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

GEOLOGIC ATLAS
OF THE
UNITED STATES

MERCERSBURG-CHAMBERSBURG FOLIO

PENNSYLVANIA

BY

GEORGE W. STOSE

WASHINGTON, D. C.
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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.

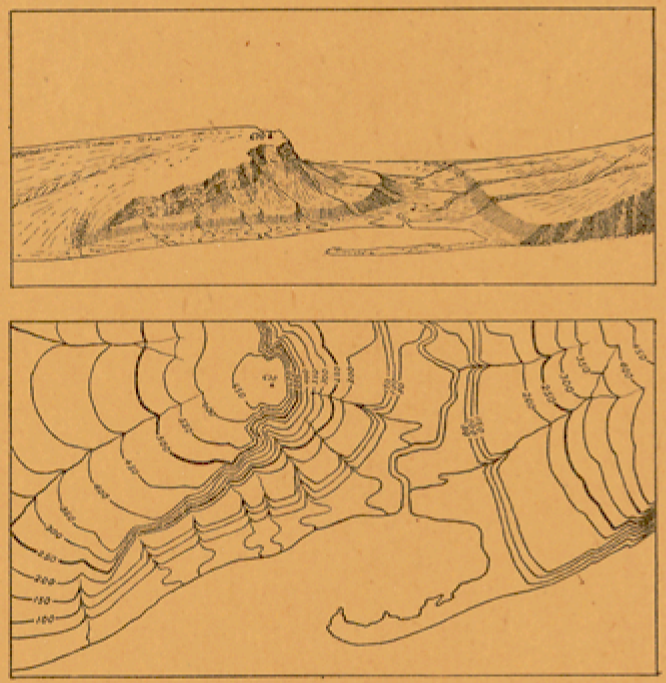

FIGURE 1.—Ideal view and corresponding contour map.

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*,

DESCRIPTION OF MERCERSBURG-CHAMBERSBURG DISTRICT.

By George W. Stose.

INTRODUCTION.

LOCATION AND AREA.

The Mercersburg and Chambersburg quadrangles are located in the south-central part of Pennsylvania, between parallels 39° 45′ and 40° and meridians 77° 30′ and 78°, and contain about 458 square miles. This area embraces the larger part of Franklin County and a small part of Fulton County. Its southern border is within 2 miles of the Maryland State boundary. (See fig. 1.)

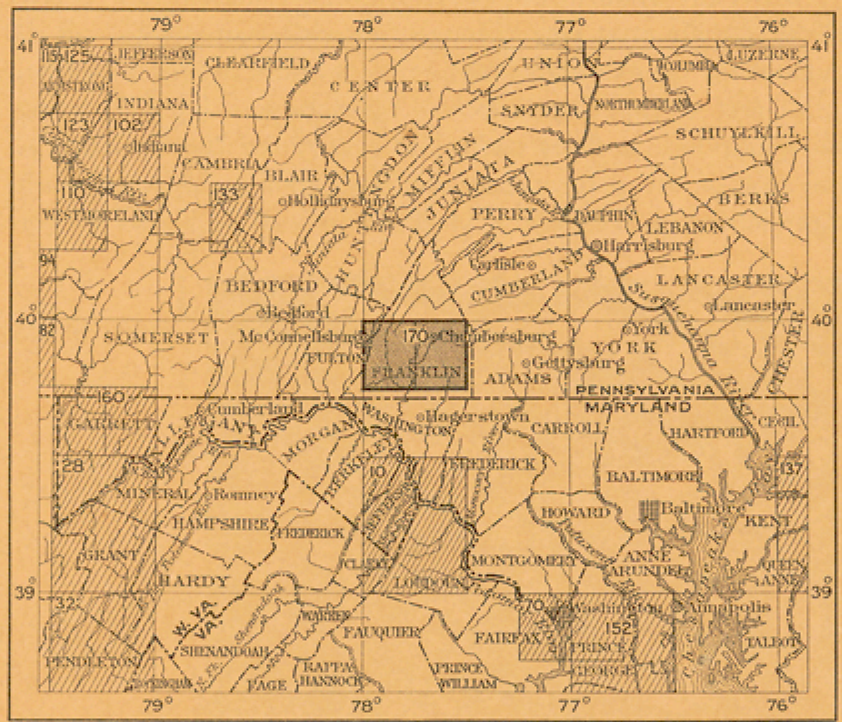

FIGURE 1.—Index map of the vicinity of the Mercersburg and Chambersburg quadrangles.

The dark shaded rectangle represents the Mercersburg and Chambersburg quadrangles. Other published folios covering parts of the area are 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.

APPALACHIAN PROVINCE.

These 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 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 Mercersburg and Chambersburg 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 characterized throughout by similar sedimentary deposits, geologic structure, and topography. The western division is named the Appalachian Plateau; the middle the Appalachian Valley; the eastern the Appalachian Mountains and Piedmont Plateau. These divisions extend the entire 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 is the Appalachian Valley. It is the most uniform and best defined of the three, being sharply delimited on the southeast by the Appalachian Mountains and on the northwest by the Appalachian Plateau. In its southern portion it coincides with the belt of closely folded and faulted rocks that form the Coosa Valley of Alabama and Georgia and the Great Valley of eastern Tennessee and Virginia; this portion varies in width from 40 to 125 miles. Throughout its central and northern portions the east side only is marked by great valleys, ranging in width from 8 to 13 miles and comprising 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 west side of this part of the Appalachian Valley is a succession of narrow valleys separated by parallel ridges, known as the Appalachian Valley ridges.

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, owing to the large amount of calcareous rock which is brought up on the anticlinal folds and exposed by erosion and the absence of some of the resistant sandstone, the surface is more readily worn down by streams and is lower and less varied than that of the mountain and plateau divisions on either side. This is true likewise of the eastern part of the northern portion of the Appalachian Valley, but in the western part sharp ridges and narrow valleys of great length follow the narrow belts of upturned hard and soft rocks.

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 minor ridges, which under various local names extend from southern New York to central Alabama. Chief among these are South Mountain in Pennsylvania, the 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 which lies at the eastern foot of the Appalachian Mountains. It stretches southward from New York to Alabama and merges on the east 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 which have been changed to slates, quartzites, schists, and gneiss by varying degrees of metamorphism, or igneous rocks, such as granite and diabase, which have solidified from a molten condition.

Appalachian Plateau.—The western division of the Appalachian province embraces not only the Cumberland Plateau of Tennessee and Georgia and the Allegheny Plateau of Pennsylvania and West Virginia but also the lowlands of eastern 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 thence crossing the States of Illinois, Indiana, and Ohio. Its eastern border along the Appalachian Valley is sharply defined in most places by the Allegheny Front and the Cumberland escarpment.

The rocks of this division are almost entirely of sedimentary origin and are but 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 the plateau is in places extensive and very flat, but it is more commonly intersected by numerous valleys and ravines, leaving small flat-topped areas. In West Virginia and portions of Pennsylvania the plateau is so largely dissected as to leave irregularly rounded knobs and ridges that bear little resemblance to the original surface. The western part 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 6700 feet. From this culminating point the eastern range descends to less than 1000 feet at its south end in Alabama and, toward the north, to 3500 feet in Virginia and 2000 feet in Maryland and Pennsylvania. The plateau division on the west of the Appalachian Valley has at its southern limit an altitude of 500 feet, ascends to 2000 feet in Tennessee, and culminates in eastern Kentucky at about 4000 feet, whence it descends 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. Thus it rises from less than 500 feet in Alabama to 2700 feet on the divide between New and Tennessee rivers, whence it descends to 2200 feet in the New River valley. It rises and falls likewise over the divides and valleys of James and Potomac rivers, reaching a minimum of 500 feet in the Potomac basin. In Pennsylvania it does not rise above 1000 feet. Throughout the length of the province the stream channels are incised 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 flows in part eastward into the Atlantic Ocean, in part southward into the Gulf of Mexico, and in part westward into Mississippi River. All of the western or Appalachian Plateau division, except a small area in Pennsylvania and another 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 Great 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, in Kentucky and Virginia, the longitudinal streams form New River, which flows westward in a deep, narrow gorge through the Cumberland Plateau and empties into Ohio River. From New River southward to the boundary of Georgia the Great Valley is drained by tributaries of Tennessee River, which at Chattanooga leaves the broad valley and, entering a gorge through the plateau, runs westward to the Ohio. South of Chattanooga the streams flow directly to the Gulf of Mexico.

General geology.—The rocks which appear at the surface of the Appalachian province comprise igneous rocks, 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 record complete. Only by combining the data from the various parts of the province can the general sequence of geologic events be determined.

The oldest rocks of the region consist chiefly of gneisses and schists and occur in the Piedmont Plateau. The original character of these rocks is entirely obliterated by the extensive alteration which has taken place during the long ages since their formation, and it is in large measure 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 while deeply buried in the earth caused the recrystallization of the mineral particles in new forms and associations and produced in the rocks a gneissoid or schistose structure. During an early period, while these schists and gneisses were still deeply buried, they were penetrated from below by great masses of molten material, which now occur upon the surface as granites, diorites, and other crystalline igneous rocks. This basal complex is generally regarded as belonging to the Archean period.

Upon these once deep-seated rocks, which were brought to the surface by uplift and long-continued erosion, lavas were poured in pre-Cambrian time. 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 confined for the most part to the Piedmont Plateau. In general, the oldest rocks lie on the east 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, which are 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 are far from being continuous sheets of deposits throughout the province, for portions of the sea bottom were at times uplifted into land and the sediments that had been deposited were exposed to erosion while other portions were still submerged. The sea in which these sediments were laid down was a body of water occupying the interior of the 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, probably as early as Algonkian time, and continued to the close of the Carboniferous.

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 were mainly calcium carbonate. This condition continued into the Ordovician period without a marked break in the sedimentation. Increased activity of the erosive agencies on the land marked the close of the Ordovician and the beginning of the Silurian, and a considerable thickness of quartz sand and pebbles equivalent in age to the Medina sandstone of New York were laid down through all but the south end of the province.

As far south as Virginia marine conditions continued to the close of Silurian time, the sediments becoming finer and finer until limestones were again deposited. Pure white sand and conglomerate equivalent in age to the Oriskany sandstone of New York ushered in the Devonian, representing another uplift of the land. This was followed by a vast accumulation of mud and sand on the sinking bottom of the shallow sea. South of Virginia the conditions during Silurian and Devonian time were different, for there only a few feet of Devonian black shale overlies the sandstone and shales 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 some of the Devonian.

The Carboniferous period began with the formation of marine deposits, in large part limestones, which in the southern part of the province are of great thickness. At the beginning of the Pennsylvanian or upper Carboniferous epoch there was an abrupt change to brackish-water and marsh conditions and the deposits of this age lie unconformably on the older Carboniferous strata and indicate a marked uplift of the sea bottom. Detrital material brought down by the streams accumulated in broad, shallow estuarine basins and with these sands and mud were occasionally buried layers of carbonaceous matter derived from dense growths of vegetation in the shallow waters of the estuaries or in marginal swamps. These layers have since been converted into the coal beds which form the great Carboniferous coal field of the Appalachians.

Sedimentation in the Appalachian province ceased at the close of the Carboniferous period, when the region was uplifted and the inland sea was drained and added permanently to the land. In local shallow basins on the eastern margin of the Piedmont Plateau flood or estuarine deposits were laid down during Triassic time. 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 mainly in the physiographic forms.

TOPOGRAPHY.

RELIEF.

The major portion of the Mercersburg and Chambersburg quadrangles is in the Appalachian Valley division of the Appalachian province. The extreme eastern portion of the area is a part of the Blue Ridge, or Appalachian Mountain division of the province. (See fig. 2.) The Appalachian Valley in this area has, as is general throughout the northern Appalachian region, two distinct divisions—an eastern or valley portion, locally known as the Cumberland Valley, and a western or mountainous portion, comprising the Appalachian Valley ridges.

Cumberland Valley.—The Cumberland Valley extends in a broad belt from Potomac River northward, curving gently eastward to Susquehanna River. It takes its name from Cumberland County, Pa., at its northeast end. It embraces the larger part of the Mercersburg and Chambersburg quadrangles, reaching from the foot of South Mountain on the eastern border of the Chambersburg quadrangle to the foot of the western ridges in the Mercersburg quadrangle, with a width of 15 to 20 miles. Its general surface in these quadrangles ranges in elevation from 550 feet at the southern margin to 800 feet in the northeast. This surface is rolling, and scattered over it are low, rounded hills rising 100 feet or more above the general level. These hills are most numerous along the eastern border of the valley, and one at Montalto reaches a height of 1100 feet. Little Mountain, in the same vicinity, with an elevation of 1200 feet, is a small rocky outlier of South Mountain and not a feature belonging to the plain.

The most pronounced elevation in the valley is the broad plateau west of Chambersburg, which has an altitude of 750 feet. It is best developed at the northern border of the area, where it is 3 or 4 miles wide and on its east side has a steep escarpment 150 feet high. On the west it merges into the valley plain and its border is not definite. To the south, although diminishing in width, it maintains its plateau character halfway across the quadrangles. Farther south it is less elevated, but flat table-lands with steep escarpments persist to the southern border of the Mercersburg-Chambersburg area. This is the only part of the valley proper which has rugged topography. The streams heading on the surface of the plateau cut deep, narrow ravines in its sides and the larger streams that cross it are intrenched in flat-bottomed valleys or canyons, but elsewhere the streams occupy open valleys in the plain, not much below the general surface.

Appalachian Valley ridges.—The western portion of the Mercersburg quadrangle is occupied by a series of straight, parallel ridges of approximately uniform height (see fig. 6, illustration sheet) which cross the quadrangle from north to south and inclose valleys—some narrow, rocky, and steep sided, others more open, flat bottomed, and fertile. The latter are called coves. The main ridge crossing the quadrangle is Tuscarora Mountain. Like the other ridges it is straight and sharp crested, with steep wooded slopes. Its general elevation is 1900 to 2000 feet, but in the northern portion of the quadrangle the ridge becomes broader and flat topped and attains an elevation of 2450 feet, the highest point in the quadrangle.

In the southern part of the quadrangle this ridge is paralleled on the east by Cove Mountain, and between them lies the narrow but flat-bottomed valley known as Little Cove. Although Cove Mountain is but 1700 feet high its crest is very rocky and jagged and difficult to traverse. (See fig. 8.) A line of high hogback hills that skirts the east foot of Tuscarora Mountain unites with Cove Mountain at Foltz and thus terminates Little Cove.

North of Foltz Cove Mountain loses its ridge character and is composed of knobs and spurs, with deep rugged valleys. It terminates in the hook-shaped ridge (Cape Horn) northwest of Fort Loudon, but Hogback Mountain, to the north, is really an outlier of Cove Mountain. On the west side of Tuscarora Mountain, near the north border of the area, another high, narrow ridge, also called Cove Mountain, branches from the main mountain, the two inclosing the narrow, steep-sided Allen Valley.

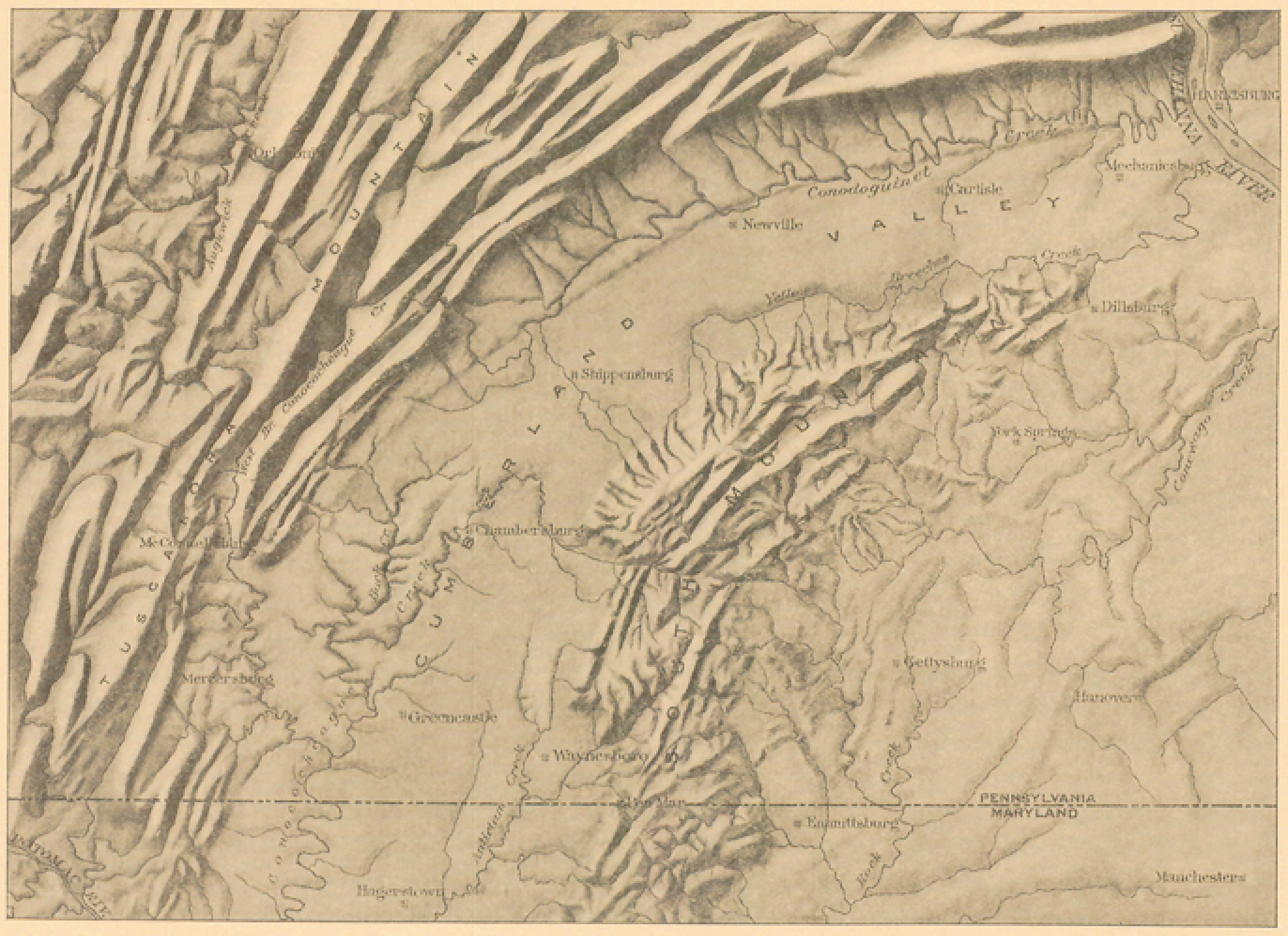

FIGURE 2.—Relief map of Cumberland Valley, the Appalachian Valley ridges (on the left), and South Mountain (on the right), in southern Pennsylvania.

The eastward curving of the valley and bounding ridges toward the northeast is clearly shown; also the offset of the west face of South Mountain into the valley opposite Waynesboro and Chambersburg. The doubling back of the ridges northwest of the valley is due to folding of the hard strata. The Mercersburg and Chambersburg quadrangles extend from McConnellsburg to the mountain front east of Chambersburg, and southward to Waynesboro. Scale, 1 inch = 10 miles.

East of this main belt of ridges four straight, narrow ridges of the usual Appalachian Valley type enter the Mercersburg quadrangle from the north and terminate toward the south in Jordans and Parnell knobs. (See fig. 7.) Their general altitude is from 1800 to 2000 feet. They inclose narrow rugged valleys, the westernmost of which, Horse Valley, widens toward the north into a cove many miles in length. This group of ridges, named North Mountain, forms the front range for some distance northeast. The offset of 4 miles in the mountain front at Jordans and Parnell knobs has its counterpart at the southern margin of the quadrangle, where the ends of the front ridges enter the quadrangle in Two Top and Claylick mountains.

Little Scrub Ridge, in the northwest corner of the quadrangle, although it has an elevation of 1700 feet, is a relatively low mountain, as the adjacent valley floor has an elevation of 1000 to 1100 feet. On its east side is McConnellsburg Cove, an elliptical fertile valley inclosed on all sides by mountains and low hills.

South Mountain.—Only a small portion of South Mountain lies in this area, in the eastern part of the Chambersburg quadrangle. It is composed in general of straight ridges trending northeast and southwest, but in this quadrangle the ridges and mountain front are offset into the valley at three points. South of East Branch of Little Antietam Creek the front ridge of the mountain enters the quadrangle near the extreme southeast corner and extends up the creek valley for several miles with a northeast trend. Curve Mountain and Sandy Ridge, which rise abruptly north of the creek, form the first offset. After running north for a short distance these ridges swing sharply to the northwest, producing another offset in the mountain front of 2 miles into the valley. To the east another ridge, Snowy Mountain, parallels these ridges and barely enters the quadrangle.

North of Quincy Mountain the ridges resume their northeast course, but are more dissected by transverse streams and their continuity is destroyed. Rocky Mountain, the highest of the front ridges, preserves its straight, narrow character beyond the quadrangle as far as Conococheague Creek, where it bends sharply toward the east. North of Conococheague Creek another offset of the mountain front into the valley is produced by a broad, flat-topped, steep-sided ridge, which is dissected by short, deeply incised lateral valleys. The portion of this ridge lying in the Chambersburg quadrangle consists of short ridges separated by deep ravines, arranged more or less radially about Big Flat, a small portion of the flat top of the mountain.

DRAINAGE.

Nearly the whole of the two quadrangles drains into Potomac River, for the most part through Conococheague Creek and its tributaries. The Conococheague rises in South Mountain several miles east of the Chambersburg quadrangle. Upon entering the quadrangle it flows north and west across the lowlands to the foot of the plateau west of Chambersburg, along which it meanders southwestward. At Williamson it is joined by one of its largest tributaries, Back Creek, which heads at Rocky Spring, near the northern border of the Chambersburg quadrangle, and flows across the upland area in a deeply incised gorge. Conococheague Creek continues to the south in a deep meandering valley, and near the southern border of the Mercersburg quadrangle is joined by its largest tributary, West Branch. This stream heads in Path Valley, several miles beyond the northern boundary of the quadrangles, and drains all the Cumberland Valley about Mercersburg and a part of the adjacent mountain area.

Little Cove Creek, Cove Creek, and Patterson Run flow independently southwestward into the Potomac. West Branch of Little Antietam Creek, which heads in the mountain just east of Montalto, and East Branch of the same creek, which rises some miles to the east of the Chambersburg quadrangle, also flow directly to the Potomac. South Branch of Little Aughwick Creek, in Allen Valley; Conodoguinet Creek, in Horse Valley; and Furnace Run, in the northeast corner of the Chambersburg quadrangle, are the only streams that drain northward into Susquehanna River.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

The rocks exposed in the Mercersburg and Chambersburg quadrangles are chiefly of sedimentary origin and include representatives of the Cambrian, Ordovician, Silurian, and Devonian systems. In South Mountain, in the eastern part of the area, volcanic rocks form the basement on which the oldest sediments were laid down. The area also contains alluvium in the stream bottoms and on terraces, wash and talus along the mountain fronts, and alluvial fans at the mouths of mountain gulches. The sequence, thickness, and composition of the sedimentary formations are concisely and graphically expressed in the columnar section.

IGNEOUS ROCKS.

Igneous rocks form a very small part of the surface of the Mercersburg and Chambersburg quadrangles. The only igneous rocks known to occur in this area are pre-Cambrian volcanic rocks—altered basalt and rhyolite—that cover large areas in the adjacent South and Catoctin mountains.

PRE-CAMBRIAN VOLCANIC ROCKS.

METABASALT.

An area of greenstone, not over half a square mile in extent, occurs in South Mountain east of Montalto, on the eastern border of the Chambersburg quadrangle. There are other small areas in the region just east of the quadrangle. In its least-altered state the greenstone is a dark, compact rock speckled here and there with dark-green chlorite, light-green epidote, or white quartz, which fill the vesicles in the amygdaloidal phases of the old lava. More generally it is a compact greenstone or chlorite schist, which cleaves roughly into thin slabs. Elsewhere it is intensely crushed, sheared, and veined with chlorite, epidote, and asbestos. All these phases are found within or near the quadrangle. The rock is an altered basalt flow, and is here called metabasalt in accordance with prior usage, but inasmuch as the texture as well as the mineral constituents have been altered it should properly be termed apobasalt.

The metabasalt is a part of the larger body of basic eruptives in South Mountain, which covers large areas in Pennsylvania, Maryland, and Virginia. It is locally called "copper rock" because of the copper ore associated with it in places and its green color. Its occurrence east of Monterey, Pa., has been described in great detail by F. Bascom,[a] who has made a special study of the petrographic character and original constitution of both the basic and the acidic lavas of South Mountain. In the adjacent region in Maryland it has been described by Keith[b] under the name Catoctin schist. In that region it is extensively intruded by granite, which occurs in long bands varying in width from a few yards to several miles. It is Rogers's "lower Primal slates" and Frazer's "chloritic schists" of the early reports of the Pennsylvania Geological Survey. The schistosity in the mountain rocks was mistaken by these geologists for bedding and the basaltic rocks were considered to underlie the rhyolitic rocks, hence the application of the term "lower" to these rocks. As the schistosity dips uniformly to the southeast, both types of volcanic rocks were supposed to overlie the quartzites and schists of the mountains and consequently to be younger.

The following petrographic description, based largely on the broader occurrences to the east, is by F. Bascom:

> The metabasalt shows little variation in texture or in mineral constitution. The texture is microphitic, and in spite of great alteration in mineral constituents the original ophitic fabric is everywhere discernible. Shearing obscures but nowhere obliterates it.
>
> The original mineral constituents, plagioclase, pyroxene, titaniferous magnetite, and olivine, have, with the exception of magnetite, almost completely disappeared. The pyroxenic constituent has been completely replaced by an amphibole mineral (usually actinolite) or by epidote or chlorite. Olivine crystals are well preserved in outline, and in some places a core of the original mineral remains. There is considerable feldspar still unaltered. It occurs both as porphyritic crystals and as a constituent of the groundmass. The crystals are synthetically twinned, but are too minute to allow an accurate determination of their species. That they belong to the basic end of the lime-soda feldspar series is shown by their extensive alteration to epidote and by the chemical analyses of the metabasalt.
>
> The vesicular character of these rocks has aided in the extensive replacement of their original minerals, and the amygdules are an index of the character of that replacement. Silicification, epidotization, and chloritization are the processes of alteration which have been most active.

APORHYOLITE.

An area of aporhyolite on the eastern border of the Chambersburg quadrangle in the valley of Rocky Mountain Creek is part of the greater area of acidic eruptive rocks which extends eastward for several miles and northward to the Conococheague and, together with basic eruptives, forms the floor upon which the Cambrian sediments were deposited. In the early reports of the Geological Survey of Pennsylvania the rhyolitic rocks were referred to by Rogers as the "Primal upper slates" and by Frazer as "orthofelsites." Under the heading aporhyolite in this report are included not only altered rhyolitic lavas that were once glassy but also less-altered rhyolites that have always been holocrystalline. In the larger area to the east the formation includes sericite schists that are rhyolites metamorphosed by pressure.

The devitrified rhyolite, or aporhyolite, has a wide distribution throughout the area of acidic volcanic rocks of South Mountain and forms a conspicuous part of the formation in the Chambersburg quadrangle. It is usually red or purplish in color, but varies to bluish gray. It is compact and fine grained, but in places is amygdaloidal. Phenocrysts are inconspicuous, while lines of flow structure are a marked feature. It also possesses a spherulitic structure, the spherulites in many places being very numerous and of large size. Where arranged in parallel dotted layers they are very striking in appearance and produce a banded effect in weathering, so similar to bedding that the term "bedded orthofelsites" was formerly applied to the rock. In this quadrangle aporhyolite with spherulitic and flow banding occurs along the western margin of the area, near the contact with the Cambrian sediments.

The lithoidal rhyolite ranges in color from deep red to purple and blue. It is a compact rock, usually containing conspicuous phenocrysts of light-colored feldspar, but in places it is a homogeneous felsite. It occurs chiefly in the level tract east of Rocky Mountain Creek. Schistose rhyolite was observed just outside the Chambersburg quadrangle along Conococheague Creek, and a short distance farther east very compact dark rhyolite, containing few phenocrysts and breaking with a conchoidal fracture, is quarried for road metal. Sericite schist is the extreme metamorphosed form of these rocks. None was seen within the quadrangle but it occurs plentifully in other portions of the volcanic area. The schistose planes, which are highly developed in the volcanic rocks of the area, strike parallel to the northeast and southwest trend of the ridges and dip from 35° to 50° SE.

The following petrographic description is by Dr. Bascom:

> The rock is composed of a fine-grained aggregate, or groundmass, of quartz and feldspar, in which occur relatively few and inconspicuous phenocrysts of the same minerals. The porphyritic feldspars are more abundant than the quartz phenocyrsts and are remarkably fresh. That they belong to the group of alkali feldspars and that both monoclinic and triclinic species are represented is indicated both by their optical properties and by their specific gravity (2.6). Anorthoclase is the prevailing species. The quartz phenocrysts are bipyramidal or rounded in outline, with characteristic embayments or inclusions.
>
> Biotite, the only ferromagnesian silicate known to be a constituent of the aporhyolite, occurs sparingly and in but few localities. Magnetite is generally present. The groundmass presents the interesting textures of the rock which testify to its original glassy character and subsequent devitrification. Chief of these are the fluidal, lithophysal, spherulitic, perlitic, micropoikilitic, and amygdaloidal textures common to glassy lavas.
>
> Fluidal texture, which is a conspicuous field feature of the aporhyolites, is due to the arrangement in parallel planes of flow of globulites and trichites of black and red iron oxide and other opaque minerals. The granular quartz-feldspar mosaic is unaffected by this texture, a fact which proves the secondary character of that crystallization.
>
> Lithophysæ and spherulitic texture are also conspicuous macroscopic features. Microscopically the original concentric or radiating arrangement of the crystals constituting the lithophysæ or the spherulites is found to be partly or completely replaced by a granular quartz-feldspar mosaic similar to that of the groundmass and, like it, secondary.
>
> Perlitic parting, or concentric ruptures due to contraction in a cooling glass, is preserved in outline in the groundmass of these lavas by means of iron oxide, but is completely obscured with crossed nicols by the granular crystalline mosaic. This fact also shows that the granular crystallization is the product of the devitrification of a once glassy groundmass.
>
> The evenly granular quartz-feldspar aggregate is locally modified by the micropoikilitic fabric—that is, the occurrence of relatively large, irregular quartz areas which include microliths of lath-shaped feldspars. This texture, as it is found also replacing the spherulites, is of secondary character, and its presence in the groundmass furnishes further proof of the secondary origin of the groundmass.
>
> Amgdaloidal texture, or filled vesicles, is common to both glassy and lithoidal lavas. In these aporhyolites the vesicles are elongated by flow movement and are universally filled with epidote or quartz or both minerals. These diminutive almond-shaped amygdules mottle the weathered surface of the aporhyolites.

RELATIONS OF THE VOLCANIC ROCKS.

The body of acidic eruptive rocks extending eastward from the border of the Chambersburg quadrangle occupies a relatively low area in the mountains, a level tract about 1600 feet in altitude, which has been dissected into open valleys and rounded slopes in the vicinity of Conococheague Creek. The hard quartzite beds of the Cambrian rise in peaks and ridges 400 to 600 feet above this undulating surface. The exact contact between the eruptive rocks and the sediments was not observed, but the basal portion of the clastic series seen in the eastern slope of Rocky Mountain and the northern face of Snowy Mountain is an arkose derived from the volcanic rocks. It is evident that the sedimentary and the volcanic rocks are separated by an erosion interval.

As to the relative age of the acidic and the basic eruptives, very little is known. In the immediate vicinity of the Chambersburg quadrangle the contact between the two was not observed. South and east of this area, where exposures of the basic rocks are more extensive, Dr. Bascom observed one place where the rhyolitic rocks apparently underlie greenstones and concluded that the acidic rocks are the older. If this conclusion is correct, the larger part of the basic rocks in the vicinity of the quadrangle were eroded during the encroachment of the early Cambrian sea, for only small areas of these rocks outcrop on the pre-Cambrian surface recently exposed. Their fragments therefore should compose a large part of the overlying clastic rocks. On the contrary, the basal conglomerate and arkose of the Cambrian, as seen in the quadrangle and in South Mountain to its end near Dillsburg, are composed so largely of rhyolitic fragments that give them a reddish color that they are with difficulty distinguished from sheared rhyolite, and little detritus has seemingly come from the basic rocks. From these data, therefore, it is tentatively concluded that the acidic rocks overlie the basic and that the latter have been but recently exposed in the small area shown on the map.

An estimate of the thickness of the volcanic rocks can not be made. In one place they are reported to have been penetrated by a well to a depth of 110 feet, and in the valley of Rocky Mountain Creek they have been dissected to a depth of 300 feet. Their total thickness is probably much greater.

SEDIMENTARY ROCKS.

The sedimentary rocks in the Mercersburg and Chambersburg quadrangles comprise the sandstones and shales of South Mountain, the limestones of the Cumberland Valley, and the shales and sandstones of the Appalachian Valley ridges. These rocks as a whole are coextensive with the Appalachian province from New York to Alabama, but they differ in detail from place to place. So far as is possible, the same formations are recognized throughout the province. Of the formations occurring in this area, some have their type section in Tennessee and the South and others in New York, but the greater number have been less widely traced and local names are employed. The columnar section shows graphically the rocks arranged in the order in which they occur and gives a concise description of the formations. In the following paragraphs they are described in detail.

CAMBRIAN SYSTEM.

The Cambrian system in this and adjacent areas includes sandstones and quartzites with interbedded schists and shales overlain by thick limestones. Named from the base up the formations represented are the Weverton sandstone, Harpers schist and Montalto quartzite member, Antietam sandstone, Tomstown limestone, Waynesboro formation, Elbrook formation, and Conococheague limestone. The sandstone formations have been recognized throughout the length of South Mountain from Dillsburg, Pa., to Potomac River. The limestones, which comprise the lower part of what has hitherto been called the Shenandoah limestone, have not been previously subdivided into formations.

WEVERTON SANDSTONE.

Character and thickness.—The oldest sedimentary rocks in the area described are a series of feldspathic sandstones and purplish conglomerate which overlie the volcanic basement complex in the Chambersburg quadrangle. Continuous exposures across the strike of the rocks in the mountains are nowhere obtainable, the softer rocks being almost invariably obscured by the débris of the harder sandstones, even in stream sections. As these rocks are exposed better in the ravines and ridges southeast of the quadrangle, in the vicinity of Monterey, than within the quadrangle, frequent reference to those sections will be made. The contact with the basement volcanic series was not observed in the area covered by this folio.

The lowest beds seen consist of soft purplish arkose, composed largely of fragments of the pre-Cambrian rhyolitic rocks and quartz grains. This rock is exposed in the north face of Snowy Mountain and at the east base of Rocky Mountain. On the road crossing Rocky Mountain east of Montalto a fresh exposure in a roadside quarry exhibits this soft arkose containing flat fragments of reddish schist 2 inches across.

Overlying the soft arkose are the mountain-making purple sandstone and conglomerate which form the crest of Rocky Mountain. The composition of these massive beds, like that of the underlying arkose, shows that they were derived largely from fragments of acidic volcanic rocks. Although markedly feldspathic, the rock has a large percentage of quartz grains and pebbles and is in general firmly cemented into a quartzite, so that it resists weathering and forms rocky ledges on the mountain tops. The crest of Rocky Mountain, as its name suggests, is composed of bare, jagged rocks, with great talus slopes on the east. At The Narrows the formation is freshly exposed with a steep dip to the west, and the coarse, feldspathic, and sheared characters of the rock are well illustrated. An unusually coarse quartz conglomerate occurs along the trail south of The Narrows.

Southeast of the Chambersburg quadrangle, on the road from Roadside to Monterey, green fissile slate is exposed above this sandstone, and farther south in Red Run and Falls Creek similar fissile slate of a darker color, banded, and minutely crinkled on the cleavage planes, together with thin shaly sandstone, outcrops along the same strike. These softer rocks were not observed in the quadrangle, however, the first rocks

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[a] Bull. U. S. Geol. Survey No 136, 1896.

[b] Keith, Arthur, Harpers Ferry folio (No. 10), Geol. Atlas U. S., U. S. Geol. Survey, 1894, p. 2.

seen above the massive sandstone being light-gray feldspathic sandstone and hard white quartzite, which are exposed on the west slope of Rocky Mountain, on the road that crosses the south end of the mountain. The best exposures of these uppermost beds of the Weverton sandstone are on the ridge just southeast of the quadrangle on the road to Monterey and on Falls Creek southwest of the Buena Vista Hotel, where the white quartzite ledges are very prominent.

