DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

GEOLOGIC ATLAS

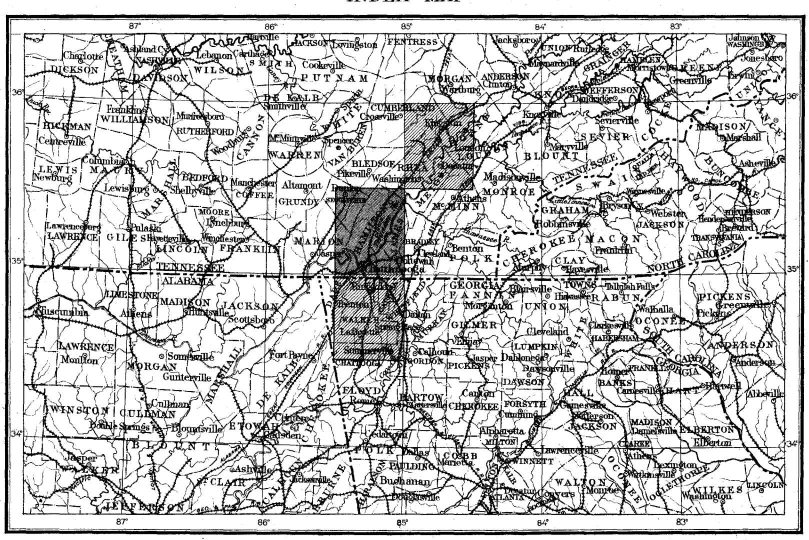
OF THE

UNITED STATES

CHATTANOOGA FOLIO

TENNESSEE

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE CHATTANOOGA FOLIO

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LIBRARY EDITION

CHATTANOOGA

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined and those which are most important are stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

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

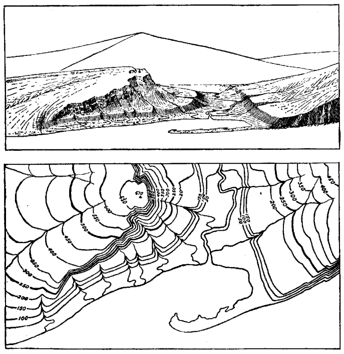

Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate height, form and slope:

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

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

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

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

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

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

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

Scales.—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "one mile to one inch" is expressed by $\frac{1}{63,360}$.

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

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree These areas correspond nearly to 4000, 1000 and 250 square miles.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the states, counties or townships. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

THE GEOLOGIC MAP.

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

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

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

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

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

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

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

If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes. The Appalachian mountains would become an archipelago in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses; and as it rises or subsides the shore lines of the oceans are changed.

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

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

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found.

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

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

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

In any district several periods may be represented, and the representation of each may include one or many formations. To distinguish the sedimentary formations of any one period from those of another, the patterns for the formations of each period are printed in the appropriate period-color; and the formations of any one period are distinguished from one another by different patterns. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

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

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

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

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

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

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

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

Metamorphic crystalline formations are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines.

If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters only.

USES OF THE MAPS.

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

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

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

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

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

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

The legend is also a partial statement of the geologic history of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

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

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

Economic geology.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors.

A symbol for mines is introduced in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

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

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial cutting which exhibits those relations is called a *section,* and the same name is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure,* and a section exhibiting this arrangement is called a *structure section.*

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

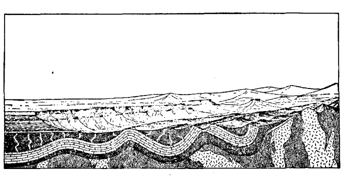

Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows the underground relations of the rocks. The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

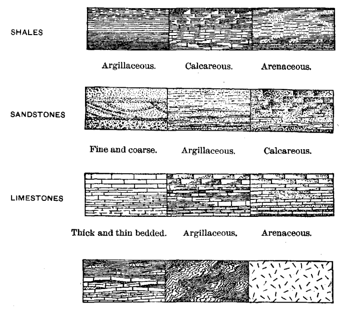

Fig. 3. Symbols used to represent different kinds of rocks.

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

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

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

When strata which are thus inclined are traced underground in mining or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales and limestones were deposited beneath the sea in nearly flat sheets. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

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

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

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

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

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

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

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

Columnar sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

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

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

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

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

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

J. W. POWELL,
Director.

CHATTANOOGA ATLAS SHEET.

DESCRIPTION.

GEOGRAPHY.

General relations.—The Chattanooga atlas sheet is bounded by the parallels 35° and 35° 30′, and the meridians 85° and 85° 30′. It embraces, therefore, a quarter of a square degree of the earth's surface. Its dimensions are 34·5 miles from north to south, and 28·2 miles from east to west, and it contains 974·64 square miles. The adjacent atlas sheets are, on the north, Pikeville, on the east, Cleveland, on the south, Ringgold, and on the west, Sewanee. The sheet lies wholly within the State of Tennessee, the southern limit being within about a mile of the Tennessee–Georgia line. It embraces portions of Bledsoe, Rhea, Sequatchie, Marion, Hamilton, and James counties.

Topography.—The country included within the atlas sheet presents several widely different types of surface. The differences are due jointly to the character of the underlying rock and to the geologic structure—the relation of the strata to the surface. This connection between the geology and the topographic features will be explained later. Beginning in the northwest corner of the sheet and passing to the southeast, the following distinct areas may be noted: (1) the Cumberland plateau, (2) the Sequatchie valley, (3) Walden ridge, (4) the Tennessee valley, (5) White Oak mountain.

A small portion only of the Cumberland plateau, about 85 square miles, is embraced within the limits of the sheet. The general surface is level or rolling, elevated approximately 2,100 feet above sea level. The drainage is by streams flowing northwest to the Cumberland river and southeast to the Sequatchie. These streams have rapid fall and the larger ones have cut deep canyons several miles back from the edge of the plateau.

Toward the southeast the plateau is terminated by an abrupt escarpment, trending N. 30° E. and forming the western edge of the Sequatchie valley. On the eastern side of the valley is an escarpment, similar, but less broken by stream channels and somewhat higher than that on the west. The width of the valley between these two parallel escarpments is about four miles and its general surface is between 700 and 800 feet above sea level, or 1,300 feet below the adjacent plateau.

East of the Sequatchie valley is Walden ridge. This is not properly a ridge but rather a plateau which resembles in many respects the Cumberland plateau. Its area within the sheet is about 330 square miles, or one-third that of the entire sheet. The surface slopes gently toward the southeast from 2,200 feet above sea level on the western edge to 1,700 on the eastern. The drainage is wholly toward the southeast. A large number of streams head near the western side, frequently within a few hundred yards of the escarpment, and, flowing southeast in gradually deepening channels, emerge into the Tennessee valley from deep rocky gorges. As the streams debouch upon the valley their descent is less rapid so that they are able to carry less sediment, hence a part of the material eroded from the gorges is deposited in a kind of delta around their mouths. Since these deposits are composed wholly of coarse sand, gravel and boulders they are quite porous and most of the streams wholly or in part disappear from the surface for short distances. Toward the southern edge of the sheet Walden ridge is cut through by the Tennessee river, which at Chattanooga turns westward almost as right angles to its upper course.

East of Walden ridge is the valley of the Tennessee river, a portion of the great Appalachian valley which extends toward the northeast through Virginia and Maryland into Pennsylvania and toward the southwest through Georgia into Alabama. The area of the portion embraced within the atlas sheet is about 440 square miles. The elevation of the Tennessee river is between 670 and 700 feet above sea level, and the general surface of the valley is a little higher, but many hills and irregular ridges rise two or three hundred feet above the river. The actual flood-plain or bottom is nowhere extensive, and on one side or the other the river usually washes the base of a steep, rocky bluff. At Chattanooga the river leaves the broad Appalachian valley, and sweeping past the foot of Lookout mountain enters the narrow canyon carved across Walden ridge. With steep wooded slopes rising from the water's edge and surmounted, a thousand feet above, by vertical cliffs of gray sandstone, the gorge affords some of the most picturesque scenery to be found in the southern Appalachians.

