DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

GEOLOGIC ATLAS

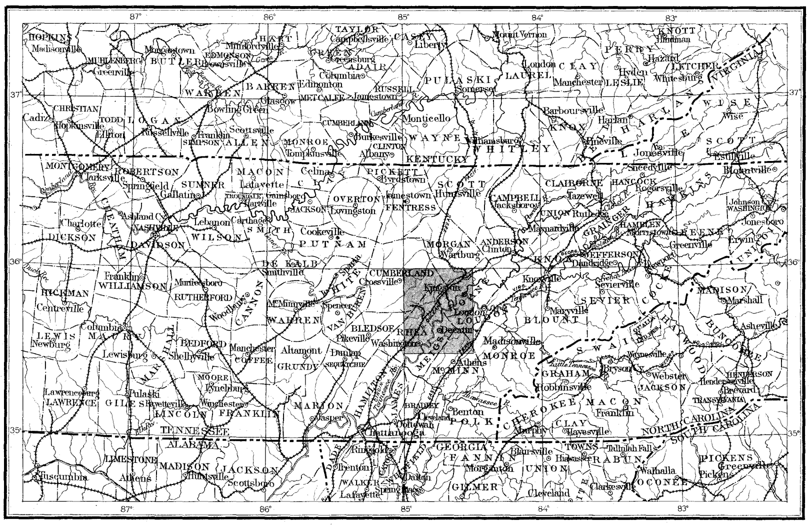
OF THE

UNITED STATES

KINGSTON FOLIO

TENNESSEE

INDEX MAP



SCALE: 40 MILES - 1 INCH

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FOLIO 4 | LIBRARY EDITION | KINGSTON

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1894

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:

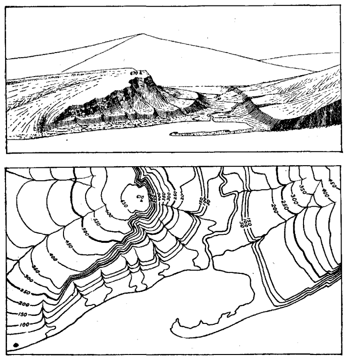

Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

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	Ꞓ	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:

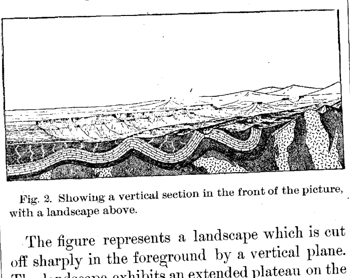

Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

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:

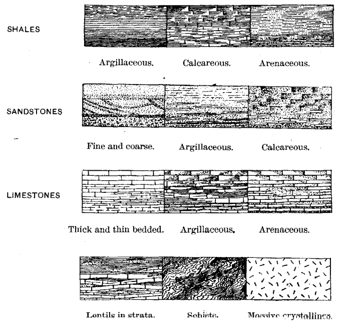

Fig. 3. Symbols used to represent different kinds of rocks.

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.

DESCRIPTION OF THE KINGSTON SHEET.

GEOGRAPHY.

General relations.—The Kingston atlas sheet is bounded by the parallels of latitude 35° 30′ and and 36°, and the meridians of longitude 84° 30′ and 85°. 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 28.1 miles from east to west, and it contains 968.7 square miles. The adjacent atlas sheets are Wartburg on the north, Loudon on the east, Cleveland on the south, and Pikeville on the west. The Kingston sheet lies wholly within the State of Tennessee and embraces portions of Cumberland, Morgan, Roane, Rhea, Loudon, Meigs, and McMinn counties.

In its geographical and geological relations this area forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west, and from central Alabama to southern New York. The region thus defined has a common history recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as that covered by a single atlas sheet; hence it is necessary to consider the individual sheet in its relations to the entire province.

