DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

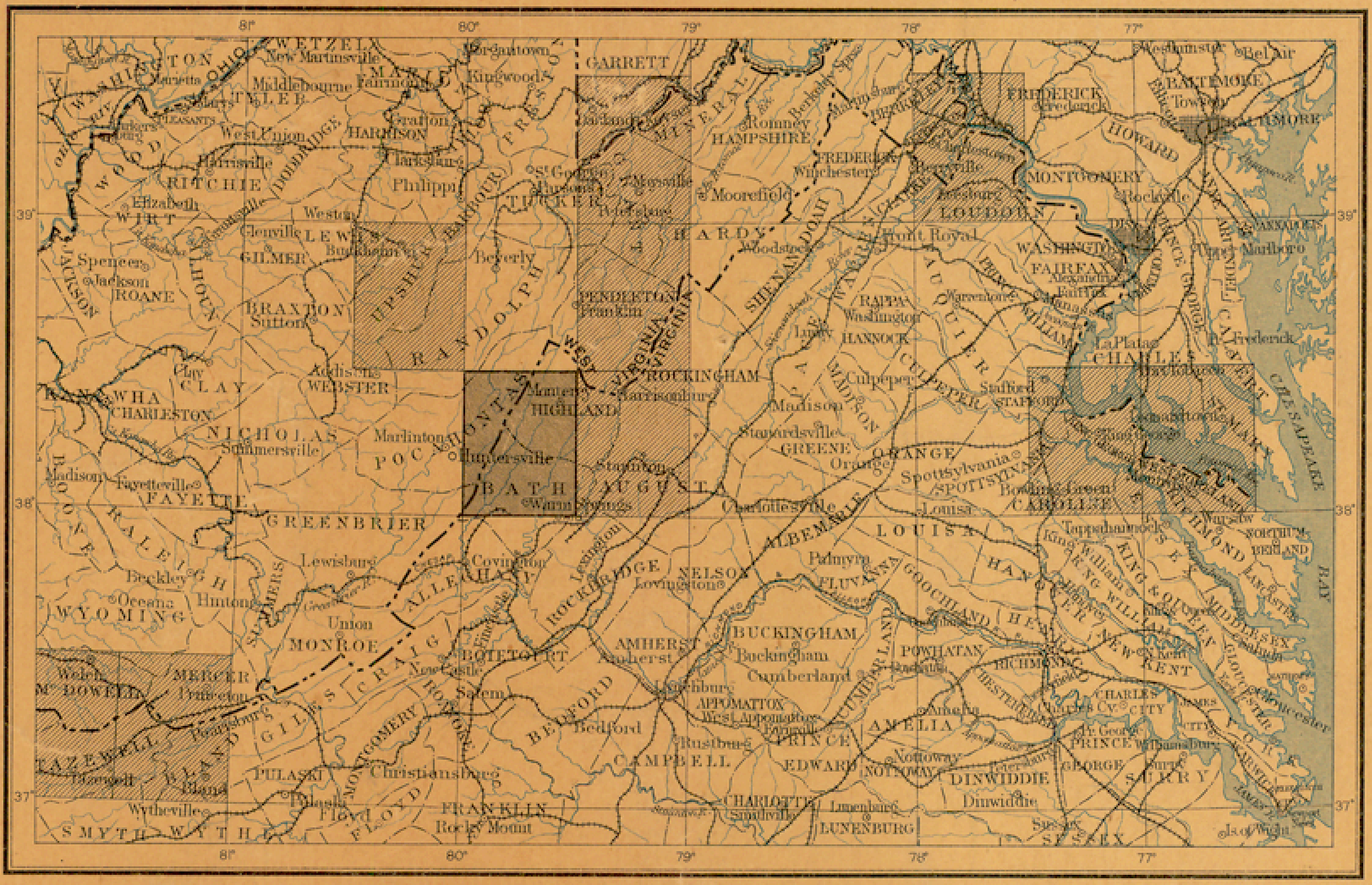
OF THE

UNITED STATES

MONTEREY FOLIO

VIRGINIA - WEST VIRGINIA

INDEX MAP



SCALE: 40 MILES=1 INCH

AREA OF THE MONTEREY FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION | TOPOGRAPHY | HISTORICAL GEOLOGY | ECONOMIC GEOLOGY | STRUCTURE SECTIONS

COLUMNAR SECTION

FOLIO 61 LIBRARY EDITION MONTEREY

WASHINGTON, D. C.

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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS. S. J. KUBEL, CHIEF ENGRAVER

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EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small area of country, together with explanatory and descriptive texts.

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 which are most important 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea-level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map:

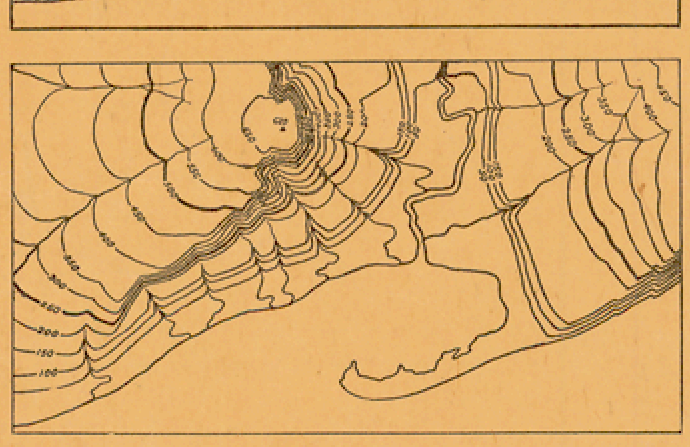

Fig. 1.—Ideal sketch and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand-bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply in a precipice. Contrasted with this precipice is the gentle descent of the left-hand slope. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while 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 sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise 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.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If the stream flows the year round the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this case it is "1 mile to an inch." 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 an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree, i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. 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 the names of adjacent sheets, if published, are printed.

Uses of the topographic sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known, and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it either consolidates in cracks or fissures crossing the bedding planes, thus forming dikes, or else spreads out between the strata in large bodies, called sills or laccoliths. Such rocks are called *intrusive*. Within their rock enclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock, it is younger than that rock, and when a sedimentary rock is deposited over it, the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses, and as it rises or subsides the shore-lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus

DESCRIPTION OF THE MONTEREY QUADRANGLE.

GEOGRAPHY.

Location of quadrangle.

General relations.—The Monterey quadrangle embraces the quarter of a square degree which lies between parallels 38° and 38° 30′ north latitude and meridians 79° 30′ and 80°. It measures approximately 34.5 miles from north to south and 27.3 miles from east to west, and its area is about 942 square miles. In Virginia it comprises the greater part of Bath County and the western portion of Highland County. In West Virginia it includes the eastern portion of Pocahontas and very small areas of Randolph and Greenbrier counties. The area is of typical Appalachian character throughout, and comprises portions of the headwater streams of the Potomac, James, Greenbrier, and Cheat rivers.

The general region.

In its geographic and geologic relations this quadrangle forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west and from central Alabama to southern New York. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as a single quadrangle; hence it is necessary to consider the individual quadrangle in its relations to the entire province.

Subdivisions of the Appalachian province.—The Appalachian province may be subdivided into three well-marked physiographic divisions, throughout each of which certain forces have produced similar results in sedimentation, in geologic structure, and in topography. These divisions extend the entire length of the province, from northeast to southwest.

Central Appalachian division.

The central division is the Appalachian Valley. It is the best defined and most uniform of the three. In the southern part it coincides with the belt of folded rocks which forms the Coosa Valley of Georgia and Alabama and the Great Valley of East Tennessee and Virginia. Throughout the central and northern portions of the Appalachian Valley the eastern side only is marked by extensive local valleys—such as the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and Pennsylvania, and the Lebanon Valley of northeastern Pennsylvania—the western side being a succession of ridges alternating with narrow valleys. This division varies in width from 40 to 125 miles. It is bounded on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the Allegheny Mountains. Its rocks are almost wholly sedimentary and in large measure calcareous. The strata, which must originally have been nearly horizontal, now intersect the surface at various angles and in narrow belts. The surface differs with the outcrop of different kinds of rock, so that sharp ridges and narrow valleys of great length in some instances follow the narrow belts of hard and soft rock. Owing to the large amount of calcareous rock brought up on the steep folds of this district its surface is more readily worn down by streams and is lower and less broken than the divisions on either side.

Eastern Appalachian division.

The eastern division of the province embraces the Appalachian Mountains, a system which is made up of many minor ranges and which, under various local names, extends from southern New York to central Alabama. Some of its prominent parts are the South Mountain of Pennsylvania, the Blue Ridge and Catoctin Mountain of Maryland and Virginia, the Great Smoky Mountains of Tennessee and North Carolina, and the Cohutta Mountains of Georgia. Many of the rocks of this division are more or less crystalline, being either sediments which have been changed to slates and schists by varying degrees of metamorphism, or igneous rocks, such as granite and diabase, which have solidified from a molten condition.

Western Appalachian division.

The western division of the Appalachian province embraces the Allegheny Mountains and the Cumberland Plateau, also extending from New York to Alabama, and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the Tennessee River from northeast Mississippi to its mouth, and then crossing the States of Indiana and Ohio to western New York. Its eastern boundary is defined by the Allegheny Front and the Cumberland escarpment. The rocks of this division are almost entirely of sedimentary origin and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely worn down. In the southern half of the province the plateau is sometimes extensive and nearly flat, but oftener it is much divided by streams into large or small flat-topped hills. In West Virginia and portions of Pennsylvania the plateau is often sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The plateau once extended much farther westward, but the rocks beyond its present border have been completely removed by erosion, and the surface is now comparatively low and level, or rolling.

Altitude of the Appalachian province.—The Appalachian province as a whole is broadly dome shaped, its surface rising from an altitude of about 500 feet along the eastern margin to the crest of the Appalachian Mountains, and thence descending westward to about the same altitude on the Ohio and Mississippi rivers.

Heights of Appalachian Mountains.

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1000 feet in Alabama to more than 6600 feet in western North Carolina. From this culminating point they decrease to 4000 or 3000 feet in southern Virginia, rise to 4000 feet in central Virginia, and descend to 2000 or 1500 feet on the Maryland-Pennsylvania line.

Heights of the Appalachian Valley.

The Appalachian Valley shows a uniform increase in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2000 feet at the Tennessee-Virginia line, and 2600 or 2700 feet at its culminating point, on the divide between the New and Tennessee rivers. From this point it descends to 2200 feet in the valley of New River, 1500 to 1000 feet in the James River Basin, and 1000 to 500 feet in the Potomac Basin, remaining about the same through Pennsylvania. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2000 feet.

Heights of the plateau.

The plateau or western division increases in altitude from 500 feet at the southern edge of the province to 1500 feet in northern Alabama, 2000 feet in central Tennessee, and 3500 feet in southeastern Kentucky. Its height is between 3000 and 4700 feet in West Virginia, and decreases to about 2000 feet in Pennsylvania. From its greatest altitude, along the eastern edge, the plateau slopes gradually westward, although it is generally separated from the interior lowlands by an abrupt escarpment.

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

Courses of the streams.

The position of the streams in the Appalachian Valley is largely dependent upon the geologic structure. In general they flow in courses which for long distances are parallel to the sides of the Great Valley, following the lesser valleys along the outcrops of the softer rocks. These longitudinal streams empty into a number of larger, transverse rivers, which cross one or the other of the barriers limiting the valley. In the northern portion of the province they form the Delaware, Susquehanna, Potomac, James, and Roanoke rivers, each of which passes through the Appalachian Mountains in a narrow gap and flows eastward to the sea. In the central portion of the province, in Kentucky and Virginia, these longitudinal streams form the New (or Kanawha) River, which flows westward in a deep, narrow gorge through the Cumberland Plateau into the Ohio River. From New River southward to northern Georgia the Great Valley is drained by tributaries of the 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.

GEOGRAPHIC DIVISIONS, DRAINAGE, AND MOUNTAINS OF THE MONTEREY QUADRANGLE.

Mountains and valleys of the quadrangle.

The Monterey quadrangle embraces a very mountainous region in the heart of the Appalachian ranges. The Allegheny Mountain extends northeast and southwest through its center, sharply dividing the waters which eventually flow into the Ohio River from those of the James and Potomac rivers. Parallel to the Allegheny Mountain on either side lies a succession of high, narrow, generally even-crested ridges, which are in most cases continuous for long distances. They are co-extensive with beds of hard rocks which strike northeast and southwest, and which occasionally pitch downward, causing the discontinuance or offset of the ridges. The ridges are also crossed by numerous gaps deeply trenched through the hard rock by streams of greater or less size. The valleys adjoining the ridges are usually continuous and relatively straight for long distances. They are cut in the soft rocks, without reference to the geologic structure, and in most cases lie from 1000 to 1500 feet below the crests of the ridges. The high mountain summits have an average elevation of about 3000 feet above sea level; the valleys range from about 1500 feet in the southeast to about 3000 feet in the northwest. The highest mountains are the Back Allegheny, where a wide area is about 4000 feet above sea level, and Bald Knob, the highest summit, which rises to somewhat over 4800 feet. In Allegheny Mountain 4600 feet is attained, and many of the knobs are over 4000 feet above sea level. In the ranges eastward the higher summits rise to about 3600 feet with a few exceptions; among the latter are Sounding Knob and Jack Mountain, which are considerably over 4000 feet.

In Virginia the valleys are occupied by branches of James River, except in the northeastern corner of the quadrangle, where the headwaters of the South Branch of Potomac River drain a small area. The divide between these two systems is about 3000 feet above sea level at Monterey, 3100 feet near Hightown, and 3200 feet at the head of Strait Creek, all in valleys deeply depressed below the summits of adjoining ridges.

James River drainage.

There are three principal branches of the James River drainage: Back Creek, which flows along the eastern foot of the Allegheny Mountain; Jackson River, which flows in a parallel valley 4 miles east for 30 miles and unites with Back Creek near the southwest corner of the quadrangle; and Cowpasture River, with its two forks, the Bullpasture and the Cowpasture rivers, which flow in parallel longitudinal valleys 8 miles east of Jackson River.

Ohio River drainage.

The West Virginia portion of the area is traversed by the Greenbrier River and its far-reaching branches, Knapp Creek, Deer Creek, North Fork, and some minor creeks. For the greater part of its course this drainage has an average altitude of about 2500 feet above sea level, with a relatively gentle declivity. West of Greenbrier River, in the elevated basin on the plateau between Back Allegheny and the Cheat mountains, are the headwaters of Shavers Fork of Cheat River, which has considerable volume at an altitude of 4000 feet and flows north with moderate declivity, out of the northwestern corner of the quadrangle.