Compared with its upper valley, the gorge of the Tennessee below Chattanooga is extremely young and there is evidence that it has been occupied by the present river but a short time. Until recent geologic ages the Tennessee probably continued southward in the broad Appalachian valley directly to the Gulf of Mexico. Since it was diverted to its present course it has lowered its bed only about 250 feet, this being the height of the divide which separates its waters from those still flowing southward.

Crossing the southeastern corner of the sheet in a direction parallel to the edge of Walden ridge is White Oak mountain, a sharp ridge steep on its western side and sloping gently to the east, with an elevation from 1,300 to 1,500 feet above sea level. East of White Oak mountain are numerous ridges, in a general way parallel with it but lower and less regular. Grindstone mountain, however, has an elevation somewhat greater, and with its level top and steep sides it forms a small isolated plateau or mesa in all respects, except in its limited extent, similar to the Cumberland plateau in the western portion of the sheet.

STRATIGRAPHY.

All the rocks appearing at the surface within the limits of the Chattanooga atlas sheet are of sedimentary origin, that is, they were deposited by water. The materials of which they are composed were originally mud, sand and pebbles derived from the waste of some older rock, or 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 covered low, swampy shores.

CAMBRIAN ROCKS.

Apison shale.—The oldest rocks exposed within the limits of the sheet consist of slightly sandy or clay shales named from their typical development at Apison near the southeastern corner of the sheet. Their most striking peculiarity is the brilliant coloring which they display in sharply contrasted bands of red, purple, green and yellow. The thickness of the formation is not known, since it is always limited on one side by a fault, but at least 1,000 feet are exposed at its type locality.

A bed of gray siliceous limestone sometimes occurs between this and the succeeding formation, but though found both north and south of this region it does not occur within the limits of this sheet.

Rome formation.—Next above the Apison shale are the sandstones and shales of the Rome formation. They are between 3,000 and 4,000 feet in thickness, but on account of the folding and crumpling which the strata have suffered it is impossible to obtain accurate measurements. The lower part of the formation is composed of alternating layers of sandstone and shale. Passing upward the proportion of shale gradually increases, so that toward the top only a few thin siliceous beds occur, which can scarcely be called sandstone. The shales are usually brown or dark olive-green, while the sandstone beds are reddish brown or purple, with occasional layers of white quartzite. The sandstone beds show ripple-marks and other signs of having been deposited in shallow water, but the water was evidently growing deeper during their deposition, and the succeeding formation contains limestone and calcareous shale, which must have been formed on a comparatively deep sea bottom and remote from any high land that could yield coarse sediments.

Connasauga shale.—This formation is composed at the base of thin limestones interbedded with shales, in the middle of yellow or greenish clay shales, and at the top of blue seamy limestone or calcareous shales. Some of the thin beds of limestone, especially those near the lower part of the formation, have a peculiar oolitic structure, being made up of rounded or flattened grains about a tenth of an inch in diameter. This oolitic limestone is sometimes absent. The boundary between the Rome and Connasauga then becomes very indefinite and their separation difficult. The same is true when the upper part of the Rome also contains beds of lime, as is sometimes the case. The thickness of the Connasauga shale probably varies between 1,500 and 2,500 feet, but on account of the great contortions which the beds have suffered, the same uncertainty attaches to their measurement as to that of the two older formations. The formation takes its name from the Connasauga valley, in Georgia, on the Dalton sheet.

The Cambrian formations occupy a comparatively small portion of the area of the Chattanooga sheet. Two narrow strips occur near the center of the Tennessee valley, and a somewhat broader belt crosses the extreme southeastern corner of the sheet. The latter is limited by faults upon both sides and consists wholly of the two lower formations, the Apison and Rome.

SILURIAN ROCKS.

Knox dolomite.—The lowest division of the Silurian, the Knox dolomite, consists of from 3,000 to 3,500 feet of massively bedded and somewhat crystalline magnesian limestone. This limestone, or more properly dolomite, contains a large amount of silica in the form of nodules and layers of chert or flint. Upon weathering, that part of the rock which consists of the carbonates of lime and magnesia is dissolved, leaving behind the chert, usually imbedded in red clay. This residual material covers the surface to great depths and the dolomite itself is seldom seen except in the channels of the larger streams.

The Knox dolomite comes to the surface in a belt about two miles wide through the center of the Sequatchie valley and occupies the greater part of the Tennessee valley between Walden ridge and White Oak mountain. In both valleys its outcrops are marked by the characteristic low, rounded, chert hills, which rise from 300 to 400 feet above the level of the streams.

Chickamauga limestone.—The next formation is the Chickamauga limestone, which occupies a broad, continuous belt along the eastern side of the Sequatchie valley and a much narrower one, not entirely continuous, along the western side. The formation is here a pure, blue, thin bedded limestone, about 1,000 feet in thickness. It appears again on the eastern side of Walden ridge with much the same character as in the Sequatchie valley. East of Chattanooga and in the South Chickamauga valley are large exposures of the formation, where it has a thickness of about 1,600 feet and contains a considerable amount of earthy impurity. Along the western base of White Oak mountain is another broad belt showing a still further increase in thickness to about 2,200 feet, and also a greater proportion of earthy material, especially in the upper part of the formation. The Chickamauga limestone takes its name from the valley of Chickamauga creek, on the Chattanooga and Ringgold sheets, where it is typically developed.

Rockwood formation.—The Rockwood formation, which is the highest division of the Silurian in this region, varies widely in character and thickness within the limits of the sheet. It forms a narrow strip along the eastern side of the Sequatchie valley, with a thickness of about 200 feet, and is composed of calcareous shales and some beds of blue limestone. On the eastern side of Walden ridge it is 300 feet thick, and consists of calcareous shales with some beds of sandstone. Still further east, in White Oak mountain, the formation attains a thickness of 1,000 feet, of which the lower 800 are made up of hard brown sandstone interbedded with sandy shale. The upper portion consists of sandy shale with a few calcareous beds. The formation is named from Rockwood, Tennessee. It is of great practical importance on account of the beds of red fossil iron ore which it usually contains. These are described under the head Mineral Resources.

DEVONIAN ROCKS.

Chattanooga black shale.—Overlying the Rockwood formation is a thin stratum of shale which appears to represent the whole of the deposition which took place in this region during the Devonian period. Typical exposures of this shale appear in the north end of Cameron hill within the city limits of Chattanooga, from which locality it takes its name.

The Chattanooga black shale has a remarkably uniform character wherever seen within the limits of the atlas sheet, and for a long distance on either side north and south. It varies in thickness from 10 to 25 feet. The upper portion of the shale, three or four feet thick, is usually dark gray in color and often carries a layer of round concretions about an inch in diameter. The remainder of the formation is jet black, from an abundance of carbonaceous matter, and when freshly broken it emits a strong odor like petroleum.

This shale, on account of its distinctive and striking appearance, has attracted much attention from miners, and has been prospected in many places for coal and various ores, especially silver and copper. Such exploitation, however, has always been attended by failure, since the shale contains nothing of present economic importance. Although it contains a large proportion of carbonaceous matter which burns when it is placed in a hot fire, the amount is not sufficient to constitute a fuel, and no true coal is ever found associated with the shale. Small concretions of iron pyrites, which it often carries, have given rise to the commonly accepted but wholly erroneous belief that the shale contains valuable ores. The formation is of economic importance only as a starting point in prospecting for the red fossil iron ore which occurs below it and at a uniform distance, over considerable areas.

