DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

59

GEOLOGIC ATLAS

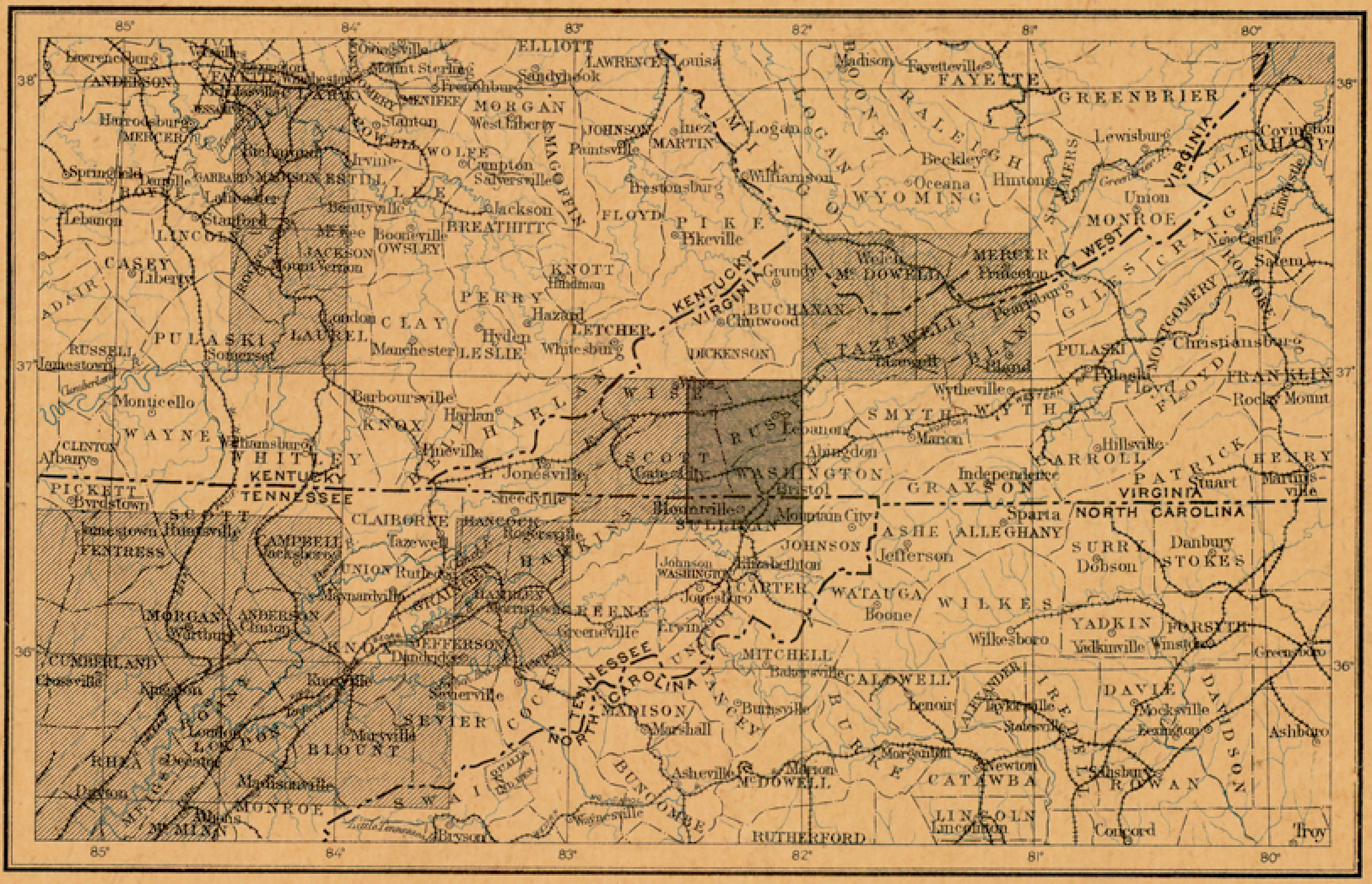
OF THE

UNITED STATES

BRISTOL FOLIO

VIRGINIA - TENNESSEE

INDEX MAP



SCALE: 40 MILES=1 INCH

AREA OF THE BRISTOL FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

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

FOLIO 59 LIBRARY EDITION BRISTOL

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1899

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

Relief.—All elevations are measured from mean sea-level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea-level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

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

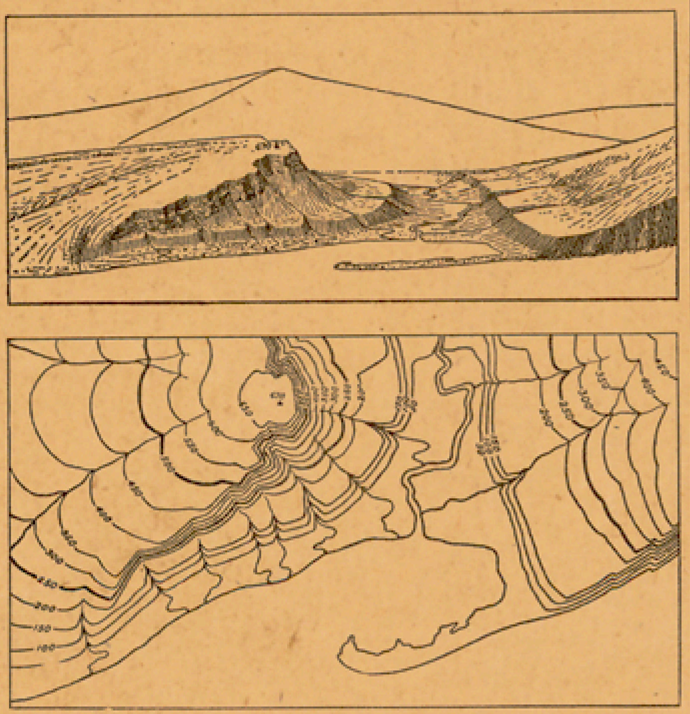


Fig. 1.—Ideal sketch and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

DESCRIPTION OF THE BRISTOL QUADRANGLE.

GENERAL RELATIONS.

The Bristol quadrangle includes one-quarter of a square degree of the earth's surface, extending from latitude 36° 30′ on the south to 37° on the north, and from longitude 82° on the east to 82° 30′ on the west. Its average width is 27.8 miles, its length 34.4 miles, and its area 956.6 square miles.

Location of quadrangle.

Politically the quadrangle is divided into two parts by an east-west line which passes through the city of Bristol. That part which lies south of this line has an area of 180 square miles and is wholly within Sullivan County, Tennessee. The part lying north of the above-mentioned line has an area of 776 square miles and is included in the counties of Washington, Scott, Russell, Wise, and Dickenson, Virginia. The quadrangle receives its name from the city of Bristol, which is the most prominent town within its borders and which is located on the boundary line between the two States.

Relation of quadrangle to Appalachian province.

In its geographic and geologic relations this quadrangle forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west, and from central Alabama to southern New York.

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

Central division—the Appalachian Valley.

The central division is the Appalachian Valley. It is the best defined and most uniform of the three. It varies in width from 40 to 125 miles, and is sharply outlined on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the Allegheny Mountains. Its rocks are almost wholly sedimentary and in large measure calcareous. The originally horizontal strata have been thrust into great folds which in many places have been compressed to such an extent that the strata forming the folds have been broken and crowded forward out of their normal positions. That portion of the Appalachian Valley which lies within the States of Pennsylvania and Virginia may be subdivided into two areas differing materially in topographic features. The eastern area consists of a broad valley which in the former State is known as the Cumberland or Lebanon Valley and in the latter as the Shenandoah Valley. In the western area the rocks lie in broad, open folds, and the outcrops of the hard beds on the sides of these folds give rise to long, generally straight ridges, which are separated by narrow valleys formed on the outcrops of the softer rocks. Farther south the rocks have been closely folded and very much broken, and consequently the surface of the entire Appalachian Valley has been worn down to an undulating lowland which, in Georgia and Alabama, is known as the Coosa Valley and farther north as the Valley of East Tennessee.

Eastern division—the Appalachian Mountains.

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

Western division: its extent and geologic structure.

The western division of the Appalachian province embraces the Cumberland Plateau, the Allegheny Mountains, and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as coinciding with the Mississippi River as far up as Cairo, and thence extending northeastward across the States of Illinois and Indiana. In the northern part of the province the eastern boundary of this division is sharply defined by the Allegheny front, and in the southern part by the eastern escarpment of the Cumberland Plateau. The rocks of this division are almost entirely of sedimentary origin, and they remain very nearly horizontal. The topography, which is dependent on the character and attitude of the rocks and the conditions under which erosion has operated in the past, is that of a series of plateaus, more or less dissected and decreasing in altitude westward from the Allegheny front and the Cumberland escarpment. In Tennessee the surface of the highest plateau is composed of hard rocks, which have withstood the attacks of erosion, and as a consequence the plateau is very perfectly preserved; in the northern part of the division it has had no such protecting cap, and the streams have cut deep and narrow valleys in its once level surface. The highest summits remain at approximately the same altitude as the former plateau, but the even surface is gone and in its stead there remains a broken, hilly region, difficult of access and poorly adapted to human habitation.

Altitude of the Appalachian province.—This province as a whole is broadly arched, 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.

Altitudes of the Appalachian Mountains.

The Appalachian Mountains rise gradually from less than 1000 feet in Alabama to more than 6600 feet in western North Carolina. From this culminating point they descend to 3000 feet in southern Virginia, rise to 4000 feet in central Virginia, and again descend to 2000 feet on the Maryland-Pennsylvania line.

Altitudes of the Appalachian Valley.

The Appalachian Valley shows a gradual increase in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2000 feet at the Tennessee-Virginia line, and 2500 or 2700 feet at its highest point, on the divide between New and Tennessee rivers. From this point it descends to 2200 feet in the valley of New River, 1500 to 1000 feet in James River Basin, and 1000 to 500 feet on Potomac and Susquehanna rivers. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2000 feet.

Altitudes of the plateau region.

The surface of the western division rises from an altitude of 400 or 500 feet along the Mississippi River to 2000 or 4000 feet along the eastern front of the Cumberland Plateau and the Allegheny Mountains. This slope is not regular, but, in a general way, is made up of three terraces rising from the river to the eastern margin of this geologic division. The lowest terrace forms the valley of the Mississippi River and its larger tributaries, and it also appears in the central basin of Tennessee. The second terrace forms the "Highland Rim" of Tennessee and the upland plain of Kentucky; its general altitude is about 1000 feet. The third terrace is formed by the even top of the Cumberland table-land, and farther north by hilltops which presumably mark the position of a deeply dissected plateau that was formerly continuous with the Cumberland table-land to the south. The altitude of this highest terrace varies from 500 feet at the southern edge of the province to 1500 feet in northern Alabama, 2000 feet in central Tennessee, and 2000 to 4000 feet in Kentucky, West Virginia, and Pennsylvania.

Direction of drainage.

Drainage of the Appalachian province.—The western division of the province, with the exception of small areas in Pennsylvania and Alabama, is drained by streams flowing westward to the Ohio River. The Appalachian Mountain division is drained eastward into the Atlantic Ocean, except the southern part, where the surplus waters of the region west of the Blue Ridge are carried to the Ohio River by the Kanawha and Tennessee rivers, and to the Gulf by the Alabama River.

Arrangement of streams.

The positions of the streams in the Appalachian Valley are mainly dependent upon the geologic structure. In a general way they flow in courses which, for long distances, are parallel to the mountains on either side, following 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 part of the province these transverse rivers are the Delaware, Susquehanna, Potomac, James, and Roanoke, each of which flows eastward to the sea. In the central part of the province the 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 to northern Georgia the valley is drained by tributaries of the Tennessee River, which also crosses the Cumberland Plateau in its course to the Ohio. In Georgia and Alabama the streams flow directly to the Gulf of Mexico.

TOPOGRAPHY.

Two groups of surface features.

The Bristol quadrangle extends entirely across the Appalachian Valley, having its southeastern corner approximately upon the summit of Holston Mountain, which is the farthest outlier of the Appalachian group, and its northwestern corner several miles within the border of the coal field. From its location with reference to the great physiographic provinces, it follows that the surface features of the quadrangle fall naturally into two groups, each of which is typical of the province to which it belongs. The dividing line which separates these topographic groups is a fault, or break in the rocks. On the southeastern side of this fault the strata have been greatly disturbed, thrown into great folds, broken by the irresistible force which crowded them together, and frequently thrust for great distances—perhaps many miles—out of their original positions and upon rocks which normally belong above them; on the northwestern side of the fault the rocks are somewhat disturbed, especially in the immediate vicinity of the break, but in a general way they are nearly horizontal and in approximately the same attitude as that in which they were deposited.

Drainage.—On an old land area, like the Appalachian province, the lines of drainage are generally so well adjusted to the attitude and outcrop of the rocks beneath that a clear understanding of the reasons for their location and direction is not difficult to obtain. But since the Appalachian province has been a land area from an early Mesozoic epoch down to the present time, it is only reasonable to suppose that the drainage systems in their development have passed through several cycles and that the systems of to-day were derived from those of a preceding cycle; consequently they may have many features which are inherited from the older systems, and which were produced under conditions very different from those which prevail to-day. This is the explanation of many of the apparently anomalous drainage features in the Appalachian province, and it must be taken into account in studying the arrangement of the present systems.

In the Bristol quadrangle the streams are generally well adjusted to the present conditions. Thus most of the trunk streams are located on the outcrops of the softer rocks, and they flow parallel to the line of strike, or to the axes of the geologic structures. They also show a disposition to avoid the sandy shales and sandstones of the coal field and seek the outcrops of the easily eroded limestones and calcareous shales of the Appalachian Valley. In a few cases the streams have disregarded the outcrops of hard rocks, but their courses at such points are probably inherited and are to be explained by the conditions which prevailed at some epoch in the past.

Divides.

The entire quadrangle is within the hydrographic basin of Tennessee River, but its drainage is effected through several branches of the main trunk stream. A glance at the prominent surface features, as shown on the map, would lead to the supposition that the highest ridge, Clinch Mountain, divides the territory into two drainage basins, but close examination shows that the comparatively low Moccasin Ridge forms the divide between Clinch River and the North Fork of Holston River, nearly as far east as Lebanon; and that the equally unimportant Walker Mountain separates the North and South forks of Holston River throughout the extent of this quadrangle.

Clinch River.

Clinch River is the largest stream in this territory. It enters the quadrangle near its northeastern corner, crosses it diagonally, and leaves it near the middle of the western side. Although this stream generally pursues a direct course, its channel is very tortuous and it crosses and recrosses geologic formations without any apparent regard for the character of the rocks. It is probable that these short bends are features inherited from a previous age, when the surface relief of the valley was slight and the streams, meandering in a wide flood plain, were measurably free from the influence of hard and soft rocks; and that, in a period of active corrasion which ensued later, this stream deepened its crooked channel, its increased fall giving it sufficient power to cut the hard as well as the soft rocks which it found in its pathway.

Copper Creek.

Copper Creek, a tributary of Clinch River, has selected for its course the outcrop of soft limestone which lies between the flinty rocks of Copper and Moccasin ridges. Near its mouth it has nearly kept pace with the trunk stream in the excavation of its valley, but along its upper course in this quadrangle it has not had sufficient volume to cut its valley below those of the other minor streams.

Guest River.

Guest River, which drains a territory entirely within the coal field, is another branch of this same system. In some far-off age this stream was doubtless located upon relatively soft shales and sandstones, but in the latest period of rapid corrasion it encountered a massive conglomerate which so retarded its development that it has not succeeded in deepening its channel, except for a few miles above the trunk stream. In this lower part of its course it has cut a narrow, rocky gorge with almost perpendicular walls, which presents a striking contrast to the broad, flat valley that marks its upper course. This upper valley presumably has changed but little since the last uplift of the land which rejuvenated most of the streams of the region.

The divide separating the Tennessee River from the Big Sandy and Ohio rivers passes through the northern part of this quadrangle, where it is known as Sandy Ridge. It separates the Clinch River system from that of the Russell Fork of Big Sandy, but the drainage basin of the latter stream within this territory is so small that it may be disregarded.

North Fork of Holston River. **Moccasin Creek.**

All of the territory southeast of Moccasin Ridge belongs to one drainage basin, but it is divided by Walker Mountain into two subsystems, one dominated by the North Fork of Holston River, the other by the South Fork. The North Fork is located on the outcrop of very soft rocks along the southeastern foot of Clinch Mountain. It has generally a broad and well-developed flood plain, with many meanders, which probably are due to the sluggishness of the current and the great amount of waste material derived from the soft rocks through which it flows. The only tributary of importance which belongs to the North Fork system in this territory is Moccasin Creek, which is noteworthy from the fact that its drainage basin lies almost wholly north of Clinch Mountain, and that it is the only stream in a distance of 190 miles that has succeeded in maintaining a water gap through this ridge. This stream rises near Hansonville and flows southwestward along the soft limestones and shales at the foot of Clinch Mountain, and at Gate City, a few miles beyond the borders of this quadrangle, it escapes through a narrow gap southward into the North

Fork. It seems quite probable that the course of this stream, directly across the most formidable barrier in the region, is an inheritance from the past; but since this gap through the mountain corresponds with a cross fault which has completely ruptured the sandstone of which the mountain is composed, it is barely possible that the gap is the result of the headward cutting of a small branch of the North Fork and the capture of Big Moccasin Creek, which previous to that time had belonged to the Clinch River system. The latter hypothesis is not probable, and if the former supposition is correct, it carries us back in the history of this region to a time when the present summit of the mountain corresponded approximately with the general surface level. If this feature were the only one of its kind in the region it might be regarded as exceptional, but the cutting of Powell River through a similar ridge at Big Stone Gap and of Clinch River through Lone Mountain, farther south in Tennessee, seems to indicate that the condition of slight surface relief was common throughout a large extent of territory and that the general arrangement of the drainage lines at that time was not entirely in harmony with the geologic outcrops. These stream gaps are mute witnesses of conditions which have long since ceased to exist, but which have continued to exert an influence on the topography and the stream arrangement down to the present time.

South Fork of Holston River.

All of the territory southeast of Walker Mountain belongs in the drainage basin of the South Fork, the trunk stream of which crosses the quadrangle near the southeastern corner. Curiously enough, this stream has here deserted the limestones of the region about Bristol and is flowing altogether on the harder rocks, sandstones and shales, which occur in this corner of the area. Presumably this is another case of an inherited course—a feature handed down from a previous age, when either the streams disregarded the hard rocks of this region or the sandstones and shales of this locality were covered by softer rocks through which the stream found no difficulty in cutting its valley.

