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GEOLOGIC ATLAS

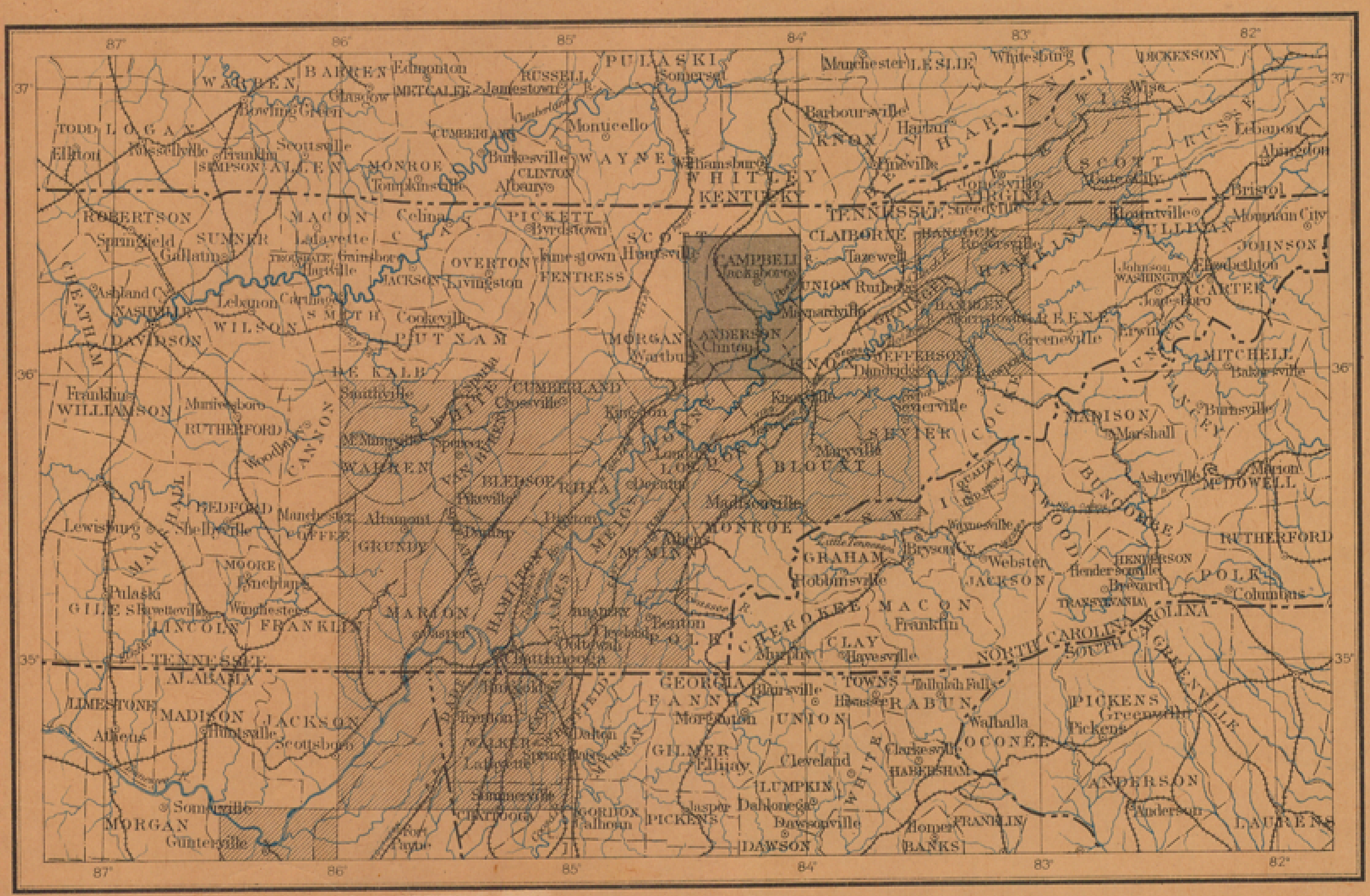
OF THE

UNITED STATES

BRICEVILLE FOLIO

TENNESSEE

INDEX MAP



SCALE 40 MILES = 1 INCH

AREA OF THE BRICEVILLE FOLIO

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DOCUMENTS

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COLUMNAR SECTIONS

FOLIO 33 | LIBRARY EDITION | BRICEVILLE

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
... GEOLOGIC MAPS ... S. J. KUBEL, CHIEF ENGRAVER
189[illegible]

EXPLANATION.

...al 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:

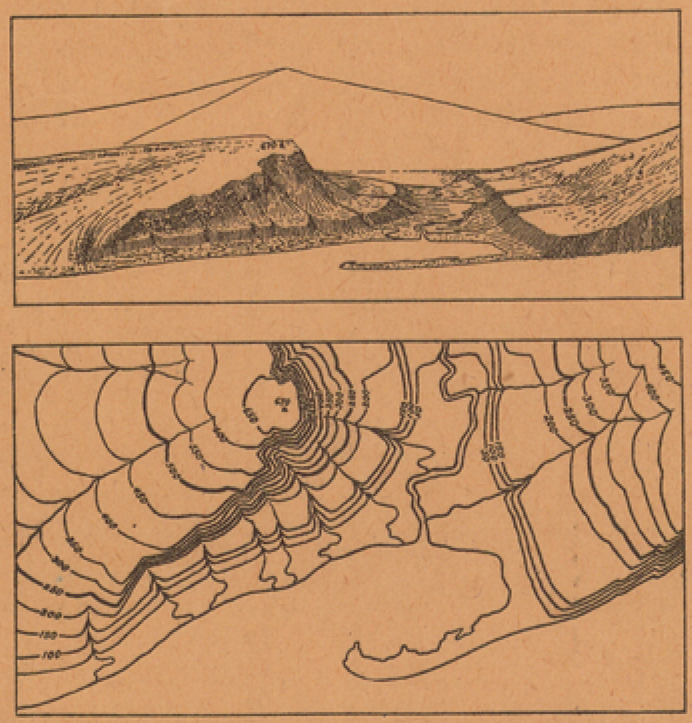


Fig. 1.—Ideal sketch and corresponding contour map.

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 to 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 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 areal geologic map represents 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 made are carried as solid particles by the 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

(Continued on third page of cover.)

DESCRIPTION OF THE BRICEVILLE QUADRANGLE.

GEOGRAPHY.

An account of the physical features of the Appalachian province and the relations of those of the Briceville quadrangle.

Extent of quadrangle. Counties.

General relations.—The Briceville quadrangle lies entirely in Tennessee. It is included between the parallels 36° and 36° 30′ and the meridians 84° and 84° 30′, and it contains 976 square miles, divided between Knox, Morgan, Anderson, Campbell, and Scott counties.

Definition of the 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. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as a single quadrangle; hence it it necessary to consider the individual quadrangle in its relations to the entire province.

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

The Appalachian Valley; its extent and character. Relation of relief to rock character.

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

The Appalachian Mountains; local ranges. Nature of the rocks.

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

The Cumberland Plateau. Its varied topography.

The western division of the Appalachian province embraces the Cumberland Plateau and the Allegheny Mountains and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the Mississippi River as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian Valley by the Allegheny front and the Cumberland escarpment. The rocks of this division are almost entirely of sedimentary origin and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely worn down. In the southern half of the province the plateau is sometimes extensive and perfectly flat, but it is oftener much divided by streams into large or small areas with flat tops. In West Virginia and portions of Pennsylvania the plateau is sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion, and the surface is now comparatively low and level, or rolling.

Altitudes of the Appalachian Mountains.

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

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

Altitudes of the Appalachian Valley.

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

Altitudes of the plateau region.

The plateau, or western, division increases in altitude from 500 feet at the southern edge of the province to 1500 feet in northern Alabama, 2000 feet in central Tennessee, and 3500 feet in southeastern Kentucky. It is between 3000 and 4000 feet in West Virginia, and decreases to about 2000 feet in Pennsylvania. From its greatest altitude, along the eastern edge, the plateau slopes gradually westward, although it is generally separated from the interior lowlands by an abrupt escarpment.

Direction of outflow.

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

Arrangement of streams.

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

TOPOGRAPHY.

Details of the plateaus, hills, valleys, and streams.

Local river systems.

Topographic divisions of the Briceville quadrangle.—Within the limits of this quadrangle two geographic divisions appear, the areas of which are nearly equal. The division lying southeast of Walden Ridge and Cumberland Mountain is part of the Great Valley of East Tennessee; that lying northwest of these ridges is part of the Cumberland Plateau. The drainage of the district is quite diverse. The valley region is drained through Clinch River into the Tennessee River, and the mountain region through New River and Elk into Cumberland River and the Ohio. That portion of the mountain region embraced in Morgan County is drained through Emory River into the Clinch. The New, Elk, and Emory rivers head within the quadrangle; the Clinch extends far beyond it.

The streams of the mountain district fall rapidly from their sources, and at a level of 900 to 1100 feet above sea they emerge into the valley. Their valleys are deep, and the slopes rise continuously from narrow bottoms to the divides. The streams of the valley fall from 900 to 1100 feet at the valley border to 780 feet at Blacks Ford of Clinch River. The larger streams are sunk in sharp, narrow troughs 100 to 500 feet below the adjacent country. Most of the surface of the smaller valleys stands at an altitude of 900 to 1100 feet; above this various ridges project from 100 to 500 feet.

Conditions determining character of topography.