CARBONIFEROUS ROCKS.

Fort Payne chert.—This formation consists of from 50 to 200 feet of very siliceous limestone. At the base, resting on the Chattanooga black shale, are usually heavy beds of chert with only a small amount of limestone or greenish calcareous shale. In the western part of the sheet the line increases toward the top of the formation and gradually replacing the chert it passes without an abrupt transition into the Bangor limestone above. It is there about 200 feet thick. In White Oak mountain and eastward the lower part of the formation is composed of heavy beds of chert, while the upper part contains coarse cherty sandstones which become porous by the solution of the calcareous matter they originally contained. The chert of this formation is readily distinguished from that of the Knox dolomite by the great number of fossils which it contains. It is often made up of a mass of crinoid stems imbedded in a siliceous cement; on weathering, the cement remains a porous chert filled with the fossil impressions. In some cases the fossils alone are silicified so that they remain in the soil after the solution of the calcareous cement. The formation occurs in a narrow strip on the eastern side of the Sequatchie valley, usually forming, with the Rockwood shale, a narrow ridge parallel to the mountain escarpments. Along the eastern base of Walden ridge the formation occupies somewhat larger areas though it is not entirely continuous across the sheet. It forms the greater part of Cameron hill in Chattanooga and the gentle eastward slopes of White Oak mountain. The formation name is taken from Fort Payne, Alabama.

Floyd shale.—As before stated, the chert, on the western portion of the sheet, passes upward directly into the Bangor limestone, but east of White Oak mountain another formation, the Floyd shale, comes in between them. This consists of from 600 to 850 feet of variable sediments, for the most part carbonaceous shales, containing local beds of fine grained, flaggy sandstone, and also some beds of blue limestone with nodules of chert. These calcareous portions are highly fossiliferous, though the black shales are generally quite barren of organic remains.

Bangor limestone.—The Bangor limestone is from 800 to 1,000 feet thick in the Sequatchie valley and on the eastern side of Walden ridge, where it forms the lower portion of the mountain slopes. East of White Oak mountain it is only 600 feet thick, resting on the Floyd shale, and only a single small area has escaped erosion, though it doubtless formed a continuous sheet over the whole of this region, and originally may have extended some distance farther eastward. The limestone shows with unmistakable clearness the mode of its formation. It is in many cases composed almost entirely of fragments of crinoids together with the calcareous coverings of other sea animals which died and left their remains on the sea bottom.

It is probable that the lower portion of the Bangor limestone on the western part of the sheet and the Floyd shale on the eastern part were deposited at the same time, the former in a comparatively deep sea and the latter near the shore where the supply of mud and sand was abundant. Although they may be of the same age, the rocks differ so widely in character that they are given distinct formation names. The name of the limestone is taken from Bangor, Alabama, and that of the shale from Floyd county, Georgia.

The presence of the Floyd shale on the eastern and its absence from the western portion of the sheet, together with the changes already noted in the lithologic character of the Rockwood and Chickamauga, indicate that during their deposition the land, from which the sediments were derived, was toward the southeast while the deep sea was toward the northwest.

Lookout sandstone.—At the close of the period occupied by the deposition of the Bangor limestone there was an uplift of the sea bottom, so that the water became shallow over a wide area while an abundant supply of mud and sand was washed in from the adjoining land. These conditions were unfavorable for the animals whose remains are so abundant in the preceding formation, and instead of limestone a great mass of shale and sandstone was deposited. The surface also stood above sea level at various times, long enough at least for the growth of the luxuriant vegetation which formed the coal beds.

The Lookout sandstone includes 450 to 550 feet of conglomerate, thin bedded sandstone, sand and clay shales, and coal. Its upper limit is at the top of a heavy bed of conglomerate or coarse sandstone from 25 to 75 feet in thickness, which forms the principal cliff about the edge of Lookout mountain, south of Chattanooga and in the escarpments of Walden ridge and the Cumberland plateau. In the eastern part of the sheet the formation occupies but a single small area, capping Grindstone mountain, although it is *probable* that, like the other carboniferous formations already described, it once extended across the intervening region in a sheet continuous with that upon Lookout mountain.

Walden sandstone.—The Walden sandstone includes all the rocks lying above the Lookout conglomerate. Its sandstones, shales and coal beds were deposited under conditions very similar to those which prevailed during the deposition of the preceding formation. The conditions, however, changed less frequently and were somewhat more favorable for the accumulation of coal. What the original thickness of the Walden sandstone may have been can not now be determined, but it is certain that much of the formation has been removed by erosion. It is confined to the western part of the sheet, forming the surface of Walden ridge, from which it is named, and of the Cumberland plateau. Its greatest thickness of from 600 to 700 feet occurs in the Cumberland plateau a few miles west of Sequatchie valley, though there may be as great a thickness in the eastern part of Walden ridge near the center of the sheet.

These two formations, the Lookout and Walden sandstones, constitute the productive coal measures. The position and thickness of the various beds of coal will be described under the head of Mineral Resources.

At the close of the Carboniferous period this region was elevated permanently above sea level, so that the constructive process of deposition was stopped and the destructive process of erosion was begun.

STRUCTURE.

Definition of terms.—As the materials forming the rocks of this region were deposited upon the sea bottom, they must originally have been in nearly horizontal layers. At present, however, the beds are not usually horizontal, but are inclined to the surface at various angles. This is the result of compression in a northwest and southeast direction, by which they have been bent into a series of arches and troughs. In describing these folded strata the term *syncline* is applied to the downward bending troughs and *anticline* to the upward bending arches. A synclinal axis is a line running lengthwise of 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. These axes may be horizontal or inclined. Their departure from the horizontal is called the pitch of the axis and is usually but a few degrees. In addition to the folding, and as a result of the continued action of the same forces which produced it, the strata along certain lines have been fractured, and the rocks have been thrust in different directions on opposite sides of the fracture: this is termed a *fault.*

Structure sections.—The three 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 strip. The vertical and horizontal scales are the same, so that the elevations represented in the profile are not exaggerated, but show the actual form and slope of the land. These sections represent the structure, as it is inferred from the position of the strata observed at the surface. On the scale of the map they can not represent the minute details of structure; 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.

Relation of topography to structure.—The most prominent structural as well as topographic feature upon the sheet is Walden ridge. It will be seen from the sections that the nearly horizontal strata which underlie this plateau dip gently away from the edges toward the middle, forming thus a broad shallow trough; this is a typical *synclinal mountain.* In Sequatchie valley the strata are more steeply inclined and dip away from the middle toward the sides; this is a typical *anticlinal valley.* East of Walden ridge, in the Tennessee valley, also, a general arching of the strata is observed, though with less regularity than in the anticline of Sequatchie valley. In White Oak mountain the strata form a deep and narrow syncline, though it is the western edge of the trough which makes the mountain through the greater part of its length.

Thus there is an intimate connection between the structure and the present topography. The surface has been fashioned by the streams which flow upon it, and the action of the streams has been controlled by the position of the hard and soft layers of rock. The valleys in general are upon anticlinal arches, and the mountains are formed by synclinal troughs. This result has been brought about by the more rapid erosion of the hard beds at the tops of the arches than in the bottoms of the troughs. The streams must originally have flowed in the synclines, but they have gradually transferred their channels to the axes of the anticlines and the original relation of high and low land has been reversed.