Surface features.—As previously described, the surface features of this quadrangle naturally fall into two groups, separated by the great fault which bounds the Appalachian Valley on its northwestern side.

A dissected table-land.

In the territory north of this fault the surface corresponds in a general way with that which characterizes most of the coal field in Kentucky and West Virginia. It appears originally to have been an extensive table-land, which is now so completely dissected by the streams draining the region that but little of the original surface can be seen; the topography consists almost entirely of innumerable hills the summits of which rise to an approximately common level. In this quadrangle the plateau surface is represented by Sandy Ridge, but over large areas it is completely eroded away.

The remaining portion of the quadrangle, or that including the Appalachian Valley, is divided by Clinch Mountain into two distinct basins, or broad longitudinal valleys. When viewed from a considerable elevation these valleys appear to have a rather uniform and flat floor, but in crossing them they are found to be made up of a number of low ridges and intervening valleys which present a relief, in many cases, of as much as a thousand feet. When studied carefully it is found that what may be called the general surface level is higher in the north than in the south, and that there is a fair degree of regularity in the ascent from near 1500 feet above tide in the southern part to 2000 or 2100 feet in the northern part. This may be termed the general level above which rise the most prominent ridges and below which the streams have cut to varying depths. The depth of stream cutting also seems to vary with the position in the quadrangle, the streams at the north being much deeper below the general surface than those at the southern margin of the field. This variation in the rate and amount of cutting done by the streams does not seem to depend upon distance from tide water, for the distances are approximately the same; nor does it depend upon local obstructions, for Holston River has not encountered more or harder rocks than has Clinch River; therefore we must look for some adequate cause wholly outside of the streams themselves. The variation may have been produced by the warping of the crust of the earth in such a way as to elevate the northern part of this quadrangle more than the southern part, and thus afford the northern streams a better opportunity to work than was presented to those farther south. It seems probable that the earth was free from crustal movements long enough for these great valleys to be worn down to a nearly uniform but not absolutely flat surface, on which the hard, flinty limestones of Copper and Moccasin ridges stood considerably higher than the surface of the softer beds along Clinch River, Copper Creek, Moccasin Creek, North Fork, and the low valley about Bristol. In the southern part of the area the subsequent uplift was not great and consequently the streams deepened their channels but little below the general surface; in the middle the elevation of the earth was greater and necessarily the streams have cut more deeply below its surface; and in the north the uplift was still greater and the subsequent cutting by the streams has been the greatest to be seen in the quadrangle.

Variation in rate and amount of stream cutting.

In the different parts of the quadrangle the rocks are of nearly uniform composition, hence under similar conditions of erosion the resultant topography in the two sections should have been much the same. The present aspect of the country is, however, very different in the different localities. In the south, where the late uplift was only slight, the surface relief is not great and the result is that the country is fairly well adapted to agricultural pursuits; in the middle zone the surface is rougher, while in Clinch Valley it is so rough and broken that it is difficult to cross and only poorly adapted to the raising of crops.

An Eocene or Neocene lowland.

The regularity of this old surface and its indifference to the presence of large streams, as shown in this quadrangle by the relations of its surface to Clinch and Holston rivers, have led to the belief that it is part of an extensive though only partially developed lowland. Lack of space here prevents the discussion of this problem and the presentation of the evidence in favor of such an origin for this surface feature, but it has been somewhat widely accepted and the age of the plain has been fixed provisionally as late Eocene or early Neocene. The conditions were favorable for the reduction to lowland of only such areas as were underlain by soft rocks, hence there are to-day many ridges and knobs rising above this general surface. These forms are of necessity older than the partial lowland, and it has been supposed that the summits of the higher ridges may represent a still older feature, a very complete plain of Cretaceous age. In this quadrangle the latter may be represented by the flat-topped Sandy Ridge, the general summit of Clinch Mountain, and the crest of Holston Mountain, in the southeastern corner. It is, however, only when broad areas are considered that this older and higher surface can be recognized. The erosion interval which ensued between the formation of these two peneplains can be measured only by the removal of from 600 to 1000 feet of rock from most of the surface of this quadrangle. Since the formation of the lower partial peneplain in this region the crust of the earth has been raised and warped so that the northwestern corner stands about 500 feet higher than the southeastern corner. The greatly increased power which has thus been given to the streams in the northern part of the quadrangle is evinced by the greater amount of corrasion which they have accomplished in the same time.

A Cretaceous peneplain.

It is thus seen that the history of this region, even since it became dry land, is extremely complicated, and that it is scarcely possible from an area so small as that of a quadrangle to read aright the history of its surface features.

GEOLOGY.

STRATIGRAPHY.

The general sedimentary record.—All of the rocks appearing at the surface within the limits of the Bristol quadrangle are of sedimentary origin, that is, they were deposited by water. They consist of sandstone, shale, and limestone, having an average total thickness of 17,000 feet, and 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 the older rocks and from the remains of plants and animals which lived while the strata were being laid down.

Origin of the rocks.

These rocks afford a record of almost uninterrupted sedimentation from early Cambrian to late Carboniferous time. Not only do they furnish a record of the conditions under which they were deposited, but they also record the conditions of the land from which they were derived during the same period. In the ocean the waves alone are sufficient to sort very coarse material; hence conglomerates are always indicative of shore conditions; they also usually denote steep slopes and rapid erosion on the adjacent land surface; but before solidification takes place the level of the land may be so changed that the pebbles and bowlders are once more exposed to the action of the waves and are worked over again and redeposited, although at the same time the surface of the land may be near base-level. Consequently, when such beds are used in interpreting the physiographic history of the adjacent land area, the evidence should be supplemented by that drawn from other sources before it is regarded as conclusive. Sand may be transported by oceanic currents to great distances, but its ultimate source must have been a land surface having considerable diversity of altitude and streams of sufficient power to transport the sand to the sea. As the waste of the land is carried into the sea it is assorted by the waves and currents, the fine mud being carried out into comparatively still water before it gradually settles to the bottom, where, in the course of time, it is solidified into shale. As the surface of the land is reduced toward base-level, the waste transported by the streams becomes finer and finer until the deposits in the sea, even near shore, consist entirely of fine mud, which in time is hardened into shale. Thus shale may represent rapid erosion on the surface of the land and deposition at some distance from the shore, or it may represent base-leveling and close proximity to the coast. In a similar manner it seems possible that limestones may be deposited near shore during the ultimate stage of a period of base-leveling, although under ordinary conditions of erosion they are formed only at considerable depths and at sufficient distances from the shore to be beyond the limit of the transportation of sand and mud. Coal is formed from deposits of peat or from buried vegetation; consequently coal seams indicate the presence of extended swamps of either fresh or brackish water, in which flourished a luxuriant vegetation that was frequently buried by great washes of sand and mud.

Conditions of deposition.

The sea in which the Paleozoic sediments were laid down covered most of the Appalachian province and the Mississippi Basin. The exact position of its eastern shore line is not known, but it probably migrated westward at intervals throughout Paleozoic time, as the folding of the rocks lifted them above sea level.

Since the character of the sediment is, to a certain extent, indicative of the attitude and configuration of the land, the history of the continental area from which were derived the sediments now forming the rocks of the Bristol quadrangle should be found recorded in them. At present our knowledge will permit only the broadest generalizations.

Geologic history of the Appalachian province.

The oldest known rocks of this quadrangle were deposited in a trough or broad strait which was bounded on the east by the continental area then existing in the Smoky Mountain and Blue Ridge region, and on the west by a land barrier which was probably located somewhere in the western division of the Appalachian province, and which separated this trough from the great interior sea. Into this trough was swept the waste of the continental area to the east which, hardened into sandstones and shales, is now known as the rocks of lower Cambrian age. The land forming the barrier west of the Appalachian Valley sank beneath the sea, and the coarse sediments of the preceding epoch gave place to an enormous and widespread limestone deposit which marks the close of Cambrian and the begining of Silurian time. This limestone presumably covers most, if not all, of the western division of the province and extends eastward to the base of the Appalachian Mountains. From the proximity of this outcrop to the supposed shore line of that period it seems probable that the land area to the east was practically at base-level and that no coarse sediments were delivered to the Appalachian sea from that quarter. In early Silurian time this land area was elevated and such great quantities of sand and mud were swept into the sea that the formation of limestone was interrupted near shore, but farther out it continued to form for some time. Finally, however, the sea became too muddy for the formation of limestone except in central Kentucky and Tennessee, and the entire Appalachian Valley was covered with a thick deposit of shale. The land continued to rise and the shore line migrated across the Appalachian Valley, leaving a heavy deposit of clean beach sand to mark its progress. Near the close of Silurian time there was an upward movement along the Cincinnati arch, making this a land area from which some of the older formations were removed by erosion. A slight subsidence allowed the next succeeding formation to be spread as a thin veneer over this eroded surface.

During Devonian time the Bristol quadrangle was doubtless covered by the sea which extended over most of the Appalachian province. In the earlier stage of this period the land to the east of the Paleozoic sea was probably near base-level, but in the closing stage the land in the northeastern part of the United States was greatly elevated and from this were swept immense quantities of sandy waste which were spread as far south as this region.

The beginning of Carboniferous time is marked by marine conditions which permitted the formation of a great wedge of limestone extending from southern Pennsylvania and Ohio to the southern extremity of the province. Following the period of limestone deposition came an uprising of the crust of the earth which produced a shallow sea and moderately high land in its immediate vicinity, from which large quantities of sandy waste were poured into the waters of the sea and mingled with the calcareous material that accumulated there from time to time. Apparently many alternations of level took place in the early part of this period, which resulted in the deposition of beds of very diverse characteristics.

Finally marine conditions passed away and the deposition of the coal-bearing rocks took place in fresh- or brackish-water basins in which coal plants flourished from time to time and in which accumulated the peat that in after ages was altered into coal. At first the coal basin consisted of a narrow trough occupying the southeastern margin of the present field, and in that trough the earliest seams of coal were deposited. With the increased load of sediments poured into this basin came further subsidence and the encroachment of the waters of the basin toward the northwest, upon a land area that, in a general way, occupied the Cincinnati arch. The continued subsidence of this basin permitted the accumulation of coal-bearing rocks over a wider and wider territory, until finally it reached the present proportions of the coal field and probably extended some distance beyond. In the later stages of the Carboniferous period the conditions must have changed materially, for the sediments consist of red and green shales of very fine texture, interbedded, curiously enough, with coarse sandstones and heavy conglomerates. The origin of these red shales is still a matter of doubt, but it is evident that they represent peculiar conditions, which would make an interesting chapter in the geologic history of this region if the conditions could be rightly interpreted from the sediments as they occur to-day.

Finally this basin was elevated above water level, and the Appalachian coal field was added to the continental area of North America.

CAMBRIAN STRATA.

Rocks belonging to the Cambrian period occur in several places in this quadrangle, but the outcrops are disconnected and no complete sequence can be found.

Unicoi sandstone.—The oldest known rock in this territory is a heavy bed of sandstone or quartzite at the base of Holston Mountain, in the extreme southeastern corner of the quadrangle. The outcrop, however, occupies so limited a territory that it is not necessary to enter into a detailed description of the formation. It is a coarse feldspathic sandstone, with an exposed thickness of about 1000 feet, but on its lower side it is bounded by a fault, and hence it is not possible to determine the full measure of the formation. No fossils have been found in this sandstone, but since it occurs in a group of strata which carries the Olenellus fauna it is here classed as lower Cambrian.

Coarse feldspathic sandstone.

Hampton shale.—Over the Unicoi sandstone lies a bed of sandy shale which has a thickness of about 600 feet and which forms most of the front of Holston Mountain.

Overlying the Hampton shale is another sandstone, which appears on the summit of the mountain, but it does not extend within the limits of this quadrangle.

Above the formations already described there is a series of beds about 3000 feet in thickness which are of lower Cambrian age, but their relation to the rocks of the same general age in the northwestern part of the Appalachian Valley can not be positively determined at present. They lie entirely outside of the Bristol quadrangle, and hence need not be considered further in this connection.

Russell formation.—In the territory north of Clinch Mountain there are two areas of lower Cambrian rocks which are the oldest strata occurring in this quadrangle northwest of Holston Mountain. One of these areas is to be found in the valley of Copper Creek and the other in the valley of Clinch River. The latter outcrop suffers several interruptions, but in general the exposures occur along the same great anticlinal fold. This formation is named from Russell County, Virginia, which includes some of the best exposures of this formation to be found in southwestern Virginia. The formation consists generally of alternating thin bands of shale, sandstone, and impure limestone, of various colors, but with a prevailing tint of red or reddish brown. The upper part of the formation is composed of a thick bed of brown, slightly calcareous shale, which gradually gives place to the complex series described above. Owing to the minor crumplings which these beds have suffered their exposed thickness is very difficult to determine, but the best estimates place it at about 1000 feet.

Shale, sandstone, and impure limestone.

Rutledge limestone.—This formation, named from Rutledge, Grainger County, Tennessee, is an impure magnesian limestone, which ranges in thickness from 240 to 300 feet. In its distinctive development the Rutledge limestone overlies the brown shale of the Russell formation, and in turn is superseded by the blue shale of the Rogersville formation; but in this region there is a zone of transition within which the Rogersville shale, a persistent and valuable horizon-marker in northern Tennessee, is replaced by limestone and becomes indistinguishable from the associated beds. On this account the Rutledge limestone can be distinguished only in that part of the quadrangle which lies northwest of a line passing through Big Branch and Jesses Mill. North of this line it is easily separated from the strata with which it is associated, but south of the line the Rutledge, Rogersville, and Maryville formations blend into one mass of limestone.

Impure magnesian limestone.

Rogersville shale.—This formation, named from Rogersville, Tennessee, occurs only in the northwestern quarter of the quadrangle. It is a blue calcareous shale which, along the western margin of the quadrangle, has a thickness of 100 feet; toward the east it decreases in thickness until it practically disappears as a shale formation. It contains an abundant fossil fauna, which is of middle Cambrian age.

Blue calcareous shale.

Maryville limestone.—Like the two preceding formations, the Maryville limestone can be differentiated as a separate formation only in that territory which lies northwest of a line through Big Branch and Jesses Mill. It is generally a heavy-bedded blue limestone, with a thickness of from 500 to 600 feet. In passing eastward from Jesses Mill, owing to the disappearance of the Rogersville shale, the Rutledge, Rogersville, and Maryville formations are represented by a single limestone bed, which necessarily must receive a new name and be designated on the map by a different pattern. This change is accomplished by merging the patterns of the three formations on the west into one on the east without separation by distinct boundary lines.

Heavy-bedded blue limestone.

Honaker limestone.—In that portion of the quadrangle which lies southeast of a line passing through Big Branch and Jesses Mill this name is given to the limestone which is the equivalent of the Rutledge limestone, the Rogersville shale, and the Maryville limestone. It rests directly upon the brown shale of the Russell formation, and it is overlain by the Nolichucky shale, which thins toward the east in a manner similar to the thinning of the Rogersville shale, and disappears along a line that is rudely parallel to that along which the Rogersville shale disappears. The line marking the known eastward extent of the Nolichucky shale passes northward from Ruthton to Montgomery Station, then swings somewhat to the east, and passes off this quadrangle in the direction of Abingdon. It has not been traced continuously beyond this point, but it seems probable that it holds a general northeast course, for it is found at Tazewell, on the northern side of the valley. In appearance the Honaker formation resembles the limestone formations of which it is composed. It outcrops in two bands along Clinch River east of Jesses Mill, in the valley of Copper Creek, in the vicinity of Lebanon, along the northern front of Walker Mountain, and in many crushed folds southwest of Bristol. The formation is named from the town of Honaker, Russell County, Virginia, and it has a thickness of from 1200 to 1400 feet.

Equivalent formations.

Nolichucky shale.— Overlying the Honaker limestone in the central part of the quadrangle, and the Maryville limestone in the lower course of the Clinch Valley, occurs a bed of shale which ranges in thickness from 0 to 400 feet. It is named from the Nolichucky River, along which, in the Greenville quadrangle, it is well developed. The formation is generally composed of calcareous shale and beds of impure, shaly limestone, but in the vicinity of Blountville, Tennessee, the material becomes coarser and the bulk of the formation is calcareous sandstone. When fresh, the shales and shaly limestones are blue in color, but they weather readily to various shades of yellow, green, and brown. They are usually very fossiliferous, carrying a fauna of middle Cambrian age, and can be easily identified by the fossils they contain.

Calcareous shale and sandstone.

This formation attains its maximum thickness along the western margin of the quadrangle; toward the southeast it gradually decreases in thickness, until, just east of Bristol, it disappears from the section. This great reduction in the thickness of the formation is doubtless accomplished by a gradual change in the character of the material from a calcareous shale to a limestone and the consequent blending of the outer portions of this formation with those which lie above and below it. East of Bristol the change seems to be complete and the three formations are united into one great mass of limestone which is of the same general composition from top to bottom. The exact line along which this change occurs is not known, but presumably it is near the zone of transition indicated on the map. In this region the Knox dolomite loses its cherty character and is indistinguishable from the Honaker limestone which underlies it. On account of this difficulty in separation it is impossible to say whether the Nolichucky shale is really absent from the section, or whether its horizon is not revealed at the surface in this area. It is positively known, however, that the Nolichucky shale does fade in passing eastward, and, in a general way, the line along which this change is accomplished is located east of and not far from the city of Bristol.

CAMBRO-SILURIAN STRATA.

Knox dolomite.—This is the greatest limestone formation known in the province. It was early named by Safford from Knox County, Tennessee, and as its outcrop has been traced continuously from the type locality, the same name is appropriate for this region. The formation is generally unfossiliferous, so its exact age can not be determined, but the occurrence of Silurian fossils in the upper portion shows that a part at least belongs to that period; as to the remaining portion the evidence is negative, but seems to favor Cambrian; therefore, as the formation is a lithologic unit, it is provisionally classed as of Cambro-Silurian age. It is generally a gray, cherty magnesian limestone or dolomite, occurring in thick beds, and it is usually covered on its outcrop by a heavy mantle of residual chert. The chert occurs in flattened nodules or irregular sheets in the limestone, and is usually white in color and very dense, but occasionally it is oolitic and resembles porous sandstone. The chert in the uppermost thousand feet of the formation is sometimes fossiliferous, containing a fauna of Calciferous age.

Gray, cherty magnesian limestone.

