DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

GEOLOGIC ATLAS

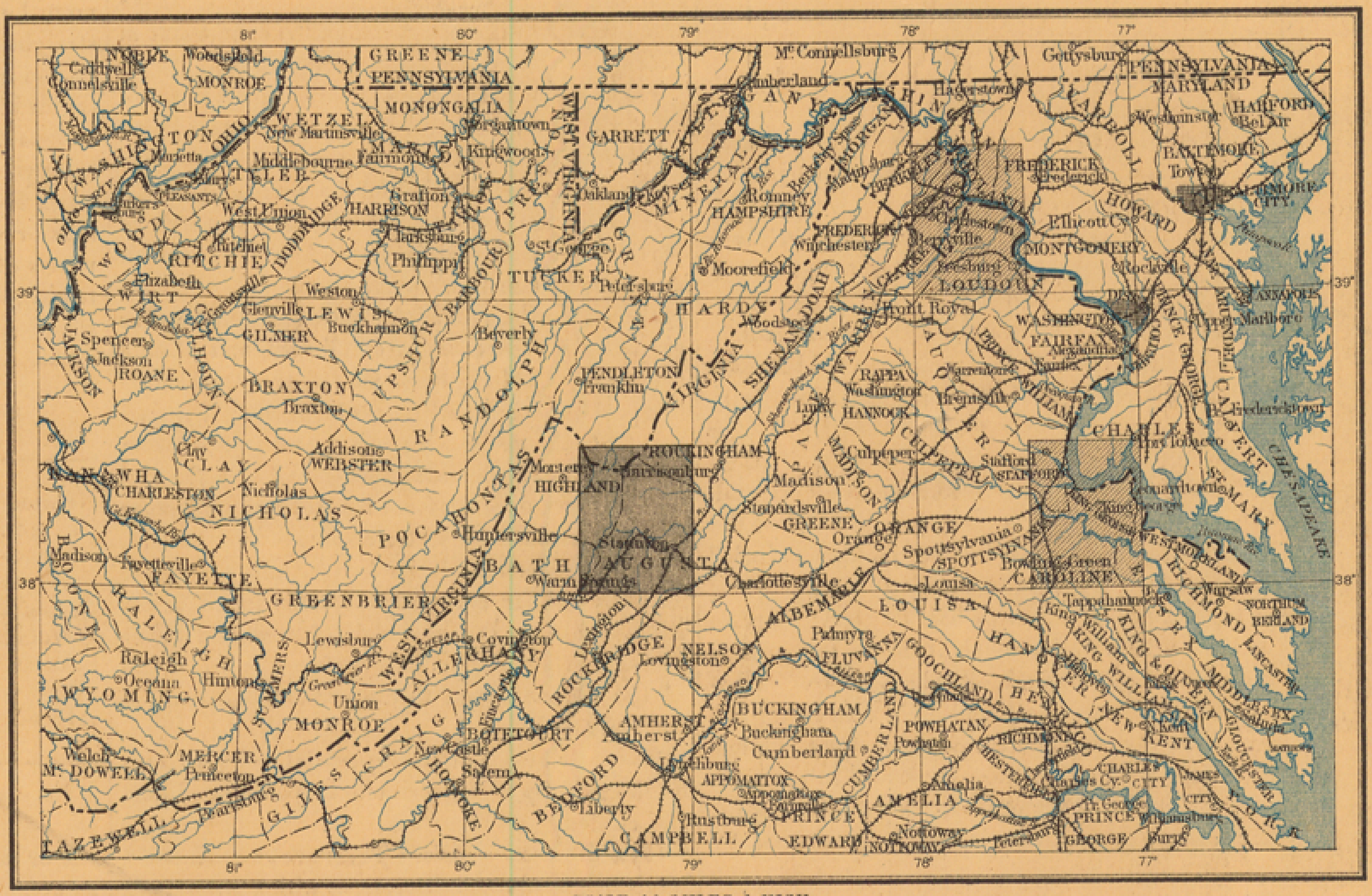
OF THE

UNITED STATES

STAUNTON FOLIO

VIRGINIA - WEST VIRGINIA

INDEX MAP



SCALE: 40 MILES - 1 INCH

AREA OF THE STAUNTON FOLIO

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FOLIO 14 — LIBRARY EDITION — STAUNTON

WASHINGTON, D. C.

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BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS — S. J. KÜBEL, CHIEF ENGRAVER

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EXPLANATION.

The Geological Survey is making a large topographic map and a large geologic map of the United States, which are being issued together in the form of a Geologic Atlas. The parts of the atlas are called folios. Each folio contains a topographic map and a geologic map of a small section of country, and is accompanied by explanatory and descriptive texts. The complete atlas will comprise several thousand folios.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, prairies, valleys, hills and mountains; (2) distribution of water, called *drainage*, as streams, ponds, lakes, swamps and canals; (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 stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

The manner in which contours express the three conditions of relief (elevation, horizontal form and degree of slope) is shown in the following sketch and corresponding contour map:

Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. 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 height, form and slope:

1. A contour indicates approximately a height above sea level. In this illustration the contour interval is 50 feet; therefore the contours occur 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 so on with any other contour. In the space between any two contours occur 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 are made heavy and are numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the horizontal 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 define all prominences. The relations of contour characters 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. Therefore contours are far apart on the gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is chosen; for a steep or mountainous country a large contour interval is necessary. The smallest contour interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for districts like the Mississippi delta and the Dismal Swamp region. In mapping great mountain masses like those in Colorado, on a scale of $\frac{1}{250,000}$, the contour interval may be 250 feet. For intermediate relief other contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—The water courses are indicated by blue lines, which are drawn unbroken where the stream flows the year round, and dotted where the channel is dry a part of the year. Where the stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Marshes and canals are also shown in blue.

Culture.—In the progress of the settlement of any region men establish many artificial features. These, such as roads, railroads and towns, together with names of natural and artificial details and boundaries of towns, counties and states, are printed in black.

As a region develops, culture changes and gradually comes to disagree with the map; hence the representation of culture needs to be revised from time to time. Each sheet bears on its margin the dates of survey and of revision.

Scales.—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding 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 special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as 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 "one mile to one inch" is expressed by $\frac{1}{63,360}$.

Three different scales are used on the atlas sheets of the U. S. Geological Survey; the smallest is $\frac{1}{250,000}$, the second $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to four miles two miles, and one mile of natural length to one inch of map length. On the scale $\frac{1}{62,500}$ one square inch of map surface represents and corresponds nearly to one square mile; on the scale of $\frac{1}{125,000}$, to about four square miles; and on the scale of $\frac{1}{250,000}$, to about sixteen square miles. At the bottom of each atlas sheet the scale is expressed as a fraction, and it is further indicated by a "bar scale," a line divided into parts representing miles and parts of miles.

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); 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 These areas correspond nearly to 4000, 1000 and 250 square miles.

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. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

THE GEOLOGIC MAP.

A geologic map represents the distribution of rocks, and is based on a topographic map,—that is, to the topographic representation the geologic representation is added.

Rocks are of many kinds in origin, but they may be classed in four great groups: Superficial Rocks, Sedimentary Rocks, Igneous Rocks and Altered Rocks. The different kinds found within the area represented by a map are shown by devices printed in colors.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. The materials composing them likewise vary with locality, for the conditions of their deposition at different times and places have not been alike, and accordingly the rocks show many variations. Where beds of sand were buried beneath beds of mud, sandstone may now occur under shale; where a flow of lava cooled and was overflowed by another bed of lava, the two may be distinguished. Each of these masses is limited in extent to the area over which it was deposited, and is bounded above and below by different rocks. It is convenient in geology to call such a mass a *formation*.

(1) *Superficial rocks.*—These are composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated.

Within a recent period of the earth's history, a thick and extensive ice sheet covered the northern portion of the United States and part of British America, as one now covers Greenland. The ice gathered slowly, moved forward and retreated as glaciers do with changes of climate, and after a long and varied existence melted away. The ice left peculiar heaps and ridges of gravel; it spread layers of sand and clay, and the water flowing from it distributed sediments of various kinds far and wide. These deposits from ice and flood, together with those made by water and winds on the land and shore after the glacier had melted, and those made by similar agencies where the ice sheet did not extend, are the superficial formations. This period of the earth's history, from the beginning of the glacial epoch to the present, is called the Pleistocene period.

The distribution of the superficial rocks is shown on the map by colors printed in patterns of dots and circles.

(2) *Sedimentary rocks.*—These are conglomerate, sandstone, shale and limestone, which have been deposited beneath seas or other large bodies of water and have usually become hard.

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 in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface 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 oceans are changed.

The bottom of the sea is made of gravel, sand and mud, which are sorted and spread. As these sediments gather they bury others already deposited and the latter harden into layers of conglomerate, sandstone, shale or limestone. When the sea bottom is raised to dry land these rocks are exposed, and then we may learn from them many facts concerning the geography of the past.

As sedimentary strata accumulate the younger beds rest on those that are older and the relative ages of the deposits may be discovered by observing their relative positions. In any series of undisturbed beds the younger bed is above the older.

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch 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.

Beds of rock do not always occur in the positions in which they were formed. When they have been disturbed it is often difficult to determine their relative ages from their positions; then fossils are a guide to show which of two or more formations is the oldest. 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 one was formed first. Fossil remains found in the rocks of different states, of different countries and of different continents afford the most important means for combining local histories into a general earth history.