Folds and faults.—The Sequatchie valley anticline is the westernmost of those remarkable parallel folds which characterize the Appalachian region. West of this the strata are nearly horizontal though broad undulations can be detected by careful measurements. On the eastern side of the valley the strata dip beneath Walden ridge at angles varying from 15° to 20°; on the western side of the valley they are much steeper, being generally vertical or overturned. Along the western side of the valley there is a fault, and this, as explained above, is the further result of the action of those compressing forces which produced the fold. In consequence of this fault some of the formations which occur on the eastern side of the valley and which should occur on the western side are concealed by other formations thrust across their broken edges. Thus the Chickamauga limestone and Knox dolomite come into contact with the Bangor limestone, while intervening formations, the Fort Payne chert, Chattanooga black shale and Rockwood shale, are concealed. This is the reason that the red fossil iron ore of the Rockwood formation is not found along the western side of the valley.

The axis of the Walden ridge syncline is considerably east of the central line of the plateau. Thus there is a slight easterly dip from the western edge almost entirely across to the eastern escarpment. This fact has great practical importance since it insures easy drainage of coal mines and hence economical mining.

Between Chattanooga and the edge of Walden ridge there are three small folds shown in section C C of the structure section sheet. Of these the western extends southward, forming Lookout valley upon the Ringgold sheet, and northward to Falling Waters creek, but almost entirely disappears before reaching the line of section B B. This folded belt is cut off on the eastern side by a fault which passes through the east side of Cameron hill in Chattanooga and extends northward a short distance from the edge of the plateau to about Retro. Beyond this a narrow syncline extends to the edge of the sheet, forming Lone mountain and the ridge east of Coulterville. This narrow syncline is separated from Walden ridge by a faulted anticline which forms the valley of Sale creek. Section A A shows the manner in which the strata of Lone mountain have been thrust over upon the eastern edge of the Walden ridge syncline.

The Tennessee valley is developed for the most part upon the Knox dolomite, which lies in broad and rather gentle folds. Two sharp anticlines bring the underlying Cambrian rocks to the surface in long narrow strips of nearly vertical strata, while two strips of nearly horizontal Chickamauga limestone occupy portions of the synclines. The one between Chattanooga and Missionary ridge is bounded on the east by a fault, on which, as shown in section C C, the dolomite forming the ridge has been thrust across the overturned edge of the syncline.

Crossing the southeast corner of the sheet is a fault which brings the oldest rocks of the region against the youngest. The displacement along this line is much greater than in the faults further west, being fully 12,000 feet. This motion has not usually taken place upon a single plane, but is distributed among several fault planes within a narrow belt in which the rocks are greatly contorted and crushed.

MINERAL RESOURCES.

The mineral resources of the Chattanooga sheet consist of *coal, iron ore, limestone, building* and *road stone,* and *brick* and *tile clay.*

Coal.—The productive coal-bearing formations, consisting of the Lookout and Walden sandstones, occupy the surface of the Cumberland plateau and Walden ridge. They have an area within the atlas sheet of about 400 square miles, and contain from one to three beds of workable coal.

The accompanying vertical sections on the columnar section sheet show the position and thickness of the various coal beds. The sections are not generalized, but each represents the actual measurements made at a single locality. It will be seen that the beds vary considerably in number, position and thickness from one part of the field to another. The datum from which their position is measured up or down in the section is the top of the conglomerate. It is not always possible to determine this point exactly, so that some uncertainty is thus introduced into the correlation of coal beds in the different parts of the field.

The vertical distance from the top of the Bangor limestone to the top of the conglomerate, that is, the thickness of the Lookout sandstone, varies between 450 and 550 feet. Wherever the rocks are well exposed, at least three beds of coal are seen between these limits and in some places as many as six. One bed immediately below the conglomerate, or heavy sandstone, is fairly constant in position though it varies considerably in thickness. From a few inches at the northern edge of the sheet it increases southward to three feet or more, and is worked at the Daisy, Ætna and McNab mines. Below this the Dade coal, which at the southern edge of the sheet has a thickness of about three feet and is worked principally at the Dade mines in Georgia, may be represented by one of the thinner beds seen in the sections further north. Of the remaining lower beds only one other is worked, namely, the lowest in the series, which is about 320 feet below the top of the conglomerate. It varies in thickness within distances of a few hundred feet from a mere streak to three or four feet.

In the first 125 feet above the conglomerate is a group of from two to four coal beds, at least one of which is generally workable. Exact correlations of the beds within this group have not been made, and it is quite probable that a single bed in one part of the field may be separated by shale and sandstone layers into two or three in another part. This is the horizon at which occurs the coal so extensively worked at Tracy city and other points west of Sequatchie valley. A bed occurs in several of the sections at a quite uniform distance of from 250 to 275 feet above the conglomerate and is worked at the Daisy and Ætna mines. Finally the Richland coal, 630 feet above the conglomerate, is worked near Dayton, just off the north edge of the sheet. The rocks containing the Richland coal have been quite generally eroded, so that the workable area of the bed is not so great as that of beds lower in the series. This coal is found only in the deeper parts of the Walden ridge syncline and in isolated hills rising above the main floor of conglomerate. The same limitation in area is applicable to the next lower workable bed, the Ætna coal, though in a lesser degree.

In conclusion, without attempting strict correlation of individual beds, the coals of the Walden formation may be grouped at three horizons, at any one of which workable coal is likely to be found. The first is within 120 feet above the conglomerate and contains the beds worked over the widest area. The second horizon is from 250 to 275 feet above the conglomerate and contains the beds worked at Ætna and Daisy. The third is about 630 feet above the conglomerate and contains the Richland coal, but is restricted in area on account of erosion.

All the coals of this region are bituminous, and all so far tested are well suited for coking. A good quality of coke is made at Daisy, Rathburn and Dayton.

Iron ore.—Two varieties of iron ore, which differ widely in appearance and in modes of occurrence, are found on the Chattanooga sheet. They are *hematite,* or *red fossil ore,* and *limonite,* or *brown ore.*

Hematite.—The red fossil ore is associated with rocks of the Rockwood formation and is very similar to the ore occurring at the same horizon in such widely separated localities as Wisconsin, New York and Alabama. It is a regularly stratified bed, retaining a constant thickness and definite relation to other strata of the formation over considerable areas. Like any other rock stratum, however, it is not absolutely constant, so that, while the map indicates within narrow limits the areas within which the ore may occur, careful examination is required to determine whether at any particular locality its quantity and quality are such as to make it commercially valuable.

The proportion of iron in the ore usually decreases with distance from the surface, and at considerable depths it becomes simply a more or less ferruginous limestone. The decrease downward in the proportion of iron is due to the fact that near the surface the lime has been largely removed by percolating surface waters, leaving behind the insoluble iron oxide as the soft ore. The presence of lime in the ore is not objectionable, except as it renders mining more difficult, for it removes the necessity of adding limestone as a flux in the furnace. The soft ore is very easy to mine, and considerable quantities are frequently obtained by trenching along the outcrop of the bed even when it is not of sufficient thickness to make deep mining now profitable. This is the character of all the ore workings on this sheet at present.

The outcrop of the Rockwood formation occupies a narrow strip along the eastern side of the Sequatchie valley, the strata dipping at low angles, 8° to 15°, toward the east under Walden ridge. The corresponding outcrop of the formation on the west side of the Sequatchie valley is concealed by a fault, as already explained. Although the ore is not worked along this strip within the limits of this sheet, it is probably present throughout its whole extent in workable quantity. The extensive Inman mines are just off the western edge of the sheet on the same belt. The ore bed is separated from the overlying Chattanooga black shale by about 60 feet of bluish calcareous shale. It has a thickness of $5\frac{1}{2}$ feet at Inman.

