DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

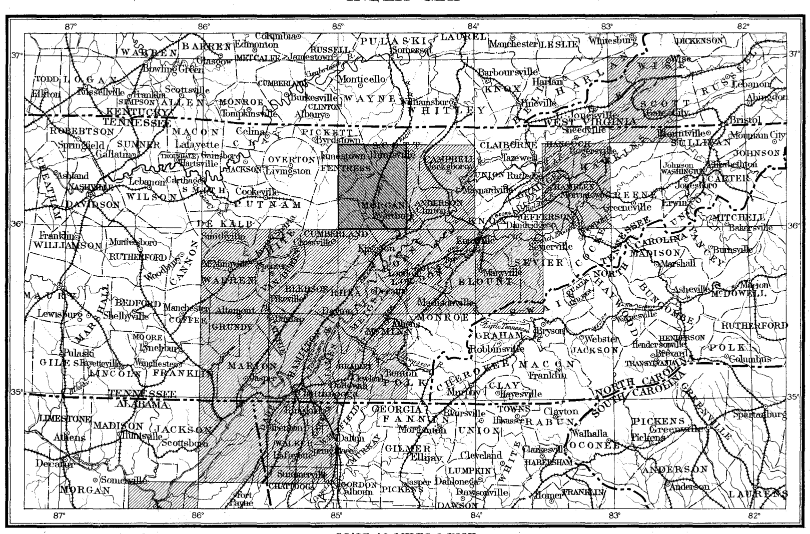
OF THE

UNITED STATES

WARTBURG FOLIO

TENNESSEE

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE WARTBURG FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

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

FOLIO 40 | LIBRARY EDITION | WARTBURG

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1897

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

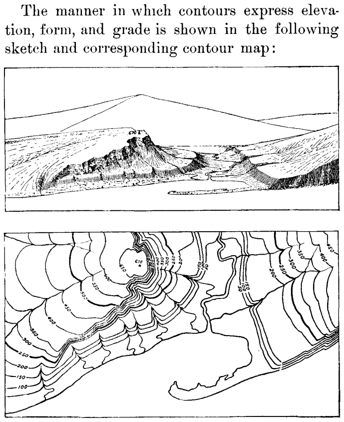


Fig. 1.—Ideal sketch and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

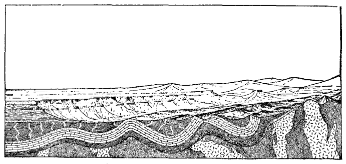


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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

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

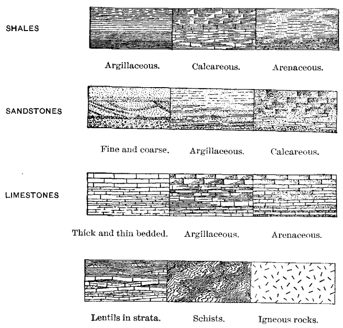


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE WARTBURG QUADRANGLE.

GEOGRAPHY.

Extent of quadrangle.

General relations.—The region represented by the Wartburg atlas sheet lies entirely in Tennessee. It is included between parallels 36° and 36° 30′ and meridians 84° 30′ and 85°, and it contains 963 square miles, divided between Scott, Morgan, Cumberland, and Fentress 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.

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.

Relation of relief to rock character.

The Appalachian Mountains; local ranges.

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.

Nature of the rocks.

The Cumberland Plateau.

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.

Its varied topography.

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.

Altitudes of the Appalachian Mountains.

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1000 feet in Alabama to more than 6600 feet in western North Carolina. From this culminating point they decrease to between 4000 and 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.

Local river systems.

Local geography of the Wartburg quadrangle.—Within the limits of the Wartburg quadrangle only one geographic division, the Cumberland Plateau, appears. By far the greater part of this area consists of a well-developed plateau, but along its eastern and southern border irregular mountains rise to considerable heights above the plateau level. The drainage of the region is tributary to several river systems. The southern half of the area is drained through the Obed and Emory rivers into the Tennessee River, the northern half through the South Fork of the Cumberland River into the Ohio, and the western edge by Obey River into the Cumberland River and the Ohio. The South Fork of the Cumberland River and the Obey River head within the quadrangle.

The streams of the mountains fall rapidly from their sources to a level of 1400 or 1500 feet, from which altitude they descend less rapidly to 800 or 900 feet at the borders of this quadrangle and near the edges of the plateau. The streams of the plateau head upon its surface at 1500 to 1800 feet above the sea, fall rapidly near their headwaters, and have many sluggish stretches in their lower courses. Their valleys are deep, and the slopes rise continuously from narrow bottoms to the divides.

Conditions determining character of topography.

Through most of the plateau the large streams are sunk in deep, narrow channels, which are lined by high cliffs and are from 300 to 1000 feet below the level of the plateau. 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.

The plateau features.

The topography of the plateau is entirely unlike that of the adjacent Great Valley. The straight valley ridges are wanting. The rocks of the plateau are composed mainly of two classes, sandstone and shale, and each, with different varieties, has a characteristic effect on the surface forms. Sandstones make cliffs, table-topped heights, and benches which stand out sharply from the smoother shale slopes. Inasmuch as the rocks are practically flat, these features are conspicuous by their regularity of level. Exceptions to this are seen along the southern border of this quadrangle in Peavine and Hartfield mountains, and on the slopes of Crab Orchard Mountain, where the ridges follow the folded Lee conglomerate.

The mountains upon the plateau.

