives its name from typical exposures of its strata at Romney, W. Va.

The strata of the formation are well exposed in the cuts of the Western Maryland Railway on the north side of Potomac River opposite Great Cacapon, W. Va., where the following section was measured by Charles S. Prosser:[a]

Section of Romney shale on Western Maryland Railway near Tonoloway station, Md., opposite Great Cacapon, W. Va.

	Feet.
Jennings formation: Thin greenish shales alternating with thin-bedded sandstones.	
Romney shale:	
Hamilton arenaceous shale member:	
Massive grayish to slightly greenish-gray sandstone, breaking into large irregular blocks; fossils rare; upper sandstone zone	59
Bluish-gray arenaceous shale, with a few intercalated thin sandstones. The shale breaks into irregular pieces and is very fossiliferous, containing *Spirifer mucronatus, Tropidoleptus carinatus, Chonetes mucronatus, Chonetes coronatus, Chonetes setiger, Prothyris lanceolata, Paracyclas lirata*, etc.	505
Bluish, not very thick bedded sandstone and interbedded shale, constituting lower sandstone zone	57
Bluish shale and some thin-bedded sandstone, exposed west of Long Hollow Run	225
Thin bluish, somewhat irregular arenaceous shale extending west to Long Hollow Run. The greater part of this zone is covered	479
Thickness of Hamilton member	1325
Marcellus shale member:	
Thin-bedded bluish black to black fissile shale containing *Leiorhynchus limitare*. The shale is greatly contorted and crushed, rendering it difficult to measure its thickness accurately. About	170
Onondaga shale member:	
Concealed, approximately	100
Interbedded greenish drab and black blocky shale in which Kindle found *Strophalosia truncata, Rhipidomella vanuxemi, Ambocœlia umbonata, Nucleospira concinna, Dalmanella lenticularis, Anoplea* cf. *nucleata, Leptænisca* n. sp., *Styliola fissurella, Phacops cristata*, etc.	60
Thickness of Onondaga member	160
Total thickness of Romney shale	1655
Oriskany-Romney contact nearly in rear of lock keeper's house.	

The thickness of the Romney varies from 1500 to 1655 feet.

Distribution.—The outcrops of the Romney shale adjoin those of the Oriskany throughout the district wherever the latter formation is exposed. The Romney forms the axis of a small anticline on the west side of the Pawpaw quadrangle. It extends in a remarkably straight band along the west side of Tonoloway Ridge and in a wider, less regular band on the east side of Warm Spring and Cove ridges, and forms a V-shaped area at the southern end of Keefer Mountain. It is exposed on the east side of the Meadow Branch syncline and along the west side of North Mountain, the two exposures merging to form a broad area over 5 miles wide at Potomac River.

Subdivisions.—The Romney shale is subdivided into three members—the Onondaga, the Marcellus, and the Hamilton. Though these members can be recognized in individual sections, the Romney is mapped as one formation because of the general difficulty of separating them in the field.

Onondaga shale member.

Character and thickness.—The Onondaga member forms the base of the Romney throughout the district. It consists of thick-bedded dark shales, alternating with some thin-bedded fissile black shales. On weathering the coarser shale breaks into irregularly shaped fragments and usually becomes yellowish or greenish, resembling some of the beds of the Hamilton member. The fissile black shale on weathering breaks into thin, fragile plates, the edges of which become whitish, or the plates may become ashen gray throughout. Several beds of black argillaceous limestones are usually present, occurring 100 to 150 feet above the base of the member. These limestones are well shown east of the iron bridge over Licking Creek, near Warren Point, Pa.

A coarse conglomerate is found at the base of the Romney in some places. It is especially well developed in the vicinity of Elbow Ridge, where it is about 6 inches thick and contains quartzitic pebbles. A few pebbles are also found in the lower 2 feet of the shale overlying the Oriskany.

The Onondaga may be separated from the Oriskany by a minor erosional unconformity, suggested by the irregular surface of the Oriskany, which appears to be eroded at many localities; by the sharpness of the lithologic break between the Oriskany and Onondaga, there being no beds of passage; and by the conglomerate locally developed at the base of the Romney. The erosion of the Oriskany, however, does not appear to have been great, and there is no observable unconformity of dip.

It is difficult to determine the thickness of the Onondaga with accuracy, owing to the facts that the beds are usually much folded and are locally concealed, in part, by wash from the Oriskany, and that their upper limit is not sharply defined. The thickness of this member is approximately 100 to 200 feet.

Surface form.—The Onondaga and Marcellus shale members outcrop between the Oriskany sandstone and the heavy lower sandstone of the Hamilton. A valley, therefore, is usually developed on them between the ridges of sandstone. In places the base of the Onondaga lies high on the flanks of the Oriskany ridges.

Correlation.—This member is highly fossiliferous in many places. Collections made and determined by E. M. Kindle, near Berkeley Springs, W. Va., and at Tonoloway station, Md., opposite Great Cacapon, W. Va., contained the following species:

Craniella hamiltoniæ.	Nucula cf. corbuliformis.
Rhipidomella vanuxemi.	Nucleospira concinna.
Dalmanella lenticularis.	Styliola fissurella.
Leptænisca n. sp.	Phacops cristata.
Pholidostrophia n. sp.	Bollia ungula.
Leptostrophia perplana.	Bollia obesa.
Anoplia nucleolata.	Craterellina n. sp.
Strophalosia truncata.	Polygnathus sp.
Ambocœlia umbonata.	

Neighboring areas have yielded many additional species, including *Anoplotheca acutiplicata*, which is restricted to the Onondaga in New York, but occurs also in the Hamilton of Maryland; many trilobites found elsewhere only in the Onondaga; and *Agoniatites expansus*, a characteristic species of the Marcellus of New York.

These strata were formerly considered a part of the overlying Marcellus and hence of Marcellus age. The fauna contained in them in Maryland and adjacent parts of West Virginia is not very decisive for the determination of their age. A few of the species are restricted in New York to the Onondaga and some to the Marcellus, but many range into the Hamilton of that State. Several ostracods are related to species occurring elsewhere in the Oriskany.

Kindle has recently studied the fauna of these shales from New York to Tennessee and reports that most of the species found in it, including many trilobites, have been observed elsewhere only in the Onondaga. For this reason, together with the lithologic resemblance, he correlates this member with the Onondaga of New York. The presence in it, however, of a considerable number of species characteristic of the Marcellus or Hamilton in New York leads the writer to consider this fauna of somewhat later age than the true Onondaga of New York.

Marcellus shale member.

Character and thickness.—The Marcellus member consists of dark fissile shale interbedded with some shale of lighter color which breaks into many-sided fragments. The dark shale is black where freshly exposed and is very fissile. On weathering it breaks into thin, flat fragments, the edges of which may become lighter colored or the entire flake may become ashen gray throughout. The lighter-colored shale is more blocky than the black shale and resembles that of the Onondaga member. Thin beds of impure argillaceous limestone develop in it locally, as in the Onondaga. The strata of this member usually resemble those of the Onondaga so closely that it has not proved practicable to separate them in field work. The Marcellus member differs lithologically from the Onondaga chiefly in the smaller proportion of thicker-bedded shale and the greater development of fissile black shale.

The Marcellus grades into the overlying Hamilton member by beds of passage, so that it has not been possible to fix a precise upper limit to it on lithologic grounds.

Certain beds of this member are somewhat carbonaceous and hence have often been regarded as coal-bearing and have been prospected for coal at a number of points. They contain no coal, however, and are without value in this respect.

It is difficult to determine the thickness of the Marcellus with accuracy, for the reasons given in the discussion of the Onondaga member. Its thickness is approximately 100 to 200 feet.

Correlation.—Fossils are rare in this member, though some beds contain locally considerable numbers. It has yielded a small fauna of which the following are the more prominent species, according to the identifications of C. S. Prosser.

Ambocœlia umbonata.	Spirifer mucronatus.
Camarotœchia prolifica.	Tropidoleptus carinatus.
Chonetes mucronatus.	Nucula corbuliformis.
Chonetes scitulus.	Nuculites triqueter.
Chonetes lepidus.	Styliola fissurella.
Cyrtina hamiltonensis.	Phacops rana.
Leiorhynchus limitare.	

The above fauna shows that this member is to be correlated with the Marcellus shale of New York, which it also closely resembles lithologically.

Hamilton arenaceous shale member.

Character and thickness.—The uppermost member of the Romney consists chiefly of arenaceous shale, which is black when freshly exposed, but contains also two or three thick and some thin beds of sandstone. It may be divided into two parts of nearly equal thickness.

The lower division consists chiefly of dark fissile argillaceous shale, which usually breaks into thin plates, and weathers to a bluish-gray color. Interstratified with this shale are some coarser, more arenaceous beds of shale and beds of sandstone. A thicker sandstone is developed near the center of this division in the vicinity of Hancock and farther east. The lower division is terminated above by a thick sandstone and some interbedded shale, which usually occurs about 500 to 600 feet above the base of the Hamilton. This sandstone is well exposed opposite Great Cacapon, W. Va.

The upper division contains more arenaceous, thicker-bedded shale, much of which shows concentric weathering. The shale usually breaks with a peculiar hackly fracture, yielding pieces of very irregular shape, and ultimately weathers yellowish green. Beds of sandstone are interbedded with it at several horizons. A conglomeratic sandstone occurs about 175 feet below the top of the Hamilton near and east of Hancock. This stratum is thin and scarcely noticeable at Hancock, but is well shown near Millstone and becomes very prominent farther east, where it forms the tops of ridges. It is well developed throughout the southern part of the Hancock quadrangle. The Romney is terminated above by a massive sandstone, which is about 60 feet thick opposite Great Cacapon and 55 feet thick at Hancock. Sandstones also occur at several other horizons in the Hamilton, the proportion of sandstone increasing in general toward the east.

The upper limit of the Romney is well defined by the massive upper sandstone. The upper shale of the Hamilton is also distinguished by its hackly fracture, contrasting sharply in this respect with the smooth fissile shale of the lower beds of the Jennings. In addition it contains an abundant brachiopod fauna which is absent from the lower part of the Jennings.

The thickness of the Hamilton member varies from 1100 to 1325 feet.

Surface form.—The heavier sandstones form a series of knobs and, in places, well-marked ridges, between which valleys develop in the upper and lower shales, producing in favorable places a drainage parallel to the strike of the strata. Coon and Pigskin ridges, bordering the Licking Creek valley, are formed by the upper sandstone and conglomerate, and similar ridges composed of the same beds continue past Holton and Baxter to the southern border of the quadrangle. Conspicuous hills west of North Mountain are also composed of the upper sandstone and conglomerate, which are infolded in a sharp syncline at this point.

Correlation.—The lower shale of the Hamilton member contains few fossils. The upper shale and sandstones are usually fossiliferous, the fauna of the shale being especially profuse. The following species are of common occurrence:

Athyris spiriferoides.	Stropheodonta concava.
Camarotœchia sappho.	Stropheodonta demissa.
Chonetes mucronatus.	Tropidoleptus carinatus.
Chonetes coronatus.	Cypricardella bellistriata.
Chonetes vicinus.	Grammysia bisulcata.
Cyrtina hamiltonensis.	Nucleospira concinna.
Reticularia fimbriata.	Palæoneilo constricta.
Rhipidomella penelope.	Loxonema hamiltoniæ.
Rhipidomella vanuxemi.	Pleurotomaria capillaris.
Spirifer granulosus.	Homalonotus dekayi.
Spirifer sculptilis.	Phacops rana.
Spirifer tullius.	

This member of the Romney is correlated with the Hamilton formation of New York, which it closely resembles faunally, lithologically, and in its stratigraphic position.

[a] Monograph on Devonian of Maryland to be published by Maryland Geological Survey. The lower part of the section is emended by E. M. Kindle.

JENNINGS FORMATION.

General features.

Character and divisions.—The Jennings formation overlies the Romney conformably throughout the area. It consists of interstratified shale and sandstone, shale predominating in the lower part of the formation and sandstone in the upper beds. It derives its name from the typical exposure of these strata at Jennings Run, W. Va. The formation comprises four divisions throughout these quadrangles—the Genesee black shale member, forming the base of the formation; the Parkhead sandstone member; the beds between the Genesee and Parkhead members; and the beds above the Parkhead member. A fifth division, the Jennings–Catskill transition zone, is separately mapped in the western part of the area.

The Genesee black shale member is distinct both lithologically and faunally. The overlying divisions are so closely connected by beds of passage that at many localities they can be separated with precision only on faunal grounds. Each division of the Jennings contains a distinct fauna. The sequence is as follows:

Jennings-Catskill transition zone at the west.
Beds above the Parkhead sandstone member, containing the Chemung fauna.
Parkhead sandstone member, containing the Parkhead fauna.
Beds between the Parkhead and Genesee members, containing the Ithaca and Naples faunas.
Genesee black shale member, containing the Genesee fauna.

Thickness. — The thickness of the Jennings formation, including the Jennings–Catskill transition zone, varies from about 4000 to 4800 feet. One of the best exposures of the lower part of the formation is on the Yellow Springs road, just east of the village of Berkeley Springs, W. Va., where the following section is shown:

Partial section of Jennings formation on the Yellow Springs road, east of Berkeley Springs, W. Va.

	Feet.
Jennings formation:	
Parkhead sandstone member:	
Massive brown conglomeratic sandstone (430 feet southeast of fork of road)	15
Concealed	114
Massive gray sandstone (170 feet southeast of fork of road) containing *Tropidoleptus carinatus* and *Camarotœchia congregata* var	12
Concealed	63.2
Concealed in part, exposing some fissile olive-green shale. (Fork of road to Riderville 2384 feet east of base of section)	127.5
Massive greenish-gray sandstone (2214 feet east of base of section) containing *Camarotœchia congregata* var., *Spirifer mesacostalis*, and *Cyclonema* n. sp.; thickness, approximately	12
Beds between the Parkhead and Genesee members:	
Very red shale having a band of green sandstone 18 inches thick at bottom	30
Fissile olive-green shale	39
Hackly olive-green shale	6
Fissile olive-green shale	30
Red shale	18
Concealed	9
Green sandstone	12
Fissile brown shale	24
Massive brown sandstone	3
Red shale	12
Red shale containing at top (1889 feet east of base of section) *Productella speciosa*, *Schizophoria striatula*, and *Spirifer mucronatus* var. *posterus*	12
Fissile green shale	43.6
Fissile red shale	11
Olive-green rusty shale containing thin beds of green sandstone	69
Olive-green shale of varied physical character	72.9
Hackly green shale and a few thin beds of brown shale containing the following fossils at top (1599 feet east of base of section): *Cyrtina hamiltonensis*, *Leiorhynchus globuliforme*, *Productella speciosa*, *Pugnax pugnus* var. *altus*, and *Spirifer mucronatus* var. *posterus*	69
Brown shale and sandstone	13.5
Hackly green shale containing at top (1482 feet east of base of section) *Leiorhynchus globuliforme*, *Productella speciosa*, *Pugnax pugnus* var. *altus*, *Schizophoria striatula*, and *Spirifer mucronatus* var. *posterus*	6
Hackly green shale containing *Productella speciosa* and *Spirifer mucronatus* var. *posterus*	10.5
Green hackly arenaceous shale, containing *Productella speciosa* at top (1455 feet east of base of section)	6
Green hackly shale and thin beds of fine-grained green sandstone. At top (1445 feet east of base of section) occur *Chonetes* n. sp., *Lingula spatulata*, *Leiorhynchus globuliforme*, *Productella speciosa*, *Spirifer mucronatus* var. *posterus*	47.5
Green shale, very fissile at bottom, becoming gradually more hackly above and containing *Spirifer mucronatus* var. *posterus* at top (1390 feet east of base of section)	185
Green shale of varied character containing *Cladochonus* sp. at top (1120 feet east of base of section)	39
Hackly green shale, one bed chocolate colored, containing the following fossils at top (1065 feet east of base of section): *Atrypa reticularis*, *Schizophoria striatula*	14
Hackly green arenaceous shale	17.5
Hackly green shale containing the following fossils at the top (1020 feet east of base of section): *Cladochonus* sp., *Atrypa reticularis*, *Productella speciosa*, *Reticularia lævis*, *Spirifer mucronatus* var. *posterus*	10.5
Fissile green shale	32
Fissile olive-green shale and thin beds of green sandstone, containing the following fossils at top (960 feet east of base of section): *Atrypa reticularis*, *Lingula* sp., *Leiorhynchus globuliforme*, *Reticularia lævis*, *Spirifer mucronatus* var. *posterus*, *Stropheodonta demissa*	89
Concealed	43
Ravine, 790 feet east of base of section.	
Concealed	48.5
Largely concealed. The bank along the road indicates strata possessing the same general character as the following unit, save that sandstone beds are more numerous	248
Fissile olive-green shale interbedded with thin layers of flaggy sandstone bearing crinoid segments at top	126
Fissile olive-green shale	74.3
Concealed	88.5
Total thickness of Jennings formation exposed	1898
Romney shale:	
Massive sandstone forming top of formation.	

An excellent exposure of the upper part of the Jennings is seen in the cuts of the Western Maryland Railway beginning 2 miles west of Pawpaw, W. Va. The base of this section is at the axis of a minor anticline 900 feet east of the western limit of the Pawpaw quadrangle. The section ends at a ravine, the center of which is 4262 feet west of the initial point. The base of the section is believed to lie 1300 to 1400 feet above the top of the Romney, the Jennings, including the Jennings-Catskill transition zone, being about 4700 to 4800 feet thick at this point.

Partial section of Jennings formation, including the Jennings-Catskill transition zone, on Western Maryland Railway 2 miles west of Pawpaw, W. Va.

	Feet.
Catskill formation:	
Red sandstone.	
Jennings formation:	
Jennings-Catskill transition zone:	
Green shaly sandstone containing at bottom (4116 feet west of base of section) *Camarotœchia eximia* and *Spirifer disjunctus*	42
Red and green shaly sandstone	18
Green and shaly sandstone	13.5
Red sandstone	27
Red and green arenaceous shale, containing at bottom (4020 feet west of base of section) *Camarotœchia eximia*, *Schuchertella chemungensis*, and *Spirifer disjunctus*	14.5
Green sandstone	12
Red sandstone, massive below, shaly above	140
Massive green sandstone	15
Red shaly sandstone	14
Massive green sandstone	52.5
Red arenaceous shale and sandstone	51
Red sandstone	17
Red shale and interbedded red sandstone	172
Thickness of Jennings-Catskill transition zone	583.5
Beds above the Parkhead member:	
Green sandstone, top of which is 3151 feet west of base of section	69.5
Red sandstone and shale	44.5
Green sandstone; at base (2862 feet west of base of section) occurs *Camarotœchia* sp.	57.9
Red sandstone	43.5
Thin-bedded sandstone and red shale	84.2
Green shale; at bottom (2809 feet west of base of section) occurs *Camarotœchia eximia*	14.5
Arenaceous green shale with bands of red shale	92.5
Green arenaceous shale and interbedded brown sandstone	76
Green arenaceous shale	29
Green sandstone	27
Green arenaceous shale	22
Green sandstone	7.6
Green arenaceous shale containing at bottom (2465 feet west of base of section) *Schuchertella chemungensis* and *Spirifer mesastrialis*	51
Concealed	58
Coarse conglomerate—the upper conglomerate	21
Massive sandstone and some interbedded shale	19
Concealed	44.5
Hackly green shale and interbedded sandstone, containing at bottom (2200 feet west of base of section) *Camarotœchia orbicularis* and *Spirifer* (*Delthyris*) *mesacostalis*	74.5
Fine-grained conglomerate	1.4
Hackly green shale	51
Massive brown sandstone	8.5
Hackly green shale	2
Conglomeratic sandstone	2.8
Massive sandstone and shale	8
Hackly green shale	46
Fissile green shale	64
Coarse conglomerate	1
Hackly green shale	61.4
Concealed	354.4
Olive-green fissile shale	81
Hackly green shale and interbedded sandstones	28.8
Coarse conglomerate—the lower conglomerate	.8
Green sandstone with shale partings	28.8
Hackly green shale	11.1
Massive green sandstone	13.9
Green hackly shale	27
Concealed	88.5
Green fissile shale	87.7
Green hackly shale	24.5
Green fissile shale	36.3
Fissile and hackly green shale	24.4
Brown fissile shale	18.6
Green fissile shale	32.5
Green hackly shale and interbedded sandstone	15.8
Green fissile shale	42
Green hackly shale containing at top (1000 feet west of base of section) *Spirifer disjunctus* and *Spirifer mesastrialis*	45.7
Brown sandstone	7.4
Green hackly shale and bands of sandstone containing at base (918 feet west of base of section) *Spirifer disjunctus*, *Cyclonema* n. sp., and *Loxonema styliolum*	22.5
Parkhead sandstone member:	
Green shale	81
Concealed	71
Green shale and flaggy sandstone	94.8
Hackly green shale and interbedded sandstone	73
Shaly sandstone containing at base (556 feet west of base of section) *Atrypa reticularis*, *Camarotœchia congregata* var., *Productella lachrymosa*, *Spirifer marcyi* var., *Spirifer* (*Delthyris*) *mesacostalis*, *Tropidoleptus carinatus*, and *Coleolus tenuicinctus*	8.9
Green shale	25
Massive sandstone (520 feet west of base of section) containing *Schizodus* n. sp., *Bellerophon mæra*, and *Platyceras* n. sp.	6
Green shale and shaly sandstone	19
Massive bluish green sandstone	8.7
Green shale and concretionary sandstones	14
Green shale and thin sandstones	109
Hackly green shale; at top (348 feet west of base of section) occur *Camarotœchia congregata* var. and *Spirifer mesacostalis*	12.3
Massive brown sandstone (327 feet west of base of section), containing *Camarotœchia congregata* var., *Camarotœchia eximia*, *Coleolus tenuicinctus*, *Bellerophon* n. sp., *Cyclonema* n. sp., *Murchisonia* n. sp., and *Murchisonia* sp.	6.8
Fissile green shale	54
Massive brown sandstone	1.8
Green hackly shale	23
Coarse hackly shale; at base (209 feet west of base of section) occur *Camarotœchia congregata* var, *Chonetes* sp., and *Loxonema hamiltoniæ*	28
Beds between Parkhead and Genesee members:	
Fissile green shale; at bottom (100 feet west of base of section) occur *Atrypa spinosa*, *Cyrtina hamiltonensis*, *Leiorhynchus globuliforme*, *Schizophoria striatula*, and *Stropheodonta demissa*	96
Green shale and thin interbedded sandstones. The following species occur in strata just east of axis of anticline: *Cyrtina hamiltonensis*, *Leiorhynchus globuliforme*, *Pugnax pugnus* var. *altus*, *Schizophoria striatula*, and *Spirifer mucronatus* var. *posterus*	88
Total thickness of Jennings formation exposed, exclusive of Jennings–Catskill transition zone	2315.8

Distribution.—This formation occupies a large part of the Pawpaw quadrangle west of Sideling Hill, occurring both west and east of Town Hill. It outcrops in a narrow strip west of Tonoloway Ridge and in a wide belt east of Warm Spring and Cove ridges. It forms a U-shaped area about Keefer Mountain and another narrow belt east of Third Hill Mountain.

Genesee black shale member.

Character and thickness.—The Genesee member consists of black fissile argillaceous shale, characterized by breaking into large flat sheets, which weather into thin, fragile plates. It is carbonaceous and becomes chocolate-brown on prolonged weathering. Many exposures of considerable thickness exhibit a system of well-developed intersecting joints nearly at right angles to the bedding, a feature frequently seen in the Genesee shale of New York.

The base of the Genesee is well defined by the contrast between the massive sandstone forming the top of the Romney and the thin fissile black shale of the Genesee. Its upper limit is not so sharply marked, the shale becoming less carbonaceous toward the top and passing into the overlying olive-green shale containing the Naples fauna.

This member is about 100 feet thick a short distance west of the Pawpaw quadrangle. It is exposed in the Pawpaw quadrangle only upon a small anticline which enters the quadrangle west of Green Ridge, where it is but a few feet thick, its precise thickness not being determinable, but it is too thin to be mapped. It thins and disappears in a short distance eastward.

Correlation.—The Genesee black shale member abounds in individuals of a few species wherever its strata are exposed. The fossils are chiefly minute pelecypods associated with pteropods and goniatites. The following are some of the more common forms observed in the strata of this zone in the adjoining quadrangles, according to the identifications of John M. Clarke:

Buchiola retrostriata.	Styliola fissurella.
Buchiola conversa.	Tornoceras uniangulare.
Buchiola livoniæ.	Probeloceras lutheri.
Pterochænia fragilis.	Bactrites aciculum.
Lunulicardium crenatum.	Orthoceras filosum.

The above-named species are found in the Genesee shale of New York, with which this member is correlated and which it closely resembles in lithologic character and stratigraphic position, as well as in its contained fauna. Its disappearance to the east is a feature observed also in the Genesee of New York.

Beds between the Genesee and Parkhead members.

Character and thickness.—The beds between the Genesee and Parkhead members consist of fissile argillaceous shale alternating with numerous fine-grained flaggy sandstones. The base of the division is formed of olive-green shale which is succeeded by numerous alternating courses of olive-green shale and thin fine-grained flaggy sandstone, with here and there a more massive sandstone. The shale is fissile and breaks into smooth platy fragments, strongly contrasting in this respect with the very irregular fragments of the underlying Romney. On weathering it becomes lighter olive green or yellowish. The sandstone is prevailingly micaceous and fine grained and on weathering usually becomes fissile, breaking into thin flat fragments. Here and there a sandstone is more massive and breaks into larger, irregular fragments. The shale is more arenaceous near the top, where some beds exhibit irregular fracture. Some of the shale and sandstone near the top of these beds have a decided reddish-brown color. In many places the bedding surface of the shale exhibits "dimpling" and indistinct wave markings.

The base of this division is drawn at the top of the Genesee black shale member, which contains a profuse *Buchiola* fauna, or, in the absence of the Genesee, at the top of the upper sandstone of the Romney.

The thickness of the beds between the Genesee and Parkhead members varies from 1200 to 1550 feet, the greater thickness occurring in the eastern sections.

Surface form.—The shale of this division occupies the slopes of the ridges formed by the more resistant sandstone of the Parkhead member.

Correlation.—These beds contain two distinct faunas, the Naples and the Ithaca.