The thickness of the several beds of the Weverton sandstone can not be accurately determined, but their relative proportions are shown in the columnar section. The total thickness of the formation, computed from dips and width of outcrop, is about 1250 feet.

In zones of great compression the rocks are so sheared and metamorphosed that the original bedding and even the character of the original sediment can not be determined. The sandstones and conglomerates become quartz schists, with cleavage planes covered with scaly sericite dipping at low angles to the southeast. The softer argillaceous layers are altered to shiny fissile schist, some of which is minutely crinkled.

Distribution and surface form.—This formation does not cover a large area in the Chambersburg quadrangle, but is extensively exposed beyond the eastern boundary, where it flanks the pre-Cambrian rocks. It has a gentle westward dip in the ridge just west of Monterey, and its massive ledges are exposed at the pike 1 mile west of the old tollgate. It enters the Chambersburg quadrangle in Snowy Mountain, the highest ridge in the quadrangle. This ridge terminates to the east in Chimney Rocks, with an 800-foot escarpment of flat-lying sandstone, from the top of which a magnificent view of the plateau and mountains to the east may be had. Rocky Mountain marks the northward continuation of the formation in a narrow belt of steeply inclined beds.

Correlation.—The formation is named the Weverton sandstone from Weverton, Md., where it is prominently exposed in the gorge of the Potomac at the south end of South Mountain. It has there a thickness of about 500 feet, as reported by Keith, who has traced and mapped the formation from the Potomac to the southeast corner of the Chambersburg quadrangle. In this quadrangle the formation corresponds in lithologic character and position with that at Weverton, except that the basal soft arkosic sediments were not separated as the Loudoun formation, described by Keith as a variable complex of slates with beds of limestone, sandstone, and conglomerate constituting the base of the sedimentary series in Maryland.

The northeastward extent of the Weverton sandstone has not been continuously traced, but at the northeast end of South Mountain it is represented by thick, coarse quartz conglomerate and sandstone. The formation is not known to be fossiliferous, but it underlies sandstones that contain undoubted Georgian (Lower Cambrian) fossils and is therefore probably the basal Cambrian sediment.

HARPERS SCHIST.

Character and thickness.—The Harpers formation in this area is composed largely of schist, hackly slate, and soft sandstone, although its most conspicuous portion is a heavy sandstone or quartzite near the middle, which everywhere forms a high ridge. The softer portion of the formation is seen in but few outcrops, as its slopes and valleys are covered by the débris from the sandstone beds. Its clearest exposure in this vicinity is just beyond the southeast border of the Chambersburg quadrangle, on the road from Waynesboro to Monterey, where the rock is largely a dark hackly slate or fine quartz schist apparently dipping 35° SE. However, the true bedding, indicated by white bands and alternation of beds of different composition, dips steeply to the west.

In the quadrangle most of the schist areas are indicated only by scattered loose fragments and by longitudinal valleys suggesting softer rocks. The only exposures of any consequence that have been observed are in Vineyard Run and in the small valley above the Waynesboro reservoir, in the southeast corner of the quadrangle. At the former place hackly black slate with white banding overlies the quartzite member, and this is overlain by thin-bedded, hard, dark ferruginous sandstone, which is exposed for more than half a mile in the bottom of the run and in the gap to the west. Above the Waynesboro reservoir dam, which is built on the outcrop of the quartzite member, lies sheared gray shaly sandstone thickly studded with minute octahedrons of magnetite; below the dam green micaceous schist outcrops. At Panther Rock, 1 mile to the northeast along the same belt, black banded slate occurs beneath the quartzite. In the northern part of the quadrangle only fragments of dark soft sandstone and red ferruginous slate were seen along the schist belts.

The thickness of the formation at Harpers Ferry, as estimated by Keith, is 1200 feet. In the Chambersburg quadrangle the most accurate determination of the thickness is obtained at the ends of the plunging anticlines northeast of Waynesboro and north of Fayetteville, where the dips are low and uniform. Here it has a calculated thickness of 2750 feet including the Montalto quartzite member, which is about 750 feet thick. The schist and slate were derived from soft shales by metamorphic processes due to compression. The purer argillaceous beds were altered by pressure into hackly slates, but none were pure enough to produce a true slate. In most places the altered rock is a schist, the impurities being changed to mica and sericite. These minerals are arranged parallel to the planes along which movement took place during compression and give the rock its schistose character.

Montalto quartzite member.—At about the middle of the Harpers schist there is a massive quartzite which forms Montalto Mountain and Sandy Ridge and is named the Montalto quartzite member. It is not as massive as the Weverton sandstone, and consequently its exposures are not so numerous. Its outcrops on the crests of the ridges are usually represented by a line of loose masses of the rock covered by a dense growth of trees and shrubs and show only here and there as undisturbed exposures.

On Sandy Ridge, where the dip is at a low angle to the southwest, scattered masses cover the gentler western dip slope and a talus of great blocks lies at the foot of the steeper eastern escarpment. Even in the deep gorge at Montalto Park the severed edges of the sandstone are concealed by coarse talus. On Vineyard Run, however, a scolithus-bearing bed of the Montalto is exposed with a steep dip under the hackly banded slate on the west. In the ravine east of White Rocks the harder portion of the Montalto is composed of two ledges, the lower a massive white vitreous quartzite, the upper a softer white sandstone containing numerous straight scolithus tubes, 8 to 10 inches in length. The massive bed is in many places streaked with black from included iron oxide, which stains the surface red on weathering. The total thickness exposed at this place was not more than 250 feet, but from the distribution of sandstone fragments the Montalto is estimated to be 750 feet thick. To the north it increases in thickness and at the northern border of the quadrangle is at least 1000 feet thick.

To the south the Montalto quartzite diminishes in thickness so rapidly that it disappears a short distance beyond the limits of the Chambersburg quadrangle. At Panther Rock, on Deer Lick, southeast of Antietam Cove, a small creek has cut a narrow passage through the vertical wall of rock, which is here less than 20 feet thick, and has excavated a small cove behind it in the slate. Farther south its ledges form the foundation of the Waynesboro reservoir dam, and on the pike from Waynesboro to Monterey it appears as a small but resistant bed in the schist and a ledge on the hilltop above the road. This is the last exposure of the quartzite seen in this direction.

Distribution and surface form.—The Harpers schist and Montalto quartzite member compose a large part of the South Mountain area in the Chambersburg quadrangle, occupying a belt about a mile wide extending across most of the eastern part. The Montalto member forms a nearly continuous prominent ridge, beginning at Antietam Cove with Sandy Ridge and continuing in Quincy Mountain, Montalto Mountain and its northward extension, and the main mass of the Big Flat ridge north of the Conococheague. The outer ridges and peaks of the Big Flat mountain mass—Pleasant Peak, Eagle Rock, Stony Knob, and others unnamed—have numerous exposures of bare rock of a higher (Antietam) sandstone horizon.

The top of Big Flat Mountain is generally free from ledges, or even large sandstone blocks, but is strewn with small scolithus-bearing sandstone fragments from the upper bed of the Montalto. In Cold Spring Run this upper bed occurs in the stream bottom east of Crawford Springs as large masses of very white sandstone, full of long scolithus tubes. The north slope of the valley is the dip slope of the underlying hard darker non-scolithus sandstone which outcrops at many places on the surface and forms the rocky crest of the knobs northeast of Eagle Rock. Similar quartzitic rock outcrops in the most deeply incised ravines in this mountain mass and the lowest beds exposed are probably part of the Montalto member. The valleys on the west side, excavated in the schist between the Montalto quartzite knobs, such as Poke Hill, and the Antietam sandstone hills, such as Stony Knob, are very narrow, owing probably to the thinning of the upper shale, which is here only about 650 feet thick as compared with 1000 feet in the southern part of the quadrangle.

Correlation.—The Harpers schist takes its name from Harpers Ferry, W. Va., where bluish-gray slate or schist of this formation is freshly exposed in the Potomac and Shenandoah river gorges. This belt of slate extends northward into Maryland for several miles, but is terminated against younger limestones by a fault before it reaches the Pennsylvania state boundary. An eastern belt of the same formation passes northward along South Mountain into Pennsylvania and enters the Chambersburg quadrangle at its southeast corner. As described by Keith, sandy layers occur at various horizons in the slate but are not a conspicuous feature of the formation at the type locality. They increase in thickness toward the north and in the Chambersburg quadrangle form a zone of sandstone sufficiently resistant to produce such elevations as Montalto Mountain and Sandy Ridge. Still farther north, in Big Flat Mountain, the sandstone zone increases in thickness and the schist is nowhere exposed. Toward the northeast it is coextensive with South Mountain. At Dillsburg, where the anticline passes beneath the Triassic sediments, the schist is concealed and sandstone apparently occupies the entire interval between the Weverton and Antietam sandstones.

No fossils except casts of *Scolithus linearis* have been found in the formation, but it is known to underlie sandstones containing a Georgian (Lower Cambrian) fauna and is therefore assigned to that age.

ANTIETAM SANDSTONE.

Character and thickness.—The Antietam sandstone is the uppermost of the mountain-making formations of South Mountain and is the bed that usually forms the front ridge in this area. It is a pure coarse-grained quartzose sandstone in which are two distinct harder members, a lower, dense, hard rock, in places bluish, and an upper, granular, white or pinkish rock with numerous scolithus tubes. These members are best exposed at White Rocks and on Cold Spring Run.

The lower rock is usually a ridge maker and weathers into blocks which mantle the tops and slopes of the mountains. Some of the upper beds are loosely cemented and weather readily into cream to buff sand, which is quarried for building purposes. At the top the quartz grains are mixed with white clay and the formation seems to merge into white clay shale or sericite schist at the base of the Tomstown limestone. The thickness of the Antietam sandstone can not be measured in the Chambersburg quadrangle, but it is calculated to be about 500 feet in the southern part of the area and apparently 800 feet in the northern part.

Distribution and surface form.—The formation occurs in a narrow irregular belt crossing the eastern part of the Chambersburg quadrangle from south to north. It outcrops at few places and its presence is usually indicated mainly by fragments. The western slope of Curve Mountain is strewn with fragments of the scolithus bed and along its crest are blocks of the lower harder bed; the latter forms a great talus below Burns Knob and in the gorge of Biesecker Run, where a few of the lower beds only are exposed, with a dip of 20° SW. At the west end of Curve Mountain a hard dark granular quartzite is prominently exposed in massive ledges striking north across the flat-topped spur between Tomstown and Tartown, with small fragments of soft scolithus sandstone on the west slope. For 4 miles to the north from this spur the formation does not make a ridge, but masses of both the hard quartzite and the soft scolithus rock are present along the lower western slope of Quincy and Montalto mountains. At the western base of Pine Knob soft disintegrated sandstone merging into harder pinkish sandstone is quarried on a large scale for building and railroad sand. Above, on the lower slope of the mountain, is a thin slabby sandstone which was once quarried for building stone. These beds are overturned and dip 65° E. The lack of ridge-making character in this strip may in part be accounted for by the weakening of the strata through crushing and shearing in this highly compressed zone and by the steep dip of the beds, which brings the Antietam sandstone and the Montalto quartzite so close together that but one ridge is formed. It is possible, however, that the massive bed of the Antietam was originally thinner or less resistant at this point.

At White Rocks the formation again appears as a ridge of milk-white vertical ledges. The upper or western beds are coarse and full of scolithus borings and have a dip of 80° W. The lower beds are massive and somewhat conglomeratic, with no well-defined bedding but a pronounced cleavage due to shearing which dips 35° E. White ledges form the top of the ridge toward the north to the point where it dwindles in height. Here several sand quarries have been opened, both the upper scolithus bed and the lower bluish sandstone being disintegrated at the surface into readily workable sand. The dip of the beds at this locality is to the west at a low angle.

North of Conococheague Creek the Antietam sandstone forms the line of knobs and short ridges that encircle the mountain mass of Big Flat. These elevations are especially well shown on the south and east sides in Eagle Rock, Pleasant Peak, and a line of sharp northeastward-trending ridges beyond the limits of the quadrangle. On the west side the rocks are steeper and the line of knobs is not so marked.

The rock is usually well exposed in these ridges, the scolithus bed forming the outer slope and the harder bed the crests and peaks. At Cold Spring Gap the scolithus ledges form the low, sharp spur which deflects the stream westward as it enters the plain. The harder sandstone bed occurs in the bottom of the gorge and ascends the slopes at a low angle to form the crests of the peaks on either side. The formation has a calculated thickness of 750 feet here.

On both sides of Phillaman Run, on the west slope of the mountain, the scolithus beds with white to yellow vitreous quartzite below form prominent ledges dipping 55° W., and a short distance to the east another ledge of vitreous quartzite occurs. At Devil Alex Hollow the same sequence may be seen, the two upper beds forming the low rocky ridge of the mountain front and the lowest bed making Stony Knob. This indicates an increase in the thickness of the sandstone to about 800 feet and a corresponding decrease in the thickness of the upper portion of the Harpers schist, as previously explained.

Little Mountain is an outlying ridge of Antietam sandstone brought up by a faulted anticline. Both the vitreous rock and the scolithus bed outcrop and their fragments are plentiful on the surface, but few rock exposures are to be seen.

Correlation.—The Antietam sandstone was named from Antietam Creek, on whose tributaries good exposures of the formation occur in the Harpers Ferry quadrangle. It has been traced by Keith from the type area to the hills in the extreme southeast corner of the Chambersburg quadrangle. In the Harpers Ferry area it has a thickness of 500 feet. The formation has been traced around the northeast end of South Mountain near Dillsburg.

A few fossils were found by Walcott in the scolithus sandstone and associated shales 1 mile south of the Waynesboro reservoir, on the pike between Waynesboro and Monterey; they consist of a small shell, *Camarella minor*, fragments of *Olenellus*, and *Hyolithes communis*. The same fossils occur in similar sandstones along the mountain front at Eakles Mills, Md., and at Mount Holly Springs, Pa. *Olenellus* fragments occur in the same beds in the southeastern portion of the Chambersburg quadrangle and also north of Conococheague Creek, half a mile east of the quadrangle border. These fossils determine the age of the formation to be Lower Cambrian.

TOMSTOWN LIMESTONE.

Character and thickness.—The limestone series of the northern Appalachian Valley is known comprehensively as the Shenandoah group. In southern Pennsylvania it is divisible into seven formations, the Tomstown, Waynesboro, Elbrook, Conococheague, Beekmantown, Stones River, and Chambersburg, which may be more or less readily recognized elsewhere in this part of the valley, especially by the aid of fossils.

The Tomstown limestone, the lowest of these divisions, is not well exposed in the area here considered, because of its nearness to the mountains, where the surface is thickly covered by wash, and knowledge of its character is obtained from scattered outcrops of limestone and shale. It is composed largely of dolomite and limestone, massive and thin bedded, and in part cherty, with considerable shale interbedded near the base. Certain of the limestones are of sufficient purity to be burned for field lime. On account of the relatively soluble character of the formation it forms a depression between the mountain and an irregular line of low ridges and knobs of the Waynesboro formation farther out in the valley. Its thickness, computed from the width of its outcrop and the dip of its beds, is about 1000 feet. This is best determined southeast of Tomstown, where the rocks have a gentle dip of 10° under the red shale and sandstone of the Waynesboro formation which compose the low hills to the south.

The base of the formation is everywhere covered by wash and the details of its character are not known. In an iron-ore pit in the northern part of Tomstown fine-grained dolomite is exposed close to a sand pit where the disintegrated uppermost bed of the Antietam sandstone and fine white clay are quarried. Coarse dolomite having a fetid odor occurs close to the sandstone in the old iron-ore pits north of Montalto Park. Pure white hydromica slate (sericite schist) was reported from many of these old mine pits, and shales outcrop in the railroad cut near Montalto Park, so that shales interbedded with dolomite compose the base of the formation.

The uppermost beds of the Tomstown, exposed just below the siliceous rock of the Waynesboro in the north and east faces of the hills north of Roadside, are massive, banded, hard blue magnesian limestones with a small amount of black chert. Within the formation occur other massive beds, chiefly magnesian or siliceous, and thinner, purer dark limestones which in places are burned for lime.

Distribution and surface form.—The formation follows the foot of South Mountain as a belt of lowland about 1 mile wide, spreading out to nearly double that width at Montalto. At Little Antietam Creek it is offset by a fault and extends up the valley into the mountains.

The largest exposure of the formation is in the village of Tomstown, whence its name. Here 75 feet of hard, massively bedded magnesian limestone outcrops. Similar beds appear along the foot of the mountain to the southeast, accompanied by chert and thinner-bedded limestone. At the schoolhouse 1 mile east of Tomstown a large surface of flat-lying massive limestone is exposed and broken up in such a way as to produce a rugged, rocky spot that is uncommon for this formation. Still farther south along the mountain front east of Roadside the massive limestone has been quarried at several points, especially just beyond the border of the quadrangle.

North of Tomstown outcrops of this formation are of rare occurrence. Small quarries in the purer dark limestone have been opened in the vicinity of Slabtown and north of Montalto Park. North of Little Mountain the wash from the mountains is so thick that the bed rock is entirely hidden, but to judge from the distribution of higher formations, the Tomstown limestone probably occupies a belt along the foot of the mountains to the limits of the quadrangle.

Correlation.—But few fossils have been found in this formation in the Chambersburg quadrangle. At Roadside excellent specimens of *Salterella* sp. undet., with an intervaginate structure, were obtained in the upper limestones of the formation. These fossils definitely determine its age as Lower Cambrian. Walcott also found in this limestone at the foot of the mountain east of Little Antietam Creek *Kutorginia* n. sp. and fragments of *Olenellus*.

In the vicinity of Mount Holly Springs, Pa., 30 miles to the northeast, the formation is exposed at few localities. The white sericite schist at the base is here very thick in places and, as seen in the clay mines, is apparently interbedded with the uppermost layers of the Antietam. The fetid coarse-grained dolomite near the base is also exposed in a few places.

In central Virginia a formation apparently occupying the same interval has been named the Sherwood limestone by H. D. Campbell. It consists of crystalline white dolomite below and heavy-bedded blue to gray magnesian limestone and shale above, and is 1600 to 1800 feet thick. This formation probably includes beds which in the Chambersburg area are calcareous sandstones and are mapped with the overlying Waynesboro formation. For this reason, and also because the large unmapped area between the two localities makes correlation indefinite, the new name Tomstown has been given to the formation in the Chambersburg quadrangle.

WAYNESBORO FORMATION.

Character and thickness.—The Waynesboro formation is a series of calcareous sandstones, red and purple shales, and minor limestones overlying the Tomstown limestone. Because of its resistant siliceous character it forms hills and knobs, parallel to the mountain front. Northeast of Waynesboro, where the formation is best exposed, the line of hills is double, forming concentric arcs 1½ and 2 miles from the foot of the mountain.

At the base is a very siliceous gray limestone which weathers to slabby porous sandstone, and this produces the innermost ridge of the formation. The residual sandstone slabs and associated large masses of round rugose chert and secondary white vein quartz cover the outer slopes of these hills and are gathered in great quantity in the fences surrounding the fields. In places the sandstone takes the form of minutely laminated iron-stained contorted cherty rock, with cavities filled with beautiful drusy quartz. The crest of the ridge west of Tomstown is composed of this rock, and large masses of it are scattered over the field on the western slope. To the north this rock is the chief marker of the basal beds of the formation.

In the middle of the formation are dark-blue limestone, dolomite, and fine-grained white marble, probably several hundred feet thick, which form a valley between the sandstone ridges and are generally not exposed. In its upper part the limestone becomes siliceous and merges into mottled slabby sandstone and dark-purple siliceous shale at the top of the formation. These hard beds form the outer ridge of the belt. The upper shales and slabby sandstones are ripple marked and show many indications of irregular bedding and current action.

The thickness of the formation, computed from the width of outcrop and the dip, varies from 1000 to 1750 feet, but minor folding is known to be present where the larger figure was computed and 1000 feet is approximately correct.

Distribution and surface form.—The Waynesboro formation occupies a belt about half a mile wide along the east side of the Cumberland Valley in the Chambersburg quadrangle. It is marked by hills and knobs, arranged in a linear direction parallel to the mountain and as a rule distinguished by outcrops of hard purplish shale. Its most complete development is in the hills northeast of Waynesboro, from which it takes its name. The hills immediately adjoining the town, on which the cemetery and reservoir are located, are composed chiefly of the hard purplish shale of the upper member. The uppermost slabby calcareous sandstone is finely exposed on the lower slope of the hill half a mile east of the town, where it is quarried for building stone and flagging. In the quarry where unweathered it passes into siliceous limestone. The upper siliceous member continues northeastward in the hill that curves sharply to the south and ends at Little Antietam Creek, where this member is cut off by a fault. The lower sandstone member forms the inner arc of hills that terminate at Roadside. Limestone, in part white marble, occupies the valley between these ridges.

North of Waynesboro the rocks are steeper and the valley between the ridges is less marked. The two sandstone members are well shown in the hills west of Tomstown, the eastern ridge consisting of iron-stained cherty sandstone and the western ridge of purple shale and thin sandstone. The high ridge west of Montalto is composed of sandstone, purplish shale, and iron-stained cherty rock, in a complicated close fold. To the north the belt of purple shale can be traced past Little Mountain; the iron-stained siliceous rock is present here and there, but the sandstone members are not so prominent as farther south and can not be traced continuously. North of Little Mountain this formation is almost entirely hidden by the wash from Conococheague Creek and smaller streams, which is here thick and widespread. A patch of the purple shale was seen on the Shippensburg road near the northern border of the quadrangle.

Correlation.—The only fossils found in this formation in the quadrangle are a few poorly preserved shells, two of which were identified as *Obolus* (*Lingulella*) sp. undet. They were obtained from sandy shale at the very top of the formation, at the tollgate just east of Waynesboro. They suggest Acadian (Middle Cambrian) age but are not conclusive.

Because of the thick covering of wash in the northern part of the quadrangle it is not known how far the formation can be recognized in that direction, but from such facts as could be gathered the sandstones seem to lose their distinguishing characters and the shale some of its reddish color. The purple shale is exposed at only a few points at the northeast end of the mountain, near Mount Holly Springs.

South of the quadrangle the red color persists but the sandstones do not seem to be so strongly developed. In central Virginia the "Buena Vista" shale described by H. D. Campbell lies at this general horizon but apparently has a different lower limit. It is described as bright variegated shale, chiefly red but in part yellow, green, and brown, with mottled limestone and shale in the lower part. It is 600 to 900 feet thick, and in it Walcott found a species of *Ptychoparia* related to Middle Cambrian species of Tennessee. From fossils recently collected in Virginia, Bassler has concluded that the purple shale is of Lower Cambrian age. The purple shale has been traced by Keith almost continuously across southern Virginia into Tennessee, where it is named the Watauga shale.

ELBROOK FORMATION.

Character and thickness.—The Elbrook formation is the thick series of gray to light-blue shaly limestone and calcareous shale which overlies the purple Waynesboro formation. The lower half of the formation is decidedly shaly, the included limestones usually being minutely laminated and weathering readily into calcareous shaly plates. Many of the shales are green, with some thin red bands. At the base are beds of purer massive limestone, which has been quarried south of the tollgate at the east edge of Waynesboro and to the northeast. Near the middle of the formation are massive beds of dolomite and very siliceous, quartzitic limestone, which weathers to porous slabby sandstone. This rock forms the high knob northwest of Quincy and the low ridges running west and south from the knob. Elsewhere it is not so strongly marked and can not be traced continuously. The dark limestone with red seams quarried in the southern part of Waynesboro is associated with the sandy beds at this horizon. The upper half of the formation is composed largely of light-colored calcareous shale and laminated impure limestones which weather shaly. The formation is limited above by siliceous conglomerate beds, flat-pebble limestone conglomerate, and oolite, which characterize the base of the overlying formation.

The thickness of the Elbrook can be best calculated west of Quincy, where it lies in an unsymmetrical syncline, with steep dips on the east side and gentle dips on the north, thus affording two independent measurements. From the thickness thus indicated—3500 feet—500 feet should be deducted for minor folding, which is apparently not great in this syncline, giving 3000 feet as the approximate thickness of the formation.

Distribution and surface form.—The Elbrook formation crosses the Chambersburg quadrangle from south to north in a belt averaging about 2 miles wide, with numerous projections and reentrants due to intricate folding. At Waynesboro it forms a crescentic area around the red shale hills of the Waynesboro formation. There are few outcrops of the Elbrook formation in the Waynesboro streets, but on the western and southern borders of the town the medial belt of limestone is more commonly exposed and at several places in the town the dark-blue massive-bedded limestone is quarried.

East of East Branch of Little Antietam Creek the formation is largely covered, but its area extends up the valley nearly to the border of the quadrangle. West of Quincy the medial limestone member forms a marked ridge running northward to a culminating knob and then turning abruptly southwest to Five Forks, where it again bends northward and continues as a broken line of low hills. The shales above and below form parallel valleys on either side. The valley on the north has minor limestone hills; that on the south is almost free from outcrops. It extends to the pike at Zullinger, and another narrower tongue to the west reaches the pike at Shady Grove.

Farther north the belt has a general width of 2 miles and is not marked by a distinct line of limestone hills in the middle, because the formation is closely plicated and the limestones are repeated a number of times. Between Falling Spring and Aqua the formation again projects into the valley, and the medial limestone forms a hill midway between these two points. The fold is closely compressed and faulted. North of the Chambersburg pike the formation renews its northward course to the border of the quadrangle and the medial limestone forms massive, vertical, finely banded ledges along the bank of Conococheague Creek west and north of Woodstock. A narrow inlier of the formation is brought up in the anticline south of Scotland.

Correlation.—The only fossils found in this formation were fragments of trilobites that were obtained from the purer limestone at the base in the quarry east of Waynesboro and from outcrops to the northeast. The age of the rocks could not be determined from these fragments, but they suggest the Middle Cambrian.

The formation has not previously been recognized elsewhere, hence it is named Elbrook, from the village of that name on the Western Maryland Railroad, where the rock has been extensively quarried for ballast. It is equivalent to the lower part of the Natural Bridge limestone of H. D. Campbell in Virginia. In the Carlisle quadrangle to the northeast it is extensively exposed and has a lithologic character similar to that in the Chambersburg quadrangle.

CONOCOCHEAGUE LIMESTONE.

Character and thickness.—The Conococheague limestone is characterized by limestones with thin wavy sandy laminæ that weather into sandy shale and thin sandstone fragments and generally give rise to hills and rugged topography. Its principal area passes from south to north across the middle of the Chambersburg quadrangle. The only other area of the formation in this district is a much smaller outcrop in the Welsh Run anticline in the Mercersburg quadrangle.

The body of the formation is a closely banded dark-blue limestone. The bands range from one-half inch or more in width to minute laminæ, which are invisible or inconspicuous in the fresh rock but are brought out by weathering as yellowish sandy streaks across a light-blue or gray surface. In the more siliceous portions, especially toward the top, the sandy partings weather out in strong relief (see fig. 15, illustration sheet) and disintegrate into hard thin sandy or slaty plates.

The base of the formation is in most places easily determined because it is marked by siliceous beds and conglomerates that produce a ridge. Some of the conglomerates are composed of rounded limestone pebbles, 1 inch or more in size, in a matrix containing numerous coarse grains of vitreous quartz; others consist of long, slender fragments of limestone in a calcareous matrix and, because the fragments are tilted at various angles, are called "edgewise" beds. (See fig. 17, illustration sheet.) Interbedded with the conglomerates are oolitic limestone and dark shaly limestone with red clay partings. Large scoriaceous cherts, composed of crystalline milky quartz, are common in the residual soil. At this horizon also occur conspicuous layers of a peculiar and characteristic fossil, *Cryptozoon.* (See fig. 13.) It consists of minute plicated laminæ, with wavy cross section and concentric horizontal section.

The basal beds strongly indicate shallow-water or temporary land conditions during their deposition. The rounded pebbles of the siliceous conglomerate were probably derived from a near-by sea cliff of limestone, but the rounded grains of quartz came from a more distant source on the land. The flat-pebble conglomerate was apparently derived from freshly deposited thin-bedded lime sediment broken up by shallow-water wave action and redeposited. The oolite was probably formed in water so shallow that the waves oscillated the growing particles on the sea bottom. The inclusions of red clay resemble the clay derived from the surface weathering of limestone left in solution cracks and partings.

The basal siliceous beds weather to a porous sandstone and form a more or less prominent narrow ridge with sandy soil and rock fragments which zigzags from south to north across the Chambersburg quadrangle. They are not exposed elsewhere in the area except in the hills west of Zentmyer, where they are brought up in an anticline.

Intercalated in the siliceous banded limestones toward the top of the formation are beds of pure, fine-grained rock, similar to the pink limestone of the overlying formation. Some of these beds are flat-pebble conglomerates or "edgewise" beds, but the predominance of siliceous layers, together with the absence of the Ordovician fauna, distinguishes them from the overlying Beekmantown limestone.

The best estimate of the thickness of the formation is obtained on the road west of Scotland, where it occurs in a steeply dipping monocline. The section as measured there is as follows:

Section of Conococheague limestone west of Scotland.

	Feet.
Rather pure light-colored limestone, much sheared, followed above by siliceous banded dark limestone and "edgewise" conglomerate (Stonehenge member of Beekmantown).	
Granular limestone with coarse "edgewise" conglomerate, oolite, and fine-grained pink marble, with numerous slaty partings	90
Covered	300
Pure dove-colored even-grained limestone interbedded with light siliceous-grained cross-bedded limestone, coarse "edgewise" conglomerate, and chert	15
Largely covered; dark impure limestone with large banded chert at the base	390
Dark and light limestone, in part banded with impurities	10
Dark, rather pure limestone with argillaceous partings weathering to slaty fragments and soft yellow shale; contains trilobites and beds of oolite	180
Dark limestone with shaly partings on weathering	90
Massive beds of light, dense, even-grained limestone with few wavy siliceous partings weathering in relief	40
Covered	70
Wavy impure siliceous banded limestone, weathering hackly and shaly	180
Dense black impure limestone, weathering with thick gray coating	30
Thick massive beds of crumpled siliceous banded limestone	40
Section folded and discontinuous. Dense siliceous banded limestone, with sandy beds, oolite, "edgewise" conglomerate, and layers of *Cryptozoon* at the base	200±
	1635±

Distribution and surface form.—The Conococheague limestone occurs in a broad, sinuous belt crossing the Chambersburg quadrangle from south to north. This belt has a general monoclinal structure, older beds passing beneath it on the east and younger beds overlying it on the west. Its intricate outline is due to the extensive folding which it and the inclosing rocks have undergone. Entering the quadrangle 1 mile west of Waynesboro it crosses the Greencastle pike several times in alternating folds. From Shady Grove it extends northward across the quadrangle with a width varying from 1 mile to a maximum of 2½ miles near New Franklin, where it is closely folded. Near Aqua it is offset 1½ miles by a fault, which also cuts off a wedge-shaped area to the west of the main belt. The formation leaves the quadrangle northeast of Scotland. The ridge formed by the siliceous beds at the base of the formation is a conspicuous feature in places, notably north of Scotland, between Aqua and Falling Spring, and at Grindstone Hill. Elsewhere it is a slightly elevated stony or rocky ridge followed by roads.

The only other occurrence of the formation in this area is a long, wedge-shaped anticlinal area west of Welsh Run, in the southern part of the Mercersburg quadrangle. Only the upper beds of the formation are here exposed; as seen at the mouth of Licking Creek they are closely plicated, very siliceous banded limestones. At the southern border of the quadrangle they form low hills with rocky outcrops and sandstone débris.

Correlation.—Few fossils have been found in the Conococheague limestone, and such as have been obtained are poorly preserved and difficult of determination. A few good specimens of trilobites and brachiopods were collected at a quarry in the western part of Scotland near the middle of the formation, and fragments were seen in the basal conglomerate. These fossils comprise *Dikelocephalus hartii* Walcott, *Dikelocephalus* sp. undet., and *Billingsella* like *B. desmopleura.* The trilobites place the formation definitely in the Saratogan (Upper Cambrian). In the basal portion of the formation occur layers of *Cryptozoon proliferum* Hall (see fig. 13, illustration sheet), which has been described by Hall and by Walcott from beds near the top of the Upper Cambrian of New York. Closely allied species, more condensed and smaller in outline, also occur in these basal beds, and larger individuals of more open structure are present at a slightly higher horizon. These fossils, somewhat resembling *Stromatopora* in appearance but probably of the nature of marine algæ, have been observed by Ulrich at this horizon at many places throughout the Appalachian Valley and in Missouri.

As the formation begins with conglomerates and other evidences of shallow water and near-by land erosion, and as this change in sedimentation is emphasized by the advent of the Upper Cambrian fauna, it is concluded that the base of the formation represents a marked change in the configuration of the land at the beginning of the Upper Cambrian epoch. Similar stratigraphic relations occur at the base of the Knox dolomite of Tennessee, which is in part of the same age. The Knox near the type locality contains Lower Ordovician fossils in its upper portion and Cambrian fossils in its lower portion and is equivalent in part to the Beekmantown and Conococheague limestones. The distinction of the Beekmantown in the Chambersburg area necessitates the selection of a new name for the underlying Cambrian sediments, and Conococheague, the name of the large stream on whose banks in the town of Scotland the best exposures occur, has been adopted.

This formation has not been traced to the south of these quadrangles, and its extent in that direction is not known. To the northeast it maintains its general siliceous banded character, and in the Carlisle quadrangle, near the end of South Mountain, ridge-forming sandstone and chert occur at the top.

ORDOVICIAN SYSTEM.

The lower portion of the Ordovician in this part of the Appalachian province is a thick series of limestones comprising the Beekmantown, Stones River, and Chambersburg limestones, which are equivalent in a general way to the Beekmantown, Chazy, Lowville, Black River, and perhaps the basal part of the Trenton of New York. The upper beds of the Ordovician are thick black and gray sandy shales and soft reddish sandstones—the Martinsburg shale and Juniata formation.

BEEKMANTOWN LIMESTONE.

The Beekmantown is a rather pure limestone lying between the siliceous Conococheague below and the very pure Stones River above. A minutely laminated appearance on the weathered surfaces of many of the beds, due to their impurities, is a characteristic feature of the formation, and another is the presence of many beds of pink to white fine-grained marble. Near the base are siliceous banded beds and large "edgewise" conglomerate (see figs. 16 and 17, illustration sheet) closely resembling the Conococheague beds. These rocks have been separated in the Chambersburg quadrangle as a basal member under the name Stonehenge limestone member of the Beekmantown.

The best exposure of the formation in the Chambersburg quadrangle adjoins the Chambersburg-Gettysburg pike. This section, however, is not continuous, as the rocks are folded and in part covered, so that the composite section may have some gaps or repetitions. The section as measured by Mr. Ulrich and the writer is as follows:

Section of Beekmantown limestone 1 mile east of Chambersburg.

	Feet.
Base of Stones River, containing fine limestone conglomerate and laminar and oolitic chert.	
Interbedded fine-grained pure and magnesian limestones, finely laminated in part and containing small quartz geodes; porous sandy chert near top; dark-blue layers near base containing numerous gasteropods and ostracods and mottled by magnesian material that weathers out, leaving pits and holes	600
Alternating pure dove-colored and gray limestone and magnesian limestone, with layer of sandy chert	375
Bluish to dove-colored fine-grained fossiliferous limestone, at the base containing rounded quartz grains	100
Pink fine-grained marble, containing layers of milky quartz chert; gasteropods of the genera *Ophileta, Maclurea,* and *Eccyliopterus* rather abundant	275
Pure dove-colored and blue fine-grained limestone, with some pink limestones; contains fragments of trilobites	285
Fine-grained dove-colored to dark-gray limestone with fine conglomeratic and oolitic beds; abundant chert in upper portion, in part oolitic and conglomeratic	145
Stonehenge limestone member:	
Fine-grained light to dark gray limestone containing wavy laminæ of sandy matter that stand in relief or fall to sandy shale on weathering, and thick beds of "edgewise" conglomerate; gasteropods in upper and fine fragments of trilobites in lower portion	225
Dark to very light gray massive limestone: containing *Orthis, Ophileta,* and trilobite fragments	260
Top of Conococheague, containing wavy and sandy laminæ and beds of coarse limestone conglomerate.	
	2, 265

Many of the beds of the upper half of the Stonehenge limestone member resemble the underlying Conococheague formation so closely that they are distinguished with difficulty. Where the sequence of the beds is clear or where fossils can be obtained the line of separation can be readily drawn, but in intricately folded or faulted areas, such as in the hills west and south of Zentmyer, the separation is much more difficult and problematical. Pure beds containing coarse "edgewise" conglomerates are more plentiful in the Stonehenge and sandy laminæ are more abundant in the underlying Conococheague. The purer limestone in the middle and upper Beekmantown is quarried and burned for field lime at many places in the Chambersburg quadrangle, especially at Stoufferstown and Stonehenge. Many of the beds are fine-grained marbles but in few places are as fine and even grained as those of the overlying Stones River limestone. They are further distinguishable from the Stones River rock by being white to pink, instead of dove color to dark gray. Chert, although present at several horizons, is not plentiful in the Chambersburg quadrangle.