In this region the topography varies much, depending in all cases upon the influence of erosion on the different formations. Such rock-forming minerals as carbonates of lime and magnesia, and to a less extent feldspar, are readily removed by solution in water. Rocks containing these minerals in large proportions are therefore subject to decay by solution, which breaks up the rock and leaves the insoluble matter less firmly coherent. Frost and rain and streams break up and carry off this insoluble residue, and the surface is worn down. According to the nature and amount of the insoluble matter the rocks form high or low ground. Calcareous rocks, leaving the least residue, occupy the low ground. Such are all the formations between the Rome sandstone and the Rockwood formation. All of these, except the Knox dolomite, yield a fine clay after solution; the dolomite leaves, besides the clay, a large quantity of silica in the form of chert, which strews the surface with lumps and protects it from removal. In many regions where the amount of chert in the dolomite is less, it is reduced to low ground, as the other limestones are. The least soluble rocks are the sandstones, and since most of their mass is left untouched by solution they are the last to be reduced in height.

The valley ridges.

Erosion of the valley formations has produced a series of long ridges, separated by long valleys, which closely follow the belts of rock. Where the formations spread out at a low dip the valleys or ridges are broad, and where the strata dip steeply the valleys are narrower. Each turn in the course of a formation can be seen by the turn of the ridge or valley which it causes. The Knox dolomite illustrates this feature well. In Black Oak Ridge its upturned edges form a straight, narrow ridge; where the formation assumes a more nearly horizontal position the direction of the ridge is less pronounced until, in the flat rocks along Clinch River, the divides run in all directions. Each rock produces a uniform type of surface so long as its attitude and composition remain the same, but with a change in either the surface changes form.

The mountain district.

The topography of the mountain district is as unlike that of the valley as its rocks are unlike those of the latter. None of the straightness of the valley ridges appears, but an equal regularity of crest is prominent, although from a different cause. The rocks of the mountain district are composed of two classes, sandstones and shales, and the varieties of each have about the same effect on the surface forms in all cases. Sandstones make cliffs, table-topped ridges, and benches, which stand out sharply from the adjacent shale slopes. Inasmuch as the rocks are practically flat, the foregoing features are conspicuous by their regularity of level, and wind in and out around the slopes of the mountains. Exceptions to this are Walden Ridge and Pine and Cumberland mountains, where the rocks are considerably tilted and run in straight belts, like those of the valley.

The divides in the mountain district vary in height from 2000 to 3600 feet, and over large areas are more than 3000 feet above sea. The crests of the mountains and ridges are usually narrow and flat; many of them have small areas of easy slopes, which are susceptible of cultivation. The arch or table of the crests gives place at once, however, to steep ravines and narrow V-shaped valleys. From the tops the spurs branch and fall rapidly to the streams, with here and there a level table or narrow bench and with frequent cross spurs in both directions. The steep and rugged slopes of these mountains have proved very effectual barriers to their settlement.

GEOLOGY.

STRATIGRAPHY.

An account of the origin and general significance of stratified rocks, with detailed descriptions of the strata in the Briceville quadrangle.

Origin of the rocks.

The general sedimentary record.—All of the rocks appearing at the surface within the limits of the Briceville quadrangle are of sedimentary origin—that is, they were deposited by water. They consist of conglomerate, sandstone, shale, coal, and limestone, all presenting great variety in composition and appearance. The materials of which they are composed were originally gravel, sand, and mud, derived from the waste of older rocks, and the remains of plants and animals which lived while the strata were being laid down. Thus some of the great beds of limestone were formed largely from the shells of various sea animals, and the beds of coal are the remains of a luxuriant vegetation, which probably covered low, swampy shores.

What the strata mean.

The rocks afford a record of sedimentation from early Cambrian through Carboniferous time. Their composition and appearance indicate at what distance from shore and in what depth of water they were deposited. Sandstones marked by ripples and cross-bedded by currents, and shales cracked by drying on mud flats, indicate shallow water; while limestones, especially by the fossils they contain, indicate greater depth of water and scarcity of sediment. The character of the adjacent land is shown by the character of the sediments derived from its waste. Coarse sandstones and conglomerates, such as are found in the Coal Measures, were derived from high land on which stream grades were steep, or they may have resulted from wave action as the sea encroached upon a sinking coast. Red sandstones and shales, such as make up some of the Cambrian and Silurian formations, result from the revival of erosion on a land surface long exposed to rock decay and oxidation, and hence covered by a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low and that its streams were too sluggish to carry off coarse sediment, the sea receiving only fine sediment and substances in solution.

The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin. The Briceville quadrangle was near its eastern margin, and the materials of which its rocks are composed were therefore derived largely from the land to the east. The exact position of the eastern shore-line of this ancient sea is not known, but it probably varied from time to time within rather wide limits.

Geologic history of the province.

Four great cycles of sedimentation are recorded in the rocks of this region. Beginning with the first definite record, coarse sandstones and shales were deposited in early Cambrian time along the eastern border of the interior sea as it encroached upon the land. As the land was worn down and still further depressed, the sediment became finer until in the Knox dolomite of the Cambro-Silurian period very little trace of shore material is seen. Following this long period of quiet was a slight elevation, producing coarser rocks; this became more and more pronounced, until, between the lower and upper Silurian, the land was much expanded and large areas of recently deposited sandstones were lifted above the sea, thus completing the first great cycle. Following this elevation came a second depression, during which the land was again worn down nearly to baselevel, affording conditions for the accumulation of the Devonian black shale. After this the Devonian shales and sandstones were deposited, recording a minor uplift of the land, which in northern areas was of great importance. The third cycle began with a depression, during which the Carboniferous limestone accumulated, containing scarcely any shore waste. A third uplift brought the limestone into shallow water—portions of it perhaps above the sea—and upon it were deposited, in shallow water and swamps, the sandstones, shales, and coal beds of the Carboniferous. Finally, at the close of the Carboniferous, a further uplift ended the deposition of sediment in the Appalachian province, except along its borders in recent times.

The rocks of this area.—These range in age from sediments which are among the earliest of the Appalachian nearly to the end of the Paleozoic, including the Cambrian, Silurian, Devonian, and Carboniferous periods. Carboniferous rocks are very fully represented here; Devonian rocks have only a small development; while the Cambrian and Silurian formations are fairly complete.

The columnar section shows the composition, name, age, and thickness of each formation.

Two distinct rock areas.

The rocks lie in two distinct areas or groups of widely different age. The valley half of the quadrangle comprises the formations from lower Cambrian to Carboniferous, about evenly divided in amount. The mountain district, excepting a narrow belt north of Pine Mountain, is covered by the Carboniferous formations.

The valley rocks are mainly calcareous and argillaceous, and the mountain rocks siliceous, argillaceous, and carbonaceous. In the valley the rocks lie in long, narrow belts and are often repeated by the different folds. In the mountains the folds are very slight, so that the belts of rock are more irregular in shape, largely depending upon the location of the stream cuts. The rocks will be described in order of age.

CAMBRIAN ROCKS.

Reddish sandstones and shales.

Rome formation.—Seven areas of this formation occur in this region, all of them lying in the Valley of East Tennessee. The formation derives its name from Rome, Georgia, where it is well developed. It is made up of red, yellow, and brown sandstones and red, brown, and green sandy shales, most of the sandstones being at the bottom. Few of the beds of sandstone are over 2 or 3 feet thick, and none are continuous for any great distance. They are repeatedly interbedded with shale, and when one dies out another begins, higher or lower, so that the result is the same as if the beds were continuous. The shales are very thin, and small seams of sandstone are interbedded with the shale. Brilliant colors are common in these strata. A few of the sandstone beds contain lime in such amounts as almost to become limestones. Four miles northeast of Clinton a bed of limestone is included with the Rome formation which may possibly represent the underlying Beaver limestone.

The series is thinnest in Beaver Ridge, where it comprises 250 feet of sandy shale at the top and 550 to 700 feet of sandstone and sandy shale at the bottom. Its full thickness is not here shown, however, for it is partly removed by a fault.

From the frequent changes in sediment from sand to sandy or argillaceous mud and the abundance of ripple-marks on many beds, it is plain that the formation was deposited in shallow water, just as many mud flats are now being formed. Animals, such as trilobites, which frequented shallow, muddy waters, have left many fragments and impressions.

The topography of the formation is quite marked and uniform. Decay makes its way slowly along the frequent bedding planes, and the rock breaks up into small bits and blocks without much internal decay. Ledges are rare on the divides, and the ridges are usually not high. They are especially noticeable for their even crests and for frequent stream gaps. In some areas this latter feature is so prominent as to secure for them the name of "comby" ridges. The lower beds, on account of their more sandy nature, are most evident in the topography.

On the divides the soils are thin and sandy; down the slopes and hollows considerable wash accumulates and the soil is deep and strong. The fine particles of rock and sand render the soil light, and it is rather easily washed unless protected. In the hollows the timber is large and vegetation strong.

Blue limestone.

Maryville limestone.—This limestone is present in the belt south of Beaver Ridge, and, like the preceding formation, is represented by shale in the other belts. It receives its name from Maryville, in Blount County, where it is well developed. The formation consists of massive blue limestone, varying but little in appearance. In thickness it shows no changes in this quadrangle. Fossils are rare in these beds, but occasional trilobites are found.

The limestone decays readily by solution and forms a deep, red clay, from which many ledges, especially of the upper beds, protrude. The formation is always situated in valleys. Its soils are clayey and are deep and strong, forming some of the best farming lands in the State.