Areas of sedimentary rocks are shown on the map by colors printed in patterns of parallel straight lines. To show the relative age of strata on the map, the history of the sedimentary rocks is divided into nine periods, to each of which a color is assigned. Each period is further distinguished by a letter-symbol, so that the areas may be known when the colors, on account of fading, color blindness or other cause, cannot be recognized. The names of the periods in proper order (from new to old), with the color and symbol assigned to each, are given below:

PERIOD.	SYMBOL.	COLOR—PRINTED IN PATTERNS OF PARALLEL LINES.
Neocene (youngest).	N	Yellowish buff.
Eocene	E	Olive-brown.
Cretaceous	K	Olive-green.
Juratrias.........	J	Gray-blue-green.
Carboniferous.....	C	Gray-blue.
Devonian	D	Gray-blue-purple.
Silurian	S	Gray-red-purple.
Cambrian	Є	Brown-red.
Algonkian (oldest).	A	Orange-brown.

In any district several periods may be represented, and the representation of each may include one or many formations. 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; and the formations of any one period are distinguished from one another by different patterns. 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. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital 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.

(3) *Igneous rocks.*—These are crystalline rocks, which have cooled from a molten condition.

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they

DESCRIPTION OF THE STAUNTON SHEET.

GEOGRAPHY.

General relations.—The area included in the Staunton atlas sheet is one-quarter of a square degree, which lies between the parallels 38° and 38° 30′ north latitude and the meridians 79° and 79° 30′ west longitude. This area measures approximately 35 miles from north to south and 27¼ miles from east to west, and embraces a little less than 938 square miles. It comprises the greater part of Augusta County, the southwestern corner of Rockingham County, the northern corner of Rockbridge County, and the eastern half of Highland County, Virginia, and the southern portion of Pendleton County, West Virginia. Its southeastern corner is very near the foot of the Blue Ridge, and it extends northwestward across the Great Valley to within a few miles of the front of the Alleghany Mountains.

In its geographic and geologic relations this area 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 that covered by a single atlas sheet; hence it is necessary to consider the individual sheet 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.

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 the eastern side only is marked by great 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 sharply outlined on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the Alleghany 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 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.

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.

The western division of the Appalachian province embraces the Cumberland Plateau and the Alleghany Mountains and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the Mississippi River as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian Valley by the Alleghany 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 perfectly flat, but it is oftener much divided by streams into large or small areas with flat tops. In West Virginia and portions of Pennsylvania the plateau is sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion, and the surface is now comparatively low and level, or rolling.

Altitude 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.

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1,000 feet in Alabama to more than 6,600 feet in western North Carolina. From this culminating point they decrease to 4,000 or 3,000 feet in southern Virginia, rise to 4,000 feet in central Virginia, and descend to 2,000 or 1,500 feet on the Maryland-Pennsylvania line.

The Appalachian Valley shows a uniform increase in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2,000 feet at the Tennessee-Virginia line, and 2,600 or 2,700 feet at its culminating point, on the divide between the New and Tennessee rivers. From this point it descends to 2,200 feet in the valley of New River, 1,500 to 1,000 feet in the James River basin, and 1,000 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 2,000 feet.

The plateau, or western, division increases in altitude from 500 feet at the southern edge of the province to 1,500 feet in northern Alabama, 2,000 feet in central Tennessee, and 3,500 feet in southeastern Kentucky. It is between 3,000 and 4,000 feet in West Virginia, and decreases to about 2,000 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.

The position of the streams in the Appalachian Valley is 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 of the Staunton area.—The area of the Staunton sheet is divided diagonally into two parts which differ in topographic character. The southeastern lies in the valley of Virginia; the northwestern includes a portion of the Appalachian ranges.

The Great Valley region has, in greater part, a gently undulating surface, consisting of rounded hills separated by meandering valleys of moderate depth. To the north, east, and southeast, the high areas rise to an average altitude of 1,500 feet, but to the southwestward this gradually increases to 2,000 feet. The very uniform altitudes of these higher lands define a general plain which formerly extended over the entire valley region. The minor drainage systems have cut channels in this old plain, giving rise to the present diversity of surface, but the former level is widely preserved on the hilltops. There are a few scattered knobs, such as Betsey Bell, Mary Gray, and the Sugar Loaf, which rise above the former level.

The Great Valley is bounded on the west by the Little North Mountain and the foothills of the Narrowback range. These generally present an abrupt and almost continuous wall to the eastward. In the central part of the area the Little North Mountain is low and is crossed by several gaps, but southward it rises as a rough, rocky range to a relatively level crest-line nearly 3,000 feet high. It is depressed at Pond Gap to about 2,700 feet, and at Buffalo Gap to 1,850 feet, or almost to its base. Narrowback Mountain averages 2,500 feet in altitude, and is separated from the low, northern range of Little North Mountain by an offset in which there is a cross valley having an altitude of 1,600 feet. It is crossed by North River and Briery Branch gaps, very nearly at the general level of the Great Valley.

West of Little North Mountain lies a succession of high, more or less continuous ranges extending from northeast to southwest. The first is the Great North Mountain, which culminates in Elliott Knob at 4,473 feet above sea-level, the highest elevation in this portion of Virginia. Crawford Mountain is the northern summit of the range; it rises to slightly over 3,800 feet. Between Elliott Knob and Crawford Mountain is Dry Branch Gap, at 2,700 feet. Southwest of Great North Mountain are Walker Mountain and Sideling Hill, two level-topped ranges about 3,000 feet high, which terminate quite abruptly to the northward. Next west is the Shenandoah range, which extends diagonally across the area of the sheet, and bears many summits over 4,000 feet in altitude. It is crossed by two principal gaps at about 3,000 feet. To the northward it is connected with the Narrowback range by long, high spurs, which give rise to a very rough region of high knobs and ridges in the northern corner of Augusta County and the adjoining portion of Rockingham. West of the Shenandoah Mountain there is a succession of long, narrow ridges of moderate height, of which Shaws Ridge and Bull Pasture Mountain are the most prominent. Beyond them the high, even crest of Jack Mountain rises to an elevation of over 4,000 feet.

The area of the Staunton sheet is drained by branches of the James and Potomac rivers, whose watersheds are separated by relatively low divides. The Potomac receives, from Augusta County, through the Shenandoah, the waters of Middle and North rivers, and its South Branch heads in Pendleton County. Three branches of the James—Calf Pasture River, in Augusta County, and Cow Pasture and Bull Pasture rivers, in Highland County—head within the area of the sheet; and Walker and Moffat creeks flow into the North Branch of the James.

GEOLOGY.

STRATIGRAPHY.

The general sedimentary record.—Most of the rocks appearing at the surface within the limits of the Staunton atlas sheet are 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, and the remains of plants and animals which lived while the strata were being laid down. Thus some of the great beds of limestone were formed largely from the shells of various sea animals, and the beds of coal are the remains of a luxuriant vegetation, which probably covered low, swampy shores.

The rocks afford a record of sedimentation from earliest Cambrian to Juratrias 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 greater depth of water and scarcity of sediment. The character of the adjacent land is shown by the character of the sediments derived from its waste. Coarse sandstones and conglomerates, such as are found in the Coal Measures, were derived from high land, on which stream grades were steep, or they may have resulted from wave action as the sea encroached upon a sinking coast. Red sandstones and shales, such as make up some of the Cambrian and Silurian 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.

The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin. The area of the Staunton sheet was near its 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 east. The exact position of the eastern shore-line of this ancient sea is not known, but it probably varied from time to time within rather wide limits.

Three great cycles of sedimentation are recorded in the rocks of this region. Beginning with the first definite record, coarse sandstones and shales were deposited in early Cambrian time along the eastern border of the interior sea as it encroached upon the land. As the land was worn down and still further depressed, the sediment became finer, until in the Shenandoah limestone of the Cambro-Silurian period very little trace of shore material is seen. Following this long period of quiet was a slight elevation, which led to the distribution and deposition of the Silurian shales and sandstones, including the Rockwood formation. This deposit closes the record of the first great cycle. The land having been again worn down nearly to baselevel, conditions were afforded for the accumulation of the Lewistown limestone, which was in turn buried beneath the sands of a fluctuating beach line, the Monterey sandstone. The deposition of this sandstone marks the passage from the Silurian to the Devonian period and the close of the second cycle. The land at the beginning of the Devonian period was low, but a slight uplift occurred, causing the erosion of the Monterey sandstone, at least locally. The next succeeding strata, the Romney black shales, record an epoch of very gradual deposition off the coast of a still baseleveled continent. They are followed, however, by coarser shales, and these by sandstones, to a thickness of more than 7,000 feet, showing that the adjacent land was raised to a considerable elevation and was vigorously eroded by swift streams. This deposit culminated in coarse sandstone, the lowest formation of the Carboniferous period, and the degradation of the continent, which had in Devonian time ceased to rise, resulted in the deposition of shales, followed by limestones. Thin streaks of coal in the shales are evidence of the beginning of marshes with luxuriant vegetation, which later produced the coal beds of the Coal Measures.

The strata exposed in the area of the Staunton sheet have a thickness of about 10,000 feet. The order of succession of the limestones, shales, and sandstones, and their general characters, are given in the accompanying columnar section.

CAMBRIAN AND SILURIAN PERIODS.