Mountains of the quadrangle.

The principal mountain ranges of the Monterey quadrangle are Warm Spring Mountain, Jack Mountain, Back Creek Mountain, Little Mountain, Allegheny Mountain, and Back Allegheny Mountains. In the southeastern corner of the quadrangle are Chestnut Ridge, Walker Mountain, Sideling Hill, and Mill Mountain, relatively short ridges, but rising with considerable steepness about 1000 feet above the adjoining valleys. Next north is the southern termination of the Shenandoah Mountain, one of the most imposing ridges of the region to the northeast. Its high peaks are very prominent for several miles, to the southern termination of the range, where there is an abrupt descent from an altitude of 3100 feet to 1700 feet.

Warm Spring Mountain.

Warm Spring Mountain extends into the area from the south and bears a number of branching ridges and knobs, including also the beautiful limestone valley in which are Warm Springs and Hot Springs. The main ridge sinks down with the northerly pitch of the hard strata near Burnsville, but one of its branches, Tower Hill, extends farther north with considerable prominence to the gorge of Bullpasture River, beyond which it continues as Bullpasture Mountain.

Jack Mountain.

Jack Mountain extends into the area from the northeast with great prominence, and along Wilson Run is bifurcated by a canoe-shaped limestone valley 12 miles long. The adjacent ridges reunite in Duncan Knob, which is very prominent, but they soon break up into a number of smaller ridges, which sink rapidly to the south. The mountain is also offset just east of Monterey, where a relatively low valley extends diagonally across it.

Back Creek Mountain.

Back Creek Mountain is one of the most prominent ranges in the area. With the adjoining Little Mountain and an extension known as Monterey Mountain it incloses the great canoe-shaped Crabbottom limestone valley, which is bordered by high mountain ridges on either side. These ridges unite again to the south in "Fodder House," and the ridge continues south with several spurs and subordinate ridges, finally widening into Boler Mountain and Collison Ridge.

Monterey Mountain.

Monterey Mountain is the northward continuation of the eastern ridge of Back Creek Mountain, from which it is separated by Vanderpool Gap, a deep depression draining a portion of the Crabbottom Valley.

Allegheny Mountain.

Next west of this series of ranges lies the Allegheny Mountain, consisting of one main, somewhat meandering crest line with many long spurs and lateral ranges. The highest passes in this crest line are considerably over 4000 feet above sea level. At Galfred Gap there is a rather sharp depression to about 3500 feet above sea level, and along the turnpike northeast of Frost a diagonal gap crosses the range, with the divide at slightly less than 3000 feet. To the south it again rises to over 4400 feet at a summit known as "Paddy," and extends south, with no deep gaps but with gradually decreasing altitude, to a shallow gap having an altitude of about 2550 feet, which is traversed by the turnpike west of Mountaingrove. The central ridge then rises again to slightly over 3500 feet in High Point, an elevation which is sustained for some distance southward.

Other ranges.

Lying between Allegheny Mountain and Back Allegheny Mountains are a number of ranges of considerable prominence. One is Browns Mountain with its extension in Big Ridge, north of which are Michael Mountain and other smaller ridges which terminate in a wide, level valley near Greenbank. This range is crossed by Suttleton Creek by a relatively low gap at the south end of Michael Mountain, and by the deep gorge of Knapp Creek which terminates Browns Mountain on the south. Just east of Greenbrier River lies a narrow range of short ridges separated by gaps of greater or less depth. These ridges bear the names Marlin Mountain, Thorny Creek Mountain, Thomas Mountain, Peters Mountain, Little Mountain, and Sandy Ridge. Their crests rise uniformly to an altitude of 3400 feet and consist of hard gray sandstones tilted westward. West of the Greenbrier River there are first some knobs which rise a few hundred feet, then a narrow shelf due to a thin bed of hard sandstone, then slopes of fertile limestone land, and finally the very abrupt front of the Back Allegheny Mountains, which rises 1800 feet in a very imposing face surmounted by cliffs of white sandstone and conglomerate.

Plateau of Back Allegheny Mountains.

At the top of Back Allegheny Mountains there is a plateau containing a shallow basin traversed by Shavers Fork of Cheat River. The western margin of this plateau is known as Cheat Mountain, which presents in turn a precipitous face of cliffs to the west, in the extreme corner of the quadrangle. The front of Back Allegheny Mountains is deeply indented by Leather Bark Run, which has cut a deep gorge back to within a quarter of a mile of the waters of Shavers Fork. This run is rapidly encroaching on the high land westward, and at no distant geologic date will tap off the headwaters of Shavers Fork. The bold escarpments which surround this plateau region, facing outward from it, and the gentle slopes at its summit are due both to the character of the strata and to their gently tilted attitude. The thick beds of sandstone and conglomerate of the Blackwater formation maintain the crests of the mountains and dip at a low angle away from the escarpments. The cliffs develop where the soft sandstone and softer shales of the Greenbrier formation, which lie beneath the sandstone and conglomerate, yield readily to erosion and undermine the hard rocks. The gentle inward slopes of the plateau are broad surfaces of hard strata, denuded of softer rocks which once overlay them.

Hot Springs.

The thermal springs in the Warm Spring Valley are features which have afforded a basis for the establishment of very extensive health and pleasure resorts at Hot Springs and Warm Springs. At Hot Springs the waters have a temperature of 104° F., and a flow of 25,000 gallons a day. By assuming that the ground temperature in the region is 40° F. and that the rate of geothermal increase is 1° for every 50 feet, it is found that the waters of Hot Springs are derived from a depth of about 3200 feet. The waters rise in a crevice in the Shenandoah limestones along the crest of the great arch which has given rise to the Warm Spring Valley.

GEOLOGY.

Rocks mainly sedimentary.

The general sedimentary record.—The rocks appearing at the surface within the limits of the Monterey quadrangle are mainly of sedimentary origin—that is, they were deposited by water. They consist of sandstone, shale, and limestone, all presenting great variety in composition and appearance. The materials of which they are composed were originally gravel, sand, and mud, derived from the waste of older rocks, chemical precipitates from inclosed seas, and the remains of plants and animals which lived while the strata were being laid down. Some of the beds of limestone were formed in part from the shells of various sea animals, and the beds of coal are the remains of a luxuriant vegetation which covered extensive swamps.

Sources and significance of the sediments.

These rocks afford a record of sedimentation from early Silurian to early Carboniferous time. Their composition and appearance indicate at what distance from shore and in what depth of water they were deposited. Sandstones marked by ripples and cross-bedded by currents, and shales cracked by drying on mud flats, indicate shallow water; while limestones, especially by the fossils they contain, indicate clear water and scarcity of sediment. The character of the adjacent land is shown by the character of the sediments derived from its waste. The sand and pebbles of coarse sandstones and conglomerates, such as are found in the lower Carboniferous, may have been originally derived from higher land, on which stream grades were steep, and they may have been repeatedly redistributed by wave action as the sea migrated back and forth over a rising and sinking coastal plain. Red sandstones and shales, such as make up some of the Silurian, Devonian, and Carboniferous formations, result from the revival of erosion on a land surface long exposed to rock decay and oxidation, and hence covered by a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low and that its streams were too sluggish to carry off coarse sediment, the sea receiving only fine sediment and substances in solution.

An ancient sea.

The seas in which these sediments were laid down covered most of the Appalachian province and the Mississippi Basin. The Monterey quadrangle was near their eastern margin at certain stages of sedimentation, and the materials of which its rocks are composed were probably derived largely from the land to the eastward. The exact positions of the eastern shore lines of these ancient seas are not known, but they probably varied from time to time within rather wide limits.

Place of the sea shore.

Pursuing these general ideas more in detail, one finds that the strata of the Appalachian province record many variations in the ancient geography and topography of the continent. In general it is true that fine-grained sediments, such as form calcareous shale and limestone, are free from coarser detritus, such as sand, only because no sand reached the place of deposit. This condition may arise when materials accumulate far from shore, but it may also extend to areas near shore when the land is low, the rivers are accordingly sluggish, and the waves are inactive along the coast. Therefore, when it is known that the shore was not very remote from the place of limestone deposition, it is reasonable to infer that the coast and a stretch of land behind it were generally low.

Origin of detrital deposits.

Coarse detritus is often largely composed of quartz sand or quartz gravel, the most obdurate of stones. Such material is derived from igneous and metamorphic rocks, including quartzite, being set free as they break down. Somewhat steep river slopes are required to carry it to the sea, and it may thus give evidence of elevated lands from which it was derived. But when sands and pebbles are once deposited in a coastal plain such as that which forms the Atlantic coast from New York to Florida, they may be handled by the waves again and again as the margin of the sea migrates back and forth over the gentle slope. They may thus come to form part of coarse deposits much younger than the date of their first accumulation, and their significance as to the elevation of the land becomes vague. Nevertheless, when formations are of great volume, of somewhat mingled coarse and fine materials, and of rapid accumulation, they indicate a rate of erosion which implies that they represent a mountain range of at least moderate elevation.

Geographic history of the continent.

Reasoning thus from the texture and bulk of sediments, and also from their distribution, the principal geographic changes of the Appalachian continent can be made out. One of the great events of North American geology is the expansion of the interior sea during Cambrian time. Early in the Cambrian period a narrow strait extended from the region of the Gulf of St. Lawrence southwestward to Alabama. It divided a western land area covering the central States from an eastern continent of unknown extent. The eastern shore of the strait was probably about where the Appalachian Mountains now extend. The great Appalachian Valley approximately coincides with the position of the strait. During Cambrian and Silurian time the Appalachian strait widened westward to Wisconsin and beyond the Mississippi. It probably also expanded eastward, but there is no evidence remaining of its farthest limit in that direction.

Orographic history.

Before the widening of the Appalachian strait, in early Cambrian time, the land to the eastward was probably somewhat mountainous. The region of the central States was comparatively low land. The continued activity of the agents of erosion reduced the mountain range, whose bulk is represented in the Cambrian sediments. Before the beginning of deposition of the great Cambro-Silurian limestone the eastern land had become a low plain, whose even surface, subsiding, permitted probably extended transgression of the sea.

Early Silurian deposits.

Following the Cambro-Silurian limestone in the sedimentary series, there is a mass of shale of widespread occurrence and of great thickness locally in the Appalachian Valley. It marks uplift of the eastern land and erosion of the residual material, perhaps together with the Silurian sediments, then lately accumulated over the surface. Thus there was toward the close of the Silurian period a restoration of moderate elevation to the eastern land and a return of the shore from its eastward excursion to a position approximately along the eastern margin of the Appalachian Valley. The changes of topography and geography from early Cambrian time to this epoch of Silurian time have been called a first cycle in Appalachian history.

Migrations of the shore.

The later Silurian sediments are of meager volume as compared with those that preceded them, and of variable coarseness. They represent the varying conditions of a zone across which the shore migrated back and forth. To the eastward lay the generally low continental area, margined by a coastal plain which stored the coarsest detritus of the land. Westward extended the shallow interior sea. The migrations of the shore are marked in variations of coarseness of the sandstones and sandy shales up to and including the Rockwood formation, as well as by overlaps of strata, with an incomplete sequence due to erosion of the missing members.

Late Silurian deposits.

The moderate elevation of the eastern land had again been canceled by erosion before the beginning of the Devonian, and the low level is recorded in the fine shaly and calcareous deposits of the last Silurian epoch and the widespread black shale herein called the Romney. The intermediate sandstone, the Monterey, marks an oscillation of the shore, with contributions of sands from the coastal plain and an overlap of later strata.

Devonian history.

The lowlands of the early Devonian were general from New York to Georgia. This topographic phase continued throughout the Devonian period in the region south of Virginia, but in the northeast, in Pennsylvania, New York, and New England, there occurred an uplift of considerable magnitude. In middle Silurian time the interior sea had been cut off from the Gulf of St. Lawrence by an elevation of New England and northern New York which closed the Lake Champlain strait. The sea, thus limited, received Devonian sediments which attained a maximum thickness of 9000 feet in Pennsylvania. They are composed of poorly assorted sands and shale, derived from the degradation of a mountain mass, probably several thousand feet in height. These Devonian mountains were possibly higher than those of the early Cambrian, though less extensive. In the interval between the two generations of mountains the land had not attained any considerable elevation.

Conditions in early Carboniferous time.

Above Devonian strata throughout the province occur calcareous shales and fine-grained limestones of early Carboniferous age. This gradation in sediments from heterogeneous coarse materials to fine silts corresponds to the similar change from lower Cambrian sandstones to Cambro-Silurian limestone; and it marks the degradation of the Devonian mountains to a general low level. In the early Carboniferous time the relations of land and sea were stable, as they had been during much of the Cambro-Silurian periods and throughout the early Devonian.

Later Carboniferous history.

During middle and later Carboniferous time, however, there ensued that general vertical movement of the eastern land area and the region of the interior sea which resulted in the withdrawal of the sea to the Mississippi embayment. The movement was not simple; it was composed of many episodes of uplift and subsidence, among which uplift preponderated. In the repeated oscillations of level the sea swept back and forth over wide areas. It received from the coastal plain the coarse quartz detritus which had accumulated during previous ages, and the waves and currents of the shallow sea spread the concentrated sands and pebbles in beds which alternated with materials of less ancient derivation. The Carboniferous strata include shale and sandy shale, derived more or less directly from lands of moderate elevation, and also the coal beds, each of which marks the prolonged existence of a marsh in which the peat-making plants grew. When the marsh sank beneath the sea the peat beds were buried beneath sands or shales, and the peat by a process of gradual distillation became coal. At the close of the Carboniferous a great volume of varied sediments had accumulated. It represents a correspondingly deep erosion of the land mass, but the uplift thus indicated appears to have gone on slowly, and it may be that the surface was not raised to the height of the mountains of to-day. The vertical movements giving rise to variations in strata, and even to mountain ranges, appear to have been independent of the horizontal movements which caused the folding of the Appalachian strata. There is at least no apparent direct connection between the two phases of earth movement. Later in the history of the region dikes of various rocks were intruded across the sedimentary beds.

DESCRIPTION OF THE ROCKS.

SEDIMENTARY ROCKS.

Thickness of the strata.

The strata exposed in the area of the Monterey quadrangle have a thickness of about 14,500 feet. The order of succession of the limestones, shales, and sandstones, and their general character, are given in the Columnar Section sheet.

SILURIAN PERIOD.

An early Silurian limestone.