Calcareous shale and limestone.

Nolichucky shale.—This formation is shown in the same belt as the preceding one, and in the other belts appears as part of the Conasauga shale. It is named from the Nolichucky River, along whose course in Greene County the shale is well exhibited. The formation is composed of calcareous shales and shaly limestones, with beds of massive blue limestone in the upper portion. When fresh, the shales and shaly limestones are bluish-gray and gray in color; but they weather readily to various shades of yellow, brown, red, and green. The thickness of the formation ranges in this quadrangle from 400 to 550 feet.

This is the most fossiliferous of the Cambrian formations, and remains of animals, especially trilobites and lingulæ, are very common.

Solution of the calcareous parts is so rapid that the rock is rarely seen in a fresh condition. After removal of the soluble constituents decay is slow, and proceeds by the direct action of frost and rain. Complete decay produces a stiff, yellow clay. In most areas the shale forms the slopes along the Knox dolomite ridges; the soil is thin and full of shale fragments, and rock outcrops are frequent. The soils are well drained by the frequent partings of the shale, but at their best they are poor and liable to wash.

Calcareous shale and thin beds of limestone.

Conasauga shale.—This is the commonest Cambrian formation in this region. It consists of calcareous shales, shaly limestones, and thin beds of massive limestone. The base of the formation is marked usually by a thin bed of calcareous sandstone, and in many other localities by a bed of oolitic limestone. This formation was accumulated during the deposition of the Rutledge limestone, Rogersville shale, Maryville limestone, and Nolichucky shale of adjacent regions and represents the nearshore, muddier sediment of those times. These limestones gradually thin out and are replaced by the Conasauga shale. In characteristics of soil and topography it is identical with the Nolichucky shale. The thickness of the formation ranges from 600 to 850 feet.

SILURIAN ROCKS.

Knox dolomite.—Although the Knox dolomite does not belong entirely in the Silurian, a large part of it does, and as the formation can not be divided it is all classed as Silurian. The lower part of it contains middle Cambrian fossils and the upper part Silurian fossils, especially gasteropods; but it is impossible to draw any boundary between the parts of the formation.

Massive cherty limestone and dolomite.

The Knox dolomite is the most important and widespread of all the valley rocks. Its name is derived from Knoxville, Tennessee, which is located on one of its areas. The formation consists of a great series of blue, gray, and whitish limestone and dolomite. Many of the beds are banded with thin, brown siliceous streaks and are very finegrained and massive. Within these beds are nodules and masses of black chert, locally called "flint," and their variations are the only changes in the formation. The cherts are most conspicuous in the middle and lower parts of the formation, and in places, by the addition of sand grains, grade into thin sandstones. The formation varies from 2800 to 3500 feet in thickness.

The amount of earthy matter in the dolomite is very small (from 5 to 15 per cent), the rest being mainly carbonate of lime and magnesia. Deposition went on very slowly, and lasted for a very long time in order to accumulate so great a thickness of this kind of rock. The dolomite represents a larger epoch than any of the other Appalachian formations.

Decay of the dolomite is speedy, on account of the solubility of its materials, and outcrops are seen only near the stream cuts. The formation is covered to great depth by red clay, through which are scattered the insoluble cherts. These are slowly concentrated by decay of the overlying rock, and where most plentiful they constitute so large a part of the soil as to make cultivation almost impossible. When weathered the cherts are white and broken into sharp, angular fragments. Very cherty areas are always high, broad, rounded ridges, protected by the cover of chert; this character prevails in this region. Soils of the dolomite are strong and of great depth. Their drawback is the presence of chert, but when this is of small amount the soils are very productive. Areas of cherty soil are always subject to drought on account of the easy drainage produced by the chert, and in such localities underground drainage and sinks are the rule. Water is there obtained only in sinks stopped up with mud, in wells, or in rare springs. Chert ridges are covered by chestnut, hickory, and oak to such an extent as often to be named for those trees.

Chickamauga limestone.—This formation occurs in four belts in the valley district. It is named for its occurrence on Chickamauga Creek, Hamilton County, Tennessee. It consists of massive blue and gray limestones, shaly and argillaceous limestones, and variegated marbles. These beds are all very fossiliferous, and fragments of corals, crinoids, brachiopods, and gasteropods are so abundant as sometimes to make most of the bulk of the rock. In Beaver Valley it consists of 500 to 600 feet of blue limestone and gray argillaceous limestone and 100 to 150 feet of variegated marble beneath thin limestones and shales. Other areas comprise only massive and slabby limestones, from 1600 feet to 2000 feet in thickness.

The beds of crystalline marble are extensively worked for ornamental stone. The rock may have been deposited in crystalline form or it may have been changed by the passage of water between its grains, dissolving and recrystallizing the carbonate of lime. The insoluble and shaly parts were left unchanged; and the forms of the fossils are plainly visible in the matrix of white carbonate of lime.

As would be expected from the amount of lime that it contains, the formation always occupies low ground. Decay is rapid by solution, but varies greatly in the different varieties of rock. The marbles and poorer limestones weather deeply into a rich, red clay, through which occasional ledges appear. Many of the massive blue limestones invariably make ledges, and are regular features of the surface of the formation. Over the shaly varieties the soil is less deep and strong, and frequent outcrops occur. Soils of the marble and heavy limestones are deep and very fertile, forming some of the best lands in the Great Valley. Those derived from the shaly limestones are also very rich whenever they attain any depth, but they are less available on account of the large amount of rock which they contain.

Red calcareous sandstone.

Bays limestone.—This formation is seen in two nearly continuous areas southeast of Clinton. The name is given for its frequent outcrops in the Bays Mountains of Hawkins and Greene counties, Tennessee. The formation is usually a red calcareous or argillaceous sandstone, changes in its composition being very slight. In this district the lime becomes more prominent than in most places, and the rock is an impure limestone. The red color, however, is very marked and persistent. The thickness of this formation ranges from 160 to 200 feet, and increases slightly toward the northeast.

Owing to the amount of calcareous matter that it contains, the Bays limestone, even when thick, never stands at great altitudes. Its surfaces form one slope of the Rockwood sandstone ridges. Decay is never deep, but the residue is loose and crumbling and does not resist wear. Soil is thin on this rock and is full of slabby fragments, and the formation outcrops more than any other except a similar part of the Chickamauga limestone. On account of their shallow and sandy nature these soils are of very little value except in the small hollows where the wash has collected. These support some fairly good timber, but are very limited in extent.

Red sandy shale.

Rockwood formation.—Five belts of this formation appear along the border of the mountain district and on Elk Creek, and three others in a nearly connected line passing southeast of Clinton. The formation consists of red and brown calcareous and sandy shales; in the southeastern belt several small beds of white sandstone are interbedded with the shale. Along Walden Ridge, Pine Ridge, and Cumberland Mountain the strata of this formation contain beds of fossiliferous iron ore derived from the replacement of limestone beds. These ores attain a thickness of 6 and 8 feet and have been widely mined and used in the local furnaces. Only the portions of the beds lying above water are available for ore, so that the depth of the deposits is not great in this region, for the beds always lie in low ground near the drainage level. The fossils contained in the ores make up much of its body and show the formation to be of Silurian age. In thickness the formation ranges from 400 feet along the mountain district to 500 feet southeast of Clinton.

The surfaces underlain by this formation vary greatly. Along the border of the mountains the formation occupies very low ground, on account of its ready solubility, and is seldom found unweathered. In the eastern belt, the interbedded sandstones resist solution and form ridges with sharp, even crests and frequent water-gaps. The soils produced by this formation are usually sandy and of little value in any locality. Far the greater part of its residual soil near the mountains is covered by wash from the Lee conglomerate, and in the eastern belt the natural poverty of the soil is increased by the wash from the interbedded sandstones. Few of the strata outcrop except the sandstones, but the cover of soil is light and the weathered rock lies near the surface.

DEVONIAN ROCKS.

Black carbonaceous shale.

Chattanooga shale.—This formation, the name of which is derived from the city of Chattanooga, where it occurs, is found within the Briceville quadrangle in belts adjoining those of the Rockwood formation. In this region it consists of black carbonaceous shale, with no variations of composition. Its lower layers grade into the Rockwood shales along Cumberland Mountain, and it is very sharply defined from the overlying Newman limestone. On account of its softness it is usually much covered with wash from adjacent formations and its thickness is hard to determine, but it ranges from 50 to 80 feet, being thinnest west of Oliver Springs. Its areas are not extensive, and neither its surface forms nor its soils are of importance.

CARBONIFEROUS ROCKS.

Fossiliferous blue limestone with cherty beds.

Newman limestone.—This formation, which derives its name from the great outcrops in Newman Ridge, Hancock County, Tennessee, lies in the same basins along the mountain border as the two preceeding formations. In this district it consists of 650 to 750 feet of massive, blue limestone with a few calcareous shale beds, being thinnest in the more northeastern outcrops. The limestone contains many fragments of crinoids, corals, and brachiopods of Carboniferous age. A considerable number of chert nodules are contained in the base of this limestone, and their white fragments strew the surface when weathered. These, like the limestone itself, are full of fossils, chiefly crinoids. In the vicinity of Big Creek Gap this chert is uncommonly developed and forms a bed 130 feet thick, composed almost entirely of layers and nodules of chert and a few eyes of quartz.