Analyses made by the Pennsylvania Geological Survey of limestones from 115 beds having a total thickness of 370 feet in a quarry opposite Harrisburg illustrate the alternation of thin beds of pure limestone with highly magnesian layers in the upper part of the Beekmantown. Throughout the section highly magnesian layers and beds nearly free of magnesium are very intimately mixed, as shown by the following portion of the published section:

Percentage of magnesium carbonate in successive beds of limestone in quarry opposite Harrisburg.

Thickness of layer.		$MgCO_3$.	Thickness of layer.		$MgCO_3$.	Thickness of layer.		$MgCO_3$.
Ft.	*in.*	*Per cent.*	*Ft.*	*in.*	*Per cent.*	*Ft.*	*in.*	*Per cent.*
2	8	1	6	11	2		9	28
1		1	6	8	1	2	5	1
1	1	31	11	5	34	1	11	34
2		3	2	5	2		2	1
1	2	19	5	6	34		4	31
2		4		8	2		8	3
1	4	31						

The purer limestones contain from 1 to 3 per cent and the highly magnesian beds from 19 to 34 per cent of magnesium carbonate.

In the Mercersburg quadrangle an excellent section of the Beekmantown is found on Licking Creek near its mouth. Unfortunately the upper part of the formation is not exposed in the creek bank and is complicated by folding and probably faulting. The section measured by Mr. Ulrich and the writer is given on page 7.

The details of this section are quite unlike those of the section in the Chambersburg quadrangle. The siliceous banding in the basal beds is not so strongly developed and does not stand out in relief on weathering, as in the Chambersburg quadrangle, nor does the residuum form hills. As a consequence, the Stonehenge member could not be mapped in the Mercersburg quadrangle. The fine-grained beds in the middle of the formation also contain more impurities, are interbedded with numerous dolomite beds, and are seldom quarried for lime in this western area. Furthermore, in the Mercersburg quadrangle chert is sufficiently plentiful in the soil derived from the Beekmantown to produce low ridges. Chert occurring at one horizon about 800 feet above the base of the formation makes a low chert-covered ridge or series of hills in the Welsh Run anticline. The cherts of this zone are of various forms. Some are large, rough scoriaceous masses; others flinty in texture, banded, brecciated, granular, and oolitic. A species of *Cryptozoon*, apparently *C. steeli*, also occurs in these cherts. This chert zone has been mapped in the Mercersburg quadrangle as far as it was traceable.

Section of Beekmantown limestone near mouth of Licking Creek.

	Feet.
Interbedded pure and magnesian limestones of Stone River type.	
Light-gray, finely laminated magnesian limestone and white dolomite with cherts of rosette type at the top	340
Dark and light coarse dolomite	140
Rocks folded and largely covered; white dolomite, dark-blue oolitic limestone, and dark coarse dolomite with yellow blocky sandstone fragments and rosette cherts; exact continuity indeterminable, but the previous beds are apparently repeated by folding.	
Interbedded pure and magnesian limestones, with beds of coarse dark dolomite, and in the lower part beds of "edgewise" conglomerate; at base contains gasteropods, cephalopods, and trilobites	350
In large part finely banded magnesian limestone with few pure limestones; contains fine conglomerate beds and gasteropods	170
Largely dolomite, some coarse and dark; large scoriaceous black chert and coarse sandstone at the base	130
Chiefly dolomite, coarse and dark in upper part, with some pure fossiliferous limestone; bed of granular limestone with numerous *Ophileta* and pinkish fine-grained limestone near middle; cross-bedded banded limestone at base, locally unconformable on underlying beds	290
Fine-grained limestone seamed with calcite and dolomite beds, with flinty chert containing *Cryptozoon steeli* at the base	65
Partly covered; lower part pure dark limestone with a few beds of finely laminated magnesian limestone and fine white oolite near base; small rough chert with casts of crystals at the base	130
Light-blue limestone with fine contorted sandy laminæ that weather in relief; contains fine dark conglomerate with red limestone pebbles and fragments of trilobites	165
Purer fine even-grained limestone with few sandy partings	530
Sandy laminated limestone, much contorted (Conococheague).	
	2,310

An upper zone of cherts, mostly of a rosette form which in the larger aggregates resembles heads of cauliflower (see figs. 14 and 18), occurs at or near the top of the Beekmantown in both the Chambersburg and the Mercersburg quadrangles and in most places may be used as a horizon marker in determining the top of the formation.

Distribution and surface form.—The Beekmantown limestone is one of the most widely distributed formations in the area, occuring in a broad belt across the western half of the Chambersburg quadrangle and in several anticlinal areas in the Mercersburg quadrangle. It produces a gently rolling country, in which outcrops are generally covered with soil, and furnishes excellent farm land.

In the eastern belt it is closely folded in common with the inclosing limestone and consequently is very irregular in outline and in width. At the northern border of the Chambersburg quadrangle it is 2½ miles in width, but elsewhere it is commonly less than a mile wide. East of Guilford Springs it is faulted out for more than a mile. This belt reaches the quadrangle boundary south of Shady Grove, but the formation reappears to the east in two synclines. Two narrow faulted inliers of the formation occur west of the general belt in the vicinity of Guilford Springs and Kauffman.

The Beekmantown limestone is characterized throughout this eastern belt by alternations of pure limestones and finely laminated impure beds, with the siliceous banded Stonehenge member at the base. The pure beds in the middle of the formation are exposed at numerous places and are accessible for burning, but have been extensively quarried and burned only near Chambersburg. The rosette cherts at the upper boundary of the formation, which are not common in this quadrangle, have been observed at several points north of Greencastle.

In the Welsh Run–Edenville anticline the formation comprises the larger part of the limestone outcrop. The southern portion of this area has a width of 2 miles and is divided by a low ridge of cherts. In the vicinity of Lemaster the belt is intricately cut up by faults.

In the Mercersburg belt of limestone the formation occupies a faulted monocline that extends from the Chambersburg pike nearly to the southern margin of the quadrangle. The lower chert-bearing bed is exposed at intervals along the center of the uplift on the eastern margin. This area of the formation is separated from a smaller area on the east by a narrow strip of down-faulted Martinsburg shale and Chambersburg and Stones River limestones.

In the Foltz belt few outcrops of the formation occur and these are largely magnesian limestones and dolomites. In the McConnellsburg uplift the lower zone of cherts is marked by scattered large masses of scoriaceous chert at the northern margin of the quadrangle and east of McConnellsburg. They occur west of the town also, indicating a second uplift there.

Correlation.—Although its fauna has been previously observed at various places in the Appalachian Valley, the Beekmantown has not heretofore been recognized as a distinct formation in this region. It is known to maintain its lithologic and faunal character as far to the northeast as Mechanicsburg, Pa., and has been observed to the northeast in the Lebanon and Lehigh valleys. It is sparingly fossiliferous as a whole, but a rather large variety of forms have been collected in this area. The determination of fossils and the correlation of this and all succeeding formations to be described were made by E. O. Ulrich.

The lower portion of the formation, including the Stonehenge member, is characterized by *Ophileta complanata*. Of the 13 species collected the following were identified by Mr. Ulrich:

Rhabdaria cf. R. fragilis Billings.
Calathium sp. undet.
Orthis wemplei ?
Ophileta complanata.
Maclurea affinis.
Eccyliopterus cf. E. triangulus.
Bathyurus near B. conicus.
Cryptozoon steeli.

In the middle of the formation two faunas have been distinguished. The lower, characterized by hornlike opercula, a small *Isochilina*, *Hormotoma artemesia*, and large thin-shelled *Maclurea*, occurs in both quadrangles, and good collections were made at Licking Creek and near McConnellsburg. Fifteen species were collected, of which the following have been tentatively determined:

Orthis cf. O. electra.
Maclurea affinis.
Hornlike opercula of an otherwise unknown gasteropod for which Mr. Ulrich suggests the generic name Ceratopea.
Liospira canadensis.
Eccyliopterus cf. E. triangulus.
Isotelus canalis.
Bathyurus cf. B. conicus.
Bathyurus caudatus.
Amphion cf. A. salteri.
Leperditia cf. Primitia gregaria Whitfield.

The upper fauna of the middle division, characterized by *Syntrophia lateralis* and found only at Stoufferstown, is as follows:

Syntrophia lateralis.
Maclurea ? sordida.
Liospira cf. L. laurentia.
Orthoceras cf. O. primigenium.

In the upper part of the formation, which is characterized by high-spired turritelloid gasteropods and by *Ophileta disjuncta*, 17 species have been collected from the quarry at Stoufferstown, and the following were tentatively identified:

Orthis (? Dalmanella) electra.
Maclurea cf. M. oceana.
Ophileta ? disjuncta.
Solenospira cf. S. prisca.
Turritoma acrea ?
Hormotoma gracilens.
Lophospira cf. Murchisonia gregaria Billings.
Cyrtocerina cf. C. mercurius.
Trocholites internestriatus.

The faunas in the above lists are correlated by Mr. Ulrich with those of the Beekmantown in the Champlain Valley of New York and Vermont, and that name is therefore applied to the formation.

STONES RIVER LIMESTONE.

Character and thickness.—Above the Beekmantown is a considerable thickness of very pure limestone with some magnesian layers. The greater portion of the limestone that is burned for lime in this region is obtained from this formation. In general the formation is composed of three divisions—a middle zone of massive, subgranular pure limestone containing large gasteropods, *Maclurea magna*, and thin beds of black chert which weather into small rectangular blocks; an upper zone of thin-bedded pure limestone; and a lower zone of massive pure limestone interbedded with magnesian layers. These divisions can not be readily distinguished in all parts of the area, and nowhere can the complete section be seen, because the exposures are not continuous and the beds are repeated a number of times by folding. A generalized section of the formation in the eastern belt, which is the most characteristic because the three divisions are here clearly marked, is as follows:

Generalized section of Stones River limestone in Chambersburg quadrangle.

	Feet.
Thin-bedded fine-grained pure dove colored limestone	275±
Massive pure limestone containing *Maclurea* and black chert layers; upper part compact, blue to dark; lower part light gray, granular, and oolitic	150–200
Massive and thin-bedded limestone interbedded with magnesian layers	600±
	1,050±

The basal division is poorly exposed in the Chambersburg quadrangle, and a detailed section could not be made. Its general character can be seen on the Cumberland Valley Railroad north of Kauffman. At Martinsburg, W. Va., 25 miles to the southwest, where this member is quarried on a large scale, the following section was measured by Mr. Ulrich and the writer:

Section of basal beds of Stones River limestone at Martinsburg, W. Va.

	Feet.
Light to dark drab limestone banded with thin earthy or magnesian seams	275
Similar beds, less well exposed	200
Dark-gray to dove-colored fine even-grained pure limestone (quarried)	100±
Similar fine-grained dove-colored limestone, increasing downward in magnesium (quarried)	100±
	675±

The character of the middle portion or *Maclurea* zone may be seen in Chambersburg, particularly in the Cumberland Valley Railroad cut at the south end of the town and in the quarry east of Wolf Lake. In the railroad cut there are about 200 feet of massive light-gray subgranular and fine-grained fossiliferous pure limestones, thin bedded and dark above, with numerous thin layers of black chert throughout. Some of the lower layers are thick and even bedded and have very rough surfaces, the depressions in which are filled with a black graphitic substance. Calcite veins are common in these lower beds.

The upper division of pure thin-bedded light-gray homogeneous limestone borders the overlying Chambersburg limestone and is exposed in numerous quarries. The best section of these upper beds is at the bridge over Conococheague Creek 1½ miles north of Marion. Here below the Chambersburg limestone 275 feet of pure thin-bedded light-gray limestone standing vertical has been quarried beside the road, to the east of which are more granular pure beds, containing thin bands of black chert of the middle division. In the cut of the Cumberland Valley Railroad 1½ miles west of Kauffman 220 feet of the upper thin-bedded pure limestone is exposed beneath the Chambersburg limestone. Just east of Rocky Spring the following detailed section of the upper division was observed:

Section of upper beds of Stones River limestone east of Rocky Spring.

	Feet.
Sandy, slabby gray limestone of the Chambersburg.	
Concealed	60±
Thin-bedded to shaly dark and light fine-grained limestone, with bed of fine conglomerate	20
Thin-bedded fine-grained limestone, with purer beds and fine conglomerate in middle	70
Hard, brittle dark fine-grained pure limestone in thicker beds	10
Thin-bedded to shaly dark fine-grained limestone	50
Thicker-bedded, somewhat magnesian fine-grained limestone	30
Black thin-bedded compact limestone and gray granular limestone, veined with calcite; middle division.	
	240±

In the western belts the cherty *Maclurea* zone is not well defined and the threefold division could not be made. At West Branch of Conococheague Creek, south of the Mercersburg-Greencastle pike, the thickness of the formation was determined to be between 800 and 1000 feet. Pure beds at the base are followed by magnesian and finely banded limestone in the middle, with very pure even-grained drab limestone above and thin-bedded pure dark limestone at the top. A mile farther south the measured thickness is only 750 feet.

At Blue Spring, southwest of Mercersburg, the formation dips gently under the Chambersburg to the east and is composed of very pure even-grained dove-colored limestone at the top, darker thin-bedded limestone below, with magnesian layers toward the base.

In McConnellsburg Cove, west of Tuscarora Mountain, the exposures are exceptionally meager. Below the recognized Chambersburg on the east side of the valley pure limestones are exposed in only a few places. In a small stream cut south of the Mercersburg pike about 100 feet of very pure fine-grained dove-colored limestone is followed below by about 475 feet of interbedded rather pure and magnesian beds. Two miles north of McConnellsburg only 160 feet of recognized Stones River formation was seen in the section, but some of the lower magnesian limestones of the formation may have been mistaken for Beekmantown.

Distribution and surface form.—The Stones River formation crosses the quadrangles from north to south in five belts, only the easternmost lying in the Chambersburg quadrangle. It forms nearly level lowlands with few outcrops, and its soils make excellent farm lands.

The eastern belt is monoclinal in structure but is in places closely folded and there expands to 2 miles in width. Between Guilford Springs and Greencastle it occurs in three parallel narrow bands, the repetition being due to faulting and close folding. The three subdivisions of the formation can be recognized along the entire length of the belt, the middle subdivision being as a rule readily distinguishable by the small blocky fragments of black chert in the soil. One mile north of Greencastle this chert bed is unusually thick and weathers into large angular blocks. In Rocky Spring Cove the Stones River limestone is brought up by an anticline in the shale area. It is here a very pure limestone, partly thin bedded and dark and partly massive and dove colored, veined with calcite, and is largely quarried and burned for lime to be used as fertilizer on the adjacent shale lands.

In the next limestone belt to the west, the Welsh Run-Edenville anticline, the Stones River forms a narrow strip about one-fourth mile in width on either side of the Beekmantown. The eastern strip is very irregular in outline on account of minor folding and faulting and in places spreads out to a mile in width. The western strip is more simple in outline but is faulted out in the middle of the area, at Markes. At Williamson the uppermost beds are of exceptional purity and the lime extracted from them is noted throughout the region for its whiteness and strength. The rock is dark, homogeneous, fine grained, and massively bedded.

In the Mercersburg belt of limestone the Stones River limestone occurs for a short distance on the west side of the Beekmantown monocline opposite Dickey and in a small area running through Mercersburg. Both areas are faulted and the pure beds have very minor extent. In the Foltz belt of limestone outcrops of the formation are not plentiful, but pure fine-grained limestone with characteristic *Tetradium syringo-*

poroides has been traced by scattered outcrops along the eastern margin of the Beekmantown limestone and in the small uplift on Licking Creek. It also forms the larger part of the limestone in Path Valley, at the northern edge of the Mercersburg quadrangle.

In McConnellsburg Cove the Stones River limestone is present here and there in the deeper ravines on the lower slopes of Tuscarora and Cove mountains, but its lower limit is not clearly defined. It is mapped as a very narrow band along the eastern margin of the cove. Fragments of the rock were found west of McConnellsburg, but it is faulted out on that side of the belt within the quadrangle.

Correlation.—Except in the middle chert-bearing portion few fossils have been found in this formation. These consist chiefly of a few Ostracoda (*Leperditia fabulites*) and *Tetradium syringoporoides,* which can usually be obtained from the fine even-grained beds in all parts of the formation in both quadrangles.

From outcrops of the subgranular beds of the middle division in the Chambersburg quadrangle, notably 1 mile north of Guilford Springs, 1 mile northwest of Marion, and at various quarries and outcrops in the town of Chambersburg, 22 species, largely gasteropods, ostracods, cephalopods, and bryozoans, were obtained. The following have been identified by Mr. Ulrich:

Girvanella cf. G. chazyensis.
Stromatocerium sp. nov.
Tetradium syringoporoides; the single-tubed form of this genus so characteristic of the Stones River.
Glyptocystites sp. undet.
Bryozoan, undetermined sp.
Lingulella ? belli (Billings).
Hebertella borealis.
Hebertella vulgaris.
Dinorthis cf. D. platys.
Strophomena aff. S. charlottæ.
Bucania sulcatina.
Maclurea magna.
Lophospira bicincta.
Isochilina cf. I. amiana.
Ampyx halli.

This fauna is correlated with the middle part of the Chazy of New York. The fossils and the lithologic character of the formation are so nearly the same as those of the Stones River limestone of middle Tennessee that they are regarded as identical. Furthermore, the formation has been recognized by Ulrich and others at intervals along the Appalachian Valley southward into Tennessee. The name Stones River is therefore applied to this series of pure fine-grained limestones. It has been traced northeastward up the Cumberland Valley to Mechanicsburg, where its threefold character is strongly marked by the medial cherty member.

CHAMBERSBURG LIMESTONE.

Character and thickness.—The Chambersburg limestone is the uppermost formation of the Shenandoah group. It is characterized throughout the area by fossiliferous, thin-bedded limestones with argillaceous partings. It varies in thickness across the strike from a maximum of about 750 feet in the Chambersburg belt to about 100 feet in the McConnellsburg Cove, and its character changes also in the different belts.

The most typical development is in the Chambersburg belt, throughout which fossils are abundant. The following section in the railroad cut 2 miles southwest of Marion, measured by Mr. Ulrich and the writer, is the most complete continuous section in this belt:

Section of Chambersburg limestone 2 miles southwest of Marion.

	Feet.
Upper 150 feet not well exposed; shale and thin-bedded limestone seen. At the top are black carbonaceous limestone and a thin sandstone, capped by a thin, coarsely crystalline limestone bed containing *Lingula,* undoubtedly the *Caryocaris* bed commonly found at the base of the succeeding Martinsburg shale. The lower 100 feet are interbedded thin calcareous shale and shaly limestone with a few fossils which indicate the *Christiania* fauna	240+
Dark nodular thin-bedded limestone; fossils rare	50
Dark fine-grained platy limestone; contains *Nidulites* and associated fossils	94
Compact dark-gray thick-bedded limestone; upper part very fossiliferous, containing numerous cystids and *Nidulites*	108
Dark argillaceous cobbly limestone, shaly in lower part; very fossiliferous, containing a layer filled with the ball cystid *Echinosphærites*	65
Limestone like overlying bed but even darker in color and interbedded with subcrystalline limestone layers; fossils scarce	40
Grayish to dark dense thin-bedded limestone, containing *Tetradium cellulosum* and *Leperditia*	150±
Contact with Stones River not exposed.	
	747±

East of this section along the railroad, near the pike, the uppermost thin black calcareous transition bed containing *Caryocaris, Triarthrus becki,* and *Trinucleus concentricus* is directly underlain by 150 feet of dark-gray to black earthy thick-bedded limestone with several calcareous and arenaceous shale partings 5 feet thick. The limestone weathers rapidly to a thick chalky coating containing *Christiania* and numerous other fossils. This limestone, locally much more arenaceous, has been observed only from this place southward to Greencastle, and whether it is absent to the west and north, where this interval is apparently occupied largely by shale, or whether it is present but because of its rapid weathering is not exposed has not been determined. Thin mottled-gray calcareous sandstone and disintegrated, sandy, highly fossiliferous limestone apparently represent these beds in other near-by sections to the north. In general the upper 200 to 300 feet of the formation in this belt is composed largely of shale with interbedded thin fossiliferous limestones and sandstones, forming a gradation into the overlying Martinsburg shale.

The formation is well exposed along the Western Maryland Railroad on the west side of Chambersburg, and, although the outcrops are not continuous, a fair composite section 608 feet thick was measured. The *Echinosphærites* bed apparently forms the base of this section and the *Nidulites* bed is especially well displayed in the railroad cuts. The "cobbly" character of the weathered outcrop of certain of the beds, which is the most noticeable feature of the formation throughout both quadrangles, is shown in many outcrops. It is due to a wavy lamination or clay parting that crosses the bedding at a high angle and on weathering gives rise to rounded lenticular fragments resembling rough cobblestones. In fresh exposures this parting is not visible and the limestone appears massive, with fine regular bedding lines about 6 inches apart. Fossils are not easily extracted from the cobbly layers but are in places finely exposed on the weathered bedding surfaces and in thin shaly layers.

West of the Chambersburg-St. Thomas shale belt the formation is not over 323 feet thick, and the limestone is more generally crystalline and not so prevailingly cobbly. In the Welsh Run-Edenville limestone belt several good sections have been measured. On the banks of West Branch of Conococheague Creek, just south of the Greencastle pike, an excellent section is presented as follows:

Section of Chambersburg limestone on West Branch of Conococheague Creek.

	Feet.
Fissile shale, overlying calcareous black shale and hard thin black carbonaceous limestones, containing graptolites and lingulas (Martinsburg).	
Granocrystalline, very fossiliferous limestone, 2 feet (*Sinuites* transition bed).	
Cobbly dark subcrystalline limestone, both massive and thin bedded (*Nidulites* bed)	73
Coarse, massive granocrystalline limestone with massive beds of pure fine-grained limestone containing *Beatricea* and *Tetradium cellulosum*	75
Platy granocrystalline limestone, very fossiliferous (*Caryocystites* bed)	25
Dark subcrystalline limestone with wavy partings of shale; fossils rare	150±
Very thin bedded pure fine-grained drab limestone underlain by more massive pure beds with magnesian layers and fine laminations containing *Leperditia* (Stones River).	
	323±

Farther north in this same belt the formation is thinner, as shown in the section 2½ miles south of St. Thomas:

Section of Chambersburg limestone 2½ miles south of St. Thomas.

	Feet.
Thin calcareous shale, underlain by calcareous black shale and hard thin black limestone (Martinsburg).	
Coarse granular fossiliferous limestone, 7 feet (*Sinuites* transition bed).	
Black cobbly thin-bedded fossiliferous limestone (*Nidulites* bed)	53
Massive granular or finely conglomeratic gray, highly fossiliferous limestone (*Beatricea* numerous)	15
Subcrystalline, very fossiliferous gray limestone (*Leperditia* numerous)	1
Granocrystalline gray limestone, in part minutely conglomeratic	18
Bluish subcrystalline limestone containing numerous *Caryocystites* plates and *Solenopora compacta*	7
Cobbly dark subcrystalline limestone, more massive in upper part	105
Fine even-grained pure limestone, drab to dark gray, thin bedded above, less pure below (Stones River).	
	199

On the pike half a mile west of St. Thomas a section measured 270 feet thick.

In the Mercersburg belt of limestone the Chambersburg is wholly or in part faulted out along a large portion of the limestone-shale contact. The following section, one-half mile northwest of Dickey, on the west side of the limestone belt, is the most complete measured:

Section of Chambersburg limestone one-half mile northwest of Dickey.

	Feet.
Fissile shale, limy at base (Martinsburg).	
Thick bed of dark-gray coarse crystalline crinoidal limestone, fossiliferous, 6 feet (*Sinuites* transition bed).	
Thin-bedded cobbly dark fine-grained limestone containing *Monotrypa hemisphericus, Plectambonites* cf. *P. sericeus, Leptæna* sp., *Dalmanella* cf. *D. subæquata*	37
Rather massive gray to dove-colored fine-grained mottled limestone, banded in part	18
Fine-grained platy to cobbly gray limestone with few *Monotrypa hemisphericus*	30
Massive fine-grained dark limestone containing *Beatricea* and *Tetradium cellulosum*	34
Dark compact subgranular to crystalline limestone, with *Caryocystites* plates	8
Concealed, 170± feet, of which probably at least 130 feet belongs to the Chambersburg	130±
Thin-bedded pure fine even-grained drab limestone (Stones River).	
	257±

Two other sections in this belt showed only 180 to 185 feet of the formation, some of the beds probably having been cut out by faulting.

In the Foltz belt of limestone good sections were obtained at several points. Half a mile south of Fort Loudon the upper portion of the formation is finely exposed and yields an abundance and great variety of fossils. The section as measured is as follows:

Section of Chambersburg limestone one-half mile south of Fort Loudon.

	Feet.
Fissile shale with thin, hard, dark calcareous beds on fresh exposure, 100+ feet, underlain by 40 feet of hard calcareous dark shale and thin limestones, weathering light gray, graptolites at top (Martinsburg).	
Subgranular black crinoidal limestone containing *Sinuites* and *Trinucleus,* 2 feet (transition bed).	
Partly exposed dark cobbly limestone and black shale (*Nidulites* bed)	29
Dark shaly limestone with fossil fragments and a few *Echinosphærites*	23
Massive dark subgranular limestone	12
Pure dove-colored fine even-grained limestone, containing *Tetradium cellulosum* and *Leperditia* in fine conglomerate	8
Thin-bedded pure granular limestone, upper beds coarsely granular; contains *Leperditia* and *Beatricea*	10
Heavy-bedded gray granular to subcrystalline limestone; very fossiliferous — trilobites, brachiopods, *Caryocystites* plates, and *Solenopora*	10
Dark-blue flaggy limestone, few fossils	8
Poorly exposed dark granular limestone, estimated	100±
Pure dove-colored limestone with *Leperditia* (Stones River).	
	200±

In this same belt, 1½ miles directly west of Mercersburg, approximately 140 feet of Chambersburg, composed of massive light-colored limestone with wavy partings and thin-bedded dark cobbly limestone above, is overlain by 80 feet of hard black calcareous shale with thin beds of barren black argillaceous limestone assigned to the Martinsburg. Another section near by contains 165 feet of cobbly and granular fossiliferous limestones with black carbonaceous limestone above. At Blue Spring, southwest of Mercersburg, the middle granocrystalline portion of the formation is finely exposed, containing numerous *Caryocystites* plates below and *Beatricea* above, with *Tetradium cellulosum* in a thin bed of fine-grained limestone in the middle. The estimated thickness here is 155 feet. In the southward extension of this anticline on Licking Creek the section is similar and the bed above the *Tetradium* layer contains *Echinosphærites.*

In McConnellsburg Cove few outcrops of the Chambersburg limestone occur and only one section was measured, 2 miles northeast of McConnellsburg:

Section of Chambersburg limestone 2 miles northeast of McConnellsburg.

	Feet.
Hard black slate and thin slaty black limestone (Martinsburg).	
Covered	10
Gray marble and massive blue limestone veined with calcite	20
Dark shaly limestone with argillaceous partings, containing *Solenopora* and Bryozoa	68
Pure fine even-grained limestone (Stones River).	
	98

On the Mercersburg pike, 1½ miles southeast of McConnellsburg, a small outcrop of granocrystalline fossiliferous limestone (Chambersburg) is overlain by 80 feet of alternating hard barren black shale and argillaceous limestone, above which is fissile black shale full of graptolites and lingulas. On the west side of the valley the Chambersburg, if originally present, is faulted out.

Although there is considerable local variation in the measurements of thickness, owing largely to incomplete data or concealed relations, they show a general thinning of the formation from east to west, the thickness being approximately 750 feet in the Chambersburg belt, 200 to 325 feet in the Welsh Run–Edenville limestone belt, 200 to 260 feet in the Mercersburg belt, 150 to 200 feet in the Foltz belt, and about 100 feet in the McConnellsburg belt.

Distribution and surface form.—The Chambersburg limestone forms a narrow belt of stony land along the margin of the Shenandoah group adjacent to the overlying Martinsburg shale throughout the Mercersburg and Chambersburg quadrangles except where it is cut out by faults. In the Chambersburg belt it crosses the quadrangle in a nearly continuous and relatively broad strip along the eastern margin of a wide shale belt. Its outline is not so serrated as that of the older limestones to the east, but the formation is repeated by folding and faulting in a long loop passing through Marion and Guilford Springs for fully half the length of the quadrangle. In Rocky Spring Cove also it forms a strip part way around the Stones River limestone.

In the Welsh Run–Edenville limestone belt the Chambersburg forms a narrow band on either side of the limestone area except at one or two points where it is cut out by faulting. It also encircles a narrow shale syncline west of Upton and one north of Edenville and occupies a shallow syncline west of St. Thomas. Along the foot of North Mountain it has nowhere been seen because of the heavy covering of wash. In the Mercersburg belt only two short strips of Chambersburg occur, one extending southward from Conococheague Creek along the west margin of the limestone area and the other passing through Mercersburg. Elsewhere along the shale-limestone contact it is faulted out, except that a small mass is preserved between two faults on the plunging end of an anticline 1½ miles northeast of Mercersburg.

The Chambersburg is present continuously along the eastern margin and around the ends of the Foltz belt of limestone, but is faulted out along the western margin. Its outcrop is a little broader in this belt because of the gentle dips. It entirely surrounds the small limestone area on Licking Creek, but occurs only on the southeast side of the Path Valley area. A narrow strip occurs continuously along the east side of the McConnellsburg Cove area, but it is faulted out on the west side.

Correlation.—The Chambersburg limestone is the most fossiliferous formation in these quadrangles. Nearly everywhere its beds yield on careful search an abundance and great variety of fossils. Although the character and appearance of the rocks as a whole are similar in the different belts, the fauna and the details of the section in the Chambersburg quadrangle are somewhat different from those in the Mercersburg quadrangle, and a detailed description is therefore necessary to warrant the statement of conclusions drawn. Little is known of the fauna in McConnellsburg Cove, as only a few Bryozoa were collected in the scanty exposures of the formation. Consequently in the references hereafter made to the fauna in the Mercersburg area, the portion east of Tuscarora Mountain is implied.

The following lists of fossils and statements of correlation are furnished by E. O. Ulrich and are based on collections made by him and the writer in this and adjacent areas.

In the Chambersburg belt the formation may be divided into four faunal zones. In addition there is a fifth very distinct faunule occupying the transition shaly limestones at the base of the Martinsburg. The lowest zone, which has been observed only to the south of Chambersburg and which where present varies in thickness from approximately 150 feet down to the vanishing point, is characterized by *Tetradium cellulosum* and *Leperditia*.

From it the following fossils have been collected:

Faunule 1 (*Chambersburg quadrangle*).

Orbignyella wetherbyi.
Strophomena n. sp. cf. S. emaciata.
Zygospira recurvirostris, the Lowville variety.
Protorhyncula n. sp., smaller and more coarsely plicated than P. dubia.
Leperditia n. sp. near L. fabulites.
Leperditella tumida.
Isotelus n. sp.
Pterygometopus callicephalus.
Ceraurus pleurexanthemus.
Tetradium cellulosum.

Except the last fossil on this list, all these species occur in the typical Lowville of New York or elsewhere in beds confidently correlated with that formation.

The second or *Echinosphærites* zone, about 60 feet thick, contains a few highly fossiliferous bands. Of a total of about 20 species, nearly all of which are characteristic, the following have been determined:

Faunule 2 (*Chambersburg quadrangle*).

Receptaculites cf. R. occidentalis.
Echinosphærites sp. undet.
?Chætetes cumulata.
Prasopora insularis?
Hemiphragma irrasum.
Dalmanella testudinaria, small n. var.
Dinorthis pectinella.
Hebertella bellarugosa.
Rafinesquina inquassa?
Rafinesquina n. sp.
Plectambonites pisum var.
Triplesia n. sp. (radially plicated like Platystrophia).
Leperditia cf. L. fabulites.
Ampyx normalis.

The next zone, 200 to 250 feet thick, contains *Nidulites* throughout, but most numerously near the middle and again near the top. With few exceptions the 38 species so far collected from this zone are confined to it. The common and more striking or important forms are included in the following list:

Faunule 3 (*Chambersburg quadrangle*).

Nidulites favus.
New genus of Amygdalocystidæ.
New genus of Pleurocystidæ.
Bolboporites n. sp.
?Carabocrinus, plates only.
Prasopora contigua.
Diplotrypa sp. undet. (small hemispheric form).
Hemiphragma irrasum?
Stomatopora inflata.
Stomatopora proutana.
Orthis sp. undet. cf. O. tricenaria.
Plectorthis n. sp. aff. P. whitfieldi.
Dalmanella testudinaria var.
Dalmanella n. sp. aff. D. subæquata.
Scenidium anthonense.
Strophomena cf. S. filitexta.
Rafinesquina cf. R. incrassata.
Leptæna n. sp.
Plectambonites cf. P. pisum.
Plectambonites asper (Ruedemann).
Triplesia n. sp.
Leperditia cf. L. fabulites.
Ampyx n. sp. cf. A. normalis and A. halli.
Illænus sp. undet. cf. I. consimilis, I. americanus, and I. simulator.
Pterygometopus cf. P. callicephalus and P. schmidti.
Ceraurus pleurexanthemus.
New genus of Merostomata (related to Hemiaspis).

At least three-fourths of the species just named are confined to the lower half of this zone. In the upper part only the *Nidulites* and the hemispheric *Diplotrypa* are common. This faunule is regarded as intermediate between the Black River and Trenton of New York.

The fourth zone, best characterized by *Christiania trentonensis* and, like the preceding, regarded as intermediate between the Black River and Trenton, comprises 280 feet or more of limestone or shales overlying the *Nidulites* bed and below the *Sinuites* horizon. It is in many places crowded with fossils; 42 species have been determined, of which the following are the most characteristic:

Faunule 4 (*Chambersburg quadrangle*).

Hemiphragma cf. H. irrasum and H. ottawaensis.
cf. Trematopora ? primigenia.
Anthropora cf. A. bifurcata.
Rhinidictya cf. R. neglecta.
Orbiculoidea cf. O. lamellosa.
Orthis cf. O. tricenaria.
Scenidium cf. S. anthonense (?merope).
Dinorthis n. sp. aff. D. subquadrata.
Strophomena n. sp.
Strophomena (?Leptæna) cf. S. charlottæ.
Plectambonites asper.
Plectambonites pisum.
Plectambonites n. sp. (with 4 or 5 strong radial lines).
Christiania trentonensis.
Christiania n. sp.
Triplesia n. sp.
Triplesia cf. T. nucleus.
Parastrophia hemiplicata.
Protozyga exigua.
Ctenodonta sp. undet.
Lepidocoleus, 2 undet. sp. (near L. jamesi).
Illænus consimilis.
Fragments of Trinucleus or Tretaspis.

The comparatively heavy bedded impure limestones weathering to a thick chalky coating which occur at the top of the Chambersburg at and for several miles north of Greencastle contain some of the common fossils of the *Christiania* zone, among them *Christiania trentonensis*, *Plectambonites asper*, *P. pisum*, *Strophomena*? cf. *S. charlottæ*, and *Protozyga exigua*. Associated with these are *Orthoceras* cf. *O. arcuoliratum*, *O.* cf. *O. junceum*, *Cyrtoceras* cf. *C. camurum*, and undetermined species of *Bucania*, *Liospira*, and *Isotelus*. Though a distinguishable facies, this faunule is regarded as the *Christiania* fauna in its decay rather than a new invasion. Provisionally it is arranged as a locally developed subzone.