Shenandoah limestone.—In the great anticlines which traverse the center of this quadrangle the Shenandoah limestone is brought to the surface over a considerable area. It gives rise to beautiful fertile valleys in the midst of high rocky ridges of the adjoining harder formations. The largest area is Crabbottom Valley, brought up along the great Back Creek Mountain anticline west of Monterey. There is another area of somewhat less extent in Jack Mountain, along the valley of Wilson Run and Dry Branch of Jackson River. The third area is along the anticline of Warm Spring Mountain, extending from north of Warm Springs southward to Hot Springs and beyond. The rocks are mainly limestones of gray and drab color, varying from moderately thin bedded to massive. The uppermost member is a rather slabby limestone with occasional shale intercalation, containing fossils of the Trenton fauna. These merge downward into more massive limestones containing beds of chert of varying degrees of prominence. This chert is conspicuous in the Crabbottom district from New Hampden nearly to the Lower Gap in Little Mountain, extending as a more or less continuous ridge along the center of the limestone valley. Softer cherty beds are also exposed quite prominently north of Hot Springs, in the center of Warm Spring Valley. The cherty limestones are the lowest formations exposed in the Monterey quadrangle. The thickness of Shenandoah limestone brought to the surface in the highest part of the Crabbottom anticline, from Hightown to New Hampden, is about 2400 feet, as nearly as could be estimated. The exposed thickness is considerably less in the areas in Jack Mountain and Warm Spring Valley. As usual in limestone areas, the surface is characterized by the presence of sinks and many small caves. Springs abound, the thermal flows at Hot Springs and Warm Springs being notable.

Gray shales.

Martinsburg shale.—This is a thick mass of gray shales which extends around the marginal slopes of the valleys of Shenandoah limestone above described. They are also exposed in small areas in some of the deeper depressions along the higher anticlinal uplifts in Jack Mountain and Back Creek Mountain, and in the gorge of Knapp Creek across Browns Mountain. Dark-gray shale is the characteristic material of the formation, but some thin limestone beds are also included, and toward its top there are intercalated beds of fine-grained, hard, gray sandstone.

The formation presents considerable variation in thickness, mainly by thinning rapidly to the west and south in a portion of the area.

Thickness of the gray shales.

In Monterey Mountain the thickness was found to be 1800 feet just east of Crabbottom post-office, and it is about the same at Vanderpool Gap. At Mill Gap in Little Mountain the thickness was found to have suddenly decreased to 830 feet. In Jack Mountain precise measurements could not be made owing to the covering of débris on the contacts. As nearly as could be estimated the thickness at Bolar Springs is 1600 feet, and the amount appears to be about the same in the northern end of the valley. On the west side of Warm Spring Valley 1237 feet was measured on Warm Spring Run below Germantown, 1500 feet on Cowardin Run, and 800 feet in the gap west of Hot Springs.

Juniata formation.—This formation extends in several belts along the larger anticlinal areas of Back Creek, Warm Spring, and Jack mountains, and is seen also in a small area in Browns Mountain. It extends along both sides of the Crabbottom limestone area, in the slopes just below the crest of the surrounding mountains. It has similar relations in the Wilson Run and Dry Branch valleys in Jack Mountain, and in the Warm Spring Valley. It is brought to the surface by the fault in Bear Mountain, Buck Hill, and associated ridges, is exposed in the gorge cut across Jack Mountain by Crab Run, appears along Knapp Creek in Browns Mountain, and extends along the high western slopes of Back Creek Mountain south of the Fodder House, surrounding the areas of Martinsburg shale. There is a small area in the gorge of Muddy Run at the south end of Jack Mountain and a similar area on Dry Run a short distance northeast of Piney Mountain.

Red sandstones and shales.

All the rocks of the formation are red sandstones and shales, interbedded in no regular succession. The sandstones are hard, moderately coarse grained, and occasionally cross bedded. They vary in thickness from 1 foot to 20 feet and are in greater part in beds from 1 foot to 4 feet thick. The shales vary in thickness from 6 to 8 feet to a thin parting between sandstone layers. Much of the formation consists of alternations of 4 to 5 feet of shale and 8 to 10 feet of sandstone. The formation varies considerably in thickness, often within relatively short distances, but there is a general decrease to the south and west. The greatest thickness observed was in Vanderpool Gap, where the amount appeared to be 1235 feet. Ten miles north, in the same range, near Crabbottom post-office, there are about 800 feet, as nearly as could be estimated. Just west of Hightown, in Little Mountain, the red sandstones and intercalated shales are very finely exposed along the road, where their thickness was ascertained to be 780 feet. At Mill Gap the limits are obscurely exposed, but there appears to be room for only 500 feet of the Juniata formation. At Lower Gap, 2 miles southwest of Valley Center, 800 feet are clearly exposed. In the ridges adjoining Warm Spring Valley the amounts are considerably less. On Warm Spring Run there were measured 545 feet, of which the upper 70 feet consist of red and gray sandstones with a few red and gray shale partings, 400 feet are concealed, 22 feet are gray sandstones with buff shale intercalations, and 45 feet are soft red sandstones and shales. Along Cowardin Run the red and gray sandstones and shales are obscurely exposed and their thickness was seen to be about 300 feet. In the gap at Hot Springs the entire thickness of the series was clearly exposed as follows: At the top, 100 feet of red shales with thin gray sandstones and buff shales, underlain by 30 feet of hard gray sandstones with red and gray shales; at the bottom 75 feet of red shale with alternating red and gray sandstones: 205 feet in all. On the east side of this valley the formation is also seen to be thin, notably along the turnpike just east of Warm Springs and in the slopes east of Hot Springs. In Browns Mountain the formation is exposed along the gorge of Knapp Creek, where it is seen to consist of red shales and red sandstones interbedded, the shales predominating in the lower members. The total thickness is about 450 feet. On Crab Run, at the north end of Bear Mountain, 820 feet are exposed, with an unknown but probably slight thickness of the basal beds cut off by the fault.

A hard, white quartzite.

Tuscarora quartzite.—This is a very hard, white rock, which gives rise to the high, rugged crests of Back Creek, Jack, and Warm Spring mountains, the line of ridges on the west side of Warm Spring Valley, the long ridges on the west side of Crabbottom and Wilson Run valleys, and the crests of the Buck Hill and Bear Mountain range. In Browns Mountain anticline it is bared along the crest of Michael Mountain and in the gap through which Knapp Creek crosses the southern end of Browns Mountain. In Panther Gap there is an exposure of the formation in the axis of Mill Mountain. It extends along a portion of the crests of Little Mare Mountain and the southern extension of Little Piney Mountain and along the double crests and associated anticlinal ranges on Back Creek Mountain in the vicinity of Fodder House. Muddy Run cuts into and through the formation in the gorge at the south end of Jack Mountain, and Dry Run affords a similar exposure in the low arch north of Piney Mountain.

The formation consists almost entirely of a homogeneous mass of coarse white or gray quartz sand in a very hard siliceous matrix, constituting a quartzite. Widely scattered, small pebbles occur frequently, and local thin conglomeratic beds were observed. The beds are mostly very thick or massive, particularly in the upper part of the formation. At the top and toward the the base there are some thinner-bedded members, usually of somewhat darker-gray color.

Thickness of the quartzite.

The thickness of the formation is variable, with an irregular decrease to the south and west. On Crab Run at Jack Mountain and Bear Mountain there are seen three cross sections of the formation. The westernmost exhibits about 250 feet of white quartzite beds, but the easternmost shows only about 130 feet. The intermediate one is too much obscured by talus for precise measurement. At the Devils Backbone, just east of Crabbottom post-office, the thickness is about 150 feet. At Vanderpool Gap 115 feet apparently comprise all the beds which should be regarded as Tuscarora, and at Mill Gap and Lower Gap the thickness is not over 60 feet. On Warm Spring Run there were measured 100 feet, on Cowardin Run 167 feet, and in the gap west of Hot Springs 115 feet. On Crab Run and in Panther Gap the upper portion of the formation is exposed, consisting of much softer and less massively bedded members than those which characterize the outcrops westward.

The most extensive exposures of the formation are along the crests of the high ridges surrounding the anticlinal limestone valleys of Crabbottom, Wilson Run, and Warm Springs. In Jack Mountain north of Crab Run, and for some distance in the southern extension of Back Creek Mountain from Fodder House, the formation is very prominent.

Dips of the quartzite.

In the mountain crests along the east sides of the anticlinal limestone valleys the quartzite dips eastward at moderate angles and presents to the west moderately high, very steep, rocky cliffs of white quartzite. A well-known locality where this feature is exhibited is at Flag Rock on Warm Spring Mountain. In Vanderpool Gap there is a fine exposure of the eastward-dipping quartzite. In the ridges west of the limestone valleys the formation has a nearly vertical attitude, and it outcrops in jagged ledges along the narrow crest line. These ridges are cut through by gaps at Hot Springs, Dunns, Germantown, Bolar, Trimble, Lower Gap, and Mill Gap, where the vertical quartzite beds are exposed in cross section. At the terminations of the limestone valleys the quartzite ridges coalesce and usually give rise to high knobs in which the formation overarches the anticline. The most prominent of these knobs are Fodder House, Duncan Knob, Boner Mountain, and the ridges adjoining Sounding Knob. Along Crab Run, in the northern extension of Jack Mountain, there is exhibited a fine arch of the Tuscarora quartzite, rising high above the valley bottom. Similar arches are exhibited at the north end of Michael Mountain, along Knapp Creek at the southern end of Browns Mountain, in the gap at the south end of Little Piney Mountain, and on Dry and Muddy runs, but they are of much less prominence. In Panther Gap the formation is exhibited in a very beautiful overturned arch, of which the principal exposures are in the railroad cut, a few feet above the stream.

A flaggy sandstone, with interbedded shales.

Cacapon sandstone.—This formation is a series of red flaggy beds overlying the Tuscarora quartzite. It is brought to the surface along both sides of the uplifts of Back Creek, Jack, and Warm Spring mountains, where it extends along the slopes for many miles. It is also exposed in the northern portion of Michael Mountain, the southern portion of Browns Mountain, along portions of Little Mare and Little Piney mountains and Tower Hill, along the eastern side of the Bear Mountain–Buck Hill range, in Panther Gap, in the bottoms of gorges at the north end of Boler and Piney mountains, at the south end of Jack Mountain, and along the Bullpasture River just a mile above Williamsville.

The rocks consist of hard, thin-bedded, deep reddish-brown sandstones with thin intercalations of red and buff shales. In part the sandstones are slabby and weather out in fragments from 1 to 2 inches in thickness, but occasionally some of the beds are more massive. The thickness varies considerably, lessening locally at a few points. Owing to scarcity of continuous exposures across the formation, only a few precise measurements were obtained, but fairly frequent approximations were practicable. The least thickness observed to the north was in Vanderpool Gap, where there are about 400 feet of red sandstone with intercalated gray and buff shales, overlying the Tuscarora quartzite. In the gorge east of Crabbottom post-office the thickness is about 550 feet. In the gorge of Crab Run, across the north end of Bear Mountain, the thickness appears to be 500 feet, but possibly some of the reddish lower beds belong to the Tuscarora formation. In this region the Juniata, Tuscarora, and Cacapon formations are not so distinct as they are farther to the west and north, and in the adjacent Staunton quadrangle they have been comprised under the name of Massanutten formation.

Thickness of the Cacapon sandstone.

In the Little Mountain ridge west of the Crabbottom Valley the thickness appears to diminish rapidly to the southward, and although the exposures in Mill Gap and Lower Gap are not decisive there appear to be less than 100 feet of the Cacapon beds in the sections. In the ridges west of the Warm Spring Valley, Cacapon exposures are in most cases unsatisfactory, but the formation is seen to have thickened again. The most complete series of outcrops is in the gap west of Hot Springs, where there are exposed above the Tuscarora quartzite 630 feet of Cacapon beds, comprising 60 feet of red and brown slabby sandstones, 20 feet of olive shale, and 50 feet of red slabby sandstone, merging upward into 265 feet of shales with red sandstone intercalations, and these in turn giving place to 240 feet of thick, red, slabby beds at the top of the formation. The unusual thickness of the formation in this vicinity appears to be due to the 265 feet of shaly beds, which were not observed to be so thick elsewhere. The formation is thick on Warm Spring Mountain, extending to the crest at some localities and covering a wide area on the slopes of Little Piney and Little Mare mountains.

At Panther Gap the formation consists of 150 feet of red slabby sandstones with thin beds of shale partings and a 15-foot bed of buff shale at the top, 165 feet in all. The overlying gray sandstones and shales are classified as a portion of the Rockwood formation.

The Cacapon sandstone usually outcrops as a talus of slabby red sandstone fragments with a few scattered exposures of the middle and lower beds. Sometimes the sandstones are so red that they are thought to be iron ore, but their sandstone nature is clearly evident.

Shales and sandstones, with quartzites.

Rockwood formation.—Overlying the Cacapon sandstone there is a series of shales with sandstones and, to the southeast, quartzites, which lie along the flanks of the high anticlinal ranges of the Crabbottom, Jack Mountain, and Warm Spring uplifts. The quartzites become more prominent to the east and south and give rise in whole or in part to ridges of considerable prominence — Mill Mountain, Sideling Hill, Walker Mountain, Chestnut Ridge, Tower Hill, Little Mare Mountain, Piney Mountain, Little Piney Mountain, and some subordinate ridges on Warm Spring Mountain and the southern part of Jack Mountain. The formation is brought to the surface over a considerable area in the Browns Mountain uplift and in the central portion of Bullpasture Mountain, Warwick Ridge, and Collison Ridge. There are some other small outcrops in gorges cut by Muddy Run in the northern end of Cobbler Mountain, and by Back Creek at the northern end of Boler Mountain. The most extensive areas are in the ridges in the southeastern corner of the quadrangle, about the southern end of Jack Mountain, in Tower Hill, in Browns Mountain uplift, in Piney Mountain, and in Crab Run Valley and adjoining ridges east of Monterey.

Color and other features of the formation.

The materials of the Rockwood formation are predominantly shales to the west, and shales, sandstones, and quartzites to the southeast. The shales are mainly dark gray to olive gray in color, and in the Back Creek Mountain and Browns Mountain anticlines they constitute the greater part of the formation; here also they include some thin beds of limestone. Throughout its extent the formation contains at its top a bed of gray sandstone from 10 to 15 feet thick, and a short distance below some thin beds of iron ore intercalated in shales. The top sandstone is gray and buff in color, quite hard, sometimes almost a quartzite, and usually moderately massive or cross bedded. It is a characteristic feature and generally gives rise to a small ridge or escarpment. Its surface is often ripple marked. The iron ores are generally in two beds in the upper third of the formation. One bed is thicker than the other, usually with only a few inches of the shale intervening. The thicker bed is reported to be 30 inches in thickness at some points. The ore is characterized by its blood-red color when scratched or crushed, and by breaking out of its ledges in block-like fragments having smooth sides. The limestones are of rather variable occurrence and thickness. In the Browns Mountain uplift, where they are mostly developed, the beds were found to be usually from a few inches to 20 feet thick. A few rods northwest of Driscol a 25-foot bed is exposed by the roadside.