Shenandoah limestone.—The eastern portion of the Staunton-sheet area lies in the Great Valley of Virginia, which is underlain by the Shenandoah limestone. This formation has a very great thickness and comprises several members. The lowest of these that comes to the surface is a thick series of dark-gray magnesian limestones, which are extensively exposed just west of Staunton. They grade upward into a series of lighter-colored beds, through which nodules and layers of chert are irregularly interspersed. The chert beds are of variable thickness and extent; the largest observed averages 30 feet thick and extends 4 miles. The chert gives rise to prominent ridges or knolls, of which the most conspicuous are Betsey Bell and Mary Gray, just southeast of Staunton, Sugar Loaf, Chestnut Ridge, and a line of knolls extending from Greenville through Round Hill to beyond Barterbrook. The chert is not always present in this member, and in many areas the limestones are not clearly characterized. The upper member of the Shenandoah limestone is a purer, more thickly bedded formation, generally also of lighter color, and very fossiliferous. Its thickness varies from 200 to 350 feet, and its lower boundary is not everywhere distinct. It extends along the foot of Little North Mountain to North River, but is cut out by the fault for several miles northward, is well developed on Dry River, covers a belt of moderate width extending around the slate area between Staunton and Churchville, and borders the great slate area east and south of Staunton nearly to Greenville, and then northeast through Barterbrook. It is finely exposed in the railroad cut 2 miles east of Staunton, where it is abundantly fossiliferous. Fossils occur also in greater or less profusion throughout its course. The fauna is that of the Trenton limestones of New York. Gasteropods of a slightly greater age occur in the chert series, but they are not abundant. No organic remains were found in the lowest series, but it is believed from evidence in other parts of the Great Valley region that a considerable thickness of its lower beds are Cambrian in age.

Martinsburg shale.—This formation occupies a wide area in the great syncline east of Staunton; a short, narrow strip in a syncline midway between Staunton and Churchville; a long, narrow belt extending for many miles along the eastern flank of the Little North Mountain on the western side of the Great Valley; and a small area in the middle of the Jack Mountain anticline.

The formation consists mainly of shales of gray and light-brown color, with occasional thin, sandy layers. In the region south and east of Staunton the sandy materials are conspicuous in the upper members, where some thin, gray and buff sandstone beds are included. Thin layers of impure limestone also occur in some localities, especially in the lower beds. At some places, notably along the railroad east of Staunton, the basal beds are buff and red shales, containing graptolites. The upper members of the formation are alternating shales and thin-bedded sandstones, which are beds of passage to the Massanutten sandstone. Along the western side of the Great Valley the shales are fine-grained and gray in greater part. The outcrop is continuous to North River, beyond which the shales are cut out by the fault, along which they reappear again for a short distance at Dry River. On the eastern slope of Little North Mountain the shales dip gently westward under the Massanutten sandstones. Their outcrops in the region are much obscured by sand and blocks of quartzite derived from the mountain crest above, but the road to Pond Gap affords an almost continuous exposure across to the fault on the west slope. Approaching Buffalo Gap, the beds gradually become overturned, and thence northward the dips are steeply to the eastward. The shales are finely exposed in this position east of Stribling Springs on the east slope of Buck Hill, and again along Dry River. The thickness of the formation in this belt south of Buffalo Gap is about 1,500 feet, at Stribling Springs 1,200 feet, and on Dry River 1,000 feet. In the wide area east of Staunton there is a thickness of at least 2,500 feet, but no precise determination was made.

West of the Little North Mountain the Martinsburg shales dip far beneath the surface, and although they rise in some of the intermediate anticlines, they do not present outcrops until Jack Mountain is reached. Here, in the heart of the mountain, a small stream cuts through the overlying Massanutten sandstone and exposes a few feet of the shale, which presents all the usual characteristics. The best exposures are along the road from Doe Hill to Monterey, where they occupy a narrow strip in the west slope of the mountain. The Martinsburg shales are usually sparingly fossiliferous. In the Jack Mountain exposures fossils are abundant, and the species are of Hudson age. Along the slopes of Little North Mountain, at Buck Hill and at Dry River, many of the beds afford casts or impressions of similar forms. In the beds east of Churchville and in the buff and red slates at the base of the formation in cuts 2 miles east of Staunton, Utica graptolites occur in considerable abundance.

Massanutten sandstone.—This formation consists of hard sandstone and quartzite, which give rise to Little North, Jack, and Walkers mountains, Sideling and Buck hills, and a short ridge on Dry River. The most prominent member is a hard, massive quartzite, usually white or gray in color, which outcrops in high cliffs or steep slopes at the crest of the mountains. This member is underlain by a considerable thickness of red or brown, thinner-bedded sandstone and quartzite, which merge into sandy beds of Martinsburg shale. The relative amounts of these two members are variable, and there are frequent local varieties in color, hardness, and thickness of beds.

The thickness of the formation varies considerably; but as there are in the region few exposures where a reliable section could be measured, there is some uncertainty as to the amount. In Jack Mountain there is a fairly complete series of exposures from the Martinsburg shale in the center of the ridge to the Rockwood formation on the west, and here the thickness is about 600 feet. In Little North Mountain the amount is about the same, or possibly slightly more. At Buffalo Gap the exposure is not over 500 feet. Along the fault northward from Buffalo Gap the beds are generally cut out, but in Buck Hill, near Stribling Springs, they are again exposed, with a thickness of 450 feet. At North River and northward for 10 miles they are entirely cut out by the fault, but in the outlying ridge, beginning at Dry River, they come in again locally, with a thickness of 700 feet.

Fossils are not abundant in the Massanutten formation in the area of the Staunton sheet, but a few impressions of shells are found in dark, shaly beds in Little North Mountain, about 200 feet above the Martinsburg shales.

Rockwood formation.—The upper member of the Massanutten sandstone merges upward into a series of red to gray sandy shales and thin-bedded sandstone, capped in part by a light-colored quartzite, which have been delineated on the map as the Rockwood formation. The strata extend along both flanks of Jack and Walkers mountains, Sideling Hill, and Black Oak Ridge, and along the western slope of Little North Mountain, Buck Hill, and the ridge north of Dry River; and they constitute Brown Ridge (the low anticlinal ridge on the western slope of Little North Mountain) and several anticlinal ridges between Bull Pasture and Jack mountains. They are cut out by the fault a short distance north of Buffalo Gap and for some distance in the vicinity of Pond Gap. The thickness varies from 150 to 200 feet, but averages about 150 feet in greater part.

The formation presents an unusual character in the Staunton area, in containing relatively little of the iron-bearing shales which are prominent in other regions not far distant to the north and south. The predominance of coarse, sandy beds is nearly everywhere conspicuous, and but little shale was observed. The cap of light-colored quartzite is the most characteristic feature of the formation, and it attains considerable thickness south and west of Pond Gap. It is also well represented to the northwestward, but is much darker-colored and often intermixed with softer beds.

Lewistown limestone.—The Lewistown limestone is exposed over a relatively large area in the Bull Pasture Mountain and the hills between the Bull Pasture River and Jack Mountain, and it also occurs in narrow outcrops skirting Walkers and Little North mountains and Brown and Black Oak ridges. It attains its greatest development in the Bull Pasture Mountain and westward, where its thickness is uniformly about 550 feet, and its outcrop constitutes high and somewhat rugged hills, generally flanked by rough ridges of Monterey sandstone and traversed by craggy ridges of the upper member of the Rockwood formation. In this region it is generally a pure, thickly bedded, fossiliferous limestone, with cherty members in its upper part, and containing occasional sandy beds and calcareous shales.

In the flanks of Walkers Mountain the thickness is about 350 feet, and the rocks consist of thickly bedded, pure limestone below and from 75 to 100 feet of cherty limestone beds above. In Brown and Black Oak ridges its outcrop is prominent, and in a fine cross-section exposure on the road to Bells Valley its thickness was found to be 400 feet, of which the upper 30 feet are cherty beds. It here lies directly on the white quartzite of the Rockwood formation, from which it is separated elsewhere by a few feet of transition members. Along the slopes of Little North Mountain the limestone is seldom seen, but its position is indicated by a débris-covered depression. It has also been exposed at one or two points by excavations for iron ore. Near Ferrol there is a complete cross-section opened, in which 200 feet of pure limestone was measured, and at Buffalo Gap there are several partial exposures in which about 150 feet of thickly bedded, pure limestone is seen. Near Stribling Springs there is a complete but somewhat indistinct cross-section in which the thickness is not over 80 feet, but it is probable that the fault traverses the limestone in this section and cuts out a portion of its members. The limestone is nearly everywhere fossiliferous, especially in its middle beds.

DEVONIAN PERIOD.

Monterey sandstone.—This sandstone is most conspicuous in the Bull Pasture Mountain and the region adjoining Jack Mountain, where it flanks the high hills of Lewistown limestone. It also constitutes a series of subordinate ridges adjacent to Walkers Mountain and Sideling Hill, and occurs less conspicuously in Black Oak and Brown ridges and along the western slope of the Little North Mountain.

The formation is usually represented by a buff, fine-grained, massive sandstone, which often varies from granular to vitreous or semi-vitreous texture. Much of the rock is characterized by an abundance of casts and impressions of fossils. In the Bull Pasture and Jack Mountain region the thickness averages about 150 feet, but the formation thins rapidly to the southeastward, and finally in some localities it is entirely absent, owing to an unconformity by erosion. This unconformity attains its maximum degree in the northeastern corner of Rockbridge County, where the Romney shales lie either on a small thickness of the sandstones or directly on the more or less deeply eroded surface of the underlying Lewistown limestone. In Highland and Pendleton counties, where the formation is thick, it is sharply separated from the shales, but there is no direct evidence of unconformity.