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

The central division is the Appalachian valley. It is the best defined and most uniform. It coincides with the belt of folded rocks which in the southern part forms the Coosa valley of Georgia and Alabama and the great valley of East Tennessee. Throughout the central and southern portions the eastern side alone 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; while the western side is ribbed by a succession of narrow ridges without continuous, intermediate valleys. This division varies in width from 40 to 125 miles; it is sharply outlined on the southeast by the Appalachian mountains and on the northwest by the Cumberland plateau and the Alleghany mountains. Its rocks are almost wholly sedimentary and in large measure calcareous. The strata, which must originally have been nearly horizontal, now intersect the surface at various angles and in narrow belts. With the outcrop of different kinds of rock the elevation of the surface differs, so that sharp ridges and narrow valleys of great length follow the upturned edges of hard and soft beds. Owing to the large amount of calcareous rock brought up on the steep folds of this district its surface is more readily worn down by streams and is lower and less broken than the divisions on either side.

The eastern division of the province embraces the Appalachian mountains, a system made up of many minor ranges 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 mountains of Maryland and Virginia, the Great Smoky mountains of Tennessee and North Carolina, and the Cohutta mountains of Georgia, together with many other less important ranges.

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 which have solidified from a molten condition, such as granite and diabase.

The western division of the Appalachian province embraces the Cumberland plateau and the Alleghany mountains, also extending from New York to Alabama, and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the Mississippi river as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian valley by the Alleghany front and the Cumberland escarpment.

The rocks of this division are almost entirely of sedimentary origin and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely dissected, or elsewhere of a lowland. In the southern half of the province the surface of the plateau is sometimes extensive and perfectly flat, but it is oftener much divided by stream channels into large or small flat-topped hills. In West Virginia and portions of Pennsylvania the plateau is sharply cut by its streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion and the surface is now comparatively low and level, or rolling.

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

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

The Appalachian valley shows a uniform increase in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2,000 feet at the Tennessee-Virginia line and 2,600 or 2,700 feet at its culminating point, on the divide between the New and Tennessee rivers. From this it descends to 2,200 feet in the valley of New river, 1,000 to 1,500 feet in the James, from 500 to 1,000 feet on the Potomac, and to about the same throughout Pennsylvania. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2,000 feet.

The plateau division increases in altitude from 500 feet at the southern edge of the province to 1,500 in northern Alabama, 2,000 in central Tennessee, and 3,500 in southeastern Kentucky. It is between 3,000 and 4,000 feet in West Virginia and decreases to about 2,000 in Pennsylvania. From its greatest altitude along the eastern edge the plateau slopes gradually westward, although along its western edge it is generally separated from the interior lowlands by an abrupt escarpment.

Drainage of the Appalachian province.—The drainage of the province is in part eastward into the Atlantic, in part southward into the Gulf, and in part westward into the Mississippi.

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 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 breaks through the Appalachian mountains by 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. South of New river to northern Georgia the Great valley is drained by tributaries of the Tennessee river, which at Chattanooga turns from the apparently natural course and, entering a gorge through the plateau, runs westward to the Ohio. From Chattanooga southward the streams flow directly to the Gulf. There is abundant evidence that the divide between the Tennessee and Coosa basins is comparatively recent and that formerly the Tennessee river flowed directly south across the present divide and by the present course of the Coosa and Alabama rivers to the Gulf.

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 southward from the New river all except the eastern slope is drained westward by tributaries of the Tennessee or southward by tributaries of the Coosa.

Topography of the Kingston sheet.—The country embraced within the atlas sheet is about equally divided between the two western divisions of the Appalachian province and is marked by the two widely different types of surface which characterize those divisions. As indicated above, these differences are due jointly to the character of the underlying rocks and the geologic structure, or to the relation of the strata to the surface. The connection between these two factors and the resulting topographic features will be more fully explained later.

The northwestern half of the sheet lies in the Cumberland plateau. The general surface west of the Crab Orchard mountains is quite level and has an elevation between 1,800 and 1,900 feet above the sea. This plain is drained northeast into Emory river by Daddy creek and its branches, which flow in narrow, rocky channels from 100 to 300 feet below the plateau surface.