In this quadrangle the Knox dolomite varies in thickness from 2300 to 3500 feet. It is one of the thickest formations of the geologic column, and, since it is quite resistant to the action of the atmosphere, its outcrop is almost everywhere marked by broad ridges of considerable elevation. The most prominent of these elevations are Copper and Moccasin ridges, Walker Mountain, and Chestnut Ridge. North of Copper Ridge there are two outliers of this formation which occupy gentle synclines in the underlying Cambrian strata. One of these troughs is found near Counts, on the north side of Clinch River, and the other is near Adelphia, on the opposite side of the river. In the region southwest of Bristol there are a number of outcrops of the Knox dolomite, but in this locality it is almost barren of chert and consequently can not be distinguished from the Honaker limestone, except by its position relative to the Nolichucky shale or the blue, fossiliferous limestone or shale which overlies it.

Shenandoah limestone.—As previously stated, the Nolichucky shale appears to be absent in the region east of the city of Bristol, and the limestone occurring below this shale is here merged into and is indistinguishable from the limestone which lies above the shale in the other parts of the quadrangle. This combination of the Honaker limestone, the Nolichucky shale, and the Knox dolomite into one formation affords a great thickness of limestone, which prevails along the eastern side of the Appalachian Valley at least as far as Pennsylvania. In northern Virginia it has been called the Shenandoah limestone, and since the formation is continuous as far as the southern line of the State, the same name will be applied in the Bristol region. The formation presents a variety of aspects, but is generally a gray or white magnesian limestone interstratified with beds of blue flaggy limestone. There appears to be no way of distinguishing the top from the bottom of the formation, and consequently geologic structure is very obscure in the wide expanse of outcrop in the southeastern corner of this quadrangle. Its thickness is presumably about the same as the combined maximum measures of the various members elsewhere distinguished.

Equivalent formations.

SILURIAN STRATA.

Chickamauga limestone.—In the territory north of Walker Mountain and Chestnut Ridge there is, above the Knox dolomite, a formation of blue flaggy limestone which has a thickness ranging from 0 to 1000 feet and which is named from Chickamauga Creek, Georgia. At present this variation in thickness is not definitely explained, but it seems probable that the base of the formation is fairly constant and that the top diagonals downward toward the southeast. This limestone shows in two lines of outcrop north of Clinch Mountain, one in the valley of Moccasin Creek and the other in the valley of Copper Creek. It shows a limited outcrop on a small faulted block in Rich Valley near Tabor and on both sides of the great syncline of Bays Mountain, which occupies the valley of Reedy Creek. It is very thin in this locality, and east of Sylvicola can not be distinguished from the beds of blue limestone which occur in the Knox dolomite and the Honaker limestone. In Russell County the dividing plane between the Chickamauga and the Knox limestones is marked either by a bed, a few feet in thickness, of red earthy limestone containing subangular pebbles of chert, or by a bed of similar thickness of bright-red shale. This distinguishing layer is classed with the inferior formation, to which it is intimately related in its physical composition. In this quadrangle the Chickamauga shows a variety of aspects, varying from a thin-bedded blue limestone to the massive variety of the same color. Near Big Branch, on the western margin of the area, it contains some beds of gray crystalline marble, but these do not extend far eastward and presumably have but little commercial importance in this region. As a rule, the upper portion of this formation is thinner bedded than the lower portion, and it is generally free from the nodular black chert which is such a persistent and characteristic feature of the lower beds.

Blue flaggy limestones.

Moccasin limestone.—Above the Chickamauga limestone, in its two bands of outcrop north of Clinch Mountain, occurs a bed of red earthy limestone having a thickness of from 400 to 500 feet. This is so distinct that it has been mapped as a separate formation and named from Moccasin Creek, along which it outcrops typically. In the quadrangle which bounds Bristol on the west this formation was found to be absent on the two sides of the Appalachian Valley, but to be present along this middle belt. In the Bristol quadrangle the horizon of this formation is not exposed north of Clinch River, hence it is impossible to tell whether it is present or not, but in the area south of Clinch Mountain it is not shown in any of the outcrops which reveal the Chickamauga limestone and the Sevier shale. The Moccasin limestone seems to occupy a zone intermediate between the great development of the Chickamauga limestone on the northwest and the feather edge of the same formation on the southeast. It has the appearance of a zone of transition, and probably if a continuous line of exposures could be obtained across the valley it would be found that the Moccasin limestone blends with the blue flaggy limestones of the Chickamauga toward the northwest, and in the opposite direction changes to shale and merges into the formation next above.

Red earthy limestone.

Sevier shale.—The next succeeding formation consists of a great mass of shale which extends completely across the Appalachian Valley, but there is such a variation, from northwest to southeast, in the coarseness of the material of which it is composed and in the total thickness of the deposit that it has been deemed advisable to subdivide the formation on the southeastern side of the valley into two formations, which together represent, presumably, the shale bed north of Clinch Mountain, the red Moccasin limestone, and possibly a part of the blue Chickamauga limestone.

In the latter locality the shale may be considered a unit, and it is indicated on the map as the Sevier, a name which is derived from Sevier County, Tennessee, where it shows a great development. North of Clinch Mountain the formation is very calcareous at its base, consisting, for the most part, of blue calcareous shale and thin beds of blue or red limestone. In passing upward it becomes less calcareous and progressively more sandy, until at the extreme top it is with difficulty distinguished from the Bays sandstone which overlies it. It has a thickness ranging from 1100 to 1300 feet.

Shale north of Clinch Mountain.

Athens shale.—In the region south of Clinch Mountain the shale formation is much more complex in its composition, and, for convenience of mapping in adjacent quadrangles, it has been divided into two formations. The basal portion, having a thickness of from 1000 to 1200 feet, is designated the Athens shale, from the town of Athens, McMinn County, Tennessee. The base of this formation consists of black carbonaceous shale which contains numerous impressions of graptolites that are regarded as of Hudson River age. In ascending order, this is replaced by blue calcareous shale, which becomes more and more sandy toward the top of the formation.

Shale south of Clinch Mountain.

The Athens shale occurs only in the region south of Clinch Mountain. The first outcrop is found in the valley of Reedy Creek, where the great syncline of Bays Mountain extends a few miles within the limits of this quadrangle. South of Bristol there are two large synclines of this formation, and east of the same city there are a number of isolated basins and troughs filled with the Athens shale. The largest area occurs in the southeastern corner of the quadrangle, where the full thickness of the shale is present. The change in coarseness of the material as one approaches the southeastern margin of the Appalachian Valley seems to indicate that the land which contributed the waste material was on that side and, presumably, at no great distance. Indeed, the occurrence in this southeastern area of conglomerates containing large limestone pebbles points clearly to the nearness of a shore during the deposition of the Athens shale.

Cambro-Silurian shore line.

Tellico sandstone.—Another indication of the proximity of the shore line during this general epoch is found in the Tellico sandstone, which is a lenticular mass of coarse material overlying the Athens shale only along the southeastern margin of the valley. It is named from the Tellico River, in eastern Tennessee, and it consists of thin-bedded sandstones which are generally red in color and of sandy shale. In this quadrangle the formation is not particularly prominent, either stratigraphically or topographically, but it is separated from the underlying formation in order that the mapping in this quadrangle shall agree with that done in adjacent territory. The exact equivalents of the Tellico and Athens on the northwestern side of the valley have never been determined, but presumably they are parts of the Chickamauga, Moccasin, and Sevier formations.

Thin-bedded sandstones and sandy shale.

Bays sandstone.—This formation attains a thickness of from 350 to 450 feet, and is named from the Bays Mountains, in northern Tennessee. It consists of red, sandy shale at the base, which passes by insensible gradations into red sandstone at the top of the formation. It outcrops near the summits of all of the valley ridges, but it is usually concealed by the débris that falls from the formation above.

Red, sandy shale and sandstone.

Clinch sandstone.—All of the more prominent valley ridges owe their existence to this plate of heavy sandstone, which has preserved their summits at or near their former general level, while the areas immediately adjacent have been worn down to form the present valleys. It is a massive, coarse, white sandstone, varying in thickness from 250 to 450 feet, and it is named from Clinch Mountain, the most prominent of the valley ridges in southern Virginia and northern Tennessee. Throughout most of its extent in this quadrangle Clinch Mountain is formed of this heavy bed, dipping steeply toward the southeast, but near the eastern margin of the area a large, flat syncline develops on the flank of the anticline and the result is an extensive area of high land with the sandstone underlying at comparatively light dips. A very small outcrop of this formation shows along the Rich Valley fault near Ketron; the part here preserved is only a remnant of what was once undoubtedly a large fold, but which, in the great disturbance that turned the rocks of this region on edge, was faulted and crushed.

Massive, coarse, white sandstone.

Rockwood formation.—Above the Clinch sandstone occurs a heterogeneous mass of shales and sandstones which range from 200 to 300 feet in thickness. This is one of the principal iron-bearing formations of the province, but in the Bristol quadrangle it carries no bodies of ore that are thick enough to work. The most conspicuous member is a coarse, white sandstone which occurs at the top and which serves to separate this formation from the one immediately overlying it. The formation takes its name from Rockwood, Roane County, Tennessee, where it has furnished ore for commercial use for twenty-five years. Its outcrop in the Bristol quadrangle corresponds to that of the Clinch sandstone, which underlies it.

Shales and sandstones.

Hancock limestone.—Along the southern slope of Clinch Mountain the Rockwood formation is overlain by a blue or gray cherty limestone which is generally regarded as the uppermost member of the Silurian series and which is named from Hancock County, Tennessee. This formation appears never to have been deposited along the southeastern side of the Appalachian Valley, for at present its outcrop is limited in that direction. In Clinch Mountain it first makes its appearance a little east of Moccasin Gap, where it is so thin that it is difficult to find; it thickens eastward to 30 feet on the western margin of this quadrangle and to 175 feet on the eastern limit. It is seldom found in place, but the residual chert left by its decay is generally very abundant in the vicinity of its outcrop.

Blue or gray cherty limestone.

DEVONIAN STRATA.

Chattanooga shale.—This formation, named from the city of Chattanooga, Tennessee, consists for the most part of fine, black, carbonaceous shale, which varies in thickness from 500 to 800 feet. In the upper part of the formation the shale becomes more sandy and shows brown or ash color, instead of the intense black of the lower members. Its principal line of outcrop extends along the southern slope of Clinch Mountain, where it forms what is locally known as the "Poor Valley." This term is used on account of the poor quality of the soil, which is nearly white in color and ill adapted to agricultural pursuits. Another line of outcrop enters this quadrangle near the northeastern corner; it extends only as far as Dumps Creek, where it is cut off by a cross fault. A small outcrop shows west of Dungannon, and also one near Ketron, in Rich Valley. The upper limit of this formation is difficult to determine, for it merges gradually into the sandy formation above. The Chattanooga shale weathers rapidly, and consequently its outcrop is generally marked by valleys; the overlying rocks are more sandy and form ridges which border the shale valleys on the southeast. The line separating these formations is generally drawn at the foot of the slope separating the ridge from the valley. This is only an approximation, but it is the best division that can be made on physical grounds.

Fine, black, carbonaceous shale.

DEVONIAN-CARBONIFEROUS STRATA.

Grainger formation.—The sandy series which overlies and merges into the Chattanooga shale has a thickness which ranges from 1000 to 1600 feet; at its upper limit there is also a transition into the limestones of the overlying formation, but the change is not so gradual as in the former case and boundary lines can be drawn with considerably more certainty. It is essentially a sandy formation, but it includes a variety of rocks within its limits. As indicated above, the base of the formation is similar to the Chattanooga shale; this passes upward into brown sandy shale, which grows progressively coarser until, near the middle of the formation, it is replaced by sandstone and beds of coarse conglomerate. From this point the material becomes finer and contains more lime, until, near the top, it consists entirely of calcareous shale with interbedded thin impure limestone.

A variable sandy series.

In the Estillville folio the Grainger shale was placed under the Devonian period, although at that time it was recognized that the age of this formation was uncertain and that it probably included strata of the Devonian and Carboniferous periods. Since the publication of that folio the region has been visited by Prof. H. S. Williams, who examined this formation and who pronounced it entirely Carboniferous in the vicinity of Big Moccasin Gap and Big Stone Gap. In an examination of the section at Mendota, in this quadrangle, in 1884, Prof. John J. Stevenson found unmistakable Chemung fossils in the sandy beds along the South Atlantic and Ohio Railroad a short distance southeast of the town. These beds are the apparent lithologic equivalents of the beds at Moccasin Gap which were pronounced by Professor Williams to be Carboniferous. Not only is there a striking resemblance in their lithologic characters, but the formation has been actually traced from one point to the other and there is no chance for any irregularities, except the gradual appearance toward the northeast of the coarse Devonian strata which on New River, Virginia, have swelled to the great thickness of 4000 to 5000 feet. This extraordinary development of the upper Devonian shales and sandstones is one of the most interesting problems in Appalachian stratigraphy. From Chattanooga southward the upper Devonian is represented entirely by a few feet of black shale; northward from this point the shale increases to 400 feet in the southern end of Clinch Mountain, and to about 800 feet at Moccasin Gap. With the addition of the sandy member in the vicinity of Mendota, the thickness increases very rapidly to nearly 5000 feet on New River, Virginia. The principal line of outcrop of this formation is along the southern side of Clinch Mountain, but there is also another area in the Clinch River Valley.

Age of Grainger formation.

CARBONIFEROUS STRATA.

Newman limestone.—This formation probably shows the greatest variability of all that are exposed in this quadrangle, and the line along which the variation occurs is at right angles to the general trend of the valley. The formation is named from Newman Ridge, in northern Tennessee, and in thickness it ranges from 1000 to 2600 feet. It shows in outcrop in only three areas within this quadrangle. The principal one lies south of Clinch Mountain and extends entirely across the quadrangle; the second is a small area in the vicinity of Dungannon; and the third lies north of Cleveland, in the northeastern corner of the quadrangle. Since the latter outcrop is in the bottom of a shallow trough or syncline, and the upper portion of the formation has been eroded, the full thickness can not be determined. The measures given in the columnar sections are derived from the other two areas. In the northern field the formation has a thickness of approximately 1000 feet; it consists mainly of blue or dove-colored limestone, which becomes somewhat thinner bedded as the top of the formation is approached. The heaviest beds are near the bottom, and they are generally characterized by considerable nodular chert. In the southeastern area the conditions of sedimentation seem to have been less regular and as a result there is more variability in the character of the beds composing the formation. More argillaceous matter seems to have been supplied, for the limestones are very much more impure, especially in the upper portion of the formation, than in the northern area. In the Clinch Mountain area there is so gradual a transition from this formation to the shales above that it is difficult to draw any line separating them. In a general way it is intended to include in this formation all of the strongly calcareous rocks of this part of the geologic column. On the accompanying map this blending of formations is indicated by the absence of boundary lines and by the merging of patterns into one another.

Blue or dove-colored limestone.

Pennington shale.—The formation which overlies the Newman limestone is so called from Pennington Gap, near the southwestern extremity of Virginia. It has a maximum thickness in this region of about 1300 feet, along the southern slope of Powell Mountain. This outcrop continues only a few miles eastward, where it is cut out by the great fault which limits the valley in this direction. In this portion of the field the strata composing the formation are generally red and green shales, frequently calcareous, and intermingled with thin beds of limestone and even some beds of heavy sandstone. At Big Stone Gap, where the contact between this formation and the Lee conglomerate is well shown, the suddenness of the change suggests an unconformity, but it is not positively known that any of the members of either formation are lacking.

Red and green shales, with limestone and sandstone.

In the great syncline of which Clinch Mountain is the northwestern limb the material composing the Pennington is coarser than on the northern side of the valley, a fact which strongly suggests the presence of a shore line a short distance southeast of Clinch Mountain. It seems altogether probable that this formation was originally much thicker in this region than along the northern line of outcrop, but the general erosion of the country has been so great that only about 800 feet of the formation still remains as a cover to the limestone below.

Lee conglomerate.—None of the Carboniferous rocks so far described are coal bearing in this region, although from the margin of the Bristol quadrangle eastward the Carboniferous rocks which underlie the Newman limestone contain coal seams that, in the New River region, have proved of considerable value. The Lee conglomerate is very much disturbed in this region, and consequently its thickness is difficult to determine, but the most reliable estimates place it at about 1500 feet. It is named from Lee County, Virginia, where it is especially prominent and forms the crest of the Cumberland escarpment.

In composition this formation varies considerably from place to place. No complete section is exposed in this quadrangle, but a little farther west, in the vicinity of Norton, Virginia, it is composed of three coarse, heavy members which are separated by relatively soft material, either soft, thin-bedded sandstone or shale. The bottom plate is especially heavy, consisting of coarse conglomerate which rests directly upon the red shales of the Pennington formation. The middle of the formation is made up of a thick bed of coarse sandstone, while the top is composed of a plate of massive sandstone nearly 100 feet in thickness and sharply differentiated from the softer sandstones and shales which overlie it.

Massive sandstone, coarse sandstone, and coarse conglomerate.

The principal outcrop of this formation is over the end of the great anticline of Powell Mountain, which lies north of Clinch River and west of Guest River. This arch plunges rapidly toward the northeast, so that the conglomerate disappears beneath the surface at a little distance beyond Guest River. From this point eastward the formation shows only as a narrow band on the upturn which accompanies the great fault that limits the coal field in this direction. Considerable speculation has been indulged in regarding the original extent of this formation in a southeasterly direction, and while there is no positive evidence to be found in this quadrangle, there are some facts which seem to have a bearing on the question that are worthy of statement in this place. The coarseness of the formation and the variability of the individual members composing it certainly indicate that the material accumulated near, if not upon, a coast line. The pebbles which abound in the conglomerates are almost wholly of vein quartz, and were doubtless transported from the Blue Ridge region of North Carolina by rivers that discharged their waters into the narrow inland basin which at that time occupied the area of the present coal field. The absence of these coarse sediments in the syncline southeast of Clinch Mountain is another fact which seems to have a bearing on this question, for if these hard rocks had been originally deposited here it seems altogether probable that, by their superior hardness, they would have prevented the erosion of the Pennington shale and to-day would exist as low mountains in this flat syncline. The evidence is negative, but it appears to show that the Lee conglomerate could have existed but little farther toward the southeast than it is to-day and that much of the valley had become dry land previous to the beginning of the coal-forming period.

Conditions of deposition.