The divides in the mountainous portion of the plateau vary in height from 2000 to 3100 feet. Over the plateau proper the summits rise gradually westward from 1500 up to 1800 feet. The crests of the mountains and ridges are usually narrow and flat, though many of them have small areas of easy slope, capable of cultivation. The table of the crests gives place abruptly, 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. Throughout the plateau the streams and branches have cut narrow, deep canyons and abrupt valleys, with lines of cliffs, in the broad, level tables or gently sloping tops. The surface is very much broken, and travel is difficult except by following along the tables.

GEOLOGY.

STRATIGRAPHY.

Origin of the rocks.

The general sedimentary record.—All of the rocks appearing at the surface within the limits of the Wartburg quadrangle are of sedimentary origin. 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 sedimentary rocks of the Appalachian province 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 Wartburg 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, gradual further uplift ended the deposition of sediment in the

Appalachian province, except along its borders in recent times.

Three distinct rock areas.

The rocks of this area.—The columnar section shows the composition, name, age, and thickness of each formation which outcrops within the quadrangle. There are also added to the columnar section the Devonian and uppermost Silurian formations, which underlie the plateau, although they do not appear at the surface in this region. The rocks of this quadrangle were deposited entirely during the Carboniferous, and they represent a large number of the strata formed during that period. The formations lie in three groups of but slightly different age. Over the eastern half of the region are spread the later formations, those above the Lee conglomerate. The latter formation makes the surface of the remainder of the plateau, while in the deep stream-cuts in the northern and western part of the plateau appear the underlying Carboniferous limestones and shales. The first group is siliceous, argillaceous, and carbonaceous; the second is mainly siliceous; and the last is chiefly calcareous. All of the formations lie in nearly horizontal layers, seldom being noticeably folded. Accordingly the belts of rock follow horizontally all the irregularities of the slopes and ravines. The rocks will be described in order of age.

CARBONIFEROUS ROCKS.

Fossiliferous blue limestone with cherty beds.

Newman limestone.—This formation, which derives its name from Newman Ridge, Hancock County, Tennessee, where it occurs in great outcrops, appears in many large and small areas along the northwestern part of the plateau. It consists of massive blue and dove-colored limestones interbedded near the top with thin layers of green and purple calcareous shale. About 300 feet of the lower limestones contain an immense amount of chert in the form of black banded concretions or of white chalcedonic nodules. Geodes lined with quartz crystals are often to be observed. Chert occurs in the upper layers also, but is much less frequent. The limestones contain many fragments of crinoids, corals, and brachiopods of Carboniferous age, and the chert also is frequently full of fossils, chiefly crinoids. The thickness of the formation is from 400 to 700 feet, and decreases in a westerly direction. In its upper portion, in Poplar Cove, occur thin beds of conglomerate formed of limestone pebbles, which indicate erosion of the formation in some neighboring locality. Alternations of limestone and green shale form a passage upward into the Pennington shale. A bed of grayish sandstone, from 10 to 30 feet thick, lies 150 feet from the top of the formation; in adjacent regions toward the west this bed thickens and becomes an important stratum. Near the base of the formation in the northwestern part of this quadrangle many beds of calcareous shale appear in the limestones.

Dark shale, sandstone, and chert, seen only in drill cores.

Below this formation and grading into it lies the Waverly shale, consisting of calcareous and sandy shales, shaly sandstones, limestones, and cherty masses. All of these beds have a prevailingly dark color, and the shales are frequently tinged with red or brown. The chert is very prominent near the base. This formation does not outcrop in the Wartburg quadrangle, but it is encountered in the borings for petroleum, and is introduced in the columnar section with the underlying Devonian and Silurian formations. The Waverly shale does not appear at the surface in the adjoining Briceville quadrangle, but dies out near the eastern edge of the Wartburg. In the structure section the Waverly is included with the Newman limestone.

The soluble nature of the Newman limestone usually consigns it to the valleys, where it forms a rolling surface. Its cherty portions resist solution well enough to form rounded hills and low ridges or, in places, obscure benches. Decay of the formation produces a stiff, red clay mingled with chert, and the soils thereon afford fairly fertile land. The best soil is found on the upper portions, where the accumulation of chert is not great, but these usually lie at rather steep slopes near the Lee conglomerate or are removed by erosion.

Calcareous shale with beds of limestone.

Pennington shale.—Outcrops of this formation are found, like the Newman limestone, in deep cuts in the plateau, occupying narrow belts protected by the Lee conglomerate cliffs. The shale receives its name from Pennington Gap, Clinch Mountain, in Virginia, where it occurs prominently. The formation is composed in the main of calcareous shale of red, purple, and green colors, and contains many beds of blue and dove-colored limestone and gray, sandy shale. In the limestone beds many fossils are found similar to those of the Newman limestone. Along the border of the plateau south of this region this formation does not appear; it thins out at some place in the central part of the plateau. The formation varies in thickness from 145 to 250 feet along the western and northern parts of the plateau.

Decay proceeds rapidly in this formation, owing to its softness and solubility, and usually only a few bright-colored shale beds project through a brownish clay. Its soils are naturally good and fertile, but they lie in small areas and their steep slopes are strewn with wash from the Lee conglomerate.

Massive sandstone with quartz conglomerate and shale.