The Naples fauna occupies the lower strata of this division in the east and the entire division in the west. It is represented by few individuals. The following include some of the more common species identified by J. M. Clarke, all of which are also found in the Genesee member:

Buchiola retrostriata.	Tornoceras uniangulare.
Pterochænia fragilis.	Bactrites aciculum.

The fauna is correlated with the Naples fauna which is found in the Portage formation of New York. It resembles that fauna not only in its composition but in the lithologic character of the rocks containing it and in its stratigraphic position. It is also like that fauna in that it extends through a greater vertical range in the western than in the eastern sections.

The Ithaca fauna appears in the sections east of Green Ridge at 500 to 1300 feet above the base of the Jennings, becoming profuse in the upper, somewhat arenaceous strata of this division. The following are the more abundant species:

Spirifer mucronatus var. posterus.	Cyrtina hamiltonensis.
Productella speciosa.	Pugnax pugnus var. altus.
Reticularia lævis.	Stropheodonta demissa.
Leiorhynchus globuliforme.	Atrypa reticularis.
Schizophoria striatula.	Ectenodesma birostratum.
	Cladochonus sp.

The species characteristic of this fauna occur also in the Ithaca fauna of the Portage formation of New York, where they occupy a similar stratigraphic position. This fauna is therefore correlated with the Ithaca fauna of New York. The upper beds containing it are probably younger than the beds containing the Ithaca fauna of central New York and may correspond more closely in age to the *Leiorhynchus globuliforme* zone described by H. S. Williams from eastern New York. This fauna also resembles the Ithaca in extending through a greater thickness of strata on the east and in disappearing on the west. It has not been observed west of Green Ridge.

Parkhead sandstone member.

Character and thickness.—The division just described is succeeded by the Parkhead sandstone member, which receives its name from Parkhead station, Md., on the Western Maryland Railway 7 miles east of Hancock, where this member is well exposed. It consists of shale interbedded with massive sandstone, certain beds of the latter being generally highly fossiliferous. The shale is more arenaceous than the shale of the underlying division and tends to break somewhat more irregularly. It weathers to a yellowish or buff color.

Conglomeratic sandstones occur at three horizons in this member in the eastern part of the area—at its base, near its middle, and at its top. The base of the Parkhead member is formed by sandstone which as a rule, is highly fossiliferous, abounding in *Camarotœchia congregata* var. and containing in many places a profusion of *Tropidoleptus carinatus.* The sandstones, which are not argillaceous as are many in the lower part of the Jennings, break into large irregular pieces. They are commonly bluish black when fresh and buff when weathered, and in places are tinged yellow and red by iron stains. The upper conglomeratic sandstone is very massive near Parkhead, where it is exposed in the cut of the Western Maryland Railway west of the railroad station. The sandstones lose their conglomeratic character farther west.

The base of this member is clearly indicated in most localities by the highly fossiliferous character of the lower sandstone, which is conglomeratic in the eastern part of the area, and by the occurrence, at many places in the Hancock quadrangle, of a bright-red band immediately beneath it. The upper limit of this member is also clearly defined east of Hancock by the upper conglomerate, which has additional stratigraphic value because the lowest occurrence of the Chemung fauna is found about 200 feet above that conglomerate. In the extreme western part of the area, however, it is not marked by any distinct lithologic feature and can be determined only by the change in the character of the contained fossils. At some localities both limits of this member are ill defined, rendering their precise determination uncertain.

The thickness of the Parkhead sandstone member varies from 400 to 800 feet, being greater in the western sections.

Surface form.—The strata of this member usually form a ridge, the middle conglomerate generally forming the crest and the flank of the ridge being occupied by the underlying shale.

Correlation.—The Parkhead sandstone member contains a profusion of fossils, many of which have marked Hamilton affinities, including the following:

Tropidoleptus carinatus.	Coleolus tenuicinctus.
Spirifer (Delthyris) mesacostalis.	Pleurotomaria capillaria.
Spirifer marcyi var.	Diaphorastoma lineatum.
Camarotœchia congregata var.	Many other species of Platyceras, Cyclonema, Bellerophon, etc.
Productella lachrymosa.	
Cyrtina hamiltonensis.	
Cypricardella bellistriata.	

This fauna occupies a stratigraphic position similar to that of the Enfield fauna, described by H. S. Williams, which occurs in the upper part of the Portage formation of New York overlying the Ithaca shale member, and with which it is provisionally correlated. Its Hamilton aspect is marked. Like the Enfield fauna of New York, it occurs in beds older than those containing the Chemung fauna in this section and is therefore classified with the Portage faunas. Because of the prevailingly sandy character of the rocks of this member, which closely resemble and grade into the overlying strata containing the characteristic Chemung fauna, they are placed by many at the base of the Chemung formation, as has been done by Williams in the folio (No. 169) on the Watkins Glen-Catatonk area of New York.

Beds above the Parkhead sandstone member.

Character and thickness.—The division overlying the Parkhead member is so intimately connected with that member by beds of passage as to forbid a lithologic discrimination between them at many localities. It consists of alternating shale, sandstone, and conglomerate, the percentage of sandstone increasing toward the top. The shale is more arenaceous than that of the lower divisions and commonly breaks into irregular pieces, whereas the sandstone is not argillaceous and usually not fissile.

Conglomeratic sandstones appear at several horizons. Two of the beds are more persistent than the others—one 600 to 800 feet and the other 1400 to 1600 feet above the base of the division. Both of these conglomerates contain flattened quartz pebbles, and jasper pebbles are found locally in the upper conglomerate. The lower conglomeratic sandstone is characterized at many places by the presence of *Tropidoleptus carinatus.* This sandstone becomes less distinct west of Green Ridge. The upper conglomeratic sandstone is very massive. It appears to lose its conglomeratic character, becoming a sandstone in the eastern sections. Similarly situated conglomerates occur in Huntingdon County, Pa., where I. C. White has named the lower the Allegrippus and the upper the Lackawaxen conglomerate. The conglomerates of the Pawpaw-Hancock area are probably to be correlated with them. The lower conglomerate is mapped east of Green Ridge and the upper conglomerate is mapped only west of Sideling Hill, so that they appear associated on the map only in the Pawpaw anticline.

The strata overlying the upper conglomerate have in places a rusty-brown color, due to iron stains. Reddish-brown colors appear below the lower conglomerate and become increasingly prevalent in the upper strata, a feature especially marked in the eastern sections.

The base of these beds corresponds very nearly with a paleontologic line determined by the first appearance of the Chemung fauna in the section. East of Hancock this line is about 200 feet above the top of the upper heavy conglomeratic sandstone of the Parkhead sandstone member. It is usually marked by an increased development of sandstones.

The thickness of these beds, including the Jennings-Catskill transition zone, varies from 2000 to 2800 feet.

Surface form.—The strata which contain the Chemung fauna generally form a prominent ridge wherever they are exposed. In the western part of the area the upper conglomerate usually occupies the crest of the ridge, if at a distance from the larger streams, and in many places the lower conglomerate forms a small ridge or crests of spurs on the flank of the larger one. Among the more important ridges so formed are the northern part of Polish Mountain, Ragged Mountain north of the Pennsylvania-Maryland State line, Gabriel Knob, and Green Ridge, although the lower conglomerate is too weak to be traced and is not shown on the map. At other places the lower conglomerate may occupy the crest of the higher ridge.

Correlation.—The strata of this division contain a profuse fauna characterized by the presence of *Spirifer disjunctus,* associated with many other species, the more important of which are the following:

Spirifer disjunctus.	Camarotœchia contracta.
Spirifer (Delthyris) mesacostalis.	Ambocœlia umbonata.
Spirifer mesastrialis.	Chonetes scitulus.
Douvillina cayuta.	Pterinea chemungensis.
Productella lachrymosa.	

This fauna is correlated with the Chemung fauna of New York. It contains *Spirifer disjunctus* and many other species characteristic of the Chemung formation of New York and the strata in which it occurs closely resemble those of the Chemung formation of New York, both lithologically and in their stratigraphic relations.

A notable feature is the recurrence of a fauna of distinctly Hamilton type in the lower conglomerate, 600 to 800 feet above the base of this division, including *Tropidoleptus carinatus, Spirifer marcyi* var., *Camarotœchia congregata* var., *Rhipidomella vanuxemi,* etc. A similar recurrence of the *Tropidoleptus* fauna has been noted by H. S. Williams in the Chemung of southern New York about 600 feet above the base of the formation. In the sections west of Cumberland, in the Frostburg quadrangle, the Chemung fauna appears about 1300 feet above the base of the Jennings. In the Pawpaw and Hancock quadrangles the Chemung fauna has not been observed lower than 1700 feet above the base of the Jennings and in some sections not lower than 2100 feet. It is not possible to affirm whether the Chemung fauna appears at a lower stratigraphic horizon west of Cumberland, or whether the zone containing the Portage fauna thins in that direction, as the formation can not be traced from one locality to the other. *Spirifer disjunctus* was found at a single locality east of Ragged Mountain, near the western limits of the Pawpaw quadrangle, in strata questionably beneath the top of the Parkhead sandstone member, the relations being obscure. This observation, if confirmed, would suggest that the *Spirifer disjunctus* fauna appeared earlier in the western part of this area than in the eastern part, and would accord with observations in New York that the first appearance of the fauna varies somewhat in stratigraphic position in different parts of the State.

Jennings-Catskill transition zone.

It is difficult to define the upper limit of the Jennings formation. Toward the top of the formation sediments of Jennings type alternate with increasing abundance with those of Catskill type. East of Sideling Hill the top of the Jennings has been placed at the upper limit of the marine brachiopod fauna, which is approximately the lower limit of the more persistent red strata of Catskill type. West of Sideling Hill bright-red beds occur in the upper part of the Jennings formation, their base being about 600 feet above the upper conglomerate. They are succeeded above by green and brown strata containing the Jennings fauna and these are overlain by the more persistent red strata of the Catskill, in which no marine fauna has been observed. The base of the red beds underlying the strata containing the upper Jennings fauna probably represents the horizon selected as the base of the Catskill east of Sideling Hill. The overlying green and brown strata are believed to thin toward the east, and the red beds to thin toward the west. Catskill conditions were thus in full force earlier in the eastern sections than in the western, the lower red Catskill sediments of the east interpenetrating the upper Jennings sediments of the west, which replace them. No fossils have been observed in the red beds of Catskill type at the base of the zone. The overlying sediments of Jennings type contain numerous fossils at some localities, including *Spirifer disjunctus, Schuchertella chemungensis,* and *Camarotœchia eximia,* which are its most abundant species. These species are all characteristic of the Chemung fauna of the Jennings. The interpenetrating Jennings and Catskill sediments are termed the Jennings-Catskill transition zone and are indicated by a separate pattern on the geologic maps. This zone is about 500 feet thick. A section of the zone is given in the preceding discussion of the section of the Jennings formation 2 miles west of Pawpaw.

CATSKILL FORMATION.

Character and thickness.—The Catskill formation, which overlies the Jennings conformably in the Pawpaw-Hancock area, is composed chiefly of red interbedded sandstone and shale. It was called the Hampshire formation in the earlier reports on Maryland and West Virginia published by the United States Geological Survey and the Maryland Geological Survey.

The sandstones of the formation vary from thin to thick bedded and are usually argillaceous. Some of the beds may appear very massive where freshly exposed, but even the most massive strata usually split into thin courses and become thin-bedded or even shaly on continued weathering, owing to their argillaceous character. They pass by insensible gradations into shales. The sandstones are in many places somewhat porous, presenting what has been described as a "worm-eaten" appearance. Many layers contain clay pellets or kaolinized feldspars and are spangled with flakes of mica. Beds of fine arkosic conglomerate with small fragments of green and red jasper were locally observed near the top of the formation, and in the Meadow Branch gorge a thick bed of greenish sandstone is composed of nodules, presenting the appearance of a cobble bed.

The shale is generally more or less arenaceous. Some beds, especially those in the upper part of the formation, contain imperfectly preserved vegetable fragments. Many such strata are charged with brown stains due to the presence of limonite.

The prevailing color of the Catskill is a deep red, due to the presence of finely disseminated ferric oxide. This color is a striking feature both of the rocks and of the soil resulting from their decomposition and is a helpful criterion in mapping. Interbedded with the red strata are others of a peculiar bright-green color that weathers yellow. The green beds are especially prominent in the lower part of the formation and produce a marked color banding in the weathered outcrops. A few beds are brown or yellowish and some even grayish.

The surfaces of many beds are ripple marked and the shales display mud cracks. The sandstones are usually cross bedded and numerous local unconformities are observable. The features of the rocks of this formation show that they were laid down in shallow terrestrial waters and not in the open sea.

The composition of the formation is extremely variable, the strata being subject to rapid change along the strike, sandstone passing into shale and vice versa. It has not proved possible, therefore, to distinguish members that can be traced over considerable areas, and detailed sections have consequently little value.

As described under the previous heading, red sediments characteristic of the Catskill are interbedded with the upper greenish beds of the Jennings which contain a Chemung fauna, and in the western part of the area these red beds appear 500 feet below the mapped base of the Catskill. These 500 feet of strata are mapped as the Jennings-Catskill transition zone. The Catskill is connected with the Pocono group also by beds of passage. Lighter-colored strata become more numerous in the upper part of the Catskill, where beds of a dirty-yellowish tone are interbedded with red strata, rendering it difficult to determine the precise upper limit of the formation. The top of the Catskill has been placed at the base of the first distinctly gray quartzose sandstones of the Pocono, which are also in many places conglomeratic.

The thickness of the Catskill varies from 2000 feet west of Sideling Hill to about 3800 feet in the eastern part of the Hancock quadrangle.

Distribution.—The Catskill occurs in the deeper synclinal areas of both quadrangles. In the Pawpaw quadrangle it outcrops in broad bands on the lower slopes of Town Hill, Sideling Hill, and Spring Gap Mountain. In the Hancock quadrangle it forms the axis of the Timber Ridge syncline extending from Pennsylvania through Maryland into West Virginia. It outcrops in an elliptical area about the axis of the Meadow Branch syncline, occurring west of Sleepy Creek Mountain and east of Short and Third Hill mountains.

Correlation. — The Catskill is nearly barren of fossils. Certain beds contain indeterminable vegetable fragments, and a few poorly preserved fish fragments have also been reported from this area. Although its organic content is very imperfect, its barrenness of fossils, stratigraphic position, and lithologic character are similar to those of the Catskill of New York, with which it is believed to be continuous and with which it is therefore identified. It thins toward the west, where its lower strata are replaced by sediments of Chemung age of which they are probably a contemporaneous terrestrial phase.

CARBONIFEROUS SYSTEM.

Carboniferous rocks are widely distributed over the interior of the North American continent, and are of great thickness in the Appalachian province. They are divisible into three distinct series, a lower (Mississippian), a middle (Pennsylvanian), and an upper (Permian). The Mississippian in the northern Appalachian region is composed in general of sandstone, limestone, and red and green shale, in the order named, comprising respectively the Pocono formation, Mauch Chunk shale and Greenbrier limestone member. The Pennsylvanian, the great coal-bearing series of the northern Appalachians, comprises the Pottsville formation at the base and the Allegheny, Conemaugh, and Monongahela coal-bearing formations above. The Dunkard, the uppermost division of the Carboniferous in this region, is in large part Permian. The Carboniferous deposits of the Pawpaw and Hancock quadrangles are widely separated from the main body of those sediments in western Maryland and Pennsylvania, and the formations here represented have not been positively correlated with those of the broader area. These formations, which are regarded as subdivisions of the Pocono group, comprise the Rockwell formation, Purslane sandstone, Hedges shale, Myers shale, and Pinkerton sandstone.

MISSISSIPPIAN SERIES.

POCONO GROUP.

ROCKWELL FORMATION.

Character and thickness.—The Rockwell formation, the basal Carboniferous deposit, is composed of coarse arkosic sandstone, fine conglomerate, and buff shale, with some dark shale containing, locally, thin coal beds. It merges downward into the soft yellowish-green arkosic sandstone at the top of the Catskill formation, and the first appearance of a distinct quartzose conglomerate or sandstone is taken as the line dividing the two formations. In the Meadow Branch syncline, in the Hancock quadrangle, this formation is not so clearly separable from the Catskill as in the Sideling Hill syncline in the Pawpaw quadrangle, where coal-bearing dark shale containing Carboniferous plant remains occurs near its base. The best exposed section in the area, that at Sideling Hill on the north side of the Potomac River gap, is as follows:

Section of Rockwell formation, Sideling Hill, north bank of Potomac River.

	Feet.
Flaggy cross-bedded sandstone stained reddish, base of Purslane sandstone.	
Poorly exposed buff to brown shale and tough hackly greenish sandstone, with some reddish shale containing small quartz pebbles and grains	400±
Hackly dark shale with thin coal bed at base	10
Hackly dark shale and thin concretionary sandstone	50
Dark shale weathering to splintery fragments	15
Hard shale	10
Thin ripple-marked sandstone and shale	5
Hard dark shale weathering to splintery fragments	6
Granular sandstone	5
Dark-gray crumbly hard shale	5
Hard massive greenish-yellow cross-bedded arkosic sandstone, containing a few quartz pebbles and vitreous quartzose gray sandstone in two ledges	35
Unexposed below.	
	541±

Other partly exposed sections on Sideling Hill both north and south of the river show about 550 feet of soft rocks, chiefly rusty brown shale and sandstone, with some dark shales in the lower part and about 50 feet of harder brown sandstone at the base. The thin coal bed appears only in the best exposures.

In the Meadow Branch syncline the formation is not at all distinct from the Catskill, being composed largely of yellowish sandy shale, arkosic sandstone, and some red shale similar to the uppermost beds of the underlying Catskill. Conglomeratic beds containing scattered white quartz pebbles have been observed in most sections in this syncline about 500 feet below the hard white Purslane sandstone, and since this is approximately the thickness of the formation in the Sideling Hill syncline this conglomerate is regarded as the base of the Carboniferous in this area. A conglomerate 300 feet below the crest of the ridge at Whites Gap on the road over Sleepy Creek Mountain, which is presumably at the base of the Carboniferous, contains small fragments of red jasper and bowlders of quartzitic conglomerate with pebbles of red jasper and vitreous quartz. The following is an approximate section on the Whites Gap road on the west slope of Sleepy Creek Mountain:

Section of Rockwell formation, west slope of Sleepy Creek Mountain.

	Feet.
Massive soft arkosic sandstone at crest of ridge	100±
Poorly exposed buff sandy shale and sandstone, with some red shale and sandstone near the top	370±
Conglomerate containing quartz and a few jasper pebbles, and gray arkose	30
Red shale of Catskill formation.	
	500±

The coal in this formation is very thin, and has been prospected at only a few places in the Pawpaw quadrangle. A tunnel reported to be 300 feet in length was opened on the outcrop on Rockwell Run, but it has now fallen in. The coal seen on the dump had disintegrated to thin shiny slivers, not much more than slickened carbonaceous films or coatings. The dump is mostly composed of dark carbonaceous clay shale with shiny carbonized plant remains. The carbonaceous shale and coal are overlain by a tough micaceous sandstone roof. Along the road on the north side of the Potomac at Sideling Hill gap several small openings have been made in this bed. The most extensive is a tunnel 50 feet or more in length below the road. The coal bed as exposed in this tunnel is about 18 inches thick but is composed mostly of dull black carbonaceous shale with shiny slickened coaly partings.

Distribution and surface form.—The Rockwell formation occurs in the Pawpaw-Hancock area in four bands, the easternmost of which forms the upper outer slopes of the Meadow Branch Mountains south of the Potomac, the second surrounds Sideling Hill across the length of the Pawpaw quadrangle, the third extends into the Pawpaw quadrangle for about a mile in Spring Gap Mountain, and the western composes the main upper portions of Town Hill.

On the upper outer slopes of the mountains surrounding Meadow Branch valley, the Rockwell formation is poorly exposed, being generally covered by débris from the harder Purslane sandstone that caps the ridges. On the west slope of Sleepy Creek Mountain it can be distinguished with difficulty from the underlying Catskill, except in a few places along the roads where the basal conglomerate shows. The harder, more granular character and brown to yellow color of the Rockwell, however, help to distinguish its outcrops from the softer redder rocks below. On the east limb of the syncline the formation is overturned and a ledge of the basal conglomerate dipping 75° E. can be seen at many places. Massive ledges of this bed are exposed in Cherry Run at the east base of Hedges Mountain, where the road branches off up Short Mountain. On Meadow Branch just below the Devils Nose the formation appears in fresh exposure as a gray, hard, gritty, cross-bedded, arkosic sandstone that resembles the upper part of the Catskill.

On the slopes of Sideling Hill the Rockwell formation is in general poorly exposed. Fair exposures appear, however, in the Potomac River and Rockwell Run gaps. The basal sandstone comes down to the railroad tracks on both sides of the Potomac, but the syncline is apparently not quite deep enough to carry the formation in the river bed. North of the river the syncline shallows and the capping of Purslane sandstone becomes gradually thinner until, at a point a mile beyond the Pennsylvania State line, it entirely disappears, having been removed by erosion. Beyond this point the crest of the ridge is composed of the Rockwell formation. The carbonaceous shales are not always visible on the roads across the mountain, but the harder beds at the base of the formation usually define the lower limits clearly.

On Town Hill the Purslane sandstone caps only the higher knobs south of the Potomac. Elsewhere the top of the mountain is composed of the Rockwell formation, and fragments of its harder beds of platy reddish-stained sandstone strew the crest and upper slopes. The carbonaceous shales above the harder basal sandstones are exposed at several places on the mountain slope, but the formation has been entirely removed by erosion where the syncline crosses the valleys of Fifteenmile and Sideling Hill creeks.

Correlation.—Fossil plants have been obtained from the Rockwell formation in this area only at the coal prospect on Rockwell Run. Careful search in the coaly shale from the openings on the north side of the Potomac failed to reveal any fossils. The carbonaceous black shales on the tunnel dump in Rockwell Run afforded the following meager flora, identified by David White:

Eskdalia.
Lepidodendron n. sp.
Megaspores.

These plants are referred by White to the Pocono group of the Carboniferous. As the formation is only a small part of the Pocono and has not elsewhere been mapped as a separate formation, the new name of Rockwell is given to it from typical exposures of the formation in Rockwell Run in the Pawpaw quadrangle.

PURSLANE SANDSTONE.

Character and thickness.—The Purslane sandstone is the ridge-making rock of the Meadow Branch Mountains, Sideling Hill, Spring Gap Mountain, and the higher parts of Town Hill. It is composed largely of heavy-bedded coarse white sandstone with bands of quartz conglomerate and some soft beds containing locally thin coal seams and a little red shale between the harder sandstones.

Throughout the Meadow Branch Mountains the formation consists of an upper and lower hard white granular sandstone, usually containing milk-white quartz pebbles, with a variable amount of shaly or soft material between. The hard sandstone makes the inner dip slope of Sleepy Creek Mountain, and the section there is consequently poorly exposed for measurement. On Short Mountain, the southern part of Third Hill Mountain, and the minor ridges at the east foot of the northern part of Third Hill Mountain the two sandstone beds make prominent ledges. Some dark shales are interbedded in the softer strata between the hard ledges, in which coal prospects have been opened at several points.

The formation makes picturesque cliffs where its gently dipping strata are cut through by Meadow Branch at the north end of the Meadow Branch syncline. (See Pl. VI.) The section at this point, called the Devils Nose, is as follows:

Section of Purslâne sandstone at Devils Nose, W. Va.

	Feet.
Coarse hard white quartzose sandstone, cross-bedded above	60
Very massive hard grayish sandstone	40
Softer thin-bedded cross-bedded sandstone with some sandy shale, in part covered	140
Coarse hard gray micaceous sandstone with some dark layers and quartz pebbles	40
White sandstone and quartz conglomerate	30
Bluish gray gritty cross-bedded sandstone, probably Rockwell formation.	
	310

In the Devils Nose section it is seen that the softer strata in the middle of the formation are largely cross-bedded sandstones. The dark shales and thin coals seen elsewhere in the basin probably occur at this horizon and are concealed by wash.

In the Pawpaw quadrangle the resistant character of the formation is exhibited in the rocky outcrops forming the crest of Sideling Hill, especially that portion south of the river.

The sandstone is in three distinct hard ledges with softer beds between, the whole aggregating about 130 feet in thickness. The harder sandstones generally contain scattered quartz pebbles and one or more of the layers is usually strongly conglomeratic. In places the lower ledge is the most resistant and forms massive outcrops; elsewhere the upper or middle ledge is the most prominent, the nature of the exposure and the effect of weathering determining in large part the particular bed.

On the Little Orleans road crossing Sideling Hill north of Rockwell Run the following section of the Purslane sandstone is exposed:

Section of Purslane sandstone on Sideling Hill north of Rockwell Run.

	Feet.
Hard red shale with some iron ore above; black fissile shale with thin prospected coal seam below	50±
Thin-bedded white sandstone	20
Covered	30
Thin-bedded hard white sandstone	10
Covered	40
Massive white conglomeratic sandstone, thin-bedded and stained reddish at the top	30
	180±

Nowhere else in Sideling Hill were the red strata above the sandstone seen. They resemble and suggest the red shale of the Myers formation but are thought not to belong to that formation, as this would indicate a marked thinning of both the Purslane sandstone and the Hedges shale. On the hill slope above the Chesapeake & Ohio Canal on the north bank of the Potomac three ledges of sandstone and a prospected coal seam have the following approximate section:

Partial section of Purslane sandstone on Sideling Hill, above Chesapeake & Ohio Canal.

	Feet.
Black shale and thin coal, with tough sandy underclay containing Stigmariæ at base	4+
Thin-bedded, cross-bedded sandstone, weathering with reddish stain	40
Massive coarse white sandstone with quartz pebbles	30
Covered	50
White cross-bedded sandstone, tarnished red on weathered surfaces	20
	144+

Where the National Pike crosses the mountain, 4 miles farther north, the following section showing details of the softer layers was obtained:

Partial section of Purslane sandstone on the National Pike, crossing Sideling Hill.