The Crab Orchard mountains consist of flat-topped ridges, or mesas, with very abrupt slopes on at least one side. They rise 800 to 1,200 feet above the general level of the plateau and lie parallel to its eastern edge, directly in line with the Sequatchie valley, which extends southwestward from the edge of the sheet. The relation between these mountains and the Sequatchie valley will be explained in describing the structure. Elevations about the head of the valley reach 3,000 feet, decreasing to about 2,500 at the northern edge of the sheet. The most peculiar topographic features of this region are the coves within the Crab Orchard range. The largest of these is Grassy cove, which is structurally the continuation of Sequatchie valley, but is separated from it by a ridge 900 feet or more above the cove. Its floor is almost perfectly level to the base of the surrounding abrupt mesa slopes, its area is about eight square miles, and its elevation is between 1,000 and 1,600 feet above sea level. Its stream flows northeast, and near the upper end of the cove disappears in a cave. This is the entrance to an underground channel, from which the stream, having doubled back on its overground course, emerges eight miles to the southwest, in the head of the Sequatchie valley.

There are several other coves similar to the one described, but much smaller, so that their streams do not attain any considerable volume before they sink. Little cove is a part of Grassy cove, being separated from it only by a low divide, through which the waters pass underground. The drainage of Crab Orchard cove is in three directions, partly by underground and partly by surface streams. The waters from the south find their way into Grassy cove beneath the intervening ridge; those of the central and northern parts flow westward into Daddy creek; while a small portion on the east is drained by the head of Berks creek.

The process by which these coves are formed is somewhat as follows. The rocks composing the surface of the Cumberland plateau and the higher portions of the Crab Orchard mountains are sandstone and conglomerate, while in the coves limestone is exposed. The sandstone is underlain by the limestone, and it once extended over the areas of the coves. Surface waters sinking down through the sandstone find underground channels, or form them by dissolving the limestone. By these they flow to some lower outlet. Wherever, in the process of erosion, the sandstone was removed—as it was over the coves—the surface of the limestone was rapidly lowered and a cove was formed, sometimes, though not always, surrounded by a sandstone-capped barrier, beneath which the streams escape. Grassy cove is further advanced in its development than the others. Its drainage is wholly underground, though several low gaps in its rim indicate the location of surface streams which formerly drained the cove, as Berks creek now drains a portion of Crab Orchard cove. When the basin of the cove is fully developed the present positions of the outward-flowing streams, Berks creek and the branches of Daddy creek, will be indicated only by low gaps in the rim of the cove.

East of Crab Orchard mountains the surface has a gentle slope to the southeast from an elevation of 2,000 feet to 1,500 or 1,600 feet at the edge of the escarpment which limits the Cumberland plateau in this direction. This belt of plateau country lying east of the Sequatchie valley extends toward the southwest as Walden ridge and sometimes bears the same name within the Kingston sheet. Its drainage is toward the east or southeast, and the streams have cut many deep channels in the generally level surface. Near the edge of the plateau the smaller streams turn and flow parallel to the escarpment till by their union they form a large stream, which emerges into the valley from a deep, rocky gorge.

The southeastern half of the sheet lies within the folded zone forming the great Appalachian valley, here occupied by the Tennessee river and its tributaries and called the valley of East Tennessee. The altitude of the Tennessee river is about 700 feet, and all its larger tributaries have cut their channels down nearly to the same level, but the surface of the valley is broken by numerous ridges rising from 300 to 500 feet higher. These ridges have a uniform northeast and southwest trend, parallel to the Cumberland escarpment, their location and height depending directly on the character and attitude of the underlying rocks. The general course of the Tennessee river from Kingston to the southern edge of the sheet is parallel to these ridges, whereas its tributaries cut directly across them, receiving smaller branches from intervening valleys.