Lee conglomerate.—Almost one-half of the plateau in this quadrangle is occupied by a broad belt of this formation. It consists in the main of massive sandstone, but it includes many beds of shale, and two layers in its lower portion are largely quartz conglomerate. The siliceous layers are thick and very massive, so that they form a series of cliffs, from 40 to 300 feet high, which rim the narrow canyons in the plateau. The topmost member of the formation consists of cross-bedded sandstone from 50 to 80 feet thick, which, with a shale bed 50 to 100 feet thick underlying it, is very regularly found, and invariably makes a series of cliffs. Around Helenwood and along Emory River these members are finely shown. In this uppermost sandstone on Emory River is found a 3-foot bed of coal, which is mined at several points. This seam outcrops at many points over the eastern part of the plateau and has an average thickness of 2 feet. Various other coal seams occur, usually in the shale beds, but they are rather irregular in thickness and extent. The most important coals occur in the shales occupying the lower part of the formation and shown on the Economic Geology sheet. West of Jamestown openings have been made in these strata on coal seams from 2 to 4 feet thick. These seams extend to the north and south for considerable distances, and are found by drilling as far southeast as Clear Fork. In this area the formation varies greatly in thickness. Ten miles southeast of Wartburg it is 900 feet thick; at the head of Obed River, 400 feet; a boring at Rugby gave 500 feet, and one at Rugby Road gave 700 feet, while the Cumberland River exposes 500 feet.

Variableness in thickness of the sandstone.

Between Rugby Road and Rugby the bottom bed, consisting of 250 feet of sandstone and conglomerate, diminishes to 80 feet, as was shown by the borings, and farther west it dies out, so that the intermediate shales and coal beds at Rugby Road form the base of the formation at Jamestown. South of Jamestown, toward Obed River, the reverse change takes place, and the conglomerate reappears beneath the shale body. In the columnar section of the formation for the adjoining Briceville quadrangle it is seen that the conglomerate and sandstone have thickened immensely, while the shales have practically disappeared. Similar but smaller unconformities are exhibited at many points along the gorges of Cumberland and Emory rivers, where sudden changes of thickness of 40 and 50 feet can frequently be observed. Evidence of the strength of the currents that deposited the coarser beds is found in the size of the conglomerate pebbles and the frequent cross-bedding of the sandstones.

Owing to the extreme hardness of the siliceous beds in this formation solution makes little headway, and the hard layers are broken down by the slow undermining of the shale beds. Where the formation comes to the surface it makes a plateau, whose level abruptly changes at the canyon edges to lines of cliffs and steep descents. Many of the cliffs along the larger streams attain a height of 200 or 300 feet and form serious obstructions to travel. Since the sandstone beds thus form most of the surface, the soils are thin and sandy. They repay careful cultivation, but are worn out easily and are subject to drought on account of their easy drainage and poor supply of water.

Dark shale with many coal seams.

Briceville shale.—Many areas of this formation are found in the eastern half of this quadrangle. Its name is taken from Briceville, Anderson County, Tennessee, 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. Like the Lee conglomerate, this formation thins toward the north and west, so that a thickness of 400 feet on the lower Emory River is represented by 350 feet at Wartburg and by 200 to 250 feet north of Helenwood. The individual beds of sandstone vary from 1 to 10 or 20 feet in thickness, and differ in appearance only by being massive or thin-bedded. Added importance is given to the formation by the mines which are located upon its coal seams.

The shales, owing to their fine grain, offer little resistance to weathering, and the formation never occupies high ground. The sandstone beds are hard enough to form ledges and small table-topped knobs, but are not thick enough to produce prominent ridges. Some of its sandstones in outlying areas may be readily confused with the overlying Wartburg sandstone. The clay soils produced by the shales are thin and poor and are considerably modified by waste from the sandstone beds.

Interbedded massive sandstones, shales, and thin coals.

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, is situated upon and furnishes the name for this sandstone. The formation consists of interbedded sandstone, 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 especially conspicuous. This is due largely to the contrast with the shales of the adjacent formations, for other sandstone layers in this formation are equally thick and massive. As many as five seams of coal occur with these strata, and one of the coal beds is mined at Glenmary. 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 4 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 600 feet in thickness.

Of the many spurs and benches which are caused by the sandstone beds the most prominent is the uppermost, 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 course. The lowest bed almost universally produces a series of cliffs from 15 to 50 feet in height, while several higher beds cause similar series that here and there may easily be mistaken for the bottom cliff. The coal beds are readily subject to weathering, and natural outcrops of coal are quite uncommon, except when the coal 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 outcrops of a coal bed are 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 growth and are of almost no value for farming purposes.

Sandy shale, sandstone, and coal seams.

Scott shale.—This formation appears in narrow belts encircling those ridges which rise over 2000 feet above the sea-level. Its name is taken from Scott County, in which it occurs frequently. 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 descriptions of individual beds would be only a repetition. In this formation, however, the amount of shale is much greater than that of the sandstone, the sandstones are thinner, and the coal beds rarely exceed 2 feet in thickness. A short distance above the Wartburg sandstone is found a coal seam 6 feet thick, the largest of the series. The total thickness of the formation ranges from 500 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 many 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 the timber growth is small.

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

Anderson sandstone.—Areas of this formation cap all portions of the mountain district which rise above 2600 feet. It occurs frequently in that position in Anderson County, hence its name. The formation consists, like the three preceding ones, of sandstones, sandy and argillaceous shale, and coal beds. The bottom of the series is marked by massive sandstones in heavy beds from 20 to 50 feet thick, with a total of 100 to 120 feet. Above these follow 300 to 400 feet of interbedded shales and thin beds 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 a short distance 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; 550 feet now remains.