This formation has been called the "Great conglomerate" and correlated with the conglomerate series which is generally supposed to underlie the coal basins of the United States. In a general way there is coarser material at the base of the coal-bearing rocks throughout the Appalachian coal field, but recent study of the fossil plants by Mr. David White has shown that the beds are not always equivalent. In this quadrangle the Lee formation represents only the lower portion of the Pottsville series as it is shown in the type locality in Pennsylvania. From the Upper Banner coal seam, which lies approximately 900 feet above the top of the Lee conglomerate, a large number of fossil plants have been collected which show that this also must be included in the Pottsville series in order to agree with the type section. In fact, it seems altogether possible that the Gladeville sandstone may be much nearer the top of the Pottsville series than the uppermost member of the Lee conglomerate.

Equivalent formations.

Norton formation.—This formation is named from the town of Norton, which lies on the summit between Guest and Powell rivers, a little west of the margin of this territory. The formation is about 1200 feet in thickness and contains most of the important coal seams of this region. The rocks which compose it are generally shale and thin-

Shale, thin-bedded sandstone, and coal seams.

bedded sandstones with intercalated coal seams. It occupies most of the region north of Guest River and the great fault which limits the coal field on the southeast, and, as before mentioned, belongs largely if not wholly to the Pottsville series.

Gladeville sandstone.—This is the first heavy bed above the Lee conglomerate that can be traced and identified over any considerable extent of territory. It is about 100 feet in thickness and is named from the county seat of Wise County, Virginia. It is a coarse sandstone or conglomerate which has proved so resistant to the action of erosion that it caps all the high land in the northern part of the quadrangle.

Coarse sandstone or conglomerate.

Wise formation.—On some of the highest ridges in the coal field there are soft sandstones and shales having a thickness of nearly 100 feet above the Gladeville sandstone. In its full development this is a thick formation which carries many seams of coal of workable thickness, but in the remnant which is left in this territory there are no seams of importance.

Soft sandstones and shales.

Rocks higher in the Carboniferous series were undoubtedly deposited over this region, but they long ago disappeared, through erosion, and there now remains no indication of the amount of material removed.

STRUCTURE.

Definition of terms.—As the materials forming the rocks of the Appalachian Valley 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 from a horizontal plane is called the *dip*. In the process of deformation the strata have been thrown into a series of arches and troughs. In describing these folds the term *syncline* is applied to the downward-bending trough and the term *anticline* to the upward-bending arch. 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 addition to the folding, and, as a result of the continued action of the same forces which produced it, the strata along certain lines have been fractured, allowing one portion to be thrust forward upon the other. Such a break is called a *fault*. If the arch is eroded and the syncline is buried beneath the overthrust mass, the strata at the surface may all dip in one direction. They then appear to be 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 scale.

Anticlines, synclines, and faults.

Structure of the Appalachian province.—Each subdivision of the province is characterized by a distinctive type of structure. In the plateau region and westward the rocks are generally horizontal 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 the form of the rocks has been changed to a greater extent by cleavage and by the growth of new minerals.

Types of structure.

In the valley region the folds and faults are parallel to the old shore line along the Blue Ridge, extending in a northeast-and-southwest direction for very great distances. Some of these faults have been traced 300 miles, and some folds even farther. Many folds maintain a uniform size for great distances, bringing to the surface a single formation in a narrow line of outcrop on the axis of the anticline, and another formation in a similar narrow outcrop in the bottom of the syncline. The folds are also approximately equal to one another in height, so that many parallel folds bring to the surface the same formations. The rocks dip at all angles, and frequently the sides of the folds are compressed until they are parallel. Where the folds have been overturned, it is always toward the northwest, producing southeastern dips on both limbs of the fold. In the southern portion of the Appalachian Valley, where this type of structure prevails, scarcely a bed can be found which dips toward the northwest. Out of the overturned folds the faults were developed, and with few exceptions the fault planes dip toward the southeast and are parallel to the bedding planes. Along these planes of fracture the rocks moved to varying distances, sometimes as great as 6 or 8 miles.

The parallel folds of the Valley.

There is a progressive increase in degree of deformation from northeast to southwest, resulting in different types of structure in different localities. In southern New York the strata are but slightly disturbed by a few inconspicuous folds, except in a narrow belt along the southeastern margin of this division, where the rocks are sharply folded and faulted to a considerable extent. In Pennsylvania many new folds are developed farther west, and all are of increased magnitude, but the folds are open, and, as a rule the dips are gentle, except along the southeastern margin, where the same structure prevails that is found in New York. This type of structure holds throughout Virginia, except that in the southern portion many of the folds are broken by great overthrust faults. In Tennessee open folds are the exception and faults are the rule. The Appalachian Valley is here composed of a succession of blocks, tilted toward the southeast and separated from one another by fault planes which dip to the southeast at the same angle that the strata dip. In Alabama the faults are fewer in number, but their horizontal displacement is much greater, and the folds are somewhat more open.

In the Appalachian Mountains the same structure is found which marks the Great Valley, such as the eastward dips, the close folds, the thrust faults, etc.; but the force of compression has resulted mainly in the development of cleavage structure in the rocks.

The structures above described are manifestly the result of horizontal compression which acted in a northwest-southeast direction, at right angles to the trend of the folds and cleavage planes. The compression probably began in early Paleozoic time and continued at intervals up to its culmination after the close of the Carboniferous.

Structure is due to horizontal compression.

In addition to the horizontal force of compression, the province has been subjected to forces which have repeatedly elevated and depressed its surface. In post-Paleozoic time there have been at least three and probably more periods of decided oscillation of the land, due to the action of vertical forces. In every case the movement has resulted in the warping of the surface, and the greatest uplift has generally coincided with the Great Valley.

Structure of the Bristol quadrangle.—Since the Bristol quadrangle includes portions of two of the great subdivisions of the Appalachian province, the area may be divided into two districts which differ very much in their geologic structure. In the district which lies south of a line passing through Weaver Creek, St. Paul, and Coeburn the strata are bent into great anticlines and synclines which have frequently broken along lines of least resistance, the southeastern limb of a fold being forced to override the northwestern limb, and thus to become displaced in its geologic relationship. North of the line mentioned the rocks are nearly horizontal and show but little effect of that force which folded and crushed the strata of the Appalachian 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 the scale of the map the minute details of structure can not be represented, and therefore the sections are somewhat generalized from the dips observed in a belt a few miles in width along the lines followed.

Underground relations of the strata.

Faults are represented on the map by a heavy solid line where their presence is well determined, and by a broken line where their existence is hypothetical. In the sections faults are represented by lines whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have moved on its opposite sides.

In discussing the geologic structure of any quadrangle it is important to determine what are the dominating or controlling structures of the region. From a glance at the map, it is apparent that they differ very greatly one from another, and, although not so apparent and not so universally accepted, it is also probable that the dominating structures are associated with a great increase in thickness of some of the formations involved in them. Southwest of this quadrangle the principal structural feature is an extensive complex syncline, or synclinorium, which is known as the Bays syncline, from the group of mountains which occupy the trough. This broad mass, which involves many very thick formations, appears to have received and transmitted the thrusts without itself suffering excessive deformation. The adjacent folds were closed and crushed against its resistant sides, with the result that the formations composing them are now standing vertical and, in many cases, are so crushed as to be almost unrecognizable.

Bays syncline.

In the Bristol quadrangle the most resistant structure is the great syncline of Clinch Mountain; it is faulted on both sides, but it is of such breadth that it has acted as a buttress against which the smaller and less resistant structures on the southeast have been thrust and broken. This fold involves known strata to the thickness of 12,000 feet and a downward extension of hypothetical amount. That part of the Clinch syncline which shows the greatest resistance to the thrust is marked by a deposit of Carboniferous limestone of greater thickness than is known at any other point in this province. The agreement in position between these controlling structures and exceptionally thick deposits of certain formations may be simply fortuitous, but there are so many cases in this region that it seems to be a relation of cause and effect.

Clinch Mountain syncline.

These resistant structures are limited in their longitudinal development, and hence at some point they are replaced by other structures in different parts of the valley. This transference of the resistance from one structure to another results in cross stresses and strains, which in many cases find expression in short cross folds or faults, offsetting the outcrops of the formations affected by them. Several such cases were mentioned in the Estillville folio, and in the following description of the details of structure in this quadrangle others will be pointed out.

The region north of Clinch Mountain is made up of two large anticlines which have many minor undulations that repeatedly bring to the surface the same formations. One of these folds, having Clinch Mountain upon its southeastern limb, has its axis along the northern face of Moccasin Ridge, and the axis of the other is located along Clinch River. The former is broken along the crest of the arch and the whole mass is thrust forward upon the next fold to the north. How far these folds were separated originally can not now be determined with certainty, but in the movement which produced the present structures the horizontal distance has been reduced at least one-half. The Clinch Mountain fold is bordered on the northwest by a great fault which follows Copper Creek to its head and from that point extends northeastward through Lebanon to the eastern margin of the quadrangle, where it is very irregular in outline, having many offsets and reentrant angles. A notable feature of this kind occurring at Lebanon is associated with a small anticline in the formation underneath the fault plane; it seems probable that it was produced by folding subsequent to the formation of the fault. Another slight offset on Cedar Creek can not be accounted for easily, unless, in the great compression of the rocks of this locality, the little fold of Elk Mountain was caught and subjected to more severe strains than the surrounding strata and thus was broken across nearly at right angles to the general trend of the fault.

Faults and folds north of Clinch Mountain.

Fig. 1.—Flat overthrust fault west of St. Paul, Virginia. This fault shows a stratigraphic displacement of 15,000 feet, with the Maryville limestone (middle Cambrian) resting upon the Lee formation (upper Carboniferous).

In the valley of Clinch River the folding and general deformation was much more severe and the rocks suffered a number of minor contortions that complicate greatly the geology of the region. On the western margin of this territory the fold is comparatively simple, consisting of a single broad arch with the Russell formation exposed on its axis. Farther west this fold is broken on its northwestern side, but in this area there is no appearance of the fault. A syncline which occasionally shows the Knox dolomite lies northwest of the axis of this fold, and its nearly horizontal rocks have served to some extent as a buttress against which the folds farther toward the southeast were thrust and broken. North of Point Truth the great limestone of Copper Ridge shows the beginning of another fold, which developed northeastward, but which was faulted and badly overthrust, so that at present no trace of the original fold, as such, remains.

Folds in valley of Clinch River.

This belt of greatly contorted strata is bounded on the northwest by one of the most profound breaks in the quadrangle; it is a broad overthrust fault, the plane of which dips lightly toward the southeast, and as a result the Cambrian limestone has presumably overridden the coal field to a considerable extent. One mile west of St. Paul this fault is beautifully shown in the cuts of the Norfolk and Western Railroad. The view above (fig. 1) is a half-tone reproduc-

Fault near St. Paul.

tion of a photograph taken at the western portal of the first tunnel west of St. Paul, looking east, or into the tunnel. The Maryville limestone is here shown forming the roof of the tunnel and extending for about half the distance down the sides, where it rests upon soft shales of the Lee conglomerate formation. The line of view is along the strike of the beds and consequently the correct dip of the fault plane is shown by the contact on either side of the tunnel. When projected across, it is found that this dip is 12° from the horizontal. Even in the great multiplicity of overthrust faults which occur in the southern Appalachians the actual exposure of a fault plane is one of the rarest phenomena of the region. In view of this fact the exposure here represented is of great interest and should be seen by every student of geologic structure who enters this region. The limestone which, in the view, forms the roof of the tunnel should normally occur at least 15,000 feet below the shale which shows at the base of the tunnel walls. When this enormous vertical displacement is considered in connection with the low dip of the fault plane, it becomes apparent that the horizontal movement must have been of immense proportions. A remarkable bend in this fault line is shown on Dump Creek, where its course for nearly 2 miles is at right angles to the general trend of the valley structures. Many minor faults are developed in Clinch Valley, which are very troublesome to one tracing the outcrop of the formations. Near Bickley Mill there are two such faults which have a very slight amount of displacement and seemingly extend for very short distances.

The structure of the Clinch Mountain syncline is apparent from the outcrops on the general map. There is only one point at which cross structures are developed, and this is a few miles northeast of Mendota. Here the ridge, composed of the Grainger formation, is offset in two places, but by amounts which have no very material effect upon the general continuity of the ridge. South of this big syncline the geologic structure is exceedingly complicated, being made up of zones of shallow synclines which suffered little deformation and intermediate bands in which the crushing was intense, and the geologic structures no longer bear much resemblance to the regular folds of the northern portion of the quadrangle.

Fault south of Clinch Mountain.

The Clinch Mountain syncline is bounded on the south by an immense overthrust fault which, although regular in its outline, is still peculiar in that it has left an isolated outcrop of Cambrian limestone and shale on the summit of the Pennington ridge near the head of Timbertree Creek. At present this outcrop is entirely isolated from the outcrop of similar rocks southeast of the fault, but before the region was so well worn down by erosion these exposures were doubtless connected. On Structure section DD this connection is indicated, and, although hypothetical, the section will give some idea of the flatness of the fault plane. Between this fault, which follows the course of Rich Valley, and the great syncline in which are situated the towns of Bristol and Blountville the compression has been more severe than at any other point in this quadrangle. The lateral compression has been carried to such an extent that there is at present scarcely a trace of a fold, and the strata are turned on edge and so badly crushed that it is frequently impossible to distinguish the various limestone formations involved.

East of Johnson Mill and Wallace the limestones are indistinguishable on physical grounds, and hence the geologic structure could not be accurately determined. The large synclines southwest of Bristol have suffered only a little deformation; they have acted as bulwarks against which the strata on either side have been crushed. This is particularly noticeable on the eastern side, where two synclines of Athens shale and Knox dolomite have been thrust nearly together, crushing the intervening Maryville limestone into fragments. The large double syncline in which is situated the town of Bristol has moved bodily toward the northeast upon the flat-lying Knox dolomite, from which it is separated by a fault of semicircular outline and very low dip. East of Bristol the rocks are but little disturbed; they are thrown into broad arches and troughs, but no faulting or other displacement was discovered. In the extreme southeastern corner of the quadrangle the Athens and Tellico formations have suffered considerable deformation, but the most of it consists of minor folds, mere crumples in the soft beds, and probably not shown in the heavy limestones underneath. These are bounded on the southeast by another great fault which separates the lowest known Cambrian rocks from the Athens shale.

Narrowing of valley from folding and faulting.

The structure sections show that the rocks of this region are intensely folded and in many places broken by great faults, along which the strata have moved to unknown distances. While it is impossible to determine the exact amount of shortening which any section across the valley has suffered on account of the folding and faulting of the rocks, still a rough minimum estimate can be made which may be of some value. By taking Section BB and restoring the folds, as best we can, to their supposed condition before faulting took place, and then measuring the length of any particular bed, it is found that the present width of the valley is about one-half of its width before crumpling occurred. This seems to be a fair approximation to a minimum estimate; what the maximum might be is an interesting but unanswerable question.

When compared with the Appalachian Valley the geologic structure of the coal field of this quadrangle is exceedingly simple, but, since the seams of coal are interbedded with the other rocks, slight disturbances in the regularity of the beds are of the utmost importance in the commercial development of the field. From this point of view it will be seen that small folds in this area are of much more importance than are the immense anticlines and synclines of the valley region.

Powell Mountain anticline.

Back of the upturn which forms the southern margin of the field the most important structure is the great Powell Mountain anticline, which enters this territory from the southwest. South of Coeburn this fold has a breadth of not less than 5 miles and a height of from 600 to 800 feet. In passing northeastward the fold diminishes, the heavy Lee conglomerate passes below water level, and, to the casual observer, all trace of the fold is lost in the soft material of the Norton formation. In the development of the coal territory, however, it has been found that the arch extends beyond the margin of this quadrangle, and presumably it is continuous with a similar feature near the margin of the field in the Tazewell and Pocahontas quadrangles. The axis of this fold crosses the railroad about 2 miles west of Virginia City, and thence extends northeastward through the post-office of John, parallel with the margin of the coal field.

MINERAL RESOURCES.

COAL.

The mineral wealth of the Bristol quadrangle is confined almost entirely to the coal which occurs in the Tom Creek and adjacent regions. The coal-bearing rocks include the highest three formations of the geologic column, but the great bulk of the coal is contained in the Norton formation, the middle of the coal-bearing series, as it is shown on this quadrangle.

In the quadrangle which lies to the westward there are a number of seams in the Lee conglomerate formation and in the measures which overlie the Norton formation, but in this region the Lee conglomerate is poorly exposed in outcrop and the coals inclosed in it seem to be of less consequence than farther west; the Gladeville sandstone and the strata overlying it also are almost barren of seams, so that the middle member is the only one in which coal may be found in paying quantities. The Gladeville sandstone is valuable, however, as a bench mark in locating and determining the equivalence of seams over most of this field.

That portion of the coal field which is included in this quadrangle has not been thoroughly or equally well prospected, consequently in some localities tracing and identification are easy matters, while in others exposures are infrequent and the determination of the horizon of a coal seam is usually based upon some supposed similarity in bed section or quality of coal to some known outcrop, or it is determined mainly from the geologic structure of the district, on the supposition that intervals between seams hold throughout the territory and that other beds have sufficient character to be identified at all points of their outcrop. Manifestly such determinations should be received with allowance, and when used will be indicated, so that the doubt concerning the identification of the coal seams may be understood. The author is greatly indebted to Messrs. McCreath and d'Invilliers for details concerning the coals of this region. Their published report on the Tom Creek region has been used freely, for they had access to many coal prospects which had not been opened when much of the present work was done, or which had fallen shut by the time subsequent visits were made to the field. Their measurements have been verified wherever possible, and in every case have been found accurate, consequently their figures have been accepted and will be found on the sheet showing detailed bed sections of the coal seams.

In the Norton formation there are six coal horizons which give promise of affording workable seams at some point within this territory. These horizons will be described in the following paragraphs, in descending order.

Edwards seam.—This coal seam occurs near the top of the Norton formation, and consequently it outcrops near the summits of the highest hills in the northern part of the field. It is about 150 feet below the base of the Gladeville sandstone and 250 feet above the Upper Banner coal seam. It has not been thoroughly prospected and is known at only two localities, one on the ridge west of Big Tom Creek, and the other on Sandy Ridge near the head of the Left Fork of Russell Creek. The first opening is near the summit of the ridge, directly west of the mouth of Banner Branch of Big Tom Creek. This outcrop, illustrated in section 1 on the Coal Sections sheet, shows 4 feet 5 inches of clean coal. The other opening is just beneath the county road which traverses the ridge between the waters of Bull Run and Russell Creek. Its aggregate thickness is almost the same as the former opening, but it has a small shale parting near the top of the seam, as is shown in section 2. If there were no better seams in this field the Edwards might repay thorough investigation, but with the Upper Banner seam more easily accessible and covering so much greater territory, it seems hardly probable that this coal will receive much attention.