On the east side of Walden ridge is a strip of Rockwood continuous from the north edge about halfway across the sheet, below which is a break of a few miles caused by faulting. Beyond this break the belt continues to the edge of the sheet. This southern portion is formed by two narrow parallel bands which are the outcrops of the formation on opposite sides of a narrow anticline. The ore in this belt east of Walden ridge has been extensively mined both north and south of the Chattanooga sheet, but within its limits only an inconsiderable amount of surface mining has been done.

In White Oak mountain the greater part of the Rockwood formation consists of hard, brown sandstones, and only the upper portion contains the calcareous shales which invariably accompany the iron ore. On the same belt some miles toward the northeast the ore forms a heavy bed and is extensively mined, but it decreases rapidly toward the south, and probably does not occur in White Oak mountain in workable quantities beyond the southern edge of the Chattanooga sheet. Considerable ore has been taken from the surface workings on both sides of the East Tennessee railroad.

Limonite.—The limonite ore does not occur in this region as a regularly stratified bed, but in irregular surface deposits. Hence the limits within which it may occur can not be indicated with the same certainty as in the case of red ore. Although iron oxide is very widely distributed throughout the rocks and soil, it is only when it becomes segregated in large quantities and in a comparatively pure condition that it is commercially valuable as an ore. The agency by which the segregation is effected is the percolating surface water, which contains small quantities of weak acids derived from the atmosphere and decaying vegetation. These acids dissolve the iron disseminated through the rocks. When the solution is exposed to air either at the surface or in cavities under ground the iron becomes insoluble and is precipitated as the slimy yellowish substance generally seen about mineral springs. This substance gradually hardens and, where it collects in sufficient quantity, forms a bed of limonite or brown iron ore.

The only considerable deposits of brown ore known to occur within the limits of the sheet are along the eastern side of the Sequatchie valley. The conditions were favorable for its accumulation near the contact of the Fort Payne chert and the Bangor limestone. Heavy deposits occur in this position at Kitner gap but they have never been worked.

Limestone.—The supply of limestone on the Chattanooga sheet, suitable for blast-furnace flux and for lime, is abundant and convenient of access. The Bangor limestone is most largely used on account of its freedom from impurities and its close proximity to the furnaces or to lines of transportation. It generally contains an appreciable amount of magnesium carbonate, which sometimes reaches as much as 35 per cent. The magnesium limestone of the Knox dolomite is also somewhat used as a flux, especially in the basic steel process, and is burned for lime very extensively at Graysville, just off the southern edge of the sheet.

Building stone.—Stone adapted to architectural uses occurs in nearly every formation on the sheet. That which has been most largely used is in the lower part of the Chickamauga limestone. At Hickson, on the Cincinnati Southern railroad, and near Chickamauga, on the Western and Atlantic railroad, are quarries of blue or dove-colored earthy limestone. The stone is evenly bedded, quite easily worked, and makes a fine building material. Sandstones especially well adapted for foundations occur in the Rockwood formation of White Oak mountain and in the Lookout and Walden sandstones. These have as yet been quarried only for local use and in a small way.

Road material.—The hard blue Bangor and Chickamauga limestones furnish an abundant supply of macadam material requiring but little transportation. The residual chert or flint of the Fort Payne and Knox dolomite formations is an ideal road material and has been used very largely in surfacing the macadam roads in the vicinity of Chattanooga.

Clays.—The residual deposits resulting from the solution of the Chickamauga limestone are red or blue clays, and are generally well adapted for making brick. Some portions of the Bangor limestone leave a residual clay suitable for brickmaking, and also for drain tile. Several beds of fire clay which are associated with the coal probably contain material well adapted for making fire brick, but they are as yet wholly undeveloped.

SOILS.

Derivation and distribution.—Throughout the region covered by the Chattanooga atlas sheet there is a very close relation between the character of the soils and that of the underlying geological formations. Except in limited areas along the larger streams and on the steepest slopes, the soils are derived directly from the decay and disintegration of the rocks on which they lie. All sedimentary rocks such as occur in this region are changed by surface waters more or less rapidly, depending on the character of the cement which holds their particles together. Siliceous cement is nearly insoluble and rocks in which it is present, such as quartzite and some sandstones, are extremely durable and produce but a scanty soil. Calcareous cement, on the other hand, is readily dissolved by water containing carbonic acid, and the particles which it held together in the rock crumble down and form a deep soil. If the calcareous cement makes up but a small part of the rock it is often leached out far below the surface, and the rock retains its form but becomes soft and porous; but if, as in limestone, the calcareous material forms the greater part of the rock, the insoluble portions collect on the surface as a mantle of soil varying in thickness with the character of the limestone, generally quite thin where the latter is pure, but often very thick where it contains much insoluble matter.

When derived in this way from the disintegration of the underlying rock, soils are called sedentary. If the rock is a sandstone or sandy shale the soil is sandy, and if it is a clay shale or limestone the soil is clay. As there are abrupt changes in the character of the rocks, sandstones and shales alternating with limestones, so there are abrupt transitions in the character of the soil, and soils differing widely in composition and agricultural qualities often occur side by side. As the attitude of the strata determines the breadth of outcrop of each formation in different places, it also determines the area of the particular soil derived from each. Where the strata are nearly horizontal at the surface, as the Chickamauga limestone at Chattanooga, the corresponding soil covers a broad area, but where they outcrop in a nearly vertical position, as the same formation at Dayton, its resulting soil occupies only a narrow strip.

Knowing the character of the soils derived from the various geological formations, their distribution may be approximately determined from the map showing the areal geology, which thus serves also as a soil map. The only considerable areas in which the boundaries between different varieties of soil do not coincide with the formation boundaries are in the river bottoms and upon the steep slopes where soils derived from rocks higher up the slope have washed down and covered or mingled with the soil derived from those below. The latter are called overplaced soils, and a special map would be required to show their distribution.

Classification.—The soils of this region may conveniently be classed as (1) Sandy soils; derived from the Walden and Lookout sandstones, some parts of the Floyd shale, the Rockwood formation of White Oak mountain and the Rome sandstone. (2) Clay soils; derived from the Bangor and Chickamauga limestones, the Rockwood west of the Tennessee river, the upper part of the Floyd and the Connasauga and Apison shales. (3) Cherty soils; derived from the Fort Payne chert and the Knox dolomite. (4) Alluvial soils; deposited by the larger streams upon their flood plains.

Sandy soils.—Cumberland and Walden plateaus are formed by sandstones and sandy shales, and their soil is a sandy loam. At the surface it is gray, while the subsoil is generally light yellow, but varies to deep red. In some places it consists largely of sand, but more often contains sufficient clay to give the subsoil considerable coherence, so that a cut bank will remain vertical for some years. The depth of soil on the plateau varies from a few inches to a dozen or more feet, depending chiefly on proximity to streams and the consequent activity of erosion. A large part of the plateau retains its original forest growth, chiefly of oak, chestnut and hickory, while pines clothe the steep sides of the stream channels. The practice of burning off the leaves each fall prevents the accumulation of vegetable mold and has delayed a just appreciation of the agricultural possibilities of this region. The Rockwood formation of White Oak mountain is made up of sandstones and sandy shales, and its outcrops have sandy soils. This is less important than that of the plateaus, since the strata are steeply inclined so that they produce ridges, and some beds of hard sandstone break up into blocks which cover most of the surface. Some calcareous sandstones near the top of the formation produce the small areas of deep fertile soil which are found at intervals along the summit of White Oak mountain. The strip of Rome sandstone east of White Oak mountain yields sandy soil, while the surface is rocky and ridgy so as to be scarcely tillable.