An examination of the topographic map shows that a considerable portion of the valley surface has an altitude of between 900 and 1,000 feet; above this level the ridges of hard rocks rise from 100 to 200 feet, while the stream channels are sunk about the same depth into it. In other words the valley may be regarded as a plain, on which the ridges remain in relief and in which the stream channels have been incised. From a study of the entire province it has been determined that this plain was formed near sea level, by the work of the atmosphere and rivers during the Eocene and Neocene periods. As the surface thus carved was almost, but not wholly level it is called a *peneplain*. Subsequent elevation of the land has brought the peneplain to its present altitude, and the streams, being thereby stimulated to renewed activity, have cut the present channels within its surface. The remnants of a very much older peneplain, probably of the Cretaceous period, may be seen in the Cumberland plateau. Like the other, it was formed near sea level and was even more perfectly developed, although the Crab Orchard mountains then, as now, rose abruptly from its surface. After the Cretaceous land had been reduced nearly to baselevel, it was elevated during the Eocene period 800 to 1,200 feet, and the streams then cut the second peneplain upon the soft limestones of the Appalachian valley. The older plain, though deeply cut by stream channels, was preserved by the hard sandstones which formed its surface. During its elevation that portion of the Cretaceous peneplain within and adjacent to the Kingston sheet was tilted towards the southeast, so that it is about 400 feet higher at the northwest corner of the sheet than at the Cumberland escarpment.

GEOLOGY.

STRATIGRAPHY.

The sedimentary record.—All the rocks appearing at the surface within the limits of the Kingston atlas sheet are of sedimentary origin, that is, they were deposited by water. They consist of sandstones, shales, and limestones, 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, 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 probably covered low, swampy shores.

These rocks afford a record of almost uninterrupted sedimentation from early Cambrian to late Carboniferous time. Their composition and appearance indicate the nearness to shore and the depth of water in which they were deposited. Sandstones marked by ripples and cross-bedded by currents, and shales cracked by the sun on mud flats indicate shallow water; while limestones, especially by the fossils they contain, indicate greater or less depth of water and absence of sediment. The character of the adjacent land is also 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. Then the sea received only fine sediment and substances in solution.

The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin. The area of the Kingston sheet was near its eastern margin, and the materials of which its rocks are composed were therefore derived largely from the land to the eastward. 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.

Two 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 (Clinch) sandstones were lifted above the sea and eroded. Following this elevation, which completed the first great cycle, came a second period, during which the land was low, probably worn down nearly to baselevel, affording conditions for the accumulation of the Devonian black shale and Carboniferous limestone, which in general show very little trace of shore waste. A second great uplift brought these rocks into shoal water and in some places above the sea, and upon them were deposited, in shallow water and swamps, the sandstones, shales, and coal beds of the Carboniferous. Finally, a further uplift at the close of the Carboniferous stopped the deposition of sediment in the Appalachian province except along its borders in recent times.

CAMBRIAN ROCKS.

Apison shale.—The oldest rocks exposed within the limits of the sheet are slightly sandy or clay shales. Their most striking peculiarity is in the brilliant coloring which they display, generally in 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 it is not less than 1,000 feet. The name of the formation is taken from Apison, Tennessee, in the southeastern part of the Chattanooga sheet.

Rome formation.—Next above the Apison shale are the sandstones and shales of the Rome formation. They are between 2,100 and 3,400 feet thick, but the strata are so crumpled that it is impossible to obtain accurate measurements.

The lower portion, 1,500 to 2,000 feet thick, is composed of layers of sandstone and shale. Passing upward the proportion of the 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 an occasional thin layer of white quartzite. The sandstone beds are ripple marked and were evidently deposited in shallow water, but the succeeding formation contains limestones and calcareous shales, probably formed on a comparatively deep sea bottom.

Connasauga shale. This formation is composed at the base of thin limestones interbedded with shales, then yellow or greenish clay shales, and at the top blue seamy or shaly limestone. The limestone at the base is oolitic, being made up of rounded or flattened grains, usually about a tenth of an inch in diameter. This oolitic limestone is sometimes absent, and the boundary between the Rome and Connasauga becomes very indefinite. The blue, seamy limestone at the top of the Connasauga is also locally wanting, especially on the eastern edge of the sheet, and brown shales indistinguishable from the Rome are found immediately under the Knox dolomite. The thickness of the formation is about 1,500 feet at the southern edge of the sheet and decreases rapidly toward the northeast till it wholly disappears or is represented only by a thin bed of blue, seamy limestone.