The sandstone members.

In the southern part of Back Creek Mountain the formation begins to show sandy intercalations among its lower members, which rapidly thicken to the eastward. These are sufficiently prominent, together with the top sandstone, to give rise to a fairly high ridge in Tower Hill and some of the other branches of Warm Spring Mountain, notably Piney Mountain and Little Mare Mountain. East of the Shenandoah Mountain syncline they are prominent ridge makers in Chestnut Ridge, Walker Mountain, Sideling Hill, and Mill Mountain.

Thickness of the formation.

The thickness of the formation is usually difficult to determine, owing to scarcity of outcrops of the lower boundaries, which are often covered by the talus from the adjoining ridges. East of the fault at the north end of Bear Mountain, in the gorge of Crab Run, a fairly satisfactory measurement of the thickness was made, amounting to 900 feet, comprising a large mass of shales with some beds of quartzite and a 6-foot bed of limestone very near the base. In the gap cut by Bullpasture River at the southern end of Bullpasture Mountain, 1 mile north of Williamsville, there is a very complete exposure of the formation, consisting of the following succession:

Section in gap at southern end of Bullpasture Mountain.

- Lewistown limestone at top.
- Gray and buff quartzite in beds 1 to 2 feet thick, ripple marked, 20 feet in all.
- Shaly and sandy beds.
- Slabby limestone, 10 feet.
- Gray shaly beds, 20 feet.
- White quartzite grading into olive shales containing limestone beds with intercalated shales, the lower limestones being massive, dark, tough, and full of fossils, and 20 feet or more thick.
- Gray quartzite with intercalated shales.
- Gray shale at bottom of exposure.

In the Crabbottom anticline the formation is represented by a moderately thick mass of shales with limestone intercalations and the typical top layer of gray sandstone. No satisfactory measurements of the thickness could be made.

In the sections at Mill Gap and Lower Gap the thickness is not over 200 feet, but it is greater than this to the north and northeast. In the ridge west of the Warm Spring Valley the formation is so obscurely exposed that no measurements could be made. It is evident, however, that the thickness is small. On Little Piney and Little Mare mountains the formation exhibits three heavy beds of quartzite, each about 30 feet thick, with shale intercalations, some of which are red near the base. Underlying these members there are buff sandy shales with thin sandstone intercalations. In Panther Gap there are exposed 425 feet of gray quartzite, including some soft sandstone beds. The bedding is not very massive and there are shale intercalations. The formation lies on the typical red slabby Cacapon beds and is overlain by 65 feet of buff and gray shales with thin beds of iron ore, terminated by the usual 15 feet of gray sandstone, above which is seen the Lewistown limestone. The high, rough ridges in this vicinity are due to the thick strata of basal quartzite in the formation, strata which outcrop widely over Mill Mountain, Sideling Hill, Walker Mountain, and Chestnut Ridge, as well as in Little Mare Mountain and the other ridges east of Warm Spring Mountain, where their prominence is somewhat diminished. Exposures of the shales and contained iron ore are not common to the southeast, for they occur mainly on the mountain slopes and are concealed by talus of harder material, but in the Browns Mountain region and east of Monterey the shale outcrops become more frequent. There are extensive exposures of shales and the contained iron ore beds in the Browns Mountain uplift, where the thickness of the formation averages about 500 feet. The beds in this region comprise a basal series of shales with limestone beds and iron ore and, at the summit, a thin mass of sandstone, which gives rise to many small ridges through Browns Mountain, along the flanks of Michael Mountain, and just west of Big Ridge.

Lewistown limestone.—This important member outcrops in many places in the anticlinal areas in the belt lying between Back Creek and Cowpasture River, in the slopes adjoining Chestnut Ridge, Walker and Mill mountains, and Sideling Hill, and it is the principal formation brought to the surface in the Browns Mountain uplift. Although its outcropping area is of somewhat greater extent than that of the Shenandoah limestone, the outcrops are as a rule narrower and more disconnected and lie on slopes where there is much overplacement by detritus from adjoining ridges. The most extensive areas are in Browns Mountain, the upper valleys of Jackson River, McClung Ridge, the valleys east of Monterey Mountain, the slopes and ridges adjoining Warwick Ridge, the belt north of Burnsville, the Bullpasture Mountain ranges, the slopes and parts of the summit of Tower Hill, the slopes of Collison Ridge, and portions of the southern end of Back Creek Mountain and the ridges southward. There is also a considerable area on the east side of Jack Mountain east of Monterey. Much of the area of this formation lies on steep mountain slopes. It often gives rise to ridges, and its beds frequently extend along narrow valleys or are revealed in gorges in different parts of the region.

A late Silurian limestone.

The formation consists of limestones which are cherty, shaly, and sandy above, more massive in the middle, and thin bedded or slabby below. The proportion of chert in the upper beds diminishes to the south, but the presence of a cherty member at the top of the formation is always characteristic. Next below there are usually alternations of shaly limestones, which to the southeast contain some very sandy layers. There are also included some thicker layers of purer limestone. The middle members are irregular in character and vary greatly from place to place. A very characteristic member near the center of the formation is a dark-blue, wavy-bedded, massive limestone 50 to 60 feet thick, merging upward into harder, sandy limestone and hard, massive limestone with thin streaks of chert. At its base there is usually a distinct coralline bed. The lower half of the formation consists of slabby limestone merging downward into an irregular series of alternations of calcareous shales and impure limestones. In one portion of the area this lower series contains a very sandy bed 15 to 20 feet thick, 50 or 60 feet above the base of the formation. The series of flaggy beds which constitute so large a portion of the formation are quite pure limestones, dark on fresh fracture, but weathering lighter on exposure. The beds are mainly from one-half inch to 2 inches thick, with smooth surfaces, along which the layers readily separate. To the southeast the upper part of the formation includes, just below the cherty beds, a very pure, massive, fossiliferous, semicrystalline limestone.

Limestones with a cherty bed at top.

The thickness of the Lewistown limestone averages about 900 feet over the greater part of the Monterey quadrangle, but to the extreme southeast it decreases to about 600 feet. In the vicinity of Monterey a number of fairly satisfactory measurements indicated a thickness of about 900 feet. Two measurements in Back Creek Mountain east of Mountaingrove were 1080 and 1100 feet. At Lower Gap a fairly satisfactory series of exposures show about 850 feet of Lewistown beds. At Panther Gap the thickness is 550 feet. On Cowardin Run, in the ridge lying on the west side of Warm Spring Valley, 710 feet were measured; and in the gap west of Hot Springs the amount appears to be slightly less than this. One of the most complete exposures of the formation is on the turnpike from Warm Springs to Mountaingrove, on the first slopes west of Jackson River, where a thickness of 1080 feet was measured. There are a number of small intervals covered by débris, but the greater part of the formation is clearly exposed, as follows:

Thickness of the limestone.

Section on road from Warm Springs to Mountaingrove, west of Jackson River.

	Feet.
At top, alternations of impure and shaly limestones, fossiliferous	460
Wavy-bedded massive limestone with coralline bed at base	?
Slabby limestone	400
Calcareous shale	25
Massive fine-grained sandstone, weathering light buff; probably cement rock	15
Sandstone	4
Shaly material	
Sandstone and sandy beds	20
At bottom, buff shales and thin, dark, semicrystalline limestone layers	100

At the top there is considerable cherty débris, and two beds of massive blue limestone overlain by the Monterey sandstone, which extends down the slope to Jackson River.

In the Browns Mountain anticline extensive exposures of the Lewistown limestone are abundant, but on some of the steeper mountain slopes and along some of the narrower valleys the beds are often covered by a greater or less amount of sandy or rocky detritus from slopes above. Throughout the area of the Lewistown limestone, cliffs and steep ledges are of frequent occurrence, and many portions of the area are traversed by streams in deep gorges. The limestones are cavernous and many extensive caves have been discovered. One of these, the Blowing Cave, is in a small anticline traversed by Cowpasture River 6 miles west of Panther Gap. This cave acts as a chimney for air that passes underground in fissures and caves and is chilled to a low temperature by its underground passage. Springs, sinks, and other evidences of underground drainage are of general occurrence in the limestone areas. They are due to the solution of the limestone by waters which have begun their underground percolation in cracks along small fissures in the limestone.

Fossil molluscan and crustacean remains occur abundantly in the Lewistown limestone, particularly in its upper members. These fossils include many distinctive species of the Helderberg fauna.

Fossils.

DEVONIAN PERIOD.

Monterey sandstone.—This sandstone occurs extensively in slopes and low ridges adjoining the Lewistown limestone areas. Owing to the hardness of the rock its outcrops give rise to knobs and ridges, which are often prominent. It extends along each side of all the larger anticlinal uplifts in the center of the quadrangle, along the lower slopes of Walker Mountain, Chestnut Ridge, Sideling Hill, and Mill Mountain, and along either side of the Browns Mountain uplift. It is also brought to the surface by the anticline of Blackoak Ridge. The prevailing material is a hard, fine-grained, calcareous sandstone of dark blue-gray color, which weathers to a dirty buff, porous, sandy rock of varying hardness. Much of the rock, especially in its weathered condition, exhibits large numbers of casts and impressions of molluscan and crustacean remains.

A sandstone with Devonian fossils.

The thickness of the formation varies from 200 to 50 feet, but over the greater part of its area is between 100 and 165 feet. The greatest thickness is east of Monterey. A very satisfactory measurement in the gap west of Hot Springs gave 120 feet of very ferruginous sandstone. At Cowardin the thickness is only 50 feet. In Panther Gap the amount is less than 100 feet. Along the west slope of Little Mountain west of Hightown the formation is locally of greatly diminished thickness, and it may possibly be absent at a few points. In the Browns Mountain uplift the thickness of the formation averages about 100 feet.

Thickness of the sandstone.

It is owing to this small thickness, and also in some measure to the complexity of flexing, that the surface distribution of this formation is so irregular. It often sheathes the slopes of ridges over considerable areas, but small streams cut through to the underlying limestone, and it is usually eroded from the crests of anticlines of any considerable magnitude. The formation rises high on the slopes of Boler Mountain, Rocky Ridge, Cobbler Mountain, and McClung Ridge, and it is of considerable areal extent on the slopes and minor adjoining ridges of Bullpasture Mountain. It is extensively exposed along both sides of the valley in which the town of Monterey is situated, and its corrugated structure in the region south of Straitcreek post-office causes it to sheathe a considerable area. It is usually conspicuously exposed especially in the many small gorges along the steeper mountain slopes. On the gentler slopes the formation is usually deeply disintegrated into sand and loose fragments. The fossil remains in this formation are in greater part those which are typical of the Oriskany of New York.

Features of distribution.

Romney shale.—Lying on the surface of the Monterey sandstone there are extensive areas of this shale, which is a prominent feature in many of the long longitudinal valleys of the Monterey quadrangle. The greater part of the valleys of the Cowpasture River, Bullpasture River, Stuart Run, Back Creek, and Bolers Draft, and the depression surrounding the Browns Mountain uplift, are excavated in the Romney shale. The formation also underlies the valleys in which are situated the town of Monterey and the Bath Alum Springs; it occupies the valley of Jackson River for some miles in the vicinity of Wilsonville and west of Rowans, and underlies a synclinal area of moderate extent west of the Warm Spring ridge. The rocks consist of dark shales, black and fissile below and somewhat lighter and more compact above. The basal beds are usually carbonaceous to a high degree, and they have been worked at several points with the mistaken idea that they might prove to be coal bearing. The formation includes occasional thin beds of fossiliferous limestone near its base, and the upper members contain alternations of pale-brown or dark-buff sandy beds, which constitute beds of passage into the next succeeding formation, the Jennings. The vertical range and stratigraphic position of these passage beds are variable, so that there is no definite line of demarcation between the two formations. Owing to this fact no precise limit can be assigned to the Romney shale, and on the map the Romney and Jennings patterns have been merged to indicate the gradation of the two formations. The approximate average thickness of the distinctive members of the Romney shale varies from 1200 to 1500 feet. The Romney shale contains fossils, including species characteristic of the Hamilton group. Those in the lowest beds comprise some species characteristic of the Marcellus. There is no evidence of structural unconformity between the Romney shales and the Monterey sandstones, but the contact between these formations is characterized by a most abrupt change from the underlying massive sandstones to the black fissile shale at the base of the Romney, often with evidence of unconformity by erosion.

A Devonian shale.

Jennings formation.—The Jennings formation is prominent in the Monterey quadrangle. It constitutes the greater part of the Allegheny Mountain excepting the higher summits to the northward, Little Mountain west of Back Creek, Shenandoah Mountain, and the range bearing the names Marlin, Thorny Creek, Thomas, Peters, and Little mountains and Sandy Ridge. At the northern end of the Browns Mountain uplift it arches over the Romney shale 2 miles north of Greenbank in the northern extension of the Deer Creek Valley. It occupies the synclinal area extending southwest from the end of Shenandoah Mountain, a small syncline east of Pig Run, and another small syncline east of the northern end of Collison Ridge.

The formation consists of light-colored shales with interbedded light-colored sandstones. The local sequence of beds is somewhat variable, but there are certain general characteristics which are quite constant. The shales are mainly of olive, gray, and buff tints. Here are occasional thin layers or lenses of conglomerate interbedded with olive and gray shales. Some of the sandstones, although fine grained, are so hard and massive that they give rise to high ridges with very steep rocky surfaces. This is particularly the case on the west side of Allegheny Mountain, the knobs and crests of Marlin, Thorny Creek, Thomas, Peters, and Little mountains and Sandy Ridge, and the Little Mountain range lying between Back Creek and Little Back Creek. These hard sandstones also cap the higher portions of Shenandoah Mountain, which rise so prominently above the slopes of the softer beds below. The upper limit of the Jennings formation is not well defined, for usually there is an extensive series of beds of passage into the next succeeding formation. It is on account of this indefiniteness that the boundary of the formation is shown on the map by a zone in which the pattern is merged into the adjacent one.

Light shales and sandstones.

The thickness of the Jennings formation ranges from 3000 to 3800 feet, the amount increasing somewhat along the central portion of the Allegheny Mountain. Fossils occur in various beds in the Jennings formation and represent the Chemung fauna.