Since the sandstones of this region occupy the highest land, the overplaced soils, or those washed down to lower levels, are mostly sandy. They are especially abundant at the foot of the escarpment surrounding the plateaus, where the Bangor limestone and its clay soil are often wholly concealed. The delta deposits formed by streams emerging from gorges cut in the plateaus also give considerable areas of sandy soil overlying rocks which would themselves produce clay or cherty soils.

Clay soils.—The most productive of these are derived from the Bangor and Chickamauga limestones, and their distribution coincides with the outcrops of those formations as shown on the geologic map. They sometimes have a deep red color, but where the mantle of residual material covering the rock is thin it is often dark bluish gray. This is its character west of Missionary ridge and of White Oak mountain where the largest areas of the limestone occur. The rocks generally weather more rapidly where they have a steep dip than where they are nearly horizontal. Hence the soil is deeper and more highly colored on the narrow belt of limestone east of White Oak mountain than on the broader belts of the same rocks above mentioned. The clay soils derived from the Cambrian shales are somewhat less productive. The Apison, Connasauga and Rome shales make stiff bluish gray soils which are usually thinner than those covering the limestones, the shaly structure often appearing a few inches below the surface.

All of these clay soils are well fitted to retain fertilizers, and hence with proper treatment may be brought to a high state of productiveness.

Cherty soils.—More than half of the area east of Walden ridge is underlain by the Knox dolomite. The soil derived from this formation consists of clay in which chert is imbedded. The proportion of chert to clay is variable; in some places only occasional fragments occur, while in others the residual material is made up almost wholly of chert. Where the clay predominates the soil is deep red, but becomes lighter with the increase in amount of chert, and in extreme cases is light gray or white. Even when the proportion of chert is very large this is a strong productive soil, especially adapted to fruit-raising. The soil derived from Fort Payne chert is similar to that from the Knox dolomite, but the areas of the Fort Payne are much smaller and usually on steep slopes, so that its soil is relatively unimportant.

Alluvial soils.—Excepting the gorges of the Tennessee through Walden ridge, the streams of this region flow in broad valleys but they are rapidly cutting narrow channels below the general level of these valleys, so that these flood plains, the alluvium covered bottom lands, are nowhere extensive. The largest flood plains are along the Tennessee river northward from the entrance to its gorge. A strip of bottom land from a quarter of a mile to half a mile wide usually occurs along one side of the river with a bluff upon the opposite side. The soil of these bottoms is a rich sandy loam, containing a considerable proportion of fine mica scales derived from the crystalline rocks far to the east. Some areas of alluvial soil also flank the smaller streams, especially South Chickamauga creek and Sequatchie river, constituting the most continuously productive land of this region.

C. WILLARD HAYES,
Geologist.

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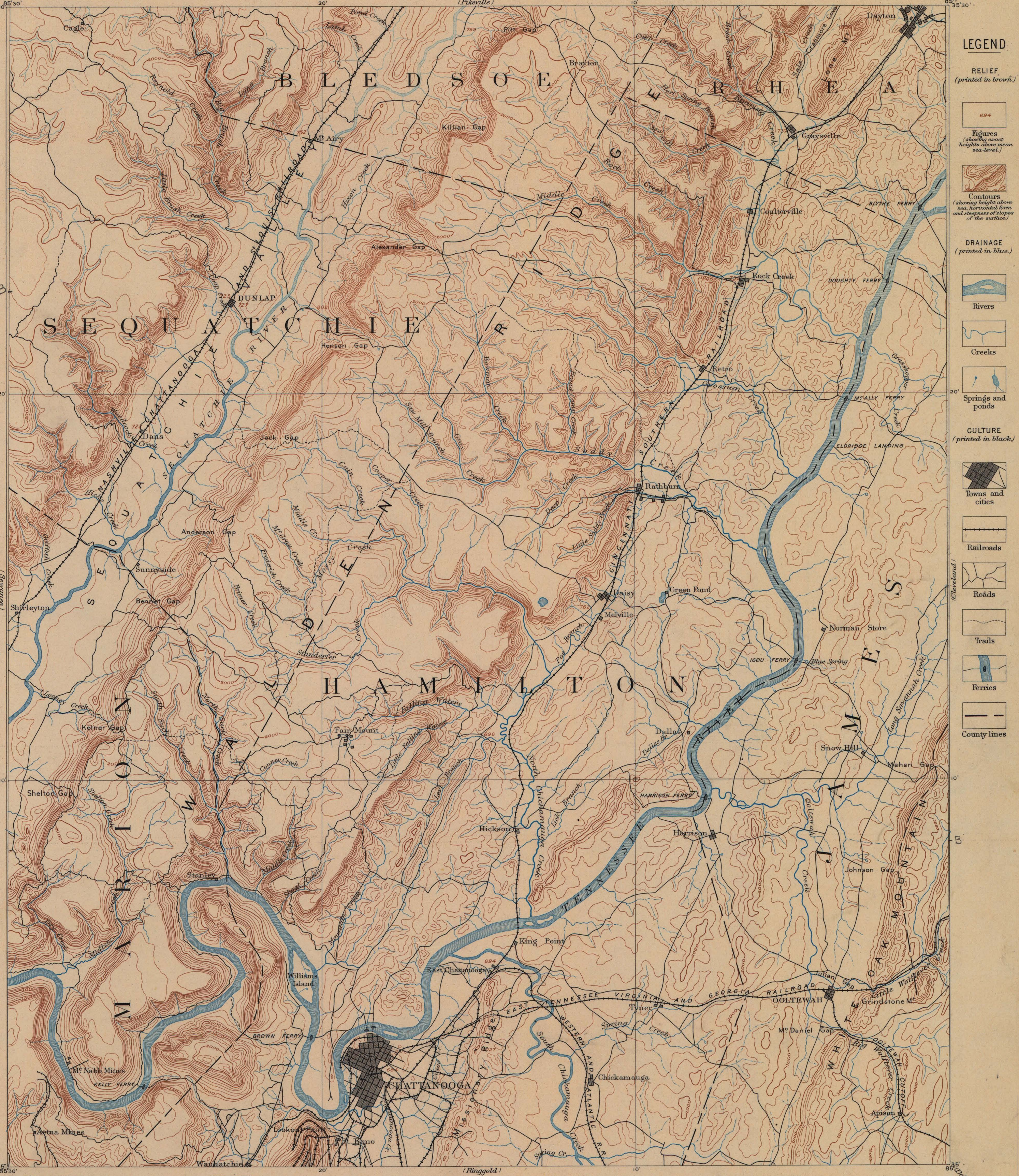
TOPOGRAPHY

TENNESSEE
CHATTANOOGA SHEET



Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in charge.
Triangulation by S.S. Gannett.
Topography by E.M. Pearson, L. Nell and M. Hackett.
Surveyed in 1884-5-6.

Edition of July 1893.