The soluble nature of the formation usually causes valleys, where it forms a rolling surface. Often its cherty portions are hard enough to cause high ground and rounded ridges, and along the steep slopes of Pine Mountain the formation produces a series of cliffs. It forms a red clay when decayed, but this is seldom seen in its natural condition on account of the wash from the adjacent formations. Its soils, which are naturally good, are thus rendered of small value for agriculture.

Shale with beds of sandstone and limestone.

Pennington shale.—Belts of this formation occur along Walden Ridge and Pine and Cumberland mountains. It is composed in the main of shales, both sandy and calcareous, and contains also thin beds of gray sandstone and gray or reddish limestone. In the latter beds are found great numbers of Carboniferous fossils similar to those of the Newman limestone. The shale receives its name from Pennington Gap, in Clinch Mountain, Virginia, where it occurs. The formation is 160 to 400 feet thick, and thins toward the north and northeast. It is sharply separated from the adjoining formations, both at top and bottom.

The amount of lime in the rock causes it to dissolve readily and occupy low ground, usually small hollows and flats next to the Lee conglomerate mountains. No soil of value is produced from the formation, as its natural soils are covered by wash from the Lee conglomerate.

Massive sandstone with quartz conglomerate.

Lee conglomerate.—Several areas of this formation occur in the quadrangle: in Walden Ridge, the Cumberland Mountain basin, a small ridge north of Elk Creek, and a group about Huntsville. The formation receives its name from Lee County, Virginia. It consists, in the main, of massive sandstone; near the base is a small bed of quartz conglomerate, and two other layers are coarse and conglomeratic, all of which appear in most sections of the formation. Toward the northeast the conglomerates become thicker and more prominent. A bed of shale, about 20 feet thick, lies 100 feet above the base of the formation, and contains a seam of coal. The top of the formation consists of 40 to 60 feet of sandstone underlain by an equal amount of shale. In this shale lies a thin bed of coal, and several small seams of coal occur at different points in the massive sandstone. Frequently the sandstone layers are cross-bedded, as if formed in shoal water. Great variations take place in the thickness of this formation. From 1150 to 1200 feet on the northeast part of Cumberland Mountain it diminishes to 900 feet west of Oliver Springs, and 450 to 500 feet a few miles west of Huntsville.

By reason of their very siliceous nature the sandstones of this formation are almost insoluble, and make sharp, prominent mountains. Lines of cliffs accompany its course, and the stream gaps are narrow, rocky gorges. Its soils are so thin and are so blocked with sandstone fragments as to be worthless except for the occasional good timber on the lower slopes. Where the formation lies nearly flat, as around Huntsville, a thin, sandy soil collects.

Shales, thin sandstones, and coal beds.

Briceville shale.—Areas of this formation abound in this district. A belt adjoins each area of Lee conglomerate and extends far up toward the head of each stream. In general, all of the valleys below 1500 feet in altitude are formed in the Briceville shale. Its name is taken from Briceville, which is situated upon one of its areas. The formation is composed mainly of bluish-gray and black, argillaceous and sandy shale, and it contains many workable seams of coal and small beds of sandstone. The sandstone beds range from 1 to 8 feet in thickness and have the same general appearance, varying from massive to thin-bedded layers. Like the Lee conglomerate, this formation thins toward the north and west, so that a total thickness of 650 feet at Big Creek Gap lessens to 500–450 feet around Oliver Springs, and to 300–250 feet around Huntsville. The principal coal mines of this region are operated in the seams of this formation.

The shales, owing to their fine grain, offer little resistance to weathering, and the formation always occupies low ground. The sandstone beds are hard enough to cause ledges and small knobs, but are seldom thick enough to produce prominent ridges. The lowest beds are almost invariably occupied by streams flowing in narrow valleys. The soils are thin and poor, and are much encumbered with waste from the sandstone beds and from the Lee conglomerate. Where the valleys widen to any extent they contain bottoms with a fairly good, sandy soil.

Wartburg sandstone.—Areas of this sandstone are very numerous in the mountain district. Since the formation usually lies above water-level, except near the larger stream divides, the sandstone occupies narrow belts winding in and out around the uplands. The town of Wartburg, Morgan County, Tennessee, is situated upon and furnishes the name for this sandstone.

Interbedded massive sandstones, shales, and thin coals.

The formation consists of interbedded sandstones, sandy shales, argillaceous shales, and coal beds. Perhaps as much as one-half of the formation is sandstone, the two beds at the top and bottom being specially conspicuous. This is due largely to contrast with the shales of the adjoining formations, for other beds in the Wartburg sandstone are equally thick and massive. As many as five seams of coal occur with these strata, and three of them are mined at various places.

The sandstone beds vary in thickness from a few inches to 50 feet, and the shale beds are of similar size; the coal beds are from 2 inches up to 6 feet thick. Most of the sandstones are pure and fine grained. Occasionally a small layer exhibits cross-bedding, but otherwise they are all very much alike. The formation ranges from 500 to 650 feet in thickness, with the thinner portions lying toward the northwest. Of the many spurs and benches which are caused by the sandstone beds the most prominent is the topmost, which is usually a long, flat-topped spur or table standing out from the overlying shales. The lowest sandstone bed forms nearly as large benches and tables. All of the sandstones resist weathering on account of their siliceous nature, and cause cliffs in some portions of their courses. The lowest bed almost universally produces a series from 15 to 50 feet in height and several beds cause similar series that here and there may easily be mistaken for the bottom layer. The coal beds are readily subject to weathering, and natural outcrops of coal are quite uncommon, except when the bed directly underlies and is protected by a sandstone bed. Coal beds which are underlain by clay-shale or fire-clay are marked by lines of seeps and springs whose waters contain alum and copperas. The position of a coal bed is usually shown by a bench from 5 to 20 feet in width. Soils derived from this formation are thin and sandy and are much encumbered with sandstone waste, as they usually lie on steep slopes. They produce but scanty natural growths and are of almost no value for farming purposes.

Scott shale.—This formation appears in narrow belts encircling the ridges which rise over 2000 feet above sea-level, and takes its name from Scott County, in which it frequently occurs.

Sandy shale, sandstone, and coal seams.

The formation consists mainly of argillaceous and sandy shales, but includes also many beds of shaly sandstone, a few massive sandstones, and five or six coal seams. All of these strata are very similar in composition to those of the Wartburg sandstone, and the description of individual beds would be a repetition. In this formation, however, there is much more shale than sandstone, the sandstones are thinner, and the coal beds rarely exceed 2 feet in thickness. Not far beneath the Anderson sandstone is found a coal bed from 4 to 5 feet thick, and the largest of the series, 6 feet in thickness, lies very near the base of this shale. The total thickness of the formation ranges from 450 to 600 feet, with no apparent system in the variations. In a few places one or two of the upper sandstones cause cliffs from 5 to 30 feet high, but ordinarily the formation occupies steep slopes marked by narrow benches and few outcrops.

Soils of this formation are thin and sandy, but are occasionally tilled near the summits of ridges where the slopes are less steep. Only scanty crops are produced and natural timber is small.

Anderson sandstone.—Areas of this formation cap all portions of the mountain district which rise above 2600 feet. Its name is given on account of its frequent occurrence in that position in Anderson County.

Shales with coal beds, and thick sandstone at the base.

The formation consists of sandstones, sandy and argillaceous shales, and coal beds, like the three preceding formations. The bottom of the series is marked by massive sandstones in heavy beds from 20 to 50 feet thick, with a total thickness of 100 to 120 feet. Above these follow 300 to 400 feet of shales interbedded with thin layers of massive sandstone which are capped in the higher mountains by thick, massive sandstones like the bottom layers. Four or more coal seams are found in and shortly above the lower, massive sandstones; few of these coals are as thick as 2 feet, and they grade into carbonaceous shale. Individual beds of this formation are precisely similar in composition to those of the two preceding formations. Inasmuch as the formation appears only on mountain tops its original thickness is not known; 650 feet now remain.

Owing to the extremely durable nature of the heavy sandstones of this formation, they are marked by lines of cliffs which encircle the mountains in steps from 15 to 50 feet high. The shales offer less resistance to weathering and make smooth, rounded summits and easier slopes; the sandstones form abrupt descents or broad, flat tables bounded by cliffs. Light, sandy soils accumulate on the tops of these tables and are here and there cultivated. Over the central, shaly portions of the formation soils are somewhat more clayey and afford fair farming land on the summits.

STRUCTURE.

An account of the relative attitudes of the strata, which they now occupy as results of movements of masses of the earth.

Definition of folds and faults.

Definition of terms.—As the materials forming the rocks of this region were deposited upon the sea bottom, they must originally have lain in nearly horizontal sheets or layers. At present, however, the beds are usually not horizontal, but are inclined at various angles, their edges appearing at the surface. The angle at which they are inclined is called the *dip*. A bed which dips beneath the surface may elsewhere be found rising; the fold, or trough, between two such outcrops is called a *syncline*. A stratum rising from one syncline may often be found to bend over and descend into another; the fold, or arch, between two such outcrops is called an *anticline*. Synclines and anticlines side by side form simple folded structure. A synclinal axis is a line running lengthwise in the synclinal trough, at every point occupying its lowest part, toward which the rocks dip on either side. An anticlinal axis is a line which occupies at every point the highest portion of the anticlinal arch, and away from which the rocks dip on either side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and is usually but a few degrees. In districts where strata are folded they are also frequently broken across, and the arch is thrust over upon the trough. Such a break is called a *fault*. If the arch is worn away and the syncline is buried beneath the overthrust mass, the strata at the surface may all dip in one direction. They then appear to have been deposited in a continuous series. Folds and faults are often of great magnitude, their dimensions being measured by miles, but they also occur on a very small, even a microscopic, scale. In folds and faults of the ordinary type, rocks change their form mainly by motion on the bedding planes. In the more minute dislocations, however, the individual fragments of the rocks are bent, broken, and slipped past each other, causing *cleavage*. Extreme development of these minute dislocations is attended by the growth of new minerals out of the fragments of the old — a process which is called *metamorphism*.