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 gentler 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.

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*.

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.

Areas of typical structures.

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.

General character of folds and faults.

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.

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.

Cleavage and metamorphism.

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.

Structures are due to compression.

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.

Oscillations.

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

Structure sections.—The sections on the Structure sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual dips of the strata are shown.

Underground relations of strata.

These sections represent the structure as it is inferred from the position of the strata observed at the surface. On the scale of the map the sections 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 Wartburg quadrangle.—One type of structure prevails over nearly the whole of the Wartburg quadrangle. With a few exceptions the rocks have scarcely been moved from the attitudes in which they were deposited and they now lie in layers so nearly flat that the dip can seldom be measured in a single outcrop. A few limited districts are found in which the rocks have been tilted to an appreciable extent, and in one area the layers have been broken by a fault.

The horizontal plateau structure.

Along a line running north and south through Jamestown the strata have the greatest general elevation, and are practically at the same height as far south as Obed River. Eastward from this line the strata dip gently toward the east until they reach a second north-and-south line which passes through Armathwaite, Burrville, Deer Lodge, and Pilot Knob. Beyond this line the rocks have a more perceptible dip toward the east, the upper formations descend and occupy most of the surface, and the Lee conglomerate appears only along the stream cuts. Three similar zones pass northeast and southwest, through Helenwood, Pilot Mountain, and Wartburg respectively, in which the strata dip toward the southeast. Sections A, B, and C illustrate these dips. Disturbances of greater amount appear south of Obed River in Lavender Knob, Peavine Mountain, Hatfield Mountain, the northern slopes of Crab Orchard Mountain, and a sharp ridge running southeast from Nemo. All of these ridges are produced by small anticlines in the Lee conglomerate, which are the terminations of folds of greater size toward the southwest. Between these anticlines synclines are formed, which are as irregular as the arches. Several minor synclines appear in the eastern part of the region, two of which, passing northeast, one through Melhorn Ford and the other just east of Rugby Road, are readily discovered. The only fault which appears in the entire area passes 3 miles southeast of Melhorn Ford and is traceable at intervals for several miles both northeast and southwest. This break is of an unusual type, in which the rocks have been snapped directly across, even the most massive sandstones. The displacement is not great—only a few hundred feet—and the dip of the fault plane is toward the northwest, which is also an unusual feature.

Sharper folding.

In addition to these features of deformation which appear at the surface, other changes of attitude are introduced by the changes of thickness among the different formations. Such occur in the Lee conglomerate, Newman limestone, Waverly shale, Chattanooga shale, and Rockwood formation. All of these formations, except the Waverly shale, thicken toward the southeast, so that the layers at the bottom dip to the southeast more than those at the top. In the Lee conglomerate the thickening amounts to 500 feet between Jamestown and Emory River. In the same direction the Chattanooga shale increases from 30 to 50 feet, and the Rockwood formation from nothing to about 400 feet. The Waverly shale thickens toward the northwest and about equalizes the thinning of the Newman limestone. The total effect of these changes is to give to the formations below the Rockwood shale rather more than double the dip of the strata at the surface.

Thickening of formations toward the southeast.

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. After the great period of Appalachian folding already described such uplifts again took place and are recorded in surface forms. While the land stood in one attitude for a long time, most of the rocks were worn down to a nearly level surface, or peneplain. One such surface was strongly developed over the Cumberland Plateau and is still well preserved in its broad, flat summits. Its elevation varies along the stream divides from about 1500 to 1700 feet above sea-level. Since the formation of this peneplain, uplift of the land gave the streams greater slope and greater power to wear; they have therefore worn down into the old surface, to depths varying according to their size. The remains of another and earlier peneplain are obscurely seen in the summits northeast of Wartburg, a few of which reach the height of 3000 feet, which is so frequently attained farther to the east. 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 sufficien length to permit peneplains to form and to record the movement.

Remnants of peneplains.

MINERAL RESOURCES.

Rocks of this region are available for use in the natural state as coal, building stone, and road material. Other materials derived from the rocks are petroleum, iron, lime, and clay. Through their soils the formations are valuable for crops and for timber; and through the grades which they establish on the streams they occasion numerous waterfalls available for power.

Coal.—Bituminous coal occurs in many seams throughout this entire region. The coal-bearing area is part of the large field extending northeast and southwest into the adjoining States. Mines have been opened at Helenwood, Glenmary, Montgomery, and the lower Emory River. The coal produced is used for coking, steam, and household purposes, the greater part being made into coke. The mines at Helenwood and Montgomery are opened in the Briceville shale, those at Glenmary are just above the lowest bed of the Wartburg sandstone, while those along Emory River are about 30 feet below the top of the Lee conglomerate. The seam at Glenmary rarely attains elsewhere as great a thickness as at that point, although its horizon is almost always represented by a thin seam. The Montgomery and Helenwood seams probably are the same, for, while they are not traced into connection, each is developed over a large area at practically the same position in the strata and is usually of considerable thickness. The small sections given with the stratigraphic column show the beds typical of the vicinity of the mines.

The chief mine openings.

Besides the main coal seams, great numbers of others appear at small intervals throughout the entire thickness of rocks above the Newman limestone. These seams are most frequent near the junction of the Wartburg sandstone and Briceville shale or in the Scott shale. While many of these seams are 20 to 30 inches thick, and occasionally exceed 4 feet, most of them are less than 2 feet thick and too thin for profitable working. More than a dozen seams appear in the mountains east of Wartburg.