Characteristic species of the *Sinuites* fauna which is so well developed and persistent in the Mercersburg bands were seen at only a single locality in the Chambersburg belt. This is at the town of Chambersburg itself, where from a thin layer about 6 feet beneath the last of the thin limestones in the passage beds to the Martinsburg shale specimens of *Sinuites cancellatus* and of *Scenella*, *Bucania*, *Trocholites*, and *Orthoceras* were procured. Immediately above this layer and apparently without break came shaly limestones with the *Caryocaris* and *Triarthrus* fauna. The following 32 species were collected from these transition beds:

Faunule 5 (*Chambersburg quadrangle*).
Transition bed.

Diplograptus sp. undet.
Lingula riciniformis?
Lingulops n. sp?
Conotreta rusti.
Rafinesquina cf. R. ulrichi.
Sinuites cancellatus.
Scenella sp.
Bucania sp.
Cyclora minuta
Cyclora parvula.
Cyclora cf. C. hoffmani.
Microceras cf. M. inornatum.
Coleolus cf. C. lowensis.
Conularia quadrata?
Trocholites sp.
Orthoceras sp.
Caryocaris sp. undet.
Turrilepas sp. undet.
Primitia, 2 sp.
Ctenobolbina sp. undet.
Ampyx n. sp.
Trinucleus concentricus?
Harpina ottawaensis?
Triarthrus becki.
Triarthrus fischeri.
Calymene senaria?
Bumastus sp.?
Bronteopsis? sp. undet.
Proetus latimarginatus.
Cyphapis matutina.
Encrinurus sp. undet.

In the Mercersburg quadrangle also five faunal zones are distinguished, the uppermost being found in the transition bed at the base of the Martinsburg. Only two of these are readily correlated with those of the Chambersburg belt and one, the lowest, is certainly absent in that most eastern band of the formation. This first or lowest zone comprises the subgranular limestone, about 150 to 170 feet thick, that makes up the lower half of the formation in the Mercersburg belts. Recognizable fossils are few in the basal two-thirds of this zone, but the upper third is in many places crowded with good specimens. The upper 8 to 10 feet is especially fossiliferous and may generally be recognized by numerous plates of a species of *Caryocystites*. Over 50 species have been collected from this zone, of which the following have been more or less tentatively determined:

Faunule 1 (*Mercersburg quadrangle*).

*Solenopora compacta (large, typical form).
Columnaria halli.
Tetradium columnare.
Carabocrinus ? cf. C. radiatus.
Caryocystites n. sp.
Anolotichia impolita.
Nicholsonella laminata.
Batostoma cf. B. magnopora.
Hemiphragma irrasum.
Helopora divaricata ?
Rhinidictya fidelis.
Pachydictya cf. P. foliata and P. robusta.
Escharopora confluens.
Graptodictya n. sp. (reticulate).
Phylloporina reticulata.
Phylloporina cf. P. sublaxa.
*Hebertella borealis.
*Hebertella vulgaris.
*Hebertella bellarugosa ?
*Rafinesquina cf. R. champlainensis.
Strophomena (?Leptæna) charlottæ.
Plectambonites asper.
*Rhynchonella plena.
Zygospira recurvirostris.
Ctenodonta cf. C. gibberula.
*Goniocerus chazyensis.
Leperditia cf. L. fabulites.
Isochilina cf. I. gracilis.
?Thaleops ovatus.
Platymetopus cf. P. trentonensis.
Bumastus trentonensis?
Bathyurus sp. undet.

The above list contains some good upper Chazy species, which are marked with an asterick. A larger number, however, confined to the top beds, are species commonly found in the Lowville and Black River limestones. The age of the bed being interpreted as late Chazy, the latter species are regarded as indicating an unusually early appearance of the Lowville fauna.

In the next zone, consisting of about 18 to 34 feet of very pure, usually fine-grained limestone, characterized by *Beatricea* and *Tetradium cellulosum*, 29 species have been found, of which nearly all of the following list are characteristic of the bed:

Faunule 2 (*Mercersburg quadrangle*).

Beatricea n. sp.
Camarocladia cf. rugosum.
Streptelasma profundum.
Tetradium cellulosum
Strophomena cf. S. emaciata.
Ctenodonta cf. C. gibberula.
Cyrtodonta sp. undet.
Helicotoma planulatoides.
Helicotoma verticalis.
Lophospira cf. L. procera.
Omospira cf. O. alexandra.
Clathrospira sp. undet.
Eunema n. sp. cf. E. salteri.
Leperditia cf. L. fabulites.
Isochilina sp. cf. I. gracilis.
Isochilina n. sp. cf. I. ottawa.
Macronotella ulrichi.
Drepanella macra.
Bumastus trentonensis?
Cerauras cf. C. pleurexanthemus.

A large proportion of the above-named species occur elsewhere in typical Lowville and Black River limestones. Most of the remaining forms have so far been found only in the Mercersburg quadrangle.

The third faunal zone is correlated with the *Echinosphærites* zone of the Chambersburg belt. It is not easily recognizable everywhere in the Mercersburg quadrangle, being in many places very sparsely fossiliferous. At Fort Loudon it occurs in a fine-grained and rather shaly limestone, approximately 12 feet thick. The most characteristic fossil is *Echinosphærites*. The associated species are mostly suggestive of Lowville and Black River faunas. The following list comprises the common species found in the zone at Fort Loudon:

Faunule 3 (*Mercersburg quadrangle*).

Licrophycus cf. L. ottawaensis.
Lockeia sp. undet.
Cleiocrinus magnificus.
Raphanocrinus? n. sp.
Echinosphærites sp.
Helopora spiniformis?
Rhinidictya neglecta.
Escharopora ramosa.
Dalmanella cf. D. testudinaria.
Dalmanella subæquata.
Rafinesquina minnesotensis.
Strophomena cf. S. filitexta.
Plectambonites asper.
Thaleops ovatus.
Pterygometopus cf. P. schmidti.

The fourth faunal zone comprises mainly cobbly beds of limestone aggregating from 10 to 80 feet in thickness, best exposed at the railroad cut west of Dickey. They constitute perhaps the least fossiliferous zone of the whole formation. A small, hemispheric bryozoan, referred provisionally to *Diplotrypa*, is the most characteristic species. Although *Nidulites favus* has not been positively observed in the Mercersburg quadrangle, the zone is correlated in a general way with the more fossiliferous and well-defined third or *Nidulites* zone of the Chambersburg belt. Seven of the following nine species are common to the two belts:

Faunule 4 (*Mercersburg quadrangle*).

Diplotrypa sp. undet.
Stromatotrypa sp. undet.
Mesotrypa? sp. undet.
Stictoporella? sp. undet.
Plectorthis n. sp. aff. P. whitfieldi.
Dalmanella cf. D. subæquata.
Leptæna n. sp.
Plectambonites cf. P. pisum.
Ceraurus sp. undet.

A thin but somewhat variable bed of dark granular limestone follows the *Nidulites* zone. This bed contains a highly characteristic and usually very prolific fauna, of which the most striking and commonest species is *Sinuites cancellatus*. As this fauna occurs in the Chambersburg belt some hundreds of feet above the *Nidulites* zone, it is assumed that the *Christiania trentonensis* zone which there occupies the intervening beds is absent in the Mercersburg belt. In all, 32 species have been found in this zone. The following selection indicates the relation of the bed to the uppermost faunal zone in the Chambersburg belt and also shows the early Trenton age of the fauna:

Faunule 5 (*Mercersburg quadrangle*).
Transition bed.

Lingula riciniformis.
Lingulops n. sp.
Dinorthis cf. D. germana and D. subquadrata.
Scenidium merope?
Leptæna cf. L. gibbosa.
Plectambonites pisum.
Christiania n. sp.
Triplesia n. sp.
Sinuites cancellatus.
Sinuites granistriatus?
Cyrtolitina nitidula.
Eccyliomphalus spiralis.
Strophostylus textilis.
Cyclora minuta.
Cyclora depressa?
Spyroceras cf. S. bilineatum.
Orthoceras junceum.
Trinucleus concentricus.
Cyphaspis matutina.

The marked difference in the thickness, character, and fauna of these rocks in the Chambersburg and Mercersburg areas leads to the conclusion that conditions of sedimentation must have been very diverse in the two areas during Chambersburg time. The character of these differences and their causes it is impossible at this time to determine. The occurrence at numerous horizons in the Chambersburg limestone of conglomerates composed mostly of microscopic fragments of limestone indicates that during their deposition the water was very shallow, if indeed actual land conditions did not exist. The preservation throughout the formation of an abundance of fossil corals, crustaceans, and mollusks—animals that thrive only at moderate depths and commonly inhabit the littoral zone—proves that the depth of the sea was not great at any time during its deposition. The shallowness of the sea and the general absence of cross-bedding preclude the supposition that the irregularity of the distribution of the faunules is due to strong current action.

It is not improbable, therefore, that local unconformities occur within the Chambersburg limestone, overlaps due to temporary withdrawal of the sea and resubmergence, or to slight differential elevation and depression of a partly submerged lowland with shallow estuaries, the conditions having been similar to those prevailing on the borders of the middle Tennessee island during Ordovician and Silurian time, described in the Columbia folio (No. 95) by C. W. Hayes and E. O. Ulrich. The correlations of the faunules of the Chambersburg limestone made by Mr. Ulrich seem to demand some such hypothesis to account for the relations found to exist. The following is a concise statement by Mr. Ulrich of the correlation of these faunules:

Faunule 1 of the Mercersburg quadrangle, the oldest faunule in the formation, correlated with the upper Chazy of New York, has not been found in the Chambersburg area nor does its type of rock occur in that belt. Regarding faunule 2 of the Mercersburg, not only a large percentage of its species but also the pure, fine-textured character of the limestone containing it are characteristic of the upper part of the Lowville of New York. This horizon has been observed in the Chambersburg belt only in the vicinity of Greencastle, where it occurs at the base of the formation, and is absent at and north of Chambersburg.

Faunule 3 in the Mercersburg area is correlated with faunule 2 in the Chambersburg area. The zone is much more fossiliferous in the latter belt, but enough species are common to both areas to make the correlation satisfactory. The peculiar ball cystid, *Echinosphærites*, is the fossil chiefly relied on. Stratigraphically this zone should correspond to the Black River limestone of New York, providing the section in that State is complete, but recent studies there prove that this is not the case. At any rate, the most characteristic species of the *Echinosphærites* fauna are not present in the New York section. They do occur, however, in the Kimmswick limestone of Missouri and Illinois, a formation regarded as belonging between the Black River and the Trenton limestone of New York.

Faunule 3 of the Chambersburg area, occurring in the *Nidulites* bed, is also poorly represented in the collections from the Mercersburg quadrangle, but the bed though much thinner is undoubtedly represented there. The thick beds of limestone and shale containing the fourth or *Christiania trentonensis* faunule in the Chambersburg belt are not present in the Mercersburg quadrangle. Both the *Christiania* and the *Nidulites* zones, like the *Echinosphærites* bed, are also regarded as younger than Black River and older than Trenton. The *Sinuites* faunal zone, well developed in the Mercersburg belts and recognized locally in the Chambersburg area, is believed to be the first bed that is not older than lower Trenton.

To sum up these conclusions: At the close of Stones River time the sea withdrew from the Chambersburg area, but sedimentation continued in the Mercersburg area through upper Chazy time. The Lowville fauna came into the Mercersburg area and mingled with the Chazy life before Lowville conditions were firmly established and before these waters extended over the Chambersburg area. The typical Black River fauna is absent from this area and probably from most of this portion of the Appalachians, and it is thought that the sea withdrew during this period, also that during the deposition of the succeeding *Echinosphærites*, *Nidulites*, and *Christiania* beds there was cessation of sedimentation in New York. There is great variation in the thickness and character of these upper beds in the Mercersburg and Chambersburg quadrangles, the sediments being much thicker in the eastern area, especially near Greencastle, where sandstones and shales reach their maximum development, and there is here evidence of further local unconformities. Trenton conditions began uniformly in both quadrangles with the advent of the *Sinuites* fauna.

No established name applied to beds that are the exact equivalent of this formation being available, the name Chambersburg, from the county seat of Franklin County, where the rocks are clearly exposed, has been adopted. The formation is known to extend northeastward as far as Carlisle, beyond which it thins, and only the upper dark shaly portion seems to be present north of Mechanicsburg. It has been observed at Martinsburg, W. Va., and farther southwest and is in part equivalent to the Murat limestone of H. D. Campbell in the vicinity of Lexington, Va.

MARTINSBURG SHALE.

Character and thickness.—The Martinsburg shale directly overlies the Chambersburg formation throughout both quadrangles. It is in general a thick mass of black shale with yellowish-green sandy strata in the upper portion. In the center of the area it forms a wide plateau of closely folded shale and soft sandstone rising above the limestone lowland.

The lower part of the shale is black, carbonaceous, and fissile, becoming calcareous at the base and grading into the Chambersburg formation. In fresh exposure the beds are hard and as much as a foot or more in thickness, but on weathering they fall to small fragments. The shale has been so intensely squeezed and plicated that slaty cleavage and jointing generally obscure the original bedding and the rock weathers into thin, fissile cleavage leaves, but true hard slates were not produced in this area. Near McConnellsburg the carbonaceous matter in the lower beds has been changed by pressure and movement into shiny graphite which has been prospected for coal at several places. The upper part of the shale is dark gray and slightly calcareous and weathers either into elongated fragments resembling wood splinters or to a soft gray to white clay.

The uppermost portion of the formation is a soft sandstone of a yellowish-green color. In the broad shale belt west of Chambersburg, where it is exceptionally hard, coarse grained, thick bedded, and easily recognized, the sandstone member has been mapped, but elsewhere its outcrops are inconspicuous and not readily distinguished from the shale. In places along the steep eastern escarpment of the plateau the massive beds produce rugged and picturesque ravines. This rock, where fresh, is a greenish-gray arkose composed of grains of sand and feldspar; the latter has been decomposed to kaolin, giving the rock a speckled appearance. Toward the base it is interbedded with shale and merges into the shale below.

On the lower mountain slopes in the Mercersburg quadrangle the sandstone member of the Martinsburg is usually covered by wash and talus. The basal portion, as seen in weathered exposures, is a soft, porous yellow fine-grained sandstone, derived, as shown in the ravine below Cowan Gap, from a blue fossiliferous calcareous sandstone, interbedded with dark shale. Toward the top it becomes coarser, arkosic, and massive and grades into the overlying Juniata formation.

The shales of the Martinsburg are generally so closely plicated and confused by cleavage planes that the thickness can nowhere be measured, and on the mountain slopes the rocks are so masked by débris from the harder rocks above that their limits can in few places be determined. The thickness of the formation, as determined by calculation from its outcrops on the Mercersburg pike 1½ miles southeast of McConnellsburg, where the formation is fairly free from plication and the dip is low to the east, is 2000 feet. This must be taken as the probable thickness of the formation throughout the area, as no other approximately accurate measurements could be obtained. The shale, the top of which is here clearly shown, measures 800 feet, making the sandstone member 1200 feet thick. In the Chambersburg area the shale appears to be much thicker, but this may be due to the soft character of the lower portion of the sandy beds which, weathering like shale, may have been mistaken for it. The harder sandstones that are separately mapped in this area are only about 600 feet thick. On Little Scrub Ridge, in the extreme northwest corner of the Mercersburg quadrangle, the width of the formation outcrop is only 1000 feet, but the shale is much squeezed and sheared and was undoubtedly partly faulted out by distributed movement accompanying the Little Scrub Ridge fault.

Distribution and surface form.—The largest area of this formation in these quadrangles occupies the low plateau that crosses the center of the area from north to south. This belt is 6 miles wide at the north and 4 miles at the south. Although much dissected, its level tracts present an upland surface declining from an elevation of 780 feet at the north to 580 feet at the south; this surface is the remnant of an old peneplain and will be referred to under the heading "Physiography." The valleys in this shale tract are steep, rugged, and narrow, except those of the larger streams, which have reached a local base-level and widened out their valleys to flat-bottomed, steep-sided gorges. A few outliers of the shale occur in the limestone east of the main belt, where they are inclosed in elongated synclines. Similar outliers occur on the west of the belt and one straight, long synclinal arm projects southward from St. Thomas for more than 3 miles.

The formation flanks North Mountain and the mountain to the west, with a deep reentrant up Bear Valley. From Parnell Knob, at the south end of North Mountain, a narrow synclinal belt, a mile or more in width, crosses the Mercersburg quadrangle to Claylick Mountain, at the south margin of the quadrangle. A narrow faulted strip passes through Mercersburg and another narrow parallel belt of the shale extends from Jordans Knob across the quadrangle to Two Top Mountain. In the southwest corner of the quadrangle the shale is 3 miles wide and terminates against Cross Mountain, an east-west ridge that joins Two Top and Cove mountains beyond the quadrangle boundary. A very narrow belt extends northward along the east slope of Cove Mountain and occupies most of Path Valley. In the McConnellsburg Cove the strip of shale on the west side is narrow and straight, but that on the east side, where the rocks dip gently, is nearly a mile in width.

Correlation.—The Martinsburg shale is named from Martinsburg, W. Va., where it forms characteristic shale hills. It is continuously exposed from that locality across Maryland into Pennsylvania. Northeast of these quadrangles it is known to have the same characteristics as far as Mechanicsburg. It has generally been referred to in older reports as the "Utica and Hudson River slates."

Comparatively few fossils have been found in the body of the formation. The fossils listed from the transition bed under the heading Chambersburg limestone should probably be regarded as the oldest fauna of the Martinsburg. The close alliance with the latter is shown by comparison with the following list of species collected from the lower 100 feet of the shales:

Climacograptus spinifer.
Climacograptus cf. C. putillus.
Glyptograptus n. sp.
Corynoides calycularis.
Leptobolus insignis.
Schizocrania filosa.
Cyclora minuta.
Caryocaris n. sp.
Trinucleus concentricus?
Triarthrus becki.

These forms are regarded by Mr. Ulrich as indicating an age corresponding to that of the lower to middle part of the Trenton limestone in New York. The bed containing them occurs directly above the *Sinuites* or transition zone at the top of the Chambersburg limestone in the Chambersburg belt, but in the vicinity of Mercersburg and McConnellsburg they are separated by 80 to 120 feet of interbedded barren, hard calcareous argillite and black shale. The shale corresponds so closely in lithologic character with the Utica shale of New York that it has been generally regarded as the exact equivalent of that formation, but it is clearly established that the base of the formation is much older.

Fossils have been found in the upper sandstone member at only two places in the Mercersburg quadrangle. On the Mercersburg pike, 1½ miles southeast of McConnellsburg, the following fossils were collected from the soft yellow sandstone at the base of the upper member:

Segments of undetermined cystid columns.
Plectambonites sericeus (thin small variety).
Lepidocoleus jamesi.
Calymene callicephalus.
Dalmanella multisecta.

In the ravine below Cowan Gap a greater variety of forms was obtained from calcareous beds probably at a higher horizon than the preceding, as follows:

Callopora sigillaroidea.
Dalmanella multisecta.
Plectambonites sericeus (large variety).
Zygospira modesta var.
Orthoceras transversum?
Lepidocoleus jamesi.
Trinucleus concentricus?
Calymene callicephalus.

In coarse brown sandstone coated red, near the top of the formation, large *Plectambonites*, *Rafinesquina squamula*, and *Zygospira modesta* were obtained, and in massive mottled yellowish-green sandstone merging into the overlying Juniata formation poorly preserved *Rafinesquina alternata* were found.

According to Mr. Ulrich these faunas comprise species characterizing the Eden shale of the Cincinnati section and the lower part of the Lorraine in New York. In both Ohio and New York the Eden fauna succeeds that of the Utica shale.

JUNIATA FORMATION.

Character and thickness.—The red sandstone and shale of the Juniata formation form the upper outer slopes of the mountains on the west side of the Cumberland Valley. This and all the succeeding consolidated formations occur only in the Mercersburg quadrangle. The Juniata is the beginning of a series of sandy sediments that mark the change from the Ordovician to the Silurian system. The formation is characteristically reddish and the predominant material on a hillside exposure is sandstone. Only in cliffs or road sections are the interbedded shales seen.

One of the clearest exposures of the formation is on the south side of Jordans Knob, along the road that ascends into Horse Valley. Here the lower portion is composed chiefly of soft dull-red cross-bedded granular sandstone containing large flat pebbles of red shale. Some beds have small rust-colored ferruginous specks that weather out and leave the surface pitted. With this sandstone is interbedded bright-red shale which forms a considerable part of the lower 200 feet of the formation. Shale beds are less numerous higher in the formation and at the top it is made up entirely of brownish to gray sandstone, harder and more massive than that below but not so hard as the overlying Tuscarora sandstone. The total thickness of the formation on Jordans Knob is approximately 400 feet.

On the Chambersburg pike, 2 miles east of McConnellsburg, the lower beds are rather massive, 6 to 15 inches thick, with a little red shale between, and contain shale pebbles 3 inches across. The upper beds are cross-bedded and grayish. At this place the thickness is about 450 feet. At the Knobsville gap in Little Scrub Ridge, 1 mile north of the quadrangle, the formation, which is vertical and clearly exposed, measures only 300 feet. All the formations are thinner in this ridge than in other sections in the area because of the squeezing out of the thin shaly beds during the intense compression and faulting on both sides of the mountain.

On the road west of Foltz leading into Little Cove the formation measures about 450 feet and is made up largely of poorly exposed soft red sandstone and shale below and 60 feet of massive, hard purplish-gray sandstone with thin red shale at the top. All the sandstones are cross-bedded and some are coarse and contain red shale pebbles. On the north side of Cove Gap one massive conglomerate bed contains round milk-white quartz pebbles 1 inch in size. A similar quartz conglomerate is strongly developed on Claylick Mountain, where it is 8 feet thick and contains, besides white quartz, pebbles of greenish chalcedony and red jasper. These pebbles were probably derived from veins and beds in the pre-Cambrian rocks of South Mountain or from a land mass farther east.

Distribution and surface form.—North Mountain and the mountain next west in the northern part of the Mercersburg quadrangle are synclinal in structure, and the Juniata formation forms the outer slopes of each. Claylick Mountain, on the southern border of the quadrangle, is capped by massive conglomerate beds of the formation, the harder overlying Tuscarora sandstone having been eroded from the faulted syncline.

The Juniata area on the slopes of Two Top Mountain is part of the belt forming the east slope of Cove Mountain, with which it is connected by means of Cross Mountain just south of the quadrangle. (See fig. 12.) North of Cove Gap a narrow arm of the Juniata ascends Buck Run on the west side of a faulted syncline, and other projections and reentrants of the formation are produced by the complicated structure. On the west slope of Tuscarora Mountain and on the east slope of Little Scrub Ridge the formation is regular in outline.

The outcrops of the Juniata are in many places inconspicuous, because the talus from the harder overlying sandstone which forms the crests of the ridges hides the softer sandstones. Their red color always shows in the roads, however, especially where the rock is used as road material, for which it is admirably suited because it is easily dug and makes a smooth road bed.

Correlation.—The Juniata formation is named from Juniata River in central Pennsylvania, where it is well exposed in gaps through the sandstone ridges. Together with the Tuscarora sandstone it makes mountains which not only cross the State into New York but also extend southward into Virginia. In Pennsylvania they have together generally been called the Oneida and Medina sandstones, but in Virginia and Tennessee the lower red sandy rocks are called Bays and the harder upper sandstone Clinch.

No fossils were found in this formation in the Mercersburg and Chambersburg quadrangles, but to the south in Virginia and Tennessee the similar and supposedly contemporaneous Bays sandstone has been determined by fossils to be of the age of the Maysville formation (Upper Ordovician) of Ohio.

SILURIAN SYSTEM.

The Silurian in this region begins a cycle of sedimentation with pure white quartz sandstone, followed by shales and ferruginous sandstones in which thin limestones appear and finally predominate. This general sequence is common throughout most of the Appalachian region from New York southward. The Tuscarora sandstone, the basal formation, is followed by the Clinton formation, the Cayuga formation, and the Helderberg limestone.

TUSCARORA SANDSTONE.

Character and thickness.—The Tuscarora sandstone is the mountain-making rock of the Appalachian Valley ridges in the Mercersburg quadrangle. It is a resistant granular white quartz sandstone. Its ledges form the crests of the mountains, and a great talus of its débris covers the slopes and hides the outcrops below. Talus composed of great blocks of the rock is especially prominent where the beds have been cut through by streams, such as in Rocky Hollow west of Fort Loudon.

In the Franklin Furnace gap, in North Mountain, hard white sandstone of the formation is well exposed in section, standing nearly vertical and at least 200 feet thick. About 150 feet of white sandstone is well exposed at the south end of the Horse Valley syncline in the double peak of Jordans Knob.

On the south side of Cove Gap the formation is 270 feet thick. The lower 170 feet is composed of thick-bedded granular sandstone with about 30 feet of very massive hard white quartzitic rock in the middle. The upper 100 feet is soft white sandstone, thin bedded at the top, and is probably concealed in the sections mentioned above. A similar thickness was measured on the road crossing Cove Mountain southwest of Mercersburg. At Knobsville Gap, in Little Scrub Ridge, only 150 feet of white sandstone occurs, the softer thin-bedded portion being probably squeezed out during the compression. Excellent exposures occur along the pikes crossing Tuscarora Mountain, but the dip and the slope of the surface are so nearly the same that the outcrop is very wide and the thickness is not readily obtainable. The great plates of coarse granular sandstone with yellow-stained surfaces are exposed almost continuously along the road and have been quarried in places for flagstones.

Distribution and surface form.—The easternmost exposure of the formation in these quadrangles is on North Mountain, where it caps both ridges of the syncline. The outcrop of the steep eastern limb is narrow, while the western limb of sandstone forms the mountain slope down to the creek. The eastern ridge, being the overturned, crushed, and unprotected side of the syncline, and consequently the weaker, has been cut through at several points by the mountain streams. Parnell Knob is the upturned end of the sandstone syncline. The outcrops of the Tuscarora sandstone on the mountain next west are very similar, though more symmetrical, and the mountain ends in a double sandstone peak, Jordans Knob. The counterparts of these two synclines of sandstone are Two Top Mountain and Caseys Knob, the latter just beyond the southern border of the quadrangle, where the synclines pitch sufficiently for the Tuscarora sandstone to be preserved.

In Cove Mountain, south of Foltz, the rocks are overturned, dipping steeply to the southeast, and the outcrop is narrow. The crest is correspondingly sharp and jagged. To the north a parallel band forming Rattlesnake Ridge unites with the Cove Mountain outcrop, forming a syncline which caps Cape Horn as well as the outlier Hogback Mountain. The west side of the Little Cove syncline is more gentle and the outcrops on Tuscarora Mountain cover the slopes to its foot. To the north the sandstone forms both slopes of the mountain, which is here anticlinal, and the outcrop is over a mile wide. West of Cape Horn the mountain slope is a sheet of almost bare white rock which makes an imposing appearance from the pike.

On both sides of Allen Valley the formation covers the steeper part of the slope in a gentle and symmetrical syncline. On Little Scrub Ridge it is nearly vertical and occupies a very narrow strip along the crest.

Correlation.—No fossils except indistinct trails have been obtained from the Tuscarora formation in this area. In lithologic character and position it is equivalent to the Clinch sandstone of Tennessee and Virginia. In adjacent areas in Maryland and West Virginia it has been mapped as the Tuscarora sandstone, named from Tuscarora Mountain, which passes through the Mercersburg quadrangle and extends northward in Pennsylvania for many miles. Together with the underlying Juniata formation it has been referred to in the reports of the Geological Survey of Pennsylvania as the Medina and Oneida sandstones and they are undoubtedly stratigraphically equivalent to the Medina formation of New York.

CLINTON SHALE.

Character and thickness.—The Clinton shale directly overlies the Tuscarora sandstone and is composed largely of shale with heavy sandstone and quartzite beds in its upper portion. The shale is a soft fissile clay shale, of gray to drab color, varying to greenish and pink and discolored along joint and cleavage planes by rust stains. The uppermost sandstone is a hard quartz flagstone, composed of several 12 to 18 inch beds that make conspicuous outcrops and in the area adjoining on the southwest are of mappable proportions. The bedding surfaces of the flags are rough, tarnished red by iron, and pitted by scolithus tubes, which, in sections across the bedding, are seen to be very short. About 100 feet below this sandstone is a zone of red sandstone and quartzite, the chief bed of which is a compact red quartzite with conchoidal fracture, so hard and massive as to form minor ridges on the mountain slope. This bed is sufficiently ferruginous elsewhere in Pennsylvania to be an ore of iron and is described in the reports of the Second Pennsylvania Geological Survey under the name "block ore." There are other thin-bedded red sandstones containing shale pebbles and pebble casts interbedded in the shale. These layers form thin slabs with shiny red surfaces on which are numerous unidentified trails of animals or plant impressions and a variety of other peculiar markings, some of which resemble mud flows, small ripple marks, and raindrop impressions.

The best exposures of the Clinton in this area are along the pike west of Cove Gap. Eastward from the tollgate on the east side of Tuscarora Mountain there is a nearly continuous outcrop with low dip. The total thickness is 750 feet and the formation is composed chiefly of soft greenish-gray clay shale. Near the base are soft yellow porous sandy layers, highly fossiliferous, probably representing weathered calcareous beds. About 150 feet from the top are thin slabby red sandstones and two beds of hard red quartzite 40 feet apart, the upper, more massive bed being 10 feet thick. At the top is a thick, flaggy white scolithus quartzite with red-stained bedded surfaces. To the east the same series is repeated by faulting in an overturned syncline, the scolithus sandstone just appearing at the road in the center of the fold. The thickness measured here is also 750 feet, but the rocks are crushed and the details of the section not clear.

Distribution and surface form.—The largest body of the Clinton shale in this area is in the Little Cove syncline, extending from the southern border of the Mercersburg quadrangle up to Rocky Hollow. Along the Mercersburg pike and the road to the head of Little Cove the details of the stratigraphy can be seen, but elsewhere the shales are rarely exposed and the sandstones are represented only by fragments. The rocks on the east side of the syncline are vertical or overturned and crushed and in consequence are poorly exposed. On the west side the dip is low and the hard red quartzites make a series of elongated knobs or short ridges on the lower mountain slope, with hopper-shaped valleys behind them. The white scolithus quartzite forms the east face of these hills. At Cove Gap the syncline is double and the formation area is about 1 mile in width. The portion west of the fault continues northward as a very slender monoclinal strip. The synclinal trough to the east is compressed in the vicinity of Rattlesnake Ridge, but at the north it opens out and the red quartzite makes prominent knobs on the mountain top.

In Allen Valley the Clinton occurs only on the lower slopes, the red quartzite does not show prominently, and the white scolithus quartzite at the top is seen only in the vicinity of Cowan Gap. In Little Scrub Ridge only a small basal portion of the shale is present next to the fault. In Horse Valley the formation occupies a large V-shaped area on the interior slopes of the mountains. The red quartzite forms prominent peaks at the head of the valley and high foothills along the west side. The white quartzite is also present at the top of the formation. In the North Mountain valleys the formation is restricted almost entirely to the east side. At the south end of the mountain the red quartzite forms the high dome which is a landmark throughout the region. At the Franklin Furnace gap the red quartzite is well exposed in the stream bottom and the scolithus quartzite forms the center of the syncline.

Correlation.—The shales and soft sandstones of this formation are usually fossiliferous and a large number of species have been collected and identified. In the soft sandy layers near the base, which are probably calcareous when fresh, minute horseshoe-shaped Ostracoda are especially abundant and, when stained yellow by iron, are conspicuous in the rock. The red sandstones are barren of fossils except trails and other markings which have not been identified. The fossils collected are as follows:

Tentaculites n. sp.
Anoplotheca hemispherica.
Bollia lata.
Bollia n. sp.
Beyrichia n. sp.
Calymene clintoni.
Buthotrephis gracilis.
Lycrophycus sp. undet.
Primitia sp. undet.
Dalmanella elegantula var.
Camarotœchia equiradiata.
Aparchites sp. undet.
Bythocypris sp. undet.
Lingula cf. L. oblata.
Camarotœchia neglecta.
Chonetes cornuta?
Orthis tenuidens.
Atrypa gibbosa.
Scolithus (short thin tubes).

According to Mr. Ulrich this fauna and the beds in which it is found are practically identical with those of the typical Clinton of New York, which makes the use of the name Clinton for this formation appropriate. In adjacent portions of Maryland and West Virginia the formation has similar characters and the same stratigraphic limits except that a fossiliferous calcareous phase is associated with the scolithus sandstone, the fauna of which corresponds closely with that of the Rochester shale of New York. If it is present in the Mercersburg region it is concealed by detritus and was not observed. The Clinton shale of this quadrangle represents not only the fossiliferous shales in Virginia and West Virginia that have been called the "Rockwood" formation but also the underlying red strata called the Cacapon sandstone, which is not recognizable in the Mercersburg area.

CAYUGA FORMATION.

Character and thickness.—The Cayuga formation overlies the Clinton and is exposed in only a few synclines in this area. The largest area and the only one in which the formation can be studied in detail is in Little Cove. Its exposures here are composed largely of shale, with minor sandstones and thin-bedded limestones.

The basal portion of the Cayuga as mapped in the Mercersburg quadrangle has not been seen and may contain calcareous beds like those that occur at the base of the formation in adjacent areas on the west. The lowest beds of the formation seen in Little Cove are made up of shale of variegated colors, conspicuously red and green. Where sandy these beds make tough resistant outcrops, similar to the sandy red beds so prominently developed near the base of the formation in the adjacent Hancock quadrangle, where they are mapped as a member of the Cayuga. In the upper part of this shale there is a soft yellow sandstone and locally a hard white sandstone.

In the area of the upper part of the formation on the east side of Little Cove only a few outcrops of thinly laminated light-gray argillaceous limestone occur. These are probably part of a thick series of thin-bedded limestone and calcareous shale that is exposed in the adjacent Hancock quadrangle. West of Hancock this impure limestone, which is a natural cement rock, occurs in thick beds that have been quarried on a large scale for cement purposes. The thickness of the formation determined in the Hancock quadrangle is 750 feet.

Distribution and surface form.—In Little Cove the red and green shale forms the bottom of the valley from the western foothills to the road and is well exposed along the road at many places. The shale is sandy and hard in places near the middle of the formation and makes the low hills north of Woods. Soft yellow sandstone is interbedded with the shale here and there, giving rise to striking color contrasts of red, green, and yellow. Just beyond the southern border of the quadrangle a hard white sandstone forms a low hill. The limestone is seen just above the shale east of the creek in only a few places. A narrow strip of the formation is also present east of the fault in this syncline, but it is concealed in most places, only a small area of the red shale being seen at the north end, near Cove Gap.

At Cowan Gap, in Allen Valley, red shale of the Cayuga occurs a short distance west of the scolithus sandstone of the Clinton which forms the wall at the head of the small run. The rest of this area of the formation is covered by flood-plain deposits, and no outcrops occur. In Horse Valley there is a large area of the formation, but exposures are few. Red and yellow shale and sandstone are scantily exposed in the valley bottom, and thin limestone occurs just north of the border of the quadrangle.

Correlation.—No fossils have been found in the basal portion of the Cayuga in the Mercersburg quadrangle. The barrenness, lithologic character, and general red color of the basal beds suggest the red gypsiferous shale of the Salina of New York, but neither gypsum nor salt deposits have been found in these rocks in this area. The limestone and calcareous shale in the upper part of the formation contain a few Ostracoda—unidentified species of *Leperditia*, *Primitia*, and *Klœdenia*—which indicate middle Cayuga age. The thin laminar character of the rock is also similar to that of the waterlimes of the Cayuga of New York, although eurypterids, so characteristic of that horizon, have not been observed in this area. The formation as a whole is correlated with the Cayuga and that name is given to it.

In recent reports of the Maryland Geological Survey this formation is called Salina, and in older reports relating to nearby portions of Maryland and West Virginia the name Lewistown was used to embrace the Cayuga and the next overlying (Helderberg) limestone. In the reports of the Geological Survey of Pennsylvania this formation was described as Salina, the limestone, however, being generally included with the overlying "Lower Helderberg." These higher formations, from the Cayuga up, are so poorly exposed in Franklin and Fulton counties that the Pennsylvania State reports barely touch on their occurrence in these counties and give no details of their character.

HELDERBERG LIMESTONE.