Upper Banner seam.—By far the most important seam of coal in this field is the Upper Banner seam, which is a coking coal of great excellence and which occurs about 400 feet below the Gladeville sandstone and 250 feet below the Edwards seam. It has been clearly identified from the western margin of the quadrangle as far east as the divide between Lick and Dump creeks, but it has been developed in a commercial way only in the valley of Big Tom Creek, where a large plant for mining and coking has been established.

A peculiar and apparently constant feature of this seam is a small sandstone parting, ranging from 1 to 3 inches in thickness, which has been found in every opening that is unquestionably upon the outcrop of this seam. True, there are a few openings on Bull Run and Russell Creek which have been assumed to be upon this seam and which do not show the sandstone parting, but in all these openings there is room for doubt as to the correct classification of the seam there opened, and in the mind of the writer there appears to be a greater probability of that seam belonging to the Lower than the Upper Banner horizon.

The most westerly opening that will be described here is located on Guest River a short distance below Tacoma, at the old Greno-Bodine mines. About 1891 extensive preparations were made here to mine not only the Upper Banner seam but also two or three coals which occur below that important seam. The project fell through and work has been long abandoned on all of the seams opened. At this point the bed section shown in section 3 is somewhat peculiar and differs in several respects from the type of the Tom Creek field. The seam as a whole is thicker than at any point farther east, but it includes a great mass of shale and coal near the center that detracts very much from its commercial value. It is also peculiar in having the sandstone parting in the bottom bench instead of the top, as seems to be the general rule farther east.

In passing eastward it is next exposed in an old prospect pit where the old State road ascends the hill west of Coeburn. At this point the total thickness of the seam has decreased to less than half that near Tacoma, but the actual amount of coal does not show the same proportion of decrease. This section could not be seen, but it is reported to be 4 feet in thickness (see section 4), and the sandstone parting is present, but its position in the seam is not given.

In passing up Big Tom Creek the seam holds a fairly constant thickness as far as Banner Branch, a small stream entering from the west about 1½ miles above Coeburn. Sections 5 and 6 represent the bed section of the coal at two mines in this interval, and they show the general character of the seam.

On Fuller Branch the seam has expanded to about its normal thickness in this field. Section 7 illustrates the character of the seam on this branch; it carries a total of 7 feet 10 inches of coal, and it is an attractive seam for mining. Immediately north of the last-described opening, on Trace Fork of Cranes Nest Creek, within a mile of Fuller Gap, it has also been opened, but, as seen from section 8, it carries too much shale to be especially valuable. On Tom Creek above the mouth of Banner Branch this seam has been opened in a number of places. Sections 9, 10, 11, 12, 13, and 14 represent this seam as it appears on both sides of the creek for a distance of 3 miles. Some of these sections show a rather heavy percentage of shale, but the most have only a few inches of the foreign material, which is easily separated from the coal as it is mined, and thus does not affect the grade of the coal placed on the market. The openings so far described cover the developed territory within the Tom Creek field. Near the mouth of the creek the dips are somewhat steep toward the north, away from the axis of the Powell Mountain anticline, but above Banner Branch, where the mines are at present located, the dip is very light toward the north—only sufficient to furnish free drainage facilities.

East of Big Tom Creek the seam does not hold quite the same thickness as in the type locality, and prospecting has not been so thoroughly done as in the developed field, hence it is difficult to determine the full value of the seam in this region. Section 15 represents this bed at an opening on Caney Creek, due north of the uppermost workings on Big Tom Creek. Although considerably reduced in thickness at this point, it presents a very favorable showing, for while the total thickness is much less than on Big Tom Creek, the number and thickness of the shale partings are also reduced.

Messrs. McCreath and d'Invilliers report openings on the Upper Banner seam on the headwaters of Little Tom Creek, Bull Run, and Russell Creek, but there is doubt about the correlation of these outcrops with the Upper Banner, and they are here classed provisionally with the next seam below. The evidence will be discussed more fully in connection with the description of the Lower Banner seam.

On the Middle Fork of Russell Creek an opening on the undoubted Upper Banner was seen near the summit of the ridge. The opening had fallen shut, but it had the appearance of having been originally about 5 feet in height. In the material thrown out from the pit were numerous blocks of the sandstone parting which has served in almost every case to identify this seam beyond the possibility of doubt.

Near the head of Lick Creek it is reported with a thickness of over 6 feet and with a bed section as shown in section 16. At this opening the seam is in excellent shape and retains the characteristic sandstone which serves to identify it beyond question. The presence of this sandstone parting so well developed on the head of Lick Creek and in the opening at the head of the Middle Fork of Russell Creek makes it seem highly probable that it should occur also on the

Left Fork of Russell Creek and in all the territory between that and Big Tom Creek, but in that region the openings that are called Upper Banner have not the sandstone parting.

In passing north of Sandy Ridge into the basin of Big Sandy River, the Upper Banner is found on the Open Fork just north of Austin Gap. At this point the total thickness is somewhat diminished (section 17), but there is still a fair body of coal left.

Southward from Austin Gap it occurs in somewhat better shape, as is shown in section 18, which represents an opening on Big Laurel Run, a small branch of Lick Creek entering the main stream nearly 2 miles below the "Turkey Foot."

Farther east than this point the author knows of no openings on this seam of coal, but from the thickness displayed on Big Laurel Branch it seems probable that it may be found of workable thickness in much of the territory east of Lick Creek and north of the outcrop of the Lee conglomerate.

The sections already described show that this seam is present in workable thickness north of Sandy Ridge, but in every case it has a diminished section, which seems to indicate that there is a general reduction in the thickness of the seam toward the north and consequently that the best territory is along Sandy Ridge and on its southern slope.

Lower Banner seam.—Approximately 100 feet below the Upper Banner coal occurs a seam which is fully as persistent as the upper one, but which is not so thick and consequently of not so great commercial importance. This is known as the Lower Banner coal, and its outcrop is below and practically concentric with that of the Upper Banner seam.

Section 19 represents this seam in the opening made by the Greno-Bodine Company. It is not very thick at this point, but its freedom from shale partings makes it even more attractive than some larger seams which are full of impurities. In passing eastward it diminishes slightly in thickness, as is shown by section 20, which represents the coal at an opening on the old State road west of Coeburn.

On Big Tom Creek it holds a fairly constant thickness of a little over 3 feet, as is shown in sections 21, 22, and 24. Section 23 is exceptionally thin, and is probably only a local variation from the normal that does not hold over any considerable extent of territory.

In passing eastward from Coeburn the first opening of the Lower Banner seam is found in the ravine back of Banner Station, above the old mine of the Virginia Gas Coal Company. At this point the seam measures 45 inches in thickness, and it is entirely free from slate partings, as shown in section 25.

There is considerable diversity of opinion concerning the identity of a seam which occurs at a distance of from 240 to 280 feet above the Kennedy seam in the region east of Banner Station, including the heads of Little Tom Creek, Bull Run, and Russell Creek. In the report of Messrs. McCreath and d'Invilliers, previously referred to, this coal is considered as doubtfully belonging to the Upper Banner horizon. The present writer is also in doubt concerning the identity of this seam, but after carefully balancing all of the available facts, it seems probable that the coal in question could with equal if not greater propriety be referred to the Lower Banner horizon. The reasons for this belief will be briefly stated.

At no point in this disputed territory has the seam been found to carry the sandstone parting which is so characteristic of the Upper Banner coal, except at the extreme head of the Middle Fork of Russell Creek. While it is true that negative evidence of this character can not be accepted as conclusive, the presence of this distinctive feature in the Big Tom Creek region, on the Middle Fork of Russell Creek, on the headwaters of Lick Creek, and on all of the streams flowing northward from Sandy Ridge, must be regarded as strong circumstantial evidence that the coal in question is at another horizon than the Upper Banner seam. The principal argument against the above conclusion is that, in this region, the interval between the openings on this seam and those on the Kennedy seam is much greater than the same interval farther west. On the supposition that this interval has been correctly determined at the old Greno-Bodine works near Tacoma, this objection has considerable weight, but it seems probable that enough allowance has not been made in this measurement for northward dips, which are rather strong along Guest River. The same is true of the measurement obtained at Banner Station, for also at that point there is a notable disturbance of the strata, and the vertical distance between the outcrops is not the interval between the seams. Thus the vertical distance is only 40 feet, but the northward dip would increase this by a considerable amount, and it seems quite within the range of possibility that the actual interval may be over 200 feet instead of 40 feet. In the valley of the Right Fork of Lick Creek it is admitted that the interval between the Lower Banner and the Kennedy seams is 225 feet, therefore either this interval thickens very rapidly eastward or else it has not been correctly determined in the western part of the field. The only point in this territory at which the undoubted Upper Banner seam has been discovered is on the head of the Middle Fork of Russell Creek; here the Kennedy seam is also well developed, and, while the openings are not directly in line vertically, the difference in position will not affect the measurement to any considerable amount. An aneroid barometer measurement on these openings shows an interval of 390 feet between them. Taking the interval between the Upper and Lower Banner seams as 100 feet, and that between the Lower Banner and Kennedy seams as 285 feet, as shown on the Left Fork of Russell Creek, the total interval between the Upper Banner and the Kennedy seams is 385 feet, which shows an error of only 5 feet in the barometer measurement.

The Upper and Lower Banner seams are so nearly identical in chemical composition that it is probably impossible to separate them. There is, however, in the limited number of analyses available, an apparent difference in the amount of sulphur contained in the two seams. The average of four analyses of the Upper Banner coal, from samples taken on Big Tom Creek and Guest River, shows 0.67 per cent, whereas the Lower Banner seam shows nowhere less than 1 per cent, except on Lick Creek, where 0.65 per cent is found. An analysis from one of the disputed openings on Bull Run shows 1.68 per cent, the heaviest percentage reported from this field. So far as it goes, the chemical composition would seem to support the view set forth here, but it is not conclusive. In view of the various facts which have been cited, after carefully balancing the probabilities, it seems to the writer that the preponderence of evidence is in favor of calling the disputed seam the Lower Banner, and not the Upper Banner, as has heretofore been done.

On a branch of Little Tom Creek which enters from the north near Banner Station an opening has been made on what will be here considered the Lower Banner seam. At this point the coal bed (section 26) is small, and on that account the seam has been considered a split of the Upper Banner seam. It improves in passing eastward, as is shown in section 27, which represents this seam at an opening on Dollarhide Hollow, one of the head branches of Bull Run.

The next opening, which occurs on the Left Fork of Russell Creek, shows a marked increase in the thickness of the seam. Section 28 represents the condition of the seam on the western side of the ravine, about a mile from its extreme head. Section 29 is from an opening on the same seam on the eastern side of the ravine, still nearer the head of the creek. On this fork an accurate measure of the interval separating this seam from the Kennedy seam beneath can be obtained, for the opening of the latter is directly beneath the former and 285 feet below it.

The next opening on the Lower Banner seam is near the head of the Left Fork of Lick Creek, where it shows 4 feet of coal and is represented by section 30. Several openings have been made on this seam on Lick Creek, but there are no records of the measurements of the seam at many of these openings, and now they are so closed up by the falling of the roof as to be inaccessible. However, two recorded measurements in this region serve to indicate the general condition of the seam. Section 31 is the bed section on Big Laurel Run, a small branch which enters Lick Creek from the east, and section 32 is from an opening on the road leading from Lick Creek across Austin Gap toward the north. The former shows a clean section of 52 inches of coal and the latter a total of 6 feet 2 inches, but in the latter the presence of 12 inches of shale and coal detracts very much from its value. On the road crossing Trammel Gap this seam shows almost as great a total thickness as at Austin Gap, but it is much less broken up by partings, as can be seen by consulting section 33. In following down Lick Creek another opening can be found on Turkey Foot Fork, which enters the main creek below Big Laurel Run. Here the seam shows 6 feet 2 inches (section 34) of clear coal, and it compares very favorably with the great development on the Left Fork of Russell Creek.

In reviewing the Lower Banner seam, throughout its known extent in this quadrangle, it is seen that in the Big Tom Creek field it is rather thin for commercial development, and certainly in the presence of the Upper Banner seam will not receive attention. In crossing the divide from Little Tom Creek to Bull Run it shows improvement, and on the Left Fork of Russell Creek it reaches such a size that, if its quality is good, it will doubtless prove of value in future mining operations. From this point eastward there is considerable variation in the thickness of the seam, but on the whole it makes a fine showing.

Kennedy seam.—For certain purposes the coal seams of this quadrangle may be divided into two groups: the Edwards, Upper Banner, and Lower Banner seams constituting the higher group; and the Kennedy, so-called Imboden, and Jawbone seams forming the lower group. The coals of the upper group are remarkably regular in thickness, composition, and bed section, whereas the seams of the lower group may almost be considered the types of variability. Each of the lower seams makes a fine showing at one or more points in this territory, and mines have been opened at a number of places, but in every case, except one, work has been abandoned on account of the irregularity of the seam and the consequent uncertainty and cost of mining.

The Kennedy seam is the uppermost coal of the lower group, and occurs at a distance of from 225 to 285 feet below the Lower Banner seam. Mining was attempted on this seam on Guest River near Tacoma, and at first the prospect was very flattering, the coal running from 3 to 8 feet in thickness, but upon driving the main entry into the hill about 600 feet the coal was found to pinch out in all directions and work was abandoned. Sections 35, 36, and 37 show some of the measurements that were obtained in this mine.

This seam is known in its outcrop along the valley of Guest River as far as Coeburn, where it has been opened at the foot of the mountain back of the village, but the opening is now closed and no information is available to show its thickness and character. The outcrop of the seam is nearly horizontal up Little Tom Creek, and passes beneath creek level near the western end of Little Tom tunnel. Mining on this seam was early attempted at Banner Station, and although the coal taken from this mine attained considerable reputation as a gas coal, the great irregularity of the seam rendered mining too uncertain and expensive and the work was abandoned. Sections 38, 39, and 40 show some sections that were made in this mine, but these do not represent the extreme variability in the thickness of the seam. This mine was driven until the coal feathered out completely, but in doing so it passed through coal of a thickness of 10 feet. The coal shows no cleavage, but breaks with an irregular fracture.

A little distance east of Banner Station this seam is seen in moderate thickness, as is shown by section 41. Still farther east, in Dollarhide Hollow, it shows a thickness of 4 feet 3 inches (section 42). On the Left Fork of Russell Creek, about $1\frac{1}{2}$ miles above the mouth of Middle Fork, the Kennedy seam shows, about 200 feet above the creek, a thickness of 6 feet 4 inches of soft coal. Farther up on this fork there is another opening, in which it shows a variation of from 2 to 5 feet in an entry not over 60 feet in length. Sections 43, 44, and 45 represent the condition of the seam in this locality.

An extensive mine has been in operation for some time on this seam on the Middle Fork of Russell Creek, but at this point it was found to retain its characteristic irregularity, and the work has been abandoned. Actual measures are on record of a variation from 8 feet 4 inches (section 46) to 2 feet 8 inches (section 47), but even greater extremes than these are reported by workmen who were engaged in the mine.

On Lick Creek at the foot of Austin Gap this coal is of moderate thickness, as is shown by section 48, which is the bed section of the seam at this point. The few openings that have been made on this seam farther east present a fine showing, but, judging from the experiences of the past, it is unsafe to develop a mine on this seam without thorough prospecting in advance to determine the body of workable coal that is available. Section 49 represents this seam on the southern side of Trammel Gap, and section 50 on the Turkey Foot Fork of Lick Creek.

So-called Imboden seam.—The development of the Coeburn region followed that of Big Stone Gap, and consequently the seams of coal which are so prominent and economically important in the latter field were expected to be present in the adjoining field to the east. In the region west of Norton the Imboden seam has proved to be a wonderful depository of coking coal, and, since it has become so noted, efforts have been made to identify it in the basin of Guest River. The popular impression is that the Imboden seam lies only a short distance above the top of the Lee conglomerate and hence should be found in the immediate valley of Guest River from Norton to Coeburn. Accordingly a seam which shows along that stream in numerous places near water level has been called the same as the great seam of the Big Stone Gap field. The prospector failed to allow for the difference in dips which characterize the anticline in the vicinity of Coeburn and those which prevail at Norton and farther west, hence the seam which has been correlated with the Imboden is much lower in the series than the true Imboden. In the Estillville folio the position of the Imboden seam was given at 180 feet below the Gladeville sandstone. If the thickness of that interval was correctly determined, it will be seen that the Imboden horizon corresponds very closely, if it is not identical, with the horizon of the Edwards seam. In either case, whether the correlation given here or the local identification of the supposed Imboden is accepted, it is apparent that the seam has lost its distinguishing features and is less valuable than other seams in the Coeburn field.

The determination of the interval between the Kennedy seam and the so-called Imboden is a matter of considerable difficulty, for they show in outcrop only on the flank of the Powell Mountain anticline, where there is generally great irregularity in dip. The best approximation places this interval at about 340 feet.

A mile east of Tacoma, and near the western margin of this quadrangle, the so-called Imboden seam was early prospected with the hope that it would afford an opportunity for the establishment of a mining plant. At the point of opening the seam is small, as shown in section 51, and the attempt was abandoned. Small seams at about this horizon show at a number of places along the railroad between Tacoma and Coeburn; they are also prominent along the railroad east of Little Tom tunnel, where the side-hill cutting has revealed almost all of the details of this complex coal horizon. The general section shown in the railroad cuts is as follows:

General section shown in railroad cuts east of Little Tom tunnel.

			Ft.	In.
1. Sandstone			—	—
2. Shale			4	0
3. Coal			2	2
4. Shale, dark blue			25	0
5. Coal			0	4
6. Shale, dark blue			20	0
7. Heavy sandstone			40	0
8. Shale			45	0
9.	Ft.	In.		
Coal	1	7		
Shale	3	4		
Coal	0	7	13	6
Sandy shale	5	0		
Coal	3	0		
10. Shale and sandstone			25	0
11. Coal			3	4
12. Sandstone to creek			60	0

There is some doubt as to which member of the above section corresponds to the so-called Imboden seam in the valley of Guest River, but it seems probable that No. 11 is the coal that has been the most extensively prospected and that has been correlated with the lowest seam at Tacoma. This coal has been opened under the high trestle of the Norfolk and Western Railway on Bull Run, about 60 feet above the creek, where it carries 40 inches of coal, as shown in section 52. The upper group of coals, or No. 9 of the above section, shows one-half mile west of Holbrook tunnel, where section 53 was measured. On Russell Creek it is reported as having been opened directly above the mine near Virginia City, where it has the bed section shown in section 54. This seam is generally small, or rather, it is composed of a number of small seams in a group, but the shale members which separate the coals are of so great thickness that the coal is of not much value. It is probably present in the valleys east of Russell Creek, but it is not known positively what its condition is in that direction; presumably it is of no greater value than in the region west of Virginia City.