Minor seams.

The seam mined in the upper part of the Lee conglomerate ranges over the eastern part of the plateau, but it seldom exceeds 2 feet. The coals opened west and southwest of Jamestown are in the shales which are at the bottom of the Lee conglomerate at that point, but which form the middle portion of the formation in districts farther southeast. These coals range in thickness from a few inches to $4\frac{1}{2}$ feet, but are quite variable, and are even absent in many sections. Although usually only one coal appears in one section, it is not probable that it is one continuous seam, for its distance below the main conglomerate stratum is very irregular—from 80 to 250 feet. The deposition of the formations of that period seems to have varied considerably from one small basin to another. The coals occupy a position very similar to the coal mined farther southwest at Bon Air.

As is shown in the structure sections, the rocks which include the coal beds are very nearly horizontal. South of Obed River the disturbances are often considerable, but elsewhere they are not sufficient to affect the mining of the coal to any extent, and crushing or dislocation is practically absent. Such areas of thinning as occur may readily be due to non-deposition. Nearly all of the coal seams of this region require heavy timbering, since the roof is usually of shale. Occasionally a seam is somewhat protected by a thin roof of massive or shaly sandstone, but never enough to do away with the timbers. The coal seam mined on Emory River, however, occurs between heavy layers of sandstone with practically no shale. Floors of fire-clay are very common, but frequently shale or carbonaceous slate replaces it, to the advantage of the mine.

Flatness of the coal beds.

Petroleum.—The occurrence of petroleum in adjacent regions 6 to 10 miles west of Jamestown has long been known, and recently fresh drillings have brought more oil to the surface. Within this quadrangle three wells have been sunk, as shown on the economic sheet. The formation in which oil is found in quantity near Jamestown is the Chickamauga limestone, the same that contains oil in the adjacent Kentucky oil fields. In this region the formation comprises limestones and shaly limestones. These appear at the surface on both sides of Cumberland Plateau and, as shown by the drillings, continue the same beneath the plateau. Oil was found at three levels in these rocks in the Lacey well, 10 miles northwest of Jamestown: 107, 236, and 296 feet below the Devonian black shale. Salt water and traces of oil occurred at one horizon in the Lee conglomerate, 500 feet below its top. Oil appeared at 440 feet below the top of the Newman limestone at Rugby, while in the corresponding stratum at Rugby Road only brine appeared. In the Strubbe well, on Black Wolf Creek, oil was found 230 feet below the top of the Newman limestone. The amount of oil at all these levels was small. Thus far none of the wells of this quadrangle have reached the Chickamauga limestone, the oil-bearing formation. The productive wells northwest of Jamestown at first yielded as much as 500 barrels per day, but diminished to 75 or less in a few days, and contained much salt water. The oil varied in color from light-green to dark-green.

The oil-bearing formation.

The productive district is situated northwest of Jamestown, upon the top of a very gentle anticline whose southeastern slope extends to Rugby Road. At the surface the dip is about 20 feet to the mile, but the productive strata, owing to the thickening of the formations, already mentioned, dip at a much greater rate, averaging 50 feet to the mile from Jamestown to Rugby Road. In addition to this general relation of dip, there is a zone of greater easterly dip passing south through Rugby, mentioned under the heading "Structure." Zones of greater southerly dip are also mentioned in the same place. South of Obed River lies the most disturbed district in this quadrangle, in which the strata are elevated to greater heights than on the anticline west of Jamestown. The well at Rugby is about two-thirds of the distance down the slope of the anticline, and the wells near Rugby Road are about at the bottom of the slope. As shown in section B, the strata rise for a short distance to the east of this point. With the exception of this narrow zone of uplift appearing at intervals along the eastern border of the quadrangle, the strata have extremely small dips in the region east of this, described in the Briceville folio.

Comparison with the Jamestown oil-field.

The existence of oil in the strata at these lowest points has not yet been shown, and it is possible that they contain only salt water. One of the layers in the Newman limestone which bears a small amount of oil at Rugby contains only salt water in the well at Rugby Road, and a similar relation may hold in the lower oil-bearing layers. Wells situated at the lower border of the eastward slope, if productive at all, would flow, under the pressure of the oil, in the whole slope of the anticline and would also drain much of the area of flat rocks lying toward the east. In the district around Jamestown, access to the oil-bearing strata is easy on account of the great erosion of the overlying beds. Wells situated farther east will have in most cases to pass through the entire thickness of the Lee conglomerate, which increases greatly eastward, and the Newman and Waverly limestones, all of which formations are extremely hard to drill. On the lower part of the South Fork of Cumberland River, wells can be started below the Lee conglomerate, where it is cut through by the stream, and low down on the slope of the anticline. Even here, however, as in all places east of the coves and gorges near Jamestown, 700 to 800 feet of tough Newman limestone and Waverly shale must be drilled through. In the more eastern parts of this region the Rockwood shale comes in above the Devonian black shale and increases the thickness of rock above the productive strata. It is possible that the Rockwood shale may become the repository of petroleum in the eastern part of the plateau.

Iron.—Many deposits of iron ore are scattered over the plateau. The ores occur chiefly in the form of limestone, and are strewn over the surface or in the clay-soils in small lumps and nodules. They result chiefly from the replacement of calcareous nodules imbedded in the shales, and are never accumulated in bodies of great size. No attempt has been made to use these ores.