Hampshire formation.—The red and gray beds of this formation constitute the higher summits of the Allegheny Mountain in the northern half of the quadrangle and the line of ridges and spurs extending along Greenbrier Valley and the lower, eastern slopes of the Back Allegheny Mountains. In these slopes it is surmounted by the Carboniferous sandstones and limestones, under which it passes in the synclinal area of the Cheat Valley, to reappear again on the western slope of Cheat Mountain. The rocks are sandstones and shales, in large part of red color, but with beds of greenish-gray, buff, and brownish-gray colors. The sandstones vary from slabby to massive, and they are usually from 15 to 30 feet thick. They are also extensively cross bedded. The reddish-brown color is a conspicuous feature of many of the beds, but dark grays are frequent, particularly in the more massive beds. The shales are in greater part of bright brown-red color, fissile, and in masses from a few inches to 10 or 15 feet thick. They occur throughout the formation, but predominate in its lower portion. Greenish and greenish-gray, brown, and olive shales are not uncommon. The relation of sandstones to shales is very irregular, and there appears to be no constant stratigraphic succession of distinctive beds. The thickness of the Hampshire deposits varies from 1500 to 1800 feet.

Red and gray sandstones and shales.

CARBONIFEROUS PERIOD.

Pocono sandstone.—This basal member of the Carboniferous period is not a prominent feature in the Monterey quadrangle. It surmounts the Hampshire deposits in the slopes of Back Allegheny Mountains west of Greenbrier River, giving rise to numerous small shelves and knobs which are not very distinct from the adjoining slopes and ridges. The greatest thickness observed was slightly less than 90 feet, and in some of the outcrops the amount appears to be less than this. The rocks are moderately hard, gray-buff sandstones, in part conglomeratic, with intercalations of softer beds. The principal exposures are along the main road skirting the limestone slopes of the Back Allegheny Mountains, which occasionally passes over a pavement of the sandstone or along the edge of a small Pocono cliff cut by some stream flowing toward the Greenbrier River. The Pocono beds dip westward under the Greenbrier limestone and other formations in Back Allegheny Mountains and the syncline of Shavers Fork of Cheat River, and outcrop again on the west side of Cheat Mountain.

Carboniferous sandstones.

There are some sandstone masses on the higher summits of Allegheny Mountain from Paddy northward to Tamarack Ridge which are probably of Pocono age, but it is possible that they are members of the Hampshire formation.

Greenbrier limestone.—The Greenbrier limestone underlies the Back Allegheny and Cheat Mountain plateau in the northwestern corner of the Monterey quadrangle. It outcrops along the middle portion of the eastern slope of Back Allegheny Mountains, in a strip of fertile farming and pasture lands, steep and narrow, but generally settled upon. On the west side of the syncline it appears on the western slope below Beech Flat Knob, in the extreme northwestern corner of the quadrangle. The formation consists of heavy beds of light-blue limestone with intercalations of brownish-red shale and occasional red sandy shales. The limestone predominates. In the upper beds there is transition into the overlying Canaan formation in such manner that the upper limit is not very distinct. The thickness of the Greenbrier limestone averages between 350 and 400 feet. Owing to the indefiniteness of its upper limits by the admixture of shale and sandy beds, the precise thickness usually can not be ascertained. The limestones contain some mulluscan fossils of species of lower Carboniferous age.

Carboniferous limestone.

Canaan formation.—Overlying the Greenbrier limestone there is an extensive series of gray shales and brown and gray sandstones known as the Canaan formation. It extends along the upper eastern slopes of the Back Allegheny Mountains and the western slope of Cheat Mountain, and is bared along the valleys of Shavers Fork of Cheat River and Leather Bark Run. Shales predominate in the lower portion of the formation and sandstones in the upper portion. Several heavy beds of sandstone, in greater part of gray color, with moderately thick shale and sandy shale intercalations, constitute the upper two-thirds of the formation. Some thin beds of dark shale with thin showings of coal also occur near the top of this series. The lower members contain thin beds of softer sandstones and toward the base of the formation occasional thin layers and lenses of limestone. The total thickness averages 1300 feet on the east side of the syncline and 1000 feet on the west side.

Gray shales and sandstones.

Blackwater formation.—The higher portions of Back Allegheny and Cheat mountains are capped by a considerable thickness of this conglomerate. It gives rise to a line of rather sharp cliffs along the crests of the mountains and smooth slopes toward the central valley. In this central valley Shavers Fork has cut through and into the underlying Canaan beds, and Leather Bark Run has also cut far back into the face of the mountain. The rocks are white conglomerates and gray sandstones, the latter containing some irregular beds of soft buff sandstone and black shale, with thin local beds of coal. The conglomerate is the most conspicuous member, for it forms the crest of the knobs and mountains, gives rise to great stone crops on the inner slopes, and is the source of extensive talus of large masses on the steeper outer slopes of the Back Allegheny and Cheat mountains. It consists of white quartzite pebbles, mainly less than an inch in diameter, and coarse sand, in a hard siliceous matrix. The conglomeratic beds are massive and their aggregate thickness is probably nearly 100 feet. The greatest thickness of the formation is in the vicinity of Bald Knob, where it appears to measure between 350 and 400 feet. The lower beds are gray sandstones, in part of considerable hardness, but usually only moderately massively bedded and frequently cross bedded, with intercalated beds of softer buff sandstone and shale, mainly dark, with thin coal seams.

Carboniferous conglomerates and sandstones.

IGNEOUS ROCKS.

The exposures of igneous rocks in the Monterey quadrangle are small and inconspicuous. They occur in the vicinity of Monterey, in connection with the Jack Mountain and Crabbottom anticlines. The principal outcrops in the Crabbottom anticline are in the limestone of the central valley and occur at intervals from north of Mill Gap nearly to New Hampden. Along the axis of the western prong of Jack Mountain anticline there is an eruptive mass of considerable prominence on Sounding Knob, and there is a series of small exposures at the forks of Strait Creek. A group of small outcrops occurs within a short distance of Monterey, on the east slope of Monterey Mountain, the most conspicuous of them rising in a conical knoll known as Pyramid Hill, a mile south of the town. The rocks appear to be in dikes or slender necks cutting across the bedding of the sedimentary formations. Few of the outcrops exhibit the relations of the igneous rocks, and the direction of the dike fissures is known only in the case of the mass north and east of Hightown, which crosses the limestone valley with northwest-southeast trend for a length of over a mile. The masses exposed north of Millgap post-office lie in linear arrangement, so as to suggest a fissure extending north-northeast, in which the intruded material occurs in lens-shaped dikes.

Dikes.

The igneous rocks are of two varieties, of very different appearance and composition. The greater number of outcrops exhibit a dark-colored, hard, heavy rock, weathering out on the surface in rusty, rounded masses. It is a basalt, consisting of plagioclase and augite with olivine and magnetite and in some cases a small amount of biotite. The structure is finely crystalline and most of the rock is porphyritic with augite and olivine. A neck-like mass of this rock constitutes the summit of Sounding Knob, cutting through the Tuscarora quartzite. It occurs also in the Crabbottom Valley from Hightown southward, at two points near Monterey, including Pyramid Hill, at the forks of Strait Creek, and at the foot of Jack Mountain northwest of the Riven Rocks. At Pyramid Hill the basalt is in the Romney shales, but it is flanked on one side by a breccia of a variety of quartzite and calcareous rocks brought up from below.

Basalt.

The other variety of igneous rock is granite-felsophyre, which is light colored and usually deeply decomposed and softened. Exposures of the hard unaltered rock occupy an area of a few square yards at the forks of Strait Creek, about 2 miles east-northeast of Monterey, across the road and valley from a dike of basalt. It is a rounded boss of light ashy gray rock, flecked with scales of mica and slightly lighter-colored crystals of feldspar. The rock is composed of a microcrystalline groundmass, consisting chiefly of plagioclase and orthoclase feldspars with some quartz and many minute crystals of magnetite or ilmenite, with scattered larger crystals of orthoclase, plagioclase, and biotite. Besides the exposures at the forks of Strait Creek this rock was observed on the roadside 2 miles farther down the creek, a half-mile north of Monterey, and at several points along the valley of South Branch below Hightown. As the rock is usually decomposed into a chalky material resembling some of the limestone, it is very difficult to detect its presence except in fresh outcrops. On close inspection it is seen to be characterized by dark flakes of biotite.

Granite-felsophyre.

STRUCTURE.

Definition of terms.—As the materials forming the rocks of this region were deposited upon the sea bottom, they originally extended in nearly horizontal layers. At present, however, the beds are usually not horizontal, but are inclined at various angles, their edges appearing at the surface. The angle at which they are inclined is called the *dip*. A bed which dips beneath the surface may elsewhere be found rising; the fold, or trough, between two such outcrops is called a *syncline*. A stratum rising from one syncline may often be found to bend over and descend into another; the fold, or arch, between two such outcrops is called an *anticline*. Synclines and anticlines side by side form simple folded structure. A synclinal *axis* is a line running lengthwise in the synclinal trough, at every point occupying its lowest part, toward which the rocks dip on either side. An anticlinal axis is a line which occupies at every point the highest portion of the anticlinal arch, and away from which the rocks dip on either side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and is usually but a few degrees. In districts where strata are folded they are also frequently broken across and the arch is thrust over upon the trough. Such a break is called a *thrust*, an *overthrust*, an *overthrust fault*, or simply a *fault*. Fault, however, is a term applied to many forms of dislocation in rocks. If the arch is worn and the syncline is buried beneath the overthrust mass, the strata at the surface may all dip in one direction. They then appear to have been deposited in a continuous series despite the thrust which divides the whole mass. Folds and faults are often of great magnitude, their dimensions being measured by miles, but they also occur on a very small, even a microscopic, scale. In folds strata change their relations mainly by motion on the bedding planes, and overthrusts arise frequently where the direction of such movement intersects the bedding

Dip.

Syncline and anticline.

Faults.

Structure of the Appalachian province.—Three distinct types of structure occur in the Appalachian province, each one prevailing in a separate area corresponding to one of the three geographic divisions. In the plateau region and westward the rocks are generally flat and retain their original composition. In the valley the rocks have been steeply tilted, bent into folds, broken by thrusts, and to some extent altered into slates and schists. In the mountain district faults and folds are important features of the structure, but cleavage and metamorphism are equally conspicuous.

Three types of structure.

The folds and overthrusts of the valley region are generally parallel to one another and to the western shore of the ancient continent. They extend from northeast to southwest, and single structures may be very long. Faults 300 miles long are known, and folds of even greater length occur. The crests of many anticlines continue at nearly the same height for great distances, so that they present the same formations. Often adjacent folds are nearly equal in height, and the same beds appear and reappear at the surface. Most of the beds dip at angles greater than 10°; frequently the dip is over 45°, and generally the western dip is overturned beyond 90°. The sides of the folds are sometimes pressed together until they are parallel. Generally the folds are smallest, most numerous, and most closely squeezed in thin-bedded rocks, such as shale and shaly limestone. Perhaps the most striking feature of the folding is the prevalence of southeastward dips. In some sections across the southern portion of the Appalachian Valley scarcely a bed can be found which dips toward the northwest.

Features of the folds.

Thrusts were developed in the northwestern sides of synclines, varying in extent and frequency with the changes in the thickness of strata above the Cambro-Silurian limestone. With very few exceptions the fault planes dip toward the southeast, and are nearly parallel to the bedding planes of the adjacent rocks. The fractures extend across beds many thousand feet thick, and sometimes the upper strata are pushed over the lower as far as 6 or 8 miles. There is a progressive change in character of deformation from northeast to southwest, resulting in different types in different places. In southern New York folds and faults occur in a relatively narrow area lying mainly east of the Hudson River. The strata have nevertheless been intensely disturbed. Through Pennsylvania toward Virginia, folds become more numerous and steeper. In southern Virginia they are closely compressed and often closed, while occasional faults appear. Passing through Virginia into Tennessee, the folds are more and more broken by thrusts. In the central part of the Valley of Tennessee, folds are generally so obscured by faults that the strata form a series of narrow overlapping blocks, all dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the overthrusts become fewer, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

Features of fractures.

In the Appalachian Mountains the southeastward dips, close folds, and faults that characterize the Great Valley are repeated. The strata are also traversed by minute breaks of cleavage and are metamorphosed by the growth of new minerals. The cleavage planes dip to the east at from 20° to 90°, usually about 60°. This form of alteration is somewhat developed in the valley as slaty cleavage, but in the mountains it becomes important and frequently destroys all other structures. All rocks were subjected to this process, and the final products of the metamorphism of very different rocks are often indistinguishable from one another. Throughout the eastern Appalachian province there is a regular increase of metamorphism toward the southeast, so that a bed quite unaltered at the border of the Great Valley can be traced through greater and greater changes until it has lost every original character.

Structure of the mountains.

The structures above described are the result chiefly of compression, which acted in a northwest-southeast direction, at right angles to the trend of the folds and of the cleavage planes. The force of compression became effective early in the Paleozoic era, and reappeared at various epochs up to its culmination soon after the close of the Carboniferous.

Origin of the folds and fractures.

In addition to this force of compression, the province has been affected by other forces which acted in a vertical direction and repeatedly raised or depressed its surface. The compressive forces were limited in effect to a narrow zone. Broader in its effect and less intense at any point, the vertical force was felt throughout the province.

Vertical earth motions.

Three periods of high land near the sea and three periods of low land are indicated by the character of the Paleozoic sediments. In post-Paleozoic time, also, there have been at least four, and probably more, periods of decided oscillation of the land due to the action of vertical force. In most cases the movements have resulted in the warping of the surface, and the greatest uplift has occurred nearly along the line of the Great Valley.

Periods of elevation and depression.

Structure sections.—The sections on the Structure sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual dips of the strata are shown. These sections represent the structure as it is inferred from the position of the strata observed at the surface. On a map with this scale it is not possible to show in the sections the minute details of structure; they are therefore somewhat generalized from the dips observed in a belt a few miles in width along the line of the section.

Mode of mapping the structure.

Structure of the Monterey area.—The principal structural features of this quadrangle are illustrated by the six structure sections on the Structure sheet. The greater part of the region is traversed by folds of the Appalachian type, consisting of a succession of parallel corrugations trending northeast and southwest, with the steeper dips predominating on the western limbs of the anticlines. West of Greenbrier River there begins the edge of the broad basin structure of the Cumberland Plateau type, comprising, in this quadrangle, the relatively flat basin occupied by the Carboniferous formations in Back Allegheny and Cheat mountains.