Along the base of Black Oak and Brown ridges the formation usually has a thickness of 25 to 30 feet, but east of Bells Valley the amount is less, and it is in this vicinity that it has been entirely removed at some points along the unconformity.

On the western slope of the Little North Mountain the formation is in greater part represented by deposits of limonite iron ore, more or less mixed with sand, but containing much ore of excellent quality. These deposits have been worked on the Esteline and Ferrol properties and at Buffalo Gap.

The restriction of the occurrence of the iron ore to the Little North Mountain area and the presence of the maximum amount of unconformity just west, probably reveal an interesting item in the geologic history. It is thought that the zone of greatest unconformity indicates a land area, which persisted so long that the Monterey formation was deeply eroded. To the east the land was out of water in what is now the Little North Mountain region, and the iron ores accumulated as bog deposits on the more or less completely bared limestone surface. The thickness of the formation and its ores in this belt could not be satisfactorily determined. North from Buffalo Gap the formation is cut out by the great fault, and its only reappearance along the fault line is at Stribling Springs, where a small thickness is exposed.

Romney shales.—Immediately overlying the Monterey sandstone there is an extensive series of dark shales in which valleys of greater or less width are excavated. These shales extend along the western side of Little North Mountain, around the Black Oak and Brown ridges, Walkers Mountain, and Sideling Hill, up the headwaters of the Cow Pasture, Bull Pasture, and Dry rivers, and along the South Fork, White Thorn, and Black Thorn; there are also several small outlying areas in the Bull Pasture Mountain and westward. The formation underlies the Great North and Shenandoah mountains, but is deeply buried beneath the overlying strata.

The rocks consist of dark shales, black and fissile below, but somewhat lighter and more compact above. Some of the basal beds are carbonaceous to a moderate 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 calcareous streaks not far from its base, and the upper members contain alternations of thin, pale-brown or dark-buff sandy beds, which constitute beds of passage into the next succeeding formation. The vertical range and stratigraphic position of these passage-beds appear to be somewhat variable, so that there is no definite line of demarcation between the two formations. Owing to this fact, no precise thickness can be assigned for the Romney beds, but they average from 700 to 1,000 feet in the slopes of the Great North and Shenandoah mountains. In the region west there remain only portions of the lower members. These have a thickness of about 500 feet in the Bull Pasture Valley.

Jennings formation.—The Romney shales grade upward into the Jennings formation, which extends far up the slopes of the Shenandoah and Great North mountains and constitutes Shaws Ridge and the line of hills extending along the eastern side of Lookout and Narrowback mountains. The thickness of the formation is about 3,000 feet. The rocks are light-colored shales, in which olive-gray and buff tints predominate, with interbedded light-colored sandstones, some of which are moderately thick-bedded. The local sequence of beds is somewhat variable. The medial members contain a predominance of the arenaceous materials. Some of the heavier sandstone beds have strongly developed concretionary structure, a feature which is well exhibited in Jennings Gap, the locality from which the formation derives its name. The upper members are predominantly shaly or of fine-grained, light-colored, argillaceous deposits, which break up into small, angular fragments on weathering. The upper limits of the formation are not well defined, for there is an extensive series of beds of passage to the next succeeding formation. It is on account of the indefiniteness of the limits of this formation that its boundary on the map is shown by a zone in which the pattern is merged into those of the adjoining formations.

Hampshire formation.—The Hampshire formation occupies the upper slopes of the Great North and Shenandoah mountains, the eastern slope of Narrowback Mountain, and the greater part of the wild ridges at the headwaters of North River and Briery Branch. Its average thickness is about 1,300 feet. The rocks are largely thin-bedded, hard, red, gray, or brown, micaceous, slabby sandstones, with intercalated masses of ocherous shale which are in greater part of dull-red, dark-gray, and brown color. Occasional streaks of conglomerate also occur. There are many local variations in the character of the beds, but northward there is a general tendency to an increase in hardness of the sandstones. Some of the shales are in thick masses, and present bright-red and rich-brown tints. The finest exposures of the formation are on the two roads across the Shenandoah Mountain and in Dry Branch and North River gaps.

No fossils were found in the Hampshire formation, except a few plant fragments of indeterminate character.

CARBONIFEROUS PERIOD.

Pocono sandstone.—This sandstone caps the highest summits of the Great North Mountain and the Shenandoah Mountains near Briery Branch Knob, and constitutes the crest and spurs of Narrowback Mountain. There is also a small area on the divide at the head of Ramsey's "draft."

The principal member is a heavily bedded white or buff quartzite, which is sometimes slightly conglomeratic. Its greatest thickness is about 300 feet. In the depression behind Narrowback Mountain occurs an upper member of the formation, consisting of a series of softer, coal-bearing sandstones and shales. These coal beds have attracted considerable attention locally and produced small supplies of a semi-bituminous coal of good quality, but they are very thin, irregular in extent, and so badly crushed as to have no wide economic importance. The coal is best exposed in the workings at North River Gap, but it occurs also at various points northward on the western slope of the mountain. There are several coal beds which vary from an inch to nearly 2 feet in thickness intercalated with thinner slaty seams in the sandstones. The structure of this region is a syncline with very gentle dips on the east side, which carry the sandstone far westward on the spurs. The beds are squeezed in the center of the flexure and sharply overturned on its eastern side. The coal measures are involved in the overturns and crumples, and for this reason the coals are crushed.

The formation attains its greatest thickness in the vicinity of North River Gap, where the total amount is about 750 feet. On the summit of Shenandoah Mountain the cap lies in a shallow syncline and consists of 250 feet of white, quartzitic sandstones. The caps of white quartzite on Elliotts Knob and Crawford Mountains are thin, and lie in the axis of the same syncline which extends along Narrowback Mountain.

The fossil remains so far observed consist only of plants in the coal-bearing sandstone and overlying shale near North River Gap. They are of Lower Carboniferous age.

IGNEOUS ROCKS.

Three small exposures of volcanic rocks have been discovered in the Staunton area, and there are a number of others in the region west. They are dikes which, while in a molten condition have been intruded into narrow cracks across the beds of sedimentary rocks. The rock is black, crystalline, and heavy, and weathers to a dull-red color, strikingly in contrast with the formations which it penetrates. The largest mass is three-quarters of a mile west-southwest of Doe Hill, in a knoll a few yards north of the road to Jack Mountain. It outcrops in a small cliff and extends across the Monterey sandstone and Lewistown limestone. Its width is about 20 feet and it could be traced only a few yards along its course, which is from northwest to southeast.

There is an obscure exposure of the rock in the road $2\frac{1}{2}$ miles due north of Doe Hill, in Romney shales, and another in Lewistown limestone the same distance due northeast of Doe Hill, near the road which extends northwest from Palo Alto. They appear to be very small dikes. Possibly there are others in the same region. The rocks are of the holocrystalline, porphyritic type of basalt, with some slight local differences in character. They have been mistaken for iron ore, but contain no useful amount of the metal.

STRUCTURE.

Definition of terms.—As the materials forming the rocks of this region were deposited upon the sea bottom, they must originally have 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 *fault*. 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. 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 and faults of the ordinary type, rocks change their form mainly by motion on the bedding planes. In the more minute dislocations, however, the individual fragments of the rocks are bent, broken, and slipped past each other, causing *cleavage*. Extreme development of these minute dislocations is attended by the growth of new minerals out of the fragments of the old—a process which is called *metamorphism*.

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 faults, and to some extent altered into slates. In the mountain district faults and folds are important features of the structure, but cleavage and metamorphism are equally conspicuous.

The folds and faults of the valley region are 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 most folds continue at 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 sides of the folds are compressed 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.

Faults were developed in the northwestern sides of synclines, varying in extent and frequency with the changes in the strata. With very few exceptions the fault planes dip toward the southeast, and are 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 are rare and small. Passing 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 faults. 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 faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

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.

The structures above described are the result chiefly of compression, which acted in a north-west-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 period.

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.

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.

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.

Faults are represented on the map by a heavy, solid or broken line, and in the section by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have been moved on its opposite sides.

The structure of the Staunton area.—The principal features of this area are illustrated by the three structure sections on the structure sheet.

There are four general structural provinces in the region: the syncline east of Staunton, the great anticline in the Shenandoah limestone belt, the wide synclinal region of Great North and Shenandoah mountains, and the anticlinal uplift which culminates in Jack Mountain. These general flexures bear subordinate corrugations of various degrees, which give rise to features of greater or less prominence. The axes of these flexures are all northeast and southwest. There is an overthrust fault extending along the western side of the anticline of the Great Valley for many miles, and there are other overthrusts to the eastward in the limestone.

The syncline east of Staunton is the southward extension of the flexure in which the Massanutten Mountain lies, and it holds a great mass of Martinsburg shales. The dips are moderately steep, but they are variable in amount, and there are many small crumples. The anticline of the Shenandoah limestone belt in the valley bears many minor flexures and is traversed by several faults of greater or less amount. East of Staunton there is a low anticline, which gives place at Staunton to steep easterly dips, which continue over a wide zone to the westward. In this portion of the uplift the lowest beds of the series are brought up. To the westward there is a syncline of considerable extent, which contains a small area of Martinsburg shale between Staunton and Churchville, and a mass of chert in Sugar Loaf.