Areas of typical structures.

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

General character of folds and faults.

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

Faults were developed in the northwestern sides of anticlines, varying in extent and frequency with the changes in the strata. Almost every fault plane dips toward the southeast and is approximately parallel to the bedding planes of the rocks lying southeast of the fault. The fractures extend across beds many thousands of feet thick, and in places the upper strata are pushed over the lower as far as 6 or 8 miles. There is a progressive change in character of deformation from northeast to southwest, resulting in different types in different places. In southern New York folds and faults are rare and small; passing through Pennsylvania toward Virginia, they become more numerous and steeper. In southern Virginia they are closely compressed and often closed, while occasional faults appear. The folds, in passing through Virginia into Tennessee, are more and more broken by faults. In the central part of the valley of Tennessee, folds are generally so obscured by faults that the strata form a series of narrow, overlapping blocks, all dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

Cleavage and metamorphism.

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

Structures are due to compression.

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

Oscillations.

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

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

Underground relations of strata.

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 they can not represent the minute details of structure, and they are therefore somewhat generalized from the dips observed in a belt a few miles in width along the line of the section.

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

Structure of the Briceville quadrangle.—The rocks of this quadrangle have been disturbed from the horizontal position in which they were deposited, and have been bent and broken to a high degree. The lines along which the changes took place run, as a rule, in a northeast-southwest direction, and the individual folds or faults extend for great distances in quite straight lines. On the accompanying sheet of sections the extent of these deformations is shown. The position of the rocks underground is calculated from dips observed at the surface and from the known thickness of the formations.

Within the quadrangle there are two structural areas, in which the types of deformation differ

Two structural areas.

materially. These are nearly coincident with the topographic and geologic divisions—the valley district, and the plateau district.

The valley folds and faults.

The rocks of the valley have been thrown out of their original position by folds and by faults. These are distributed over the whole area and are of the same type. The folds are long and straight, and are usually closely squeezed, often so far that the rocks on the western side of the anticlines were bent up until vertical and then pushed beyond the vertical. The dips range from flat to vertical and thence to 50° overturned; the average fold dips 40° on the southeast and 70° to 90° on the overturned side.

The valley folds.

The rocks in this area have been compressed so far that the folds are almost universally overturned; in section D, running completely across the valley belt, only one limited area shows northwest dips. The folded belt, owing to this great compression, is narrower than at any point toward the northeast. Sections A and C illustrate the only open fold of the region, an anticline passing southeast of Jacksboro. The Rome formation in sections D and E illustrates the closed folds. Complete overturned folds appear in section C, near Coal Creek, and in section E.

Transverse fault.

Associated with the anticlinal uplifts are the faults, fifteen in number. Like the broken arches from which they are formed, the faults are long and straight. They are situated on the northwestern side of the anticlines; at that point the horizontal pressure is square across the beds, so that they are least able to resist it, and break there if anywhere. The fault passing through Coal Creek and Pioneer lies on the southwestern side of the anticline owing to the change in direction of the anticline, but its position relative to the fold is the same. The great change in direction of the Coal Creek fault and its continuation in Elk Creek is one of the most striking exceptions in Appalachian structures. It shows that the strata were compressed in a northeast-southwest direction, as well as in the usual northwest-southeast direction. The planes of the faults are nearly parallel to the beds on the southeast side of the folds; so that, when motion along the break has been great or when the upper parts of the fold have been worn away, only rocks with the same dip remain. This is illustrated especially well in section D. None of the principal folds remain unbroken, and few sections of this length across the valley districts show as many faults as this. The planes of the faults dip from 30° to 60° southeast, most of them about 45°. The amount of displacement varies from a few feet up to more than 3 miles, the latter being the least measure of the fault 2 miles southeast of Clinton. On most of the faults the displacement is from 1 to 3 miles. The arch and corresponding basin north and south of Jacksboro (sections A and C) illustrate the formation of a fault from a fold, by the overturning and final breaking of the northwestern beds.

The plateau structures.

The second structural area of this district lies northwest of a line along Cumberland Mountain and Walden Ridge, occupying more than half of the quadrangle. In this province the rocks have scarcely been deformed by folds and faults, as in the valley, but have merely changed their attitudes by a very slight tilting toward the southeast. The slight folds and faults which appear have some features not shown in the valley. Two small faults occur, one north of Jacksboro and one north of Oliver Springs. The latter fault usually crosses the strata at a considerable angle, and its plane dips to the north, both of which features are quite uncommon.

The valley of Elk Creek contains several faults which are of the type of the Great Valley structures rather than of the plateau structures. The sharp upturning of the plateau rim is associated more closely with the valley structures. At a few other points the amount of tilting is noticeable. Along Walden Ridge and from Round Mountain northeastward, the basin of the plateau is slightly more depressed than at other points. Two anticlinal domes appear at Big Mountain and Huntsville, the former raising the strata 350 feet above adjoining regions. A third slight anticline passes along the southeast side of Scott County in a northeast course. Besides these structures and a slight tendency along the main valleys to anticlinal dips of 1° to 5°, the strata of the plateau have been very little deformed.

Vertical uplift.

The latest form in which yielding to pressure is displayed in this region is vertical uplift or depression. Evidence can be found of such movements at various intervals during the deposition of the sediments, as at both beginning and end of the epoch of deposition of the Knox dolomite, and following the deposition of the Newman limestone. After the period of great Appalachian folding already described such uplifts took place again, and are recorded in surface forms. While the land stood at one altitude for a long time, most of the rocks were worn down nearly to a level surface, or peneplain.

Remnants of peneplains.

One such surface was developed over all of the valley district, and its more or less worn remnants are now seen in the hills and ridges, at elevations of 1500 to 1700 feet. Since its formation, uplift of the land has given the streams greater slope and greater power to wear; they have therefore worn down into the old surface to varying depths, according to their size, and have begun the formation of peneplains at 1000 to 1100 feet. Still later uplift has started the process again and has produced the present narrow stream channels. As they are still wearing their channels downward, and but little laterally, they have not reached the grade to which the old peneplain was worn. The amount of uplift was possibly 500 to 600 feet, much more than the depth of the present stream-cuts. The remains of another and earlier peneplain can be found in Pine and Cumberland mountains, at 2100 to 2200 feet, and in various ridges forming the lower portion of the plateau district. This plain was almost removed during the formation of the later ones. The oldest period is recorded in the tops of the plateau at heights of 3000 to 3200 feet, and appears only at the main divides. It is probable that there were many such pauses and uplifts in this region, but their records have been almost entirely removed. Doubtless still others occurred which were not of sufficient length to permit peneplains to form and to record the movement.

MINERAL RESOURCES.

A statement of the relative positions of coal in the strata, and of the occurrence of marble and other building stones, brick-clays, iron ore, lead ore, limestone, and soils.

The rocks of this district which are available for use in the natural state are coal, marble, building stone, and road material. Other materials derived from the rocks are iron, lead, lime, cement, and clay. Through their soils they are valuable for crops and timber; and in the grades which they establish on the streams they cause abundant water-power.

Chief mining centers.

Coal.—Bituminous coal occurs in many seams in the Carboniferous rocks in the northwestern half of this quadrangle. The coal-bearing area is part of the large field extending northeast and southwest into the adjoining States. Active mining operations are carried on around four centers, Coal Creek and Briceville, Oliver Springs, Almy, and Pioneer; at Careyville, Elk Valley, and Big Creek Gap mines are operated on a smaller scale. The coals of this region are used for coking, steam, and household purposes, considerably the greater part being made into coke. The seams now mined are all situated in the Briceville shale, except those of Pioneer and Careyville, which are in the overlying Wartburg sandstone. The mines near Oliver Springs, Briceville, and Coal Creek are all worked in the same seam; those of Almy, Elk Valley, and Big Creek Gap are opened in beds at the same position in the Briceville shale. The chief coal seam at Careyville lies just above the lowest bed of Wartburg sandstone and in the same position as the lowest seam at Pioneer. All of these coal beds are remarkably similar in thickness, being about 4 feet thick, with portions locally squeezed to nothing or thickened up to 7 feet. The small sections given with the stratigraphic column show the beds typical of the main mining centers.

Undeveloped coal seams.

Besides the main coal seams great numbers of others appear at small intervals through the entire thickness of Carboniferous rocks above the Pennington shale. These seams are most frequent in the lower part of the Wartburg sandstone, the upper part of the Scott shale, and the lower part of the Anderson sandstone. While many of them are from 20 to 30 inches in thickness, and occasionally, as in the Scott shale on Walnut Mountain, seams as thick as 60 inches are found, the most of these minor beds are too thin for profitable working. In the mountain above Careyville no less than 15 seams appear, and in Cross Mountain over 30 large and small seams are known.

Thinning of the coals toward the west.