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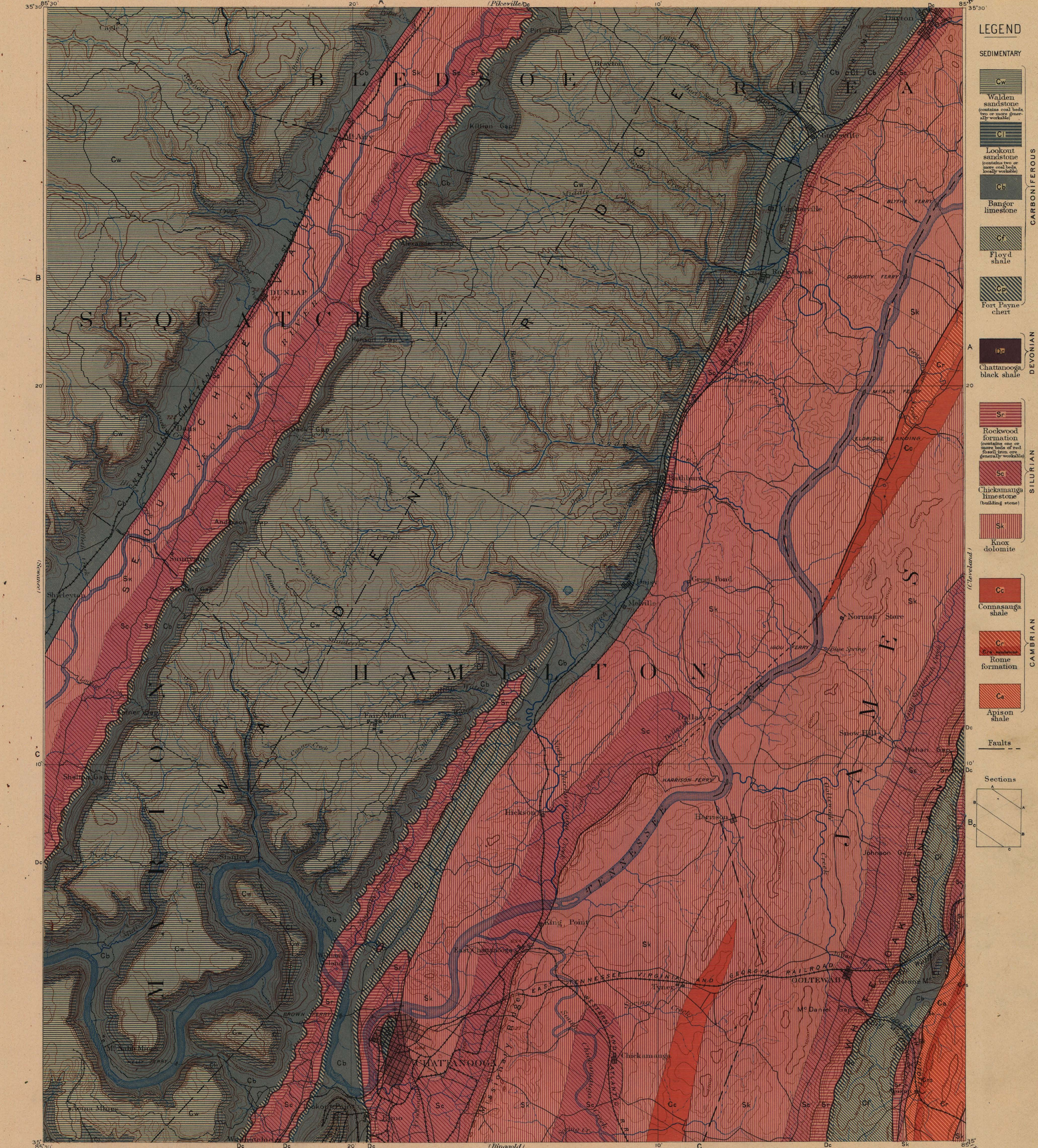
AREAL GEOLOGY

TENNESSEE
CHATTANOOGA SHEET



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Hackett | Pearson | Nell

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

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet

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ECONOMIC GEOLOGY

TENNESSEE
CHATTANOOGA SHEET

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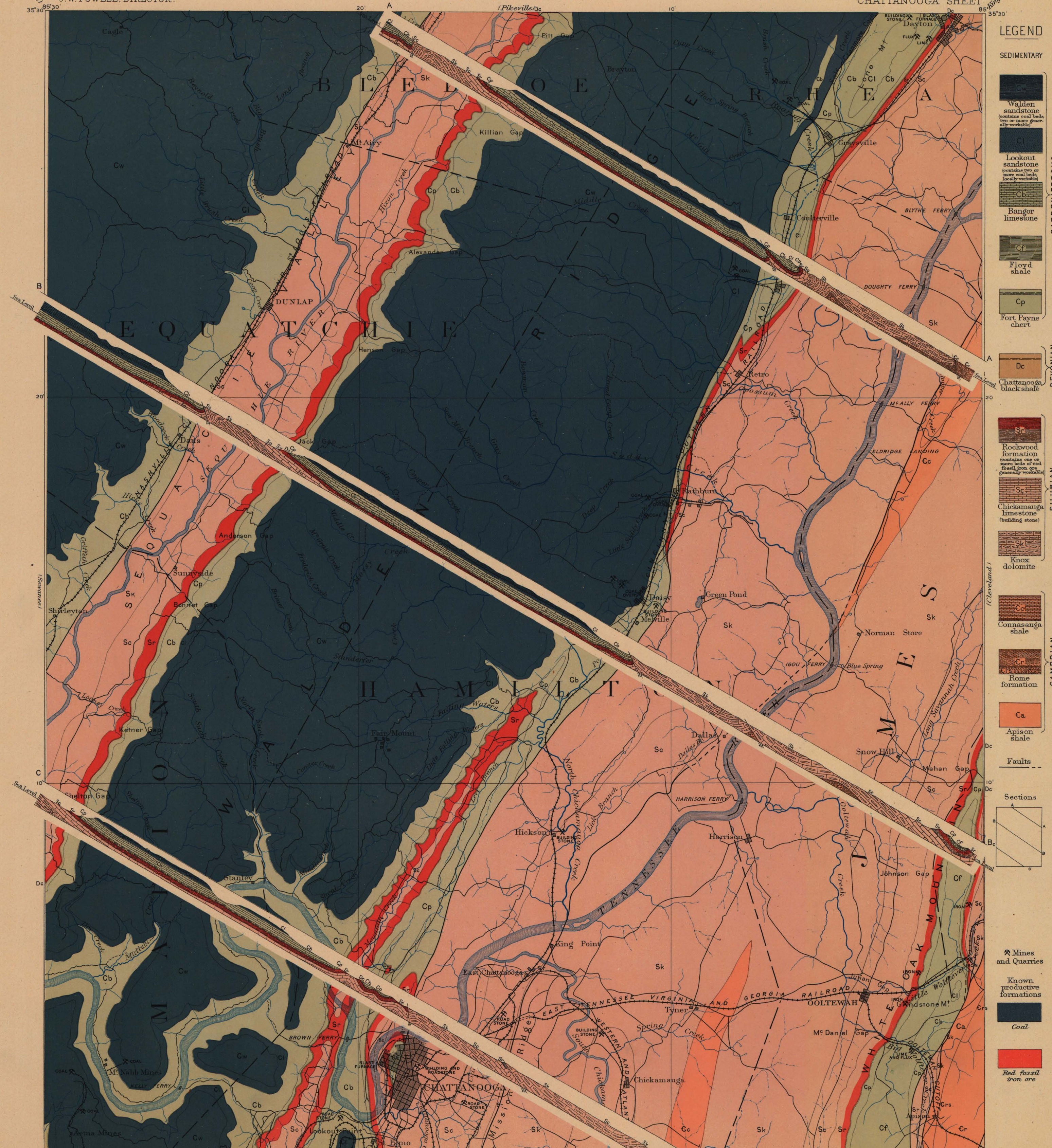
STRUCTURE SECTIONS

TENNESSEE
CHATTANOOGA SHEET



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COLUMNAR SECTIONS

GENERALIZED SECTION WEST OF TENNESSEE RIVER AND SOUTH CHICKAMAUGA CREEK.

SCALE 1000 FEET = 1 INCH.