	Feet.
Thick-bedded white sandstone	20±
Thin-bedded hard sandstone	10
Covered	8
Black carbonaceous shale containing plant remains	2
Gray shale containing plant remains	4
Thin sandstone containing carbonaceous matter	8
Massive hard sandstone containing quartz pebbles	20
Gray shaly sandstone, weathering rusty, and rusty shale containing calcareous concretions and quartz pebbles	40±
Hard gray sandstone with quartz pebbles	20
	132±

Distribution and surface form.—The Purslane sandstone caps the mountains of the four main synclines in the area, Meadow Branch, Sideling Hill, Spring Gap Mountain, and Town Hill. The crest and east slope of Sleepy Creek Mountain are composed of ledges and fragments of the massive white sandstone beds of this formation which constitute the west limb of the Meadow Branch syncline. At the north end of the plunging trough the upper surface of the hard strata makes an inclined shelf called the Devils Nose that descends to the valley bottom and forms picturesque cliffs where Meadow Branch cuts into it. These strata rise east of the stream in a less regular shelf to the crest of Short Mountain, where they outcrop in a narrow band of vertical or steeply overturned ledges. South of Short Mountain, where the Purslane sandstone is strongly overturned, it forms only low discontinuous ridges at the foot of Third Hill Mountain, but south of Pinkerton Knob it rises to the crest of the mountain in a closed syncline and covers its broad top in a gentle anticline to the southern border of the quadrangle, with the exception of an area of included overlying shale.

The sandstone caps Sideling Hill from the river north beyond the Pennsylvania State line and exhibits in places the coal-bearing dark shales that have been prospected on the mountain slope above the Potomac. South of the river the syncline deepens and the formation widens to a broad trough, its harder beds forming separate ridges that develop south into Purslane Mountain on the west and Sideling Hill on the east. The syncline has minor folds that give the formation a wide outcrop and produce the detached areas on the sides of Rockwell Run.

On Sideling Hill east of the mouth of Rockwell Run red shales overlying the sandstones and thin coal are included in the closely compressed syncline, but these strata were not seen elsewhere in the area, though they may be present in the wide trough to the south. In the upper part of Rockwell Hollow the slopes on both sides are the dip slopes of the hard Purslane sandstone, the slope on the east side being more abrupt because the dip is steeper. On the broader part of Purslane Mountain the sandstone arches over in a minor anticlinal fold and caps the mountain nearly to the south border of the quadrangle. The twofold character of the syncline is shown by the occurrence of the formation in Stinebaugh Point and Piney Point.

A small area of the formation extends into the quadrangle on Spring Gap Mountain, and four small areas cap the higher peaks of Town Hill. Doubtless the other summits of Town Hill were covered by a capping of Purslane sandstone which has only recently been removed by erosion.

Correlation.—Few fossils have been obtained from the Purslane formation in the area. Casts of *Lepidodendron* trunks are found in the sandstones and a few plant remains have been obtained from the carbonaceous layers near the top, but none could be specifically determined. The specimens of *Lepidodendron* are of Mississippian type and the formation is considered to be part of the Pocono group. The name Purslane applied to it is from Purslane Mountain in the Pawpaw quadrangle, which is formed of the sandstone.

HEDGES SHALE.

Character and thickness.—The Hedges shale is a dark coal-bearing shale that overlies the Purslane sandstone in the Meadow Branch syncline. This shale and the succeeding Carboniferous formations are absent in the Pawpaw quadrangle. Because of its soft and unresistant character it is seldom exposed and is usually deeply covered by the talus from the adjacent sandstone. The best estimate of its thickness is obtained from a section south of Devils Nose, where the shale lies nearly flat in the bottom of the syncline. Dark shale with several coal seams and a few thin sandstone beds are exposed for 170 feet above the top of the Purslane sandstone, and this figure represents the approximate thickness of the Hedges shale. There are at least three horizons of coal, the lower one a few feet above the base, the second about 100 feet higher, and the third near the top. Some of the coal beds exposed in prospects have considerable thickness, one opening showing a width of 9 feet. This exceptional thickness was due to repetition of the bed by folding and crumpling, the coal bed being crushed to small fragments and pieces of the coal and interbedded shale being intimately mixed and confused. The following is a partial section of the coal-bearing shales exposed on the road to Myers along the east side of Third Hill Mountain, near the south border of the quadrangle:

Partial section of Hedges shale on Third Hill Mountain east of Myers.

	Feet.
Black shale and thin coal seam	10±
Massive granular thin-bedded white sandstone	15
Covered	40±
Thin-bedded hard sandstone	1
Carbonaceous shale and thin sandstones with coal streak and plant remains	15
Covered	10±
Gray and black shale and thin sandstones	1
Covered	10±
Thin slabby sandstone	2
Dark shale and coal streak	2

Distribution and surface form.—The Hedges shale occurs only in the Meadow Branch syncline in the Hancock quadrangle. Its gently eastward dipping strata occupy a relatively wide strip of lowland bordering Meadow Branch and the low foothills of Sleepy Creek Mountain. Outcrops of the shale are seen only at a few places where the coals have been prospected. Toward the north end of the basin, where the valley is constricted, the slopes steeper, and the outcrop narrower, erosion is more active and the shale is better exposed. Small prospects are numerous around the north end of the syncline, and some extend into the roadway so far as to make travel with a vehicle difficult. The entire width of the formation has been thoroughly and systematically prospected on the upper west slope of Short Mountain, where it stands vertically. The steeply overturned shale forms a narrow belt along the low foothills from this point south to the slope of Pinkerton Knob, where it ascends to the upper western side of Third Hill Mountain and continues to the border of the quadrangle. It is also included in a shallow syncline on the east side of Third Hill Mountain at the southern border.

Correlation.—The Hedges shale is the most fossiliferous of the Carboniferous strata in the Pawpaw and Hancock quadrangles. David White, in reporting on the fossil plants of the Meadow Branch coal field, makes the following statement:

> The collections in this region typically illustrate the paucity of species characteristic of the Pocono along the eastern border of the basin, though plant fragments, many in fine condition, are very abundant, as is natural, in the roof shales over the coals of that age. I have seen but a few species, which appear to have almost exclusively occupied the ground, doubtless furnishing the land-plant material for the composition of the coal throughout the coal-bearing series, extending from near Pottsville, in eastern Pennsylvania, to the vicinity of Wytheville, in southwestern Virginia.

The following plants collected from the Hedges shale in the Meadow Branch syncline were identified by White:

Sphenopteris vespertina.	Lepidocystis siliqua.
Triphyllopteris lescuriana.	Triletes sp.
Triphyllopteris virginiana.	Carpolithes sp.
Protolepidodendron scobiniforme.	Eskdalia sp.

These are regarded by White as of Pocono age, and the formation is placed in the Pocono group. The formation is named from Hedges Mountain, in the Hancock quadrangle, on the slopes of which the coals have been prospected.

MYERS SHALE.

Character and thickness.—The distinctive feature of the Myers shale is its bright red colored shales, by which it may generally be readily identified. The basal 60 feet, composed of cross-bedded reddish-gray gritty arkosic sandstone, weathering to shaly fragments, outcrops on the lower slope of Third Hill Mountain along the Meadow Branch from Little Mountain north. Its upper layer is a massive harder bed of the same character. Above this are bright-red crumbly shales and impure sandstone, succeeded by yellow shale with brown argillaceous sandstone and more hard red shale. At the top thin reddish-stained sandstone merges into the overlying hard white sandstone of the Pinkerton. The thickness of the formation has been determined to be about 800 feet, although one measurement was over 900 feet.

Distribution and surface form.—The Myers shale occurs only in the Meadow Branch syncline in the Pawpaw-Hancock area. Hard ferruginous red shales above the upper sandstones on Sideling Hill resemble very closely those of the Myers, but from their stratigraphic relations they are regarded as part of the Purslane sandstone. The Myers shale occupies most of the valley of Meadow Branch east of the stream from the southern border of the quadrangle nearly to Devils Nose. The red shales are conspicuous in the lowlands north from the Myers place, and the thick sandstones at the base make low ridges near the stream. Farther north in the steeper part of the valley the sandstones form prominent cliffs on the east bank of the stream with the red shale above in the steep slopes of the mountain. The stream has cut a narrow gorge in these sandstones at Little Mountain, which is left as a remnant on the west side of the stream. Near Devils Nose the syncline rises rapidly and the formation swings around the end of Hedges Mountain to the east side of the fold, where the strata are more steeply inclined and even overturned in places. The band of the formation on the east slope of Third Hill Mountain is much narrower and largely concealed by the débris from the overlying sandstone. South of Pinkerton Knob the formation lies on the west slope of Third Hill Mountain.

Correlation.—The red color and general character of the shale of the Myers formation, together with its stratigraphic position, suggest its correlation with the Mauch Chunk shale of the Mississippian. No fossils have been obtained from this formation. Scant collections of fossil plants from coal beds in the overlying Pinkerton sandstone have been pronounced by David White to be older Mississippian, and the Myers shale is therefore also regarded as of Pocono age. The relation of the Myers shale to the Mississippian formations of the western Pennsylvania coal field will be discussed under the heading "Correlation of the Carboniferous formations." The formation is named from the Myers place in the Meadow Branch valley, where the red shales and flaggy sandstones of the formation are well exposed.

PINKERTON SANDSTONE.

Character, thickness, and distribution.—Only two comparatively small areas of the Pinkerton sandstone occur within the quadrangles, both being in the Meadow Branch syncline in the Hancock area—one at Pinkerton Knob and the other on the northern part of Third Hill Mountain. At the base are gray platy sandstone and white quartz conglomerate with soft crumbly sandstone above. The upper layers, however, are very massive, cross-bedded coarse white sandstone, with numerous quartz pebbles and conglomerate, about 40 feet thick. A thin coal seam in dark-gray shale overlying the hard sandstone is the highest bed of the formation seen. Its thickness on Pinkerton knob is about 125 feet.

Correlation.—The following plant remains from the coaly shale at the top of the formation were identified by David White:

- Lepidodendron sp.
- Lepidodendron cf. corrugatum (=Protolepidodendron).
- Eskdalia sp.
- Megaspores.
- Triletes, form with very thick glossy exine.

In regard to the age indicated by these specimens, White writes as follows:

> Notwithstanding the considerable body of red shales and sandstones between the coal-bearing division (Hedges shale) and the conglomerates with the thin coal (Pinkerton sandstone) in the upper portion of the syncline, I can find no evidence of post-Mississippian age. On the other hand, the very small amount of fossil material is not only characteristic, so far as known, of the older Mississippian, but it is closely related to the Pocono flora itself. A similar association of the same forms, likewise preserved in coaly shales, is observed in the Allegheny Valley just above the group of sandstones and shales there correlated with the Pocono.

The formation is named Pinkerton from the highest point on Third Hill Mountain in the area, which is composed of this sandstone.

CORRELATION OF THE CARBONIFEROUS FORMATIONS.

As previously stated, the Carboniferous strata in the Pawpaw-Hancock area are widely separated from the main body of Carboniferous of the northern Appalachian coal field. The Meadow Branch syncline is entirely detached and isolated and is probably the southeasternmost occurrence of Carboniferous in the northern Appalachians outside of the anthracite region. A similar isolated Carboniferous area, forming Scrub Ridge and Meadow Ground Mountain about 10 miles north of the Hancock quadrangle, lies in the deeper portion of a parallel syncline, just west of the Meadow Branch trough. The sections of these two isolated remnants of the Carboniferous can not at this time be compared, for a measured section of the Scrub Ridge rocks has not been published.

The next nearest occurrence of Carboniferous strata in Pennsylvania is on Sideling Hill, a northward continuation of the ridge of that name in the Pawpaw quadrangle. A section of the rocks of this mountain, measured in great detail by C. A. Ashburner, of the Pennsylvania Geological Survey, in the tunnel of the East Broad Top Railroad, in southern Huntingdon County, about 28 miles beyond the northern limit of the Pawpaw quadrangle, is condensed from Report F of the Second Geological Survey of Pennsylvania, as follows:

Section of the Pocono group in tunnel of East Broad Top Railroad, Huntingdon County, Pa.

[From detailed section by C. A. Ashburner.]

	Feet.
Upper Gray Sandstone group (massive and flaggy sandstone; 610 feet):	
Hard, coarse, massive, gray to brown sandstone alternating with thin flaggy sandstone and shale. Some red shale and sandstone near top	580
Massive gray sandstone, containing bed of black carbonaceous shale	30
New River Coal series (313 feet):	
Massive gray sandstone and thin-bedded sandstones with numerous thin seams and partings of coal	164
Shaly sandstone and some massive sandstones with many thin coal seams	149
Middle Conglomerate group (380 feet):	
Soft black carbonaceous shale alternating with fine conglomerate	25
Yellowish shale containing thin coal seams	26
Hard massive gray sandstone in part conglomeratic and strongly cross bedded, with thin black carbonaceous shales	156
Soft dark-gray shale, with thin hard sandstone	49
Massive hard gray sandstone and fine conglomerate	38
Fine dark-gray shale and hard gray to black sandstone	26
Thin hard gray sandstones interbedded with gray and black shale	60
Lower Green Sandstone group (830 feet):	
Green and gray shale with thin dark slaty sandstone	77
Hard, coarse, reddish-gray, yellow, and greenish sandstones in part flaggy, interbedded with soft yellow sandy shale	313
Soft greenish flaggy sandstone and hard massive sandstone (partly concealed)	440
	2133

The upper 580 feet and the lower 777 feet of the section do not occur in the tunnel, but were measured in near-by exposures.

Other detailed sections were measured in the Broad Top coal field in Bedford and Fulton counties, Pa., a deepened northward extension of the Town Hill syncline, in which appear not only the Pocono but Mauch Chunk, Pottsville, and succeeding coal-bearing formations. The following section of the Pocono exposed in the Juniata River gap through Allequippa Mountain in the Broad Top field is taken from Report T2, Second Geological Survey of Pennsylvania, by J. J. Stevenson:

Section of the Pocono group in the Juniata River gap in Allequippa Mountain.

[Condensed from report by J. J. Stevenson.]

	Feet.
Gray sandstone with many pebbly layers, flaggy near top and containing little shale, one thin layer of which was carbonaceous	620
Red shale	70
Sandstone	45
Shale with some irregularly bedded sandstone	248
Flaggy, irregularly bedded gray sandstone containing conglomerate layers of red shale balls and brown hematite nodules	125
Sandstone and red shale in alternate beds	257
	1365

I. C. White in Report T3, on Huntingdon County, gives a section measured in Shoups Run gap in Terrace Mountain, a few miles north of the preceding section, from which the following is condensed:

Section of the Pocono group, Shoups Run gap in Terrace Mountain.

[Condensed from report by I. C. White.]

	Feet.
Gray massive coarse sandstone, somewhat pebbly, and with thin dark shales	560
Gray sandy flags, red shale, and greenish sandstone	170
Black shale with few thin flags, fossiliferous	100
Gray sandstone, very massive at the base and some shale in upper part	300
Green sandstone and red shale interbedded [regarded by White as Catskill]	250
Red shales, undoubted Catskill.	
	1380

Another section by I. C. White, made at the Juniata River gap at Riddlesburg, in the same report, is summarized as follows:

Section of the Pocono group, Juniata River gap at Riddlesburg.

[Condensed from report by I. C. White.]

	Feet.
Sandstone, in part massive and pebbly, and shale in alternating beds, with a little red and black shale	609
Dark, very fossiliferous shale	50
Sandstone with some shale	85
Alternating thin sandstone and shale, the latter mostly red	218
Massive gray sandstone	140
Red shale and greenish sandstone [regarded by White as Catskill]	340
Red shales, undoubted Catskill.	
	1442

The Mauch Chunk shale overlies the Pocono in the valley west of Town Hill in Fulton County and surrounds Round Top Mountain in Fulton, Bedford, and Huntingdon counties, and the following section is condensed from the detailed description of the red Mauch Chunk shale and associated limestone by Ashburner in Report F:

Composite section of Mauch Chunk shale and associated limestone in the Broad Top district.

[Condensed from report by C. A. Ashburner.]

	Feet.
Red, gray, and yellow flaggy sandstone and shale	150
Hard, reddish, cross-bedded sandstone, softer red sandstone, and bright-red shale	760
Soft red shale alternating with thin red and gray fossiliferous limestones	49
Massive and thin red and gray sandstone interbedded with red, green, and gray hard shale	141
	1100

In the following table the above sections of the Pocono, arranged geographically from west to east, are compared with the composite section in the Meadow Branch syncline in the Hancock quadrangle.

Summarized sections of the Pocono group.

	Riddlesburg (I. C. White).	Shoups Run (I. C. White).	Juniata River (Stevenson).	Sideling Hill tunnel (Ashburner).	Meadow Branch Mountains (Stose).
Massive and flaggy sandstone and shale, some red	609	730	620	610	825
Dark shale containing thin coal seams in massive and thin-bedded sandstone	50	100	70	313	170
Massive sandstone and conglomerate, generally cross bedded	85	55	45	380	310
Red to green or gray shale and flaggy sandstone	698	495	630	830	541
Total	1442	1380	1365	2133	1846

All the above sections show in general the following fourfold divisions: A lower group of shales and soft sandstones, generally reddish in color where weathered; a middle heavy sandstone and conglomerate, usually cross-bedded; a variable thickness of black shale with thin coal seams and sandstone; and an upper series of shales, usually red, and thick sandstones. The thicknesses in the first three columns of the table correspond rather closely, the total thickness varying from 1365 to 1442. The Sideling Hill tunnel section is much thicker, all the members except the top sharing in the increase.

In the Meadow Branch Mountains section the fourfold division is also strongly marked and corresponds with the formations mapped in the folio with the exception that the uppermost hard sandstones were separated from the softer shaly red strata. The thickness of the middle sandstone agrees closely with that of Sideling Hill tunnel, whereas the coal-bearing shales are thinner and the overlying sandstones and shales thicker. This may be in part accounted for if the cross-bedded sandstones at the base of the Myers shale were included with the coal-bearing strata instead of with the red beds above. The Rockwell formation is much thinner than the lower division in the Sideling Hill section, but corresponds fairly closely with that of the other three sections. The total thickness shows a corresponding diminution from that of the Sideling Hill tunnel.

It is concluded from the above comparison that all the Carboniferous strata now remaining in the Meadow Branch Mountains are Pocono in age, and correspond to the rocks in the Broad Top coal field below the Mauch Chunk. The red shale of the Myers formation has its counterpart in the upper red strata of the first three sections, the tunnel section possibly not exhibiting this color because in the fresh exposures the rock is probably greenish gray. There is furthermore no indication in the Myers of calcareous strata which are so conspicuous in the Mauch Chunk of the Broad Top field.

Ashburner states in Report F that a heavy sandstone (No. 152) in the upper part of his Middle Conglomerate Group, the hardest and most massive of the Pocono, forms the crest of Sideling Hill apparently throughout its whole extent. The sandstone capping Sideling Hill in the Pawpaw quadrangle is a very massive, hard, white conglomeratic sandstone similar to bed No. 152 described by Ashburner, and it is the only rock of this character in this ridge. As this bed has been correlated with reasonable certainty with the heavy sandstones (Purslane) of the Devils Nose in the Meadow Branch Mountains, the above conclusions are further corroborated.

In the western part of the coal field of Pennsylvania the Pocono has a thickness of only 300 to 400 feet. The much greater thickness reported in the Broad Top field threw some doubt on the early measurements in that area, but they have been corroborated by recent investigations. As pointed out by Stevenson in Report T2, the thickening of the Pocono eastward is progressive. From 300 feet in Laurel Ridge, Fayette County (folio 82 of the U. S. Geologic Atlas), the Pocono increases to 1030 feet in the southeastern part of Cambria County (folio 133), to 1400 feet in the western side of the Broad Top syncline, and to 2133 feet in Sideling Hill, Pa. If these measurements are correct, it apparently reaches its culmination in Sideling Hill and decreases eastward to 1850 feet in the Meadow Branch Mountains. Martin[a] reports the Pocono as only 450 feet thick in Garrett County, western Maryland, but he states that accurate measurement could not be made. Inasmuch as Garrett County is about on strike with the Cambria County rocks, where the thickness is 1030 feet, and as Stevenson in Report T2 gives 930 feet as the thickness on Wills Creek in Bedford County, it is probable that the increase in thickness of the Pocono is not so rapid in a southeasterly direction as in a northeasterly direction.

TERTIARY AND QUATERNARY DEPOSITS.

The Tertiary and Quaternary deposits of this region comprise surficial gravels and sands resting unconformably upon the older hard rocks. They were accumulated in stream channels and are in general unassorted mixtures of coarse gravel and sand. The older of these deposits cap terraces along the present drainage courses; the more recent compose the alluvium in the flood plains of the present streams.

TERRACE GRAVEL.

Character and thickness.—The unconsolidated terrace gravels in the Pawpaw and Hancock quadrangles are remnants of deposits laid down by Potomac River and its larger tributaries when their channels were higher than the present stream bottoms and the surface of the land was nearer sea level than it is now. After the gravel was deposited the land rose and the streams became more active. Their valleys were cut deeper and patches of gravel were left on elevated benches. The gravel in the tributary streams is of local origin, having been derived from the rocks of the adjacent ridges. That along the Potomac, however, comprises not only local débris but hard rocks transported from the Alleghenies of western Maryland and West Virginia. It is in general coarser than the gravel on the smaller streams, large bowlders 5 or more feet across being not uncommon on the lower terraces.

The pebbles and bowlders of the gravel along the Potomac consist almost entirely of quartzite, hard sandstone, and quartz. One of the best exposures of this material is in a recent cutting on the Baltimore pike, 1 mile east of Great Tonoloway Creek. The material is coarse cobble, fine gravel, and sand, rudely stratified and containing scattered large bowlders. On the surface of one large bowlder was a cast of a long, slender *Scolithus* tube resembling the form found commonly in the Cambrian rocks of South Mountain, but since Cambrian rocks do not outcrop west of this area the sandstone bowlder probably came from a higher horizon. Much of the coarser material was derived apparently from the Tuscarora sandstone, the hardest and most resistant rock west of South Mountain, but the Clinton and the Pocono also furnished much material. Red quartzite from the Clinton, which is plentiful in the local gravels in the adjacent Mercersburg quadrangle and occurs sparingly along Licking Creek in the Hancock quadrangle, was not seen along the Potomac, where the sandstone cobble is almost entirely white or cream colored.

Along the Potomac the gravel ranges in thickness from a thin mantle to 10 feet or more. The thicker deposits are usually coarse at the bottom and grade into fine sand and silt at the surface. At some points, as east of Ernstville, the whole slope up to 100 feet above the river is covered with gravel, but it is seen to occupy terraced steps at several levels, and therefore forms only a thin veneer over the whole surface.

Distribution.—The terrace gravels are chiefly found along the present and former courses of the Potomac. They occur at various heights above the river level from Keyser, W. Va., to Harpers Ferry and beyond, down the river to its mouth. The gravels occupy benches at various altitudes from 20 to 300 feet above mean water level. These benches are remnants of planes sloping downstream which once formed the channel of the river, and the gravels are remnants of flood-plain deposits preserved at favorable places. The formation and history of these terraces are discussed under the heading "Historical geology." No gravel has been found on the highest (oldest) terrace, the local representative of the Harrisburg peneplain, but it may occur in some undiscovered spots. Where the surface of the deposit consists of sand and soil, it is distinguished with difficulty from disintegrated shale and other soft rocks, and may easily be overlooked. High gravels are especially to be expected on the necks of land between the great bends of

[a] Martin, G. C., Accident-Grantsville folio (No. 160), Geol. Atlas U. S., U. S. Geol. Survey, 1908, p. 4.

the river northeast of Pawpaw, where the river may have abandoned a straighter course for the winding one it now occupies.

The highest gravel observed in the Pawpaw-Hancock area is that mapped at the western margin of the Pawpaw quadrangle on the north side of the Potomac, at 800 feet elevation, 300 feet above the present stream level. The surface is strewn with gravel, cobble, and rounded bowlders, and marks the ancient bed of the river. The hilltops 1½ miles west of Hancock, the highest of which are 300 feet above the Potomac, are also covered with cobble and gravel which were probably deposited by the Potomac when it passed through the Tonoloway Creek gap, as explained under "Historical geology."

A larger number of remnants of gravel are preserved at about 200 feet above the river. Gravel covers a conspicuous terrace at 700 feet elevation across the Potomac from Little Cacapon, a smaller remnant caps a bench just east of Pawpaw, and another the hill above Orleans Crossroads. Several pronounced benches at this altitude on the bends of Sideling Hill Creek, 2 miles above its mouth, are covered with sand and fine gravel, indicating abandoned short cuts or older meanders of the stream. A broad level terrace deeply covered with gravel marks the course of the river opposite Great Cacapon 200 feet above its present level. A gravel-covered hill which rises 200 feet above the river at the mouth of Great Cacapon River was also probably mantled by the gravel at the same time. One of the largest and best preserved gravel terraces is situated west of Cherry Run, 200 feet above the river. It is almost level for nearly a mile. Other small remnants at this level are on the east side of Licking Creek due west of Moore Knob and south of Indian Springs.

Below this 200-foot terrace there are many minor gravel levels, and in some places the gravel strews the slope to the river in successive steps. Only the important occurrences will be mentioned. An old oxbow which existed at a stage a little below the 200-foot height opposite Pawpaw forms the oval valley that leaves the river gorge opposite Little Cacapon in a northwest direction and, passing over a low flat gravel-covered divide at 670 feet elevation, returns along Purslane Run to the Potomac opposite Pawpaw. The abandonment of this oxbow can not be explained by normal cut-off, for the old channel bends are not near enough together to have been cut through. This matter is discussed more fully and the probable explanation of the conditions described under the heading "Historical geology."

An oxbow less than 100 feet above water level, which formerly occupied the embayment in which Pawpaw is situated, and the surface of the narrow neck of land just below Pawpaw are strewn with river gravel. An abandoned cut-off at about the same altitude on the neck of land just south of Little Orleans, where the Western Maryland Railway now goes through, is also gravel covered. Narrow remnants of gravel are known to occur at many places in the large bends of the Potomac between Pawpaw and Little Orleans, and many have doubtless been overlooked on the uncultivated densely wooded slopes of this sparsely inhabited area. They lie on the concave side of the bends, the channels having been gradually shifted in the ever-increasing swing of the stream as it cut away the bank on the convex side. No abandoned cut-offs or oxbows in this portion of the river's course, except those already mentioned, were observed.

Terraces and abandoned oxbows on Fifteenmile and Sideling Hill creeks are recognized by their topographic form rather than by the sediment deposited upon them, because these streams drain areas of soft rocks and the alluvial deposits are largely silts and fine sand, distinguished with difficulty from the shale soils in place. Few terrace deposits, consequently, have been mapped along these streams, and no doubt many more exist than are shown on the geologic map. A wide level tract with a steep circular back wall 2 miles above the mouth of Sideling Hill Creek, which is largely covered with fine gravel and sand, marks a prominent abandoned oxbow.