Jawbone seam.—The opening last mentioned on the so-called Imboden seam is the only place in the field, known to the writer, where a satisfactory measurement can be obtained of the interval between this seam and the Jawbone seam, which underlies it. At the mine near Virginia City one opening is directly above the other, and consequently there is no opportunity for the dip of the strata to interfere with the correct measurement of the interval between them. At this point the distance is reported to be 90 feet, and presumably the coal referred to is No. 11 of the section measured along the railroad.

The Jawbone is the lowest workable coal that is known in the Norton formation. The many minor folds which occur in the soft shales composing the lower part of this formation render the determination of the interval between this coal and the base of the formation very difficult, but the best approximation makes it about 150 feet. The Jawbone seam is known over a very small portion of the coal field in this quadrangle; it seems to be a local development on Bull Run and Russell Creek of an otherwise unimportant seam. In this respect it may be considered the type of the irregular seams of the lower group.

The original opening, and the one from which the seam took its name, occurs in Jawbone Hollow, a small tributary of Bull Run which comes down out of the hills on the western side of the creek, $1\frac{1}{4}$ miles above the mouth of Dry Fork. The character of the seam at this point is shown in section 55. The coal is very irregularly bedded and carries near the middle a large parting of bony coal, which detracts very much from the value of the seam. This coal is also opened on the eastern side of Bull Run about a mile above the mouth of Dry Fork, where it shows a greater bed section than in the type locality. This is shown in section 56. By comparison it will be seen that the same bony streak is present as in the other section, and an examination of the pit will show the same irregularity in the bedding and the same general characteristics. A large number of openings have been made on this seam in the valley of Bull Run, but at the time of examination the two described were the only ones accessible.

On Russell Creek this seam has been developed to a considerable extent on the Right Fork by a mine which has been in operation since the building of the railroad into this region. The bed section is shown in section 57 and the character of the coal is much the same as on Bull Run. This seam does not extend far beyond Virginia City toward the southeast, for, by the upturn along the fault, its horizon has been raised above the surface, but it holds its thickness and character in this direction, as is shown by section 58, which is the section at an opening on Russell Creek below the mine and near the disturbed rocks that mark the fault.

IRON ORE.

Iron ore in small quantities is of very common occurrence, but deposits of sufficient size to be of use commercially are rare in this quadrangle. There are two modes of occurrence of the ore in this general region; it occurs either in regular strata and bedded with the rocks, or else as secondary deposits in the clay resulting from the decay of limestone or calcareous shale. The former, the bedded ore, occurs frequently in the Rockwood formation, but in this area it seems to be entirely wanting. The nearest point at which this ore is found in quantity is in the vicinity of Big Stone Gap, Virginia, about 20 miles west of this quadrangle. The secondary ores, or those which form during the process of decay of some other formation, are liable to occur at any point, and, in fact, traces of them can be seen at numerous localities in this quadrangle, but, so far as known, there are none that give promise of furnishing commercial supplies of ore.

ZINC.

The limestones of this region have suffered severely from the force which folded and faulted the rocks, and as a result they are in many cases traversed by fissures which have been filled with calcite. Accompanying the calcite are frequently zinc and lead ores, which have been mined at a number of places in the Appalachian Valley. In the Bristol quadrangle zinc is known to occur at one point only, and that is about a mile south of the post-office of Lucile, Scott County, Virginia. At this point the limestones are vertical and a shaft has been sunk some distance, bringing to light very good samples of zinc blende, but the work has not been extended along the strike of the rocks far enough to determine the extent of the zinc-bearing strata.

Very lately zinc has been reported from the Cambrian rocks of Clinch Valley by Mr. C. R. Boyd, who claims to have traced a continuous lead of ore from near Dungannon to Clinchport. The best prospect on this lead seems to be west of this quadrangle, where the folding of the strata has repeated the ore belt several times.

BARITE.

This mineral has been found along the valley of Clinch River from Tazewell to Honaker, and it has been reported from near Lebanon in this quadrangle, on the continuation of the same belt of rocks that characterizes it in the region to the eastward. It occurs in the clays which result from the disintegration of the upper part of the Knox dolomite or the Shenandoah limestone. At one time the mining and grinding of barite for the market was a rather important industry near Honaker, but the work has been suspended and little interest is taken in discovering new localities of the mineral.

MARBLE.

Throughout East Tennessee the top of the Chickamauga limestone is frequently characterized by a stratum of marble which has been extensively quarried and used in the fine arts. In southwestern Virginia marble also sometimes occurs at about this horizon, but it is not generally of as fine a quality as that which occurs farther south. A marble of this age is found in the Bristol quadrangle in the valley of Moccasin Creek, near the western margin of the quadrangle. It is the eastern extension of a belt of gray, coarsely crystalline marble which is particularly well shown in the vicinity of Gate City, Virginia. Its texture is so coarse that it can be used only for structural purposes, and its distribution in this quadrangle is so limited that its presence adds but little to the prospective mineral wealth of the quadrangle.

In the great syncline south of Clinch Mountain there occur, in the Carboniferous limestone, one or two narrow bands of red or mottled marble which greatly resembles the red marble of East Tennessee. Much of this Carboniferous rock is merely red, earthy limestone, but some bands are highly crystalline and full of fossils, like the best Tennessee marble. The amount in this locality is small, however, and probably will not pay for development.

LIMESTONE.

Rock of this nature is extremely abundant in this quadrangle. Much of it is of sufficient purity for the production of lime, but the demand is not great enough to warrant the establishment of a large plant. Two or three kilns were in operation on Susong Branch north of Bristol, burning lime for the supply of the town, and kilns have been burned from time to time in almost all parts of the valley for local consumption. Limestone for building purposes is rather abundant, but it has been utilized only for bridge abutments and a few mill buildings. Limestone adapted to road making is presumably abundant also, but it has never been utilized, even on the principal roads.

CLAY.

Brick making from the residual limestone clays has been carried on in almost all parts of the quadrangle, but the product has been generally restricted to the immediate needs of the community. This clay exists in great abundance and doubtless could be made to yield considerable revenue if the demand for structural material were such as to warrant the erection of a brick-making plant.

SOILS.

In this territory the soils are, as a rule, derived from the rocks which immediately underlie them, and, as a consequence, each geologic formation is marked by that peculiar kind of soil that results from its decay and disintegration. Since this is the case, the geologic map of the region may be regarded as a soil map also, but in its use in this capacity it must be understood that, in the process of soil making, the rocks lose, through solution, many of their principal mineral constituents, and hence the resulting soil will consist simply of those which remain. Thus soil resulting from the decay of limestone is frequently very poor in lime, but rich in silica and silicate of alumina, the less soluble components.

Regarding the quality of soil produced, the rocks of this quadrangle may be divided into three general classes: limestone, shale, and sandstone; but in making such a classification it must be remembered that limestone frequently merges imperceptibly into shale, and shale into sandstone, so that there will be a merging of soils produced from the different classes of rocks.

Limestone soils.—The value of a limestone soil depends largely upon the percentage of phosphate of lime which it carries, hence there are many grades in this class. In the Bristol quadrangle the Chickamauga limestone produces the richest soils; they are generally spoken of as the "bluegrass" soils, and they have brought a large amount of wealth to this section in return for the fine stock raised upon them. These soils are practically limited to two belts north of Clinch Mountain, one in the valley of Copper Creek and the other in the valley of Moccasin Creek. The next soil in point of excellence is derived from the Newman limestone, which shows only in the valley of the North Fork of Holston River. In a general way the Maryville and Rutledge limestones are next in order; they produce some fine farming lands along the valley of Clinch River, in the vicinity of Lebanon, in Rich Valley, and in many other localities in this territory. Lastly come the Knox dolomite and Shenandoah limestone, which are too siliceous and frequently contain too much chert to produce rich soils. The low relief in the vicinity of the city of Bristol, however, has made this a prosperous farming community, although the character of the soil is not equal to that found in other sections.

Shale soils.—In any quadrangle there is, as a rule, a greater variety of shales than of any other rock, hence the soils produced from them will show a corresponding variation. The Sevier is probably the most calcareous shale to be found in this territory. It produces a very rich soil, which ranks almost as high as that derived from the Chickamauga limestone, but the formation always outcrops on the steep northern side of high ridges, and hence its outcrop is not well disposed for farming. Owing to its position it is also frequently deeply covered by the débris from the more sandy formations which form the crest of the ridge. The several Cambrian shale beds produce a fair soil, except where they become sandy, but their outcrop is so limited that they are not very important members of the good soil-making rocks. The shales of the Carboniferous probably rank next in order; the soil produced from them is thin and easily exhausted and in every way poorly adapted for use. The soil of the Chattanooga black shale has already been referred to as a type of unproductive soil; it certainly deserves this distinction, for it is difficult to imagine a more cold and unresponsive soil than that produced from these shales. They have, however, in this territory a rival in this respect which seems to exceed them. This is the Athens shale in the southeastern corner of the quadrangle, where it assumes its more sandy feature. The region is rough and the outcrop of this shale is practically uncultivated.

Sandstone soils.—There is not much variety in this class, but the soil depends largely upon the thickness of the formation and upon its association with beds of other character. The Clinch sandstone is the type of a pure white sandstone. If it outcropped horizontally and over a wide expanse of territory it would be marked by a soil of clean beach sand without any admixture of foreign material, except such as has been added since the disintegration of the rock. Such a soil is the poorest that can be imagined, but fortunately the formation covers only a limited extent of country and hence its waste has not much effect upon the productiveness of the region. The sandstones and conglomerates of the Lee formation resemble the Clinch, but their outcrops are also very much restricted and they have little effect, except on Powell Mountain. The sandstones which lie above the Lee conglomerate are not quite so pure; many of them are distinctly argillaceous, and consequently the soils formed from them have an admixture of clay which renders them of greater value to the farmer.

From an agricultural standpoint the quadrangle consists of two parts, which correspond to the two geologic divisions. That part which includes the coal field has extremely poor soils, even in the most favored localities. That part which lies in the Appalachian Valley has generally good soils, but in many places the surface is so rough and broken that it is difficult to make it support the population found there.

Along the North Fork of Holston River there are some well-developed flood plains which are the most productive lands of the region, but their area is so small that they play an unimportant part in the agricultural wealth of the region.

MARIUS R. CAMPBELL,
Geologist.

January, 1900.

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

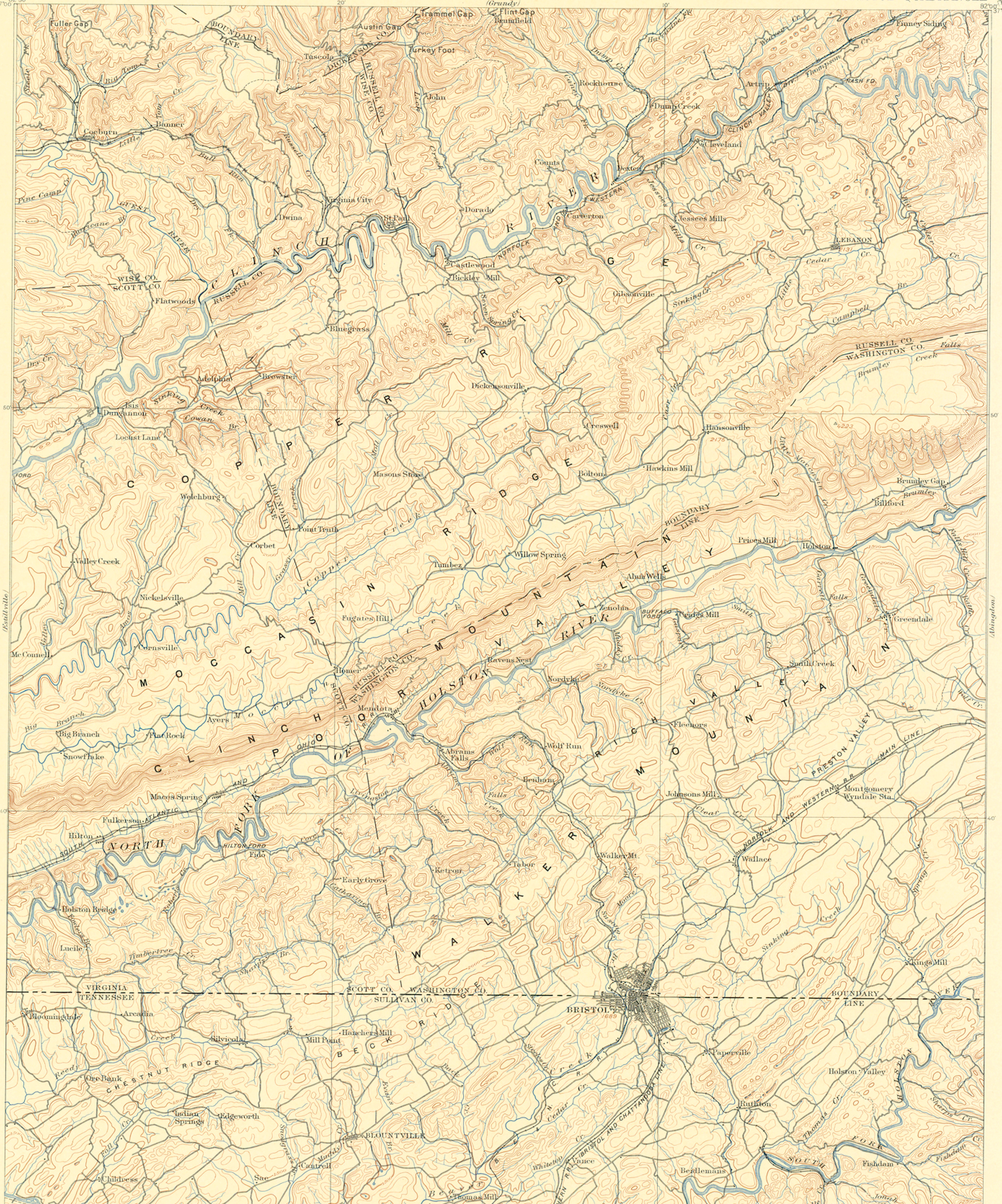
TOPOGRAPHIC SHEET

VIRGINIA-TENNESSEE
BRISTOL QUADRANGLE

CONVENTIONAL SIGNS

CULTURE
(printed in black)

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



Henry Gannett, Chief Topographer.
H.M. Wilson, Chief Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by D.C. Harrison and Gilbert Thompson.
Surveyed in 1887-88 and 1894-95.

Scale $\frac{1}{125000}$
1 0 1 2 3 4 5 Miles
1 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of Feb. 1899

CONVENTIONAL SIGNS

RELIEF
(printed in brown)

- 5463 Figures *(showing heights above mean sea level instrumentally determined)*
- Contours *(showing height above sea, horizontal form, and steepness of slope, of the surface)*
- Depression contours
- Levees
- Cliffs
- Mine dumps

DRAINAGE
(printed in blue)

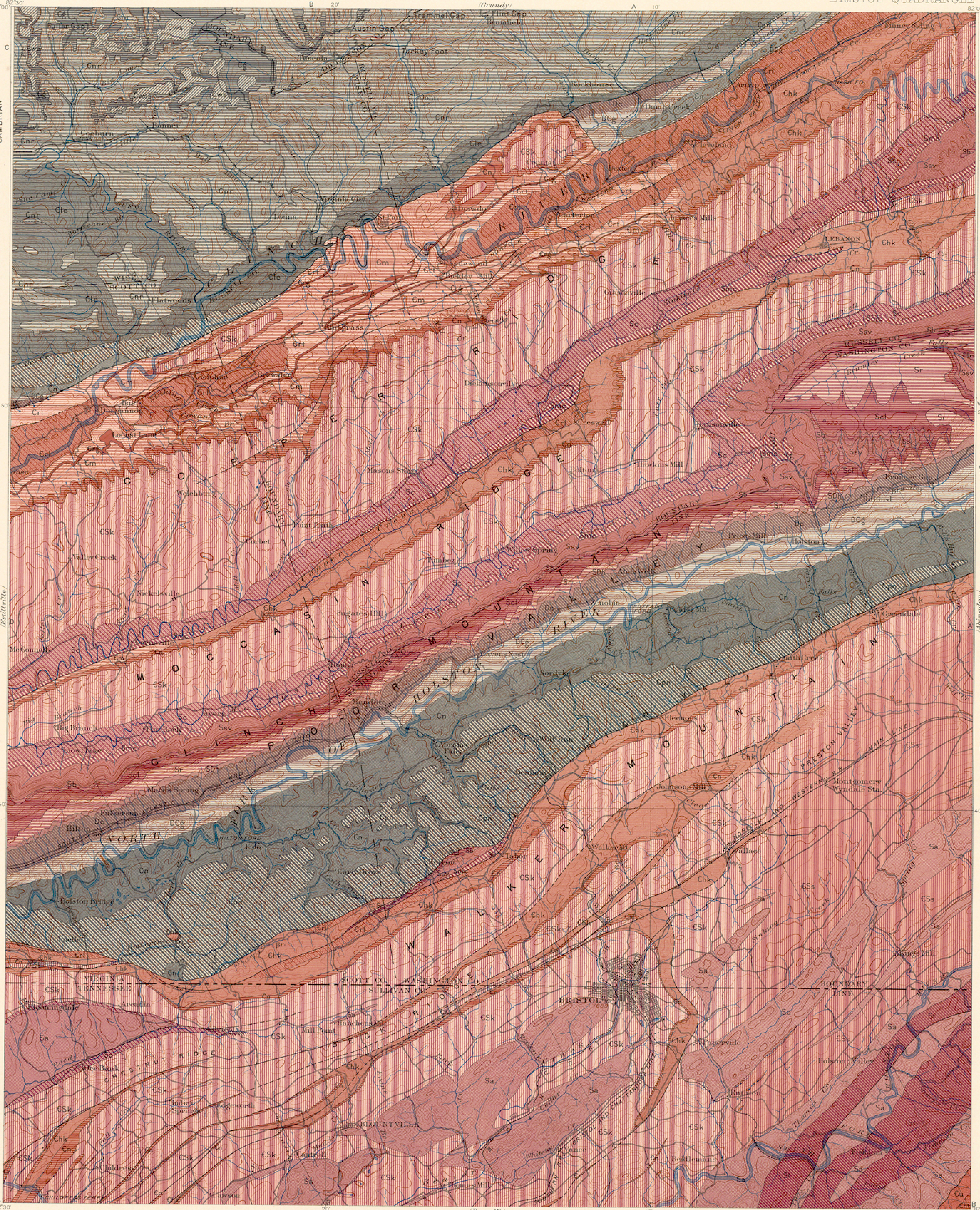
- Streams
- Falls and rapids
- Intermittent streams
- Canals and ditches
- Lakes and ponds
- Intermittent lakes
- Glaciers
- Springs
- Salt marshes
- Fresh marshes
- Tidal flats