Lime.—In the Pennington shale and the Newman limestone material for the manufacture of lime occurs. Most of the latter formation contains too much silica in the form of chert to be available, but many of its upper beds are pure enough for the purpose. Thus far there has been almost no demand for lime, and the formation is practically untried.

Clays.—Clays for brick making are commonly found in the hollows along the surface of the plateau, and also occur in many layers imbedded in the coal-bearing strata. The former deposits consist of the wash from the various Carboniferous shale beds. They are widely distributed, and are of considerable size. No use has been made of them, however. The fire-clay interbedded with the sandstones and shales ranges from a few inches to 4 feet in thickness and extends over great areas, like the other sediments. It is seldom thick enough to be worked independently, and in the only mine where it is obtained in this region the clay and the associated coal are worked together. This clay is of very fine and even texture and is used in the manufacture of pottery.

Brick-clays.

Fire-clays.

Timber.—Much the greater part of this quadrangle is forest-covered, and only in a few districts along the larger streams has the timber been removed. The covering of trees is scanty on the tables of the plateau, and the trees are only of moderate size. In the hollows and gorges soils are richer and the timber growth is strong. Such trees as hickory, chestnut, and oak make up the bulk of the forest, and pine, hemlock, and spruce are numerous near the watercourses. Lumbering is easy on account of the small amount of underbrush, but the distance to market, for the most of this region, has checked all attempts at developing this resource.

ARTHUR KEITH,
Geologist.

May, 1897.

COLUMNAR SECTIONS

GENERALIZED SECTION FOR THE WARTBURG QUADRANGLE.

SCALE: 1000 FEET = 1 INCH.

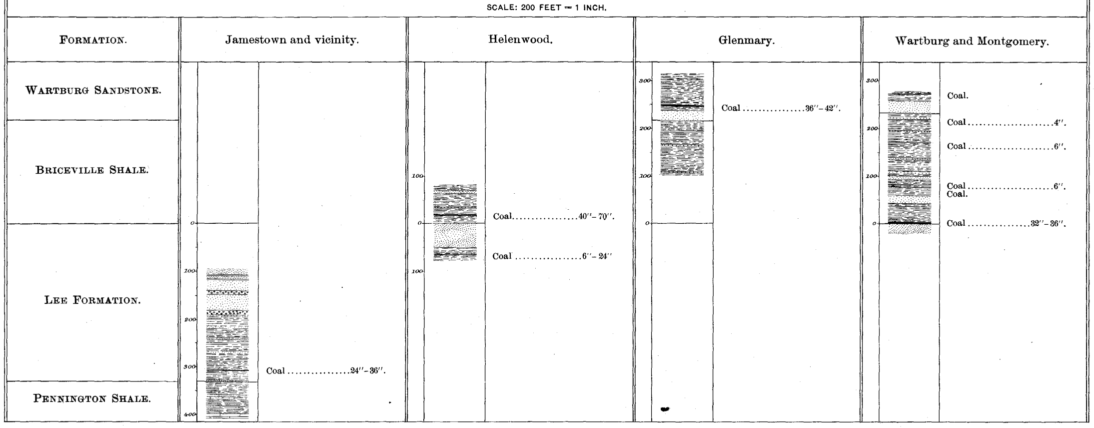
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	Anderson sandstone.	Can		500	Sandstone, thin and massive, interbedded with sandy and argillaceous shales and thin coal beds.	Flat-topped ridges and mountains with lines of cliffs and ledges. Thin, sandy and clayey soil.
	Scott shale.	Csc		500-600	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 plateaus with numerous low cliffs. Thin clay-soil on the shales, usually covered with sandy wash.
	Briceville shale.	Cbv		250-400	Black, bluish, and gray, argillaceous shale with small beds of sandy shale, sandstone, and thick coal beds.	Slopes of Wartburg sandstone tables, and low hills. Thin clay-soil with sandy wash.
	Lee formation. (Shale in Lee formation.)	Cle (Cles)		375-900	Massive sandstone with beds of cross-bedded sandstone and conglomerate, thin shale beds, and beds of coal.	Plateaus bounded by steep slopes and lines of high cliffs. Thin, sandy soil.
	Pennington shale.	Cpn		145-250	Purple and green, argillaceous and calcareous shales interbedded with blue limestone.	Slopes of Lee conglomerate plateaus. Dark clay-soil with sandstone wash.
	(Newman sandstone-lentil.) Newman limestone.	(Cns) Cn		400-700	Massive, blue and dove limestones with calcareous shale beds; grayish white sandstone near the top; chert nodules and layers more prominent in the lower strata.	Valleys with rounded hills and benches. Red clay-soil with many cherts and geodes.
	Waverly formation.	Cwv		0-300	Red and brown, calcareous and sandy shales, limestone, and cherty beds.	
DEV.	Chattanooga shale.	Dc		28-80	Black, carbonaceous shale.	
	Rockwood formation.	Sr		0-400	Red and brown, calcareous and sandy shales with beds of fossiliferous red hematite.	
SILURIAN	Chickamauga limestone.	Sc		1000+	Blue and gray limestone, argillaceous limestone, flaggy limestone, and calcareous shale, with a little chert. Blue and gray, massive limestone with a few nodules of black chert.	

NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		Arthur Keith: Briceville Folio, U. S. Geological Survey, 1897.	C. W. Hayes: Kingston Folio, U. S. Geological Survey, 1894.	Safford: Geology of Tennessee, 1869.
Carboniferous	Anderson sandstone.	Can	Anderson sandstone.		Coal measures.
	Scott shale.	Csc	Scott shale.	Walden sandstone.	
	Wartburg sandstone.	Cwb	Wartburg sandstone.		
	Briceville shale.	Cbv	Briceville shale.		
	Lee formation.	Cle	Lee conglomerate.		
	Shale in Lee formation.	Cles		Lookout sandstone.	
	Pennington shale.	Cpn	Pennington shale.	Bangor limestone.	Mountain limestone.
	Newman limestone.	Cn	Newman limestone.		
	Newman sandstone-lentil.	Cns		Fort Payne chert.	Siliceous group.
	Waverly formation.	Cwv			
Dev.	Chattanooga shale.	Dc	Chattanooga shale.	Chattanooga black shale.	Black shale.
Sil.	Rockwood formation.	Sr	Rockwood formation.	Rockwood formation.	Dyestone group.
	Chickamauga limestone.	Sc	Chickamauga limestone.	Chickamauga limestone.	Trenton and Nashville group.

DETAILED SECTIONS OF THE COAL-BEARING STRATA IN THE MINING AREAS.

SCALE: 200 FEET = 1 INCH.



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

TOPOGRAPHIC SHEET

TENNESSEE
WARTBURG QUADRANGLE

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by A.E. Murlin.
Surveyed in 1893.

Scale 1:125000
Miles
Kilometers

Contour Interval 100 feet.
Datum is mean Sea level.
Edition of Mar. 1896

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

HISTORICAL GEOLOGY SHEET

TENNESSEE
WARTBURG QUADRANGLE

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, thin sandstones, and thick coal beds)*

Cle — Lee formation *(massive sandstone and conglomerate, with shale beds and thin coal seams)*

Cles — Shale in Lee formation *(argillaceous and sandy shales with thin sandstone layers and coal beds)*

Cpn — Pennington shale *(purple and green, argillaceous and calcareous shales, with interbedded blue limestone)*

Cn — Newman limestone *(massive, blue and dove limestone, cherty in its lower layers)*

Cns — Newman sandstone-lentil *(coarse, yellow sandstone layer in Newman limestone)*

Faults

Sections

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Triangulation by U.S. Coast and Geodetic Survey.
Topography by A.E. Murlin.
Surveyed in 1893.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of Nov. 1897.

Geology by Arthur Keith.
Assisted by H. B. Goodrich.
Surveyed in 1894.

U.S. GEOLOGICAL SURVEY
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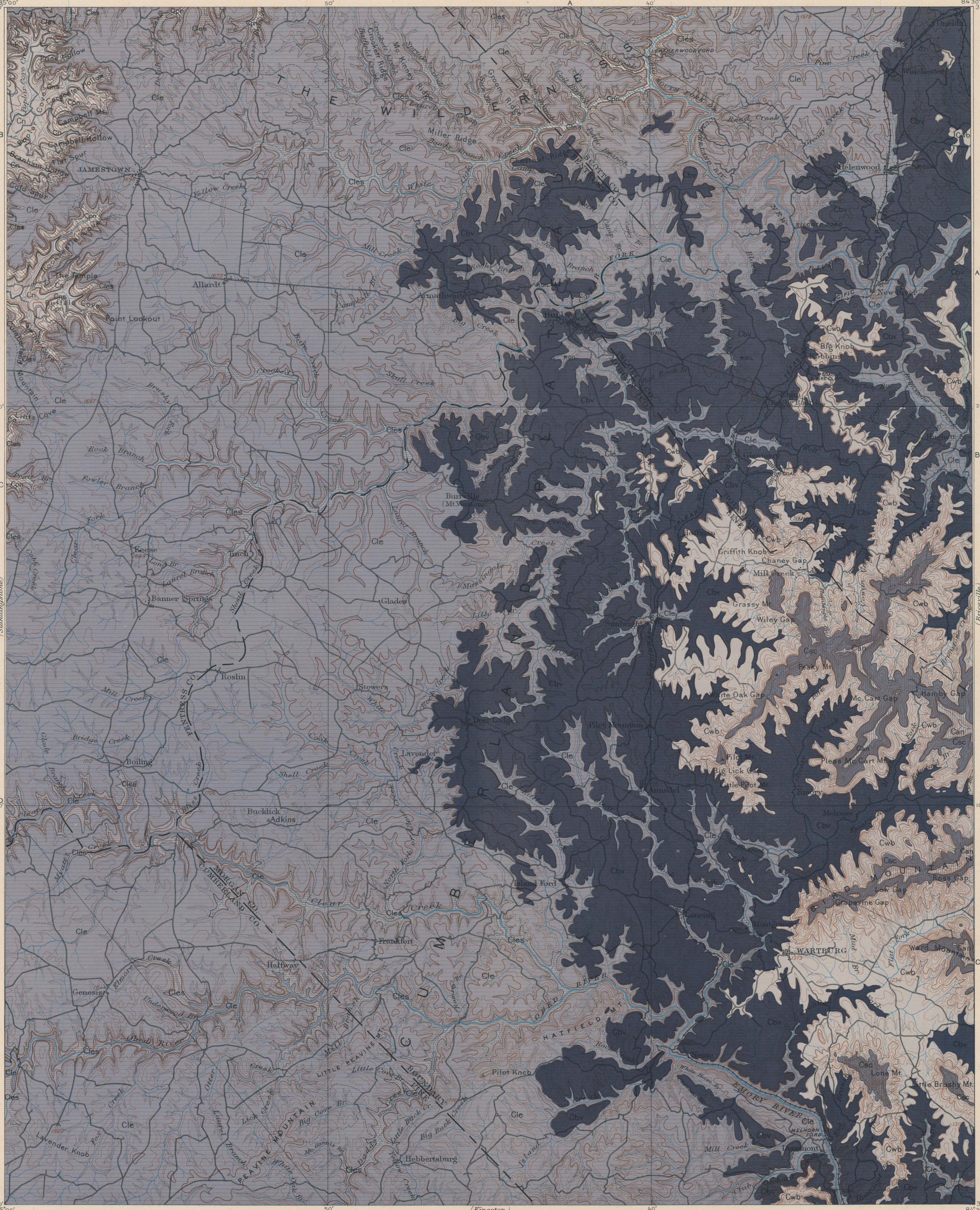
ECONOMIC GEOLOGY SHEET