Great Cacapon River drains the west slope of Cacapon Mountains, whose hard sandstone strata furnish coarser débris than the two streams just mentioned. Gravel-covered terraces and abandoned oxbows are common in the tortuous portion of its course, and the broad slope at its mouth down to the town of Great Cacapon is entirely mantled with gravel. The lower level of this embayment may have been occupied by the Potomac in one of its larger swings. Below this point nearly to Cherry Run the later course of the river has not changed much, and only remnants of the lower flood-plain deposits are preserved. Small areas of higher gravel at a few points, two on the front of the ridges east of Timber Ridge, lie 150 feet above the river.

Although Sleepy Creek drains chiefly areas of soft rocks, it has many readily recognized low alluvial terraces, most of which occupy the inside of the big embayments of the stream. Several of these terraces in the lower reaches of the creek are 100 feet above the stream. Licking Creek, on the other hand, drains several prominent mountain ridges, and its gravel is generally coarse and composed mostly of quartzite and sandstone, some of which is red, derived from the Clinton ferruginous beds. The gravel on the high terrace west of Moore Knob, previously referred to, is of this character, as well as that on numerous lower terraces along the stream. Back Creek, although it traverses only soft rocks in the Hancock quadrangle, drains mountain ridges to the south from which coarse siliceous material is derived, and its terraces and abandoned courses are marked by thick gravel deposits. A high terrace remnant is preserved 1 mile south of Tomahawk at 600 feet, and several others at 500 feet occupy the flat tops between the stream bends east and northeast of Ferrel Ridge.

The gravel along the Potomac from Munson to the east edge of the Hancock quadrangle is of special interest because of its extent and range of altitude. Attention has already been called to the high-level gravels at Cherry Run, Indian Springs, and other places in the vicinity, indicating that the old channel in this part of its course was more meandering than the present one. As the stream cut its channel deeper it occupied successively lower planes, which are preserved on the gravel-covered slope on the Maryland side of the river. This is well shown along the road between Indian Springs and Big Pool, as seen in the section in figure 6.

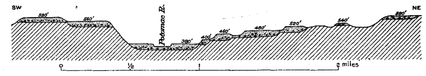

FIGURE 6.—Section across Potomac River near Big Pool, Md., and Cherry Run, W. Va., showing gravel-covered terraces.

Age.—The terrace gravel shown on the areal geology maps, ranging in altitude from 40 to 300 feet above the present river level, was deposited during a prolonged period of continental uplift and erosion. By tracing these deposits down the Potomac, those on the highest benches, ranging in altitude from 800 to 600 feet in the Pawpaw and Hancock quadrangles, were found to correspond with the gravel-covered terrace at 525 feet elevation at Harpers Ferry, on which the Hill Top Hotel is located. Just east of Catoctin Mountain in Maryland and Virginia remnants of gravel on terraces 500 feet in elevation have been regarded as equivalent to the Lafayette formation, which also caps Peach Grove Hill, in Virginia, about 12 miles farther east, at the same elevation. The Lafayette is of late Tertiary age, and some of the highest terrace gravels in the Pawpaw-Hancock area are therefore undoubtedly of the same age. The lower terrace gravels are of Quaternary age, and were deposited while the northern part of the continent was covered by glaciers. Although glacial waters are not known to have flowed into the Potomac, a moist climate undoubtedly prevailed and heavy precipitation caused floods in the streams. The origin and the correlation of these gravel-covered terraces are more fully discussed under the heading "Historical geology."

RECENT ALLUVIUM.

The flood plains of the Potomac and its larger tributaries are covered with gravel and silt carried by the streams in flood season and deposited along their courses. The alluvium deposits are usually composed largely of coarse gravel and cobble, but the surface is generally covered with sand and silt, which forms excellent farm land. In places exposed to swift currents during the flood season, as in the alluvial plain at Pawpaw and in the narrow present channels of streams, the silt is removed and the coarse gravel forms the surface.

Alluvium is mapped on the geologic sheets along most of the course of the Potomac in this area and in the broader-bottomed portions of the larger tributaries. Many flats along the Potomac are not cultivated because they are so frequently inundated, but along the tributaries the best farm lands are found in these alluvial bottoms, a condition especially true of Sleepy Creek, where the flood plain is most widely developed. The channels of most of the smaller streams also have alluvium, but the deposits are too narrow to be shown on the geologic maps.

GEOLOGIC STRUCTURE.

INTRODUCTION.

Structural geology has to do with the deformation of the strata since they were deposited. Sediments when laid down on the sea bottom are essentially horizontal, though they may have a slight inclination near the land, especially if the shores are steep. The rocks as found at the surface in this region are as a rule not horizontal but incline at high angles. When the strata are traced from place to place it is seen that they are bent into folds called anticlines and synclines, whose axes lie in a northeast-southwest direction, and at exceptionally favorable points in stream gorges and railroad cuts a complete rock fold may be exposed to view.

APPALACHIAN PROVINCE.

Throughout the length of the Appalachian province similar structures prevail. It is a region of parallel folds which trend northeast and southwest, in the same direction as the mountain system. Individual folds do not extend the whole length of the province but diminish in magnitude gradually and are replaced by others. Single folds more than 300 miles long are known, but more commonly they are 25 to 50 miles in length. The intensity of the folding increases from west to east throughout the length of the province.

In the Appalachian Plateau the folds are very gentle and symmetrical, with dips generally less than 10°, decreasing toward the west to horizontality. The rocks are unaltered, even the shales being free from cleavage planes, and the coals have attained only the bituminous stage.

In the Appalachian Valley region the folding is intense. The dips are generally 30° or more, and in many areas the rocks are vertical. Most of the folds are unsymmetrical, the northwest side of the anticlines being shorter and steeper than the southeast side, and many are overturned so that the beds on the northwest limb dip to the east but at steeper angles than those on the southeast limb. The crest of such compressed and overturned folds is likely to be broken and the beds on the east to be pushed over those on the west in the form of a thrust fault. The displacement along many of these planes of breakage is very great, being measurable in miles in the southern Appalachians. The folds are likewise of considerable magnitude, reaching 5 miles or more in vertical dimension. The larger folds are not a simple unit but are composed of numerous minor folds, and these in turn have still smaller folds, down to minute wrinkles.

The rocks in the valley have undergone a greater alteration than those of the plateau. The sandstones and limestones are much jointed and hardened, and in places limestone is changed into marble. Toward the eastern margin of the valley cleavage is developed to a moderate degree in the limestones, and along fault zones the rocks are sheared and recrystallized. The shales are more crumpled than the inclosing harder rocks, and cleavage is developed to such a degree that the bedding is largely obliterated. Coal, where it occurs in this division of the province, is in the anthracite or semianthracite stage.

In the Blue Ridge and Piedmont Plateau the compression reached a maximum, and cleavage, schistosity, and recrystallization of the particles of the rocks over broad areas have obliterated all original structures and much of the original texture of the rocks. Shale has been altered to slate or schist, limestone and sandstone to marble and quartzite, and igneous rocks to gneisses and schists.

The folding and faulting observed throughout the Appalachians are the result of horizontal forces acting on the nearly level strata in a direction about at right angles to the axes of the folds. The origin of these forces is not positively known, but it is considered that they were due in part to the shrinking of the interior of the earth and in part to the sinking of ocean basins and corresponding uplift of the continent. Shrinking of the earth and corresponding shortening of its radius would produce in the surficial harder portions tangential stresses that would find relief in folding of the strata. The circumference of the globe would by this process be correspondingly shortened. The sinking of ocean basins would tend to cause deep-seated flowage toward the rising continents and corresponding pressures in the overlying harder rocks against the interior of the continent, which would also result in their folding.

The general overturning of folds toward the northwest, with attendant southeastward-dipping cleavage and schistose planes, and the prevalent northwestward thrust faulting, indicate that the aggressive force throughout the Appalachian province came from the southeast. To be sure, there are in places thrusts and overturned folds in the reverse direction and a few at right angles, which indicate stresses acting locally in these directions; but the prevailing forces came from the southeast. Further evidence of this is afforded by the increasing intensity of folding and alteration of the rocks from west to east, reaching a maximum in the Blue Ridge and Piedmont Plateau.

The Carboniferous and all older rocks throughout the Appalachian province are generally much folded, whereas the Triassic strata east of South Mountain are relatively little disturbed. The intense compression of the rocks and attendant uplift of the sea bottom into permanent land must have taken place in late Carboniferous and early Triassic time. Incipient folding undoubtedly occurred during Paleozoic sedimentation, but it culminated in the great disturbance near the close of the Carboniferous.

STRUCTURE IN THE PAWPAW AND HANCOCK QUADRANGLES.

General statement.—The Pawpaw and Hancock quadrangles exhibit the customary Appalachian Valley structure—longitudinal close folds striking northeast-southwest. Consistent with the Appalachian structure, the folding becomes more intense toward the east, the gentle open folds of the western part of the area giving place to close folds with steeper dips, in places overturned toward the northwest and broken by thrust faults. In like manner older rocks successively come to the surface eastward, and the oldest rocks of the region are exposed in the extreme southeast corner of the area, where they form the western edge of the Shenandoah Valley.

In the Hancock quadrangle the structures are not so continuous as in most portions of the northern Appalachians, many folds plunging and overlapping each other in the area. This condition is caused by the greater compression of the rocks and the production of higher folds opposite the westward offset of the South Mountain mass in the vicinity of Chambersburg, Pa. Erosion has accordingly exposed the Tuscarora sandstone at the surface in the higher folds at Dickeys and Cove mountains and in other ridges east of the quadrangle. In plunging southward these anticlines finger out, one or more of the branches continuing for some distance as low arches. Conversely the Meadow Branch syncline rises northward and dies out beyond the area.

The Cacapon Mountain and Pawpaw anticlines to the west, on the other hand, pitch gently northward, giving place to deeper synclines in that direction. This condition is due to the general change in the trend of the structures from N. 20° E. south of the Potomac to nearly due east at the eastern end of South Mountain near Harrisburg, which is not only produced by a change of strike of the beds but by a northward deepening of the synclines and an eastward deflection of the folds.

The Meadow Branch, Sideling Hill, and Town Mountain synclines, and the Foltz or Cove Mountain, Dickeys Mountain, and Cacapon Mountain anticlines are the major folds in the area. The more important will be discussed separately, beginning with the easternmost.

North Mountain uplift and faults.—The older rocks east of North Mountain are part of a large anticline in the limestones of the Shenandoah Valley. From studies in the Cumberland Valley of Pennsylvania, northeast of this area, it is known that the limestone lies in close folds, many of which are overturned and faulted. The westernmost anticline has been faulted against younger rocks in North Mountain, and the overthrust has taken place along two principal planes. (See section D–D of the Hancock structure-section sheet.) Along the eastern plane, at the foot of North Mountain, the crushed and sheared Beekmantown limestone is faulted against the crumpled Martinsburg shale. In ascending order the Juniata, Tuscarora, and Clinton appear in compressed outcrops, dipping 75° SE. (overturned) and faulted against the Oriskany sandstone on the west. All the formation outcrops are very narrow, owing to the great compression and probably to distributed faulting. Northward at the gap at Hedgesville the Clinton and Tuscarora formations are also faulted out and at the Baltimore & Ohio Railroad cut through a low gap in the mountain the Martinsburg shale is faulted against the Romney shale. (See fig. 7.) The Tuscarora sandstone, however, forms the mountain crest on both sides of the gap and continues to be a ridge maker to the Potomac, north of which it is faulted out at the surface and the ridge ends. Southward the mountain continues to the Virginia State boundary, where it dwindles into low hills, the hard sandstone probably being again faulted out.

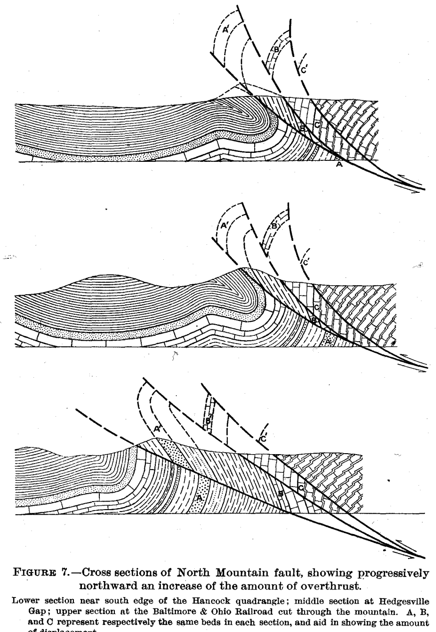

FIGURE 7.—Cross sections of North Mountain fault, showing progressively northward an increase of the amount of overthrust.

Lower section near south edge of the Hancock quadrangle; middle section at Hedgesville Gap; upper section at the Baltimore & Ohio Railroad cut through the mountain. A, B, and C represent respectively the same beds in each section, and aid in showing the amount of displacement.

Foltz anticline and fault.—The next important structure toward the west is an anticline bringing up the Tuscarora sandstone in Cove Mountain in the extreme northeast corner of the area. In the Mercersburg quadrangle the Beekmantown limestone is exposed in this fold near Foltz, and the fold is described in the folio covering that area as the Foltz anticline. The fold spreads out southwestward and, plunging at the southern border of the Mercersburg quadrangle, gives rise to two minor anticlines, of which the western enters the northeast corner of the Hancock quadrangle. Where it enters the quadrangle the strata are nearly vertical and strike parallel to the mountain, but southward the fold plunges and the strata swing eastward around its end and pass out of the quadrangle. The dip decreases to about 20° in the hills north of Indian Springs, and the formations here cover wide areas.

The fold is broken on the west by a longitudinal fault which branches as it enters the quadrangle, inclosing between the two thrust planes an elongated lens-shaped area of the Helderberg and Oriskany. These faults and the point of the anticline cross the Potomac west of Cherry Run and enter the Romney shale, through which they can not be clearly traced, but the structure is probably continuous with the sharp infold of the Jennings shown on the map south of Baxter.

Ferrel Ridge anticline.—The eastern minor fold of the Foltz anticline enters the quadrangle at Fort Frederick, but is lost in the Romney shale south of the river. The fold again rises into prominence south of Soho, where the Wills Creek, Tonoloway, and Helderberg formations are exposed within a narrow band of ridge-making Oriskany sandstone, culminating at the north in Ferrel Ridge. The dips are steeper on the west side of the fold and the outcrops correspondingly narrow. The fold is broken by a faulted minor syncline which indents the formations in a southwesterly direction, a narrow band of the Tonoloway cutting diagonally across the uplift. This is probably the southern continuation of a shear zone exposed in the Baltimore & Ohio Railroad cut in the Romney shale at the Potomac River, just east of the Hancock quadrangle, which probably represents the prominent fault on the east side of Two Top Mountain in the southern part of the Mercersburg quadrangle, Pennsylvania.

East of the Ferrel Ridge fold a gentle syncline inclosing Romney shale and a small mass of Jennings formation west of Hedgesville is turned up abruptly along the North Mountain fault. The Ferrel Ridge anticline has not been traced far beyond the southern limit of the Hancock quadrangle.

Meadow Branch syncline.—This syncline, one of the most important structural features in the area, is best shown south of the Potomac, where hard Carboniferous sandstones preserved in the deeper parts of the trough make conspicuous mountains. It is the most eastern deep syncline in this part of the Appalachians and preserves Carboniferous rocks structurally as far southeast as the anthracite coal fields of north-central Pennsylvania.

The syncline is shown in cross section in sections C–C, D–D, and E–E, on the Hancock structure-section sheet. The thick Catskill rocks form an unsymmetrical trough, turned up steeply on the east, in which lie the thinner Carboniferous rocks. The axis of the unsymmetrical syncline passes through the lower end of Devils Nose, just west of the sharp northward bend in the stream, then along the upper western slope of Third Hill Mountain to the western base of Pinkerton Knob, where it follows the foot of the mountain slope to the border of the quadrangle. On the west the dips are gentle, the hard Purslane sandstone descending with the eastern slope of Sleepy Creek Mountain. On the eastern side, however, the beds rise more rapidly in a secondary sharp fold which is traceable more or less clearly the full length of the basin. A narrow tongue of the coal-bearing Hedges shale projects at the north end in a closely compressed syncline with vertical dips on the east which become overturned 75° E. on Cherry Run. The overturning continues to Pinkerton Knob, south of which the secondary fold passes into the Purslane sandstone. A narrow tongue of Hedges shale is infolded at the southern border of the quadrangle. In passing through the rising end of the syncline at Devils Nose, Meadow Branch cuts a deep gorge in the hard Purslane sandstone and divides it into two lobes at its termination.

Northward the syncline is well shown in the red sediments of the Catskill, the V-shaped ridge of the upper conglomerate of the Jennings on the north bank of the Potomac, and the upper sandstones of the Romney, the principal element in the formation of Coon and Pigskin ridges, which terminate at the Pennsylvania State boundary. The fold continues north beyond the quadrangle in Little Cove, which terminates in the Mercersburg quadrangle.

Southward the syncline is marked by mountains to the Virginia State line, about 8 miles beyond the quadrangle, where the fold rises and the Carboniferous rocks are eroded.

Dickeys Mountain anticline and fault.—At McConnellsburg, on the western border of the Mercersburg quadrangle, an anticline forms a large limestone cove inclosed on the east by Tuscarora Mountain and on the west by Little Scrub Ridge. A great thrust fault along its western margin brings the Beekmantown limestone into contact with the Jennings formation in a part of its course, and represents a displacement of at least 9000 feet, the thickness of the strata cut out. This master fault and the southern end of the McConnellsburg anticline enter the Hancock quadrangle in Dickeys and Keefer mountains. The oldest rocks exposed by the anticline in the quadrangle are Tuscarora sandstone forming Dickeys Mountain, around which point swing in concentric loops the overlying formations, the harder beds forming Keefer Mountain and Elbow Ridge. The rocks are steeper on the western side where the fault cuts out the Oriskany and most of the Helderberg. (See section A–A on the Hancock structure-section sheet.) As the fold plunges steeply to the south, the fault fades out and is lost in the Jennings formation. The fold bifurcates south of the river, the eastern arm dying out rapidly, the western one continuing in the anticline marked by the Parkhead sandstone member of the Jennings. The axis of the fold is deflected west here by the deep Meadow Branch syncline.

Timber Ridge syncline.—This is a minor syncline barely traceable across the quadrangles. South of the Potomac the bottom of the syncline is shown by the gentle synclinal dips of the Jennings formation and by the attitude of the upper conglomerate member, which is generally present in the middle of the fold, where it forms Hogback Ridge, most of Pious Ridge, Wolf Hill, and similar unnamed ridges. The trough deepens and widens near Potomac River and incloses the red Catskill rocks, the harder beds of which form Timber Ridge and other flat-topped hills north of the river. A few miles beyond the north boundary of the quadrangle the deepening syncline incloses coal-bearing Carboniferous rocks which form the Meadow Ground and Scrub Ridge mountains.

Cacapon Mountain anticline.—This great anticline is the backbone of the structure in the Pawpaw-Hancock area, which it divides into two nearly equal parts. It raises the top of the Tuscarora sandstone to 2200 feet elevation, nearly 1000 feet higher than these rocks stand at present in North Mountain, although the height to which they originally rose over the North Mountain anticline of limestone before erosion was probably greater than in Cacapon Mountain. The difference in elevation of the Cacapon Mountain anticline and the Meadow Branch syncline, as shown by the following outline section (fig. 8) across the two quadrangles, is about 14,000 feet.

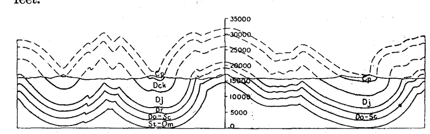

FIGURE 8.—Outline northwest-southeast section across the Pawpaw and Hancock quadrangles. (Horizontal and vertical scales the same.)

The maximum displacement of the strata by folding is shown to be about 14,000 feet, and the probable minimum amount of erosion of strata is represented by the dashed lines above the surface profile. Cp, Purslane sandstone; Dck, Catskill formation; Dj, Jennings formation; Dr, Romney shale; Do-Sc, Oriskany sandstone to Clinton shale, inclusive; St-Om, Tuscarora sandstone to Martinsburg shale, inclusive.

The Cacapon Mountain anticline is unsymmetrical, the westward dips being somewhat the steeper. In Cacapon Mountain, where the massive Tuscarora sandstone controls the folding, the anticline is simple, rising with dips of 35° to 45° E., which gradually decrease to horizontal over the top, and descending with dips of about 55° W. On the west flank of the mountain the softer and thinner overlying strata, chiefly the Clinton formation, McKenzie formation, and Wills Creek shale, are complexly folded and crinkled. The minute folding of the strata is especially well shown in the vicinity of Great Cacapon and south of Rock Ford, as indicated on the areal geology map and in sections B–B, C–C, and D–D of the Pawpaw structure-section sheet. At Fluted Rocks, also, Great Cacapon River has exposed a wonderful series of these flutings in the Keefer sandstone member of the McKenzie, shown in Plates X, XI, and XIV of the illustration sheet and in figure 9.

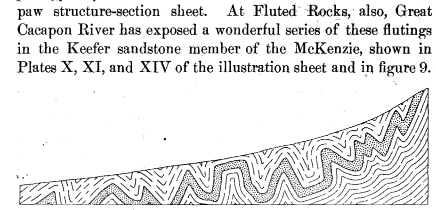

FIGURE 9.—Sketch of the structure at Fluted Rocks, W. Va.

The formation shown by the dot pattern is the Keefer sandstone member of the McKenzie formation, which stands in relief, as shown in Plates X, XI, and XIV.

At Edes Fort an anticlinal pucker in the Tuscarora is cut through by Great Cacapon River. (See Pls. VII and VIII.)

The anticline pitches northward, so that the Tuscarora sandstone does not cross the Potomac but is last seen on the banks of the river at Sir Johns Run. The anticline branches here, the eastern fork, a direct continuation of the main fold, dying out in minor plunging wrinkles just north of the river. One of these symmetrical folds in the Bloomsburg red sandstone member, finely exposed in the Chesapeake & Ohio Canal bank at the east base of Roundtop (see Pl. XVII), is classic in geologic literature. The western fork develops in the northern part of Maryland into an elongated fluted dome, exposing again the Keefer sandstone member of the McKenzie formation in the valley of Little Tonoloway Creek. (See section B–B of the Hancock structure-section sheet.) The minor syncline between these branch folds, in which Helderberg and Oriskany formations cap Roundtop, is cut by a longitudinal thrust fault.

At the north edge of the quadrangle the anticline flattens out, but the Silurian rocks continue to be exposed for 7 or 8 miles north in Pennsylvania. Southward in West Virginia the fold increases in prominence, and the Silurian extends for many miles beyond the quadrangle.

Sideling Hill syncline.—This fold crosses the entire length of the Pawpaw quadrangle without much variation in width. The fold incloses Carboniferous strata throughout the quadrangle but is deepest and widest in the Rockwell Run region where the heavy Purslane sandstone forms two ridges, Purslane Mountain and Sideling Hill, the inner slopes of which are the dip slopes of the syncline. The dips in the eastern limb on this portion of Sideling Hill are very steep, locally vertical or overturned. The softer rocks have been mostly eroded from the center of the syncline, giving rise to the deep synclinal valley of Rockwell Run, but some coal-bearing strata and red shale, overlying the hard sandstone, are preserved on the ridge where the Little Orleans road crosses. A minor fold is exposed in Piney Point and in the narrow synclinal outlier of the Purslane sandstone on Stinebaugh Point.

The west limb of the syncline exposes other minor folding. On the broader part of Purslane Mountain, east of Doe Gully tunnel, the Purslane sandstone mantles the surface in a gentle anticline which descends the west slope several hundred feet. This minor anticline appears to cross the head of Rockwell Valley and pass back of Piney and Stinebaugh points, thus dividing the syncline in two. The minor anticline is also cut through to the north, leaving remnants of the sandstone capping the high points on opposite sides of Rockwell Run. Sections B–B, C–C, and D–D of the Pawpaw structure-section sheet show the structure at these places.

The deep Potomac gorge probably just cuts through the Carboniferous strata, but the sandstone and overlying coal-bearing strata of the Purslane are again inclosed in the syncline on the high point north of the river. A small fold on the east side of the main syncline is also preserved in the lower beds of the Carboniferous seen along the river road in Maryland.

The syncline maintains about the same height across Maryland and appears to be a simple, open, nearly symmetrical fold in this part of its course, though some irregularities of dip are seen in the Catskill on the lower slopes of Sideling Hill, and the Carboniferous in the center of the fold is locally steeply upturned on the east. A narrow strip of the Purslane sandstone caps Sideling Hill as far as the Pennsylvania State line. The syncline continues its straight even course for 12 or 15 miles into Pennsylvania, where it seems to merge with the Town Hill syncline on the west. Southward the main fold decreases in depth, and the Purslane sandstone does not pass out of the quadrangle. A minor syncline, however, poorly discerned in the Catskill sediments on the west flank of Sideling Hill, deepens southward, and near the southern border of the quadrangle incloses Carboniferous rocks forming Spring Gap Mountain, which is capped by Purslane sandstone.

Pawpaw anticline.—Although this anticline is continuous across the quadrangle, it can not be readily studied because it exposes only the Jennings formation. If the sandstone and conglomerate members were not mapped, the detail of the structure could not be made out, but the distribution of these sandstone members on the map shows that the fold is wide and double in the middle, fingering out into tapering points northward in the direction of the pitch. It eventually fades out north of the quadrangle, where the Sideling Hill and Town Hill synclines merge.

Opposite Pawpaw there is more minor folding, and the Parkhead sandstone member is repeated several times in closed synclines.

Town Hill syncline.—This is another deep syncline carrying Carboniferous strata, but only the highest peaks of Town Hill in the Pawpaw quadrangle are capped with the Purslane sandstone. The eastern limb is somewhat steeper than the western, but in general the fold is open and nearly symmetrical. Wide breaks in the Carboniferous strata are made by Sideling Hill Creek, Fifteenmile Creek, and Potomac River; in fact, they are preserved in the syncline for only a short distance south of the Potomac. North of Sideling Hill Creek the Carboniferous band widens as the syncline deepens and merges with other synclines at the northwest corner of Fulton County into the Broad Top Mountain coal fields.