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

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

HISTORICAL GEOLOGY SHEET

VIRGINIA–TENNESSEE
BRISTOL QUADRANGLE



LEGEND

SEDIMENTARY ROCKS
(continued)

CAMBRIAN

- I — Cht — Hampton shale *(sandy shale)*
- Cu — Unicoi sandstone *(quartzite, or fine bluish feldspathic conglomerate)*

Faults

Sections

LEGEND

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

CARBONIFEROUS

- Cws — Wise formation *(sandy shale and sandstone)*
- XII — Cg — Gladeville sandstone *(coarse white sandstone, sometimes conglomeratic)*
- Cnr — Norton formation *(sandstone and shale; contains many seams of workable coal)*
- Cle — Lee formation *(sandstone, conglomerate, and shale; contains thin seams of coal)*
- XI — Cpn — Pennington shale *(red and green shale with occasional beds of sandstone and impure limestone)*
- Cn — Newman limestone *(blue fossiliferous limestone and calcareous shale)*

DEVONIAN

- X, IX, VIII — DCg — Grainger formation *(shale, sandstone, and conglomerate)*
- Dc — Chattanooga shale *(black carbonaceous shale)*

SILURIAN

- VII, VI — SDh — Hancock limestone *(blue cherty limestone)*
- V — Sr — Rockwood formation *(sandy shale and ferruginous sandstone)*
- IV — Scl — Clinch sandstone *(coarse white sandstone)*
- Sb — Bays sandstone *(red sandstone and sandy shale)*
- III — Ssv — Sevier shale *(calcareous and sandy shale with thin beds of impure limestone)*
- Smc — Moccasin limestone *(red argillaceous limestone)*
- St — Tellico sandstone *(sandstone and sandy shale)*
- Sa — Athens shale *(sandy shale and thin sandstone with occasional beds of limestone and limestone conglomerate)*
- Sc — Chickamauga limestone *(blue fossiliferous limestone)*

CAMBRIAN

- CSk — Knox dolomite *(cherty, gray or white magnesian limestone)*
- II — CSs — Shenandoah limestone *(gray and blue limestone)*
- Cn — Nolichucky shale *(blue, calcareous and sandy shale)*
- Cm — Maryville limestone *(generally blue limestone)*
- Chk — Honaker limestone *(blue and gray limestone)*
- Crg — Rogersville shale *(blue calcareous shale)*
- Crt — Rutledge limestone *(dark impure limestone)*
- Crl — Russell formation *(red and green shale, sandstone, and ferruginous limestone)*

Legend is continued on the left margin.

Henry Gannett, Chief Topographer.
H.M. Wilson, Chief Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by D.C. Harrison and Gilbert Thompson.
Surveyed in 1887-88 and 1894-95.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

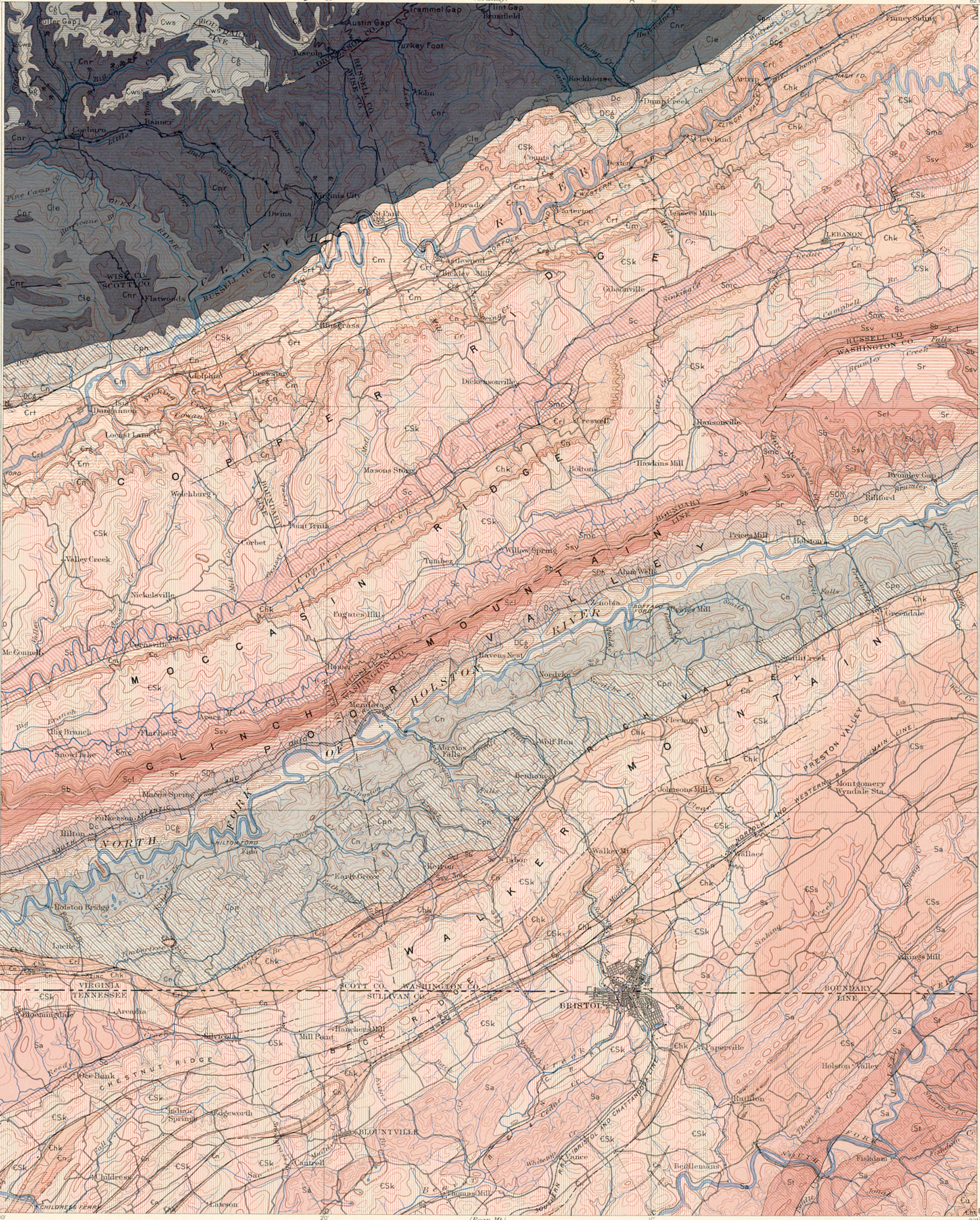
Contour interval 100 feet.
Datum is mean sea level.
Edition of Sept. 1899.

Geology by Marius R. Campbell.
Assisted by Walter C. Mendenhall.
Surveyed in 1891, 93, 94, 95, and 98.

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

ECONOMIC GEOLOGY SHEET

VIRGINIA–TENNESSEE
BRISTOL QUADRANGLE



LEGEND

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

CARBONIFEROUS

Cws — Wise formation (sandy shale and sandstone)

Cg — Gladeville sandstone (coarse white sandstone, sometimes conglomerate)

Cnr — Norton formation (sandstone and shale, contains many seams of workable coal)

Cle — Lee formation (sandstone, conglomerate, and shale, contains thin seams of coal)

Cpn — Pennington shale (red and green shale with occasional beds of sandstone and impure limestone)

Cn — Newman limestone (blue fossiliferous limestone and calcareous shale)

DEVONIAN

DCg — Grainger formation (shale, sandstone, and conglomerate)

Dc — Chattanooga shale (black carbonaceous shale)

SILURIAN

SDh — Hancock limestone (blue cherty limestone)

Sr — Rockwood formation (sandy shale and ferruginous sandstone)

Scl — Clinch sandstone (coarse white sandstone)

Sb — Bays sandstone (red sandstone and sandy shale)

Ssv — Sevier shale (calcareous and sandy shale with thin beds of impure limestone)

Smc — Moccasin limestone (red argillaceous limestone)

St — Tellico sandstone (sandstone and sandy shale)

Sa — Athens shale (sandy shale and thin sandstone with occasional beds of limestone and limestone conglomerate)

Sc — Chickamauga limestone (blue fossiliferous limestone)

CAMBRIAN

CSk — Knox dolomite (cherty gray or white magnesian limestone)

CSs — Shenandoah limestone (gray and blue limestone)

Chk — Honaker limestone (blue and gray limestone)

Cn — Nolichucky shale (blue, calcareous and sandy shale)

Cm — Maryville limestone (generally blue limestone)

Crg — Rogersville shale (blue calcareous shale)

Crt — Rutledge limestone (dark impure limestone)

Crl — Russell formation (red and green shale, sandstone, and ferruginous limestone)

Legend is continued on the left margin.

LEGEND

SEDIMENTARY ROCKS
(continued)

CAMBRIAN

Cht — Hampton shale (sandy shale)

Cu — Unicoi sandstone (quartzite, or fine bluish feldspathic conglomerate)

Faults

Sections

⚒ Coal mines
X Zinc prospect

Known productive formations

Cws–Cg — Coal (Wise formation and Gladeville sandstone nearly coal seams in Norton formation)

Cnr — Coal (Norton formation contains many seams of workable coal)

Cle — Coal (Lee formation contains thin coal seams)

Henry Gannett, Chief Topographer.
H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr and S. S. Gannett.
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Scale $\frac{1}{125000}$
Miles
Kilometers
Contour interval 100 feet.
Datum is mean sea level.
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U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

STRUCTURE-SECTION SHEET

VIRGINIA-TENNESSEE
BRISTOL QUADRANGLE

LEGEND

SEDIMENTARY ROCKS (continued)

SHEET SYMBOL / SECTION SYMBOL

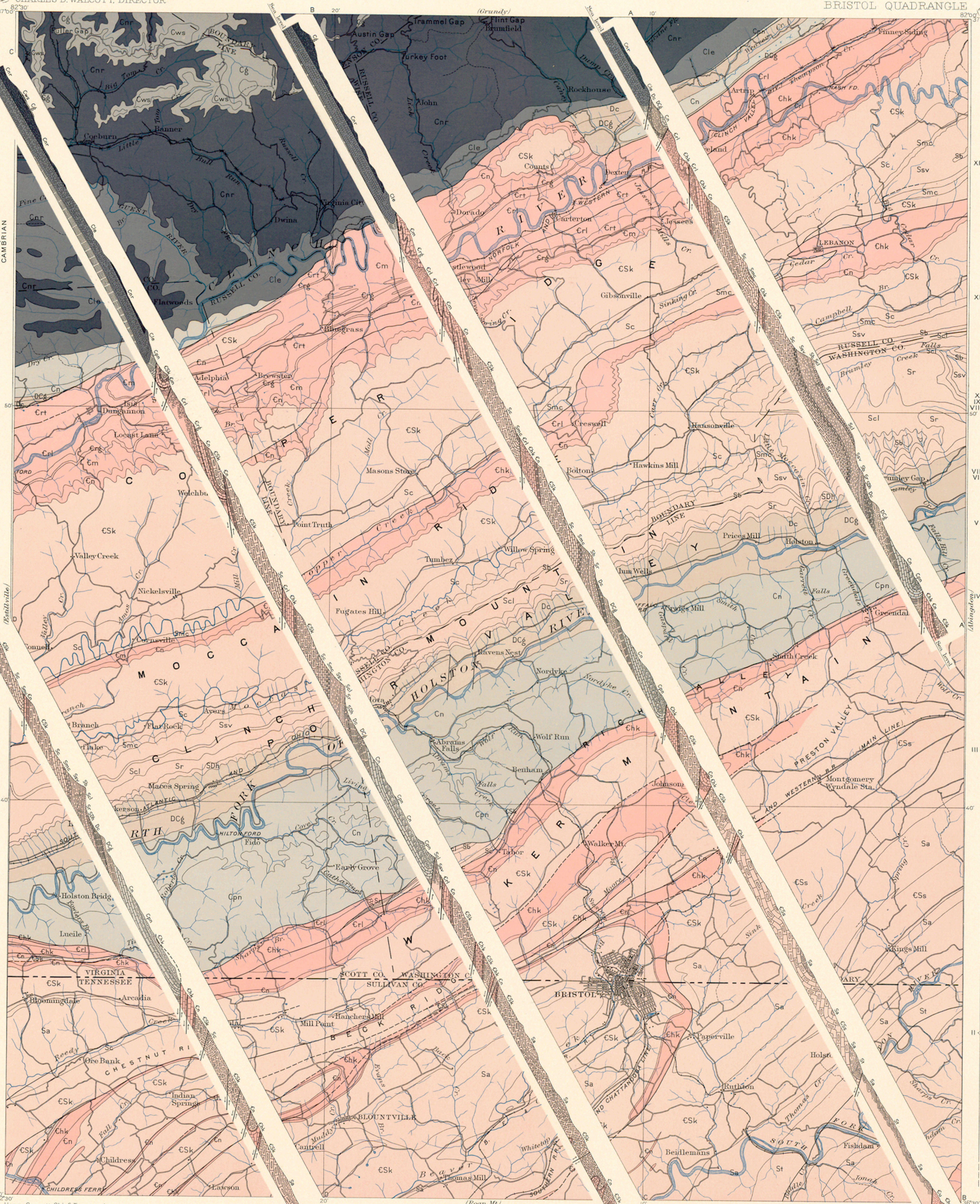
CAMBRIAN

I
- Cht / Cht — **Hampton shale** (sandy shale)
- Cu / Cu — **Unicoi sandstone** (quartzite, or fine bluish feldspathic conglomerate)

Faults

Known productive formations

- Cws-Cǵ — Coal (Wise formation and Gladeville sandstone overly coal seams in Norton formation)
- Cnr — Coal (Norton formation contains many seams of workable coal)
- Cle — Coal (Lee formation contains thin coal seams)



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Scale $\frac{1}{125000}$

Miles

Kilometers

Edition of Nov. 1899.

Geology by Marius R. Campbell.
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Surveyed in 1891, 93, 94, 95, and 98.

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

CARBONIFEROUS

- Cws / Cws — **Wise formation** (sandy shale and sandstone)

XII
- Cǵ / Cǵ — **Gladeville sandstone** (coarse white sandstone, sometimes conglomeratic)
- Cnr / Cnr — **Norton formation** (sandstone and shale; contains many seams of workable coal)
- Cle / Cle — **Lee formation** (sandstone, conglomerate, and shale; contains thin seams of coal)

XI
- Cpn / Cpn — **Pennington shale** (red and green shale with occasional beds of sandstone and impure limestone)
- Cn / Cn — **Newman limestone** (blue fossiliferous limestone and calcareous shale)

DEVONIAN

X, IX, VIII
- DCǵ / DCǵ — **Grainger formation** (shale, sandstone, and conglomerate)
- Dc / Dc — **Chattanooga shale** (black carbonaceous shale)

SILURIAN

VII, VI
- SDh / SDh — **Hancock limestone** (blue cherty limestone)

V
- Sr / Sr — **Rockwood formation** (sandy shale and ferruginous sandstone)

IV
- Scl / Scl — **Clinch sandstone** (coarse white sandstone)
- Sb / Sb — **Bays sandstone** (red sandstone and sandy shale)

III
- Ssv / Ssv — **Sevier shale** (calcareous and sandy shale with thin beds of impure limestone)
- Smc / Smc — **Moccasin limestone** (red argillaceous limestone)
- St / St — **Tellico sandstone** (sandstone and sandy shale)
- Sa / Sa — **Athens shale** (sandy shale and thin sandstone with occasional beds of limestone and limestone conglomerate)

II
- Sc / Sc — **Chickamauga limestone** (blue fossiliferous limestone)
- €Sk / €Sk — **Knox dolomite** (cherty, gray or white magnesian limestone)
- €Ss / €Ss — **Shenandoah limestone** (gray and blue limestone)

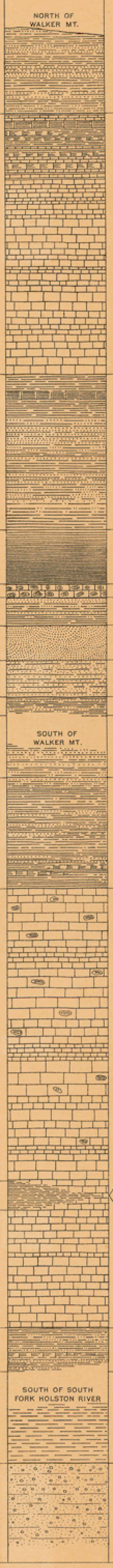
CAMBRIAN

- €n / €n — **Nolichucky shale** (blue, calcareous and sandy shale)
- €m / €m — **Maryville limestone** (generally blue limestone)
- €hk / €hk — **Honaker limestone** (blue and gray limestone)
- €rǵ / €rǵ — **Rogersville shale** (blue calcareous shale)
- €rt / €rt — **Rutledge limestone** (dark impure limestone)
- €rl / €rl — **Russell formation** (red and green shale, sandstone, and ferruginous limestone)

Legend is continued on the left margin.

COLUMNAR-SECTION SHEET

GENERALIZED SECTION FOR THE PORTION OF THE QUADRANGLE SOUTH OF CLINCH MOUNTAIN.
SCALE: 1000 FEET = 1 INCH.