It appears that all workings in the coals of the Briceville shale are situated around the borders of the plateau district. In passing westward into the center of the Carboniferous area the coal beds grow much thinner and are usually from 15 to 30 inches thick. This change is similar to the diminution in thickness of the Briceville shale in the same direction. Along the western edge of the basin, represented on the Wartburg sheet and appearing near Huntsville and Almy, these coals increase again and attain an average thickness of 4 feet. In the Cumberland Mountain basin, where the Briceville shale is thickest, the greatest development of coal appears, and seven seams occur of 36 inches or more.

Flatness of the coal beds.

As is shown in the structure sections, the rocks which include the coal beds are very nearly horizontal. Around the border of the basin slight disturbances occur for a short distance away from the upturned Lee conglomerate, a feature which is well shown in the northward rise of the coal seam at Coal Creek and at Big Mountain. The dip is very seldom enough, however, to affect the working of the mines except in giving good or poor drainage, and crushing or dislocations of the coal are as a rule absent. The few lines of thinning which are known may be due to non-deposition.

The coal seams of this district almost invariably require heavy timbering, because the roof is usually of shale. Occasionally a seam is somewhat protected by a thin roof of sandstone or shaly sandstone, but never enough to do away with timbering. Floors of fire-clay are very common, but frequently shale or carbonaceous slate replace it, to the advantage of the mine. The seams retain their thickness very well and are continuous over large areas.

Marble.—Beds of marble are found in this district in a belt along Beaver Valley. Although large quarries are worked immediately south of this quadrangle, none have been opened here. The marbles are of a quality inferior to those of adjacent districts, both in color and regularity, and the bodies are of much less size. Their occurrence here in one belt, while the same formation a few miles northwest contains no marble, illustrates the irregularity of the deposits.

Brown hematite and limonite.

Iron ore.—Ores of iron occur in two forms in this district: as beds of red hematite in the Rockwood formation, and as deposits of brown hematite and limonite in the clays of the Knox dolomite and in the shales of the coal-bearing formations. The latter ores are distributed over the whole Carboniferous area and are found in a great many different strata in the form of small lumps and nodules. Usually they occur in the residual clays, but fresh sections show the nodules distributed in distinct beds through the shale and derived from limestone by substitution of oxides of iron for lime. These deposits are not of sufficient body to repay working. Brown hematite also occurs in the form of irregular masses in the residual clay of the Knox dolomite. These deposits are irregular and of small amount, and have not been mined in this district.

Red hematite; "fossil iron ore."

Red hematite occurs in large bodies in most areas of the Rockwood formation. Where the formation contains much sandstone the amount of iron ore is very small, but along the borders of the coal field the formation becomes decidedly calcareous and large beds of ore are found. The ore occurs as beds in shale from 4 to 8 feet thick, and represents the replacement of the lime in an original limestone bed by iron oxide. The fossils that were imbedded in the limestone perfectly retain their forms and make up so large a proportion of the mass that the ore has long been known as the "fossil iron ore."

When the fossil ores are worked down to the water-level of the adjacent country, the percentage of iron is so much less that they are practically limestones and are valueless as ores. Here the amount of ore is strictly limited by the water-level, and, as the formation always occupies low ground, the amount of ore is much less than would be supposed, although the formation underlies the whole coal field. Owing to the great tilting of the formation near the borders of the coal field, the beds of ore dip at high angles and are sometimes repeated. This repetition is most frequent in the broad areas of the formation which occur in Elk Valley. Mining operations were long carried on at many points along the mountain borders but are now abandoned.

Lead.—Lead ore is found in the broad area of Knox dolomite lying south of Fincastle. The ore outcrops at several points in a narrow belt running northeast and southwest for nearly a mile. It occurs in the form of cerussite lining cavities and occupying portions of the body of the rock, which is a gray, coarsely crystalline limestone. No developments of this ore have been made, and its quality is therefore doubtful.

Lime and brick-clays.—Many beds in the Chickamauga limestone are adapted to burn into lime, especially such strata as the marbles. Only local use has been made of this material, but it is abundant through the valley district.

Brick-clays can be obtained from two sources in this district. In the hollows and low grounds in the valley, clays collect from the wash of the adjacent limestone formations, and are locally used in the manufacture of brick. These clays are very widely distributed and may be obtained within short distances of the point of use. Another source of clay is found in the mountain district in the fire-clays associated with the coal seams. Beds of fire-clay are nearly as abundant as the coal beds, but seldom attain a thickness of 2 feet. On account of their thinness the fire-clay seams can not usually be advantageously worked; if the clay bed is associated with a workable bed of coal it is most available. In this region no use has been made of these clays.

Limestones.

Building stone.—The Chickamauga limestone, Knox dolomite, and the Carboniferous sandstones are the chief sources of building-stone in this district. The two former are in use in the valley for stone houses and bridge abutments. Stone quarried from these formations is compact, durable, and easily opened in the quarry; the beds range from 6 inches to 3 feet thick, and are thus suited only for small work. The extent of the formations is such that quarries can readily be worked near the point of use for the stone.

Sandstones.

Abundant building material can be obtained from the sandstones of various Carboniferous formations. Beds of small size, from 6 inches to 6 feet in thickness, are frequent in the Briceville shale and Wartburg sandstone, while those of the Lee conglomerate are much heavier. Along the mountain divides many more massive layers occur, in places as thick as 50 feet, but they are too remote to be available. The rock is extremely hard and durable and can be readily worked along the natural partings. The colors of the different beds vary from reddish or grayish-white to a pure white. Natural quarry sites are readily to be found along all of the streams of the mountain region.

Road material.

Rocks of many formations are in use for road building. The Knox dolomite and Chickamauga limestone are most commonly used and form a hard road-bed, the lime in the rock recementing the mass firmly. The cherts of the Knox dolomite have long been used and in many localities are so abundant as to form natural road-beds. Their fragments are angular, pack firmly, and secure good drainage to the road by their open structure. The rapid wear of iron tires and shoes by the sharp edges of the chert is the only objection to its use. Road material of another class is found in the sandy shales of the Rome formation and the Carboniferous shales. These are readily obtained from the weathered outcrops, are easily broken, and produce a well-drained and fairly durable road.

Timber.—Much of the valley and by far the most of the mountain region is timber-covered. As a rule the mountain surfaces are thinly covered, but many of the areas of Scott shale and all of the hollows and deep valleys support a good growth of timber. Hickory, chestnut, and oak make up the bulk of the timber, but pine, hemlock, spruce, and poplar are frequent near the waterways. In the valley the cover of timber has been largely removed except along the ridges, where large areas of oak, chestnut, and hickory remain untouched. Poplar, ash, and linn are common, and a few hemlocks and pines appear. The grouping of oaks, chestnuts, and hickories along the ridges of Knox dolomite is quite noticeable; almost equally so is the growth of red cedar on the Chickamauga limestone. Along the lines of railroad the best of the mountain timber has been cut, but vast bodies yet remain which are inaccessible with the present facilities.

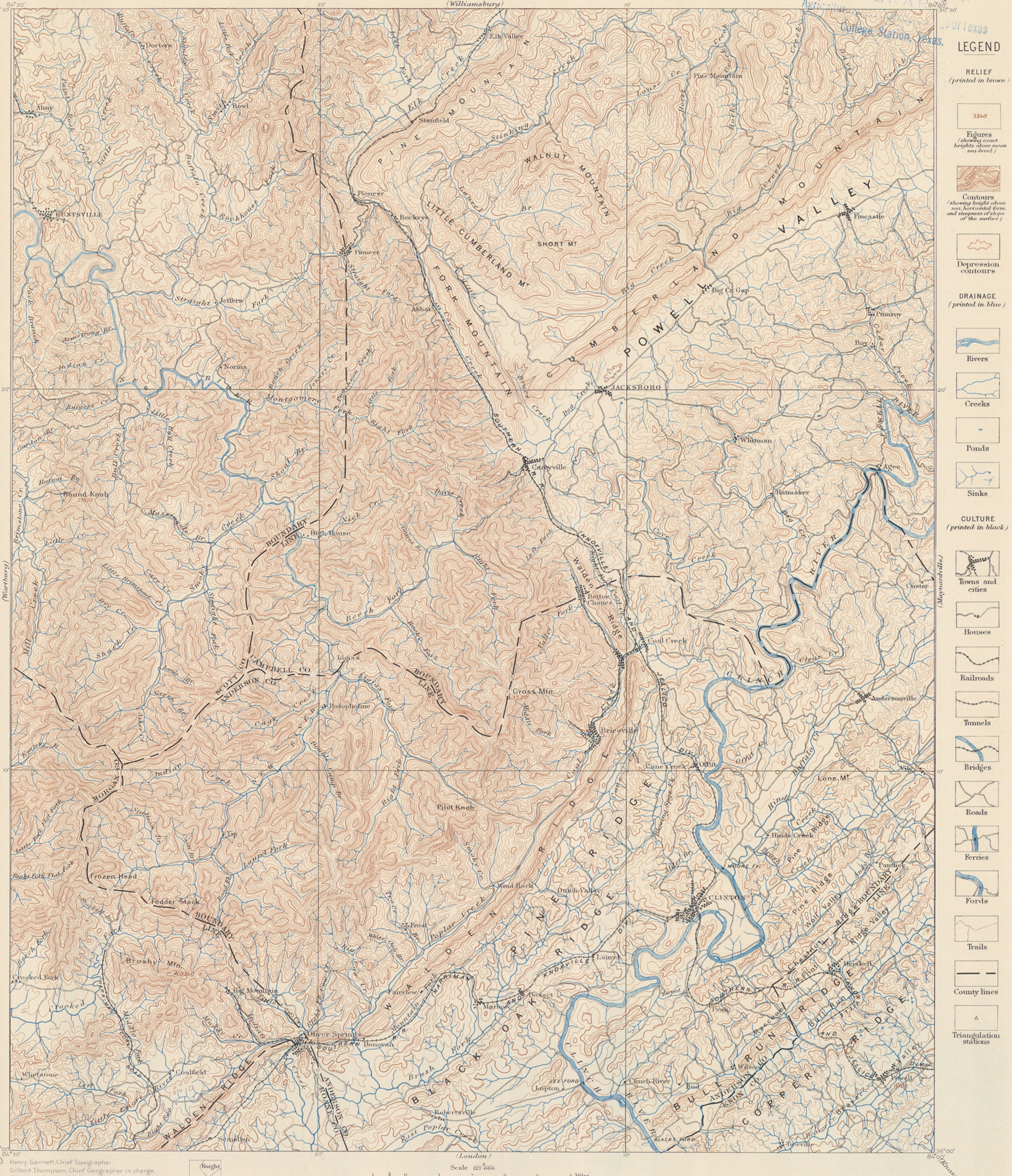
ARTHUR KEITH,
Geologist.