Stratford Ridge anticline.—A minor anticline brings to the surface the Oriskany sandstone in Stratford Ridge and South Branch Mountain on opposite sides of the Potomac in the adjacent Flintstone quadrangle, and the northward-plunging end of the overlying Romney shale enters the Pawpaw quadrangle for about 2 miles. Across the rest of the quadrangle the anticline is traceable in the bands of the Parkhead sandstone member of the Jennings formation, which not only show a bifurcation of the fold as it plunges beneath the surface northward but whose wide outcrop and somewhat fluted edges indicate still further crumpling that repeats the beds and widens their outcrop. Gabriel Knob, near the north border of the quadrangle, is the southern end of the heavy conglomerate above the Parkhead member in the minor syncline between the branch anticlines.

Polish Mountain syncline.—This minor syncline, in the extreme northwest corner of the area, is entirely in the Jennings formation, and is so shallow that it incloses only the higher conglomerate bed which forms the crests of the northern part of Polish Mountain and of Ragged Mountain. The sinuous outline of the conglomerate on the map indicates the gentle and open character of the fold. The extent of the fold northward beyond the quadrangle is not known and is indicated chiefly by the ridges made by the sandstone and conglomerate beds of the Jennings.

LATE REGIONAL UPLIFT.

Since the great disturbance of the strata near the close of Carboniferous time the attitude of the rocks has changed little. There is no evidence that the formations in the Pawpaw and Hancock quadrangles were tilted and faulted like those in the Triassic basins on the Piedmont Plateau, although it would be difficult to detect such slight movement in an area of earlier great disturbances. It is known, however, from the physiographic relations described on pages 18 and 20 that this region as a whole has been uplifted several hundred feet since Jurassic time and tilted toward the sea, but this was accomplished by such gentle and gradual movements that the rocks themselves were not noticeably disturbed.

HISTORICAL GEOLOGY.

The geologic history of the Pawpaw and Hancock quadrangles and vicinity is recorded chiefly in the rocks underlying the area, and in so far as these are exposed at the surface can the history be interpreted. The later history is imperfectly recorded in the gravels, stream terraces, gorges, and other topographic features. The post-Paleozoic part of the story, therefore, is the least complete.

The following history is interpreted largely from the facts already presented in the description of the formations.

PRE-CAMBRIAN TIME.

The oldest rocks in this general region are the crystalline rocks and ancient lavas of South Mountain and the adjacent Piedmont Plateau, and the first events of geologic history must be interpreted from these rocks. The oldest rocks, which are found farthest east and comprise gneisses, granites, and schists, are so greatly altered that their origin can not be positively determined, but they apparently represent very ancient sediments intruded by igneous rocks. These rocks were compressed, intricately folded, and then planed off and became the basement on which the lavas of South Mountain were poured. They have been therefore assigned to the Archean period.

The lavas, which are considered to be Algonkian in age, are of two types, acidic and basic, indicating either two distinct periods of eruption or separate sources of supply of the molten magma. Both kinds of rocks contain amygdules and other evidences of having cooled at or near the surface. The wide distribution of these old lavas suggests that they reached the surface through great cracks and rifts in the earth. An epoch of erosion intervened between the pouring out of the lava and the subsidence of the land when Cambrian strata began to form.

It is not known whether all these rocks underlie the Pawpaw and Hancock quadrangles, but it is probable that conditions in the area were similar to, if not identical with, those indicated for the South Mountain region during this beginning of the geologic record.

PALEOZOIC SEDIMENTATION.

EARLY CAMBRIAN SILICEOUS DEPOSITION.

At the beginning of Cambrian time the area where South Mountain and the Blue Ridge now stand was depressed and was occupied by a long strait or arm of the sea. The first sediments deposited were composed of fragments of the adjacent volcanic rocks, and the basal beds are soft purplish arkose, whose color and composition indicate that the volcanic rocks from which it was derived had previously been disintegrated on the surface of the land. Upon the arkose and feldspathic sandstones rest beds of pure white sand and fine arenaceous silt. These siliceous sediments formed the Weverton sandstone, the Harpers schist and Montalto quartzite member, and the Antietam sandstone, the harder beds of which form the ridges of South Mountain. During these epochs stream erosion on the land was active and quartz sand was carried into the strait and spread out on the bottom by currents. The water, which was probably shallow, was inhabited by crustaceans and low forms of life whose remains, chiefly the carapaces of trilobites, are now sparingly preserved in the rocks. Marine worms burrowed in the sand of the shore, and casts of their holes are commonly preserved in the purer sand rocks. In swampy places near the shore, iron was deposited with the sediments, forming beds of highly ferruginous sandstones. The Pawpaw-Hancock region was probably included in this narrow sea whose western shore line has not been determined, as the rocks are deeply buried.

CAMBRIAN AND ORDOVICIAN CALCAREOUS DEPOSITION.

Long before the close of Lower Cambrian time sand and clay deposition was replaced by calcareous sedimentation, which lasted almost continuously through the rest of Cambrian and a large part of Ordovician time and formed the rocks comprising the Shenandoah group of the Cumberland, Shenandoah, and other great valleys of the Appalachian Valley region. The major part of this great thickness of deposits is free from detrital material, except for minute particles of clay and fine grains of sand that were included in some of the limestones. Accompanying this change of sediment was an expansion of the interior sea, which in Upper Cambrian time covered a large part of the North American continent. This sea continued to occupy a large part of the interior of the continent throughout the rest of Paleozoic time, alternately expanding and contracting.

Land erosion was insignificant during the lime-depositing epoch, for little land waste was transported to the sea. In its stead the streams carried to the sea calcium and magnesium carbonates and other soluble salts dissolved from the decomposing rocks by rain water. Some of this calcareous material was secreted from the sea water by mollusks, crustaceans, corals, and other living organisms and deposited on the sea bottom as shells and skeletons. Many of the purer beds are almost entirely made up of such calcareous organic remains. The larger portion of the limestones, however, contain few or no visible fossils, so that there is ground for the belief that most of the limy sediment was precipitated directly from the water rather than produced by the secretion of organisms.

A number of beds are oolitic, many others are minutely conglomeratic, and it is safe to assume that a considerable proportion of the limestone is clastic, made up of grains of lime rock more or less enlarged and rounded by a coating of calcium carbonate and cemented by the same material. The occurrence in the Beekmantown of nonmagnesian and highly magnesian limestones in abrupt alternation suggests that these beds were probably deposited by chemical action in a shallow sea. The land during most of this lime-depositing period was of low relief, but there was local uplift in Waynesboro time, during which red soil, fine mud, and quartz grains from the decomposition of the hard rocks were temporarily swept into the sea and deposited as shale and sandstone.

Again at the beginning of the Conococheague an uplift occurred that raised a part of the sea bottom into land. The freshly deposited sediment was broken into fragments which were worn round and were formed into conglomerates the matrix of which contained numerous rounded quartz grains. Other thin layers of limestone were broken up by the waves or tides into "shingle" or flat fragments that were shuffled about on the beaches and formed "edgewise" conglomerates. The oolite, which is also present, was formed in water shallow enough for the particles on the sea bottom to be oscillated by the waves, and the red clay that occurs in crevices and solution pockets of the beds was the residuum of limestone decay on land. These features indicate a relatively important uplift in the midst of otherwise uniformly quiescent conditions that marks the beginning of Upper Cambrian time, for trilobites and other fossils characteristic of that epoch first appear at this horizon.

Although in the earlier stages of the lime-depositing sea conditions were apparently not very favorable to life, during its later stages brachiopods, cystids, and bryozoans became very abundant. The paucity of life seems to have been associated with the large amount of magnesium carbonate present in the water.

The sea throughout the limestone deposition was probably of moderate depth—not more than 250 to 300 feet—such as is favorable to the existence of trilobites and mollusks, and was frequently shallow enough in many parts of the area for the formation of limestone conglomerate. Many of the fragments are long, slender plates with angular edges, indicating that they were not carried far from their source. Lime silt, to be broken up and form conglomerate, must first be hardened. Some of the angular conglomerates resemble silt on mud flats that has been dried by the sun, broken into thin slabs, and again submerged, tumbled about, and covered with silt. In fact, it is reasonably certain that the silt from which the conglomerates were derived was air dried, hardened, broken up, and redeposited in some such way, and that at intervals throughout late Cambrian and early Ordovician time portions of the bottom of the shallow sea probably emerged temporarily. The occurrence of sun cracks on some of the bedding surfaces of slabby limestone, shaly intercalations with crinoids and bryozoans attached to the worn limestone surfaces, the irregularity of bedding, and the disappearance of recognized lithologic and faunal zones in the closing Chambersburg epoch afford proof that is practically conclusive.

The wide valley east of North Mountain extending into the Hancock quadrangle is composed of these limestones containing conglomerates and sand beds, and the entire Pawpaw-Hancock area is undoubtedly underlain by the same kind of rocks and experienced the same history.

ORDOVICIAN SILT AND SAND DEPOSITION.

After the close of the lime-depositing epoch the distant land to the east was gradually elevated so that the streams brought terrigenous material to the sea. Fine silt, forming the carbonaceous black shale at the base of the Martinsburg, was first deposited; then, as the elevation increased, the arkosic sand of the upper portion of the formation and later the coarser red sand with white quartz pebbles, also coated red, of the Juniata were laid down. These coarser sediments were probably derived from the quartzose pre-Cambrian rocks of the Appalachian land, the red sand and clay being the iron-stained residuum of rocks exposed to long decomposition. The fauna of the Martinsburg is characteristic of the Ordovician, and such fossils as have been found in the Bays, the supposed representative of the Juniata in southern sections, have also been referred to the Ordovician.

SILURIAN SEDIMENTATION.

During the deposition of the pure-white quartz sand of the Tuscarora the elevation of Appalachia—the Appalachian land area of which the Piedmont Plateau was a part—was increased, and erosion and transportation reached their maximum. The weathered residuum on the land had been removed and fresh quartz sand and pebbles, derived from the siliceous pre-Cambrian rocks of this land mass, were swept into the sea and were widely distributed over its gently sloping floor. Trails of unknown animals that lived on the sand during its deposition are the only indications of organic life found in these rocks.

During Clinton time land erosion was again less active, for the terrigenous sediment was largely made up of fine silt, which formed shales. In favorable places quantities of iron oxide in the form of hematite were precipitated with the sediments, and these deposits now form bodies of highly ferruginous sandstones, some of which are workable iron ores. The surfaces of these ferruginous sandstones in this area show ripple marks, mud flows, and trails of animals that crawled in the soft mud, and indicate extremely shallow water and tidal flats. These shallow-water and low-land conditions culminated in the deposition of red and green mud rock and fine argillaceous magnesian and calcareous silts that inclosed chiefly small bivalve crustaceans of early Cayugan age. These thin limestones and shales are ripple marked and sun cracked and contain pseudomorphs of salt crystals. In many respects they closely resemble the Salina rocks of New York, which contain beds of gypsum and salt and a peculiar eurypterid type of crustacean, and they were, like the New York rocks, probably deposited in semi-inclosed basins whose waters were partly evaporated and whose tidal flats were alternately submerged and raised. These semi-inclosed basins, or conditions of the sea that produced a similar character of sediment and fauna, probably continued through Tonoloway time, until the resubmergence of the land barriers in Helderberg time restored marine conditions.

DEVONIAN AND CARBONIFEROUS SEDIMENTATION.

The general absence of argillaceous and siliceous deposits in the Helderberg formation shows that the distant land areas were not generally elevated at the time marine conditions were restored. Pure lime silt was deposited, and coral reefs, sponges, brachiopods, and a variety of other marine forms were abundant. The waters inhabited by such prolific life, especially by corals, were without doubt considerably warmer than those existing at the same latitudes on the Atlantic coast to-day. At one stage in Helderberg time coarse sands closely resembling those of the next later (Oriskany) formation were locally laid down near the northeastern shore, indicating incipient elevation of the land which initiated the general uplift during the Oriskany epoch.

In the western part of the area the finer silts of the lower Oriskany followed without break the calcareous Helderberg deposits, but in the rest of the area there must have been land during the earliest Oriskany time, for the Devonian sedimentation began with coarse sands of the upper Oriskany. This marked an uplift of some distant land composed of Cambrian and pre-Cambrian rocks, from which was derived the coarse quartz sand and well-rounded pebbles composing so large a part of the Oriskany. The Oriskany sea probably did not at any time extend far beyond the northeastern limit of the Hancock quadrangle, for the few feet of beds composing the formation there are highly ferruginous and indicate that marshes existed at or near the shore. The calcareous nature of the formation in the eastern part of the area suggests that the coast to the east was of low character, and comprised a limestone lowland. The sands forming the main body of the formation must then have been transported across this lowland by streams from the mountainous land to the east or been carried by currents from the distant Adirondack land in the north. The Oriskany sea teemed with marine life, particularly lime-secreting brachiopods and other mollusks. Their shells compose a large portion of the calcareous rocks, and the finer sandstones are crowded with their casts.

Sediments of terrigenous material continued in the fine black silt of the Romney, which was succeeded in turn by fine arenaceous shales and sandstones of the upper part of the Romney, by fine siliceous silt of the Portage phase of the Jennings, and by coarser sands with rounded quartz pebbles and sandy shales of the Chemung phase of the Jennings. In all but the Portage epoch a large variety of marine life inhabited the shallow portions of the sea, and the fossil shells in these rocks are numerous and finely preserved. Fossils are rare in the sediments of the Portage epoch. Those that do appear are small, and were probably very thin shelled, as their impressions are very dim. They are of peculiar types, unlike those of associated faunas. The absence over nearly this entire area of the black shale of the Genesee, which occurs at the base of the Jennings at the western edge of the Pawpaw quadrangle and in the regions to the west, signifies that the Pawpaw-Hancock area was above water during that time, but no other indication of unconformity was observed at this horizon. The Onondaga has usually been regarded as also absent in this area, but it has at least a small representative in the base of the Romney.

Devonian sedimentation closed with the series of red arkosic sands and sandy shales of the Catskill, which are apparently a fresh-water phase of the Chemung, as they are poorly assorted and carry only fragments of vegetable matter and fish remains. Fresh-water conditions, which began earlier and apparently originated in the east, were caused possibly by excessive rains and floods from the land, which changed the margin of the shallow sea from salt to fresh and brought unassorted detritus from deeply weathered areas. This condition gradually spread westward in the sea and resulted in the substitution of Catskill deposition of red arkosic débris with few organic remains for Chemung sedimentation and marine life.

Conglomerates composed of round white quartz pebbles and quartz sand indicate renewed uplift of and erosional activity on the distant land at the beginning of Carboniferous time. The presence in these conglomerates of red jasper pebbles and bowlders of quartzitic conglomerate containing jasper and vitreous quartz suggests that these pebbles were transported by streams and ocean currents from distant lands in the Lake Superior region, where jasper is known to occur plentifully in pre-Cambrian rocks, but they may possibly have been derived from the pre-Cambrian of the adjacent Appalachian Mountains, which also carries jasper in small quantities.

Certain of the layers contain fragments of tree trunks and thin seams of coal, but it was not until Pennsylvanian time that thick deposits of vegetal matter accumulated in swamps and inclosed basins. The vegetal remains became compressed and hardened into coal, and now comprise the rich coal beds of the Appalachians. These higher Carboniferous strata do not now occur in the Pawpaw-Hancock area, but it is probable that they were originally deposited there and that they have been removed by erosion. Beneath each coal bed there is usually a tough, arenaceous black shale, which contains the roots of the trees that formed the coal and was the soil in which the coal plants grew. This shale is generally refractory and is called fire clay. Above the coals is usually another clay or sandstone containing leaves of the trees forming the coal.

Both marine and fresh-water shells occur in limestones interbedded with the coal-bearing strata, indicating that marine and fresh-water conditions alternated while the strata were being laid down. The earth's surface over much of the interior of the continent must have been of very low relief, so that marshes of wide extent were alternately submerged and raised. The Permian epoch of the Carboniferous is poorly represented by sediments in the Appalachian province, and it is probable that the Pawpaw-Hancock area became dry land before the close of Carboniferous time.

MESOZOIC AND LATER TIME.

POST-CARBONIFEROUS FOLDING AND UPLIFT.

The greater part of the folding and compression of the Paleozoic rocks of the Appalachian province took place at the close of Carboniferous sedimentation and prior to the deposition of the Newark group, of Triassic age. Incipient folding no doubt occurred long before this time and caused irregularities of deposition in various portions of the geologic column, in places amounting to the absence of certain beds or entire formations.

The great folding of the Appalachian strata was produced by horizontal forces acting transversely to the trend of the province and its structures. The active force came from the southeast, as may be determined from the overturned folds, thrust faults, and increase of metamorphism in that direction. This force, the result of the contraction of the earth, of isostatic adjustment of sinking sea bottoms and rising land masses, or of some other equally potent factor not yet understood, probably accumulated during the quiet periods of deposition from Cambrian to Carboniferous time. At or near the close of Carboniferous time the pent-up stresses were greater than the strength of the rocks, and as the firmer underlying crystalline rocks yielded, the newly deposited sedimentary rocks were folded and faulted and compressed into about half their original horizontal extent. At the same time the interior of the continent was uplifted, the bottom of the interior Paleozoic sea was raised into land, and sedimentation in this area ended. The muds, calcareous silts, and sands had been compacted and to a large extent hardened by their own weight. Compression and folding further consolidated them into firm rocks and permeating solutions in places cemented the particles firmly together. The pressure modified them by the formation of cleavage and joint planes. In South Mountain and the Piedmont Plateau, where the intensity of the compression was greatest, the rocks were more markedly metamorphosed, and their constitution and texture were materially changed by the growth of new minerals.

EROSION AND PRODUCTION OF PHYSIOGRAPHIC FORMS.

Whereas the Pawpaw-Hancock area has not been beneath the sea since the close of the Carboniferous period and its rocks have been subjected to erosion during the enormous lapses of time to the present, a narrow basin east of South Mountain, about 50 miles east of this area, was flooded during Triassic time, and red arkosic sand and silt were deposited in it and in similar inclosed basins along the Atlantic coast. These deposits closely resemble the red beds of the Catskill in composition and were probably laid down under somewhat similar conditions. They are marked by ripples, rills, raindrop impressions, sun cracks, and footprints of great three-toed reptiles that walked over the soft mud flats.

Erosion has not continued uniformly on the land during all this time but has varied in intensity with the change of attitude of the land and sea. When the land rose, erosion was accelerated; when it halted or sank, erosion gradually decreased or ceased. In the topography of the Pawpaw-Hancock region are preserved records of several prolonged halts in the general rise of the land that accompanied the removal of the rocks by erosion. During these halts the land was worn down more or less to a gently sloping, rolling plain near sea level, which is called a peneplain.

Schooley (Jurassic-Cretaceous) peneplain.—During Jurassic time the eastern part of the North American continent, which had emerged from and risen above the sea, became nearly stationary, and remained so for such a long time that the surface of the land in the Appalachian province was reduced by erosion to a rolling plain that sloped gently toward the sea. In the northern part of the province only a few ridges and peaks, harder or better protected from erosion than the rest, stood above this plain as monadnocks. Uplift of the land has raised this surface higher above sea level, and it is now found emerging from beneath early Cretaceous sediments of the Coastal Plain. In the vicinity of the Potomac the smooth floor on which the Cretaceous sediments lie emerges from cover 100 feet above sea and is preserved to the westward in small patches capped by remnants of Cretaceous at gradually higher altitudes, which attain 500 feet elevation at Peach Grove Hill, 10 miles west of Washington. This fragment of the old peneplain floor is the farthest inland remnant in this vicinity still capped by Cretaceous. The peneplain is not clearly traceable over the Piedmont Plateau as so few remnants of it remain in that region, but the summit of Catoctin Mountain, Md., the first mountain west of the Piedmont, which is from 1800 to 1900 feet in elevation, is regarded as representing this peneplain. The summits of South Mountain are also of about this elevation near the Potomac, but in southern Pennsylvania extensive level tracts on the mountain top, representing the peneplain surface, are between 2000 and 2200 feet elevation.

In the vicinity of the Pawpaw and Hancock quadrangles the only remnants of the peneplain are the tops of the highest mountains, composed of the hardest rocks, the intervening softer portions of its surface having been entirely removed. There is not sufficient evidence in these quadrangles alone to warrant the assumption that a peneplain once existed at the level of the summits of their highest mountain, but the long, level-topped ridges of even height in adjacent areas afford more conclusive proof. Cross and Cove mountains, whose flat-topped summits lie just beyond the northeast corner of the Hancock quadrangle, and sharp-crested narrow ridges whose level crests are traceable northward for many miles indicate that the general altitude of the peneplain remnants immediately west of the valley and near the Potomac is about 2100 feet. It may rise as high as 2450 feet farther north, near Foltz, Pa., where the flat crest of the mountain attains this altitude, but this elevated summit may be an unreduced monadnock rising above the old surface.

The name Schooley peneplain is taken from New Jersey and eastern Pennsylvania, where a peneplain, with which the one here discussed has generally been correlated, forms the flat top of Schooley Mountain.

The mountains of the Hancock quadrangle do not reach the altitude of the Schooley peneplain and it has doubtless been entirely obliterated in that quadrangle. On Cacapon Mountain, in the eastern part of the Pawpaw quadrangle, the peneplain is well preserved, the elevation of its flat top ranging from 2000 feet to more than 2200 feet at the southern border of the quadrangle. Sideling Hill and Town Hill attain a little over 2000 feet elevation at only one or two places, and elsewhere their irregular crests are much lower, indicating that the peneplain surface has probably been eroded. Directly west of this area also the peneplain level is not clearly defined.

From the foregoing description it is at least clear that the plain that once sloped gently to the sea at the close of Jurassic time has been tilted and raised to about 2200 feet elevation in western Maryland and Pennsylvania. It was not elevated to its present position in one movement, however, for other incipient or partial peneplains on the softer rocks at lower levels indicate halts of greater or less duration in the uplift.

A succession of many elevated level tracts that fall below the Schooley peneplain in the Pawpaw-Hancock area indicate temporary halts of the rising continent. Several flat-topped portions of mountains range from 1550 to 1700 feet in elevation; a few broad gaps in the northern part of Meadow Branch Mountains and many of the smaller level-topped ridges in the area are at 1200 feet elevation. These are probably remnants of intermediate erosion plains that are not well defined in this area, but the 1200-foot elevation corresponds in a general way with a plain at Weverton, Md., that has been called the Weverton peneplain.[a] That there was a depression in the general surface of the Schooley peneplain in the vicinity of the present course of the Potomac that might mark the early course of a trunk stream is suggested by the apparent rise in the remnants of this surface away from the Potomac. It is evident also from the stream gap in Sideling Hill and from those in Blue Ridge and Catoctin Mountains near Harpers Ferry that a trunk stream had its course passing these points during the early stages of the uplift of the Schooley peneplain. The water flowing eastward down the slope of the peneplain established a channel which became incised in the plain, and although its course over the softer rocks has changed it became fixed where it cut through the resistant rocks composing the mountains. As the surrounding country became lowered by erosion, these hard layers stood out of the general surface as ridges through which the trunk stream passed in narrow gaps, which have been gradually deepened to their present proportions. The deep gap in Town Hill through which Fifteenmile Creek flows is in line with Sideling Hill gap and suggests that the Cretaceous Potomac River had its course through both of these gaps. If such were the case, Town Hill gap was abandoned by the river during the formation of the Harrisburg peneplain, as a broad level terrace at 920 feet altitude stands out prominently on both sides of the gap. (See Pl. IX.)

Harrisburg (early Tertiary) peneplain.—The best-preserved erosion plain in this area forms the floor of the intermontane areas, into which the present stream channels are deeply incised. It ranges from more than 1000 feet elevation at the western border of the Pawpaw quadrangle to 700 feet at the eastern margin of the Hancock quadrangle, and descends eastward down the Potomac to 650 feet on the uplands back of Harpers Ferry. It forms the surface of much of the Piedmont Plateau and passes beneath the early Tertiary strata of the Coastal Plain. It is, therefore, of early Tertiary age. Its present gradient is much less than that of the Schooley peneplain, which shows that the post-Schooley uplift was greater in the interior than toward the coast, resulting in the tilting of the surface toward the sea.

The Harrisburg peneplain is finely developed on a shale plateau at 750 feet altitude in the vicinity of Chambersburg, 30 miles northeast of the Hancock quadrangle. Its name is derived from its development on a similar plateau still farther northeast in the vicinity of Harrisburg. As several lower terraces or partial peneplains have been developed on the softer rocks near the larger streams, it is not always easy to decide which of the terraces in the Pawpaw and Hancock quadrangles belong to the Harrisburg. The problem is further complicated by the fact that the peneplains rise somewhat away from the river, especially along the foot of the mountains, where gradation was not so complete.

East of Third Hill Mountains the surface of the Harrisburg peneplain, preserved on the sandstones of the Jennings formation, stands at about 750 feet elevation. The softer rocks have been reduced below this level, and the unreduced hills of harder Oriskany and Tuscarora rocks stand somewhat higher. This level is also preserved on the higher sandstone ridges in the Jennings, Romney, and Catskill areas bordering the Potomac east of Hancock. Southwest of Hancock the peneplain rises 800 and 850 feet. Highland Ridge, Wolf Hill, and the southern part of Pious Ridge and associated hills stand above this level because the conglomerate bed of the Jennings of which they are composed is unusually coarse and resistant in these hills. The western foothills of Sleepy Creek Mountain also were not completely reduced to this level, partly because of their remoteness from the trunk stream and partly because of the aggrading influence of the mountain rivulets. In the southeast corner of the Pawpaw quadrangle, the sandstone ridges of the Jennings formation are over 900 feet in altitude, and low broad divides between higher ridges are at this elevation.

[a] Keith, Arthur, Geology of the Catoctin belt: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 388. Clark, W. B., and Matthews, E. B., The physical features of Maryland: Maryland Geol. Survey, vol. 6, 1906, pp. 87, 88.