Character and thickness.—The only outcrops of the Helderberg limestone in this area are on the east side of Little Cove. Massive dark crystalline coralline limestone forms the lower part of the formation, and fossiliferous cherty limestone the upper part. The crystalline bed was seen about 1 mile northeast of Woods, where about 30 feet is exposed, the lower massive portion being a coral reef of *Favosites* and the upper portion shaly and thin-bedded limestone. One bed containing numerous *Stromatopora* and corals emits a peculiar fetid odor when struck by the hammer. The upper part of the formation is represented at the surface almost solely by numerous chert fragments, which form projections and flat-topped ridges on the lower western slope of Cove Mountain. The thickness of the formation can be only approximately determined as 300 feet. In adjacent portions of Maryland and West Virginia it measures from 380 to 425 feet.

Correlation.—Fossils have been collected from both the crystalline limestone and the upper cherty portion of the formation. From the outcrop of the coralline limestone in the Mercersburg quadrangle *Favosites helderbergiæ* were collected, and in the upper shaly part of the limestone crinoid stems and *Uncinulus vellicata.* Farther south in Little Cove the following additional fossils were obtained: *Stromatopora* (two species), *Cyathophyllum*, Bryozoa, and numerous *Leptæna rhomboidalis.* These forms are referred to the Coeymans ("Lower *Pentamerus*") horizon of the Helderberg limestone of New York.

The cherts of the upper part of the formation are very fossiliferous and the following species were collected in the quadrangle:

Leptæna rhomboidalis.
Stropheodonta becki.
Spirifer perlamellosus.
Spirifer macropleura.
Spirifer cycloptera.

In the adjoining portion of the Hancock quadrangle the additional forms *Monotrypa* (*Ptychonema*) *tabulatum* and *Platyceras gebhardi* were found. This is undoubtedly a New Scotland ("*Delthyris* shaly limestone") fauna. A Becraft fauna was also found in this formation in the Hancock quadrangle by the Maryland Geological Survey, so that correlation of the formation as a whole with the New York Helderberg is positively established. The Helderberg and Cayuga formations were together formerly called the Lewistown limestone in West Virginia and Maryland. In Pennsylvania the Helderberg has long been recognized by its fossils and was described in the State reports under the heading "Lower Helderberg."

DEVONIAN SYSTEM.

The Devonian system throughout the northern Appalachian province is composed chiefly of shale interspersed with sandstones. Limestone occurs at two horizons but not persistently throughout the region. The Oriskany, which in general is composed largely of sandstone, is in the Mercersburg quadrangle and adjacent area to the west highly calcareous. It is followed by the Romney and Portage shales and the Chemung formation. The Catskill red sediments lie at the top of the Devonian system.

ORISKANY FORMATION.

Character and thickness.—Few outcrops of the Oriskany formation are present in the Mercersburg quadrangle. On the lower western slope of Cove Mountain a few fragments of quartz conglomerate, coarse porous sandstone, and fossiliferous chert occur on the upper side of the Helderberg chert hills, so that a narrow area is shown on the map between the Helderberg limestone and the fault to the east. In the southern part of Little Cove, beyond the quadrangle boundary, the formation is composed of cherty limestone and fossiliferous white quartz sandstone, with a fine conglomerate at the base made up of pea-sized, smoothly rounded white quartz pebbles, rather loosely cemented. It is here overlain by black shale which some distance above the base contained Hamilton fossils. The thickness is estimated to be 175 feet.

Correlation.—Both the sandstone and the cherty limestone are fossiliferous. In the Mercersburg quadrangle only one fossiliferous outcrop was observed and from this *Spirifer cumberlandiæ*, *Spirifer arrectus*, and *Rhipidomella* cf. *R. musculosa* were obtained. Just outside the quadrangle, in the lower part of Little Cove, the following additional species were collected:

Stropheodonta magnifica.
Stropheodonta lincklæni.
Anoplia nucleata.
Spirifer arenosus.
Rensselaeria ovoides.
Platyceras gebhardi.
Megalanteris cf. ovalis.
Camarotœchia barrandii.

This is a typical upper Oriskany fauna, and other Oriskany species are found in adjoining areas, so that correlation with the Oriskany of New York is established. The formation is characteristically developed toward the west in Maryland and West Virginia, where the name "Monterey" sandstone was applied in earlier reports. In the Pennsylvania State reports the term Oriskany was early used for these rocks.

ROMNEY AND PORTAGE SHALES.

The Romney and Portage shales of the Devonian in the adjacent region to the west come normally above the Oriskany and undoubtedly occur beneath the Chemung formation in the northwest corner of the Mercersburg quadrangle, but are faulted out at the surface. The Romney shale has been generally considered to represent the undifferentiated Marcellus and Hamilton of New York, which can be faunally distinguished in the adjacent region but can not readily be mapped separately. The Onondaga limestone and associated hard shaly rocks, which occur directly above the Oriskany in New York, have not heretofore been recognized in this vicinity, but the Onondaga fauna has recently been discovered by Kindle at the base of the Romney. The Genesee shale, which occurs between the Hamilton and Portage farther west in Maryland, is absent in the adjacent areas. The next succeeding formation that outcrops in the quadrangle, the Chemung, is separated from the older rocks by a profound fault on the west side of Little Scrub Ridge.

CHEMUNG FORMATION.

Character and thickness.—The Chemung formation is an alternation of shale and thin sandstone beds. The shale is generally sandy and greenish gray to chocolate-colored. The sandstones are gray to reddish or chocolate-colored and somewhat micaceous. In the Hancock quadrangle, to the southwest, two sandstones, one at the base and the other near the middle of the formation, are usually conglomeratic and more generously fossiliferous than the shale. The thickness determined there is between 2000 and 2500 feet. In the Mercersburg quadrangle the Chemung occurs only in the northwest corner, west of the Little Scrub Ridge fault. The lowest strata seen adjacent to the fault were fossiliferous crinoidal sandstones, and it is estimated that not more than 1000 feet of the formation is exposed in the quadrangle. Toward the top the red color becomes more prominent and just beyond the corner of the quadrangle the formation grades into bright-red micaceous and arkosic sandstone of the Catskill formation.

Correlation.—Fossils are not numerous in either the shale or the sandstone in the quadrangle. Large crinoid joints, stained yellow by iron, are usually conspicuous in the sandstone beds. Only a few fossils have been obtained from the formation in this quadrangle — *Spirifer mesistrialis, Chonetes scitula, Schuchertella chemungensis arctostriatus* and undetermined Bryozoa.

A larger number have been collected by the writer from these beds in the Hancock quadrangle to the southwest, as follows:

Spirifer disjunctus.
Spirifer mesistrialis.
Schuchertella cf. S. chemungensis.
Delthyris mesicostalis.
Productella cf. P. lachrymosa.
Camarotœchia sappho.
Tropidoleptus carinatus.
Schizodus oblatus.
Glyptodesma cf. G. erectum.

These forms are not all diagnostic of the typical Chemung fauna of New York, as recently restricted by Williams to the *Spirifer disjunctus* fauna. *Spirifer disjunctus* was not found in the Mercersburg quadrangle and its range was therefore not determined. In the Hancock quadrangle the lower part of this formation, characterized by the presence of sandy strata with granular sandstone beds, does not contain the typical Chemung or *Spirifer disjunctus* fauna but a recurrent Hamilton fauna characterized by *Spirifer mesistrialis.* In New York the sandy strata that characterize the Chemung at Chemung Narrows, the type locality, descend below the base of the *Spirifer disjunctus* fauna toward the east, and the Chemung formation there includes strata that contain a *Spirifer mesistrialis* fauna. The formation in the Mercersburg quadrangle is therefore mapped as Chemung.

In the reports of the Geological Survey of Pennsylvania the formation has been described and mapped as Chemung. In adjacent portions of Maryland and West Virginia it has been included with the underlying Portage as the Jennings formation by the Maryland Geological Survey and in earlier folios of the Geologic Atlas of the United States.

CATSKILL FORMATION.

Red arkosic sand and shale of the Catskill formation occur just beyond the northwest corner of the Mercersburg quadrangle. Some of the upper beds of the Chemung are red and closely resemble the Catskill both in color and composition. The boundary is drawn where the red sediment begins to prevail. The material is made up of poorly assorted, cross-bedded sands and fine muds stained red and spangled with flakes of mica, with some coarse layers. No fossils except unidentified plant remains have been found in this formation, but its lithologic character and stratigraphic position establish its correlation with the Catskill of New York and northeastern Pennsylvania. It is undoubtedly a land or fresh-water deposit replacing the upper part of the marine Chemung.

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 deposits cap terraces above the present drainage level; the more recent compose the alluvium in the flood plains of the present streams.

TERRACE GRAVELS.

Character.—The unconsolidated terrace gravels are remnants of deposits laid down by streams in channels that were higher than the present stream bottoms, when the surface of the land was nearer sea level than it is now. After these gravels were deposited the land rose and the streams became more active. Their valleys were cut deeper and patches of gravels were left on elevated benches. The gravels are local in origin, having been derived from the rocks of the mountains from which the streams flowed. The bowlders and pebbles that came from South Mountain are mostly white quartzite and coarse sandstone, many containing scolithus tubes; there are also some of quartz, metabasalt, and aporhyolite. The gravels from the western range of mountains contain a large amount of hard red sandstone from the Clinton and Juniata formations with the coarse white Tuscarora bowlders.

At the point where the larger streams, such as Buck Run, Wilson Run, and Conococheague Creek, leave the mountains, large alluvial fans of coarse material have accumulated, forming high terraces from 700 to 850 feet in elevation, with abrupt frontal slopes. Along the foot of South Mountain, especially north of Conococheague Creek, there are large areas covered by wash formed by innumerable coalescing small fans, and as the underlying formations are entirely concealed by these gravels they are mapped and included with the terrace deposits. As observed in mine pits the wash is very thick in places. In English Valley several shafts were sunk from 100 to 130 feet in unconsolidated gravel before limestone bed rock was encountered, and many of the open pits on the steeper slope of the mountain side showed 50 to 60 feet of loose material. This thick sheet of wash was accumulated by the small streams and rivulets from the mountain ravines, which drop their load of detritus as soon as they emerge upon the gentler grades of the valley floor. Except during heavy rains the water sinks rapidly into the gravels and disappears from the surface, in most places finding its way into subterranean channels in the underlying limestone. This process has been going on ever since the present topography has existed, certainly since late Tertiary time.

Over thirty years ago a deposit of lignite was discovered in a shaft in the wash at the Pond iron-ore bank, near Little Mountain. The shaft section as reported by J. P. Lesley, of the Pennsylvania Geological Survey, was as follows:

Section of shaft at Pond iron-ore bank, near Little Mountain.

	Feet.
Soil and wash	5
White clay, some ore	5
Light-colored sand	5
Yellow and red clay and sand	25
Tough black clay with small organic particles	1
Lignite	4
Gray sandy clay	1
Lignite	18
Sand	1
Variegated clay	2

The lignite lay nearly horizontal and was followed by a drift for 48 feet, to a point where it began to change to clay. The lignite was described as solid, glistening, and hard, burning freely but disintegrating on exposure.

Distribution.—The stream gravels have a natural gradation in altitude from the mouth of the mountain gorge to the middle of the open graded valley. Remnants of three such gravel-covered benches can be more or less clearly distinguished in the Mercersburg and Chambersburg quadrangles. The highest gravels, at 700 to 840 feet elevation, are represented chiefly by the alluvial fans and associated terraces in front of stream gaps in the mountains. Terraces occur at this altitude also along the larger streams but are generally not gravel covered. Two lower gravel-capped terraces occur along the lower courses of the larger streams, the upper one ranging in elevation from 680 feet upstream to 620 feet at the southern margin of the quadrangles and the lower one from 640 to 480 feet.

The highest gravels occur in alluvial fans at Cove Gap, the Franklin Furnace gap, Nancys Saddle, and Black Gap, and in terraces and aprons of wash along the South Mountain front from Little Antietam Creek to the northern border of the Chambersburg quadrangle. They also cap the hills southwest of Scotland and in the vicinity of Beautiful. The best example of a high alluvial fan in this area is that at Cove Gap. The gravel-capped terrace at an elevation of 700 to 760 feet is 2 miles in width and has an irregular fan shape. The stream now flows at the extreme northern edge of the fan and has cut a deep channel. Other deep serrations on the border of the fan probably mark earlier channels of Buck Run. The gravels extend out on adjacent lower slopes and benches, one of which reaches nearly to Mercersburg, a distance of 3 miles. The gravels are composed largely of the red ferruginous sandstone of the Clinton. Edenville is on a similar high-level fan, which was deposited by Wilson Run where it leaves North Mountain through the Franklin Furnace gap. Its elevation is approximately 800 feet.

A broad level-topped terrace borders Conococheague Creek where it escapes from its gorge in South Mountain. It has an elevation of 840 to 820 feet, and the gravels, which are not cut through by the present stream, are at least 80 to 100 feet thick. The ancient course of the stream can be traced southwest of Scotland by the gravel-covered terrace at an elevation of 760 to 700 feet. The high gravels on the plateau north of Beautiful suggest that at a very early stage the stream may have taken a northerly course toward Susquehanna River, but the history of these gravels has not been traced.

Gravels at an elevation of 680 feet along Conococheague Creek indicate that its southerly course was established when that level was reached by the stream in its downward cutting. This stage of stream cutting is preserved in gravel terraces bordering the creek at intervals and especially in the 620-foot hilltop at the double bend southeast of Williamson, which is capped with gravel and marks the stream channel at that stage.

Gravel-covered terraces at lower levels occur along the Conococheague below Chambersburg and along the West Branch, but a distinct bench is not so well defined. They range in level from 640 to 480 feet, though in many places they grade by uniform slope into the present flood plain. They are not distinguished on the map from the higher gravels.

Age.—No fossils have been found in the terrace gravels, but from their elevation above sea and the present drainage, as described more fully under "Historical geology," most of the terrace gravels in this area are regarded as of late Tertiary age, being probably equivalent to the Lafayette of the Piedmont Plateau and Coastal Plain. Those on the lowest benches that merge into the present flood-plain deposits are no doubt Pleistocene.

In the shaft at the Pond iron-ore bank, above referred to, lignitized logs showing rings of growth, rays, and bark fiber and nuts were found in the lignite and were regarded by Lesley, of the Pennsylvania Geological Survey, as indicating Tertiary age, but no definite determination of the specimens was reported. It is probable that the basal part of the wash is Tertiary and that deposition with occasional erosion has been going on at the foot of the mountain during all of Quaternary time.

The origin of these gravel-covered terraces and their probable age and correlation are more fully discussed under the heading "Historical geology."

RECENT ALLUVIUM.

The larger streams that cross the limestone plain have flat-bottomed valleys and are bordered by flood plains of considerable width. Although gravels and cobbles brought from the mountains make up a large part of this filling, the surface is usually covered with rich loam and sand and makes excellent farm land. The Conococheague above Scotland has a broad alluvial bottom, but from Scotland down to the big bend opposite Kauffman the bottom land is in small patches on the convex sides of the oxbows, which are very numerous in this portion of the stream. Another broad strip of level bottom land extends from this bend to the junction with Back Creek at Williamson. Below this point the flood plain is narrower and lies at the bottom of a steep-walled valley or canyon which becomes narrower and more tortuous toward the southern border of the Mercersburg quadrangle. West Branch up to the vicinity of Mercersburg has a similar deeply incised valley with small alluvium patches. Farther upstream the valley is more open and there are several broader patches of bottom land extending up Path Valley to the northern border of the quadrangles. Back Creek is the only other large branch of the Conococheague that has a silted flood plain of mappable size. Alluvium is present in most of the smaller valleys, especially those in or descending from the mountains or large elevated tracts of shale, but it is too narrow to be shown on the map.

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. 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 gradually and are replaced by others. Single folds more than 300 miles long are known, but the folds are more commonly 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 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 source 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. Shrinking of the earth and corresponding shortening of its radius would produce in the surficial harder portions tangential stresses that would find relief in the folding of the strata. The circumference of the globe would by this process be correspondingly shortened. The sinking of ocean basins would cause deep-seated flowage toward the rising continents and corresponding pressures in the overlying harder rocks against the interior of the continent.

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 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.

STRUCTURES IN THE MERCERSBURG AND CHAMBERSBURG QUADRANGLES.

GENERAL DESCRIPTION.

The Mercersburg and Chambersburg quadrangles are part of the greater westward-dipping monoclinorium between the South Mountain uplift on the east and the Appalachian coal fields of western Pennsylvania and Ohio. From South Mountain, where the oldest rocks in the area occur, younger rocks successively appear westward to the Back Creek belt of Martinsburg shale, the first pronounced syncline. Successively deeper synclines follow to the west—first, the Parnell Knob and Jordans Knob synclines, deep enough in part of their course to carry Clinton and Cayuga shales above Silurian sandstones, and next the faulted synclines of Allen Valley, Buck Run, and Little Cove, the Little Cove fold inclosing Oriskany formation at the south end. The last syncline in the area is the faulted fold in the northwest corner containing Chemung and, just beyond the border, Catskill beds. The total differential uplift represented by the monoclinorium from the Catskill on the west to the pre-Cambrian of South Mountain is 24,000 feet, which means that the combined uplift of South Mountain and sinking of the sea bottom to the west have resulted in this amount of vertical movement.

SOUTH MOUNTAIN UPLIFT.

General character.—The general structure of South Mountain in this region is that of a broad uplift, with minor folds on its surface. It rises steeply from the limestone valley on the west, exposing a core of pre-Cambrian volcanic rocks beneath Cambrian quartzites. Minor synclines on the broad top of the uplift inclose Cambrian quartzites, and, pitching toward the southwest, produce offsets in the western front of the mountain. The eastern edge of the uplift is some distance outside of the Chambersburg quadrangle, where the pre-Cambrian rocks and Cambrian quartzite give place to the lowland Triassic deposits which are underlain by Paleozoic limestone.

A striking feature of this portion of the South Mountain uplift is the change in the direction of its trend from nearly due north at the Maryland state boundary to nearly due east at its terminus at Dillsburg, as is shown by the change in the direction of the ridges on the relief map, figure 2. This bending was accompanied by imbricating minor folds on the western margin that successively plunge toward the southwest, produce the offsets in the mountain front already referred to, and die out in the limestone of the valley.

Tomstown anticline.—The offset of the mountain at Tomstown is produced by a sharp anticline followed to the east by a broad gentle syncline and another sharp anticline. The name Tomstown anticline is applied to this compound fold. East of Montalto the fold is a flat-topped anticline with nearly vertical dips on the west (see section D–D), and the pre-Cambrian volcanic rocks exposed in Rocky Mountain Creek are overlain by gently dipping strata of the Weverton in Snowy Mountain. In Rocky Mountain and at The Narrows these sandstones dip steeply down the west side of the anticline, and on the west slope of Montalto Mountain the beds are vertical and even overturned. To the southwest a broad, gently pitching syncline develops in Sandy Ridge and Curve Mountain and is continued in the valley rocks in the purple shale hills north and east of Waynesboro.

Antietam Cove fault.—The strike of the limestone in Antietam Cove is directly across the end of the sandstones of the Tomstown fold. Southeast of the cove the quartzite ridges are parallel with the bedding in the limestone and are offset from the Curve Mountain beds 5 or 6 miles. This break is the faulted acute fold on the east side of the Tomstown anticline, the Antietam quartzite of Curve Mountain having been brought into contact with the Elbrook limestone apparently by an overthrust from the northwest. (See section F–F.) Overthrust faults from the northwest are exceptional in Appalachian structure, and no positive data have thus far been obtained to determine the direction of thrust on this fault. If the overthrust was from the southeast the fault is of much greater magnitude, and the syncline of limestone was thrust over on the anticline of Cambrian quartzites.

Big Flat anticline.—North of Conococheague Creek another offset of the mountain front is produced by the development of an independent anticline forming the Big Flat ridge, which is also a flat-topped, steep-sided fold. The Antietam sandstone flanks it on the west and east with steep dips, but in Pleasant Peak and Eagle Rock, where the anticline pitches south, it dips at only 20° to 30°. Between this fold and the northward continuation of the Tomstown anticline is a crushed and faulted zone which continues out into the valley and connects with the faulted anticlinal uplift of Little Mountain.

Longitudinal faulting.—The absence of faults of any moment along the front of South Mountain north of Antietam Creek in this area is clearly demonstrated by the attitude of the strata. There the rocks of the valley, so far as they are exposed to view, are conformable to the mountain strata, the oldest limestone occurring next to the youngest sandstone of the mountains without any apparent hiatus; and the way in which the formations lap concentrically around the offset in the mountain front at Tomstown precludes the possibility of longitudinal faulting at this point. Those faults that do occur in the mountains, such as the Antietam Cove and the Little Mountain faults, pass out into the limestones of the valley, and do not follow the mountain front. The fault that passes under the wash at Conococheague Island probably continues northward in the limestones parallel to the face of the mountain, but its relations could not be determined in this area. A fault east of Antietam Cove, which probably dies out in this quadrangle, develops farther south, according to Keith, into an important thrust that follows the front of the mountain and separates the harder Cambrian beds from the younger limestones of the valley.

The reports of the Second Geological Survey of Pennsylvania record a master fault along the front of South Mountain with an estimated displacement of 20,000 feet. This was assumed because of the erroneous interpretation of the structure and stratigraphy, as explained under the heading "Metabasalt," whereby there was a stratigraphic hiatus of about 20,000 feet between the limestone of the valley and the adjacent quartzite of the mountain.

FOLDS IN THE LIMESTONE EAST OF GREENCASTLE.

In the limestone area only the larger folds and faults have been traced, and many of these with difficulty because of the relatively large units of mapping and the similarity of the beds. There are no doubt many faults of considerable size that have not been observed and possibly some erroneous structures have been postulated because of lack of outcrops. The major structures, however, have been worked out with care and their delineation is reasonably accurate.

The anticlines and synclines in the limestone east of the Cumberland Valley Railroad and southeast of New Franklin are the extensions of the larger folds of South Mountain, and those in the Waynesboro formation northeast of Waynesboro are the continuation of the Tomstown anticline. The anticline in the Elbrook and Conococheague formations that crosses the Waynesboro pike at Zullinger passes through Five Forks and west of Montalto into the faulted fold of Little Mountain. The sharp folds in the limestone at Shady Grove and Clay Hill, east of Greencastle, also trend northeastward and are the finger ends of the minor folds on the plunging end of the Big Flat anticline of quartzite.

The New Franklin anticline is the westernmost of these folds, and at Falling Spring Branch is so compressed that it is faulted on each side in a fan-shaped fold. (See section C–C.) It is not traceable to the Big Flat anticline but is probably a valley fold that is faulted out to the north.

GREENCASTLE FAULTS.

A fault zone passes just west of Greencastle and through Kauffman and Marion, swings northeastward through Aqua, and passes under the cover of wash west of the Big Flat ridge. These faults are the western limit of the South Mountain structures described above and are the result of an extensive overthrust from the southeast. To the west of the fault zone the structures are in general more simple, straight, and of even keel.

The main fault cuts diagonally across the New Franklin anticline and a smaller anticline to the west, and then strikes southward through Greencastle. At Kauffman the Chambersburg limestone east of the fault was thrust over on an anticline of Beekmantown limestone. This anticline in turn was so compressed by the advancing overthrust that it broke along the line through Marion. The thrust still further compressed the strata beyond until the next anticline yielded and the long syncline of Martinsburg shale from Muddy Run to a point near Guilford Springs was carried over on the anticline of Stones River and Beekmantown limestones. This in turn was somewhat faulted along Conococheague Creek. (See section F–F and fig. 3.) The maximum horizontal displacement along the main fault is apparently 2 miles, and the total horizontal movement must be much greater.

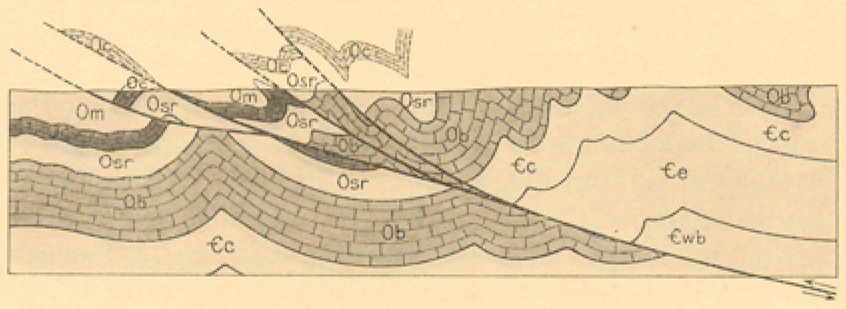

FIGURE 3.—Cross section of the Greencastle faults, illustrating progressive movement along successive fault planes.

Section along the line F–F on the Chambersburg areal geology map; reduced about one-fourth. Єwb, Waynesboro formation; Єe, Elbrook formation; Єc, Conococheague limestone; Ob, Beekmantown limestone; Osr, Stones River limestone; Oc, Chambersburg limestone; Om, Martinsburg shale.

East of Chambersburg the fault plane probably lay higher and the overthrust beds have been removed by erosion, exposing the more gentle and continuous folds in the overridden limestone. The long, straight anticline at Scotland plunges south of Stonehenge.

MASSANUTTEN SYNCLINE.

The Massanutten syncline embraces the wide shale belt between St. Thomas and Chambersburg and between Welsh Run and Greencastle. Its northern portion is drained chiefly by Back Creek, which has cut a deep, flat-bottomed gorge with numerous side ravines into the shale plateau. Although the shale is closely folded, the underlying limestone is not exposed in these deep trenches and, as the shale is only 2000 feet thick, it is concluded that in the underlying limestone the syncline is shallow and only gently folded, the close folding being restricted to the soft shales. (See fig. 11, illustration sheet.) The deepest part of the syncline is near its east side, where the upper sandstone is infolded in two parallel bands. The shale belt narrows somewhat toward the southern border of the quadrangle, owing to the encroachment of anticlines and faults on both margins. Its general broad, shallow synclinal character is, however, preserved. It extends southward across Maryland into Virginia and there incloses the overlying Silurian sandstone which forms Massanutten Mountain, after which the syncline is named. North of these quadrangles the syncline merges into the general westward-dipping monocline.

A fault of an unusual kind, a shear directly across the strike of the strata, is exposed 1 mile northwest of Guilford Springs. Where the fault crosses the road the rocks are sheared along a northwest vertical plane and the Stones River limestone, which stands nearly vertical, strikes into flat-lying Martinsburg shale. To the south the fault is taken up at the top of the Stones River and the overthrust is exposed in a small quarry.

A minor anticline brings up the limestones in Rocky Spring Cove. The Stones River and overlying Chambersburg dip gently southeastward beneath the Martinsburg shale, but on the west they are overturned and the Chambersburg is faulted out in most places. At the north boundary of the Chambersburg quadrangle the Chambersburg limestone is faulted out on the east side also and the limestone cove expands and unites with the main limestone area not far beyond the boundary.

WELSH RUN–EDENVILLE ANTICLINE.

In the southern half of the area the Welsh Run–Edenville anticline is a simple open fold in limestone, with minor folding and faulting on its margins. The dip of the eastern limb is in general 35° or 40° E. and that of the western limb 50° to 55° W. Two small faulted folds on the eastern margin that show faintly east of Vanilla become more prominent west of Upton and at Williamson. West of Williamson the anticline pitches abruptly northward and is diverted by the development of synclines of shale on its eastern margin. This is accompanied by several overlapping faults on the west side of the anticline, the main one of which brings the Beekmantown up against the Martinsburg as shown in section C–C. Farther north the simple anticlinal fold is more compressed and the dips are steeper and somewhat unsymmetrical. (See section A–A.) The fold has along its east side a gentle syncline which incloses Chambersburg limestone west of St. Thomas and Martinsburg shale west of Sandy Hook. A short distance beyond the northern border of the quadrangles the limestone in the anticline disappears beneath the Martinsburg shale and the anticline loses its identity.

NORTH MOUNTAIN ANTICLINE.

North Mountain is a closely compressed syncline which includes the Tuscarora sandstone and the Clinton shale as the highest formations. The western limb, dips 30° to 40° E. and is but little dissected, while the eastern limb which dips 60° to 80° W., is correspondingly narrower and weaker and is broken by water gaps. The syncline rises to the north beyond the boundary of the Mercersburg quadrangle and the sandstone ridges terminate. South of Parnell Knob also the syncline is not so deep and only the Martinsburg shale is preserved across most of the quadrangle. At the southern border of the quadrangle the syncline pitches again and incloses the Juniata sandstone forming Claylick Mountain, with a fault on its east side. South of the quadrangle the Tuscarora sandstone is again infolded in the syncline and forms Caseys Knob.

MERCERSBURG ANTICLINE.

The anticlinal belt of limestone in which Mercersburg is situated is the most complicated structural feature in the area. It comprises two lens-shaped areas of Beekmantown limestone dipping away from a central strip of Martinsburg shale and subjacent limestones. The rocks of these areas seem to form two closely compressed anticlines and a narrow syncline, which are not only bounded by faults but are intersected by them. (See section E–E.) The main lens-shaped area is a westward-dipping mass of Beekmantown limestone which extends from the south border of the quadrangle to the Chambersburg pike. The rocks dip uniformly 50° to 70° W. except at the extreme east margin, where cherty layers near the base of the Beekmantown stand vertical. This appears to be an anticline overturned to the east and faulted, the basal Beekmantown being thrust against the Martinsburg shale and associated limestones. On the west the limestone mass is bounded by an overthrust from the east of the usual type. Its displacement, which is not great at the north, increases toward the south (see structure sections) and has been traced south of the quadrangle to Potomac River.

The lens-shaped area of Beekmantown east of Mercersburg is a similar monoclinal mass dipping 45° to 50° E. It is undoubtedly an anticline overturned to the west, for at its north end the anticline plunges and the Stones River, Chambersburg, and Martinsburg formations wrap successively around the Beekmantown limestone. It is also bounded by faults, which are considered to be overthrusts. The fault planes must be steep, as can be seen by the attitude of the adjacent beds, and the movement was largely an upthrust. The structure would be much simplified if the relations were explained by drop faults, but since all the other structures in the area are the result of intense compression and the beds next to the faults also are squeezed and crushed, normal or tension faults can not logically be considered.

The Mercersburg anticline, in a comprehensive way, is a minor anticline in a general synclinal depression. In the mountains to the north, where the rocks at the surface are resistant, it is a narrow, closely compressed fold forming Bear Valley and continues beyond as a distinct fold to the place where the North Mountain syncline fades out. In the vicinity of Mercersburg the fold is higher and broader, but it narrows again toward the south between the mountains. The unusual structures in the vicinity of Mercersburg may be due to the arching of the overlying resistant strata at this point, thus affording relief to the stresses in the limestone and allowing it to arch up. The anticlines are supposed to have first become closely squeezed isoclines, then fan-shaped, and finally to have broken along steep planes of overthrust or upthrust on both sides. (See fig. 4.) In the lower rocks the compression must have been taken up by slipping along the bedding planes, possibly in the shaly Elbrook formation. It is impossible to determine the source of the pressure, but it may have come from an anticline to the east in the underlying Cambrian quartzites, as suggested in the section.

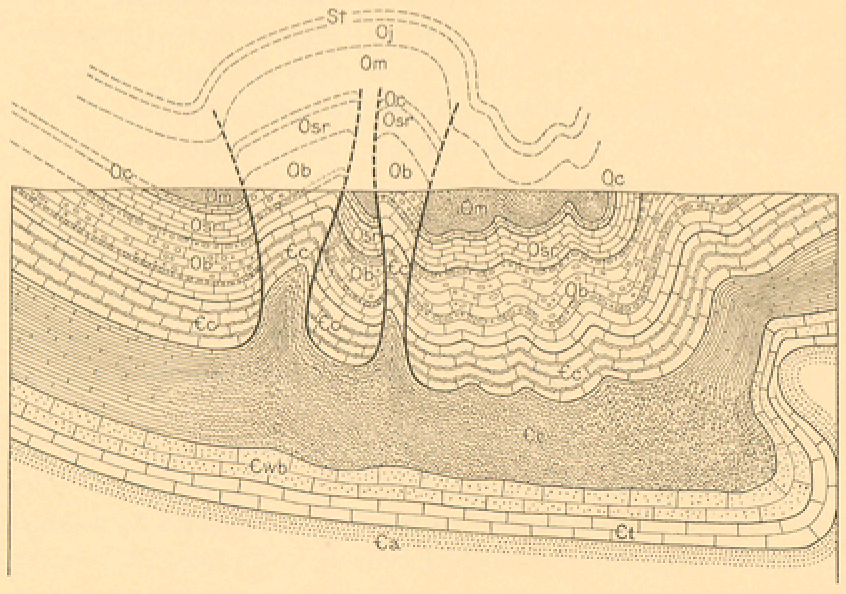

FIGURE 4.—Cross section of Mercersburg anticline along the line E–E on the Mercersburg areal geology map; reduced one-fourth.

The faults on both sides of the double fold are represented as steep overthrusts, or upthrusts, which die out downward at the top of the Elbrook, in which the horizontal movement is supposed to have taken place by slipping and crumpling.

Єa, Antietam sandstone; Єt, Tomstown limestone; Єwb, Waynesboro formation; Єe, Elbrook formation; Єc, Conococheague limestone; Ob, Beekmantown limestone; Osr, Stones River limestone; Oc, Chambersburg limestone; Om, Martinsburg shale; Oj, Juniata formation; St, Tuscarora sandstone.

HORSE VALLEY SYNCLINE.

Horse Valley is a more open syncline than its companion, the North Mountain syncline. (See fig. 7.) It is nearly symmetrical, the western limb dipping 40° to 50° E. and the eastern limb 60° W. It pitches strongly to the north and incloses a broad area of Cayuga formation at the northern border. (See section A–A.) The syncline is shown on the geologic map of the Geological Survey of Pennsylvania continuing as a separate fold for 30 miles to the northeast. Southward across the Mercersburg quadrangle it is represented only by a narrow but regular belt of Martinsburg shale, shown in sections C–C and E–E. At the southern margin of the quadrangle the fold pitches again and incloses the Tuscarora sandstone, forming Two Top Mountain. Here, on account of the thrust faulting on the east side, the syncline is overturned, the eastern limb dipping 55° E.

FOLTZ ANTICLINE AND FAULT.

The anticline that brings up the broad belt of limestone east of Foltz produces Path Valley to the north, which is cut in Martinsburg shale between the sandstone mountains on each side. (See section A–A.) At the northern border of the Mercersburg quadrangle the Beekmantown and overlying limestones are again exposed by a rise in the anticline and continue northward for 15 miles or more. The limestones in the Foltz area have a general eastward dip of 40° beneath the shale, disturbed only by a small faulted anticline at and to the south of Fort Loudon. At the south the limestone goes under cover of the shale at the very gently southward-pitching end of the fold and rises again in the limestone inlier on Licking Creek. The anticline here is very flat topped, as shown in section F–F, and gives rise to the surrounding broad area of shale. Flat-lying sandstone on the top of the anticline caps Cross Mountain, which swings around the southward-plunging end of the shale from Two Top Mountain to Cove Mountain, about 2 miles south of the border of the quadrangle. (See fig. 12, illustration sheet.)

The west side of the limestone area is deeply covered by soil and débris from the mountain, but the few exposures seen indicate that the lower Beekmantown is overturned to 65° E. near Foltz and faulted against the Martinsburg shale, which is itself nearly squeezed out at Cove Gap. (See structure sections.) The fault passes into the shale in Path Valley, but at the northern border of the quadrangle it once more brings up the Beekmantown, here against the Tuscarora sandstone. The fold opens out to the north into a wide area of limestone and shale. South of Foltz the fault can not be traced beyond the point where it passes into the shale, but apparently is the cause of prominent offset in Cross Mountain.

TUSCARORA MOUNTAIN SYNCLINE AND FAULT.

A deep, complex syncline comprises Tuscarora and Cove mountains and the associated ridges and knobs to the north. It is primarily an overturned syncline broken by a longitudinal fault that has been traced across the Mercersburg quadrangle and southward to Potomac River. This simple form is exposed in Little Cove, where the dips on the west limb are 20° to 40° E., while those on the east limb are from vertical to 40° E. (overturned). The fault lies on the western slope of Cove Mountain between the Cayuga and Oriskany formations. (See sections E–E and F–F.)

At the head of Little Cove the fault crosses to the west of the axis of the syncline, and the compressed Cayuga formation in the bottom of the syncline appears on the overthrust east side of the fault. (See section D–D.) North of Cove Gap the bottom of the syncline in the overthrust rises higher and higher, exposing the Tuscarora and the Juniata, and finally in Cape Horn and Hogback Mountain only a small remnant of the Tuscarora is left. This is shown in structure sections B–B to D–D. At the northern border of the quadrangle the syncline temporarily deepens and a small remnant of the Tuscarora is preserved next to the Foltz fault, but farther north it is not traceable in the shale.