TENNESSEE
WARTBURG QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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CARBONIFEROUS

- **Can** — Anderson sandstone *(sandstone with argillaceous and sandy shale and thin coal beds)*
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- **Cns** — Newman sandstone-lentil *(coarse, yellow sandstone layer in Newman limestone)*

Faults

Sections

Mines and wells

Known productive formations

- **Csc** — *Scott shale* *(contains thin coal seams)*
- **Cbv** — *Briceville shale* *(contains thick coal beds)*
- **Cle** — *Lee formation* *(contains thin coal beds locally thick)*

Henry Gannett, Chief Topographer.
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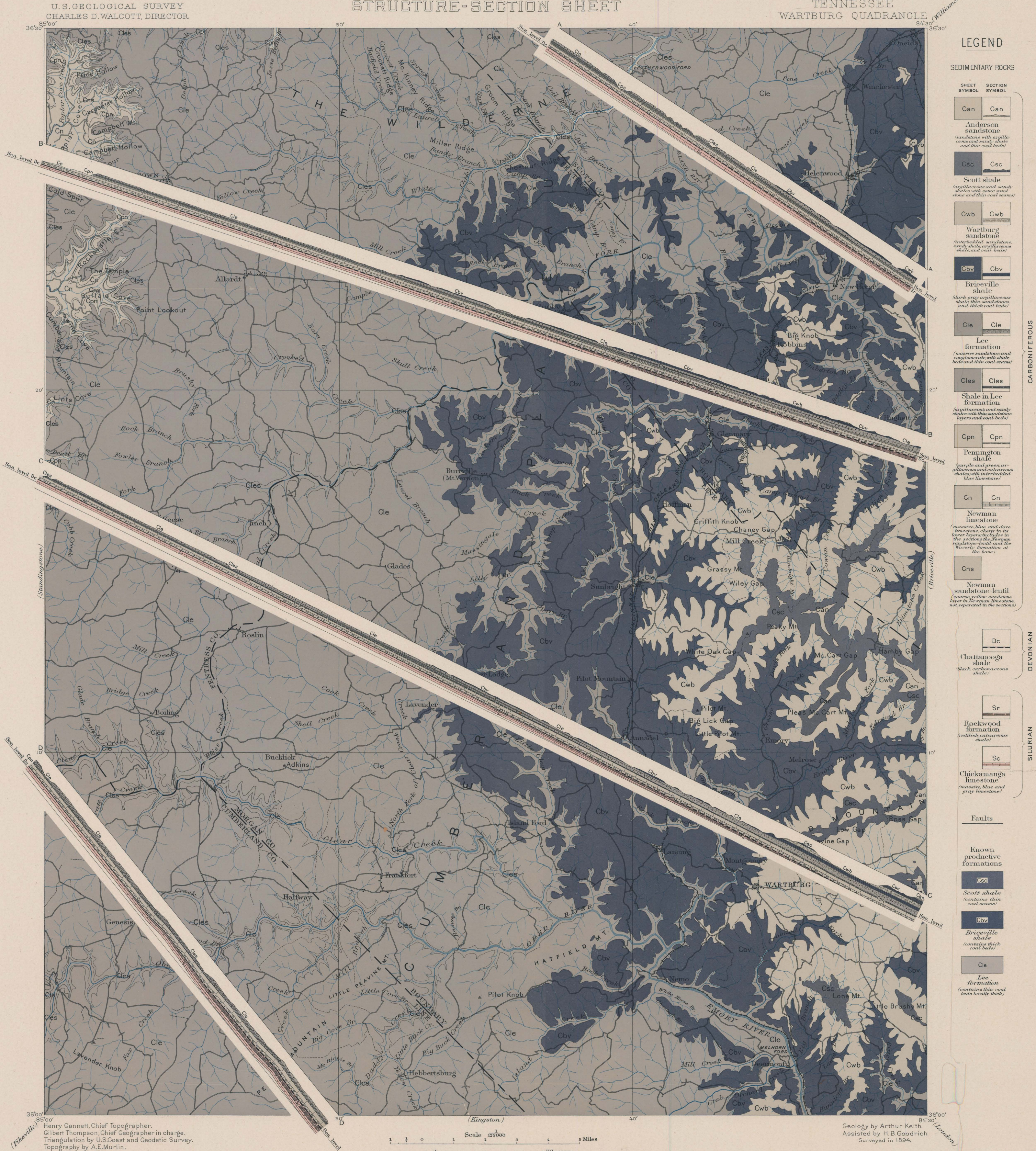
STRUCTURE-SECTION SHEET

TENNESSEE
WARTBURG QUADRANGLE



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