At the western edge of the Great Valley, to the southward, the limestones dip gently [illegible] the west and pass beneath the Martinsburg [illegible] in the eastern face of Little North Mountain. This mountain is a gently west-dipping monocline of the eastern side of the great central syncline. It bears a number of small corrugations, which give rise to the "Double of the Mountain," Black Oak and Brown ridges, and some intermediate ridges. At Pond Gap the arch of the first of these corrugations is broken by a fault, which extends for a short distance along the western slope of the mountain and brings the Massanutten and Romney shales in contact near the road to Pond Gap station. Near Buffalo Gap the western dips rapidly increase in steepness and the monocline is finally overturned. The dips in the overturn are steeply to the eastward, and these dips continue northward all along the western side of the valley. An overthrust fault develops in this overturn near Buffalo Gap, and it extends northward to and through Rockingham County. The amount of its throw varies considerably; for 12 miles the lower portion of the Massanutten sandstone is overthrust on the Romney shale, except near Stribling Springs, where the Monterey sandstone and the Lewistown limestone come in for a short distance along the west slope of Buck Hill. North of the hill the Martinsburg shale lies against the Romney shale, and then, with an increase in the amount of throw, the Shenandoah limestone is brought against the lower members of the Jennings formation. Near Dry River the amount of overthrust decreases, and Martinsburg shale and Massanutten sandstone come in successively east of the fault, and the Romney shale west of it. From North River northward, the overturning of the beds deepens and extends westward to Narrowback Mountain, in which the Pocono sandstones dip steeply eastward.

The great central synclinal belt is a region of gentle dips, except along the overturned eastern edge, as above described, and constitutes a very deep basin containing a thickness of over 5,000 feet of Devonian sediments, with several areas of Pocono sandstones. The general flexure bears an anticline along its middle, which is flat and low to the northward but rises and bifurcates to the southward, bringing up the Massanutten sandstone in Walker Mountain and Sideling Hill. The axis of the eastern subbasin is along the Great North Mountain and the valleys just west of Narrowback Mountain, and the western subbasin holds the great mass of sediments in Shenandoah Mountain.

The general anticline which lies west of Shenandoah Mountain bears a series of long, narrow, parallel corrugations of greater or less amount. The deepest of these is a syncline which holds a belt of Romney shales along the valley of Bull Pasture River, and the highest is Jack Mountain, in which the Massanutten sandstones are brought high above the surface and the top of the Martinsburg shale is exposed.

Bull Pasture Mountain is an anticlinal corrugation, and there is another similar flexure in the next ridge west. Just east of McDowell there is a local slip in one of the flexures which brings Romney shales into contact with Lewistown limestone for a short distance.

MINERAL RESOURCES.

The mineral resources of the region are iron ore, marble, lime, brick-clays, flux, and coal. At present the production of these materials is very small and many of the works are abandoned.

Iron ore.—Iron ores were formerly worked to a considerable extent at several points along the western slope of Little North Mountain. There were furnaces at Buffalo Gap and Ferrol and near Pond Gap. The ore occurs at intervals along the mountain slope, and it constitutes the greater part of the Monterey sandstone formation in that vicinity. Its beds are often of considerable thickness, and the ore is of excellent quality. It outcrops on the surface at several points, and has been extensively explored by trial pits and trenches. There are small showings of ore in the Monterey sandstones west of Little North Mountain, but no large deposits have been discovered.

Marble.—The Shenandoah and Lewistown limestones are often suitable for marble, but the only attempts at its production have been in the Lewistown limestone at Craigsville and Bells Valley. The quarries at Craigsville were moderately extensive, but the marble there was found to be too soft and broken for profitable working.

Lime.—The limestones are quarried and burnt for lime for local use at many localities. The largest quarries are at Swoope, where lime is produced for shipment.

Clays.—Many areas of the Great Valley are mantled with clays suitable for bricks and other products, but they are not worked to any great extent. Bricks are made in small amount near Staunton and at various minor points for local use, and at the Virginia Clay Works a variety of products have been manufactured.

Flux.—The iron ores Little North Mountain are underlain by Lewistown limestone, and at Ferrol and Buffalo Gap this was quarried for flux. The supply of this material is very large and its quality was found to be good.

Coal.—A semi-anthracite coal has been mined to a moderate extent in North River Gap, and the supply is sufficient for local use. The beds are thin and the coal is often much crushed, but it is not difficult to obtain small supplies. Several attempts to find thicker beds have been made by excavations and deep diamond-drill borings, but without success.

SOILS.

The soils of the region are closely related to the underlying rocks, for they are in greater part the residuary products of the rock decay. The exceptions are on the flats along the streams, where there are mixtures of various materials derived from the higher lands, brought down largely at times of freshet, and the wash and talus on slopes. These exceptions are relatively unimportant, as such soils occupy but small areas. Soils are also affected by topography, for on steep slopes they are thin and unusually sandy. Limestones and the purer shales give rise to clay soils; the sandstones and sandy shales, to sandy soils; and the finer stream deposits are sands or sandy loams. Owing to the frequent variations in character of the rocks in nearly all the formations, there are corresponding changes in the character of the soils derived from them, but on the whole the general relations of rock and soil are so intimate that the geological map of the region is also a soil map for the principal types of soil. These types are limestone soils, shale soils, and sandstone soils; and there are also the alluvial soils.

Limestone soils.—The soils of the Great Valley belong to this class in greater part, for they are the residual products of the decay of the rocks of the Shenandoah Valley. In the Bull Pasture Mountain and the ridges westward also there are limestone soils in the Lewistown limestone areas. The soils of the Great Valley present considerable variability, but on the whole the region is a very fertile one. There are areas in which the residual clays are rather too stiff for fertility; portions of the cherty areas are too stony, and the rocks are often bare; but these areas are not relatively large. The Bull Pasture Mountain region is steep, and consequently somewhat rocky, but the narrow limestone areas are of great fertility. They are used mainly for pasture lands and natural blue-grass districts. The limestone areas adjoining Walker Mountain, Sideling Hill, and Brown and Black Oak ridges are very narrow and largely overwashed with sandy detritus, but there are a number of small fertile tracts along them.

Shale soils.—The Martinsburg shale area east of Staunton has shale soils in greater part, and they are of considerable fertility. In the districts in which there are limestones interbedded with the shales the soils are of great fertility.

The Romney shale soils are not very fertile, except at a few points where there are calcareous beds included in the series. As the formation occupies the valleys, it is often overlain by alluvial deposits. There are many moderately fertile tracts of this character, notably the Bull Pasture Valley in the vicinity of McDowell.

The shales of the Jennings and Hampshire formations are very barren, and as they lie mainly on the steep slopes of the mountains they are mostly bare of soil.

Sandstone soils.—The Massanutten, Rockwood, Monterey, Hampshire, and Pocono sandstones produce the thin, barren soils of the mountains, and these soils characterize all the more elevated areas of the western portion of the region. Much of the land is steep and rocky and is not farmed to any material extent.

Alluvial soils.—Nearly every stream in the Great Valley and among the mountains has deposited a greater or less amount of alluvium along portions of its source, and these deposits are usually very fertile. They are sandy loams in large part, but present many local variations in proportions of sand, clay, and gravel. Along the smaller streams the deposits are often too narrow and too pebbly to be of service to the farmer, but in the larger valleys there are many moderately wide areas. Those along the South River Valley and adjacent to the North and Dry rivers are the most extensive, and the Bull Pasture and Cow Pasture valleys contain much land of this character. Nearly all the farms in the mountain region are on alluvial soils in the shale valleys, and many of these lands are notably fertile.

NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		Names which have been used by Various Writers.	Names used by H. D. Rogers.	Numbers used by W. B. Rogers.
Carb.	Cp	Pocono sandstone.	Pocono.	Vespertine.	X.
Devonian	Dh	Hampshire formation.	Catskill.	Ponent.	IX.
	Dj	Jennings formation.	Chemung.	Vergent.	VIII.
	Dr	Romney shale.	Hamilton.	Cadent.	
Silurian	m	Monterey sandstone.	Oriskany.	Meridian.	VII.
	Sl	Lewistown limestone.	Lower Helderberg.	Pre-meridian.	VI.
	Sr	R..kwood formation.	Clinton.	Surgent.	V.
	Sm	..sanutten sandstone.	Medina.	Levant.	IV.
	Sm.	Ma..tinsburg shale.	Hudson River.	Matinal.	III.
	Ss	Shenandoah limestone.	Valley limestone.	Auroral.	II.

N. H. DARTON,
Geologist.

COLUMNAR SECTION.

GENERALIZED SECTION FOR THE STAUNTON SHEET.