All along the eastern side of Sideling Hill, both north and south of the river, there is a serrated shelf between 900 and 1000 feet in elevation. The level top and steep front of this terrace west of Woodmont on the south bank of Potomac River is shown in Plate III on the illustration sheet. West of Sideling Hill the level hilltops on the sandstones of the Jennings and Catskill formations range between 1000 and 1100 feet, except close to the river, where they have been eroded lower. Viewed from about the level of this plain (Pl. IV on the illustration sheet), the ridges appear very uniform in height and show clearly their derivation from an approximately level plain. A broad cultivated shelf at an elevation of more than 1100 feet on the east side of Town Hill is in the distance, but is not distinguishable in the illustration. West of Town Hill and Green Ridge the hilltops are between 1000 and 1100 feet, but they are less uniform in altitude in the northwest corner of the Pawpaw quadrangle than they are south of the Potomac near Okonoko, where the little-dissected upland surface at 1000 feet elevation is cut off abruptly by the river gorge.

The present intrenched course of the Potomac, its straight stretches and its windings, particularly the great meanders between Pawpaw and Orleans Crossroads, originated on the Harrisburg peneplain. As the stream was slowly cutting through the resistant rocks of Sideling Hill the gradient above this local base-level dam was low and the stream meandered on the plain. As the peneplain was uplifted and tilted toward the sea the Sideling Hill obstruction was worn down, and the stream in the meandering portion of the channel began cutting and became gradually intrenched in the circuitous course it has occupied ever since. Local changes have since occurred in the amount of swinging of the stream, in some places a circuitous channel being abandoned for a short cut and vice versa. Some of these will be described below.

If, as previously stated, the Potomac in Cretaceous time probably flowed through the Fifteenmile Creek gap in Town Hill, it abandoned this course during the Harrisburg stage. The river apparently flowed around the south end of Warrior Mountain over the shale lowland to the Fifteenmile Creek gap and thence directly through Sideling Hill gap. The present valley of Potomac River was probably occupied by the waters of South Branch which flowed around the south end of Town Hill and thus avoided the hard rock of that ridge which operated as a local base level to the Potomac drainage at Fifteenmile Creek gap. South Branch, therefore, was able to cut to grade quicker than the Potomac, and a minor tributary from the west probably captured the latter stream and deflected its waters from the Fifteenmile Creek gap to its present course. The high terraces in the gap are well illustrated on the topographic map and in Plate IX on the illustration sheet, but no rounded gravels were found on them as evidence of their previous occupation by the Potomac. They are deeply covered by soil containing angular sandstone fragments.

Below the Sideling Hill gap the stream takes a straight course through Tonoloway Ridge until it impinges against Cacapon Mountain, where it bends at a right angle to the north and passes around the obstruction. Its present course was probably not its course on the Harrisburg peneplain, for the stream would not have been deflected by the hard strata of Cacapon Mountain but would have made a gap through them as it cut its way down from a higher level. The fact that the gap in Tonoloway Ridge through which Tonoloway Creek flows is wider at the Harrisburg level than would be consistent with the character of that stream, and the presence of an adjacent wide wind gap at 650 feet elevation through which the Baltimore pike passes, suggest that the Potomac during the Harrisburg stage, after passing through Sideling Hill gap, flowed north in the shale valley and thence eastward through the Tonoloway Creek gap or Baltimore pike gap, which are in direct line with the present course of the river below Hancock. The thick capping of coarse gravel on the 660 to 700 foot hills between the gap and Hancock is additional proof that this course was followed at a later stage, the Somerville, when peneplanation reached this level. As this change of the channel of the Potomac to its present course is more closely associated with the Somerville stage, it will be described in connection with that subject.

East of Hancock there is no evidence of any marked change in the course of the river in the quadrangle, and it is probably flowing very nearly where it was established on the rising Schooley peneplain.

As was previously stated, the peneplains were formed near sea level and had a gentle incline inland, so that in the Pawpaw-Hancock area the Harrisburg peneplain was not much above the sea. Since then it has been elevated to its present altitude.

Somerville (late Tertiary) terrace.—After the partial elevation of the Harrisburg peneplain, the earth movement again halted for a prolonged period and erosion once more removed the softer rocks along major drainage lines nearly to sea level, producing a lower partial plain bordering the larger streams. This plain is preserved in terraces and level hill tops along the valleys of the larger streams, and ranges from 850 feet on the western border of the Pawpaw quadrangle to 600 feet at the eastern edge of the Hancock quadrangle. It descends to 525 feet elevation at Harpers Ferry, and to 500 feet a few miles east of Catoctin Mountain, where its surface is covered by gravels, probably of Lafayette age. In tracing the plain across the Piedmont Plateau to the vicinity of Washington it is seen to pass beneath the Lafayette formation at about 500 feet elevation, and if the tracing is correct this terrace is Pliocene or late Tertiary in age. Its gradient is less steep than that of the preceding Harrisburg peneplain.

This terrace has been followed northward into the Mercersburg and Chambersburg quadrangles, where it has 600 feet elevation, and has been described by Campbell[a] as occurring at 500 feet in the vicinity of Harrisburg, Pa. Campbell correlated it with the late Tertiary plain at Somerville, N. J., which is named the Somerville peneplain.

Terraces and flat-topped hills between 800 and 700 feet elevation, bordering the Potomac from Little Cacapon to Little Orleans, were part of the Somerville peneplain and were probably in part the channel of the river at this stage, for at least two places were covered with stream gravel. Remnants of these higher gravels have been found on the 700 to 800 foot terrace opposite Little Cacapon in the southwest corner of the Pawpaw quadrangle and on the 700-foot terrace east of Orleans Crossroads. Others no doubt exist on isolated points or on densely wooded hilltops, where they were not observed.

East of Sideling Hill important changes in drainage seem to have taken place at this stage. The history of the drainage as here hypothetically interpreted is as follows: The Potomac, as previously stated, is supposed to have flowed north between Sideling Hill and Tonoloway Ridge to the Tonoloway Creek gap, possibly occupying the 750-foot shelf on the west flank of Tonoloway Ridge, although no evidence of this in the form of gravel was obtained. The course of the river east of the gap is, however, preserved in the gravel-capped hills at 600 to 700 feet elevation west of Hancock.

The antecedent of Great Cacapon River then occupied the plain east of Tonoloway Ridge and joined the Potomac near Hancock. The 700-foot gravel-covered terraces in the vicinity of Great Cacapon, marking its course there, suggest that a meander of the stream was cutting into Tonoloway Ridge at this point and gradually wore it down, in which process the Potomac probably assisted by impinging against the ridge on the west side, just as it now does against Cacapon Mountain. The ridge was eventually lowered sufficiently for the Potomac to be diverted into the Great Cacapon channel, and thenceforth it followed the course it now occupies between Woodmont and Hancock. By the impetus of the Potomac waters the stream was forced to the east side of the valley and has gouged into the hard rocks of Cacapon Mountain where it was deflected northward.

Directly east of Hancock the Somerville terrace, which is here about 660 feet in elevation, was cut only a short distance back from the river and along its main tributaries, because erosion was not sufficient to reduce the sandstones of the Jennings below the Harrisburg plain. The Somerville terrace is restricted to the intervening soft shale. Up Sleepy Creek this terrace rises in the quadrangle to an elevation of over 700 feet. East of the Meadow Branch Mountains the Somerville terrace was formed over a wide area of the softer Romney shale at about 600 feet elevation, and thick river gravels that mantle the hilltops at this elevation west of Cherry Run mark the course of the Potomac at this stage. Similar high gravels west of Moore Knob on the north side of the river represent the channel of Licking Creek at this stage, and other gravels on the high terrace south of Indian Springs suggest that a tributary entered here from the mountains to the northeast. The Somerville terrace is also well shown in the valley of Back Creek, and the low marshy divide at 620 feet elevation at the south end of Ferrel Ridge probably marks the abandoned course of Whites Run which, heading on the slope of Third Hill Mountain, seems formerly to have crossed the two Oriskany sandstone ridges. It was apparently captured through the activity of Tilhance Creek, which cut down its channel through the soft Romney shale more rapidly and diverted into the new channel around the north end of Ferrel Ridge not only Whites Run but all the drainage south of Baxter.

The duration of Somerville peneplanation was not as long as that of the Harrisburg, and, as has been shown, only narrow terraces on moderately hard rocks were developed along the larger streams. After this interval of rest the renewed elevation of the interior of the continent and tilting of the plain revived active erosion, and many of the softer portions of the Somerville terrace were removed.

[a] Campbell, M. R., Geographic development of northern Pennsylvania and southern New York: Bull. Geol. Soc. America, vol. 14, pp. 277–296.

Quaternary drainage modifications.—Of the local terraces between the Somerville and the present flood plain that appear along the larger streams, many are covered by gravel, indicating minor changes in their channels, particularly in the meandering portions. Indications of a noticeable halt in the elevating movement are present throughout the area about 100 feet below the Somerville stage, but no attempt has been made to trace its extent or to correlate it with similar occurrences elsewhere. Granting that the Somerville terrace is of Lafayette age, the later bench probably corresponds to the Columbia terrace and is of early Pleistocene age.

A few of the most important of the many local stream changes since Somerville peneplanation will be mentioned. The Potomac formerly occupied a large oxbow west of Pawpaw, as is shown in figure 10 by the open valley leaving the river 1 mile

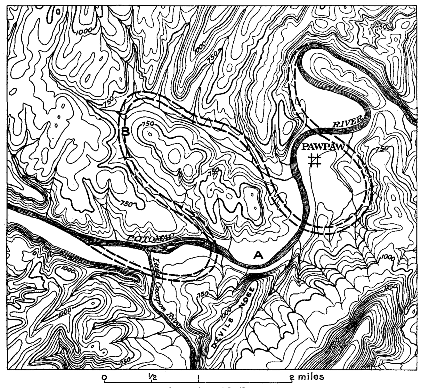

FIGURE 10.—Abandoned channel of Potomac River near Pawpaw, W. Va.

The former channel, shown by the dashed lines, was at about 650 feet elevation and was probably abandoned because of deep silting of the channel, still preserved at B, which caused overflow at A, and not because of normal cut-off at A.

east of the margin of the quadrangle and, swinging northwest for 2 miles, returning to the river down Purslane Valley. This channel at the divide is deeply silted to an elevation of 670 feet, but the depth of the floor is not known. The oxbow has been abandoned for a shorter and straighter course, but the evidence of a cut-off by the overlapping of the meanders of the stream is lacking. It has been suggested by Shaw,[a] in explaining similar high-level channels of the upper Ohio drainage abandoned in the early Pleistocene, that these channels, deeply excavated during an epoch of active erosion, were choked with alluvium brought in during excessive floods from the melting of the glaciers and possibly also from heavy rainfall, and that the bed of the stream was raised by this filling until the waters passed over a low divide; afterward, upon a renewal of normal conditions and the cleaning out of the channels, the course over the low divide became established as the bed of the stream. This explanation fits the conditions in the Purslane oxbow so satisfactorily that it is accepted as probably the correct interpretation.

The town of Pawpaw is located in a low amphitheater-like plain that was once occupied by the river in its lateral swing upon leaving the Purslane oxbow. When the latter was abandoned the river tended to straighten its course below, and the big bend has consequently moved downstream to its present position, where the impingement of its current on the right bank has nearly severed the narrow neck of land at the Baltimore & Ohio Railroad cut and has left a broad alluvial flat on the opposite side of the bed.

The river undoubtedly once flowed over the low divide across the neck of land south of Little Orleans, which is partly covered with river gravel, but the rock revealed beneath the gravel by the Western Maryland Railway cut demonstrates that if this short cut was abandoned owing to the channel being filled with alluvium, in the same way that the change in the Purslane oxbow is explained, the early channel was not cut as deep as the present river bed.

A very interesting oxbow cut-off is in process of formation at Johnsons Mill on Sleepy Creek, 5 miles south of Berkeley Springs, shown in figure 11. The creek formerly flowed in the swampy alluvium-filled valley south of its present course. The rock cliff on the eastern face of the amphitheater, more than one-fourth mile from the present stream, deflected the current against the narrow neck of land around which the stream used to swing, and by combined sapping from above and below a narrow gap was cut through the neck, leaving the severed portion as a high isolated hill or island. The stream now passes through this narrow rock gorge with a fall over bedrock of 8 to 10 feet into a deep pond, from which it turns abruptly to the left and flows close under the rocky bank that it has so recently cut through. Plate XX on the illustration sheet shows this feature to possess not only physiographic but scenic interest.

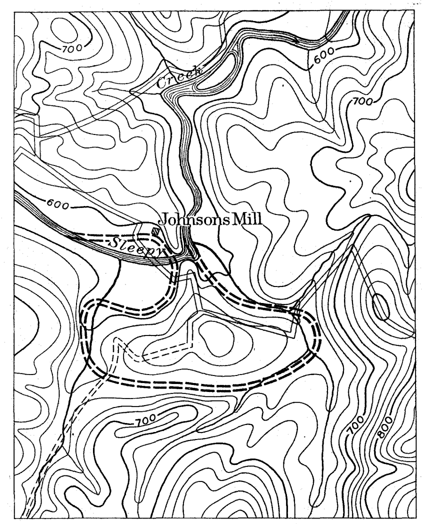

FIGURE 11.—Oxbow cut-off in Sleepy Creek at Johnsons Mill, W. Va., southeast of Berkeley Springs. (Scale, 5 inches equals 1 mile. Contour interval, 20 feet.)

The former channel is shown by heavy dashed lines. The present course was established by the stream cutting through the narrow neck of land, where there are at present rapids in the stream, as shown in Plate XX.

At the present time Potomac River and its larger tributaries have reached their base level and are widening their channels. Most of them have in parts of their courses broad flood plains, which generally furnish excellent soil for farm land. The smaller streams, except those in the softest rocks, occupy narrow valleys and ravines and are actively degrading their channels.

MINERAL RESOURCES.

The mineral deposits of economic value that are found in the Pawpaw and Hancock quadrangles are glass sand, cement rock, limestone, coal, iron, road material, building stone, brick clay, and gravel. Of these minerals, glass sand, cement rock, and coal have been extensively exploited.

GLASS SAND.

Occurrence.—Pure quartz sandstone suitable for glass sand has been mined in the Hancock quadrangle for many years. The sand is obtained chiefly from the friable white sandstone of the Oriskany composing the Warm Spring Ridge, which runs southwest in West Virginia from Potomac River opposite Hancock, Md. The Oriskany sandstone outcrops at many places in the Hancock and Pawpaw quadrangles but has not been proved to be of the quality suitable for glass sand except in a portion of the Warm Spring Ridge a few miles in length. Northward, in Maryland, it changes to a yellow, impure, coarse sand rock, suitable only for building purposes. Southward in the ridge it is mined as far as Berkeley Springs, the end of the branch railroad, but the same character of surface rock continues far beyond that point, and the land is regarded as glass-sand property.

The Warm Spring Ridge quartz sand is exceptionally white and pure. It is free from silt and other fine detritus, except particles of milky cryptocrystalline silica, and its particles are subrounded and of a uniform size. The grains are of medium fineness, practically all passing a 40-mesh sieve and 25 per cent passing a 60-mesh sieve, and are loosely cemented by lime. The spring water which issues from the upper beds of sandstone at Berkeley Springs contains a small percentage of calcium carbonate. At the surface the rock is hardened and slightly glazed by the solution and redeposition of silica between the grains. In depth, however, the rock is generally friable, the grains separating readily during blasting or by the use of the sledge hammer.

Mining industry.—The oldest mine, which is operated by the Pennsylvania Glass Sand Co., is located 2 miles from Hancock, on the top of the Warm Spring Ridge near its north end. Here the sandstone beds outcrop in rocky ledges 300 feet above the Baltimore & Ohio Railroad track at the west foot of the ridge. This mine was established before the Berkeley Springs branch was built up the Warm Spring Valley, and the only transportation facilities were by the main line. The other mines on the ridge were made accessible by the construction of the branch road and have been opened in comparatively recent years. The western side of the ridge is composed of Heldersberg limestone, through which a tunnel had to be constructed by the operating company to reach the sandstone. The mine is a large open cut, 120 feet deep, about 130 feet wide, and 400 feet long. At its south end is a tunnel from which much rock had been stoped, but this method of mining has been abandoned and the whole width of the ledge is now being worked as an open cut.

About 130 feet of rock, most of which is available for glass sand, is exposed in the quarry. The total thickness of the formation at this place is about 150 feet. The upper part is a hard bed 20 feet thick which is not mined, but forms the east or hanging wall of the pit. The sandstone as quarried varies from pure white to a creamy color; it is generally fine grained, but has here and there a coarse bed. Below the surface it crumbles in quarrying, and the sand is handled largely by shovel. Large lumps are readily broken with a sledge hammer; the few masses from harder beds that do not yield to this treatment and which were formerly thrown aside are now put through a crusher.

The mill is at the river, 200 feet below, which is reached by a narrow-gage railroad. The sand is passed through a roller or mull and is then washed and dried, the product being a pure white quartz sand suitable for table, window, and plate glass.

On the east side of the ridge 8 mines are operated by the Pennsylvania Glass Sand Co., West Virginia & Pittsburg Sand Co., Berkeley Springs Sand Co., Spier White Sand Co., and Foust & Bechtol Sand Co. All are open-cut mines, located near the middle of the eastern slope about 200 feet above the valley. They enter near the base of the sandstone exposure, some through a short tunnel in the hard capping sandstone and some through a narrow open cut in this stratum; in others all the rock is quarried as a wide open cut in the mountain side. The cap rock and the stained surface rock produce second-grade sand, but about 90 per cent of the product is of grade No. 1 and is reported to contain 98 per cent silica. The very choicest sand obtained which is used for the finest cut-glass ware, is reported to run 99.8 per cent silica.

Each mine has its mill at the foot of the slope, the mills being reached generally by aerial cable tramways. The newer mills are so constructed that the material is handled largely by gravity, passing consecutively through rock crusher, mulls, screens, washers, and driers to the storage bins or direct to the cars. The tailings are deposited in settling yards, and are sold for building and railroad sand.

Some of the purest sand is pulverized in roller mills, of which there are two in the area. Here the quartz is reduced to a flour for use in the manufacture of porcelain, china, and glazed brick.

A sand mine was opened by the Silica Sand Co., of Pittsburgh, Pa., on the west side of Cacapon Mountain, 1½ miles west of Berkeley Springs on the road to Great Cacapon, and a pit 20 feet wide and 150 feet long was quarried into the face of the hill in hard quartzitic sandstones of the Tuscarora formation, somewhat stained with iron. The quarry is admirably located for handling the product by gravity 500 feet down the steep mountain slope to the railroad, where a mill has been constructed with the different compartments arranged in terrace form, utilizing gravity in crushing, washing, drying, and storing the product ready for loading on the cars. The rock, however, is hard, even at the greatest depth in the quarry, and when crushed and ground does not separate into grains but breaks into fragments of various sizes, much being reduced to a powder. The product, therefore, is not a high-grade glass sand, and the amount of crushing and grinding necessary makes the cost of production high. The plant has been closed, and neither the possibility of its economic operation nor the availability of the Tuscarora sandstone as a source of glass sand has been demonstrated.

BUILDING AND RAILROAD SAND.

Quartz sand suitable for building purposes, concrete, and locomotive use, may be obtained from most of the outcrops of Oriskany sandstone in the area except those in the extreme eastern part, where the formation is largely cherty limestone. It may also be obtained for local use from the finer alluvial deposits.

The surface rock and the tailings from the settling yards of most of the glass-sand quarries are used for this purpose, and comprise a large per cent of their total output. At Hancock, on the Maryland side of the river, the coarse yellow Oriskany sandstone of Cove Ridge is quarried for building sand. It disintegrates readily at the surface and is dug at the top of the hill back of the town and hauled to the railroad, where it was extensively used in the concrete work of the Western Maryland Railway. Similar sand is quarried opposite Great Cacapon, where the Oriskany outcrops in Tonoloway Ridge, and large quantities were used by the Western Maryland Railway during construction. The sand is carried by gravity trams from the top of the mountain to the railroad. At several other points where roads cross the Tonoloway or Warm Spring ridges shallow openings have been made and sand has been extracted for local use.

[a] Shaw, E. W., High terraces and abandoned valleys in western Pennsylvania: Jour. Geology, vol. 19, 1911, pp. 140-156.

CEMENT ROCK.

Cement is made either by burning impure limestone of such composition that it makes natural cement, or by burning a mixture of non-magnesian limestone and shale or other argillaceous siliceous material, the product of which is called Portland cement.

Much of the Helderberg limestone in this region is sufficiently pure and free from magnesium to make good cement mixtures. The compact dark-blue or dark-gray beds of this formation occur in thick massive layers suitable for quarrying, and although most of them are more or less impure, the impurities are generally argillaceous and siliceous material that are essential to cement mixture. There are usually present in the exposures some purer limestone beds that can be utilized if necessary to bring the percentage of calcium carbonate up to the required amount, and shales of adjacent formations can supply ample argillaceous and siliceous material.

The general composition of the thicker limestone beds may be judged from the analysis of the rock from the quarry at Hancock, given below. The analysis shows that it is nearly free from magnesium and that it contains less siliceous and other impurities than are required for cement mixture, so that shale would have to be added. The percentage of each would have to be determined by careful analyses of each kind of rock and by practical tests of the resultant mixtures.

The Helderberg limestone occurs in several bands that cross the Pawpaw and Hancock quadrangles from south to north. The areas most readily available for cement manufacture are those on the east slope of Tonoloway Ridge and the west slope of Warm Spring and Cove ridges near the Potomac.

Such exposures as those at Lovers Leap, where the rock can be handled by gravity and where there is direct transportation and a near market, are especial inducements for economic production of cement, and more remote outcrops of similar rock will be made available as railroad facilities are extended away from the Potomac. The outcrops in the eastern part of the area are mostly remote from railroad transportation and are either poorly exposed or contain excessive amounts of siliceous impurities.

Several of the shaly limestones in the Wills Creek shale are natural cement rock similar to the water-lime strata so extensively worked in New York. These impure limestones have been mined and burned for cement for many years at Roundtop station, 2½ miles southwest of Hancock. The rock outcrops on the north bank of the Chesapeake & Ohio Canal, and dips on the average 50°. The section, showing the beds mined, is given in figure 5, page 6.

The beds worked are 6 to 8 feet thick, and were mined by tunnel from the canal bank. Since the beds dip steeply they have no lateral extent, so that when the readily accessible material was removed the cost of operation rapidly increased.

The Roundtop cement plant was in operation for many years prior to 1903 and its product was widely known and used. It has been closed for the past few years, largely on account of the decrease in demand for natural cement in favor of Portland, but in part because readily accessible beds of workable thickness have been removed and the cost of mining greatly increased. The composition of the Roundtop cement rock, with an analysis of one of the best natural cement rocks of New York for comparison, is given in the accompanying table.

Analysis of natural cement rock.[a]

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	CO_2 and H_2O.	Cementation index.
Roundtop, Md.	19.81	7.35	2.41	35.76	2.18	31.71	1.68
Rosendale, N. Y.	18.52	6.34	2.63	25.31	12.13	33.31	1.43

[a] Eckel, E. C., Cement, limes, and plaster, 1905, pp. 206-209.

The Wills Creek shale contains cement beds of variable thickness throughout its occurrence in both quadrangles, and the distribution of the formation is shown on the geologic maps. At no place in the area do the beds appear so favorable for cement manufacture as at the Roundtop mines, but this may be largely due to lack of good outcrops, the rock generally disintegrating to shaly particles on long exposure. It is reasonable to assume that along the strike of these beds on both sides of the Cacapon anticline, in West Virginia and Pennsylvania as well as in Maryland, cement beds occur in the Wills Creek shale equal in thickness and cement properties to those at Roundtop.

LIMESTONE.

Limestone is burned for lime only locally in the Pawpaw and Hancock quadrangles, although much of the Helderberg and some of the Cayuga beds are pure enough for this purpose.

At many places along the limestone outcrops in both of the quadrangles the rock has been quarried in small openings and been burned for field lime. On the upper west slope of Cove Ridge, 1 mile north of the Pennsylvania State line, a very pure limestone that will make an excellent quality of lime is obtained from the Helderberg limestone. It should warrant burning for building purposes and hauling to the railroad at Hancock. A mile farther north on the same ridge, where Great Tonoloway Creek temporarily enters the quadrangle, there is a rather large quarry of less pure rock that is burned largely for field use.

At Hancock the dark-blue compact limestone of the Helderberg, which is burned for local building purposes, has the following composition:

Analysis of Helderberg limestone, Whitmeyer-Bridges quarry, Hancock, Md.[a]

SiO_2	5.65
Al_2O_3	2.57
Fe_2O_3	0.68
CaO	50.48
MgO	.76
Ignition	40.17
	100.31

The Oriskany sandstone is very calcareous in the eastern part of the Hancock quadrangle, so much so that it is burned for field lime at the Licking Creek bridge east of Warren Point, at a small quarry 1 mile west of Cherry Run, and at Tomahawk. The Helderberg limestone is also quarried for burning at numerous points in this part of the area, especially on the flanks of Moore Knob and vicinity, and in the anticline west of Tomahawk.

COAL.

Occurrence.—Coal has been diligently sought in these quadrangles, and reports of its occurrence in wells and other indefinite places in various parts of the area are common. Coal may be expected within the quadrangles in only three narrow belts which are indicated on the geologic maps by the bluish color of the Carboniferous—the Meadow Branch Mountains, Sideling Hill including Spring Gap Mountain, and Town Hill. No commercial deposits have thus far been discovered, but the Meadow Branch field is now being systematically prospected on an extensive scale by a Pittsburg syndicate.

The coal occurs chiefly in the Hedges shale, but thin seams and coal smuts have been observed in the Rockwell formation and in the Purslane and Pinkerton sandstones.

Meadow Branch field.—In the Meadow Branch field the coal in the Hedges shale has been prospected by open pit, shaft, and slope. The best-known opening is the Chappelle shaft, which is sunk on the lower coal on the west side of Short Mountain on the east limb of the syncline, where the beds are vertical, and is reported to be 90 feet deep. The following section was measured by M. R. Campbell:[b]

Section of coal in the Chappelle shaft.

[By M. R. Campbell.]

	Ft.	in.
Coal, badly mixed with slate	4	4
Clay	1	3
Coal with two or three irregular partings	5	3
Clay	0	6
Coal reported but covered with slide	11	0
	22	4

An open pit at this place examined by the writer exposed a total width of 9 feet of coal with several thin shale partings standing nearly vertical but with a suggestion of close folding, indicating a repetition of the bed. At the Nihiser shaft farther south on the eastern limb, reported to be 130 feet deep, Campbell measured the following section:

Section of coal in the Nihiser shaft.

[By M. R. Campbell.]