In the region in which the structure is of the Appalachian type there are five principal anticlines of considerable magnitude, with four intervening synclines. The most prominent of these anticlines are in a group of three corrugations which diagonally cross the quadrangle near the center. They are bordered on both sides by profound synclines, the one on the east containing the mass of Devonian formations in Shenandoah Mountain, east of which rises the relatively moderate anticlinal group of Mill Mountain, Sideling Hill, Walker Mountain, Chestnut Ridge, and Blackoak Ridge; and the one on the west being a still deeper basin, containing the Devonian formations of Allegheny Mountain, west of which rises the anticlinal uplift of the Browns Mountain range.

Five great anticlines.

The central series of corrugations comprise the anticline of the Warm Spring Mountain and the northward continuation of one of its branches through Tower Hill and Bullpasture Mountain; Jack Mountain and its southward continuation in Collison Ridge; and Crabbottom uplift, marked by Back Creek, Little, and Boler mountains. The larger flexures carry subordinate corrugations of varying degrees of prominence, and they also show considerable irregularity in pitch, notably in Jack Mountain anticline, which is crossed diagonally by a shallow syncline east of Monterey, and in Warm Spring Mountain anticline, which is similarly offset south of Burnsville from the main Warm Spring Mountain to Tower Hill and Bullpasture Mountain, giving place to a flexure which in a measure is structurally the continuation of the Little Piney Mountain and Piney Mountain branch of the main Warm Spring Mountain anticline.

Three central anticlines.

The geanticline of Mill Mountain, Sideling Hill, Walker Mountain, Chestnut Ridge, and Blackoak Ridge is a somewhat complex structural feature. It rises a few miles northeast of Armstrong, in the Staunton quadrangle, and one of its arches extends many miles south of Panther Gap, in the Natural Bridge quadrangle. It consists of five principal anticlines, each giving rise to a prominent ridge of sandstone, with the intervening synclinal valleys of limestone or shale. The anticlines are of moderate height, and they pitch downward rapidly at their terminations, which, in the case of Walker Mountain, Sideling Hill, and Mill Mountain, are en échelon both to the northward and to the southward. The greatest degree of uplift is to the west in Chestnut Ridge, but the differences in altitude between Mill Mountain, Sideling Hill, Walker Mountain, and Chestnut Ridge anticlines are relatively small. The anticline of Blackoak Ridge is much lower, and it brings to the surface the Monterey sandstone, with the Lewistown limestone appearing in some of the deeper depressions which cross the ridge and its extension southward. The Blowing Cave is in a small anticline lying just west of the southern termination of the anticline of Blackoak Ridge, in an exposure of the Lewistown limestone bared of the overlying Monterey sandstone in the gorge cut by Cowpasture River. The anticline of Chestnut Ridge rises abruptly along Pig Run and brings to the surface sandstone beds of the Rockwood formation. The anticline consists of two low arches with an intervening shallow syncline. Walker Mountain brings to the surface the sandstones of the Rockwood formation, and is nearly surrounded by Lewistown limestone in the adjoining valleys. Sideling Hill is a precisely similar ridge, but its anticline is prolonged much farther south in Lewistown and Monterey formations. Mill Mountain is a ridge of the same type as the others, but has steeper dips and exposes lower beds in the gorge known as Panther Gap, cut across it by Mill Creek. The mountain begins a short distance east of the quadrangle and extends many miles farther south than the southern end of Sideling Hill. Its summit is, as in the other ridges, an overarching sheet of quartzites of the Rockwood formation, with adjoining valleys containing Lewistown limestone, but to the east there is the wide syncline of Devonian rocks in Cowpasture Valley. Panther Gap gives a beautiful exhibition of the structure and formations in Mill Mountain. It exposes great beds of quartzite and sandstone in the Rockwood formation, the red Cacapon beds, and the quartzitic sandstones of the Tuscarora formation, which exhibit an overturned arch along the railroad cut in the center of the gap. The exposure of this arch is one of the finest in the Appalachians. There are several minor crumples, anticlines and synclines, and in or near the center is a sharply overturned arch with rather square crown in some of the beds and an axial dip of about 45° to the east.

An eastern anticlinal group.

The synclines in the area between Blackoak Ridge and Mill Mountain contain areas of Devonian rocks in the deepest portions of the basins between the declining ends of anticlines. In the wide basin between Chestnut Ridge and Walker Mountain anticlines, between Pig Run and Mill Creek, there is a narrow area of the Jennings formation. Between Sideling Hill and Mill Mountain anticlines the syncline is sufficiently deep to the south to contain some Romney shale, and then, with the upward pitch to the north, there rise in succession the Monterey sandstone, the Lewistown limestone, and the quartzite and sandstone of the Rockwood formation.

Synclines in southwestern part of area.

Next west of this area of anticlines lies a deep syncline filled with Devonian strata, which to the northward rise in Shenandoah Mountain. Cowpasture River flows along the western limb of this syncline for many miles, but crosses it southeast of Bath Alum Springs. Stuart Run flows along the Romney shale valley on its eastern side, from Armstrong south to the southern end of Blackoak Ridge. South of Green Valley the basin contains in its center a moderately thick mass of the lower beds of the Jennings formation and an inclosed anticlinal area of Romney shales. To the northeast the basin widens and deepens, and in Shenandoah Mountain there is represented the entire thickness of the Jennings deposits, the harder beds giving rise to the high ranges and summits which characterize this mountain. On the border of the quadrangle the mountain is capped by transition beds to the Hampshire formation.

In the Warm Spring Mountain region there is a central prominent anticline with several branching subordinate flexures. The first of these from the east is the anticline which brings up the hard rocks constituting Little Mare Mountain. This range extends from the south with considerable prominence along the southern edge of the quadrangle, as shown in Cross Section F. To the northward the beds pitch down, and just east of Bath Alum Springs the sandstones of the Rockwood formation sink beneath the surface. Thence north in McClung Ridge there are steep slopes of Lewistown limestone flanked by Monterey sandstone. Cowpasture River cuts into the crest of this anticline 2 miles southwest of Fort Lewis, in a gorge with high cliffs of Lewistown limestone. In the valley at Bath Alum Springs there is a syncline of Romney shale which extends north a short distance beyond Dry Run and south for 2 miles up the valley west of Little Mare Mountain. Next west there is an anticlinal range constituting Little Piney Mountain, Piney Mountain, and Tower Hill. The principal surface formation in these ridges is the sandstone of the Rockwood formation. In Little Piney Mountain and its southern continuation there is a considerable area of Cacapon sandstone, through which finally rises the Tuscarora quartzite. This mountain is traversed by two deep gorges exhibiting arches of this quartzite. Thompson Springs Creek crosses the range at the south end of Piney Mountain in a gorge which exposes the red sandstones of the Cacapon formation. At Dry Run, in the gap between Tower Hill and Piney Mountain, along the same uplift, there is a local area of Cacapon, Tuscarora, and Juniata formations. Tower Hill consists principally of Rockwood sandstones, with the Lewistown limestone extending for some distance up the flanks. At the southern end of this hill the limestone rises to the crest and presents toward the southwest a high cliff and partial arch. Farther north, along the summit, there are some narrow outcrops of Cacapon red beds and Tuscarora quartzite. Just west of Williamsville the Rockwood formation pitches beneath the surface, passing under the Lewistown limestone, which constitutes the higher crests of Bullpasture Mountain. In the gorge of Bullpasture River just above Williamsville the relations of this anticline are clearly exhibited. In the center of the gorge a small area of the red sandstones of the Cacapon formation is exposed. Next above are Rockwood shales and sandstones, and then, on the north side of the gorge, there is a great arch of Lewistown limestone.

Little Mare Mountain and adjacent ridges.

The Tower Hill area.

The western ridge of Bullpasture Mountain is a subordinate anticline, exhibiting Lewistown limestone more or less completely covered by Monterey sandstone. Next west is a syncline containing a wide area of Romney shale, and west of Clovercreek is a narrow outlier of the Jennings formation, 6 miles in length. This syncline pitches up to the south, giving rise to a considerable area of Lewistown limestone near Burnsville, and runs out in some minor flexures, as the northern end of Warm Spring Mountain. This mountain consists of a prominent anticline which begins on the eastern flank of Jack Mountain west of Burnsville, among ridges of Rockwood sandstone. The red Cacapon sandstone soon rises, and then the Tuscarora white quartzite, which constitutes the mountain crest to the "White Rocks" at Boner Mountain. Thence south the arch rises, its western limb steepens, and its crest has been deeply eroded down through the Martinsburg shale into the Shenandoah limestone, which constitutes Warm Spring Valley. On the east side of this valley are slopes of Martinsburg shale and Juniata shale and sandstone, surmounted by cliffs of the white Tuscarora quartzite, one notable point of which is at Flag Rock, on the west side of the valley. The other limb of the anticline presents vertical beds of a regular succession of formations from Shenandoah limestone to Romney shale, with the thin bed of white Tuscarora quartzite giving rise to a sharp ridge. This ridge is crossed at short intervals by Chimney Run, Warm Spring Run, Cowardin Run, and Cedar Creek, which all afford instructive exposures of the formations. To the west lies the synclinal depression containing marginal belts of Romney shale and a central syncline of rough, low ridges of Jennings formation.

Western ridge of Bullpasture Mountain.

Warm Spring Mountain.

The Jack Mountain anticline rises out of this syncline near Chimney Run and rapidly attains prominence west of Boner Mountain. Where it is crossed by Muddy Run the Juniata, Tuscarora, and Cacapon beds are exposed, but to the north there is a ridge of Rockwood sandstone for some distance. Near Duncan Knob the Cacapon sandstone and Tuscarora quartzite rise rapidly, and thence northward the anticline is high and widely truncated down to Shenandoah limestone, which is exposed along the valley of Wilson Run and the upper waters of Dry Branch. At Sounding Knob the anticline begins to pitch down and the Tuscarora quartzite closes over the arch. At the knob its continuity is interrupted by a plug of basalt. Just north of the knob there are depressions which cut through into the Juniata and Martinsburg beds, but to the northward the Tuscarora quartzite again constitutes the crest of the arch in the top of the ridge. The arch sinks rapidly east of Monterey, and the Cacapon sandstone, Rockwood formation, and Lewistown limestones pass around its end in the vicinity of Strait Creek, beyond which the anticline is finally lost in a wide undulating arch of Monterey sandstone. Jack Mountain anticline branches along its east side, east of Trimble post-office, in an anticline which is faulted for some distance. Just west of this there rises steeply the high arch by which Jack Mountain is continued north of Crab Run. Buck Hill and Bear Mountain consist of eastward-dipping beds of Juniata, Tuscarora, and overlying formations, faulted onto Lewistown limestone. There is a continuation of this ridge along the same fault north of Crab Run. The portion of Jack Mountain northwest of this fault is a high ridge of Tuscarora quartzite, with the underlying Juniata formation exposed in the gorge of Crab Run. Next west lies an anticline of Cacapon sandstone and a synclinorium of Rockwood sandstone and shale. Monterey lies in a valley of Romney shale, with low bordering ridges of Monterey sandstone and extensive higher slopes of Lewistown limestone. This syncline extends southward by Pinckney, where it is entirely in Lewistown limestone, and down Jackson River, where it contains a long, narrow belt of Romney shales. For many miles in the vicinity of Warwick Ridge this syncline gives place to a number of irregular corrugations lying along the west side of the main Jack Mountain anticline. In this area there are Warwick Ridge, an anticline of Rockwood sandstone; Cobbler Mountain, an anticline mainly of Lewistown limestone and Monterey sandstone; Little Mountain and Rocky Ridge, consisting mainly of Monterey sandstone; and the valley of Jackson River, which flows in a narrow syncline of Romney shale east of Rocky Ridge and then through a gorge in nearly horizontal Lewistown limestone. On the west side of Cobbler Mountain the river crosses Monterey sandstone and thence for several miles, beyond Cowardin, flows in a Romney shale valley, in a syncline which extends up into the center of Collison Ridge.

The Jack Mountain anticline.

Back Creek Mountain consists of an anticline of relatively uniform relations. It rises in Boler Mountain, where there is a considerable extent of Lewistown limestone flanked and more or less overarched by Monterey sandstone. Just east of Mountaingrove the arch pitches upward and the Tuscarora white quartzite soon appears. East of Sunrise the crest of the arch is eroded through to the Juniata formation and the deeper hollows are excavated in the Martinsburg shale. At the Fodder House the general anticline is seen to comprise two arches, one extending to north of Wilsonville and lying along the main flank of the mountain, the other terminating east of Sunrise post-office. Just north of Fodder House the western anticline rises rapidly and there are soon bared the Martinsburg shale and a wide, long area of Shenandoah limestone, known as the Crabbottom. Back Creek Mountain, on the east side of this valley, consists of eastward-dipping Tuscarora, Cacapon, and overlying beds. Little Mountain, on the west side of the valley, consists of a narrow ridge of almost vertical or very steeply westward-dipping beds. West of the anticline of Back Creek Mountain are the several ranges of the Allegheny Front and Little Mountain, a broad syncline mainly of Jennings formation. The summits lying north are capped by Hampshire beds, and a few of the higher summits, comprising Elleber Ridge, Watering Pond Knob, Bear Mountain, and Tamarack Ridge, are capped by quartzite supposed to be of the Pocono formation.

Back Creek Mountain.

Little Mountain.

Ranges of Allegheny Front.

Browns Mountain consists of an anticline that brings the Silurian formations to the surface. It is composed of a central axis and two or three subordinate corrugations. At Michael Mountain it attains its greatest altitude, bringing the Tuscarora quartzite to the surface along the crest of a high ridge. This quartzite and the underlying beds are also exposed in the gorge of Knapp Creek west of Driscol. Much of the area of Browns Mountain consists of the Lewistown limestone, but there are a number of ridges of Rockwood sandstone, and at See All and Big Ridge there are some outlying caps of Monterey sandstone. Along the flanks of Browns and Michael mountains there is a continuous outcrop of Monterey sandstone in low knobs and ridges which slope down to the Romney shale depression that surrounds the mountains. This depression is occupied for many miles by Knapp Creek, Browns Creek, Thomas Creek, Moore Run, and Rosen Creek. Marlin Mountain, Thorny Creek Mountain, Thomas Mountain, Peters Mountain, Little Mountain, and Sandy Ridge consist of westward-dipping sandstones and shales of the Jennings formation, the highest summits being due to hard beds of sandstone. The valley of Greenbrier River and the adjoining slopes are in the red beds of the Hampshire formation. Dipping gently westward, this formation is surmounted on the slopes of Back Allegheny Mountains by a narrow shelf of Pocono sandstone, on which lies the Greenbrier limestone. This limestone and the overlying Canaan formation constitute the middle slopes of Back Allegheny Mountains. The crest of this mountain and that of Cheat Mountain west consist of the white and gray conglomerates and sandstones of the Blackwater formation, lying in a shallow basin with the valley of Shavers Fork of Cheat River near its axis. Cheat Mountain is on the western side of the basin, and in the western slope of the mountain there are gently east-

Browns Mountain anticline.