SCALE: 1000 FEET = 1 INCH

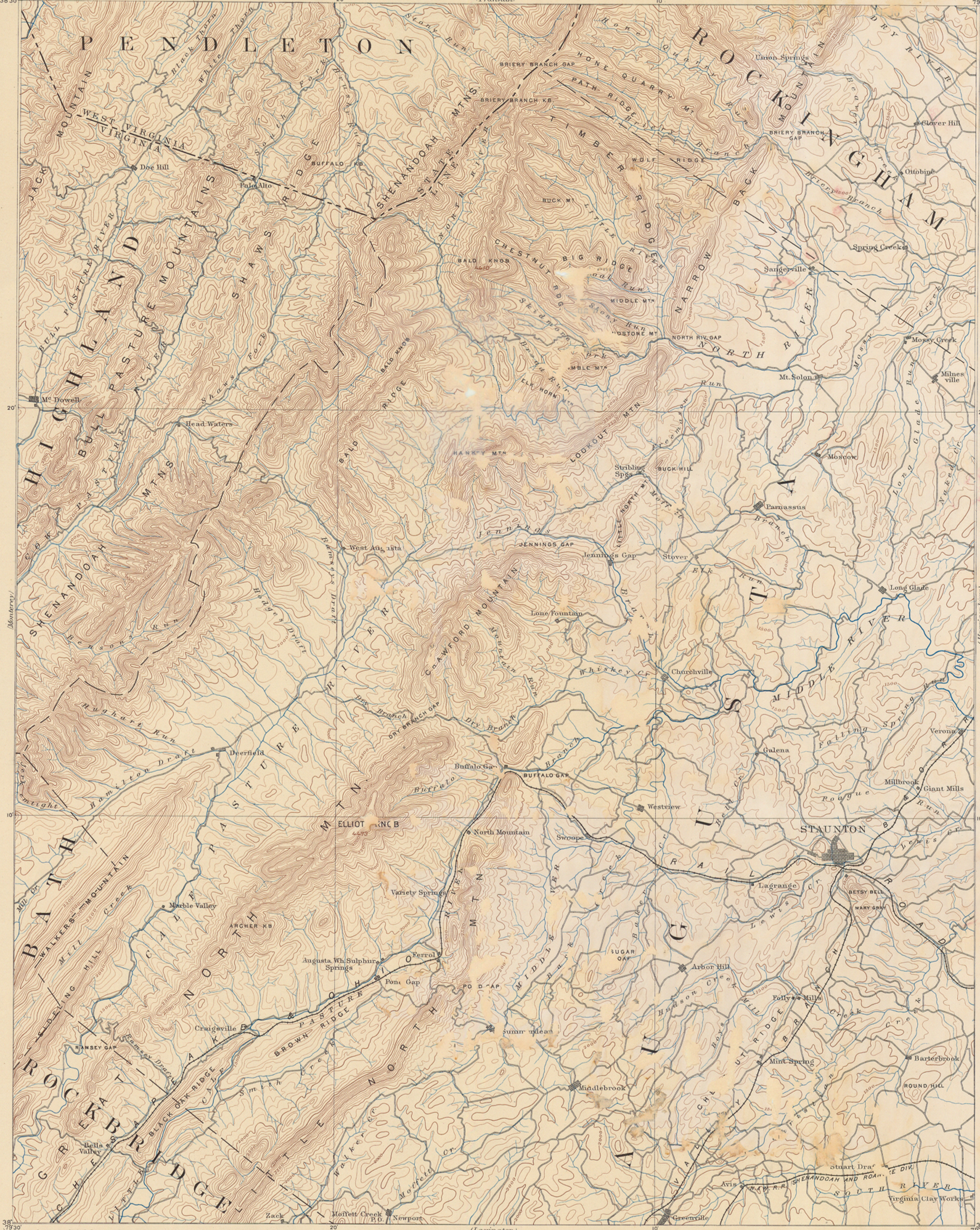
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARB.	Pocono sandstone.	Cp		700+	Shale. Coarse sandstone of light color, with sandy shale and thin coal beds.	Sharp ridges, with thin, sandy, and rocky soils.
DEVONIAN	Hampshire formation.	Dh		1000–1400	Thinly bedded, gray and reddish sandstone, with more-massive beds of fine-grained sandstone, all interbedded with thin layers of shale.	High mountains, with thin, sandy soils.
	Jennings formation.	Dj		2800–3400	Shales, varying from olive color to buff, interstratified with massive, mainly fine-grained sandstone.	Mountain slopes and moderately high ridges, with thin, sandy soils.
	Romney shale.	Dr		600–1000	Dark shale, bl..k below.	Wide valleys and low, rounded ridges. Thin soils, usually clayey. The valleys usually contain alluvial deposits of varying width.
SILURIAN	Monterey sand..tone.			0–300	San.. ..n part ..lcareo..s.	Knobs and ridges along the base of higher hills.
	Lewistown lim..tone.	Sl		300–500	Cherty limestone. Pure limestone.	Knobby ridges and elevated valleys. Thin but rich soils.
	Roc..ood form..	Sr		150–200	Gray quartzite. Sandy shale.	Mountain slopes, overplaced by sandy soils.
	..as..nutten sand..tone.	Sm		500–600	Reddish sandstone. Gray quartzite. Red and gray sandstones.	High rocky ridges, with thin, sandy soils.
	Ma..	Smb		800–1400	Gray shale, with sandy beds above and calcareous beds below.	Low, rounded hills in the Appalachian Valley, and the eastern slope of Little North Mountain. Thin, sandy clay-soils.
	Shenandoah limestone.	Ss		1500+	Massive fossiliferous limestone. Cherty limestone. Dolomitic (magnesian) limestone, varying from light gray to dark gray.	Moderately steep ridges in the Appalachian Valley. The undulating surface of the Appalachian Valley, with clay-soils of variable depth.

U.S.GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR

TOPOGRAPHY

VIRGINIA-WEST VIRGINIA
STAUNTON SHEET

(Beverly) 38°30' 79°30' 20' (Franklin) 10' 79° 38°30' (Woodstock)



LEGEND

RELIEF
(printed in brown.)

4410

Figures
(showing exact heights above mean sea-level.)

Contours
(showing height above sea, horizontal form, and steepness of slopes of the surface.)

DRAINAGE
(printed in blue.)

Rivers

Creeks

CULTURE
(printed in black.)

Towns

Railroads

Roads

Trails

State lines

County lines

38° 79°30' 20' (Lexington) 10' 79° 38° (Natural Bridge) (Buckingham)

Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in Charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by L.C. Fletcher.
Surveyed in 1886-7

Scale $\frac{1}{125000}$

0 1 2 3 4 5 6

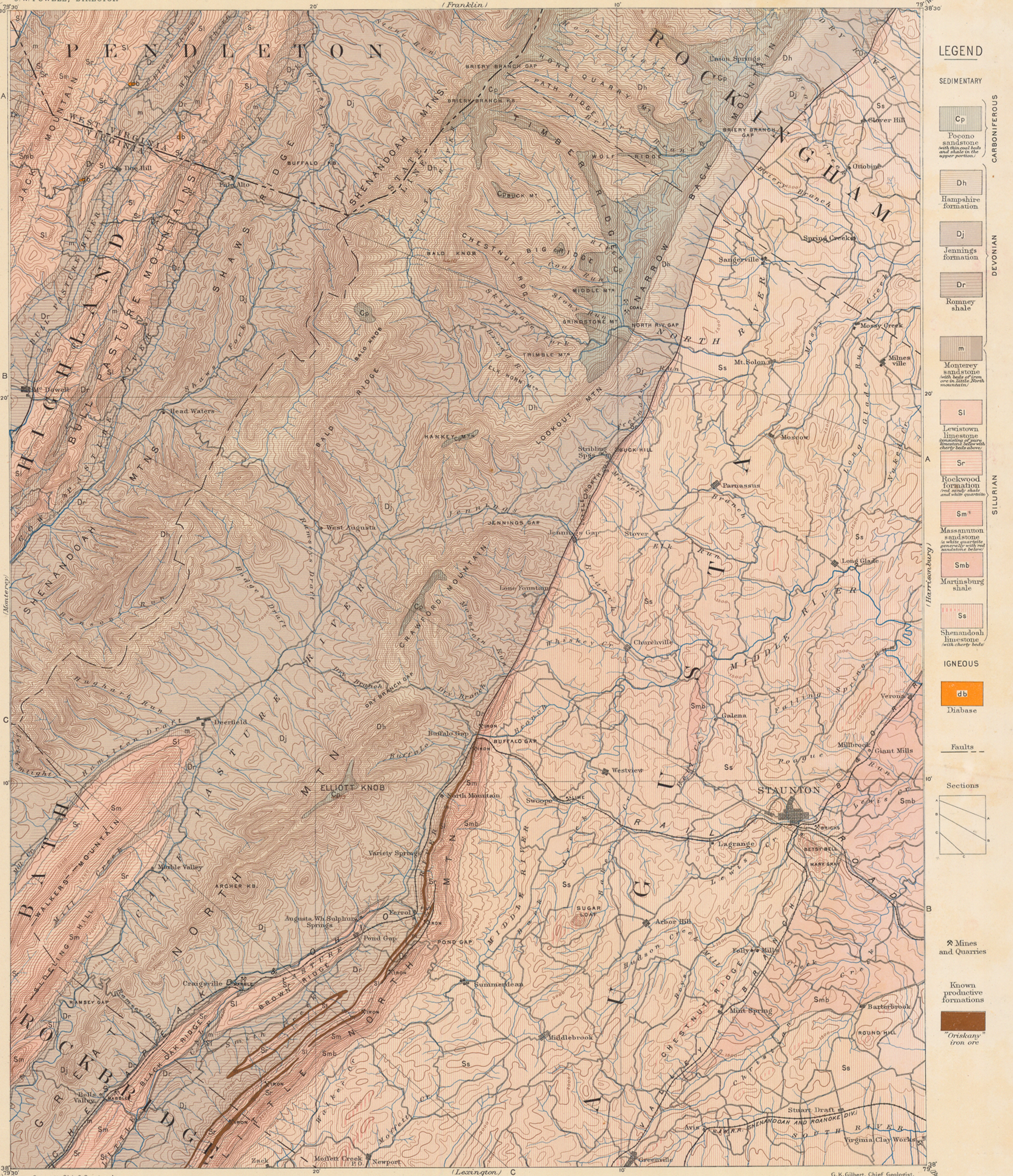
Contour Interval 100 feet
Datum is mean Sea level