	Ft.	in.
Coal	4	4
Slate	1	4
Coal	4	0
Slate	1	7
Coal	2	0
	13	3

This is apparently the same coal bed as that at the Chappelle shaft and corresponds very closely with the shaft section at that place except in the lower bench, which was reported as covered in the northern shaft. At a shallow slope on the west limb of the syncline northeast of Whites Gap, apparently on this same bed, Campbell measured the following badly weathered section:

Section of coal northeast of Whites Gap.

[By M. R. Campbell.]

	Ft.	in.
Coal, badly weathered	1	6
Clay	0	1
Coal, badly weathered	0	8
Clay	0	3
Coal	1	0
	3	6

Just south of the point where the Whites Gap trail ascends the mountain the Hunter slope enters at an incline of 35° SE. and shows from 3 to 4 feet of crumbled coal with several shale partings. The slope is reported to be 175 feet long and to show 2 feet of blocky coal at the bottom. This bed was also reached by the Rolly shaft on the east side of Meadow Branch, which struck the coal at 20 feet depth and was drifted east 150 feet down the slope of the coal, according to reports.

[a] Maryland Geol. Survey, vol. 8, 1909, p. 435.

[b] Campbell, M. R., The Meadow Branch coal field of West Virginia: Bull. U. S. Geol. Survey No. 225, 1904, pp. 330-344.

This coal bed near the base of the Hedges shale has been prospected by surface pits at many other places in the Meadow Branch field, conspicuously on the trail west of Myers and at several places on the road south of the Devils Nose. A somewhat higher seam is prospected on the trail from the Devils Nose toward the Chappelle shaft. A shaft among the sandstone débris on the north side of Hedges Mountain at Cherry Run gap is probably on the lower coal, which is here overturned and dips about 60° E. under the Purslane sandstone. The black shales interbedded with sandstone, and containing thin coal seams below the crest of Third Hill Mountain on the road east of Myers appear to occur in a local syncline of Hedges shale. A prospect in gray shale on the mountain 1 mile farther north showed no signs of coal on the dump.

There is a small prospect on the highest coal seam in the area in the Pinkerton sandstone near the north end of the west side of Third Hill Mountain. Only a crumbled coaly shale was found on the dump here.

Analyses of coal from the middle bench in the Chappelle shaft sampled by Mr. Campbell are given below. In the table, sample No. 1 represents the run of mine after large fragments of shale partings have been removed, and sample No. 2 is selected lump coal.

Analyses of coal samples from the Chappelle shaft.

[E. T. Allen and George Steiger, analysts.]

	1.	2.
Fixed carbon	73.20	79.64
Volatile carbon	9.00	11.51
Moisture	1.94	1.04
Ash	15.86	7.81
	100.00	100.00
Sulphur	.91	.81
Phosphoric oxide	.04	.02

The fuel ratios of the two samples of coal—the ratio of the fixed carbon to the volatile hydrocarbons—are 8.13 and 6.92 respectively, and indicate that the coal is a low semianthracite.

Should coal be found in commercial quantities in this field it will find a ready market because of its low volatile properties. The coal thus far exposed on the eastern limb is too badly crushed and mixed with shale to be profitably handled, however, and that on the western limb is too thin and impure.

Sideling Hill area.—Coal occurs at two horizons in the Sideling Hill syncline. A thin seam of coal in black shale near the base of the Rockwell formation is opened by a 30-foot tunnel in the north bank of Rockwell Hollow. Only carbonaceous shale with thin slivers of coal and plant remains were found on the dump, and the section of the strata could not be seen. This seam or its black shale is exposed at many points along the crest of the ridge on both sides of the river, but is best shown on the road above the Chesapeake & Ohio Canal, where the following section was measured:

Section of shale and coal at Sideling Hill above Chesapeake & Ohio Canal.

	Feet.
Hackly dark shale	8½
Thin coal and shale	1½
Hackly dark shale and thin concretionary sandstone beds	50
Dark "shoe peg" shale	15
Hard well-bedded shale	10
Thin-bedded ripple-marked sandstone and shale	5
Hard hackly dark shale	6
Granular sandstone	5
Hard dark-gray crumbly shale	5
Massive coarse sandstone.	

The coal is prospected in a small pit at the road and is opened by a 50-foot tunnel below the road. The bed is composed of very thin sheets of slickened coal mixed with black carbonaceous shale.

The other coal horizon in Sideling Hill is above the heavy sandstones of the Purslane formation. This seam has been prospected on the mountain top east of Little Orleans and on the upper slope of Sideling Hill gap north of the river. At the latter place the black shale and coal are underlain by a tough sandy underclay. North along the crest of Sideling Hill this coal streak has been traced at intervals and prospected at the road crossings.

Town Hill.—On Town Hill the lower dark shale is exposed at many places and a coal bloom has been prospected just south of the National Pike. On the slopes of Spring Gap Mountain the shale is barely exposed and the coal was not seen.

Conclusion.—It may be concluded from general observations and from the coals seen in prospects and natural exposures that commercial coals do not exist in the Pawpaw quadrangle. In the Hancock quadrangle also, unless the systematic search now going on in the Meadow Branch field proves the existence of coal beds less crushed and less mixed with shale than those heretofore reported, the coal field will be of no commercial value.

IRON ORE.

Small quantities of iron ore have been mined in this area at several horizons. The Clinton contains workable beds of hematite in many parts of the Appalachians, but the only known occurrence of such workable ore in these quadrangles is in the valley of Sir Johns Run, west of Berkeley Springs, where a considerable amount was dug several years ago. Heavy beds of red ferruginous quartzite on the west flank of Cove and Cross mountains and capping Keefer Mountain, in the northeastern part of the Hancock quadrangle, which are too siliceous to be worked for their iron content, represent an ore of the Clinton mined elsewhere in Pennsylvania.

Local deposits of very siliceous iron ore occur at the base of the Oriskany in the northeast section of the Hancock quadrangle. North of Moore Knob scattered fragments of ore, mingled with chert from the limestones of the Oriskany, cover the surface, and 1½ miles north of the knob a small prospect has been opened in a crumbly, porous, ferruginous sandstone. Small pits were also opened in bog iron ore on shale at the base of the Romney, 1 mile northwest of Yeakle Mill. These seem to be secondary surface deposits, probably leached from the adjacent Oriskany and deposited in swampy depressions in the shale. Probably no iron ores in the area have commercial value at the present time, but the highly siliceous ores of the Clinton and Oriskany may some day prove economically important.

BUILDING STONE.

Building stone for local construction can be obtained from most of the formations in the area. Sandstone is the most widespread material. Where present in shaly formations, like the Juniata, Jennings, and Catskill, it is generally thin bedded, somewhat earthy, and soft and can be readily quarried. The massive sandstones of the Tuscarora, Keefer, Purslane, and Pinkerton formations are quartzose and hard and not easily extracted in blocks of commercial size. The Purslane sandstone on Sideling Hill east of Little Orleans was, however, quarried for use in the construction of bridge piers and tunnels for the Baltimore & Ohio Railroad. The softer sandstones, especially those of the upper part of the Jennings, were extensively used in the construction of the Western Maryland Railway, and a large quarry is located east of Millstone. Much of the harder rock was crushed for concrete used in the culverts and retaining walls and for ballast.

At several places in the vicinity of Hancock the limestones of the Helderberg and Tonoloway are quarried for foundation stones, and in former times dwellings were constructed of these limestones. Slabby limestone from the Tonoloway is also quarried near Hancock for curbing and flagstones, and the red sandstone of the Bloomsburg member of the Wills Creek is quarried for foundations 2 miles northwest of that town.

ROAD METAL.

The rock best suited for road material in this area is the limestone of the Helderberg, Oriskany, Beekmantown, and Conococheague formations. Although the roads in general are badly in need of repair, limestone is at present not systematically crushed and used for this purpose. The Baltimore pike, where it was destroyed during the construction of the Western Maryland Railway, was surfaced in part when rebuilt with fine-grained marble from quarries farther east in Maryland. In road repairs, shale or soft sandstone from the nearest outcrops or gravel from near-by streams are generally used.

The longitudinal ridge roads, such as those on Timber, Pigskin, Coon, and parallel ridges north of the Potomac and on Highland, Pious, and Horse ridges south of the river, being nearly level, well drained, and made of shale and soft sandstone, are generally well kept and much used, but the abrupt ascent and descent at their ends makes heavy hauling over them almost impossible. The transverse roads are so hilly and of so diverse composition that it is impossible to keep them in satisfactory condition without frequent repair with good road material. The Beekmantown and other limestones of the Shenandoah group, which are extensively quarried just east of the Hancock quadrangle, as well as the Helderberg and Tonoloway limestones in this area, can be made available for this purpose over large areas at small cost.

BRICK CLAY.

Plastic clay commonly used for brick manufacture is not plentiful in these quadrangles. A small amount forms the subsoil over deeply weathered limestone and shale outcrops that are protected from erosion, and some is present in the finer alluvium on the river bottoms and terraces. A thin layer from the latter source was formerly dug back of Hancock, and dry pressed brick were manufactured from it, but the supply was soon exhausted. The brick plant is now being operated in the eastern section of the town, using shale from the Jennings formation. Similar soft shales suitable for brick manufacture occur in this and other shaly formations throughout the area but are not at present used. Tough clays underlying the coal beds in the Meadow Branch Mountains and in Sideling Hill are probably sufficiently refractory to make fire brick, and if beds can be found thick enough to be worked they may prove of economic value.

GRAVEL.

Gravel, composed chiefly of quartz and quartzite pebbles, occurs in the terrace deposits and alluvium along the Potomac and the other large rivers of this area but has been only locally used for concrete and road repair. A great variety of sizes can be obtained by screening the coarser terrace gravels, which can be handled largely by gravity because of their altitude and which in most places are conveniently located for transportation. The large deposits on the north side of the Potomac at and above Big Pool, those on the hill west of Cherry Run, and those on the high terrace west of Pawpaw are worthy of mention. As the demand for gravel in concrete work has so greatly increased, the deposits in this area may prove of value.

SOILS.

The soils of the Pawpaw and Hancock quadrangles are in general derived directly from the rocks beneath or from those immediately adjacent. Where the rocks are deeply mantled by alluvium or terrace gravels the soils are independent of the underlying rocks. The land immediately adjacent to the higher mountains is largely covered by a deep sandstone wash.

The alluvium and terrace soils, where not too stony, are rich, light, and loose, and make excellent farm land. They are located in the flat bottoms of the larger streams and on terraces along their sides, not only where terrace deposits are indicated on the areal geology maps but also where alluvial gravels not thick enough nor sufficiently widespread to be mapped are mixed with the rock soil and greatly enrich it. A continuous line of farms stretches along the banks of the Potomac and the bottom lands of the larger tributaries far back from the river where the uplands are but little cultivated.

The limestones weather to deep, rich, red or yellow clay soils that generally yield large crops. They comprise only a small portion of the area of the quadrangles, and are represented on the map by the patterns for the Helderberg, Tonoloway, Beekmantown, and Conococheague limestones. Much of the limestone soil is impaired by its content of chert, sandstone, and other detritus.

A large portion of the soils of the quadrangles is derived from formations of interbedded shale and sandstone, such as the Jennings and Catskill formations. These soils are prevailingly sandy, with frequent "stone breaks" and rock ledges, and occupy hilly land with steep slopes, seldom cultivated. The more gentle slopes and terraces composed of such rocks have proved to be especially suited to fruit culture. The more rugged portions are in woodland or pasture. A large tract of this land west of Little Orleans, lying on both sides of Lower Hill and extending to the Potomac, has recently been divided into 40-acre tracts, opened by roads, and successfully put on the market for fruit farming.

The Romney, Clinton, Martinsburg, McKenzie, and Wills Creek formations generally yield thin clay soils of fine texture but of comparatively low fertility. Because they are easily cultivated they are generally farmed and comprise, in fact, a large portion of the cultivated part of the quadrangles. The Tuscarora, Juniata, and all Carboniferous formations have prevailingly rocky soil, derived either from their own hard outcrops or from adjacent sandstone beds, and their steep mountain slopes are in general suitable for little else than the dense forest growth with which they are ordinarily covered.

SURFACE AND UNDERGROUND WATER.

The water resources of the Pawpaw and Hancock quadrangles may be considered perhaps most conveniently with respect to water transportation, water power, springs, and other sources of domestic supply.

Water transportation.—The Chesapeake & Ohio Canal parallels the Potomac River across these quadrangles and much of the coal, lumber, and other products of the regions to the west is transported over it to the seaboard. The canal, which begins at Cumberland, on the Potomac, tunnels a peninsula along the crooked part of the river one mile below Pawpaw, and has 16 locks in the two quadrangles. It passes over many streams by means of viaducts, and at two places in its lower course spreads out into wide lakes or pools. Its waters are replenished at Great Cacapon by a dam across the river which diverts part of the latter into the canal. The canal is used almost exclusively for commerce, but a few pleasure craft seek its placid water and beautiful scenery.

The canal was constructed before the Civil War, and in former times was the main source of transportation from western Maryland to tidewater. It is now largely supplanted by the two railroads that parallel its course and furnish much more rapid transportation.

The Potomac in this area has many rapids and shallows and has too strong a current to be serviceable for navigation but is used by pleasure craft. It is crossed by but one highway bridge in the quadrangles, that at Hancock. At Pawpaw Little Orleans, and Cherry Run vehicles can usually cross the river by ferry. Elsewhere the river can be forded only during low water.

Water power.—Many of the larger streams and their tributaries are available for the development of water power. By the construction of dams and of tunnels through necks of land water grade may be artificially increased or concentrated, and in mountain valleys with narrow outlets spring freshets may be stored in reservoirs and used for power as needed.

The only water power at present developed on a commercial scale is on the Great Cacapon, 1 mile above its mouth. A long narrow neck of land has been tunneled and a 15-foot dam diverts most of the water of the stream through the tunnel, which is 14 by 10 feet and 234 feet long. A fall of 18 feet is obtained by this means and an electric plant has been installed, equipped to generate over 750 horsepower. Electricity is transmitted from this plant to Great Cacapon, Berkeley Springs, and Hancock, where it is used in lighting, operating sand mines, mills, and in other industries. Small streams are dammed at a number of places in the area, and furnish power for small grist mills and saw mills. The most interesting of these small power plants was the one near Ziler Ford, where the water of a spring was formerly used to run an overshot wheel.

Springs.—Small springs are numerous in the mountain valleys and ravines throughout the area and are locally utilized for domestic purposes. The small streams issuing from ravines of both the mountains and lower hills, which are in general unadulterated spring water, are also used for this purpose. An interesting spring is the one at Ziler Ford in the southern part of the Pawpaw quadrangle, which, as has been stated, is of so great volume that it was formerly used to run a grist mill. Its waters issue from the Tonoloway limestone and are pure and uncontaminated, although hard from dissolved calcium carbonate, and could supply a large community. At Indian Springs, in the eastern part of the Hancock quadrangle, is a historic spring on the old Baltimore pike.

The west flank of Tonoloway Ridge and the east flanks of Warm Spring and Cove ridges, where the porous Oriskany sandstone dips steeply under impervious Romney shale so that water circulating under pressure in the sandstone finds an outlet at the contact, are especially favorable places for deep-seated springs. Some of the springs along these ridges are medicinal, such as the Sulphur Spring 2 miles north of Hancock.

At Berkeley Springs, W. Va., springs issue from numerous vents at the Oriskany-Romney contact. The four main springs have been walled up with masonry, and the water bubbles continuously through sand at the bottom into the inclosed pools of limpid water. Pipes lead underground to the bathhouses, which are equipped with tubs, individual pools, and two large swimming pools about 20 feet by 80 feet and 4½ feet deep, through which the surplus water flows continuously at its natural temperature, 73° F. For the individual baths the water is heated to any desired temperature by the injection of steam. These springs are historic, their use as a health resort dating back to Washington's time. They were originally owned by Lord Fairfax, and in 1776 the tract of land including the spring was set apart by an act of the Virginia legislature as a health resort under the control of 14 trustees. Washington, Lord Fairfax, and other noted men of their time had cottages there. The locality was then reached by the Bath or Warm Spring road, which after crossing the Shenandoah Valley from Washington enters the Hancock quadrangle at Hedgesville and passes over the hilly country around the north end of Meadow Branch Mountains. Residents of many eastern cities now visit this resort not only in search of health but for pleasure and rest. In addition to its use for bathing, many gallons of the almost tepid water, which is said to be especially beneficial to those afflicted with rheumatism and gout, are drunk daily by patrons of the springs. It can hardly be regarded as a mineral water, however, for a gallon contains only 13½ grains of mineral matter and small amounts of oxygen, carbon-dioxide, and nitrogen gases. The analysis of the water as determined for the company is as follows:

Analysis of water at Berkeley Springs, W. Va.

[J. H. Dickson, analyst.]

	Grains per gallon.
Iron	0.506
Calcium carbonate	9.577
Magnesium carbonate	1.951
Calcium sulphate	1.098
Sodium chloride	.244
Silica	.122
Total residue	13.498

The high temperature of the water can be accounted for most reasonably by assuming that it has come up through the sandstone from a depth of more than 1500 feet. Most springs of the region are formed by the seeping down of surface waters from higher levels. The cause of the rise of the water in the sandstone and its issuance at this place is not known. The flow from the combined springs has been roughly estimated at 1560 gallons per minute.

Other sources of domestic supply.—In the towns and villages as well as in the rural districts in the area water for domestic purposes is obtained from wells, springs, and running streams. Water is so plentiful at the surface and in shallow wells that deeper underground supplies need not be considered at the present time. However, the structure of the rocks is such that artesian water can be predicted for most of the synclinal areas. Porous sandy strata inclosed in impervious argillaceous beds occur at many horizons and serve as underground reservoirs, receiving their supply where the porous strata outcrop at the surface. If these were tapped by wells, water would rise to an elevation depending on hydrostatic pressure in the basin, and in favorable locations might flow at the mouths of the wells. No deep wells are known to have been drilled in the area. Hancock, Hedgesville, Berkeley Springs, Great Cacapon, and Pawpaw are the only towns in the area, and with the exception of Berkeley Springs they all depend on individual wells for their water supply. Because of lax sanitary precautions these wells are likely to be contaminated, as certain of the wells are known to have become, and as the towns grow greater care must be exercised. Sooner or later town water systems will be necessary; indeed, Hancock is at present planning such a town supply. As stated under the previous heading, small springs and uncontaminated streams furnish an abundant supply of water for the rural settlements except in very dry seasons, and this supply is not at the present time in much danger of contamination.

July, 1911.

FORMATION NAMES AND EQUIVALENTS.

System.	Virginia and West Virginia. (Franklin Folio, No. 32, U. S. Geol. Survey, 1896.)	Pawpaw-Hancock Folio.		Maryland. (Maryland Geol. Survey, vol. 6, 1906.)		New York. (New York State Museum Reports.)
CARBONIFEROUS (MISSISSIPPIAN SERIES)	Pocono.	Pinkerton sandstone.		Pocono.		Carbonic.
		Myers shale.				
		Hedges shale.				
		Purslane sandstone.				
		Rockwell formation.				
DEVONIAN	Hampshire.	Catskill formation.		Hampshire.		Catskill.
	Jennings.	Jennings formation.	(Parkhead sandstone member.)	Jennings.	Chemung.	Chemung.
					Portage.	Portage.
			Genesee black shale member.		Genesee.	Genesee.
	Romney.	Romney shale.	Hamilton arenaceous shale member.	Romney.	Hamilton.	Hamilton.
			Marcellus shale member.		Marcellus.	Marcellus.
			Onondaga shale member.			Onondaga.
	Monterey.	Oriskany sandstone.		Oriskany.		Oriskany.
	Lewistown.	Helderberg limestone.	(Becraft.)	Helderberg.	Becraft.	Becraft.
			(New Scotland.)		New Scotland.	New Scotland.
			(Coeymans.)		Coeymans.	Coeymans.
				Cayuga.	Manlius.	
SILURIAN		Tonoloway limestone.			Salina.	(?) Manlius and Cobleskill.
		Wills Creek shale.	Bloomsburg red ss. member.			Salina.
		McKenzie formation.	Keefer sandstone member.	Niagara.		(?) Shawangunk grit.
	Rockwood.	Clinton shale.		Clinton.		Clinton (including representative of Rochester shale).
	Cacapon.					
	Tuscarora.	Tuscarora sandstone		Tuscarora.		Medina.
ORDOVICIAN	Juniata.	Juniata formation.		Juniata.		
	Martinsburg.	Martinsburg shale.		Martinsburg.		Lorraine.
						Utica.
						Trenton.
	Shenandoah.	Chambersburg limestone. (Not exposed.)		Shenandoah.		Black River.
						Lowville.
		Stones River limestone. (Not exposed.)				Chazy.
		Beekmantown limestone.				Beekmantown.
CAMBRIAN		Conococheague limestone.				Upper Cambrian.
		Elbrook formation. (Not exposed.)				
		Waynesboro formation. (Not exposed.)				Lower Cambrian.
		Tomstown limestone. (Not exposed.)				

TOPOGRAPHY

STATE OF MARYLAND
WILLIAM BULLOCK CLARK
STATE GEOLOGIST

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

MARYLAND - WEST VIRGINIA - PENNSYLVANIA
PAWPAW QUADRANGLE

H. M. Wilson, Geographer in charge.
Triangulation by Geo. T. Hawkins.
Topography by J. H. Jennings and W. Carvel Hall.
Surveyed in 1898 in cooperation with the States of Maryland and Pennsylvania.

(Romney $\frac{1}{125000}$) (Winchester $\frac{1}{125000}$)

Scale $\frac{1}{62500}$

Contour interval 20 feet.

Datum is mean sea level.

TRUE NORTH / MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1910.

Edition of April 1900, reprinted April 1910, with corrections.

AREAL GEOLOGY

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MARYLAND - WEST VIRGINIA - PENNSYLVANIA
PAWPAW QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles.)

Qal	**Alluvium** *(gravel and silt in flood plains of the larger streams)*		QUATERNARY
Qtg	**Terrace gravels** *(stream gravel and sand on terraces and in abandoned channels 20 to 250 feet above present drainage)*		TERTIARY
Cp	**Purslane sandstone** *(massive white sandstone and quartz conglomerate)*	Mississippian (Pocono group)	CARBONIFEROUS
Cr	**Rockwell formation** *(buff shale, dark-gray shale with thin coal beds, and soft coarse arkosic sandstone)*	Mississippian (Pocono group)	CARBONIFEROUS
Dck	**Catskill formation** *(red micaceous sandstone and shale, with green, yellow, and grayish sandy layers)*		DEVONIAN
Djc	**Jennings-Catskill transition zone** *(red sandstone and shale of Catskill type at base; yellow sandy strata containing Chemung fossils in upper portion)*	Portage and Chemung	DEVONIAN
Dj, Dph	**Jennings formation** *(platy gray shale and buff sandy shale, with thin conglomerate beds and Parkhead sandstone member; Dph; Spirifer disjunctus fauna occurs directly above the Parkhead)*	Portage and Chemung	DEVONIAN
Dr	**Romney shale** *(dark-gray to black sandy shale, fissile at base, hackly above, with several hard sandstones in upper portion)*	Hamilton, Marcellus, and Onondaga	DEVONIAN
Do	**Oriskany sandstone** *(white quartzose sandstone, gray sandy and cherty limestone, and fine quartz conglomerate)*		DEVONIAN
	UNCONFORMITY		
Dh	**Helderberg limestone** *(massive dark-blue limestone and shaly cherty limestone)*		DEVONIAN
Stw	**Tonoloway limestone** *(finely laminated drab to dark-gray limestone, weathering to shaly limestone)*	Cayuga group	SILURIAN
Swc, Sb	**Wills Creek shale** *(platy drab calcareous shale, shaly limestone, and natural cement rock; Bloomsbury red sandstone member, Sb, at base)*	Cayuga group	SILURIAN
Smk, Sk	**McKenzie formation** *(gray shale with thin crystalline and laminated limestones; Keefer sandstone member, Sk, hard white sandstone, at base)*	Cayuga group	SILURIAN
Sc	**Clinton shale** *(drab to pink fine shale and thin sandstones, with locally thin iron-ore beds)*		SILURIAN
St	**Tuscarora sandstone** *(hard white massive and thin-bedded quartzose sandstone)*	Medina	SILURIAN
Oj	**Juniata formation** *(soft red sandstone and shale and locally quartz conglomerate)*	Medina	ORDOVICIAN

Faults

Concealed faults *(covered by surficial deposits)*

Strike and dip of stratified rocks
Strike of vertical strata
Horizontal strata

Quarries
Prospects

Note: *Glass sand and building sand can be obtained from the Oriskany; natural cement rock from the Wills Creek; limestone for lime and cement from the Helderberg and Tonoloway; thin coal from the Rockwell and Purslane; iron ore from the Clinton; shale for brick and cement, and stone for building, ballast, and road material from most of the formations in the area.*

H.M. Wilson, Geographer in charge.
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TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1910.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.

Edition of Oct. 1910.

Swartz, Stose, Martin, and Ohern | Stose

Geology by George W. Stose, Charles K. Swartz, George C. Martin, and D.W. Ohern. Ohern assisted by T.P. Maynard.

SURVEYED 1904-10 IN COOPERATION WITH THE STATE OF MARYLAND.

STRUCTURE SECTIONS

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Structure sections by George W. Stose.
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Ohern assisted by T. P. Maynard.
SURVEYED 1904–10 IN COOPERATION WITH THE STATE OF MARYLAND.