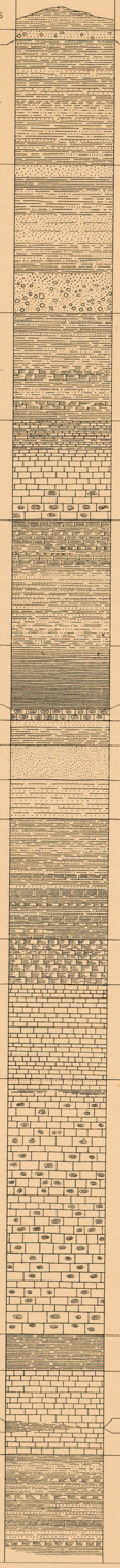
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CARBONIFEROUS	Pennington shale.	Cpn		800+	Green sandy shale and thin-bedded sandstone.	Forms the rugged region between Walker Mountain and the North Fork of Holston River. Soil very thin and poor.
CARBONIFEROUS	Newman limestone.	Cn		2000–2600	Blue calcareous shale, grading downward into impure limestone. Heavy-bedded blue limestone.	Rough, rolling lands with fairly productive soil.
CARBONIFEROUS / DEVONIAN	Grainger formation.	DCg		1400–1600	Dark argillaceous shale with interbedded calcareous shale and impure limestone. Sandy shale. Sandstone containing locally beds of quartz conglomerate. Green shale.	The valley of the North Fork of Holston River. Sharp, serrate ridge separating the Holston River Valley from the Poor Valley at the foot of Clinch Mountain.
DEVONIAN	Chattanooga shale.	Dc		500–800	Black carbonaceous shale which merges with the green shale above.	The Poor Valley. Soil unproductive.
SILURIAN	Hancock limestone.	SDn		30–175	Cherty limestone.	The base of the southern slope of Clinch Mountain.
SILURIAN	Rockwood formation.	Sr		200–300	Sandy shale and ferruginous sandstone.	Southern slope of Clinch Mountain.
SILURIAN	Clinch sandstone.	Scl		250–450	Coarse-grained white sandstone.	Sharp mountainous ridges.
SILURIAN	Bays sandstone.	Sb		350–450	Red sandstone and sandy shale.	Steep slopes.
SILURIAN	Sevier shale.	Ssv		200+	Sandy shale.	Gentle slopes.
SILURIAN	Tellico sandstone.	St	SOUTH OF WALKER MT.	300+	Sandstone and sandy shale.	Caps the highest ridges in the southeastern corner of the quadrangle.
SILURIAN	Athens shale.	Sa		1000–1200	Sandy shale and thin sandstones with occasional beds of impure limestone and limestone conglomerate. Dark argillaceous shale at the base.	Groups of barren hills in the vicinity of Bristol. The soil is extremely poor and the hills are generally uncultivated.
SILURIAN / CAMBRIAN	Knox dolomite.	€Sk		2800–3500	Blue and gray limestone. Very cherty along Walker Mountain, but farther toward the southeast the chert disappears and the formation merges with and becomes indistinguishable from the Honaker limestone beneath, and the whole is called the Shenandoah limestone.	Forms low ridges where it is cherty, but under other conditions it produces a gently rolling country well adapted to agricultural pursuits. Soil generally fertile, unless covered with chert.
CAMBRIAN	Nolichucky shale.	€n		0–300	Blue calcareous and sandy shale. Toward the east this changes to limestone.	Gently rolling country and the northern slope of Walker Mountain.
CAMBRIAN	Honaker limestone.	€hk		1200–1400	Blue and gray limestone. Toward the east this formation merges with the Knox dolomite, and the whole is known as the Shenandoah limestone.	Gently rolling country in the southeastern quarter of the quadrangle and Rich Valley along the northern side of Walker Mountain.
CAMBRIAN	Russell formation.	€rl		400+	Red and green shales and thin-bedded sandstones.	Sharp hills along the north side of Rich Valley.
CAMBRIAN	Hampton shale.	€ht	SOUTH OF SOUTH FORK HOLSTON RIVER	600+	Sandy shale.	The northern slope of Holston Mountain, which passes through the southeast corner of the quadrangle.
CAMBRIAN	Unicoi sandstone.	€u		1000	Quartzite or fine, bluish, feldspathic conglomerate.	Forms a subordinate ridge on the northern face of Holston Mountain.

MARIUS R. CAMPBELL,
Geologist.

COLUMNAR-SECTION SHEET

GENERALIZED SECTION FOR THE PORTION OF THE QUADRANGLE NORTH OF CLINCH MOUNTAIN.

SCALE: 1000 FEET = 1 INCH.



Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in feet.	Character of Rocks	Character of Topography and Soil.
CARBONIFEROUS	Wise formation.	Cws		100+	Shale, sandstone, and coal beds.	Caps the hills in northwestern corner of quadrangle.
	Gladeville sandstone.	Cg		100	Coarse white sandstone, sometimes conglomeratic.	Forms a mesa, or table-land. Sandy soil.
	Norton formation.	Cnr		1200–1300	Shale, sandstone, and coal beds. The most important coal-bearing formation in the quadrangle.	Steep slopes and irregular hills. Soil generally sandy and poor.
	Lee formation.	Cle		1500±	Massive sandstone. Shale with coal seams. Sandstone, generally free from pebbles, with shaly layers. Shale with coal seams. Coarse massive conglomerate.	South of Guest River this stratum forms a low, broad arch which is known as Powell Mountain. Sandy soil.
	Pennington shale.	Cpn		1040–1100	Red and green argillaceous shale with occasional beds of sandstone and impure limestone.	Steep southern slopes of Powell Mountain. Soil generally good, but the slopes are too steep for economic farming.
	Newman limestone.	Cn		1000±	Calcareous shale with beds of impure limestone. Heavy-bedded blue limestone, slightly cherty toward the base.	Gentle slopes. Yields a fairly productive soil, but not so rich as that from the Silurian limestones.
DEVONIAN	Grainger formation.	DCg		1000–1500	Argillaceous and calcareous shale. Sandy shale and thin-bedded sandstone.	Forms the southern slope of Powell Mountain.
	Chattanooga shale.	Dc		500–800	Black carbonaceous shale, grading upward into the sandy shale of the Grainger formation.	Valleys and lands of low relief. Yields a white soil which is extremely unproductive.
SILURIAN	Hancock limestone.	SDh		30–175	Blue, fossiliferous, cherty limestone.	No appreciable effect upon the topography.
	Rockwood formation.	Sr		200–300	Sandy shale, sandstone, and red fossil iron ore.	
	Clinch sandstone.	Scl		250–450	Coarse-grained white sandstone.	Sharp mountainous ridges.
	Bays sandstone.	Sb		350–450	Red sandstone and sandy shale.	Steep slopes.
	Sevier shale.	Ssv		1100–1300	Sandy shale. Blue calcareous shale which generally weathers yellow upon exposure. Occasional beds of impure limestone near the base.	Steep northern slope of Clinch Mountain. Soil productive, but the slopes are generally too steep for advantageous farming.
	Moccasin limestone.	Smc		400–500	Red argillaceous limestone.	Occurs on the northern slope of Clinch Mountain. Produces a fair soil, but not so productive as the soil derived from the Chickamauga limestone.
	Chickamauga limestone.	Sc		900–1000	Blue limestone with occasional small lentils of red and gray marble.	Rolling valley land. Yields the most productive soil in the quadrangle.
CAMBRIAN	Knox dolomite.	€Sk		2300–2800	Limestone conglomerate with pebbles of chert or beds of red earthy limestone. Gray or white magnesian limestone with nodular cherts occurring at intervals throughout the formation.	Low rounded ridges, generally covered with a mantle of residual clay and chert.
	Nolichucky shale	€n		250–400	Blue calcareous shale with local developments of sandy shale and beds of limestone.	Forms the northern slopes of the Knox dolomite ridges.
	Maryville limestone.	€m		500–600	Gray or blue limestone.	Gentle slopes. Soil generally good, and the surface well disposed for farming.
	Rogersville shale.	€rg		0–100	Blue calcareous shale.	No effect upon the topography.
	Rutledge limestone.	€rt		240–300	Impure magnesian limestone.	Soil about same as that from the Maryville limestone.
	Russell formation.	€rl		1000±	Shales, sandstones, and impure limestones of various colors, green and red predominating.	Sharp serrate ridges. Soil poor.

MARIUS R. CAMPBELL,
Geologist.

TABLE OF FORMATION NAMES.

<table>
<tr><th>Period.</th><th colspan="4">Names and Symbols Used in this Folio.</th><th>Campbell: Estillville Folio, U. S. Geological Survey, 1894.</th><th>Safford: Geology of Tennessee, 1869.</th><th>Stevenson: A Geological Reconnaissance in Part of Lee, Wise, Scott, and Washington Counties, Va., 1881.</th></tr>
<tr><td rowspan="7">Carboniferous</td><td colspan="3">Wise formation.</td><td>Cws</td><td>Wise formation.</td><td rowspan="4">Coal Measures</td><td rowspan="4">Coal Measures.
Quinnemont or Seral conglomerate.</td></tr>
<tr><td colspan="3">Gladeville sandstone.</td><td>Cg</td><td>Gladeville sandstone.</td></tr>
<tr><td colspan="3">Norton formation.</td><td>Cnr</td><td>Norton formation.</td></tr>
<tr><td colspan="3">Lee formation</td><td>Cle</td><td>Lee conglomerate.</td></tr>
<tr><td colspan="3">Pennington shale.</td><td>Cpn</td><td>Pennington shale.</td><td rowspan="3">Mountain limestone.
Siliceous group.</td><td rowspan="3">Mountain limestone.
Siliceous group.</td></tr>
<tr><td colspan="3">Newman limestone.</td><td>Cn</td><td>Newman limestone.</td></tr>
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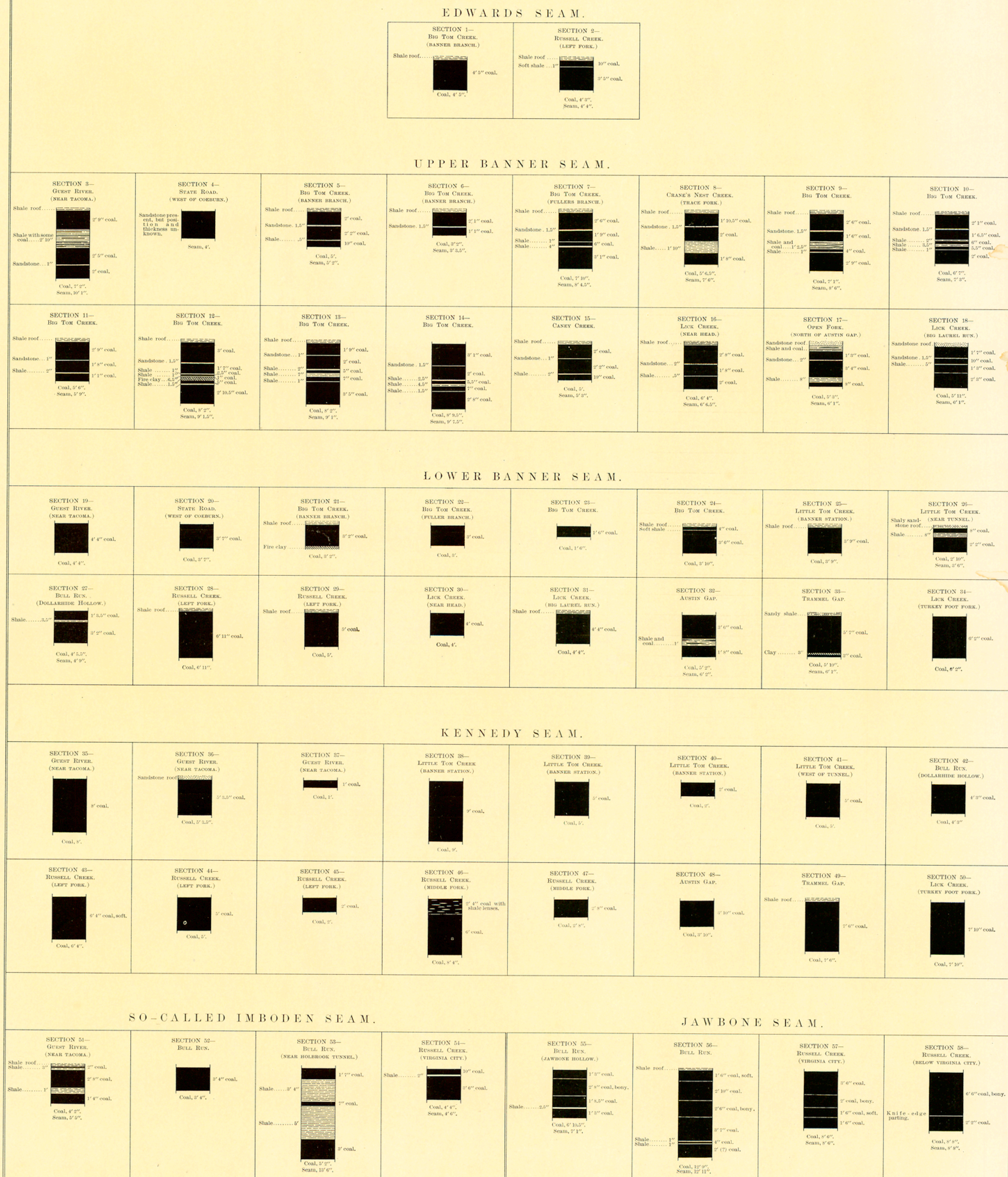
<tr><td rowspan="9">Silurian</td><td colspan="3">Hancock limestone.</td><td>SDh</td><td>Hancock limestone.</td><td>Meniscus limestone.</td><td>Oriskany and Lower Helderberg.</td></tr>
<tr><td colspan="3">Rockwood formation.</td><td>Sr</td><td>Rockwood formation.</td><td>Dyestone group.</td><td>Clinton group.</td></tr>
<tr><td colspan="3">Clinch sandstone.</td><td>Scl</td><td>Clinch sandstone.</td><td rowspan="2">Clinch Mountain sandstone.</td><td rowspan="2">Medina sandstone.</td></tr>
<tr><td colspan="3">Bays sandstone.</td><td>Sb</td><td>Bays sandstone.</td></tr>
<tr><td colspan="3">Sevier shale.</td><td>Ssv</td><td rowspan="4">Sevier shale.
Moccasin limestone.</td><td rowspan="5">Trenton and Nashville series.</td><td rowspan="5">Trenton and Nashville group.</td></tr>
<tr><td colspan="3">Moccasin limestone.</td><td>Smc</td></tr>
<tr><td colspan="3">Tellico sandstone.</td><td>St</td></tr>
<tr><td colspan="3">Athens shale.</td><td>Sa</td></tr>
<tr><td colspan="2">Chickamauga limestone.</td><td rowspan="6">Shenandoah limestone. (€Ss)</td><td>Sc</td><td>Chickamauga limestone.</td></tr>
<tr><td rowspan="8">Cambrian</td><td colspan="2">Knox dolomite.</td><td>€Sk</td><td>Knox dolomite.</td><td>Knox dolomite.</td><td>Knox dolomite.</td></tr>
<tr><td colspan="2">Nolichucky shale.</td><td>€n</td><td>Nolichucky shale.</td><td rowspan="4">Knox shale.</td><td rowspan="4">Knox shale.</td></tr>
<tr><td>Maryville limestone.</td><td rowspan="3">Honaker limestone. (€hk)</td><td>€m</td><td>Maryville limestone.</td></tr>
<tr><td>Rogersville shale.</td><td>€rg</td><td>Rogersville shale.</td></tr>
<tr><td>Rutledge limestone.</td><td>€rt</td><td>Rutledge limestone.</td></tr>
<tr><td colspan="3">Russell formation.</td><td>€rl</td><td>Russell formation.</td><td>Knox sandstone.</td><td>Knox sandstone.</td></tr>
<tr><td colspan="3">Hampton shale.</td><td>€ht</td><td rowspan="2"></td><td rowspan="2">Chilhowee sandstone.</td><td rowspan="2"></td></tr>
<tr><td colspan="3">Unicoi sandstone.</td><td>€u</td></tr>
</table>

COAL-SECTION SHEET

SECTIONS OF COAL SEAMS EXPOSED IN THE QUADRANGLE.

SCALE: 10 FEET=1 INCH.



MARIUS R. CAMPBELL,
Geologist.

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

AGES OF ROCKS.

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

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

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

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are characteristic types, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present.

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

Fossil remains found in the rocks of different areas, provinces, and continents, afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the color or colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period name.

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

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

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

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

Historical geology sheet.—This sheet shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern and its letter-symbol on the map the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

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

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

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

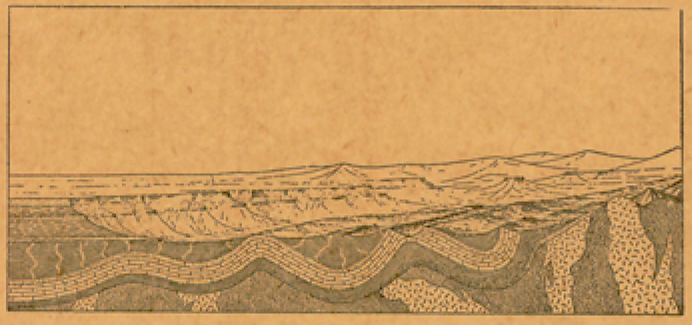


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

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

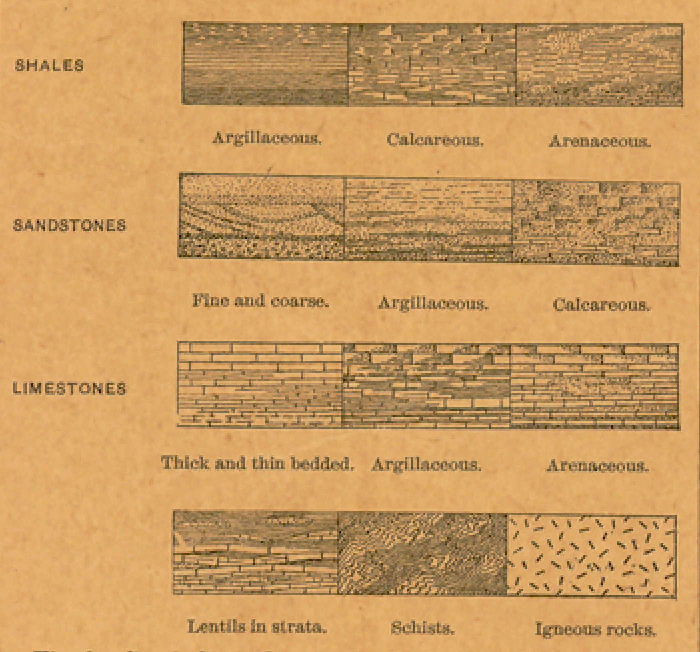


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

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

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

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

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

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

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

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

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

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

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

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

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Director.

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