Back Allegheny Mountains.

ward-dipping beds, commencing with the Blackwater quartzite at the top and extending down to the Hampshire red sandstone, in the northwestern corner of the quadrangle.

Faults.—The principal fault in the Monterey quadrangle extends for 8 miles along the west side of Buck Hill, Bear Mountain, and the ridge opposite Bear Mountain on the north side of Crab Run. It is an overthrust of about 2200 feet vertical displacement, apparently with a moderately steep hade to the eastern or upthrown side. The fault begins in the Tuscarora quartzite, in a branch anticline on the east slope of Jack Mountain, northeast of Trimble. In a short distance it brings the Juniata red beds onto the Lewistown limestone, a relation which is sustained for 6 miles. The fault dies out near the eastern margin of the quadrangle.

A great overthrust fault.

A small local fault is indicated in Back Creek Mountain a mile northeast of Mountaingrove, which is exposed in the Cacapon, Rockwood, and Lewistown formations. There is apparently another small overthrust which begins along the west side of Little Mare Mountain near the southern boundary of the quadrangle, in which a portion of the quartzites of the Rockwood formation is cut off. Very small local slips are often exposed in the Monterey quadrangle, and some very instructive ones in the Tuscarora quartzite are exposed in Panther Gap.

Local faults.

MINERAL RESOURCES.

Iron ore.—In the shales of the Rockwood formation there is an extensive bed of iron ore, which is often sufficiently pure to give promise of economic importance. It is a red hematite, occurring in regular beds and breaking out in heavy, smooth-sided blocks, a characteristic which has given it the name of "block ore." It is rusty brown in color on exposed surfaces, but when scratched or crushed it is seen to be a bright blood-red. It is the same bed which is worked at intervals along the Appalachian region from New York, where it is known as Clinton ore, to Alabama. It is regularly stratified between the shales, about one-third way below their top.

The area of outcrop of the Rockwood formation is shown on the Areal Geology sheet, and again by a heavy tint on the Economic Geology sheet. It will be seen that it extends along both sides of the anticlinal uplifts of Back Creek, Jack, Warm Spring, Mill, and Walker mountains, Sideling and Tower hills, and Chestnut Ridge; occurs at intervals along Browns Mountain and Michael Mountain; and is exposed in the gorge of Back Creek at the north end of Boler Mountain and in the valley of Rocky Branch west of Duncan Knob. For the greater part of their course the shales of the Rockwood formation are often more or less completely hidden by overplaced sand and rocky talus from adjoining mountain slopes, so that exposures of the iron-ore horizon are but rarely observed. For this reason it is not possible to give a specific account of the extent and variations of the ore. It is known to be variable in purity and thickness, and occasionally there are intervals in which it either is absent or is represented by thin beds of limestone.

Careful exploitation by trenching or shafting will be necessary at most localities for a determination of the presence and quality of the ore. In the central portion of the Browns Mountain area the ore has been explored to some extent and found to average about 2 feet in thickness for a considerable distance, but this thickness is not maintained throughout. In the valley between Little Piney and Piney mountains and Warm Spring Mountain the ore has been examined and a thickness of about 2 feet reported. Moderately thick beds of fine ore were observed in the slopes just west of Sounding Knob, but the thickness could not be determined without trenching.

Fragments of limonite iron ore are frequently found in the Monterey sandstone throughout its extent, and often this rock is more or less deeply stained with iron, so that it is mistaken for iron ore. A careful examination of the entire area of the formation has revealed only a few small local deposits, which do not promise to be of economic importance. The principal limonite exposures observed are on McClung Ridge, by the roadside 2 miles northeast of Burnsville, in the slopes east of Vanderpool, and on the west slope of Jack Mountain 3 miles southwest of Duncan Knob. Iron ore also occurs in fragments in the Lewistown limestone in the Browns Mountain area, but not in large amount.

Coal.—The higher coal measures, which contain workable coal beds to the north and west, do not extend into the Monterey quadrangle. The Blackwater formation contains a few thin irregular beds of coal along the Allegheny Front, but, although they may possibly be of local use, they are not of wide economic importance. They are in the sandstones under the conglomerate, and are associated with black shales. Owing to the heavy talus from the cliffs above, exposures are very rare, and but little could be ascertained as to the distribution of the beds.

The lower members of the Romney shales have been worked at many points with the very mistaken idea that they would lead to coal at a greater or less depth beneath the surface. This shale has much the appearance of the black shales occurring in connection with coal in the regular coal basins, but it was deposited long prior to the era of coal deposition. The more carbonaceous portions of the shale often will burn for a few moments when placed in a hot fire, leaving a very bulky ash; but it is futile to expect that the Romney shales are in any way connected with true coal deposits.

Limestone.—There are large supplies of limestone suitable for blast furnaces and for lime for use in building and agriculture. The greater part of the Lewistown, Shenandoah, and Greenbrier limestones is available for these uses. Some of the lower beds of the Lewistown limestone may prove to be serviceable for the manufacture of cement, but they have not as yet been tested.

Building stone.—Building stones are very plentiful in the Monterey quadrangle, for they may be obtained in nearly every formation. It can not be said that any of them are particularly attractive in appearance or of special value for shipment, but they answer every purpose for local use. One of the most serviceable materials is the Monterey sandstone, which in its fresh state can often be hewn out into smooth blocks for building chimneys. It is claimed that at some localities the limestones are suitable for marble, but this claim has not been fully authenticated. There is usually great difficulty in obtaining large blocks of massive limestone sufficiently free from flaws and of a character that will appear attractive when polished.

Clay.—Clay available for the manufacture of brick for local use occurs at many localities, mainly in the limestone areas and on some of the shale belts. Smaller areas of alluvial clays also occur in many of the stream bottoms. It is probable that some of the dark shales of the Romney formation would, after grinding, be suitable for the manufacture of fire bricks, but they have not yet been tested for this use.

Road metal.—Throughout the area of the Monterey quadrangle there are abundant materials of which to make smooth and durable roads. In many parts of the region there are hard shales and thin sandstones, which make almost perfect beds for roads excavated in them. For roads along the bottom lands there generally are large supplies of rock at hand suitable for macadamizing—broken limestone or sandstone for the foundation and crushed rock or hard shale for a top dressing. In the limestone areas the roads ordinarily require a foundation of large fragments, a top dressing of crushed rock or shale, and adequate lateral drainage. The roads in the sandstone areas usually need only smoothing, with proper drainage on the steep slopes to prevent washing.

SOILS.

Derivation and distribution.—Throughout the quadrangle there is a close relation between the character of the soils and that of the underlying formations. Except in limited areas along the larger streams and on the steeper slopes, the soils are residuary products of the decay and disintegration of the rocks on which they lie. The exceptions are the wash and talus on the steeper slopes and the flats along the streams, where there are mixtures of various materials washed from the higher lands and brought down largely at times of freshet. Sedimentary rocks such as occur in this region are changed by surface waters more or less rapidly, the rapidity depending on the character of the cement which holds their particles together. Siliceous cement is nearly insoluble, and rocks in which it is present, such as quartzite and some sandstones, are extremely durable and produce but a scanty soil. Calcareous cement, on the other hand, is readily dissolved by water containing carbonic acid, and the particles which it held together in the rock crumble down and form a deep soil. If the calcareous cement makes up but a small part of the rock, it is often leached out far below the surface, and the rock retains its form but becomes soft and porous, as in the case of the Monterey sandstone; but if, as in limestone, the calcareous material forms the greater part of the rock, the insoluble portions collect on the surface as a mantle of soil, varying in thickness with the character of the limestone, being generally thin where the latter is pure, but often very thick where it contains much insoluble matter.

When derived in this way from the disintegration of the underlying rock, soils are called *sedentary*. If the rock is a sandstone or sandy shale the soil is sandy, and if it is a clay shale or limestone the resulting soil is clay. As there are abrupt changes in the character of the rocks, sandstones and shales alternating with limestones, so there are abrupt transitions in the character of the soils, and soils differing widely in composition and agricultural qualities often occur side by side. If the characters of the soils derived from the various geologic formations are known their distribution may be approximately determined from the map showing the areal geology, which thus serves also as a soil map. The only considerable areas in which the boundaries between different varieties of soil do not coincide with the formation boundaries are in the river bottoms and upon the steep slopes, where soils derived from rocks higher up the slope have washed down and mingled with or covered the soil derived from those below. The latter are called *overplaced* soils, and a special map would be required to show their distribution.

Classification.—The soils of this region may conveniently be classed as (1) sandy soils, derived from the disintegration of the various beds of sandstone occurring at intervals from the Juniata to the Blackwater formation; (2) clay soils, derived on the one hand from the Shenandoah, Lewistown, and Greenbrier limestones, and on the other hand from the shales mainly of the Martinsburg, Rockwood, Romney, Hampshire, and Canaan formations; (3) alluvial soils, deposited by the larger streams on their flood plains.

Sandy soils.—Nearly all of the larger mountain areas and many of the small ridges consist of sandstone, and their soils are sandy. Much of the land is steep and rocky, and the soils are so thin and barren that they are not available for agriculture. The Blackwater, Pocono, upper Jennings, Tuscarora, and Juniata beds furnish the thinnest and poorest soils, and the mountains composed of these rocks are very barren. The Monterey sandstone often disintegrates deeply, but owing to the almost complete removal of its calcareous constituent, the residual sand is usually rather sterile. Much of the surface is so steep also that the sand washes away and leaves wide areas of rocky surface. The upper beds of the Canaan formation are too sandy to furnish good soil, but on the gentler slopes there are some areas which produce fairly good pasture land.

Owing to the alternation of sandstone and shale beds in the Hampshire formation, portions of the Allegheny Mountain are available for pasturage, and some areas have been partially cleared, or "hacked," for this purpose.

Clay soils.—The limestone lands of the Monterey quadrangle are mainly slopes of considerable steepness or rolling valleys. Their soils are exceptionally rich. On the steeper slopes these limestone soils are usually thin and much interrupted by outcropping ledges of rock. The greater part of the limestone areas are employed mainly for grazing, but they are tilled at many localities. The areas of Shenandoah limestone exposed by the uplift of the Crabbottom, Wilson Run, and Warm Spring valleys are the most favorable for agriculture, and the first named is famous for its fertility.

Lewistown limestone areas are used mainly as pasture land, although at many points the slopes are too steep for this purpose, while at others there is extensive overplacement of sand from sandstones on higher slopes. The most extensive available areas of Lewistown limestones are in Browns Mountain uplift, the district extending northward from Burnsville, about Straitcreek post-office, and the valley of Jackson River from Vanderpool to the mouth of Dry Branch. There are many small farms along the outcrop of the Greenbrier limestone all along the eastern slope of the Back Allegheny Mountains. On the steeper slopes this limestone is much overplaced by sand and talus from the sandstones and conglomerates above.

Clay soils from the shales occur mainly along the Romney, Martinsburg, and Rockwood formations. The Romney shale soils lie mostly in narrow belts along the river bottoms, and, with the alluvium in these bottoms, form excellent farming lands. They extend along portions of the valleys of Knapp, Browns, Rosen, Thomas, and other creeks skirting Browns, Michael, and the other ranges of the Browns Mountain uplift, and are found in a wide district around Greenbank. They are the lands of the bottoms of Back Creek, the Bolers Draft Valley, the Jackson River for several miles near Rowans and again near Wilsonville, the Monterey Valley, and the greater part of the valleys of the Bullpasture and Cowpasture rivers and Stuart Run. They occupy a detached area passing through Bath Alum Springs and extend along Pig Run and Mill Creek in an area west of Panther Gap.

Portions of the Martinsburg shale area in the Crabbottom, Wilson Run, and Warm Spring valleys extend the width of the area available for pasture, and in some cases they are tilled. The soils are somewhat sandy, but, on the other hand, they contain considerable calcareous matter. The greater part of the Martinsburg area has very steep slopes, which are rather difficult to farm, and on the higher portions of these slopes there is considerable overplacement by sand and talus from the overlying Juniata and Tuscarora beds. The soils from the shales of the Rockwood formation usually lie on steep mountain slopes where there is much overplacement of sand and talus. In the region a short distance east of Monterey and in portions of the Browns Mountain area the formation is so exposed as to give rise to numerous small tracts of farming or pasture land. The shales in the Hampshire formation furnish occasional areas of pasture land on the summits of Shenandoah Mountain and along Greenbrier River. About Cloverlick post-office there is a farming area of small extent in this belt. The shaly portions of the Canaan and Jennings formations lie mainly on very steep slopes, but some portions of their area are available for pasture land.

Alluvial soils.—There are no wide areas of alluvial soil in the Monterey quadrangle. Along nearly all of the larger valleys there are narrow strips of alluvial soils, which are farmed in greater part. These soils are sandy loams, which were deposited by the streams at various times. They are widest about Greenbank, in the Cowpasture Valley from Williamsville to beyond Fort Lewis, in the Bullpasture Valley about Clovercreek, along Jackson River west of Warm Springs, along Knapp Creek east of Browns Mountain, and along Suttleton Creek east of Charley Ridge. There are also some alluvial flats on Shavers Fork of Cheat River. Along the smaller streams there are alluvial deposits of greater or less extent, but mainly narrow. The soils present considerable variability and, as a rule, become predominantly sandy along the upper courses of the larger streams. Along the runs they are usually very sandy and often mixed with shingle. This admixture with shingle also occurs at intervals along the larger streams, especially on their higher courses and immediately below gorges, through which the streams often pass.

N. H. DARTON,
Geologist.

July, 1898.

TABLE OF FORMATION NAMES.

Period.	Names and Symbols used in This Folio.		Names used by Various Authors.	H. D. Rogers: Final Report of Pennsylvania, 1858.	H. D. Rogers: First Report of Pennsylvania, 1836; and W. B. Rogers: Geology of the Virginias, 1838, and later.
Carboniferous	Blackwater formation.	Cbw	Pottsville conglomerate.	Seral.	XII.
	Canaan formation.	Ccn	Mauch Chunk shales.	Umbral.	XI.
	Greenbrier limestone.	Cgr	Greenbrier limestone.		
	Pocono sandstone.	Cpo	Montgomery grits. Pocono sandstone.	Vespertine.	X.
Devonian	Hampshire formation.	Dh	Catskill.	Ponent.	IX.
	Jennings formation.	Dj	Chemung.	Vergent.	VIII.
	Romney shale.	Dr	Hamilton.	Cadent.	
	Monterey sandstone.	SDm	Oriskany.	Meridian.	VII.
Silurian	Lewistown limestone.	Sl	Lower Helderberg. Salina. Niagara	Premeridian.	VI.
	Rockwood formation.	Sr	Clinton.	Surgent.	V.
	Cacapon sandstone.	Scn	Medina. Massanutten sandstone.	Levant.	IV.
	Tuscarora quartzite.	Stc			
	Juniata formation.	Sj			
	Martinsburg shale.	Smb	Hudson River.	Matinal.	III.
	Shenandoah limestone.	€Ss	Trenton. Chazy. Calciferous.	Auroral.	II.