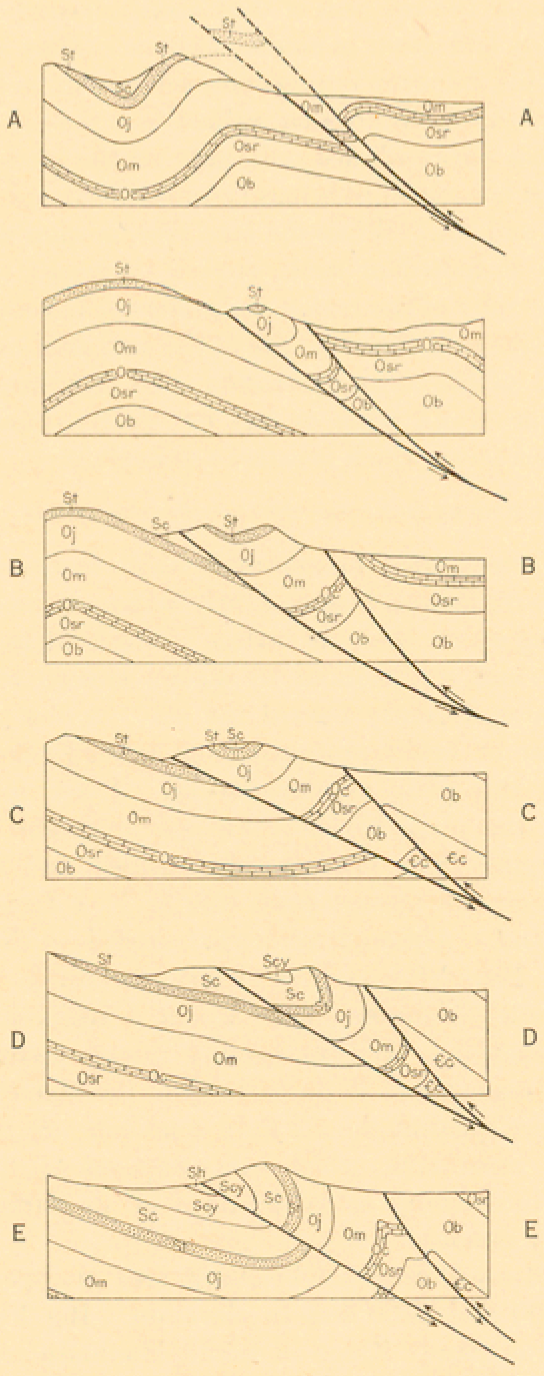

FIGURE 5.—Cross sections of Tuscarora Mountain and Foltz faults.

Sections are along lines A–A to E–E on Mercersburg areal geology map; reduced about one-fourth. The second section from the top is interpolated along a line through Big and Hogback mountains.

Ꞓc, Conococheague limestone; Ob, Beekmantown limestone; Osr, Stones River limestone; Oc, Chambersburg limestone; Om, Martinsburg shale; Oj, Juniata formation; St, Tuscarora sandstone; Sc, Clinton shale; Scy, Cayuga formation; Sh, Helderberg limestone.

As the syncline gradually rises and nearly disappears at Hogback Mountain, another syncline occupied by Allen Valley develops on the west side of the mountains. Tuscarora Mountain becomes anticlinal at this point, the Tuscarora sandstone forming the crest and both sides of the mountain and giving it unusual massiveness and height. North of Big Mountain the eastern limb of the anticline is eroded and the mountain changes to a westward-dipping monocline.

At the northern border of the quadrangle the Tuscarora Mountain fault cuts diagonally across the shale anticline and through the mountain rocks at Cowan Gap into the Allen Valley syncline, offsetting the line of the mountain nearly one-half mile. It brings the Martinsburg into contact with the Cayuga at the gap. The fault passes on down the Allen Valley syncline, which continues northward and finally merges into a larger syncline on the west.

The faulting of the Tuscarora Mountain syncline was apparently produced by the overthrusting of the Foltz fault, which compressed the east side of the syncline, overturning it in the southern part of the area and faulting up the bottom of the trough across the whole quadrangle. The sections in figure 5 illustrate the gradual northward rise of the bottom of the syncline, and the apparent relation of the two faults.

McCONNELLSBURG ANTICLINE AND FAULT.

McConnellsburg Cove is a folded area of limestone (see section B–B) in which the basal Beekmantown is brought up in two separate folds at the south. The eastern axis lies just east of McConnellsburg with gentle dips on the east and dips of 60° on the west. The western axis does not enter the quadrangle. Opposite the Allen Valley syncline the limestone is constricted to less than a mile in width, and not far beyond the northern border of the quadrangle the limestone pitches beneath the shale and the anticline fades out. Toward the south it widens within a short distance to 3 or 4 miles and then again contracts to a point, forming another lens-shaped area. The Stones River and Chambersburg limestones are faulted out on the west side of the anticline in an overthrust fault of the usual kind.

LITTLE SCRUB RIDGE FAULT.

The Little Scrub Ridge fault is one of the most profound faults in the area. It has been traced in Pennsylvania by the State Geological Survey for 20 miles and is known to extend southward into Maryland. In the Mercersburg quadrangle the Clinton shale is thrust on this fault against the Chemung formation in the syncline to the west, as shown in section A–A. At the Knobsville Gap, 1 mile north of the quadrangle, where the relations at the fault are clearly exposed, the beds are vertical and the Tuscarora sandstone is succeeded on the west by 150 feet of red shale and sandstone of the Clinton, and this by rusty fissile sandy shale of the Chemung. The faulting is partly taken up among the beds of the formations composing Little Scrub Ridge, for they are all reduced in thickness and are jointed and slickensided. Along the mountain crest the bedding is so disturbed and broken that in places both the Tuscarora and the Juniata are squeezed out.

The Little Scrub Ridge and McConnellsburg faults are probably the surface manifestation of a single deeper-seated break, the movement being distributed at the surface along the two planes, as in the Tuscarora and Foltz faults. (See fig. 5.) West of McConnellsburg Little Scrub Ridge ends by the Tuscarora and Juniata sandstones being faulted out where the two faults unite. For several miles to the south the Ordovician limestones are brought into contact with the Chemung. The formations cut out by the fault are about 9000 feet thick, but the displacement along the break is probably much greater.

LATE REGIONAL UPLIFT.

Since the great disturbance of the strata near the close of Carboniferous time the attitude of the rocks has been changed little. There is no evidence that the formations in the Chambersburg and Mercersburg quadrangles were tilted and faulted like those of the Triassic to the east, although it would be difficult to detect such slight movement in an area of earlier great disturbance. It is known from the physiographic relations, described on page 16, that this general region has been uplifted since late Tertiary time and tilted toward the sea, but the movement was so gentle that the rocks were not noticeably affected.

HISTORICAL GEOLOGY.

The geologic history of the Mercersburg and Chambersburg quadrangles and vicinity is recorded chiefly in the rocks but partly in the stream terraces, gravels, and gorges. It may be interpreted from the facts already presented in the description of the formations. The later part of the story is the least complete because its records are only partly preserved.

PRE-CAMBRIAN TIME.

The oldest rocks in the area are the ancient lavas of South Mountain. Still older rocks are exposed in adjacent portions of the Piedmont Plain to the southeast, and the earliest records must be sought there. These rocks are gneisses, granites, and schists, probably igneous in the main, although they are so greatly altered that their origin can not everywhere be positively determined. These earliest igneous rocks formed the basement on which the lavas of South Mountain were poured They are evidently much older than the volcanic rocks, for they had been intricately folded and metamorphosed and their planes of foliation truncated by erosion before the lava was extruded. They have been assigned to the Archean period, whereas the lavas are considered to be Algonkian in age, although this can not be positively determined.

The lavas are of two types, acidic and basic, indicating two distinct periods of eruption. The basic lava appears to be the older, as set forth in the description of the volcanic rocks on page 3. Both kinds of rocks contain amygdules, indicating that they cooled at or near the surface. The acidic rocks show in addition flow structure, spherulitic bands, and other evidences of having once been more or less glassy. These old lavas are exposed to the north end of South Mountain and southward into Virginia, and their wide distribution suggests that they reached the surface through great cracks and rifts in the earth. In Maryland and Virginia they were intruded by large masses of granite. Although the attitude of the bedding of the volcanic rocks was not observed in this area, the facts that the sediments overlap both lavas and that the basal conglomerate is composed largely of their fragments show that an epoch of erosion intervened between the pouring out of the lava and the subsidence of the land in Cambrian time.

PALEOZOIC SEDIMENTATION.

EARLY CAMBRIAN SILICEOUS DEPOSITION.

At the beginning of Cambrian time the area where now stands South Mountain and the Blue Ridge was depressed and occupied by a strait or narrow arm of the sea. The first sediments deposited were composed of fragments of the adjacent volcanic rocks. The basal beds are made up of soft purplish arkose, whose color indicates that the volcanic rocks from which it was derived had previously been disintegrated on the surface of the land. Upon the arkose rest feldspathic sandstones in which the fragments of volcanic rock are fresher and in which are inclosed rounded grains and pebbles of quartz, forming a conglomerate. Still later, beds of pure white quartz sand and fine arenaceous silt were deposited. These siliceous sediments formed the Weverton sandstone, the Harpers schist and Montalto quartzite member, and the Antietam sandstone. 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 was probably shallow and 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 rocks.

It is not likely that the thick beds of mud or fine argillaceous sediment of the Harpers schist that alternated with the coarser sands were deposited in the quiet waters of embayments between headlands of erosion, because the shale beds are coextensive with the sands along their strike and represent a uniform condition along the shore. Their deposition may have been caused by the shifting of the shore line farther east, whereby only the finer particles reached this area, or more probably by a depression of the land so that the streams became less vigorous and only the finer silts reached the sea.

CAMBRIAN AND ORDOVICIAN CALCAREOUS DEPOSITION.

Long before the close of Lower Cambrian time sand and clay deposition were replaced by calcareous sedimentation, which lasted almost continuously through the rest of Cambrian and a large part of Ordovician time. These calcareous deposits form the Shenandoah group of the Cumberland, Shenandoah, and other great valleys of the Appalachian Valley region and comprise the Tomstown, Waynesboro, Elbrook, Conococheague, Beekmantown, Stones River, and Chambersburg formations of the Mercersburg and Chambersburg quadrangles. The major part of this great thickness of deposits is free from detrital material, except 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 the interior of the continent through the rest of Paleozoic time, alternately expanding and contracting.

Land erosion must have been very feeble during the lime-depositing epoch, or at least little land waste was transported to the sea. In its stead the streams carried 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, corals, and other minute living organisms and deposited on the sea bottom as shells and skeletons. Many of the purer beds of the Chambersburg and Stones River limestones are almost entirely made up of the remains of such shells and other calcareous invertebrates, and certain beds in the Conococheague are composed of wavy laminated *Cryptozoon* that were probably low alga-like organisms. In the larger portion of the deposits, however, few or no fossils can be found, so that there is ground for the belief that most of the limy sediment was the result of direct precipitation from the water and was not produced by the secretion of organisms.

A number of beds are oolitic, others are minutely conglomeratic, and it is safe to assume that a small 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 rapid and abrupt alternation, suggests that these beds were probably deposited by chemical action in a shallow sea. In portions of the section, particularly in the Beekmantown, highly magnesian beds, varying in thickness from a few inches up to 6 or 8 feet, are interbedded in rapid alternation and in sharp contact with pure limestone, with a total thickness of many hundreds of feet. Such pronounced changes in the composition of beds and rapid alternations can be accounted for only by sudden changes in conditions of sedimentation when the deposits were laid down and not by alteration of the limestone through chemical processes since the rocks were formed. They favor also the theory of the original chemical precipitation of the limestones.

Although during this lime-depositing period the land was of low relief, there must have been local uplift in Waynesboro time, during which red soil, fine mud, and quartz grains from the decomposition of the hard rocks were swept into the sea and deposited as shale and sandstone. In the following (Elbrook) epoch land sediment in the form of very fine clay was still carried to the sea and gave to the limestone a finely laminated, shaly character.

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 up and its fragments formed conglomerates, which also contain 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 oölite, which is also present, was formed in water that was 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 these beds was the residuum of limestone decay on the land. These features indicate a relatively important uplift, in the midst of otherwise uniformly quiescent conditions, that seems to mark the beginning of Saratogan (Upper Cambrian) time, for trilobites and other fossils characteristic of that epoch first appear at this horizon. This uplift initiated a greater expansion of the interior sea. Similar "edgewise" conglomerates are associated with the siliceous banded limestones higher in the Conococheague and at the base of the Beekmantown, where they are very coarse and thick bedded.

Conditions were apparently not very favorable to life in the lime-depositing sea, for comparatively few fossils are preserved in most of its rocks. The paucity of life seems to have been associated with the large amount of magnesium carbonate present in the water, although dolomites deposited in other parts of the Paleozoic sea are crowded with organic remains.

During Stones River and Chambersburg time there was less magnesium in the sea water and the deposit of lime silt was much purer. Small bivalved crustaceans and gasteropods were rather abundant in the Stones River sea, but it was not until Chambersburg time that brachiopods, cystids, and bryozoans became abundant in this immediate area.

The sea throughout the limestone deposition was probably of moderate depth, not more than 250 to 300 feet, such as trilobites and mollusks inhabit, 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 reasonable to conclude that the silt from which the conglomerates were derived was air dried, hardened, broken up, and redeposited in some such way. Conglomerates occur not only at the base of the Conococheague, where other definite evidence of land conditions exists, but at intervals throughout the Beekmantown, Stones River, and Chambersburg, and portions of the bottom of the shallow sea probably emerged temporarily at frequent intervals. Where conglomerates are composed of small rounded fragments, the particles were transported farther from their source, but emergence must have taken place in some neighboring part of the sea bottom.

The time of emergence was generally so short that the sequence of beds was as a rule little disturbed, and none of the mapped formations is known to be absent in the area of these quadrangles. As stated in the description of the Chambersburg limestone, certain readily recognized beds and faunules within the formation are missing over wide areas, and it is probable that during the Chambersburg epoch the sea bottom emerged for considerable periods, and low islands and projections of land separated shallow bays in which the faunas of the time thrived and lime sedimentation continued.

ORDOVICIAN SILT AND SAND DEPOSITION.

After the close of Chambersburg time the area was again completely submerged and the 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 as the land rose slightly. Then, as the elevation increased, the arkosic sand of the upper portion of the formation and the coarser red sand and pebbles 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. Lithologically the Juniata is connected with the period of active erosion that prevailed at the close of the Ordovician and introduced the Silurian.

SILURIAN SEDIMENTATION.

During the deposition of the pure white quartz sand of the Tuscarora the elevation of Appalachia—the Appalachian land area to the east, where the Piedmont Plateau now stands—was increased, and erosion and transportation here reached their maximum. Quartz sand and pebbles, derived from the siliceous pre-Cambrian rocks of this land mass, were swept into the sea and deposited on its gently sloping floor. These quartz sands were widely distributed and are equally pure and thick on Cacapon Mountain, 20 miles farther west.

During Clinton time the sea shallowed and land erosion was less active, for the terrigenous sediment was largely made up of fine silt, which formed shales, with only local sandstones. At times there was precipitated with the sediments a large amount of iron oxide in the form of hematite, which now forms workable iron ores in some places. In this area the deposits are highly ferruginous sandstones, whose surfaces are marked by ripple marks, mud flows, and numerous trails of animals that crawled in the soft mud. These shallow-water and lowland conditions culminated in the deposition of the red and green mud rock and argillaceous limestone of the Cayuga, which contain chiefly small bivalved crustaceans. They resemble so closely the Cayuga rocks of New York that contain beds of gypsum and salt and a peculiar eurypterid type of crustacean that they probably, like the New York rocks, were deposited in inclosed or semi-inclosed basins whose waters, however, were not subjected to quite so long desiccation.

Resubmergence restored marine conditions in Helderberg time, 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 those in which corals were formed, must have been considerably warmer than those existing at the same latitudes on the Atlantic coast to-day.

DEVONIAN AND CARBONIFEROUS SEDIMENTATION.

The Devonian period opened with an uplift of the distant land to the east composed of Cambrian and pre-Cambrian rocks, which caused a renewal of siliceous sedimentation in the coarse quartz sand and well-rounded pebbles of the Oriskany formation. The rocks that contain the record of succeeding events are not exposed in the Mercersburg and Chambersburg quadrangles but occur beneath the surface in the northwest corner of the area; so the continuation of the geologic history must be drawn chiefly from adjacent areas.

Sedimentation of terrigenous material continued in the form of fine black silt of the Romney, finely siliceous silt of the Portage, and coarser sands and mud of the Chemung. In all but the Portage a large variety of marine life inhabited the shallow portions of the sea, and the fossil shells in these rocks are unusually beautiful and numerous. In the Portage fossils are rare. Those that occur are small and were probably very thin shelled, as their impressions are dim. They are also of peculiar types, unlike those of associated faunas.

Devonian sedimentation closed with the series of red arkosic sands and sandy shales of the Catskill, which are apparently land and fresh-water deposits, for they are poorly assorted arkosic materials and carry only fragments of vegetable tissue and fish remains. Fresh-water conditions apparently originated in the east and were caused possibly by vast floods from the land, which changed the shallow seas from salt to fresh and brought detritus from deeply weathered areas. This condition gradually spread westward in the sea, replacing Chemung sedimentation and marine life by Catskill deposition of red arkosic débris without organic remains.

Carboniferous rocks do not occur in these quadrangles and probably never were deposited there. If such is the case, this area has been land since the close of Devonian time, but the emergence was probably slight during the Carboniferous period, for the sea was not more than 10 miles distant and the character of its sediments indicates low shores and shallow water. It was at this time that the great deposits of coal were formed in the marshes and shallow basins that now comprise the Appalachian coal fields.

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 began long before this time and caused certain irregularities of deposition, especially the overlaps and unconformities within the Chambersburg formation, previously mentioned.

The great folding of the sedimentary strata of the Appalachian province was produced by horizontal forces acting transversely to the trend of the province and its structures. As stated under the heading "Geologic structure," the active force, as determined by overturned folds and thrust faults, came from the southeast. This force, the result of the contraction of the earth, isostatic adjustment of sinking sea bottoms and rising land masses, or some other equally potent factor, probably accumulated during the quiescent depositional period from Cambrian to Carboniferous. At the close of the Carboniferous the pent-up stresses were greater than the strength of the rocks, and the newly deposited sedimentary rocks yielded by folding and faulting and were 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 and sands were compacted and to a large extent hardened by their own weight, but the compression and folding consolidated them into firm rocks and materially altered their constitution and texture by the growth of new minerals and the formation of cleavage and joint planes.

EROSION.

The Mercersburg-Chambersburg area has not been beneath the sea since the close of the Carboniferous, possibly of the Devonian, and its rocks have been subjected to erosion during the enormous lapses of time to the present. In the area east of South Mountain a narrow basin was flooded during Triassic time and red arkosic sand and silt were deposited in this and similar inclosed basins along the Atlantic coast. These deposits closely resemble the red beds of the Catskill in composition and were probably laid down in similar fashion. 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 decreased or stopped. In the topography of the 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 continent, which had emerged from and risen above the sea, became nearly stationary and remained so for so long a time that the surface of the land in the Appalachian province was reduced by stream erosion to a rolling plain that sloped gently toward the sea. A few ridges and peaks, harder or better protected from erosion than the rest, stood about this plain as monadnocks. Later uplift of the land raised the plain higher above sea level, and it is now found emerging from beneath late Jurassic and Cretaceous sediments near the present coast line in New Jersey and extending inland. Although somewhat eroded in New Jersey and eastern Pennsylvania, it is clearly discernible in the flat top of Schooley Mountain, from which it received the name Schooley peneplain. It rises steadily inland, becoming more and more dissected, and in the vicinity of the Mercersburg and Chambersburg quadrangles its only remnants are the tops of the highest mountains, which are composed of the hardest rocks, the intervening softer portions of its surface having been entirely removed.

In the Mercersburg-Chambersburg area the peneplain is between 2000 and 2100 feet in elevation. Big Flat, Snowy Mountain, and Sandy Ridge in South Mountain are the only elevated level tracts that can be assigned to the peneplain surface in the Chambersburg quadrangle. Although from a distance South Mountain presents a nearly smooth, level sky line, most of its ridges in this quadrangle are below the 2000-foot plain, ranging down to 1700 feet. Tuscarora Mountain, in the Mercersburg quadrangle, has a very level sky line at an elevation of about 2000 feet and even the knife-edge portions of the ridge rise to more than 1900 feet. Cove Mountain is so narrow and weak that it has been worn down to a comblike crest, 1600 to 1700 feet in elevation, but Cross Mountain, connecting Cove and Two Top mountains, has a level, flat summit at about 2100 feet. (See fig. 12, illustration sheet.) The peneplain surface is also fairly well preserved in the peaks at the south ends of the Horse Valley and North Mountain synclines and in the knife-edge crests of the flanking ridges. (See fig. 6.) The broad, level top of Big Mountain and the adjoining portion of Tuscarora Mountain rise to an elevation of 2400 feet, and this unusually resistant anticlinal mass of sandstone was probably not reduced to the peneplain level but stood above it as a monadnock. From the general altitude of the peneplain remnants it appears that in Tuscarora Mountain its elevation is 2000 to 2100 feet.

To the west small remnants of the surface can be seen capping successively higher ridges until it reaches an elevation of 2600 feet in the Appalachian Plateau west of Cumberland. The plain that once sloped gently toward the sea has been tilted and raised to 2600 feet at Cumberland. 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.

In South Mountain east of Montalto an extensive plain is developed on the softer pre-Cambrian volcanic rocks at an elevation of about 1600 feet, and several broad, flat divides in the vicinity range from 1450 to 1600 feet. There are several gently sloping benches in the shale foothills on the east side of Path Valley, the most prominent one being at 1100 to 1200 feet. These terraces are not clearly marked and probably represent stages of short duration which can not be definitely correlated with events in other regions. Some of them may correspond to the Weverton peneplain, which has an elevation of 1300 feet near the Potomac at Weverton, Md., as described by Matthews.[a]

HARRISBURG PENEPLAIN.

The most pronounced erosion plain in this area, representing a relatively prolonged period of quiet, now stands at an elevation of about 750 feet. It has been named the Harrisburg

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[a] Matthews, E. B., Maryland Geol. Survey, vol. 6, 1906, pp. 87–88.

peneplain because of its prominent development in the vicinity of the Pennsylvania capital. It was formed only on the softer rocks, the limestones and shales of the valley, for the quiescence was not long enough for the sandstone ridges to be removed as they were during the great Jurassic-Cretaceous peneplanation, so that they stood as monadnocks on the plain.

The best-preserved remnant of this peneplain is the shale plateau west of Chambersburg. It is a very level tract from 1 to 3 miles wide and extends 8 miles into the Chambersburg quadrangle. It rises abruptly 150 feet above the flats along the Conococheague and maintains an elevation of 750 feet throughout its length except at the margins, where it has been terraced at lower elevations. At Beautiful, in the northern part of the quadrangle, it is locally 780 feet high. It is sharply dissected on both sides by tributaries of Conococheague and Back creeks, which have cut deep, rugged ravines. These ravines are especially steep and picturesque on the eastern edge of the plateau, where the sandstone of the Martinsburg is infolded in the shale.

The Harrisburg peneplain has not been well preserved elsewhere in the area. It may be represented by gently rolling tracts at elevations of 700 and 750 feet on the flanks of higher ridges of siliceous limestone to the east and by low divides at the same general elevation. A flat-topped shale hill at 700 feet west of Mercersburg and two smaller ones at the same elevation southwest of Fort Loudon are probably part of the plain. In Path Valley a very smooth shale terrace at 820 feet may belong to this level, its higher elevation being due possibly to its greater distance from the main drainage channel.

At Black Gap, where Conococheague Creek leaves the mountains, it has built a broad, level alluvial terrace, composed largely of quartzite cobble. Although this gravel apron has as altitude of 820 feet, somewhat higher than the shale plateau west of Chambersburg, it is considered to be of the same age as the Harrisburg peneplain, the mountain stream, as it left its steep grade, having built its fan to a considerable height above the plain. Farther from the mountain, in the bend of the stream west of Scotland, similar gravels covering the hills at 740 to 760 feet mark the course of the stream on the old peneplain. Coalescing alluvial aprons, modified by recent stream cutting and filling, are present all along the west face of South Mountain at approximately the same elevation and represent the same period of deposition.

Other fine examples of high alluvial fans on the Harrisburg peneplain occur in front of the Franklin Furnace gap and Nancys Saddle in North Mountain and Cove Mountain, where they stand as gravel-capped terraces 150 feet above the general level of the limestone valley. (See the areal geology map.) The explanation of the fine gravel deposits on the top of the shale plateau in the vicinity of Beautiful is not clear, but they suggest that during the Harrisburg stage the Conococheague escaped from Black Gap in South Mountain by this path to the Susquehanna. This plateau is directly in line with the cobble-covered hills at elevations of 740 to 760 feet west of Scotland, which mark the course of the Conococheague at that time.

The Harrisburg peneplain was formed near the level of the sea and had only a gentle grade eastward, but has since been uplifted to its present position and tilted toward the sea. It has been observed to rise gradually up the Potomac Valley to an elevation of 900 or 1000 feet at Pawpaw, W. Va., and to descend down the Potomac to 650 feet on the heights back of Harpers Ferry. It is considered to be of early Tertiary age and is reported to pass beneath the earliest Tertiary sediments exposed on the Coastal Plain.

Toward the close of the Harrisburg epoch the streams were near base-level and meandered sluggishly over the lowland. When uplift took place the larger streams cut down their channels in the positions they then occupied, and their meanders became incised into the hard rock. These meanders are finely preserved in Conococheague and Back creeks where they were cut in the shale, but have been largely obliterated in the limestone areas. Such as are present in the limestone region were probably developed on the later (Somerville) peneplain. Still finer examples of deeply intrenched drainage developed on the Harrisburg peneplain may be seen along the Potomac and its larger tributaries a few miles west of this area.

SOMERVILLE PENEPLAIN.

Evidence of later prolonged halts in the uplift of the land is not so clearly preserved in this area. There are numerous terraces along the larger creeks at various levels below the Harrisburg plain, preserved almost exclusively in the shale. Many of them are covered with quartzite cobble. A high bench or series of terraces at 680 to 700 feet is preserved on the shale in the vicinity of Chambersburg. The most widespread and best developed of the lower terraces is the extensive level plain at 600 to 620 feet in the southern half of the quadrangles, particularly in the vicinity of Upton and Greencastle, west of Kauffman, north and east of Williamson, and south of Mercersburg. The upland in this part of the area is a level tract at this elevation preserved alike on shale and limestone but deeply dissected by the streams. The portion of this plain in the big bend east of Williamson is covered with gravel and marks the course of the Conocoheague at this stage. It is probably the representative of the Somerville peneplain of New Jersey, described by Campbell as occurring about 100 feet below the Harrisburg peneplain in the vicinity of Harrisburg.

Up the Potomac the Somerville peneplain rises to an elevation of 700 to 750 feet near Pawpaw and is thickly covered with coarse gravel in many places. Down the Potomac it descends to 530 feet at Harpers Ferry. A few miles east of South Mountain remnants of gravel regarded as Lafayette in age rest on the plain at an elevation of 500 feet. In the vicinity of Washington the plain passes under the Lafayette at 460 to 480 feet. The Somerville plain and the terrace gravels that occur on it in the Mercersburg-Chambersburg area are therefore probably of late Tertiary (Lafayette) age.

Since Somerville time uplift has been renewed and the streams have been cutting their channels deeper and enlarging their meanders. Wherever these meanders are abandoned a portion of the old channel is left as a gravel-covered terrace, many of which occur below the Somerville level. At present the major streams are only locally widening their valleys and building flood plains, and either uplift is still in progress or else the major streams have not yet been been fully graded.

ECONOMIC GEOLOGY.

The mineral deposits known to occur in these quadrangles are iron ore, barite, white clay, quartz sand, building stone, limestone, cement materials, and brick clay. In addition to these the soils and water supply are of economic value.

IRON ORE.

GENERAL OCCURRENCE.

Large quantities of iron ore in the form of limonite, or "brown hematite," have been mined in this area, particularly in the eastern portion of the Chambersburg quadrangle at the foot of South Mountain. The deposits are of the residual type, occurring in the clay and wash from the mountains and usually overlying the limestone. Most of the workable deposits of ore occur at the foot of the mountain slope, near the contact between the Tomstown limestone and the Antietam sandstone. The rest are associated chiefly with the shales of the Waynesboro formation, but a few are scattered over the other limestone areas.

Although there was active mining in this area for many years during the ninteenth century, the ore has not been exhausted. Most of the deposits under light cover that could be extracted by means of open pits have been removed, and those that remain can probably be worked only by drifting. Partly for this reason but chiefly because of the immense deposits of rich and easily accessible ore discovered in the Lake Superior and southern Appalachian regions, mining practically ceased in this area forty years ago.

THE MINING INDUSTRY.

Several iron furnaces were in operation in this region during the height of the mining activity. Chief among these was the Montalto furnace, located at the present site of Montalto Park, which handled most of the ore extracted in this area. Other furnaces in this part of South Mountain were one at Caledonia Furnace, a few miles east of the Chambersburg quadrangle on the Gettysburg pike, which was destroyed during the civil war, and another on Furnace Run in the extreme northeast corner of the quadrangle.

The Richmond furnace in Path Valley and the Franklin furnace north of St. Thomas smelted the ore from the western part of the valley and from the adjacent mountains. The Carrick furnace was located in Path Valley just beyond the border of the Mercersburg quadrangle. All that remains of these old industries are ruins of the furnaces, remnants of dams and sluiceways, and slag heaps. The huge pile of slag at Montalto Park bears testimony to the great quantities of ore smelted here.

These furnaces burned charcoal and the mountains are interlaced with old wood roads and dotted with abandoned charcoal pits, now round, level bare spots in the dense timber. The pig iron from the furnaces was wrought in a forge and rolling mill in Antietam Cove just east of the Chambersburg quadrangle, and another on the Conococheague just east of Black Gap.

The only important ore banks in the area were those of the Montalto Iron Company, situated along the mountain front north of what is now Montalto Park. Mining was begun in 1808 and was at its height between 1850 and 1860. The furnace was located at the present site of the park and stood for nearly a hundred years but was remodeled during that time. It was dismantled in 1904, when the property, including thousands of acres of fine timber land in the surrounding mountains, was acquired for a forest reserve by the State of Pennsylvania. The ore banks of the company were scattered along the base of the mountain slope from the park to the head of English Valley and encircling Little Mountain, as shown on the areal geology map. Deep pits filled with water and heaps of débris are all that remain as evidence of former activity. Several of the mines were worked by drifting when stripping became excessive, and some of the deeper deposits were thus extracted. The five or six deep pits just beyond the furnace are located almost exactly on the contact between the limestone and the quartzite, which are about vertical here. The ores dipped steeply toward the mountain and stripping became excessive as the ore was followed down. Limestone was exposed in the bottom of most of the pits.

Another important group of mines lies west and northwest of White Rocks, scattered over the flat bottom of English Valley, which is a gentle syncline between the main ridge and Little Mountain. The ore was reported to lie nearly flat in this valley, and large areas were uncovered, the more deeply buried portions being worked by underground drifting. Limestone was struck at a depth of 110 feet. The ore followed around the anticlinal end of Little Mountain and was extensively worked on the flanks of the low ridge to the south for a mile. The largest pit remaining open in the area is the Pond bank, just west of the south end of Little Mountain.

No iron deposits of consequence are known north of Little Mountain in the Chambersburg quadrangle. Some ore was mined on the slopes north of Fayetteville, and in the extreme northeast corner are the outlying deposits of the Cleaversburg group of mines, the pits of which are of considerable size. South of Montalto occurs another relatively barren strip in which only a few small pits have been operated or prospected. South of Tomstown several deposits have been worked, the Menser mine near Biesecker Gap being the largest.

Several smaller pits in the area of purple slate of the Waynesboro formation near the present village of Montalto were also operated by the Montalto Company, and fragments of good ore occur to-day in the wash on the slopes of ridges of the Waynesboro formation.

It is difficult to obtain an estimate of the amount of ore that has been extracted from these mines. J. P. Lesley, in the reports of the Second Geological Survey of Pennsylvania, states that 100,000 tons was taken from one of the Montalto pits in fifteen years. An early estimate by Lesley of the ore in sight in one of the mines was 250,000 cubic yards, and in another 850,000 cubic yards, but these estimates were based on insufficient data. Immense quantities have no doubt been removed, and probably as much more still lies untouched, too deeply buried for economical extraction at the present time.

The ore varies considerably in its content of iron, phosphorus, and manganese. The phosphorus is generally higher in the ores at the foot of the mountain than in those on the limestone and shale of the valley, and good Bessemer ore was often difficult to obtain. The mean of 13 analyses of ores from the Montalto property, as given in the report of A. S. McCreath (Second Geological Survey of Pennsylvania), shows iron 46.05 per cent, manganese 1.11 per cent, phosphorus 0.27 per cent. Some samples ran as high as 55 per cent of iron and 0.44 per cent of phosphorus. Sulphur is usually low but much of the ore is "cold short," the silica ranging from 8 to 20 per cent.

NATURE OF THE DEPOSITS.

The origin of these ores is a much-controverted subject. The early investigators had the opportunity, which later geologists have not, of examining the freshly exposed sections in the extensive open cuts and drifts then in operation and of being able to see the relation of the ore to the clay and in places to bed rock. At present the openings are mere water-filled holes with slumped clay banks; in a few of them limestone is exposed in the bottom.

Not only in this part of South Mountain but along its entire length the chief bodies of ore occur persistently at or near the base of the limestone series. As above described, the ore on the Montalto property follows the steep limestone-quartzite contact north of the park in a straight line, flattening out into a broad belt in the gentle syncline of English Valley and swinging northward around the south end of the Little Mountain anticline. The ores are undoubtedly at present closely associated with the contact of the limestone and sandstone, but whether this association is due to original richness in iron of the rocks at this horizon or simply to mechanical and chemical concentration in the process of disintegration is not certain. In a few places the ore lies on the sandstone side of the contact, but generally it is found to rest on either limestone or associated shale.

The ores are, without question, secondary deposits in residual clay, and the iron was segregated from the sedimentary rocks of the vicinity. Some investigators assign its source to the limestones, others to the shales and sandstones. The unaltered limestones contain very little iron and could furnish scarcely enough by disintegration to form such a deposit. Many of the beds of sandstones and shales, on the other hand, are so heavily impregnated with iron that they form a low-grade ore, while others are studded with magnetite crystals. The shales and sandstones appear to be the more favorable source from which the iron could have been derived. Surface waters dissolved the iron from the disintegrating shales and sandstones of the mountains, and as they percolated through the porous sands at the foot of the slopes the iron was set free, cementing the sands. Much of the ore is in consequence very siliceous, being nothing more than cemented grains of quartz sand. In favorable places the solutions dissolved the underlying limestone and the iron was precipitated in its stead, forming purer ores.

Other ore bodies scattered over the limestone area are usually associated with ferriferous shales, which probably supplied the iron for these ore deposits in a similar way. The purple Waynesboro formation includes a large amount of highly ferruginous shales and a rust-stained laminated siliceous rock, and the wash on its slopes usually contains iron ore, which has been mined in a few places, as indicated on the areal geology map.

The deposits which have been mined on the west side of Path Valley, from Richmond Furnace far beyond the northern border of the Mercersburg quadrangle, are located on the outcrop of a fault which, in part of its course, brings the Stones River limestone against the red shale and sandstones of the Juniata formation. The iron was probably leached from adjacent ferruginous shales by water that circulated along the fault plane, and was precipitated in the wash at the surface. Although the ore contains but 40 per cent of iron it is so low in phosphorus, 0.04 per cent, that it is a good Bessemer ore. It was extensively mined in the quadrangle and to the north, and was smelted largely at Richmond Furnace.

CLINTON ORES.

The Clinton shale can not be said to be ore bearing in this area, though some of its upper sandstones are very ferruginous. A sample of ferruginous quartzite obtained near Franklin Furnace showed on analysis 33.54 per cent of iron, but the rock is too siliceous for profitable ore. A few miles to the north and west of the Mercersburg quadrangle several beds of richer iron ore occur in the formation and have been successfully mined.

MANGANESE.