The Cambrian rocks are seen only in the southeastern half of the sheet, where they form long, narrow strips extending in a direction parallel to the Cumberland escarpment. Each of these strips is limited by a fault along its western side, and there is a regular sequence in the order of the occurrence of the formation; the older lie next to the fault and the younger in successive narrow bands toward the east.

The Rome sandstone forms ridges varying in height and continuity with its thickness, while the upper part of that formation and the overlying Connasauga shale produce long, narrow valleys.

SILURIAN ROCKS.

Knox dolomite.—The lowest division of the Silurian consists of from 3,300 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, and the chert remains, usually imbedded in red clay. This residual material is often of great depth and forms low, rounded hills and irregular ridges.

The Knox dolomite occurs only in the southeastern half of the sheet, in long, narrow strips, alternating with the Cambrian rocks. Its outcrops are marked by the characteristic chert hills, and the dolomite itself seldom comes to the surface.

Chickamauga limestone.—This formation shows a decided change in character between its exposures on the western and eastern sides of the sheet. In the head of Sequatchie valley it is a hard, blue, flaggy limestone. In the narrow strip along the foot of the Cumberland escarpment and in the broader belt in Tennessee valley from Rockwood landing southward, the Chickamauga is mainly a blue limestone, but it also contains many mottled, earthy and shaly beds. It is here about 1,500 feet thick. In the belt which extends from near Kingston southwestward to Decatur, the formation, 1,500 to 1,800 feet thick, consists of blue and mottled limestones, while above are yellow, calcareous shales, probably equivalent to the upper beds of limestone farther west.

The formation is named from Chickamauga creek, on the Chattanooga and Ringgold sheets.

Athens shale.—East of the Tennessee river the upper part of the Chickamauga limestone is replaced by shales from 300 to 500 feet in thickness. Eastward beyond the edge of this sheet this formation increases to several thousand feet in thickness, where the strata represent the rapid and variable accumulation of sediment near the shore.

The formation takes its name from Athens, Tennessee, on the Cleveland sheet.

Rockwood formation.—This 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 about the head of Sequatchie valley, where it is 165 feet thick, and is composed of calcareous shales interbedded with blue limestone. Along the foot of the Cumberland escarpment it is about 600 feet thick, and consists of calcareous and sandy shales. Still further east, in the ridge which extends from Iron Divide to Ten Mile Stand, the formation attains a thickness of from 850 to 1,000 feet, a considerable part of which is coarse sandstone interbedded with sandy shales. Toward the top are sandy shales and a few calcareous beds, with which is associated the iron ore that gives the formation such great economic importance. It takes its name from Rockwood, Tennessee, where the rocks are intermediate in character between the western and eastern phases and where the ore is extensively mined.

The presence of the Athens shale on the eastern portion of the sheet only and the changes noted in the Chickamauga and Rockwood formations indicate that while these formations were being deposited the land from which the sediment came was toward the southeast and the deep sea toward the northwest.

DEVONIAN ROCKS.

Chattanooga black shale.—Overlying the Rockwood formation is a thin stratum of shale which appears to represent the whole of the deposition that 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 this atlas sheet and for a long distance on either side north and south. It varies in thickness from 15 to 35 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 resembling that of 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 for various ores, especially silver and copper. Such exploitation, however, has always been attended by failure, since there is nothing of present economic importance in the shale. 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 at a uniform depth over considerable areas.

CARBONIFEROUS ROCKS.

Fort Payne chert.—This formation consists of from 75 to 150 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. The lime increases toward the top, gradually replacing the chert, and the formation passes upward into the Bangor limestone. East of Emory river the Fort Payne chert is represented by a slightly cherty limestone, and beyond the edge of the sheet it is not separable from the Bangor. The chert of this formation is readily distinguishable from that of the Knox dolomite by the fossils which it contains. It is often made up of crinoid stems imbedded in a siliceous cement. On weathering, the cement remains as a porous chert filled with the fossil impressions.