March, 1897.

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

TOPOGRAPHY

TENNESSEE
BRICEVILLE SHEET



Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Triangulation by S.S. Gannett.
Topography by J.F. Knight and E.C. Barnard.
Surveyed in 1888-91.

Contour Interval 100 feet.
Datum is mean Sea level.

Edition of July 1896.

U.S. GEOLOGICAL SURVEY
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AREAL GEOLOGY

TENNESSEE
BRICEVILLE SHEET

LEGEND

SEDIMENTARY ROCKS

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

CARBONIFEROUS

- Can — Anderson sandstone *(sandstone with argillaceous and sandy shale and thin coal beds)*
- Csc — Scott shale *(argillaceous and sandy shales with some sandstone and thin coal seams)*
- Cwb — Wartburg sandstone *(interbedded sandstone, sandy shale, argillaceous shale, and coal beds)*
- Cbv — Briceville shale *(dark-gray argillaceous shale with sandy beds and thick coal beds)*
- Cle — Lee conglomerate *(massive sandstone and conglomerate with thin coal seams)*
- Cpn — Pennington shale *(calcareous shale, sandstone, and limestone)*
- Cn — Newman limestone *(massive, blue limestone, cherty at the base)*

DEVONIAN

- Dc — Chattanooga shale *(black, carbonaceous shale)*

SILURIAN

- Sr — Rockwood formation *(reddish, calcareous shale with white sandstone and iron beds near the top)*
- Sb — Bays limestone *(red, argillaceous and sandy limestone)*
- Sc — Chickamanga limestone *(blue and gray, shaly limestone and massive limestone)*
- Sk — Knox dolomite *(light and dark magnesian limestone with chert nodules)*

CAMBRIAN

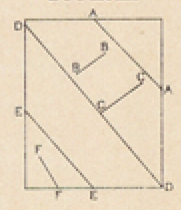
Subdivisions of the Conasauga shale:

- Cn — Nolichucky shale *(brown, calcareous shale with thin limestone beds)*
- Cm — Maryville limestone *(massive, dark-blue limestone)*

- Cc — Conasauga shale *(reddish, calcareous shale with thin beds of limestone)*
- Cr — Rome formation *(reddish and green sandy shale with thin sandstone)*
- Crs — Rome sandstone-lentil *(red, yellow, and brown sandy shale, with thick beds of sandstone)*

Faults

Sections



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Surveyed in 1888-91.

Knight
Barnard

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

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 July 1896.

Geology by Arthur Keith.
Assisted by H.B. Goodrich.
Surveyed in 1893.

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ECONOMIC GEOLOGY

TENNESSEE
BRICEVILLE SHEET

LEGEND
(continued)

⚒ Coal mines

Known productive formations

Scott shale (contains thin coal seams)

Briceville shale (contains thick coal beds)

Rockwood formation (contains beds of red hematite iron ore)

Lead

LEGEND

SEDIMENTARY ROCKS

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CARBONIFEROUS

Can — Anderson sandstone (sandstone with argillaceous and sandy shale and thin coal beds)

Csc — Scott shale (argillaceous and sandy shales with some sandstone and thin coal seams)

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Cle — Lee conglomerate (massive sandstone and conglomerate with thin coal seams)

Cpn — Pennington shale (calcareous shale, sandstone, and limestone)

Cn — Newman limestone (massive, blue limestone, cherty at the base)

DEVONIAN

Dc — Chattanooga shale (black carbonaceous shale)

SILURIAN

Sr — Rockwood formation (reddish calcareous shale with white sandstone and iron beds near the top)

Sb — Bays limestone (red, argillaceous and sandy limestone)

Sc — Chickamanga limestone (blue and gray, shaly limestone and massive limestone)

Sk — Knox dolomite (light and dark, magnesian limestone with chert nodules)

CAMBRIAN

Subdivisions of the Conasauga shale

Єn — Nolichucky shale (brown, calcareous shale with thin limestone beds)

Єm — Maryville limestone (massive, dark-blue limestone)

Єc — Conasauga shale (reddish, calcareous shale with thin beds of limestone)

Єr — Rome formation (reddish and green sandy shale with thin sandstone)

Єrs — Rome sandstone-lentil (red, yellow and brown sandy shale, with thick beds of sandstone)

Faults

Sections

Legend is continued on the left margin

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Triangulation by S.S. Gannett.
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Surveyed in 1888-91.

Knight
Barnard

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

1 ½ 0 1 2 3 4 5 Miles

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Edition of July 1896.

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Surveyed in 1893.

U.S. GEOLOGICAL SURVEY
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STRUCTURE SECTIONS

TENNESSEE
BRICEVILLE SHEET

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
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Knight / Barnard

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

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LEGEND

SEDIMENTARY ROCKS

CARBONIFEROUS

- Can — **Anderson sandstone** *(sandstone with argillaceous and sandy shale and thin coal beds)*
- Csc — **Scott shale** *(argillaceous and sandy shales with some sandstone and thin coal seams)*
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- Cn — **Newman limestone** *(massive, blue limestone, cherty at the base)*

DEVONIAN

- Dc — **Chattanooga shale** *(black, carbonaceous shale)*

SILURIAN

- Sr — **Rockwood formation** *(reddish calcareous shale with white sandstone and iron beds near the top)*
- Sb — **Bays limestone** *(red, argillaceous and sandy limestone)*
- Sc — **Chickamauga limestone** *(blue and gray, shaly limestone and massive limestone)*
- Sk — **Knox dolomite** *(light and dark, magnesian limestone with chert nodules)*

CAMBRIAN

Subdivisions of the Conasauga shale:

- Ꞓn — **Nolichucky shale** *(brown, calcareous shale with thin limestone beds)*
- Ꞓm — **Maryville limestone** *(massive, dark-blue limestone)*

- Ꞓc — **Conasauga shale** *(reddish, calcareous shale with thin beds of limestone)*
- Ꞓr — **Rome formation** *(reddish and green sandy shale with thin sandstone)*
- Ꞓrs — **Rome sandstone lentil** *(red, yellow and brown sandy shale, with thick beds of sandstone)*

Faults

Known productive formations

- *Scott shale* (contains thin coal seams)
- *Briceville shale* (contains thick coal beds)
- *Rockwood formation* (contains beds of red, hematite iron ore)

COLUMNAR SECTIONS

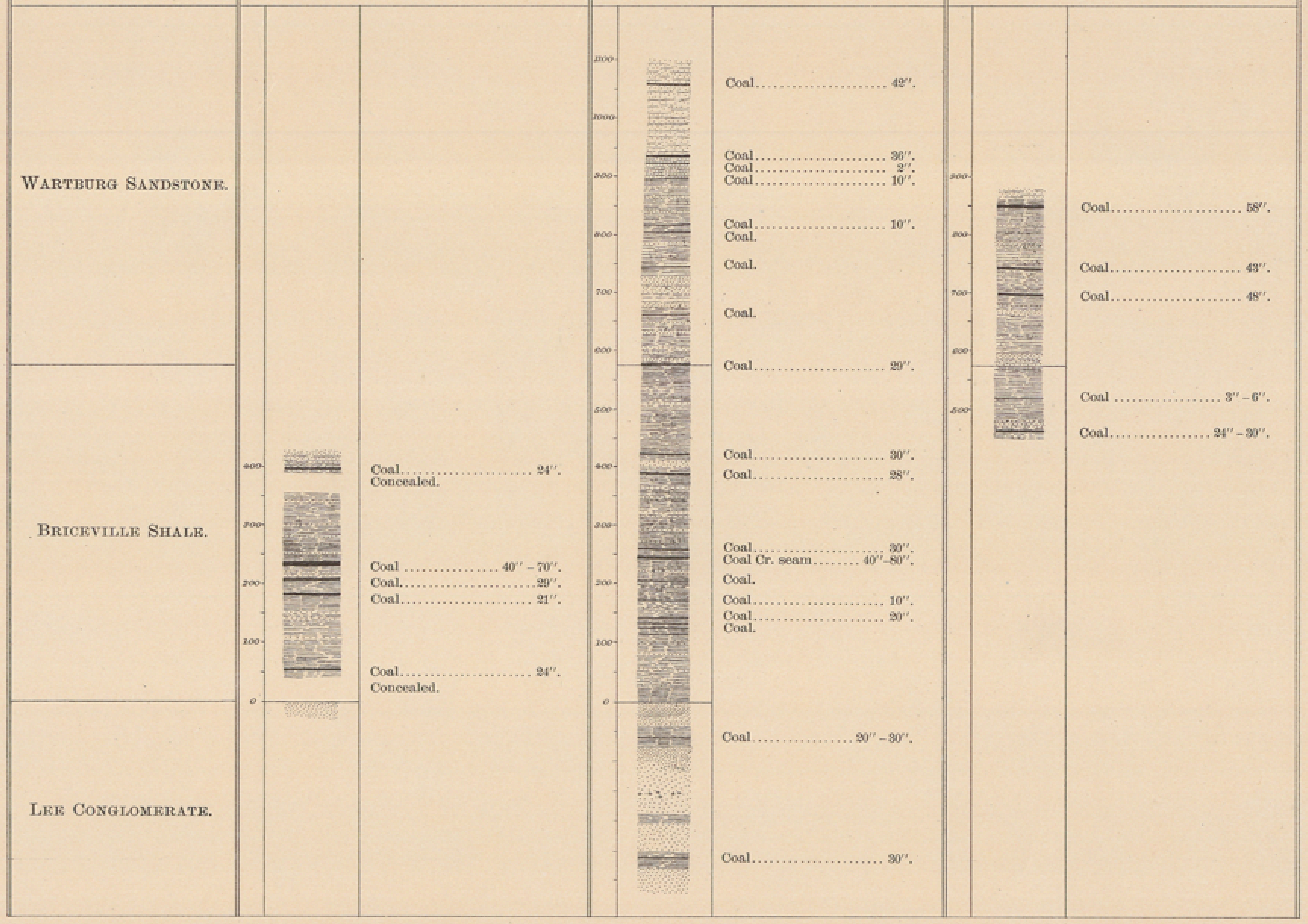
GENERALIZED SECTION FOR THE BRICEVILLE SHEET.

SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	Anderson sandstone.	Can		1000+	Sandstone, thin and massive, interbedded with sandy and argillaceous shales and thin coal beds.	Flat-topped ridges and mountains with lines of cliffs and ledges. Thin, sandy and clayey soil.
	Scott shale.	Csc		500–650	Argillaceous and sandy shales with some beds of sandstone and thin coal seams.	Rounded summits and steep slopes of Anderson sandstone mountains.
	Wartburg sandstone.	Cwb		500–600	Interbedded sandstone, sandy shale, argillaceous shale, and coal beds.	Flat-topped spurs, benches, and small ridges, with many low cliffs. Sandy, sterile soil.
	Briceville shale.	Cbv		250–650	Black, bluish-gray, and gray, argillaceous shale with small beds of sandy shale, sandstone, and thick coal beds.	Low valleys with small hills and spurs. Thin clay-soil with sandy wash.
	Lee conglomerate.	Cle		500–1500	Massive sandstone with beds of cross-bedded sandstone and conglomerate, a few thin shale beds, and thin coal seams.	Sharp, rugged ridges and mountains with many cliffs and ledges. Thin, sandy and rocky soil with much sandstone waste.
	Pennington shale.	Cpn		160–400	Calcareous shale, sandstone, and limestone.	Small hollows. Sandy clay-soil.
	Newman limestone.	Cn		650–750	Massive blue limestone and a few shale beds. Massive beds of chert and cherty blue limestone.	Rolling ground, small ridges, and a few cliffs on the slopes of Lee conglomerate mountains. Cherty, red clay-soil.
DEV.	Chattanooga shale.	Dc		50–80	Black, carbonaceous shale.	Narrow depressions.
SILURIAN	Rockwood formation.	Sr		400–500	Red and brown, calcareous and sandy shales with local beds of white sandstone and fossiliferous red hematite.	Valleys and sharp, even-topped ridges. Thin, sandy soil.
	Bays limestone.	Sb		160–200	Red, argillaceous and sandy limestone.	Valleys and low slopes. Thin, sandy clay-soil with many outcrops.
	Chickamauga limestone.	Sc		1600–2000	Blue and gray limestone, argillaceous limestone, flaggy limestone, and calcareous shale. Blue and gray, massive limestone with a few nodules of black chert.	Smooth, open valleys. Red and yellow clay-soil. Low, rounded hills. Red, clayey soil and chert fragments.
?	Knox dolomite.	Sk		2800–3500	Magnesian limestone, white, gray, light-blue, and dark-blue, with nodules of chert.	Broad, cherty ridges and high, rounded hills. Deep, red clay-soil with many chert fragments.
CAMBRIAN	Conasauga shale. { Nolichucky shale. / Maryville limestone. }	Єc { Єn / Єm }		650–800 (250)	Yellow, red, and brown, calcareous shale with thin beds of limestone, those at the base assuming the importance of a separate formation in the extreme southeast.	Valleys, and slopes of Knox dolomite ridges. Thin, yellow clay-soil.
	Rome formation.	Єr		600–800	Bright-colored, red, green, and brown, sandy shale interbedded with layers of thin sandstone.	Slopes of sandstone ridges. Thin, brown clay-soil with much sandstone wash.
	Rome sandstone-lentil.	Єrs		500+	Red, yellow, and brown, sandy shale with thick beds of sandstone.	Sharp ridges with notches and gaps. Thin, sandy soil with ledges and fragments of sandstone.

SECTIONS SHOWING THE POSITION AND THICKNESS OF COAL BEDS AT THE PRINCIPAL MINING CENTERS.

SCALE: 250 FEET = 1 INCH.



NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		Arthur Keith: Loudon Folio, U. S. Geological Survey, 1896.	C. W. Hayes: Kingston Folio, U. S. Geological Survey, 1894.	Safford: Geology of Tennessee, 1869.
CARBONIFEROUS	Anderson sandstone.	Can		Walden sandstone.	Coal measures.
	Scott shale.	Csc			
	Wartburg sandstone.	Cwb			
	Briceville shale.	Cbv	Briceville shale.		
	Lee conglomerate.	Cle	Lee conglomerate.	Lookout sandstone.	
	Pennington shale.	Cpn	Pennington shale.	Bangor limestone.	Mountain limestone.
	Newman limestone.	Cn	Newman limestone.	Fort Payne chert.	Siliceous group.
DEV.	Chattanooga shale.	Dc	Chattanooga shale.	Chattanooga black shale.	Black shale.
SILURIAN	Rockwood formation.	Sr	Rockwood formation.	Rockwood formation.	Dyestone group.
	Bays limestone.	Sb	Bays sandstone.	Chickamauga limestone.	Trenton and Nashville group.
	Chickamauga limestone.	Sc	Chickamauga limestone.		
	Knox dolomite.	Sk	Knox dolomite.	Knox dolomite.	Knox dolomite.
CAMBRIAN	Conasauga shale { Nolichucky shale. / Maryville limestone. }	Єc { Єn / Єm }	Nolichucky shale. / Maryville limestone. } Conasauga shale.	Connasauga shale.	Knox shale.
	Rome formation.	Єr	Rome formation.	Rome formation.	Knox sandstone.
	Rome sandstone-lentil.	Єrs	Rome sandstone.	Rome sandstone.	

ARTHUR KEITH,
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	Є	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:

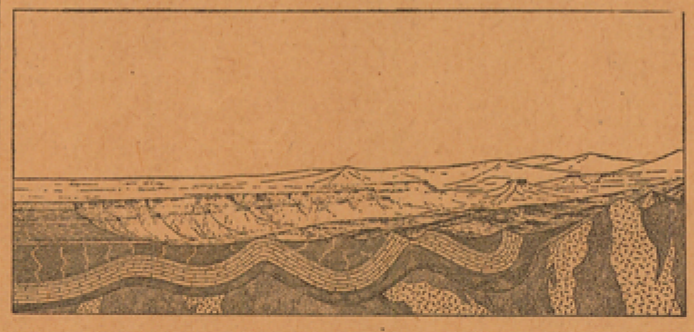


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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:

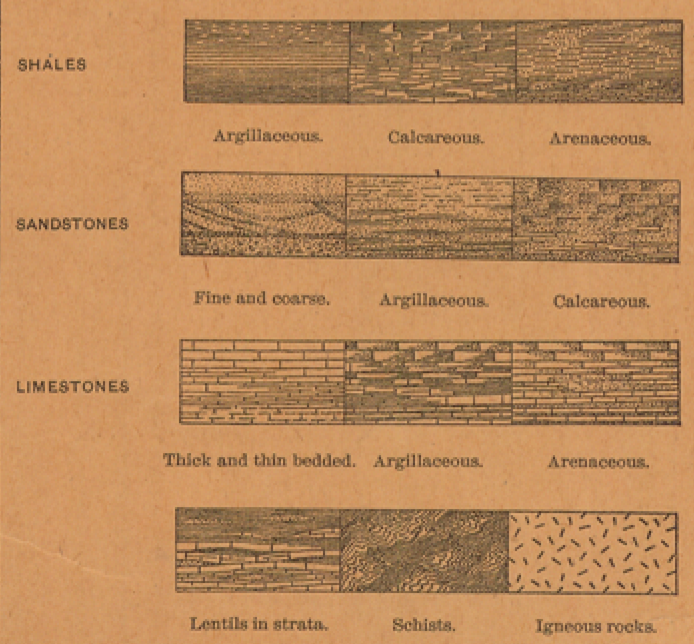


Fig. 3.—Symbols used to represent different kinds of rock.

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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