Manganese ore is commonly associated with the residual iron ores of the Appalachian Valley, but no deposits have been found in the Mercersburg and Chambersburg quadrangles. In Little Cove, at the west border of the Mercersburg quadrangle, manganese was found replacing the sandstone of the Oriskany, but the quantity was small and it probably is not a workable body. Manganese occurs also in the wash on the slopes of South Mountain, a few miles northeast of the quadrangle.

BARITE.

Barite (barium sulphate or heavy spar) is a white crystalline mineral somewhat resembling calcite but nearly twice as heavy, having a specific gravity of 4.5. When pulverized it is used chiefly as the base of paint, but it has many other commercial uses. It has been mined on a small scale at several places in the limestone area of the Chambersburg quadrangle, where it occurs as weathered masses in the red clay residuum from limestone. Deposits are known to occur on the Lindsay farm, 1 mile south of Chambersburg; on the Stamey farm, at Knepper; on the Bonebreake farm, southeast of Roadside; and on the Snobarger farm, 2 miles northeast of Waynesboro. (See areal geology map.) The Snobarger deposit is of special interest because the ledge from which the loose masses were derived can be studied. At the top of the hill to the south a pit in bed rock has disclosed the barite cementing a brecciated limestone, the decomposition of which has given rise to the masses of barite that have gradually worked down the slope to the base of the hill.

The barite in this area has been mined only in a small way during dull seasons of the year by farmers, who discover the masses of heavy white rock in the soil when plowing. It occurs throughout the superficial clay down to the bed rock. In the crude form it sells for about $3 a ton. Samples obtained near Waynesboro analyzed 95.91 to 98.65 per cent $BaSO_4$, with small quantities of iron, aluminum, calcium, magnesium, and silicon.

WHITE CLAY.

A very pure white siliceous clay, suitable, when refined, for use in the manufacture of paper, paint, and chinaware, is associated with the iron ores at many places along the west base of South Mountain. It has been mined for several years in the vicinity of Mount Holly Springs, near the north end of South Mountain, where it has unusual thickness and purity.

In the Chambersburg quadrangle it was reported in considerable thickness in many of the old iron workings of the Montalto Company, but the old pits have slumped in and the original exposures of the white clay are so covered that the presence of workable bodies of clay can not now be determined except by reopening them. A clay of excellent quality was reported from a prospect near Black Gap, owned by A. B. Lehman, and another sample from the Chambersburg area has been successfully used by the Penn Tile Company at Aspers in making light-colored vitrified tile. Small pockets of white clay were observed in a sand pit in Tomstown at the top of the Antietam sandstone.

As shown by the analysis of the clay from one of the mines in the Mount Holly region, given below, the clay is highly siliceous and not a kaolin. For brickmaking it must be mixed in proper proportion with more plastic clays.

Analysis of crude white clay from Henry Clay, Pa.

[W. T. Schaller, analyst.]

SiO_2	69.61
TiO_2	.90
Al_2O_3	16.83
Fe_2O_3 (total iron)	.95
CaO	.11
MgO	1.51
Na_2O	.08
K_2O	3.41
P_2O_5	.14
Loss on ignition	6.35
	99.89

The exposures of white clay in the Chambersburg quadrangle are so meager that no conclusion can be drawn as to the nature of these deposits, but it has been definitely proved in underground workings in the Mount Holly region that there the clay is a sedimentary bed at the base of the Tomstown limestone. Pre-Cambrian volcanic rocks, now represented by sericitic schists interbedded with the aporhyolite, decompose to clays of exactly similar character and composition, and it is probable that the sedimentary clays were originally derived from the decomposition of these volcanic rocks on the old Cambrian land and washed into near-by sedimentary basins. Large quantities would be preserved only where the conditions of weathering and accumulation were specially favorable, which would account for the irregularity of the distribution of the workable deposits.

LIME AND FLUX.

Lime is extensively used in this area for enriching the soil, and the various limestones are quarried for this purpose throughout both quadrangles. Much of the limestone, especially that of the Conococheague and lower formations, is very impure, usually containing a large percentage of magnesium carbonate and fine siliceous and argillaceous matter, but beds can be found almost anywhere that will yield lime suitable for local use as fertilizer. Lime is especially beneficial to the sandstone and shale soils, and kilns are consequently more numerous along the shale border. Much of the lime is burned in heaps in the field without permanent kilns. Only those quarries that are large and have more than a local trade are shown on the geologic maps. The Stones River limestone is the purest of the Shenandoah group and all the high-grade lime is made from it. The largest and most widely known quarry in the area is the Peckman quarry at Williamson, which uses a very dark, fine, even-grained limestone from the upper part of the Stones River. The product of its kilns is widely used for building purposes and ranks above all other local makes. Two additional quarries have recently been opened in the same pure bed of limestone at Williamson.

A sample from the Stones River limestone near Mercersburg showed on analysis 96.4 per cent of calcium carbonate. Although these pure beds are not so thick as those at Martinsburg, W. Va., where the rock is quarried on an enormous scale for shipment as flux to the iron furnaces of Pittsburg, the analyses compare favorably. Three samples of Stones River limestone from the Martinsburg quarries contain 96.2, 97.7, and 98.1 per cent of calcium carbonate.

The outcrop of the Stones River formation is shown on the areal geology maps, and rock suitable for lime production can be obtained at most places within its area. Numerous quarries are located in the belts between Chambersburg and Greencastle adjacent to the shale lands, and a large industry has been developed in the Rocky Spring cove, which is surrounded by shale farm lands. The Stones River limestone is exceptionally pure and thick bedded in this locality and the large quarry 1 mile north of Beautiful runs six kilns.

Certain beds in the Chambersburg and Beekmantown formations are also fairly pure and make a lime of good grade. Large quarries and kilns in the Beekmantown are located at Stonehenge and Stoufferstown, east of Chambersburg. Exceptionally pure beds in the Chambersburg limestone occur at Fort Loudon and in the vicinity of Blue Spring, southwest of Mercersburg. A sample from the Chambersburg limestone near Mercersburg showed on analysis 93.2 per cent of calcium carbonate and only 0.07 per cent of magnesium carbonate, the rest being largely insoluble impurities.

MAGNESIUM CARBONATE.

A large number of beds in the Shenandoah group, especially in portions of the Tomstown and Beekmantown limestones, contain a high percentage of magnesium carbonate. Beds ranging from 25 to 40 per cent in magnesium carbonate alternate with almost pure limestone containing 1.4 to 3 per cent, but by selection in quarrying the highly magnesian layers can be segregated. In the vicinity of Philadelphia magnesian limestone of this character is quarried for the extraction of magnesium carbonate, and some beds in the Chambersburg and Mercersburg quadrangles, particularly those near the base of the Beekmantown in the Welsh Run–Edenville anticline, are probably suitable for this industry.

CEMENT MATERIALS.

Certain black limestones in the transition beds at the base of the Martinsburg formation are probably suitable for the manufacture of natural cement. These beds are generally too thin and too much mixed with shale to be economically used for this purpose, but they thicken toward the west, and beyond Mercersburg, especially in the eastern part of McConnellsburg Cove, individual beds are 1 foot thick and the more massive portion aggregates 6 to 8 feet in thickness. An analysis of a sample of rock from this horizon in the Rocky Spring cove is as follows:

Analysis of black limestone at base of Martinsburg formation in Rocky Spring cove.

[W. T. Schaller, analyst.]

$CaCO_3$	68.82
$MgCO_3$	.20
$FeCO_3$	1.34
Fe_2O_3	.55
Al_2O_3	2.82
SiO_2, etc. (insoluble)	22.93
	96.66

This rock differs from the best natural cements in its low percentage of $MgCO_3$, which may vary in the different beds, and the use of the rock for cement purposes can be determined only by a number of analyses and practical cement tests.

Better cement can be made by mixing pure limestone with shale, the proportion of each to be determined by careful analysis of the constituents and thorough test of the product. The purer beds in the Stones River, Chambersburg, and Beekmantown limestones are suitable for this purpose, and shale can be procured from the adjacent shale belts. Cement could be commercially manufactured at almost any place in the Stones River limestone areas not too distant from the Martinsburg shale and convenient to the railroad. No plant is established in this area at present.

QUARTZ SAND.

Quartz sand for building and railroad purposes is obtainable along the entire front of South Mountain. The upper member of the Antietam sandstone usually disintegrates readily into easily workable sand deposits. Sand that lies on the parent ledge is as a rule clean and sharp and of excellent quality. It is exposed in some of the abandoned iron pits close up to the foot of the mountain, and several of them have been converted into extensive sand quarries. A large pit at Montalto Park and several on the south and west slopes of Little Mountain are now in operation. Several other quarries are located on the White Rocks ridge east of English Valley and there is one at Tomstown. On the mountain slope and valley floor below the outcrops of the Antietam occurs sand more or less mixed with wash, and although the product is inferior to that on the parent ledge it has been worked on a small scale in the vicinity of Pondtown.

The best sand from the Chambersburg quadrangle commands a price of $1.75 a ton in Chambersburg and to be economically worked a deposit must be conveniently located for railroad transportation. Those on the ridge east of English Valley are rather distant, and the profits are largely consumed in hauling to the railroad spur at the south end of Little Mountain.

Some of the sandstone beds of South Mountain are so white that they appear pure enough to be used for glass sand, but analyses have not been made to determine this point. Most of the beds are so hard and vitreous, however, that they would not yield readily to crushing, which would make the work expensive and the product inferior. The White Rocks ridge, just east of Pond Bank, is the most inviting location to test the rock for this purpose, because of the apparent purity of the rock and its accessibility to the railroad.

Large quartz veins, commercially and locally called "flint," occur in the pre-Cambrian volcanic rocks and in some of the sandstones. Quartz is also present in small quantities in the siliceous beds of the Waynesboro formation, where its fragments cover the slopes of the hills. A large vein just east of the Chambersburg quadrangle, south of the Gettysburg pike, was formerly quarried and pulverized for use in pottery manufacture, but the expense of operating and shipping was excessive.

BRICK AND TILE CLAY.

Clay suitable for brick manufacture is found as a residuum of decomposition over most of the limestone area, and in most of the larger towns in this area red brick is manufactured from such clays for local use. The Martinsburg shale can also be used for this purpose if properly ground and mixed, and it is used to some extent in a brick plant at Greencastle but the product is not of the best quality.

The clays associated with the iron ores along the foot of South Mountain furnish good material for brick. At Mount Holly, near the north end of South Mountain, a handsome buff to cream-colored semivitrified brick is made from white clay at this horizon, and similar deposits in the Chambersburg quadrangle will be suitable for this purpose, if found in sufficient quantity. Samples of white clay from this area have been tested at Aspers and found to make excellent vitrified tiles.

BUILDING STONE AND FLAGSTONES.

Stone for local building purposes is plentiful in this area, but none suitable for shipment is known. Limestone of convenient thickness for quarrying can be obtained in most portions of the Shenandoah group, and it makes very enduring structures, as attested by the old stone dwellings and artistic arches across the streams throughout the valley. At present it is used very little for building stone, except in foundations, walls, bridge piers, and rubble fences.

The Cambrian sandstones are in general too hard and massively bedded for building purposes but are suitable for lining limekilns and iron furnaces, and have been carried far into the valley for this purpose. However, at Montalto Park a very handsome dwelling was constructed with a reddish thin-bedded quartzite from near-by outcrops of the Antietam formation. The sandy beds of the Conococheague, Waynesboro, and Martinsburg formations are more readily quarried and dressed and are used for foundations and other building purposes. At Grindstone Hill massive sandstones from the Conococheague have been quarried but are not suited for grindstones, as the name of the hill might suggest. The sandy limestones at the top of the Waynesboro formation are thin bedded and flaggy and are quarried in the town of Waynesboro for flagstones and curbstones. Some of the thin beds of the Chambersburg limestone also furnish flags.

The Tuscarora sandstone is generally very massively bedded, but at the accessible exposures along the pikes on the east slope of Tuscarora Mountain large slabs of the thinner beds have been quarried for use in road crossings, culverts, sidewalks, and bridge piers. Its coarse, ripple-marked surfaces may be seen in the streets of Chambersburg. In Little Cove and other inclosed valleys the Tuscarora sandstone is locally used as a building stone and the iron-stained blocks give a very pleasing effect to the old dwellings.

MARBLE.

Marble for building or ornamental purposes has not been quarried in this area, but several beds of possible value have been seen. The most attractive bed is a pink marble irregularly veined with green that occurs near the base of the Beekmantown. Several of the purer white limestones of the Beekmantown are finely crystalline marble and have a faint pink tint, but 1½ miles southeast of the village of Clay Hill, at a point indicated on the map by a prospect symbol, the marble has unusually good color. Specimens collected here, although from the surface and considerably fractured, acquire a fine polish. If the color is found to continue with depth and sufficiently large blocks can be quarried, this marble may prove to be of commercial importance.

Other beds of marble, probably of little commercial value, observed in the area, are as follows: A fine-grained milk-white marble, badly sheeted, in the Waynesboro formation 1 mile northeast of Waynesboro; a coarse mottled reddish variety in the Conococheague limestone in the vicinity of Scotland; a black conglomerate with reddish pebbles near the base of the Beekmantown, seen in both the Chambersburg and the Mercersburg quadrangles; light-colored fine conglomerates and oolites in the Chambersburg and Beekmantown formations of both quadrangles; and layers of concentric, wavy *Cryptozoon* at the base of the Conococheague near Falling Spring and Zentmyer that make "bull's-eye" marble (see fig. 13, illustration sheet) when polished parallel to the lamination.

ROAD MATERIAL.

Limestone is one of the best rocks for road material and railroad ballast, and the limestones of the Shenandoah group in this area are extensively used for this purpose. Limestone crushes readily to angular fragments of any desirable size, and furnishes top dressing for finished roads as well as the coarser foundation stones. Many small quarries for crushed rock are located along the pikes and electric railroads, and waste rock from the larger building-stone quarries is also crushed for this purpose. The harder, impure limestones are better than the purer limestones for road material, as they do not powder so readily. Most of the roads in this area are kept in fair condition but could be much improved by a generous use of fine crushed limestone as a top dressing or of shale as binder so as to form a smooth surface.

The shale of the Martinsburg formation is quarried along roadsides for local use and makes excellent roads. There are no better roads in the area than those on the level top of the shale plateau west of Chambersburg, but those that descend from the upland become badly gullied, and crushed limestone, sandstone, and river cobbles are hauled great distances to repair them. On the pikes and roads crossing the mountains the soft red sandstone of the Juniata and the sandy shales of the Clinton along the roadsides are locally used to good effect.

SOILS.

The soils in the Mercersburg and Chambersburg 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 mountains, especially that along the foot of South Mountain, is largely covered by a deep sandstone wash, resembling the terrace deposits but more bowldery.

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 the various terraces along their sides, not only where terrace deposits are indicated on the areal geology maps but also where the alluvial gravels are not thick or continuous enough to be mapped but are mixed with the rock soil and greatly enrich it. The more stony soils, especially those made up of the wash from the mountains, are well adapted to fruit culture.

The limestones weather to a deep, rich red or yellow clay soil that yields the large crops for which the Cumberland Valley is noted. The shaly and sandy soils on the low ridges of the Waynesboro formation are better adapted to fruit culture than to farming. The hills on the Conococheague limestone are generally rough and rocky and the soil is thin and slaty, so that it makes poor farm land. In many places it is used for woodland or grazing.

The Martinsburg shale areas have as a rule only a thin soil, which washes badly on slopes and drains quickly so that it is usually dry. It is easily worked and on the level lands is generally cultivated, although its crops are poorer than those of the limestone areas. The steep slopes of the plateaus and some of the uplands are still in forest.

The portion of South Mountain in the Chambersburg quadrangle is nearly all in forest, a few patches only on the tops of ridges and in the valley bottoms having been permanently cleared. The ridges are generally covered with rocky soil and ledges, but in places the rock is deeply disintegrated to white sand. The slopes and most of the valley bottoms, which are narrow and steep sided, are covered by the débris from the harder rocks above and the schist is exposed in few places. The forests comprise several varieties of oak, chestnut, birch, and maple, with hemlock and white pine along the watercourses. Nearly the entire South Mountain area in this quadrangle is a part of the State forest reserve and has standing some of the largest and best timber in the State, preserved by the former owner, the Montalto Iron Company. Portions from which all the timber has been cut, or which have been repeatedly burned over by forest fires, are grown up with scrub oak and jack pine.

The soil of Tuscarora and the associated mountains on the west side of the valley is similar to that of South Mountain, except that the slopes of some of the wider intermontane valleys are not entirely covered by sandstone débris. The mountain tops and slopes are covered by talus and rocky soil. They are largely forested with a thin growth of hard wood similar to that on South Mountain but have been burned off in many places and are grown up with scrub oak. Allen Valley is heavily forested with good timber, which is rapidly being cut and taken out by way of a tram road to Richmond Furnace. In the few places where the soil of the mountain tops is composed of hard slaty shale it has been cultivated, but generally it is too exposed for farming or even fruit culture.

In Little Cove and Horse Valley the Clinton and Cayuga shales have rather barren soils, bearing scanty crops, but the Helderberg limestone soil of the lower part of Little Cove is more fruitful.

SURFACE AND UNDERGROUND WATERS.

SURFACE WATERS.

In the mountains there is an abundance of flowing water in the form of streams and clear cold springs, but on emerging from the mountains the streams rapidly sink into the wash and soil and find their way into subterranean channels in the limestone, so that in the valley only the larger streams carry water throughout the year. Conococheague Creek and its main branches are large streams in wet seasons, but during droughts even these dwindle to insignificance in the limestone valley. They are locally used for power to run grist and saw mills and small electric plants, but in recent years many of these have been abandoned. Others have been equipped with supplementary steam or gasoline plants for use during low stages of water. Some of the mountain valleys are of such form that with little construction large areas could be converted into reservoirs for power purposes.

UNDERGROUND WATERS.

Limestone springs. — There are numerous large limestone springs in the area, the water from which appears very pure and limpid but is hard, being highly charged with salts, chiefly carbonate of lime, in solution. It is also likely to be contaminated by the sewage from the larger towns that have no sewer systems, where it is customary for private cesspools to be connected with subterranean crevices and caverns, which communicate with underground streams flowing in the direction of the the Potomac and emerging at favorable places as springs.

These limestone springs were sought by the earliest settlers and have been continuously used for domestic and farm purposes. The largest springs of this class are at Aqua and Falling Spring, where large streams issue from the crushed and faulted strata of a compressed anticline. The water cress that grows luxuriantly in these streams is marketed in New York and Philadelphia and furnishes a minor industry.

Sandstone springs.—Fine springs of clear sandstone water are plentiful in the mountains, and the streams themselves, being practically spring water, are cold and refreshing. Where not subject to contamination, these mountain streams could be made to furnish supplies of excellent water for towns or villages. Many of the springs have water of such purity and volume as to warrant bottling for table use, and would make excellent sites for mountain sanitariums and summer resorts. The Crawford Spring, in Cold Spring Run, north of Fayetteville, and the Tarburner Spring, east of Montalto Park, were formerly used for sanitarium purposes. Montalto Park was long a resort of attractive beauty, with magnificent mountain scenery and refreshing springs, and it is now a part of the State forest reserve and the site of the State forest school. There are many undeveloped spots of natural beauty and health in the mountain gorges. The recent opening by the Chambersburg-Gettysburg electric railroad of Caledonia Park, just beyond the eastern border of the Chambersburg quadrangle, makes the springs, mountain streams, and wild mountain scenery of this vicinity accessible to the residents of Chambersburg and the smaller towns along the line of the railroad.

Wells.—The rainfall in this area is heavy and during most of the year the water supply in shallow wells is adequate for all purposes. In dry seasons, however, well water is scarce in many portions of the limestone and shale belts, especially where the surface clay and soil are thin. In most of these places, especially in the shale and shaly limestone areas, more permanent water supplies could probably be obtained by drilling deeper. Water in the limestone beneath the Martinsburg shale would probably be under pressure and would rise in wells that penetrated the argillaceous beds. The synclinal belts of shale, such as that west of Chambersburg and Greencastle, would therefore be the most favorable locations for deep bored wells and might yield artesian water that would rise above the level of the adjacent limestone plain. A deep well is being drilled by the State in the aporhyolite area in the extreme eastern part of the Chambersburg quadrangle and, when reported, was down 375 feet.

In the shale belt and other areas where the supply of shallow well water is uncertain, rain water is caught in cisterns and used not only for washing but for general domestic purposes. Where large cement cisterns are constructed and the pipes so arranged that the first fall of rain is allowed to carry away the impurities before the water is turned into the cistern, rain is not an unhealthy or unpleasant water for all domestic uses, and the supply is always adequate. Rain water that is conducted from the eaves through rusty, unclean troughs or pipes to a wooden cistern, which is seldom if ever cleaned out, is unfit for drinking and is likely to harbor disease.

TOWN SUPPLIES.

All the larger towns in the area have a water system of some sort, but none have a proper sewer system. Those near the mountains depend on gravity for pressure, but those in the plains either pump the water to some adjacent shale table-land or have a water tower.

Chambersburg obtains its water from Conococheague Creek, a stream of pure sandstone water coming from springs and runs in South Mountain. Although subject to possible contamination from small towns and sawmills on its upper course, the water at present is pure and wholesome. It is pumped from the stream to reservoirs on the adjacent shale plateau, about 100 feet above the town. Many of the other towns in this area get their water supply from springs and runs in the mountains. Waynesboro is supplied by a reservoir 200 feet above the town on a small stream on the mountain side, 4 miles to the east. Fayetteville pipes its water direct from Cold Spring Run, 2 miles north, in the mountains, with 150 feet head. Fort Loudon has a continuous flow from a spring 150 feet above the town, on the mountain slope, 1 mile to the west. McConnellsburg has a reservoir on a small mountain stream 1 mile east, with 220 feet fall. Mercersburg pipes its water from Buck Run, 1 mile above Cove Gap, to a storage reservoir at Charlestown having about 200 feet head, and thence throughout the town, a total distance of 5 miles. Greencastle gets its water from limestone springs 2 miles to the east, where it is stored in a reservoir 120 feet above the village. The smaller towns and villages depend on individual wells. The State Soldiers' Orphans' Industrial School, at Scotland, has a water tower and pumping plant and obtains water from limestone springs on the premises.

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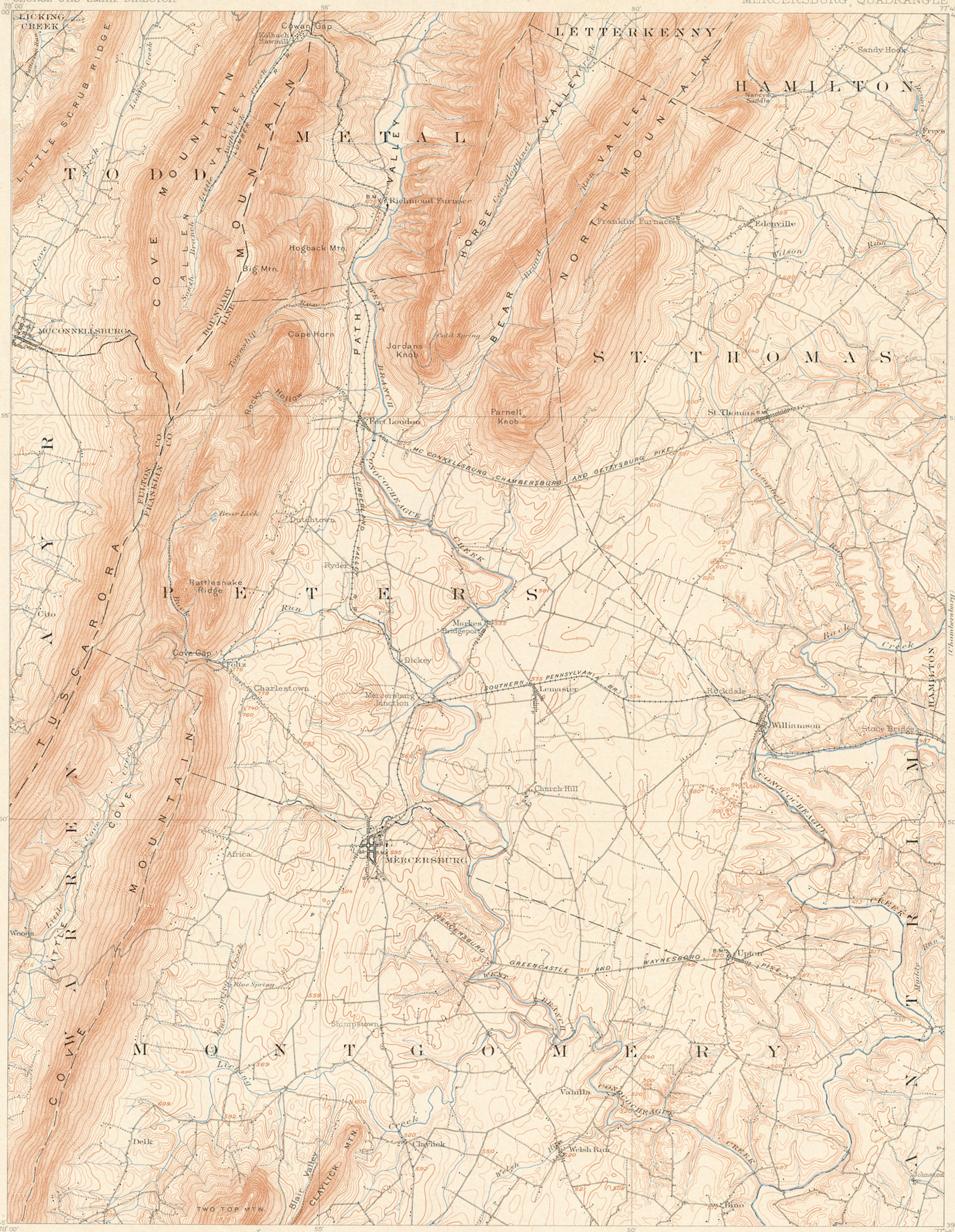
U.S.GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

PENNSYLVANIA
MERCERSBURG QUADRANGLE



LEGEND

RELIEF
printed in brown

- Figures showing heights above mean sea level instrumentally determined
- Contours showing height above sea, horizontal form, and steepness of slope of the surface
- Depression contours

DRAINAGE
printed in blue

- Streams
- Marshes

CULTURE
printed in black

- Roads and buildings
- Churches and school houses
- Private and secondary roads
- Railroads
- Bridges
- Dams and ponds
- County lines
- Township lines
- City, village and borough lines
- Triangulation stations
- Bench marks

H.M. Wilson, Geographer in charge.
Control by Sledge Tatum and J.H. Wheat.
Topography by Robt. D. Cummin.
Surveyed in 1900.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

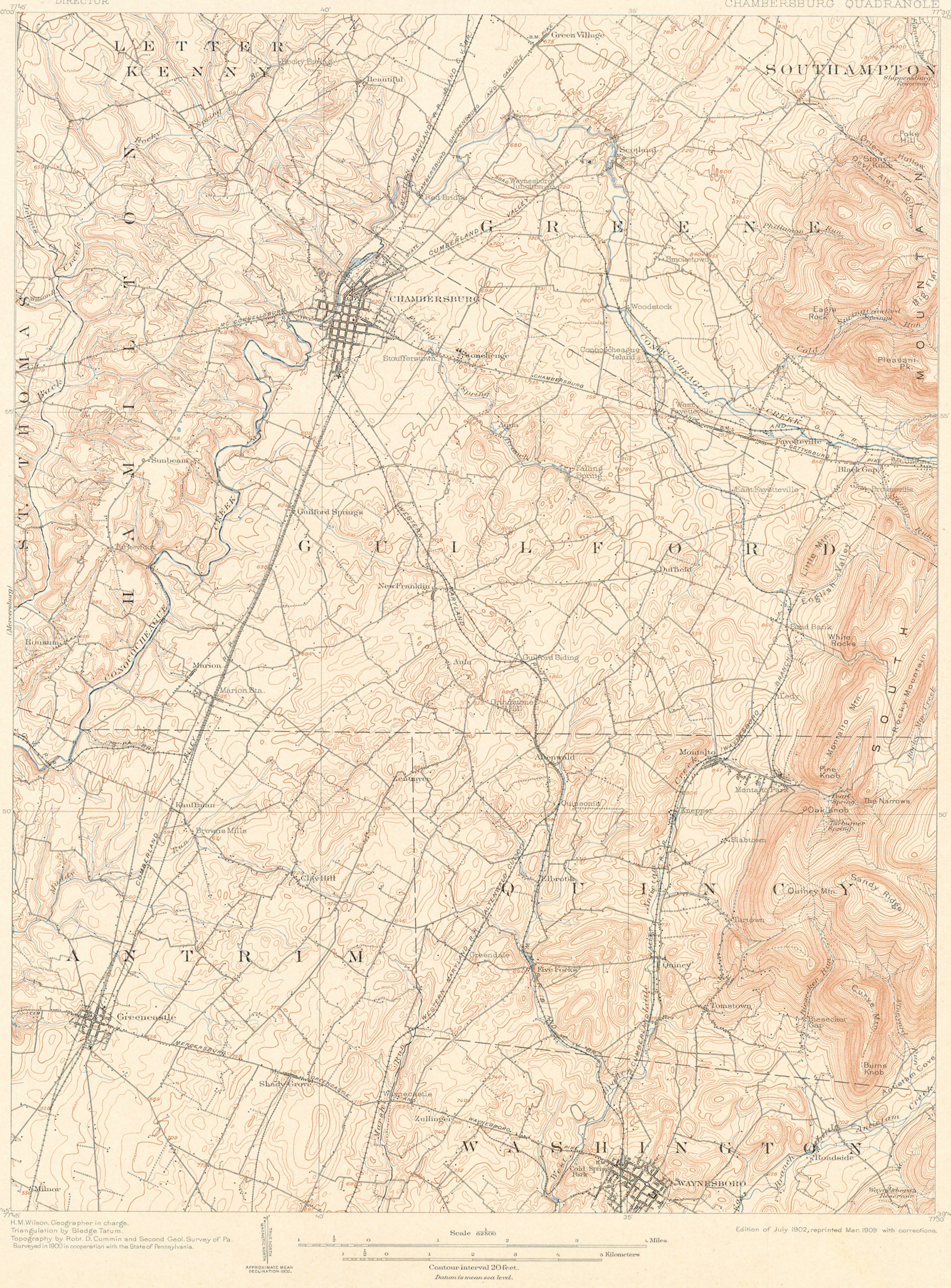
Contour interval 20 feet.
Datum is mean sea level.

Edition of July 1902, reprinted Mar. 1909 with corrections.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH
DIRECTOR

TOPOGRAPHY

PENNSYLVANIA
(FRANKLIN COUNTY)
CHAMBERSBURG QUADRANGLE



LEGEND

RELIEF
printed in brown

- Figures *showing heights above mean sea level instrumentally determined*
- Contours *showing height above sea, horizontal form, and steepness of slope of the surface*
- Depression contours and open pits

DRAINAGE
printed in blue

- Streams
- Intermittent streams
- Lakes, ponds, and reservoirs
- Springs
- Marshes

CULTURE
printed in black

- Roads and buildings
- Churches and school houses
- Private and secondary roads
- Trails
- Railroads
- Electric railroads
- Bridges
- Dams
- Township lines
- City, village and borough lines
- Triangulation stations
- Bench marks (BM ×)

H. M. Wilson, Geographer in charge.
Triangulation by Sledge Tatum.
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U.S. GEOLOGICAL SURVEY
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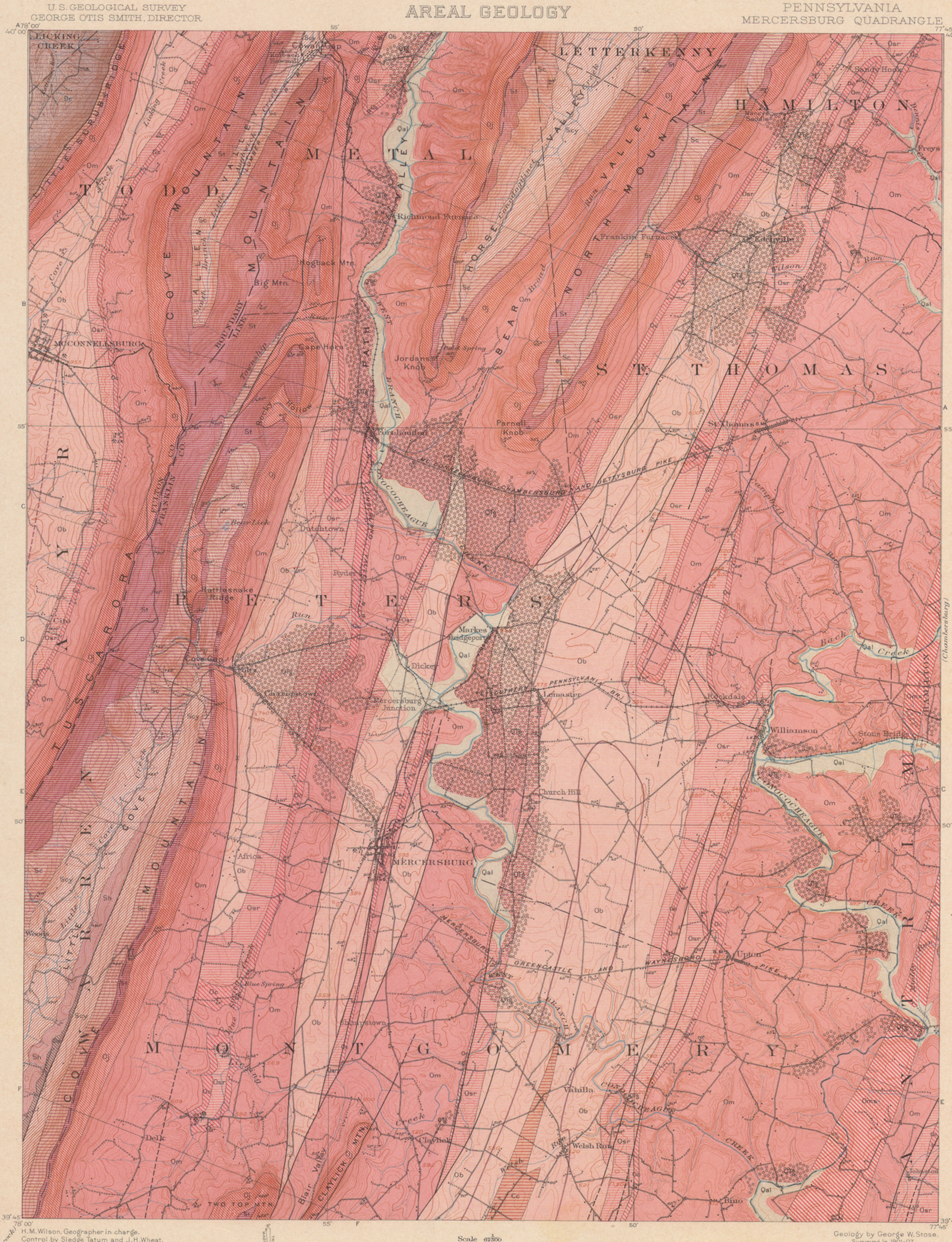
AREAL GEOLOGY

PENNSYLVANIA
MERCERSBURG QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

Qal — **Alluvium** *(gravel and silt in valley bottoms)*

TERTIARY

QTg — **Terrace gravels** *(coarse gravel and sand on stream terraces and elevated alluvial fans)*

DEVONIAN

Dc — **Chemung formation** *(gray, green, and dark-red shale and micaceous sandstone)*

SEQUENCE CONCEALED

Do — **Oriskany formation** *(cherty limestone, sandstone, and conglomerate)*

SILURIAN

Sh — **Helderberg limestone** *(massive and thin-bedded dark limestone, upper part cherty)*

Scy — **Cayuga formation** *(red, green, and yellow shale, with thin laminated limestone)*

Sc — **Clinton shale** *(drab clay shale with ferruginous red sandstone and white quartzite beds)*

St — **Tuscarora sandstone** *(massive hard white quartzose sandstone)*

Equivalent to Medina

ORDOVICIAN

Oj — **Juniata formation** *(red sandstone and shale with some quartz conglomerate)*

Om — **Martinsburg shale** *(black fissile shale and soft greenish arkosic sandstone, harder sandstone beds, Oms, locally at the top)*

Equivalent to upper Trenton, Utica, and Eden

Oc — **Chambersburg limestone** *(rather pure thin-bedded fossiliferous limestone with argillaceous partings)*

Equivalent to upper Chazy, Lowville, Black River, and lower Trenton

Osr — **Stones River limestone** *(very pure even-grained limestone, with some magnesian beds)*

Equivalent to lower and middle Chazy

Ob — **Beekmantown limestone** *(interbedded pure and magnesian limestones, bed of rougous and "cauliflower" chert in lower part)*

Shenandoah group

CAMBRIAN

Cc — **Conococheague limestone** *(dense dark limestone with numerous contorted sandy laminae)*

Faults

Concealed faults *(covered by surficial deposits)*

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

Economic data: *Lime for plaster can be obtained from Osr, lime for fertilizer chiefly from Osr, Ob, and Oc, cement materials from Osr, Oc, and Om, road material from limestones of the Shenandoah group, Om, Oj, and Sc, flagstones from Oc, St, and Sc, building and foundation stone from limestones of the Shenandoah group, and St, shale and clay for brick from Om, Sc, and residuum from weathered limestones, building sand from St and Qal. Ob, Osr, and Oc furnish the best soils for farm land, Om and slopes of mountains mantled by wash furnish poorer soils adapted to fruit culture, farming, and grazing, mountain areas, mantled largely by sandstone débris adapted chiefly to woodland, grazing, and fruit culture.*

Quarries, chiefly limestone for foundations flagstones and road material

Quarries with limekilns only the larger ones shown

x *Abandoned iron mines and prospects*

H.M. Wilson, Geographer in charge.
Control by Sledge Tatum and J.H. Wheat.
Topography by Robt. D. Cummin.
Surveyed in 1900.