N. H. DARTON,

Geologist.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

TOPOGRAPHIC SHEET

VIRGINIA - WEST VIRGINIA
MONTEREY QUADRANGLE

CONVENTIONAL SIGNS

CULTURE
(printed in black)

Roads and buildings
Private and secondary roads
Trails
Railroads
Street railroads
Tunnels
Bridges
Ferries
Fords
Dams
Locks
U.S. township and section lines
Located township and section corners
Township and section corners not found
Triangulation stations
Bench marks
Mines and quarries
Prospects
Shafts
Mine tunnels *(showing direction)*
Mine tunnels *(direction unknown)*

CONVENTIONAL SIGNS

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
Levees
Cliffs
Mine dumps

DRAINAGE
(printed in blue)

Streams
Falls and rapids
Intermittent streams
Canals and ditches
Lakes and ponds
Intermittent lakes
Glaciers
Springs
Salt marshes
Fresh marshes
Tidal flats

The above signs are in current use on the topographic maps. Variations from this usage appear in some maps of earlier dates.

Henry Gannett, Chief Topographer.
Gilbert Thompson, Geographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey.
Topography by L. C. Fletcher.
Surveyed in 1886-87.

Scale $\frac{1}{125000}$

Contour interval 100 feet.
Datum is mean sea level.

Edition of Jan. 1899.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

HISTORICAL GEOLOGY SHEET

VIRGINIA - WEST VIRGINIA
MONTEREY QUADRANGLE

LEGEND

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

CARBONIFEROUS

- XII — Cbw — Blackwater formation *(conglomerate, sandstone, and shale containing thin coal seams, locally workable)*
- XI — Ccn — Canaan formation *(red and green shale and greenish and brown sandstone)*
- XI — Cgr — Greenbrier limestone *(limestone, shale, and sandstone)*
- X — Cpo — Pocono sandstone *(gray sandstone, in places conglomeratic)*

DEVONIAN

- IX — Dh — Hampshire formation *(shale and sandstone mainly red)*
- VIII — Dj — Jennings formation *(gray, olive, and buff shale and gray sandstone)*
- VIII — Dr — Romney shale *(dark shale with thin limestone beds near the base)*
- VII — SDm — Monterey sandstone

SILURIAN

- VI — Sl — Lewistown limestone *(limestone including at the top cherty limestone, and at the base shaly and impure limestone with thin beds of cement rock)*
- V — Sr — Rockwood formation *(thin sandstone at the top and shale with iron ore below)*
- IV — *Subdivisions of Massanutten sandstone*:
  - Scn — Cacapon sandstone
  - Stc — Tuscarora quartzite
  - Sj — Juniata formation *(red sandstone and shale)*
- III — Smb — Martinsburg shale *(gray shale with sandy beds at the top)*
- II — €Ss — Shenandoah limestone

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs.)

JURATRIAS ?

- bs — Basalt *(dikes)*
- gf — Granite-felsophyre *(dikes)*

Faults

Sections

Henry Gannett, Chief Topographer.
Gilbert Thompson, Geographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey.
Topography by L.C. Fletcher.
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Contour interval 100 feet.
Datum is mean sea level.
Edition of Oct. 1899.

Geology by N.H. Darton.
Surveyed in 1896 and 1897.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

ECONOMIC GEOLOGY SHEET

VIRGINIA - WEST VIRGINIA
MONTEREY QUADRANGLE

(Buckhannon) (Beverly) (Franklin)

(Lewisburg) (Natural Bridge) (Lexington) (Staunton) (Huntersville)

Henry Gannett, Chief Topographer.
Gilbert Thompson, Geographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey.
Topography by L. C. Fletcher.
Surveyed in 1886-87.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

Edition of Oct 1899

Geology by N. H. Darton.
Surveyed in 1896 and 1897.

LEGEND

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- III — Smb — Martinsburg shale *(gray shale with sandy beds at the top)*
- II — CSs — Shenandoah limestone

Subdivisions of Massanutten sandstone

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs.)

JURATRIAS ?

- bs — Basalt *(dikes)*
- gf — Granite-felsophyre *(dikes)*

Faults

Sections

X Iron ore prospects

Known productive formations

- Sr — *Iron* *(thin bands of hematite iron ore, "block ore" in the Rockwood formation)*
- *Limestone* *(Greenbrier, Lewistown, and Shenandoah limestone formations)*

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

STRUCTURE-SECTION SHEET

VIRGINIA - WEST VIRGINIA
MONTEREY QUADRANGLE

Henry Gannett, Chief Topographer.
Gilbert Thompson, Geographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey.
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Surveyed in 1886-87.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of Jan. 1900.

Geology by N.H. Darton.
Surveyed in 1896 and 1897.

LEGEND

SEDIMENTARY ROCKS

	Sheet symbol	Section symbol		
XII	Cbw	Cbw	Blackwater formation (conglomerate, sandstone, and shale containing thin coal seams, locally workable)	CARBONIFEROUS
XI	Ccn	Ccn	Canaan formation (red and green shale and greenish and brown sandstone)	CARBONIFEROUS
XI	Cgr	Cgr	Greenbrier limestone (limestone, shale, and sandstone)	CARBONIFEROUS
X	Cpo	Cpo	Pocono sandstone (gray sandstone, in places conglomeratic)	CARBONIFEROUS
IX	Dh	Dh	Hampshire formation (shale and sandstone mainly red)	DEVONIAN
VIII	Dj	Dj	Jennings formation (gray, olive, and buff shale and gray sandstone)	DEVONIAN
VIII	Dr	Dr	Romney shale (dark shale with thin limestone beds near the base)	DEVONIAN
VII	SDm	SDm	Monterey sandstone	
VI	Sl	Sl	Lewistown limestone (limestone including at the top cherty limestone, and at the base shaly and impure limestone with thin beds of cement rock)	SILURIAN
V	Sr	Sr	Rockwood formation (thin sandstone at the top and shale with iron ore below)	SILURIAN
IV	Scn	Scn	Cacapon sandstone	SILURIAN
IV	Stc	Stc	Tuscarora quartzite	SILURIAN
IV	Sj	Sj	Juniata formation (red sandstone and shale)	SILURIAN
III	Smb	Smb	Martinsburg shale (gray shale with sandy beds at the top)	SILURIAN
II	€Ss	€Ss	Shenandoah limestone	SILURIAN

Subdivisions of Massanutten sandstone (Scn, Stc, Sj)

IGNEOUS ROCKS

Sheet symbol	Section symbol		
bs	bs	Basalt (dikes)	JURATRIAS ?
gf		Granite-felsophyre (dikes)	JURATRIAS ?

Faults

Known productive formations

Sr — Iron (thin bands of hematite iron ore, "block ore," in the Rockwood formation)

Limestone (Greenbrier, Lewistown, and Shenandoah limestone formations)

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

COLUMNAR-SECTION SHEET

VIRGINIA-WEST VIRGINIA
MONTEREY QUADRANGLE

GENERALIZED SECTION FOR THE MONTEREY QUADRANGLE.

SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CARBONIFEROUS	Blackwater formation.	Cbw		400	Conglomerate, sandstone, and shale with thin impure coal in very irregular beds.	Steep mountain crests and wide, bare, rocky plains.
	Canaan formation.	Ccn		1000-1300	Red shales with brown sandstones. Thin limestone.	Steep, smooth, mountain and hill slopes. Thin soil, in greater part not very fertile.
	Greenbrier limestone.	Cgr		350-400	Limestone and red shale.	Mountain slopes. Rich soil.
	Pocono sandstone.	Cpo		70-90	Coarse, hard sandstone, in part conglomeratic.	Knobs and narrow terraces. Thin, sandy, barren soil.
DEVONIAN	Hampshire formation.	Dh		1500-1800	Sandstones and shales, mainly of red color.	Steep mountain slopes. Thin, sandy soils. Some of the ridges have thin, moderately fertile soil, suitable for pasture.
	Jennings formation.	Dj		3000-3800	Gray and buff sandstones and olive and gray shale.	Mountain slopes. Thin, sandy, barren soil.
	Romney shale.	Dr		1000-1300	Shale, black and fissile below, lighter colored and more sandy above. Thin bed of limestone. UNCONFORMITY.	Wide valleys and low rounded ridges. Thin soil, usually clayey. The valleys generally contain alluvial deposits of greater or less width.
SILURIAN	Monterey sandstone.	SDm		50-200	Calcareous sandstone; weathers to buff, porous sandstone.	Knobs and ridges. Bare surfaces or thin, sandy and cherty soil.
	Lewistown limestone.	Sl		550-1050	Cherty limestone. Massive limestone. Flaggy limestone. Thin-bedded impure limestone and calcareous shale.	Knobby ridges and elevated valleys. Thin, rich soil. Fertile slopes on the sides of ridges.
	Rockwood formation.	Sr		100-900	Gray sandstone. Shale with thin sandstone and limestone beds and iron ore. Includes quartzite at the base in the eastern portion.	Slopes and rounded hills. Thin, moderately fertile soil.
	Cacapon sandstone.	Scn		100-630	Red sandstone, mainly flaggy.	Rocky slopes. Thin, sandy soil.
	Tuscarora quartzite.	Stc		50-300	White and gray quartzite.	Rocky mountain summits. Mainly bare surfaces.
	Juniata formation.	Sj		205-1250	Brownish-red sandstones and red shales.	Steep slopes. Thin, sandy, barren soil.
	Martinsburg shale.	Smb		800-1800	Gray shale with sandy beds near the top.	Slopes and high rounded hills. Thin, moderately fertile soil.
	She[illegible]estone.	€Ss		2400+	Light-gray fossiliferous limestone. Darker-gray limestone containing chert. Massive gray limestone, in part magnesian.	Valleys with undulating slopes. Fertile clay soil.

N. H. DARTON,
Geologist.

forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be discovered by observing their relative positions. This relationship holds except in regions of intense disturbance; sometimes in such regions the disturbance of the beds has been so great that their position is reversed, and it is often difficult to determine the relative ages of the beds from their positions; then *fossils*, or the remains of plants and animals, are guides to show which of two or more formations is the oldest.

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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.

When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was dep[illegible] first.

Fossil remains found in the rock[illegible]fferent areas, provinces, and continents, af[illegible] most important means for combining [illegible]tories into a general earth history.

Colors and patterns.—To show t[illegible]e ages of strata, the history of the sedi[illegible]cks is divided into periods. The na[illegible]riods in proper order (from new to [illegible]), with the color or colors and symbol assigne[illegible] to each, are given in the table in the next column. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period name.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

PERIOD.	SYMBOL.	COLOR.
Pleistocene	P	Any colors.
Neocene { Pliocene / Miocene }	N	Buffs.
Eocene (including Oligocene)	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic / Triassic }	J	Blue-greens.
Carboniferous (including Permian) . .	C	Blues.
Devonian	D	Blue-purples.
Silurian (including Ordovician)	S	Red-purples.
Cambrian	€	Pinks.
Algonkian	A	Orange-browns.
Archean	AR	Any colors.

Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations of the Pleistocene render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the metamorphic rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Historical geology sheet.—This sheet shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern and its letter-symbol on the map 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 given formation, its name should be sought in the legend and its color and pattern noted, when 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet by fainter color-patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same name 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 the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

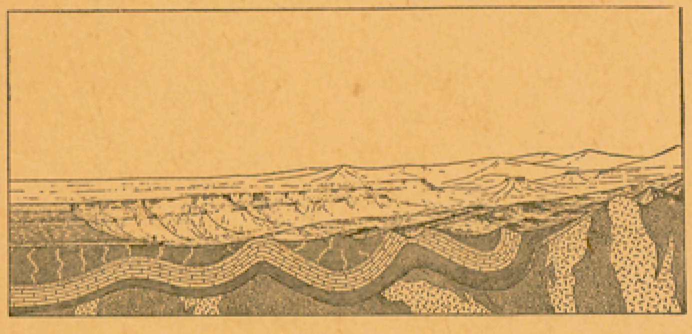

Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane that cuts a section so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

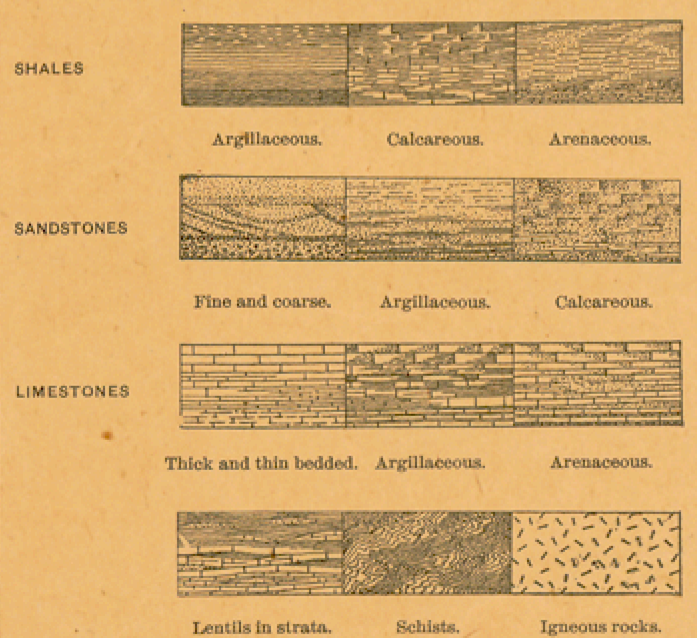

Fig. 3.—Symbols used to represent different kinds of rock.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section.

The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which have from time to time caused the earth's surface to wrinkle along certain zones.

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. 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 well-founded inference.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has swelled upward from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. 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 at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their 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 plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets, marking a time interval between two periods of rock formation, is another unconformity.

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

Columnar-section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. The diagrams and verbal statements form a summary of the facts relating to the character of the rocks, to the thicknesses of the formations, and to the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied by its name, a description of its character, and its letter-symbol as used in the maps and their legends.

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Director.

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