Edition of Sept. 1894

U.S. GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

ECONOMIC GEOLOGY

VIRGINIA-WEST VIRGINIA
STAUNTON SHEET



Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in Charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by L.C. Fletcher.
Surveyed in 1886–7

Scale $\frac{1}{125,000}$

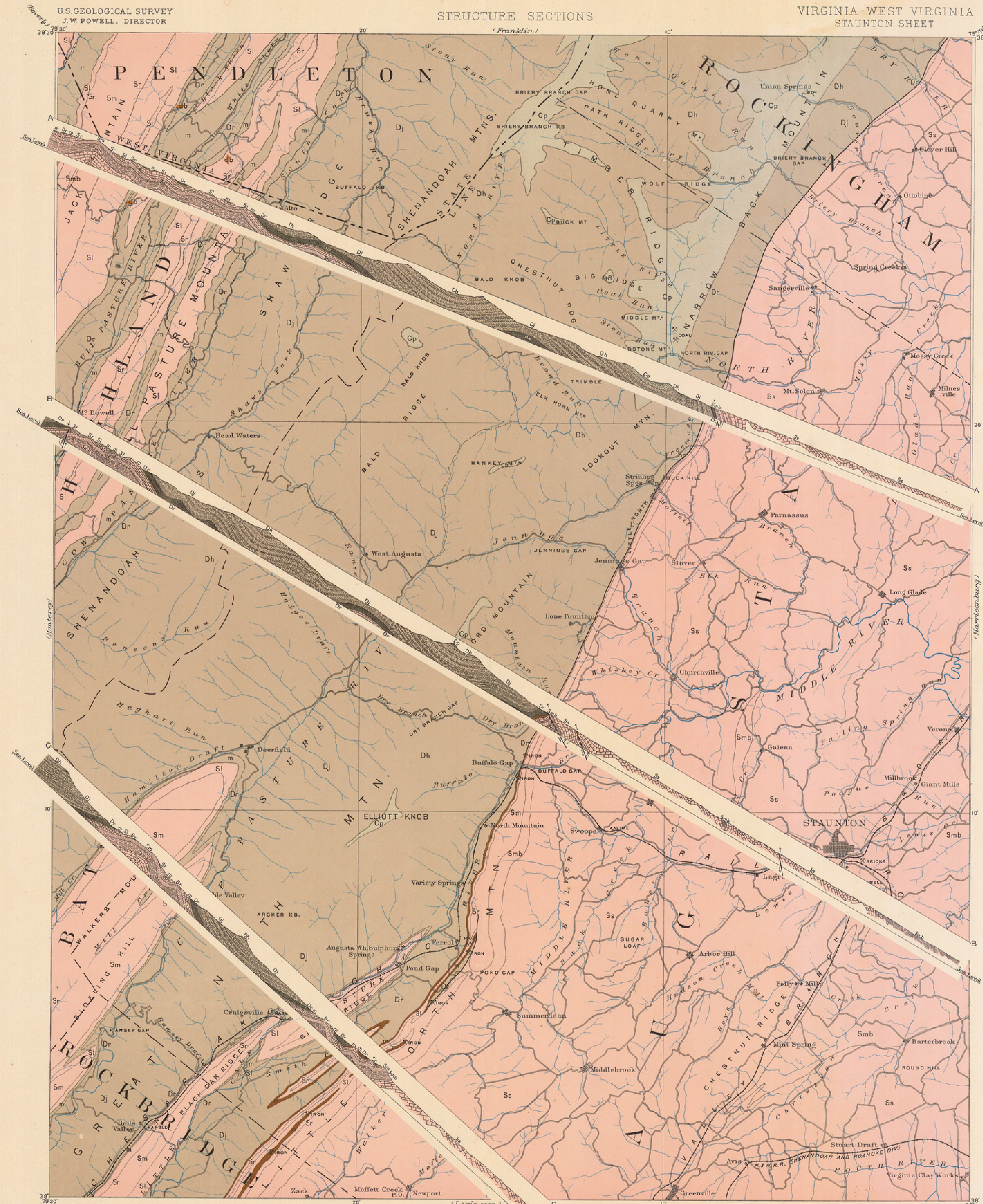
0 1 2 3 4 5 6

Contour Interval 100 feet
Datum is mean Sea level
Edition of Sept. 1894.

G. K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in Charge.
Geology by Nelson H. Darton.
Surveyed in 1888 & 1889

U.S. GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

STRUCTURE SECTIONS



LEGEND

SEDIMENTARY

CARBONIFEROUS

Cp — Pocono sandstone (with thin coal beds and shale in the upper portion)

DEVONIAN

Dh — Hampshire formation

Dj — Jennings formation

Dr — Romney shale

m — Monterey sandstone (with beds of iron ore in Little North mountain)

SILURIAN

Sl — Lewistown limestone (consisting of pure limestone below with cherty beds above)

Sr — Rockwood formation (red sandy shale and white quartzite)

Sm — Massanutton sandstone (a white quartzite generally with red sandstone below)

Smb — Martinsburg shale

Ss — Shenandoah limestone (with cherty beds)

IGNEOUS

db — Diabase

Faults

Mines and Quarries

Known productive formations

"Oriskany" iron ore

Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in Charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by L. C. Fletcher.
Surveyed in 1886–7

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6

Contour Interval 100 feet
Datum is mean Sea level

Edition of Sept. 1894.

G. K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in Charge.
Geology by Nelson H. Darton.
Surveyed in 1888 & 1889

U.S. GEOLOGICAL SURVEY
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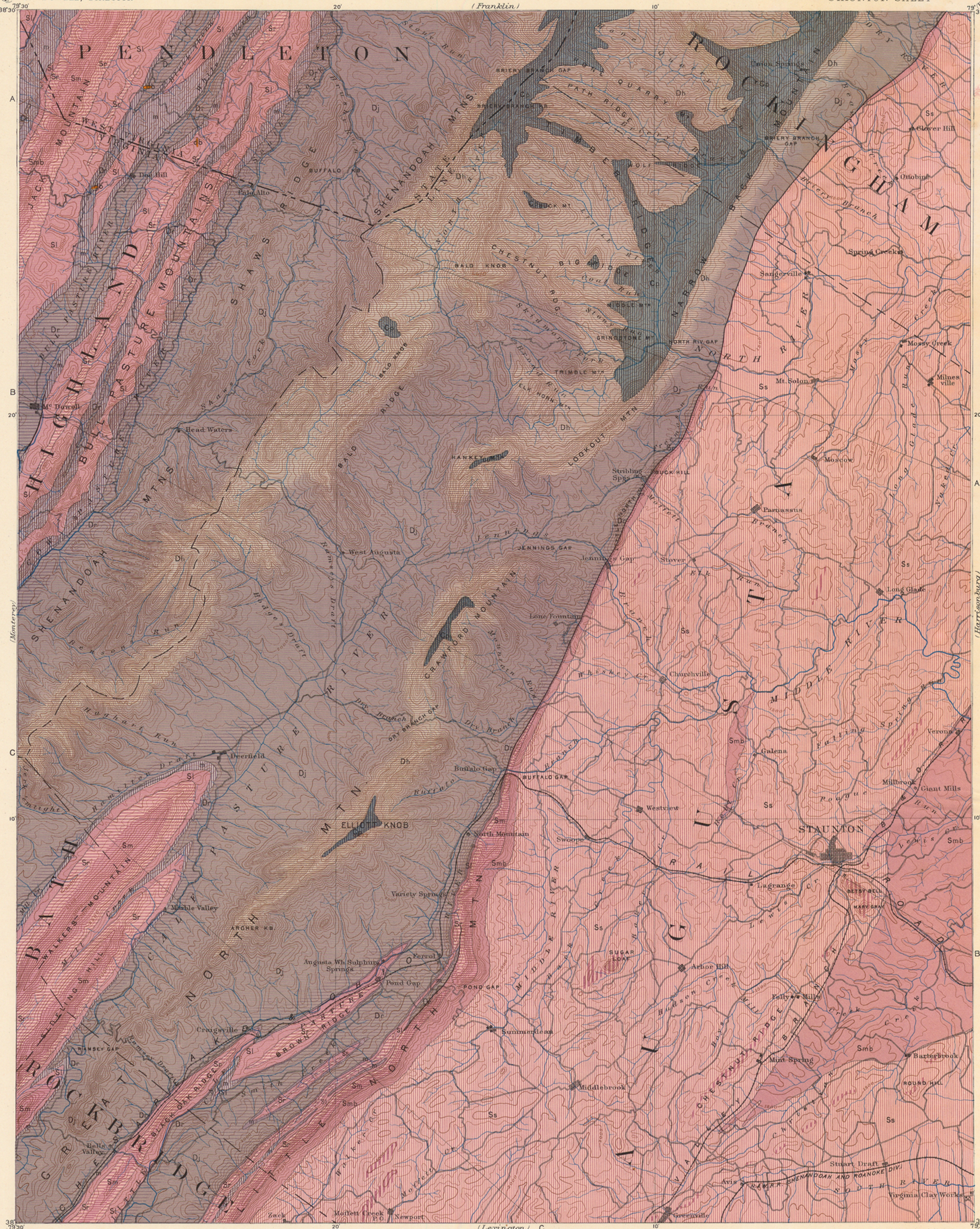
AREAL GEOLOGY