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

QUATERNARY

Qal — **Alluvium** (gravel and silt in flood plains of the larger streams)

TERTIARY

QTg — **Terrace gravels** (stream gravel and sand on terraces and in abandoned channels 20 to 250 feet above present drainage)

CARBONIFEROUS — *Mississippian (Pocono group)*

Cp — **Purslane sandstone** (massive white sandstone and quartz conglomerate)

Cr — **Rockwell formation** (buff shale, dark-gray shale with thin coal beds, and soft coarse arkosic sandstone)

DEVONIAN

Dck — **Catskill formation** (red micaceous sandstone and shale, with green, yellow, and grayish sandy layers)

Portage and Chemung

Djc — **Jennings-Catskill transition zone** (red sandstone and shale of Catskill type at base; yellow sandy strata containing Chemung fossils in upper portion)

Dj, Dph — **Jennings formation** (platy gray shale and buff sandy shale, with thin conglomerate beds and Parkhead sandstone member, Dph; Spirifer disjunctus fauna occurs directly above the Parkhead)

Hamilton, Marcellus, and Onondaga

Dr — **Romney shale** (dark-gray to black sandy shale, fissile at base, hackly above, with several hard sandstones in upper portion)

Do — **Oriskany sandstone** (white quartzose sandstone, gray sandy and cherty limestone, and fine quartz conglomerate)

UNCONFORMITY

Dh — **Helderberg limestone** (massive dark-blue limestone and shaly cherty limestone)

SILURIAN — *Cayuga group*

Stw — **Tonoloway limestone** (finely laminated drab to dark-gray limestone, weathering to shaly limestone)

Swc, Sb — **Wills Creek shale** (platy drab calcareous shale, shaly limestone, and natural cement rock; Bloomsburg red sandstone member, Sb, at base)

Smk, Sk — **McKenzie formation** (gray shale with thin crystalline and laminated limestones; Keefer sandstone member, Sk, hard white sandstone, at base)

Sc — **Clinton shale** (drab to pink fine shale and thin sandstones with locally thin iron-ore beds)

Medina

St — **Tuscarora sandstone** (hard white massive and thin-bedded quartzose sandstone)

ORDOVICIAN

Oj — **Juniata formation** (soft red sandstone and shale and locally quartz conglomerate)

Do not outcrop in quadrangle — **Martinsburg shale and underlying limestones**

Faults

Concealed faults (covered by surficial deposits)

45° Strike and dip of stratified rocks
Strike of vertical strata
Horizontal strata

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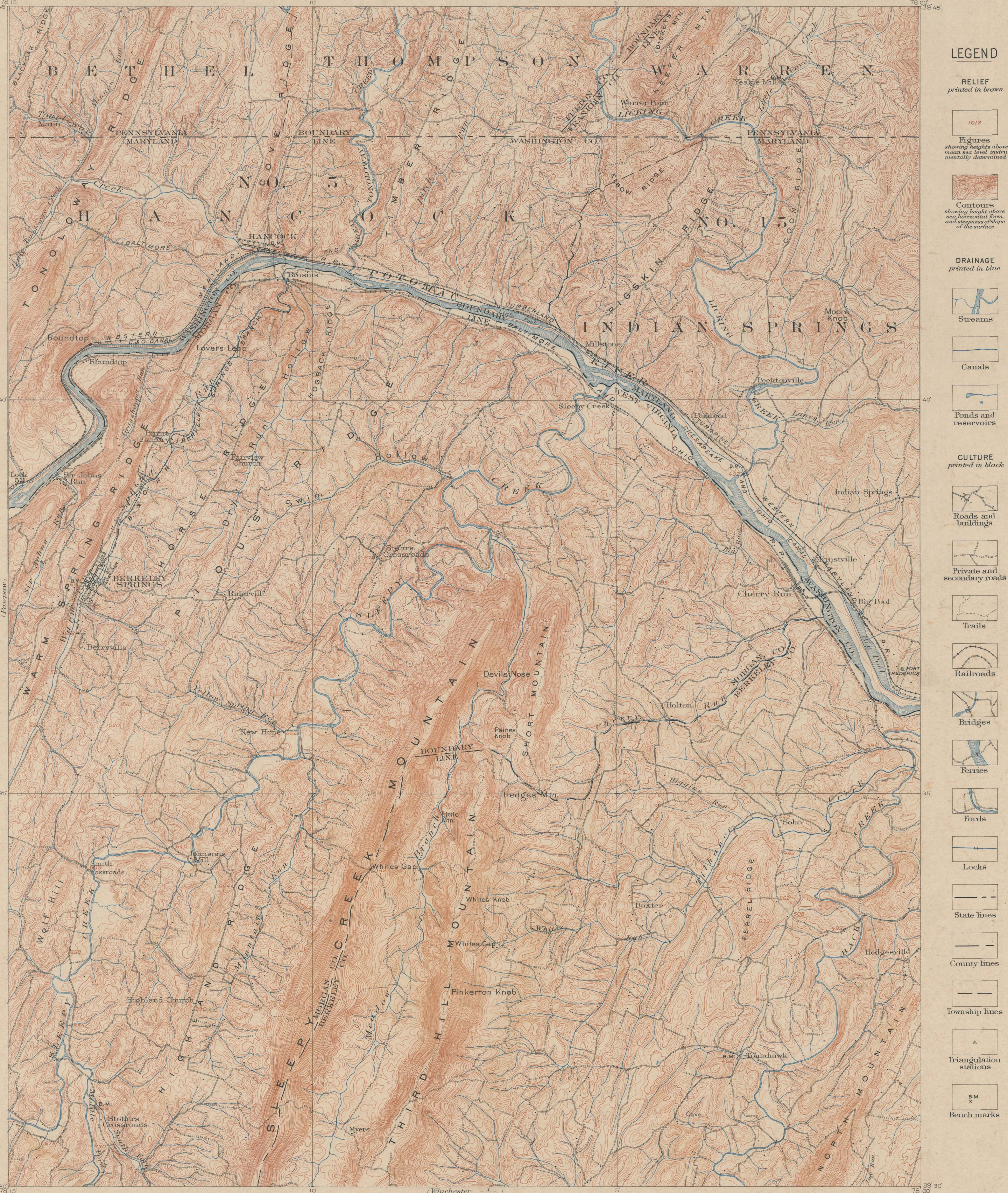

(Mercersburg)

(Winchester $\frac{1}{125000}$)

(Harpers Ferry $\frac{1}{125000}$)

H. M. Wilson, Geographer in charge.
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Hall | Morrill | Morrill

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TRUE NORTH · MAGNETIC NORTH · 5°

APPROXIMATE MEAN DECLINATION 1910.

Edition of Dec. 1901, corrected Nov. 1907, reprinted May 1910.

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TERTIARY

- Tg — **Terrace gravels** *(stream gravel and sand on terraces and in abandoned channels 20 to 250 feet above present drainage)*

CARBONIFEROUS — *Mississippian (Pocono group)*

- Cpk — **Pinkerton sandstone** *(massive white sandstone, quartz conglomerate, and platy sandstone with thin coal beds)*
- Cm — **Myers shale** *(red sandy shale and sandstone and cross-bedded arkosic sandstone)*
- Ch — **Hedges shale** *(dark-gray shale and thin sandstones with several thin coal beds)*
- Cp — **Purslane sandstone** *(massive white sandstone and quartz conglomerate)*
- Cr — **Rockwell formation** *(buff shale, dark-gray shale with thin coal beds, and soft coarse arkosic sandstone)*

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- Sc — **Clinton shale** *(drab to pink fine shale and thin sandstones with hard ferruginous quartzite at the top and locally thin iron-ore beds)*
- St — **Tuscarora sandstone** *(hard white massive and thin-bedded quartzose sandstone)* — *Medina*

ORDOVICIAN

- Oj — **Juniata formation** *(soft red sandstone and shale, and locally quartz conglomerate)* — *Medina*
- Om — **Martinsburg shale** *(soft buff sandy shale)* — *Trenton, Utica, and Eden*

SEQUENCE BROKEN

- Ob — **Beekmantown limestone** *(light-gray magnesian limestone and shaly cherty limestone)*

CAMBRIAN — *Upper Cambrian*

- Єc — **Conococheague limestone** *(hard siliceous banded limestone and calcareous sandstone with limestone pebbles)*

Faults

Concealed faults *(covered by surficial deposits)*

85° *Strike and dip of stratified rocks*
Strike of vertical strata
Horizontal strata

Quarries
x *Prospects*

Note: Glass sand and building sand can be obtained from the western areas of Oriskany; natural cement rock from the Wills Creek; limestone for lime and cement from the Helderberg, Tonoloway, Beekmantown, and eastern areas of Oriskany; thin coal from the Hedges; iron ore from the Clinton, Oriskany, and Romney; shale for brick and cement, and stone for building, ballast, and road material from most of the formations in the area.

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Edition of Oct. 1910

Stose, Martin and Swartz
Stose

Geology by George W. Stose, George C. Martin, and Charles K. Swartz.
Swartz assisted by W. F. Prouty.

SURVEYED 1904-10 IN COOPERATION WITH THE STATE OF MARYLAND

STRUCTURE SECTIONS

U.S. GEOLOGICAL SURVEY
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Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of Dec. 1910.

Stose, Martin and Swartz
Stose

Structure sections by George W. Stose.
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Swartz assisted by W.F. Prouty.
SURVEYED 1904-10 IN COOPERATION WITH THE STATE OF MARYLAND.

COLUMNAR SECTION

GENERALIZED SECTION OF THE ROCKS EXPOSED IN THE PAWPAW AND HANCOCK QUADRANGLES.

SCALE: 1 INCH = 1000 FEET.

System.	Series or group.	Formation.	Symbol.	Section.	Thickness in feet.	Character of rocks.	Character of topography and soils.
CARBONIFEROUS	MISSISSIPPIAN SERIES POCONO GROUP	Pinkerton sandstone.	Cpk		125+	Massive white sandstone and quartz conglomerate, in part cross-bedded, with a thin coal seam.	Wooded mountain tops. Stony soil with numerous rock outcrops.
		Myers shale.	Cm		800+	Largely bright-red crumbly sandy shale and thin argillaceous sandstones with thick cross-bedded dirty-gray gritty sandstone at base.	Wooded valleys and steep slopes. Sterile soil, in part covered by wash.
		Hedges shale.	Ch		170	Dark-gray to black carbonaceous shale containing thin seams of semianthracite coal.	Valleys. Largely covered by wash.
		Purslane sandstone.	Cp		180-310	Massive hard coarse white sandstone and milky quartz conglomerate, alternating with softer cross-bedded sandstone with a little shale and thin coal seams.	Wooded mountain tops and steep slopes. Stony soil with numerous rock outcrops.
		Rockwell formation.	Cr		500-540	Soft arkosic sandstone, fine hard conglomerate, and buff hackly shale; crumbly dark-gray carbonaceous shale with thin coal seams near the base in western part of area.	Steep wooded slopes. Largely covered by wash.
DEVONIAN		Catskill formation.	Dck		3000-4200	Chiefly red micaceous sandstone and shale with some yellow, green, and gray sandstones and shales. Gray to buff soft arkosic sandstone in upper portion, becoming harder platy gray sandstone in western part of area.	Wooded uplands, deeply trenched by valleys generally having a northeast-southwest trend. Sandy soil, suitable for woodland and fruit culture.
		Jennings-Catskill transition zone.	Djc		(0-500)	In western part of area yellow sandy shale and sandstone containing a Chemung fauna occur above the lowest red strata of Catskill type.	
		Jennings formation. (Contains Chemung and Portage faunas.)	Dj		4000-4800	Upper part, buff sandy shales and soft sandstones with two prominent beds of conglomerate and hard sandstone; lower part, crumbly gray fossiliferous shale, with greenish to drab fissile shale and very thin beds of fine sandstone at the base.	Wooded uplands, deeply trenched by valleys generally having a northeast-southwest trend. Sandy and clayey soil, stony on the higher ridges.
		(Parkhead sandstone member.)	(Dph)		(600)	Fine quartz conglomerate and gray and red sandstone interbedded with buff shale. Thin band of dark-red shale just below. Lowest known occurrence of *Spirifer disjunctus* fauna, 200 feet above Parkhead sandstone member.	
		Romney shale. (Contains Hamilton, Marcellus, and probably Onondaga faunas.)	Dr		1400	Chiefly dark-gray shale, fissile in lower part, hackly and lighter gray in upper part, with two thick sandstones in upper part and a thin bed of fine white conglomerate below.	Rolling upland and broad valleys. Soft clayey soil suitable for light farming.
		Oriskany sandstone.	Do		52-417	Granular white quartzose sandstone with fine conglomerate at the top and shale locally at the base. Largely cherty and siliceous limestone in eastern part of area.	Rocky ridges. Sandy soil with numerous rock outcrops.
		UNCONFORMITY					
		Helderberg limestone.	Dh		270-380	Massive dark-blue and thin-bedded gray limestones, weathering nodular, and calcareous shale; contains much chert at the top and a thick calcareous sandstone in eastern part of area.	Fertile slopes and valleys. Deep rich clay soil.
SILURIAN	CAYUGA GROUP	Tonoloway limestone.	Stw		400	Finely laminated light-gray limestone and calcareous shale, generally more shaly toward the top.	Cultivated valleys with minor stony ridges. Clay soil, largely fertile.
		Wills Creek shale. (Bloomsburg red sandstone member.)	Swc (Sb)		445 (60)	Soft light-gray calcareous papery shale and finely laminated impure limestones and cement rock; white sandstone bed, locally massive, generally present in upper part and red tough argillaceous sandstone and red mud rock at the base.	Valleys and low ridges. Deep clay soil in general. Barren soil over hills of Bloomsburg member.
		McKenzie formation. (Keefer sandstone member.)	Smk (Sk)		170-300 (40)	Thin beds of gray crystalline limestone in gray shale, with hard white sandstone beds at the base.	Sharp rocky ridges and slopes. Clay soil, largely covered by sandstone débris.
		Clinton shale.	Sc		550	Drab to pink fissile argillaceous shale with rusty-colored sandy beds. Hard red ferruginous sandstone occurs near the top in eastern part of area.	Broad valleys. High rocky ridge in northeast corner of area. Generally deep clay soil, in part covered by wash, suitable for light farming.
		Tuscarora sandstone.	St		200-270	Massive and thin-bedded fine-grained hard white quartzose sandstone.	High rocky ridges. Stony soil, generally forested.
ORDOVICIAN		Juniata formation.	Oj		200-400	Soft red micaceous sandstone and shale in alternating thin beds. Thick bed of white sandstone, containing scattered pebbles, near the base.	Slopes of ridges. Stony soil, in part cultivated.
		Martinsburg shale.	Om		1000+	Soft buff shale generally breaking to blocky fragments but in part argillaceous and fissile. Somewhat calcareous and sandy toward the top. Black fissile argillaceous shale at base faulted out in the area.	Slopes and open valleys. Clay soil suitable for light farming.
				SEQUENCE BROKEN			
		Beekmantown limestone.	Ob		1000+	Light-gray magnesian limestone and purer drab limestone. Calcareous shale and cherty limestone in upper part of exposure. Basal beds containing "edgewise" limestone conglomerates faulted out in the area.	Cultivated open valleys. Deep rich clay soil.
				SEQUENCE BROKEN			
CAMBRIAN	UPPER CAMBRIAN SERIES	Conococheague limestone.	€c		1250+	Highly siliceous and argillaceous limestone, some beds finely laminated with the impurities, others weathering to hard shaly particles. Purer oolitic light-colored limestone at the top. Basal beds of calcareous sandstone containing limestone pebbles not exposed in the area.	Open valleys with low rolling hills. Rich clay soil, stony and shaly in places.

PLATE I.—POTOMAC RIVER ABOVE CACAPON MOUNTAIN.
Looking west from the Silica sand mine on Cacapon Mountain. Sideling Hill gap in the distance; Tonoloway Ridge on the right. High terraces shown on both sides of the river.

PLATE II.—POTOMAC RIVER GAP IN SIDELING HILL, FROM PROSPECT ROCK ON CACAPON MOUNTAIN.
A remnant of the Harrisburg peneplain forms the terrace to the left of the gap. Tonoloway Ridge on the left and long oxbow of Great Cacapon River in the middle foreground.

PLATE III.—THE 900-FOOT TERRACE WEST OF WOODMONT.
Looking west. Sideling Hill gap in the distance. The terrace is the remnant of the Harrisburg peneplain shown in Plate II.

PLATE IV.—POTOMAC RIVER AND LEVEL-TOPPED RIDGES NEAR MAGNOLIA, W. VA., FROM SIDELING HILL.
The ridges preserve remnants of the Harrisburg peneplain. Town Hill in the distance.

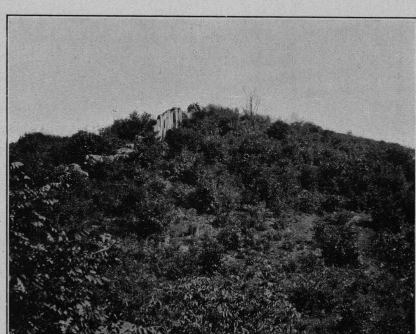

PLATE V.—WALL-LIKE OUTCROP OF KEEFER SANDSTONE MEMBER OF THE McKENZIE FORMATION.
Top of knoll at Fluted Rocks, east of Great Cacapon.

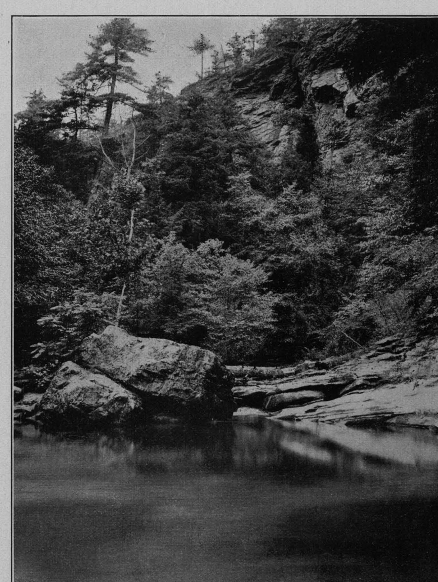

PLATE VI.—PURSLANE SANDSTONE CLIFFS, EXPOSED ON THE DEVILS NOSE BY MEADOW BRANCH NEAR NORTH END OF SLEEPY CREEK MOUNTAIN.
The beds are nearly horizontal in the bottom of the syncline.

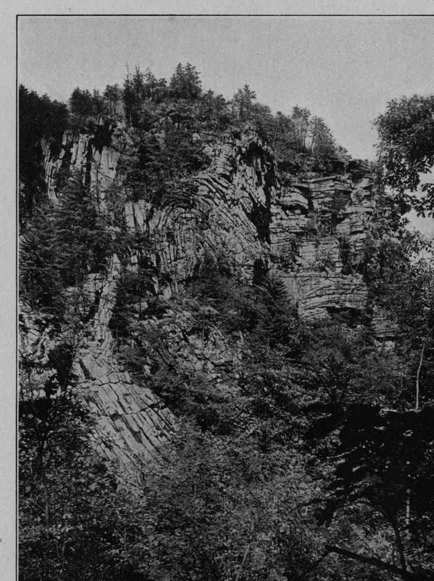

PLATE VII.—DETAILS OF THE STRUCTURE IN THE TUSCARORA SANDSTONE CLIFF AT EADES FORT WEST OF CACAPON MOUNTAIN.
Horizontal beds at the right connect the minor overturned anticline at the left with the major anticline of Cacapon Mountain to the right of the view, as shown in Plate VIII.

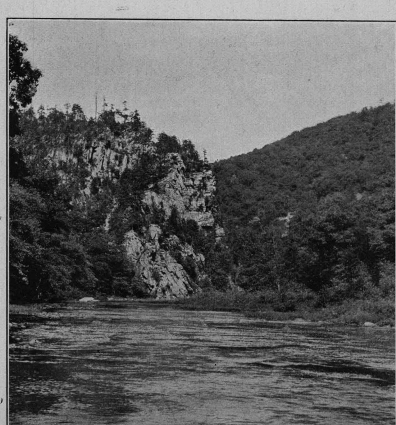

PLATE VIII.—EADES FORT, ON GREAT CACAPON RIVER.
The river has cut into these hard sandstone rocks and separated this mass from the main body of Tuscarora sandstone forming Cacapon Mountain at the right. Details of structure shown in Plate VII.

PLATE IX.—HIGH TERRACES AT THE GAP OF FIFTEENMILE CREEK IN TOWN HILL, FROM TOP OF KEENAN RIDGE.
Level top of Keenan Ridge in the foreground and other level terraces and ridges in the middle ground are remnants of the Harrisburg peneplain. Sideling Hill in the distance.

ILLUSTRATIONS II

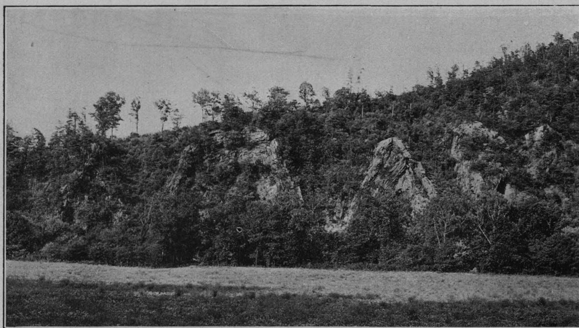

PLATE X.—GENERAL VIEW OF FLUTED ROCKS, NEAR MOUTH OF GREAT CACAPON RIVER.
Looking north. The resistant beds are the Keefer sandstone member of the McKenzie formation. The folds are largely concealed by summer foliage.

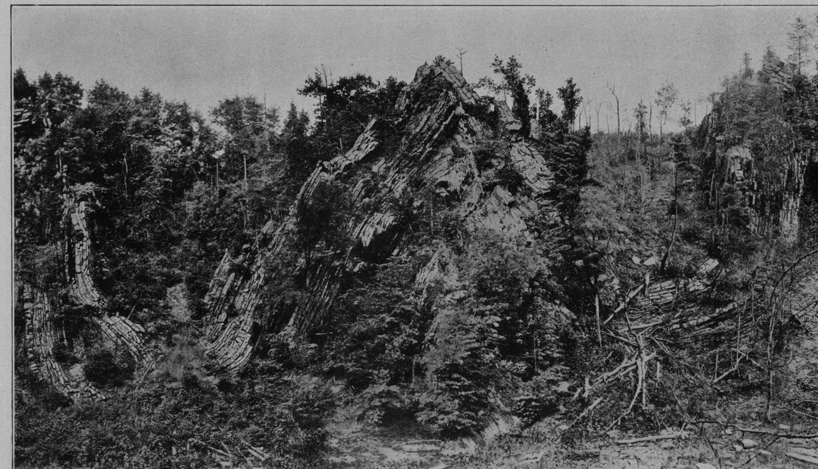

PLATE XI.—DETAIL OF THE MOST PROMINENT ANTICLINE AND ADJACENT SYNCLINES OF THE FLUTED ROCKS ON GREAT CACAPON RIVER.

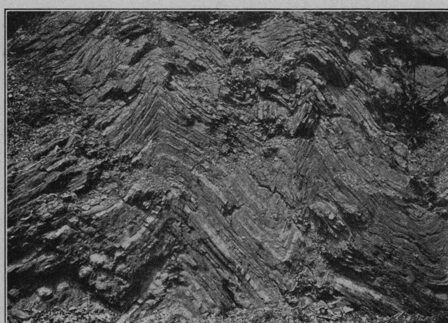

PLATE XII.—CLOSELY FOLDED THIN-BEDDED CRYSTALLINE LIMESTONE AND SHALE OF THE McKENZIE FORMATION.
In the Western Maryland Railway cut opposite Great Cacapon. Looking north.

PLATE XIV.—DETAILS OF STRUCTURE OF THE FLUTED ROCKS, ON GREAT CACAPON RIVER, AS SEEN IN THE LATE FALL UNOBSCURED BY FOLIAGE.

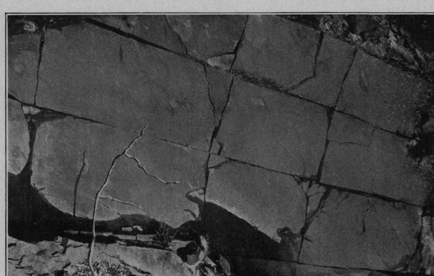

PLATE XIII.—RECTILINEAR JOINTING IN SANDY SHALE OF THE JENNINGS FORMATION.
In southwestern part of Hancock quadrangle 1 1-2 miles west of Stotlers Crossroads. Looking down on the surface of a horizontal bed.

PLATE XV.—CREEP IN ROMNEY SHALE.
Exposed in Western Maryland Railway cut northwest of Great Cacapon. The nearly vertical beds have been bent to 45° E. dip by the creep of the surface layers down the westward slope.

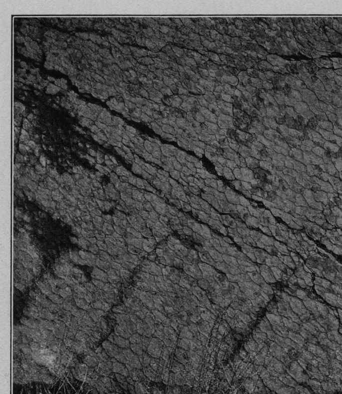

PLATE XVI.—SUN-CRACKED CALCAREOUS BEDS OF THE WILLS CREEK SHALE.
At mouth of cement-rock tunnel, Potomac, Md., 20 miles west of this area.

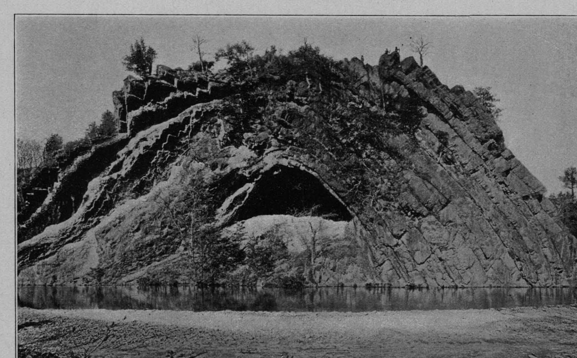

PLATE XVII.—SYMMETRICAL ANTICLINE OF BLOOMSBURG RED SANDSTONE MEMBER OF THE WILLS CREEK SHALE.
In bank of Chesapeake & Ohio Canal east of old cement works at Roundtop, Md. Looking north.

PLATE XVIII.—PECULIAR MARKINGS RESEMBLING BURROWS IN THE FINE MUD ROCK OF THE WILLS CREEK SHALE.
Exposed in the Western Maryland Railway cut 1 mile east of Great Cacapon. Narrow light-colored bands or filled channels lead diagonally downward across the mud-rock layer to a knotty contorted calcareous layer.

PLATE XIX.—CROSS-BEDDING IN THE SANDSTONES OF THE ROCKWELL FORMATION EXPOSED IN MEADOW BRANCH AT THE NORTH END OF SLEEPY CREEK MOUNTAIN.

PLATE XX.—RECENTLY FORMED CUT-OFF ON SLEEPY CREEK AT JOHNSONS MILL.
Looking downstream through the rock cut over which the stream is now falling into the ponded waters of the old channel.

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