SURVEYED IN COOPERATION WITH THE STATE OF PENNSYLVANIA.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

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.

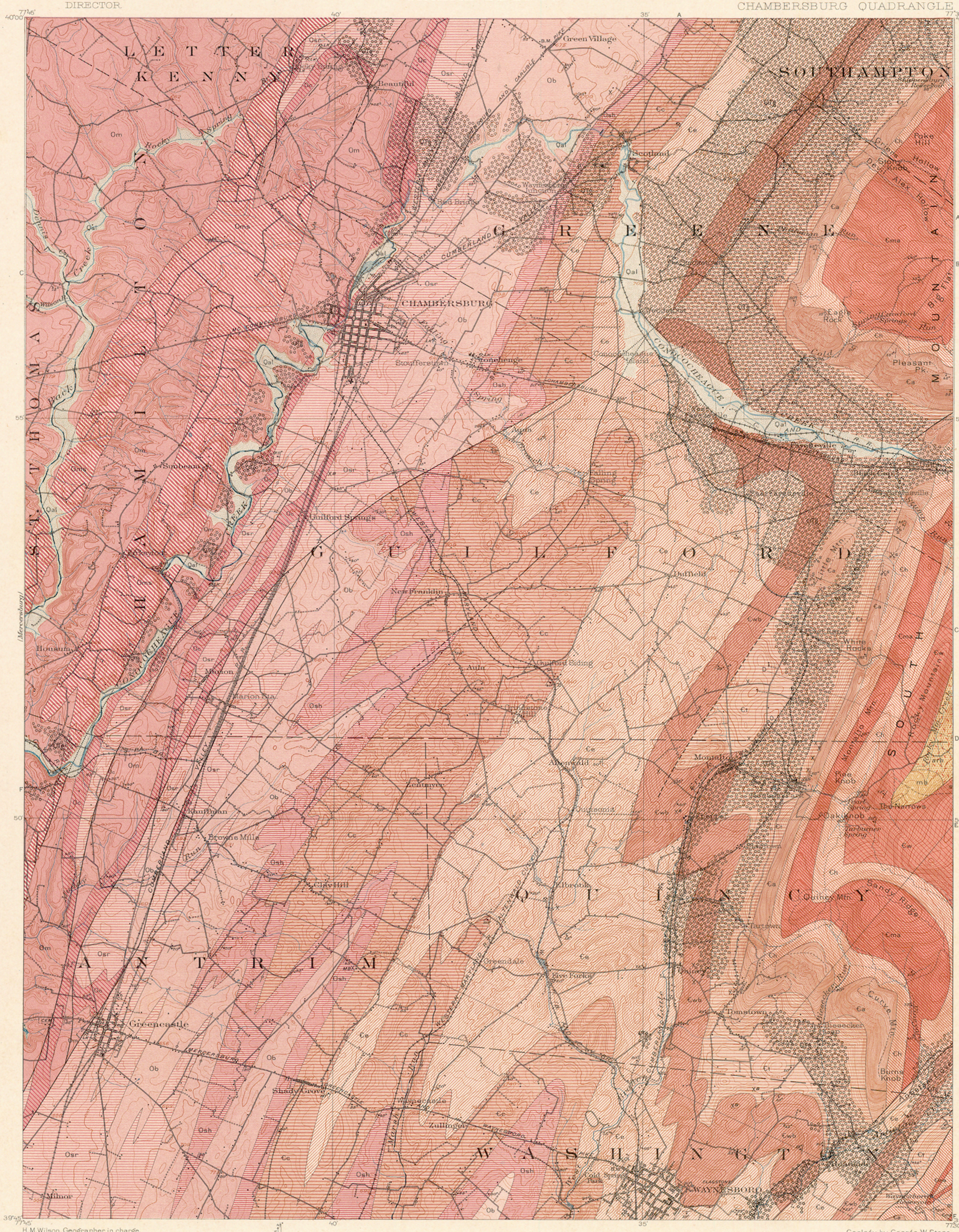
Edition of April 1909.

Geology by George W. Stose.
Surveyed in 1901-07.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH
DIRECTOR

AREAL GEOLOGY

PENNSYLVANIA
(FRANKLIN COUNTY)
CHAMBERSBURG QUADRANGLE



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LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY

- Qal — **Alluvium** *(gravel and silt in valley bottoms)*

TERTIARY

- Tg — **Terrace gravels and wash** *(coarse gravel and sand on stream terraces and at the foot of mountain slopes)*

ORDOVICIAN

Equivalent to upper Trenton, Utica, and Eden

- Oms / Om — **Martinsburg shale** *(black fissile shale and soft greenish arkosic sandstone, harder sandstone beds, Oms, at the top)*

Equivalent to upper Chazy, Lowville, Black River, and lower Trenton

- Oc — **Chambersburg limestone** *(rather pure thin-bedded fossiliferous limestone with argillaceous partings)*

Equivalent to lower and middle Chazy

- Osr — **Stones River limestone** *(very pure even-grained limestone, with some magnesian beds)*
- Ob / Osh — **Beekmantown limestone** *(interbedded pure and magnesian limestones, at the base, siliceous-banded and conglomeratic Stonehenge member, Osh)*

CAMBRIAN

Shenandoah group

Saratogan series

- Ꞓc — **Conococheague limestone** *(dense dark limestone with numerous contorted sandy laminae, at the base, very sandy beds with limestone conglomerate and chert)*

Acadian series

- Ꞓe — **Elbrook formation** *(light-gray shaly limestone and calcareous shale, with a few thick limestone beds)*
- Ꞓwb — **Waynesboro formation** *(slabby sandstone, hard purple sandy shale, and limestone)*

Georgian series

- Ꞓt — **Tomstown limestone** *(massive and thin-bedded limestone and shale)*
- Ꞓa — **Antietam sandstone** *(coarse white sandstone and quartzite)*
- Ꞓh / Ꞓma — **Harpers schist and Montalto quartzite member** *(dark banded slate or schist, with massive hard white quartzite member)*
- Ꞓw — **Weverton sandstone** *(gray feldspathic sandstone and purplish quartz conglomerate)*

IGNEOUS ROCKS

(Areas of igneous rocks are shown by patterns of triangles and rhombs; metamorphism is indicated by hachures)

PRE-CAMBRIAN

Algonkian?

- arh — **Aporhyolite** *(devitrified rhyolite lava, chiefly red or purplish)*
- mb — **Metabasalt** *(basalt flows altered to greenstone)*

Faults ___ _ _

Concealed faults *(covered by surficial deposits)* ....

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

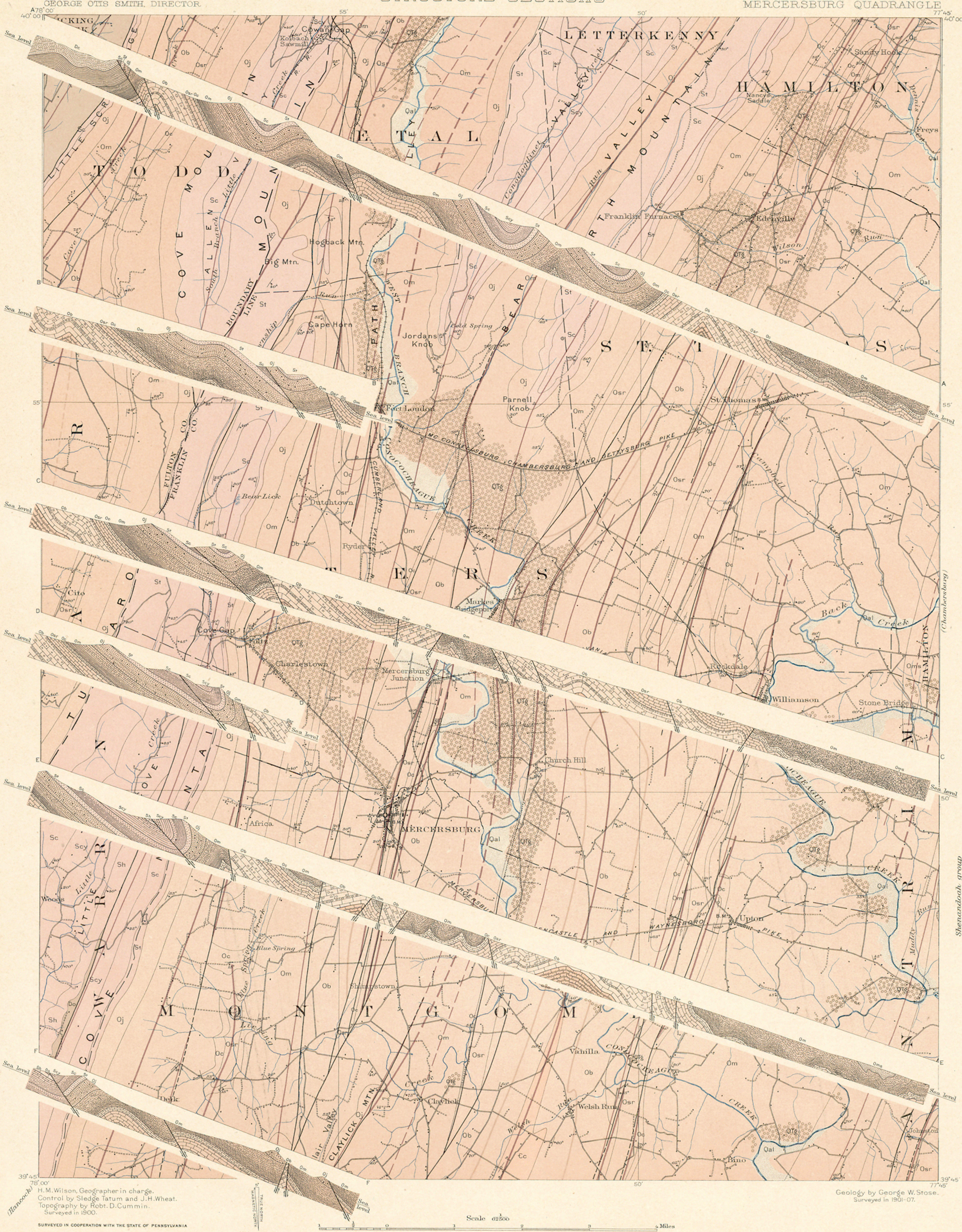
- ⚒ *Quarries, chiefly limestone for foundations, flagstones, and road material*
- ⚒ LK *Quarries with limekilns only the larger ones shown*
- X *Abandoned iron mines and prospects*
- X B *Abandoned barite mines and prospects*
- X MB *Marble prospect*
- ⚒ S *Sand pits*
- ⚒ CL *Clay pits and brick kilns*

Economic data: *Lime for plaster can be obtained from* Osr, *lime for fertilizer chiefly from* Osr, Ob, Oc, *and* Ꞓt, *cement materials from* Osr, Oc, *and* Om, *road material from limestones of the Shenandoah group,* arh, *and* Om, *flagstones from* Ꞓwb *and* Oc, *building and foundation stone from limestones of the Shenandoah group,* Oms, *and* Ꞓa, *shale and clay for brick from* Ꞓh, Om, *and residuum from weathered limestones, building sand from* Ꞓa, Ꞓma, *and* Qal, *iron ores from wash overlying* Ꞓt *and* Ꞓwb. Ꞓt, Ꞓe, Ob, Osr, *and* Oc *furnish the best soils for farm land,* Ꞓwb, Ꞓc, Om, *and slopes of mountains mantled by wash furnish poorer soils adapted to fruit culture, farming, and grazing, mountain areas, mantled largely by sandstone débris, adapted chiefly to woodland, grazing, and fruit culture.*

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

STRUCTURE SECTIONS

PENNSYLVANIA
MERCERSBURG QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL	SECTION SYMBOL	Formation	System
Qal		**Alluvium** *(gravel and silt in valley bottoms)*	QUATERNARY
QTg		**Terrace gravels** *(coarse gravel and sand on stream terraces and elevated alluvial fans)*	TERTIARY
Dc	Dc	**Chemung formation** *(gray, green, and dark-red shale and micaceous sandstone)*	DEVONIAN
	▨	**Romney and Portage formations** *(not exposed in the quadrangle)*	
Do	Do	**Oriskany formation** *(cherty limestone, sandstone, and conglomerate)*	
Sh	Sh	**Helderberg limestone** *(massive and thin-bedded dark limestone, upper part cherty)*	SILURIAN
Scy	Scy	**Cayuga formation** *(red, green, and yellow shale, with thin laminated limestone)*	
Sc	Sc	**Clinton shale** *(drab clay shale with ferruginous red sandstone and white quartzite beds)*	
St	St	**Tuscarora sandstone** *(massive hard white quartzose sandstone)*	
Oj	Oj	**Juniata formation** *(red sandstone and shale with some quartz conglomerate)*	ORDOVICIAN
Om Oms	Om Oms	**Martinsburg shale** *(black fissile shale and soft greenish arkosic sandstone, harder sandstone beds, Oms, locally at the top)*	
Oc	Oc	**Chambersburg limestone** *(rather pure thin-bedded fossiliferous limestone with argillaceous partings)*	
Osr	Osr	**Stones River limestone** *(very pure even-grained limestone, with some magnesian beds)*	
Ob	Ob	**Beekmantown limestone** *(interbedded pure and magnesian limestones, bed of rougous and "cauliflower" chert in lower part)*	
Ꞓc	Ꞓc	**Conococheague limestone** *(dense dark limestone with numerous contorted sandy laminae)*	CAMBRIAN

Equivalent to Medina (Tuscarora sandstone and Juniata formation)

Equivalent to upper Trenton, Utica, and Eden (Martinsburg shale)

Equivalent to upper Chazy, Lowville, Black River, and lower Trenton (Chambersburg limestone)

Equivalent to lower and middle Chazy (Stones River limestone)

Shenandoah group (Chambersburg limestone to Conococheague limestone)

Faults

Concealed faults
(covered by surficial deposits)

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

Axes of anticlines and synclines
(heavy lines are anticlines; light lines are synclines)

H.M. Wilson, Geographer in charge.
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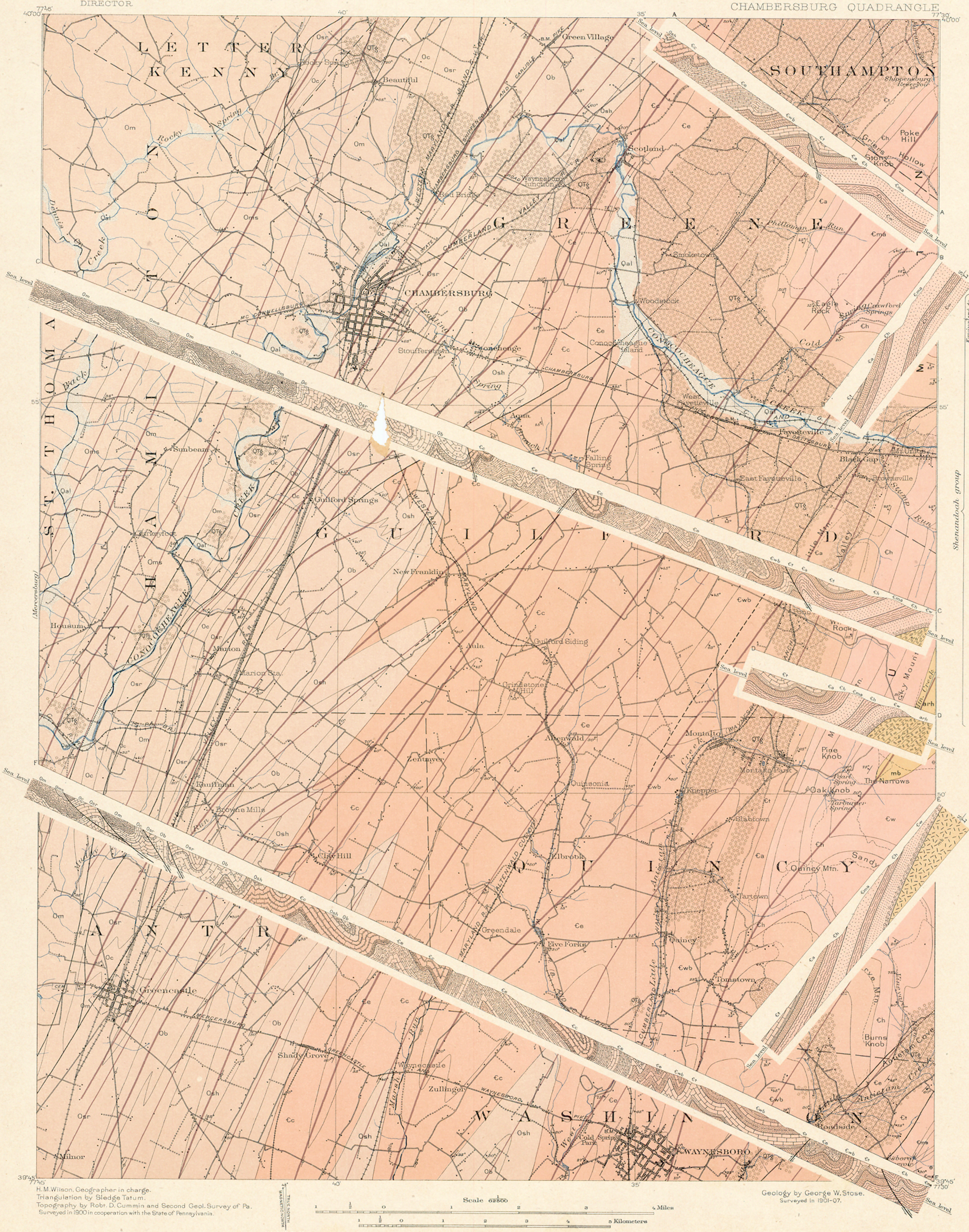
STRUCTURE SECTIONS

PENNSYLVANIA
(FRANKLIN COUNTY)
CHAMBERSBURG QUADRANGLE



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TRUE NORTH
MAGNETIC NORTH
4°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of April 1909.

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LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

QUATERNARY

Qal
Alluvium
(gravel and silt in valley bottoms)

TERTIARY

QTg
Terrace gravels and wash
(coarse gravel and sand on stream terraces and at the foot of mountain slopes)

ORDOVICIAN

Equivalent to upper Trenton, Utica, and Eden

Oms / Om — Om
Martinsburg shale
(black fissile shale and soft greenish arkosic sandstone, harder sandstone beds, Oms, at the top)

Equivalent to upper Chazy, Lowville, Black River, and lower Trenton

Oc — Oc
Chambersburg limestone
(rather pure thin-bedded fossiliferous limestone with argillaceous partings)

Equivalent to lower and middle Chazy

Osr — Osr
Stones River limestone
(very pure even-grained limestone with some magnesian beds)

Ob / Osh — Ob
Beekmantown limestone
(interbedded pure and magnesian limestones, at the base, siliceous-banded and conglomeratic Stonehenge member, Osh)

Shenandoah group

CAMBRIAN

Saratogan series

€c — €c
Conococheague limestone
(dense dark limestone with numerous contorted sandy laminae at the base, very sandy beds with limestone conglomerate and chert)

Acadian series

€e — €e
Elbrook formation
(light-gray shaly limestone and calcareous shale, with a few thick limestone beds)

€wb — €wb
Waynesboro formation
(slabby sandstone, hard purple sandy shale, and limestone)

Georgian series

€t — €t
Tomstown limestone
(massive and thin-bedded limestone and shale)

€a — €a
Antietam sandstone
(coarse white sandstone and quartzite)

€h / €ma — €h €ma €h
Harpers schist and Montalto quartzite member
(dark banded slate or schist, with massive hard white quartzite member)

€w — €w
Weverton sandstone
(gray feldspathic sandstone and purplish quartz conglomerate)

IGNEOUS ROCKS

PRE-CAMBRIAN

Algonkian?

arh — arh
Aporhyolite
(devitrified rhyolite lava, chiefly red or purplish)

mb — mb
Metabasalt
(basalt flows altered to greenstone)

Faults

Concealed faults
(covered by surficial deposits)

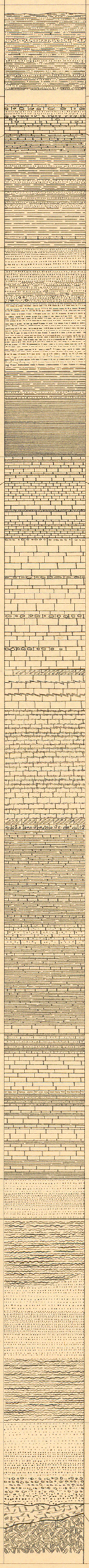
45° *Strike and dip of stratified rocks*
Strike of vertical strata
Horizontal strata

Axes of anticlines and synclines
(heavy lines are anticlines; light lines are synclines)

COLUMNAR SECTION

GENERALIZED SECTION OF ROCKS FOR THE MERCERSBURG AND CHAMBERSBURG QUADRANGLES.

SCALE: 1 INCH = 1000 FEET.



System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
DEVONIAN	Chemung formation.	Dc		1500±	Alternating greenish-gray to chocolate-colored sandy shale and thin micaceous sandstones.	Hilly upland, in part cultivated. Poor sandy soil.
	(Portage and Romney shales not exposed.)					
	Oriskany formation.	Do		175+	White fossiliferous granular sandstone and fossiliferous cherty limestone with conglomerate of small round white quartz pebbles at base.	Foothills and ridges, in part cultivated. Cherty sandy soil.
SILURIAN	Helderberg limestone.	Sh		300±	Massive to thin-bedded dark crystalline fossiliferous limestone with numerous fossiliferous cherts in upper portion.	Valley slopes and low foothills, generally cultivated. Rich clay soil, very cherty on the hilltops.
	Cayuga formation.	Scy		750	Upper part finely laminar impure light-gray limestone and calcareous shale; lower part red, green, and yellow sandy shale with hard white sandstone bed. Tough red argillaceous sandstone near the base.	Valley bottoms and lower mountain slopes, generally densely forested. Clay soil, in large part covered by sandstone wash.
	Clinton shale.	Sc		750	Soft gray to pink fissile clay shale, with massive and thin-bedded red ferruginous sandstones in upper portion and flaggy white quartzite containing short scolithus tubes at the top. Thin soft calcareous sandstone beds in lower portion.	Steep slopes and foothills of high mountains, generally wooded. Clay soil, generally covered by sandstone wash.
	Tuscarora sandstone.	St		270	Massive granular white quartz sandstone.	Forest-covered crests of mountains. Talus slopes and ledges.
ORDOVICIAN	Juniata formation.	Oj		400–450	Soft red sandstone and shale with some hard quartz sandstone and conglomerate.	Steep upper slopes of mountains. Forested. Thin rocky sandy soil.
	(Sandstone member.)				Soft greenish arkosic sandstone mapped as a separate member in eastern part of area.	Elevated level plateau, deeply cut by narrow winding valleys and steep ravines, and lower slopes of mountains. Dry shaly soil, suitable for fruit culture and general farming where surface is not too steep; usually covered by sandstone wash and heavily forested near mountains.
	Martinsburg shale.	Om		2000	Chiefly dark shale, black, carbonaceous, fissile to blocky at the base; dark-gray crumbly "shoe-peg" shale, some weathering to soft whitish clay, in the upper portion.	
	Chambersburg limestone.	Oc		100–750	Thin-bedded tough dark limestone, usually very fossiliferous, with irregular clayey partings giving rise to limestone "cobble" on weathering. Interbedded shale at the top in most places forms gradation into Martinsburg.	Gentle to steep slopes of shale ridges. Thin residual clay soil with numerous rock outcrops.
	Stones River limestone.	Osr		675–1050	Very pure, thin-bedded, even-grained dove-colored limestone at top and bottom with some magnesian layers; granocrystalline gray fossiliferous limestone with thin layer of black blocky chert in middle.	Gently rolling lowland with few rock outcrops. Deep residual yellow clay soil, suitable for general farming.
	Beekmantown limestone.	Ob		2300	Small rosette and "cauliflower" cherts at or near the top. Thick-bedded, rather pure limestone, in large part finely laminated, interbedded with magnesian beds and fine-grained pink to white marble; contains beds of oolite, fine conglomerate, chert nodules, and quartz geodes at several horizons. Prominent layers of cherts in the Mercersburg quadrangle.	Low, gently rolling plains with few rock outcrops and low chert-covered ridges. Deep residual clay soil, suitable for general farming, and cherty soil on ridges suitable for fruit culture.
	(Stonehenge siliceous limestone member.)	(Osh)		(485)	Blue limestone with hard siliceous laminæ, coarse "edgewise" conglomerate, and purer fine-grained marble. Not clearly separable in the Mercersburg quadrangle.	Rough hilly land with numerous rock outcrops, partly wooded, and low narrow ridges. Thin sandy clay soil with numerous hard shale fragments, suitable for grazing and fruit culture.
CAMBRIAN UPPER CAMBRIAN (SARATOGAN)	Conococheague limestone.	€c		1635	Thin-bedded blue limestone finely banded by thin, hard, siliceous, generally contorted laminæ that weather in relief and finally disintegrate to slaty sandstone and shale fragments. "Edgewise" conglomerate, chert, oolite, and limestone conglomerate containing quartz grains and weathering to porous sandstone, at the base.	
MIDDLE CAMBRIAN (ACADIAN) SERIES	Elbrook formation.	€e		3000	Gray to pale-blue shaly limestone and calcareous papery shale with some heavier limestone beds at the base and thick-bedded siliceous limestone in the middle.	Rolling cultivated plains with low ridges and knobs. Light sandy residual clay soil, suitable for farm land.
	Waynesboro formation.	€wb		1000±	Slabby gray calcareous sandstones or sandy limestones and hard slaty purple shale, with limestone and fine-grained white marble in middle. Large scoriaceous white chert heads and vein quartz in lower portion.	Low ridges and rounded hills. Thin sandy soil with numerous hard slaty fragments, suitable for fruit culture and grazing.
? LOWER CAMBRIAN (GEORGIAN) SERIES	Tomstown limestone.	€t		1000±	Massive and thin-bedded limestone, in part cherty and magnesian, with considerable shale and soft white clay at the base.	Rolling cultivated lowlands and broad valleys. Rich clay soil largely covered by alluvium and sandstone wash, suitable for fruit culture and general farming.
	Antietam sandstone.	€a		500–800	Coarse-grained white and bluish-gray quartzite and sandstone containing numerous long scolithus tubes; generally weathers readily to sand.	Sharp rocky wooded ridges and slopes. Sandy soil, rock talus, and ledges.
	Harpers schist.	€h		2750	Dark-banded tough hackly schist or slate and thin flaggy sandstones with massive hard white scolithus-bearing quartzite member in middle, which thickens from 20 feet at the south border of the Chambersburg quadrangle to about 850 feet at the north border.	Smooth-topped, high wooded ridges and deep densely forested intermontane valleys. Clayey and sandy soil, with sandstone talus on steep slopes.
	(Montalto quartzite member.)	(€ma)		(20–850)		
	Weverton sandstone.	€w		1250	Coarse gray feldspathic sandstone and white quartzose sandstone, with purplish arkose and hard purple quartz conglomerate at the base.	Sharp high wooded ridges. Rocky ledges with meager sandy soil.
	UNCONFORMITY					
PRE-CAMBRIAN	Aporhyolite.	arh			Altered rhyolitic lava, finely laminated by flow structure and in places spherulitic and porphyritic; usually red to purple in color.	Rolling intermontane valley, densely forested. Poor, thin soil largely covered by sandstone wash.
	Metabasalt.	mb			Altered basalt flows, containing amygdules filled with chlorite, epidote, and quartz and veined by epidote and asbestos. Usually altered to greenstone and chlorite schist.	Rolling intermontane valley, densely forested. Thin, rich red soil.

FIGURE 6.—SCHOOLEY PENEPLAIN PRESERVED ON THE NORTH MOUNTAIN RIDGES.
Parnell Knob at the left. Foreground and middle ground are part of the dissected shale plateau of the Harrisburg peneplain From point 3½ miles southwest of Chambersburg.

FIGURE 7.—JORDAN KNOB SYNCLINAL MOUNTAIN, FROM FORT LOUDON.
The western limb of the syncline is shown terminating in Jordan Knob in the center of the picture. The crest of the mountain is composed of Tuscarora sandstone; the cleared fields on the slope are of Martinsburg shale.

FIGURE 8.—COVE MOUNTAIN AND THE MERCERSBURG LIMESTONE VALLEY SEEN FROM DUNNS GAP ROAD, ON THE SLOPE OF CROSS MOUNTAIN.
The comblike ridge on the left is Cove Mountain. Parnell and Jordan synclinal ridges are in the distance.

FIGURE 9.—CHAMBERSBURG LIMESTONE AT CHAMBERSBURG.
The planes dipping steeply to the left are the bedding; those dipping gently to the right are the argillaceous partings that give rise to "cobbly" fragments on weathering.

FIGURE 10.—CHARACTERISTIC THIN-BEDDED LIMESTONE OF THE CHAMBERSBURG FORMATION, IN RAILROAD CUT 2 MILES SOUTHWEST OF MARION.

FIGURE 11.—SYNCLINE IN MARTINSBURG SHALE, 3 MILES NORTHEAST OF UPTON.
Shows the cleavage planes radiating from the center of the fold.

FIGURE 12.—SCHOOLEY PENEPLAIN PRESERVED ON CROSS MOUNTAIN.
The level-topped ridge in the middle distance is Cross Mountain. At the right is the lower ridge of Cove Mountain, and at the left is Two Top Mountain. The foreground represents the Somerville peneplain preserved on Martinsburg shale.

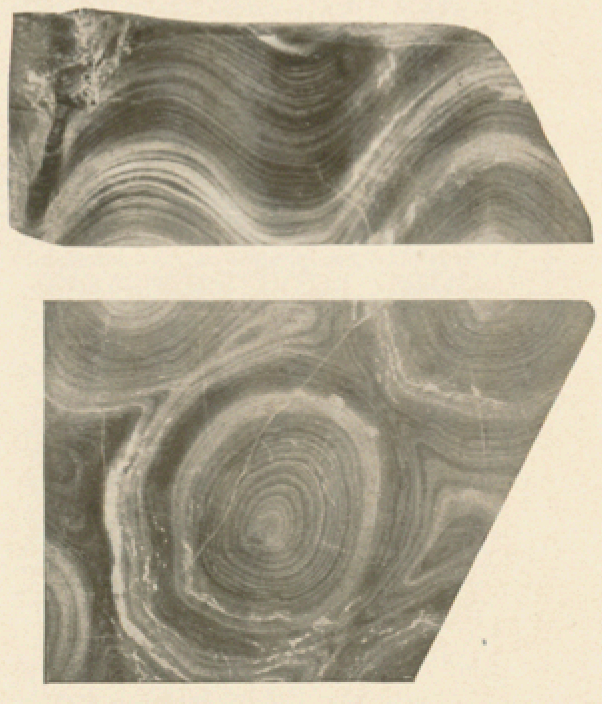


FIGURE 13.—CRYPTOZOON PROLIFERUM FROM LOWER PART OF THE CONOCOCHEAGUE FORMATION, 2 MILES WEST OF FAYETTEVILLE.
Natural size. Upper figure, cross section; lower figure, under side of same specimen.

FIGURE 14.—"CAULIFLOWER" CHERT FROM THE UPPER PART OF THE BEEKMANTOWN LIMESTONE IN THE MERCERSBURG QUADRANGLE.

FIGURE 15.—CRINKLED SILICEOUS BANDING IN THE CONOCOCHEAGUE LIMESTONE, LEFT IN STRONG RELIEF BY WEATHERING.

FIGURE 16.—IRREGULAR ARGILLACEOUS AND SILICEOUS BANDING IN THE LOWER BEDS OF THE BEEKMANTOWN LIMESTONE, 1 MILE SOUTHWEST OF AQUA.

FIGURE 17.—"EDGEWISE" CONGLOMERATE IN THE STONEHENGE MEMBER OF THE BEEKMANTOWN LIMESTONE 4 MILES SOUTHEAST OF GREENCASTLE.

FIGURE 18.—ROSETTE CHERT FROM THE TOP LAYERS OF THE BEEKMANTOWN LIMESTONE.
Occurs in both the Chambersburg and the Mercersburg quadrangle.

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 in 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		€	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.

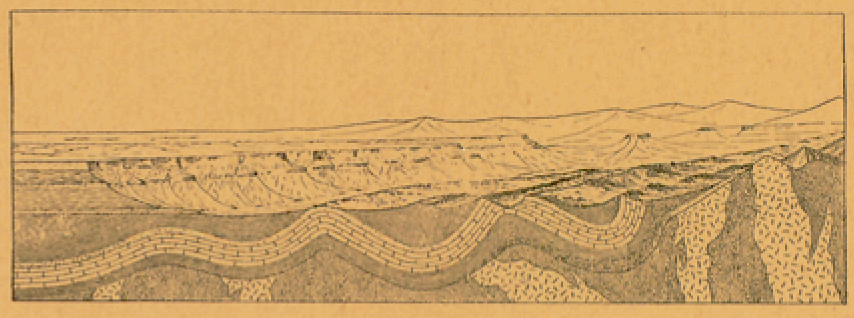
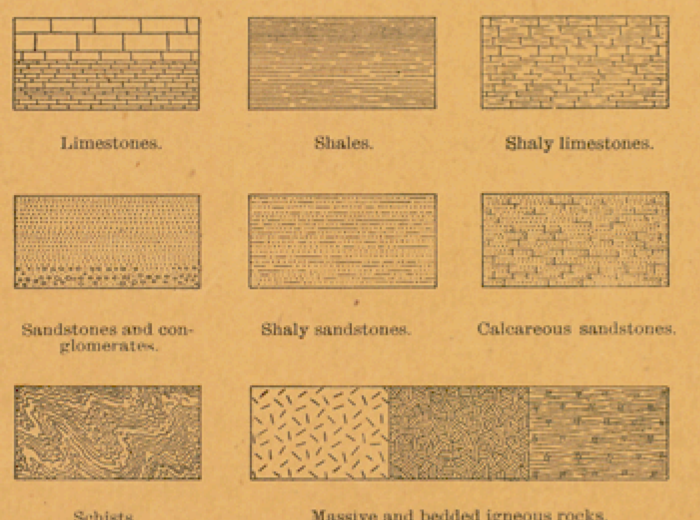


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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.



Limestones. Shales. Shaly limestones.

Sandstones and conglomerates. Shaly sandstones. Calcareous sandstones.

Schists. Massive and bedded igneous rocks.

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.

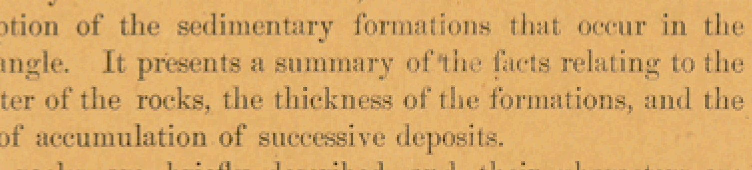


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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,
Director.

May, 1909.

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