VIRGINIA-WEST VIRGINIA
STAUNTON SHEET



LEGEND

SEDIMENTARY

CARBONIFEROUS

- Cp — Pocono sandstone *(with thin coal beds and shale in the upper portion)*

DEVONIAN

- Dh — Hampshire formation
- Dj — Jennings formation
- Dr — Romney shale

SILURIAN

- m — Monterey sandstone *(with beds of iron ore in Little North mountain)*
- Sl — Lewistown limestone *(consisting of pure limestone below with cherty beds above)*
- Sr — Rockwood formation *(red sandy shale and white quartzite)*
- Sm — Massanutton sandstone *(a white quartzite generally with red sandstone below)*
- Smb — Martinsburg shale
- Ss — Shenandoah limestone *(with cherty beds)*

IGNEOUS

- db — Diabase

Faults

Sections

Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in Charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by L.C. Fletcher.
Surveyed in 1886–7

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6

Contour Interval 100 feet
Datum is mean Sea level
Edition of Sept. 1894.

G.K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in Charge.
Geology by Nelson H. Darton.
Surveyed in 1888 & 1889

pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

It is thought that the first rocks of the earth, which formed during what is called the Archean period, were igneous. Igneous rocks have intruded among masses beneath the surface and have been thrown out from volcanoes at all periods of the earth's development. These rocks occur therefore with sedimentary formations of all periods, and their ages can sometimes be determined by the ages of the sediments with which they are associated.

Igneous formations are represented on the geologic maps by patterns of triangles or rhombs printed in any brilliant color. When the age of a formation is not known the letter-symbol consists of small letters which suggest the name of the rocks; when the age is known the letter-symbol has the initial letter of the appropriate period prefixed to it.

(4) *Altered rocks of crystalline texture.*—These are rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized.

Both sedimentary and igneous rocks may change their character by the growth of crystals and the gradual development of new minerals from the original particles. Marble is limestone which has thus been crystallized. Mica is one of the common minerals which may thus grow. By this chemical alteration sedimentary rocks become crystalline, and igneous rocks change their composition to a greater or less extent. The process is called *metamorphism* and the resulting rocks are said to be metamorphic. Metamorphism is promoted by pressure, high temperature and water. When a mass of rock, under these conditions, is squeezed during movements in the earth's crust, it may divide into many very thin parallel layers. When sedimentary rocks are formed in thin layers by deposition they are called *shales;* but when rocks of any class are found in thin layers that are due to pressure they are called *slates.* When the cause of the thin layers of metamorphic rocks is not known, or is not simple, the rocks are called *schists,* a term which applies to both shaly and slaty structures.

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

Metamorphic crystalline formations 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 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 only.

USES OF THE MAPS.

Topography.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage and culture of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable.

It may guide the traveler, who can determine in advance or follow continuously on the map his route along strange highways and byways.

It may serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold.

It may save the engineer preliminary surveys in locating roads, railways and irrigation ditches.

It provides educational material for schools and homes, and serves all the purposes of a map for local reference.

Areal geology.—This sheet shows the areas occupied by the various rocks of the district. On the margin is a *legend,* which is the key to the map. To ascertain the meaning of any particular colored pattern on the map the reader should look for that color and pattern 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 colored 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 of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

The legend may also contain descriptions of formations or of groups of formations, statements of the occurrence of useful minerals, and qualifications of doubtful conclusions.

The sheet presents the facts of historical geology in strong colors with marked distinctions, and is adapted to use as a wall map as well as to closer study.

Economic geology.—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 geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. 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 in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

Structure sections.—This sheet exhibits the relations existing beneath the surface among the formations whose distribution on the surface is represented in the map of areal geology.

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial 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.*

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. 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. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

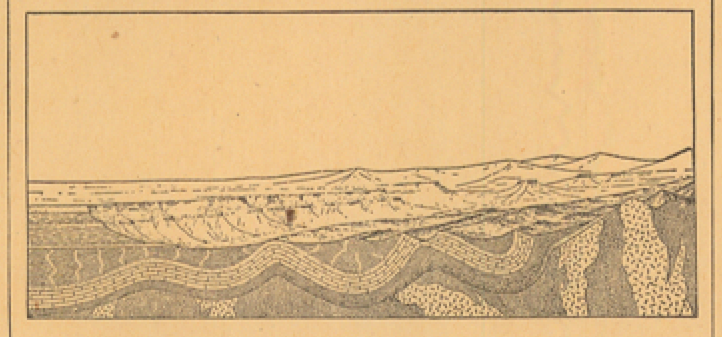


Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows 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:

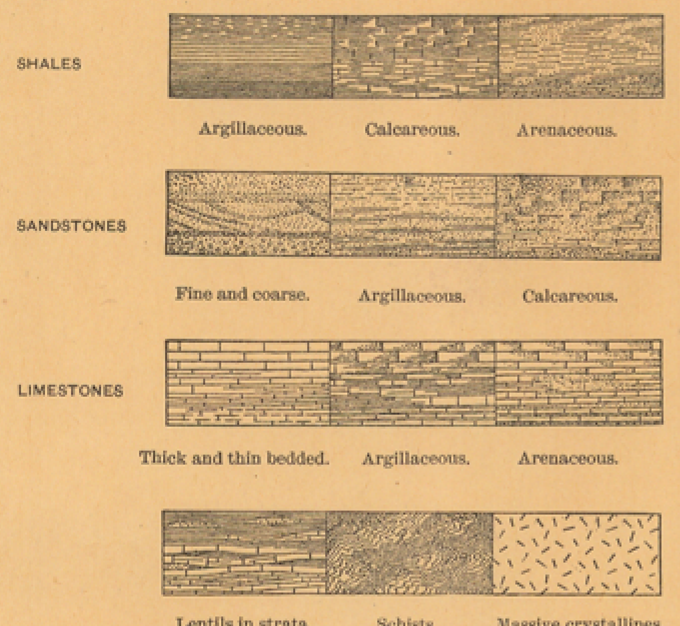


Fig. 3. Symbols used to represent different kinds of rocks.

The plateau in Fig. 2 presents toward the lower land an escarpment which is made up of cliffs and steep slopes. These elements of the plateau-front correspond to horizontal beds of sandstone and sandy shale shown in the section at the extreme left, the sandstones forming the cliffs, the shales constituting the slopes.

The broad belt of lower land is traversed by several ridges, which, where they are cut off by the section, are seen to correspond to outcrops of sandstone that rise to the surface. The upturned edges of these harder 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 thicknesses 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. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

The mountain peaks on the right of the sketch are shown in the section to be composed of schists which are traversed by masses of igneous rock. The schists are much contorted and cut up by the intruded dikes. Their thickness cannot be measured; their arrangement underground cannot be inferred. Hence that portion of the section which shows the structure of the schists and igneous rocks beneath the surface delineates what may be true, but is not known by observation.

Structure sections afford a means of graphic statement of certain events of geologic history which are recorded in the relations of groups of formations. In Fig. 2 there are three groups of formations, which are distinguished by their subterranean relations.

The first of these, seen at the left of the section, is the group of sandstones and shales, which lie in a horizontal position. These sedimentary strata, which accumulated beneath water, are in themselves evidence that a sea once extended over their expanse. They are now high above the sea, forming a plateau, and their change of elevation shows that that portion of the earth's mass on which they rest swelled upward from a lower to a higher level. The strata of this group are parallel, a relation which is called *conformable.*

The second group of formations consists of strata which form arches and troughs. These strata were continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first group, being parallel, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second group on the left of the section. The overlying deposits are, from their position, 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 or upon their upturned and eroded edges, the relation between the two is *unconformable,* and their surface of contact is an *unconformity.*

The third group of formations consist of crystalline schists and igneous rocks. At some period of their history the schists have been 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 group. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of strata of the second group. During this interval the schists suffered metamorphism and were the scene of eruptive activity. The contact between the second and third groups, marking an interval between two periods of rock formation, is an unconformity.

The section and landscape in Fig. 2 are hypothetical, but they illustrate only 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 sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

The characters of the rocks are described under the corresponding heading, and they are indicated in the columnar diagrams by appropriate symbols, such as are used in the structure sections.

The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest thicknesses. The average thickness of each formation is shown in the column, which is drawn to a scale,—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement of the descriptions and of the lithologic symbols in the diagram The oldest formation is placed at the bottom of the column, the youngest at the top. The strata are drawn in a horizontal position, as they were deposited, and igneous rocks or other formations which are associated with any particular stratum are indicated in their proper relations.

The strata are divided into groups, which correspond with the great periods of geologic history. Thus the ages of the rocks are shown and also the total thickness of deposits representing any geologic period.

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, not only by the description of its character, but by its name, its letter-symbol as used in the maps and their legends, and a concise account of the topographic features, soils, or other facts related to it.

J. W. POWELL,
Director.