Period.	Formation Name.	Formation Symbols.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	Walden sandstone.	Cw		1200 +	Coarse sandstone and sandy shale with beds of coal and fire clay.	Flat topped, plateau-like mountains. Gray, yellow or red sandy loam.
	Lookout sandstone.	Cl		400— —500	Conglomerate. Sandstone and sandy shale with beds of coal.	Cliffs; abrupt plateau escarpments. Scanty soil, rocky and sandy.
	Bangor limestone.	Cb		800— —850	Shaly limestone. Massive, blue, crinoidal limestone. Shaly limestone.	Steep mountain slopes and valleys. Black clay soil with more or less sand from rocks above. Narrow valleys. Red clay soil with sand and chert from adjacent slopes.
	Fort Payne chert.	Cp		60—150	Heavy bedded chert	Sharp narrow ridges parallel to plateau escarpments. Sandy clay soil with abundant fragments of chert.
DEV.	Chattanooga black shale.	Dc		10—25	Carbonaceous shale	
SILURIAN	Rockwood formation.	Sr		200—320	Greenish clay shale with beds of fossil iron ore.	
	Chickamauga limestone.	Sc		1050— —1300	Blue flaggy limestone.	Level valleys; shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestone is nearly horizontal, and deeper red clay where they are steeply inclined.
SILURIAN — ? — CAMBRIAN	Knox dolomite.	Sk		3300— —2500	Magnesian limestone; white, gray, or light blue; generally granular and massively bedded; containing nodules and layers of chert.	Low ridges and irregular rounded hills; deep residual deposits of red clay and chert. Red clay soil with a few fragments of chert, grading into white or gray soil, composed almost entirely of chert.

GENERALIZED SECTION EAST OF TENNESSEE RIVER AND SOUTH CHICKAMAUGA CREEK.

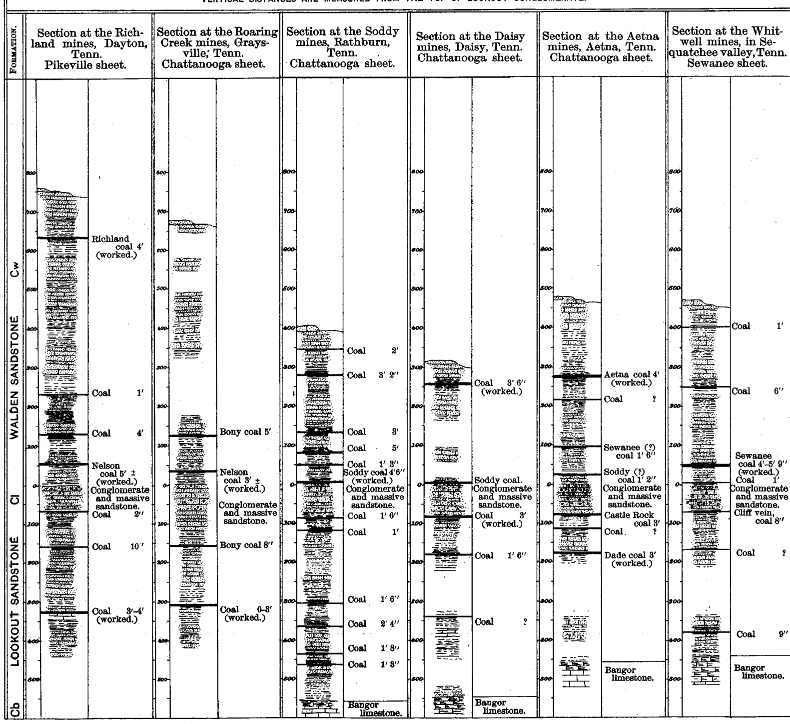
SCALE 1000 FEET = 1 INCH.

Period.	Formation Name.	Formation Symbols.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	Lookout sandstone.	Cl		75 +	Sandstone and shale.	Level top of Grindstone mountain.
	Bangor limestone.	Cb		450— —530	Massive, blue, crinoidal limestone.	Steep mountain slopes. Red clay soil with more or less sand from rocks above.
	Floyd shale.	Cf		600— —660	Carbonaceous shale with beds of blue crinoidal limestone.	Valleys with low rounded hills. Sandy clay soil.
	Fort Payne chert	Cp		50—75	Calcareous sandstone and beds of chert.	Knobs parallel with Rockwood ridges; sandy soil with fragments of chert.
DEV.	Chattanooga black shale.	Dc		15—20	Carbonaceous shale.	
SILURIAN	Rockwood formation.	Sr		950— 1000—	Greenish sandy shale with beds of red fossil iron ore. Brown and purple sandstone and sandy shale.	Prominent ridges with uniform elevation and slope. Rocky, sandy soil.
	Chickamauga limestone.	Sc		2000— —2200	Earthy limestone; mottled, purple and gray. Blue flaggy limestone.	Level valleys; shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestone beds have low dips and deeper red clay where they are steeply inclined.
SILURIAN — ? — CAMBRIAN	Knox dolomite.	Sk		3300— —3500	Magnesian limestone; white, gray or light blue; generally granular and massively bedded; containing nodules and layers of chert.	Low ridges and irregular rounded hills; deep residual deposits of red clay and chert. Red clay soil with a few fragments of chert, grading into white or gray soil, composed almost entirely of chert.
CAMBRIAN	Connasauga shale.	Cc		1500— —1700	Blue seamy limestone interbedded with clay shale. Olive green or brown clay shale. Thin beds of blue limestone, generally oolitic, interbedded with clay shale.	Level or rolling valleys. Stiff yellow or bluish gray clay soil.
	Rome formation.	Cr		3000— —3500	Greenish or brown shale with thin siliceous layers. Purple, brown and white sandstone interbedded with sandy shale.	Valleys with low ridges. Thin sandy clay soil. Comby ridges. Rocky, sandy soil.
	[Sandstone in the Rome formation.]	Crs		[500— —800]		
	Apison shale.	Ca		1000 +	Sandy or clay shale in brightly colored alternating bands.	Narrow rolling valleys. Stiff clay soil.

VERTICAL SECTIONS; SHOWING THE POSITION AND THICKNESS OF COAL BEDS.

SCALE 250 FEET = 1 INCH.

VERTICAL DISTANCES ARE MEASURED FROM THE TOP OF LOOKOUT CONGLOMERATE.



NAMES OF FORMATIONS.

Period	Symbol	Names and symbols used in this sheet.	Smith: Geology of the valley region adjacent to the Cahaba coal field, Alabama, 1890.	Smith: Outline of the Geology of Alabama, 1878.	Safford: Geology of Tennessee, 1869.
Carboniferous	Cw Cl	Walden sandstone. Lookout sandstone.	Coal measures.	Upper coal measures. Lower coal measures. Millstone grit; conglom.	Coal measures.
	Cb Cf Cp	Bangor limestone. Floyd shale. Fort Payne chert.	Bangor limestone. Oxmoor shale. Fort Payne chert.	Upper sub-carboniferous or mountain limestone. Lower subcarboniferous.	Mountain limestone. Siliceous group.
Dev.	Dc	Chattanooga black shale.	Black shale.	Genesee or black shale.	Black shale.
Silurian	Sr	Rockwood formation.	Red mountain or Clinton.	Clinton or Dyestone.	Dyestone group: White Oak mountain sandst.
	Sc Sk	Chickamauga limestone. Knox dolomite.	Trenton or Pelham limestone. Knox dolomite.	Trenton, Chazy or Maclurea. Quebec or Knox dolomite.	Trenton, Lebanon or Maclurea limestone. Knox dolomite.
Camb.	Cc Cr Crs Ca	Connasauga shale. Rome formation. Rome sandstone. Apison shale.	Choccolocco or Montevallo shales.	Knox shales. Calciferous or Knox s. s.	Knox shale. Knox sandstone.

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