The formation occurs in a narrow belt around the head of Sequatchie valley, over a small area in Grassy cove, and in a narrow strip along the Cumberland escarpment. An occurrence east of the Tennessee river suggests that the formation once covered the entire area of the sheet, but its original eastern limit is not known. It takes its name from Fort Payne, Alabama.

Bangor limestone.—The Bangor limestone is from 800 to 1,100 feet thick at the head of Sequatchie valley and along the Cumberland escarpment, where it forms the lower portion of the mountain slopes. It also forms the coves of Crab Orchard mountains. The limestone shows clearly the mode of its formation. It is often composed almost entirely of fragments of crinoids and calcareous coverings of other sea animals which left their remains on the sea bottom.

Although in general a massive, blue, crinoidal limestone, the upper 50 or 100 feet often weathers to a brightly colored clay shale, and in Grassy cove there is a layer of sandstone about 70 feet thick near the middle of the formation.

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. Under these conditions 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 a luxuriant vegetation, which formed coal beds.

The Lookout sandstone consists of strata of conglomerate, thin-bedded sandstone, sandy and clay shale, and coal between the top of the Bangor limestone and the top of a heavy bed of conglomerate. The formation is about 260 feet thick in the Crab Orchard mountains and increases to 510 feet along the Cumberland escarpment. The bed of conglomerate at the top of the formation varies in thickness from 25 to 60 feet, and usually forms a bold cliff. The formation takes its name from Lookout mountain.

Walden sandstone.—This formation includes all the rocks within the sheet above the Lookout conglomerate. The conditions of its deposition were similar to those of the Lookout, but were somewhat more uniform and more favorable for the accumulation of coal. The rocks are mainly thin-bedded sandstones and sandy shales, with some massive sandstones. The original thickness of the Walden sandstone cannot be determined, as it is probable that much of the formation has been removed by erosion. A thickness of about 1,300 feet remains a short distance west of the escarpment.

The Lookout and Walden sandstones constitute the productive coal-measures of this region. They at present occupy the entire surface west of the Cumberland escarpment, except at the head of Sequatchie valley and in the coves of Crab Orchard mountains. It is probable that they formerly extended over the whole area of the sheet, but the portions which covered the present Tennessee valley have been entirely removed by erosion. The position and thickness of the various beds of coal which occur in these formations will be described under the Mineral Resources.

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

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 at various angles. When any particular bed is followed for a considerable distance it is often found forming 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, towards 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*. The rocks are also altered by production of new minerals from the old, or by *metamorphism*.

Structure of the Appalachian province.—These three methods of change which the rocks of the province have suffered are grouped very distinctly along the three geographical divisions.

In the plateau region and westward the rocks are but little tilted from their original horizontal positions and are almost entirely unchanged; in the valley the rocks have been steeply tilted, bent into anticlines and synclines, broken by faults, and to some extent altered into slates; in the mountain district faults and folds are prominent, but the rocks have been changed to a greater extent by the minute breaks of cleavage and by the growth of new minerals.

In the valley the folds and the faults developed from them are parallel among themselves and to the old land body, extending in a northeast-southwest direction for great distances. Some faults have been traced for 300 miles, and some folds have even greater length. The crests of the anticlines are very uniform in height, so that for long distances they contain the same formations. They are also approximately equal to each other in height, so that many parallel folds bring to the surface the same formations. Most of the rocks dip at angles greater than 10°, and frequently the sides of the folds are compressed till they are parallel. The folding is greater in thin bedded rocks, such as shale and shaly limestone, because the thin layers were most readily bent, and slipped along their bedding planes. Perhaps the most striking feature of the folds 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 towards the northwest.

Out of the close folds the faults were developed, and with extremely few exceptions the fault planes dip toward the southeast. The planes on which the rocks broke and moved are often parallel to the bedding planes, as the rocks slipped on the beds in folding. Along these planes of fracture the rocks moved to distances sometimes as great as six or eight miles. There is a progressive increase in degree of deformation from northeast to southwest, resulting in different types in different places. In northern Pennsylvania folds are inconspicuous. Passing through Pennsylvania toward Virginia they rapidly become more numerous and dips grow steeper. In southern Virginia the folds are closely compressed and often closed, while occasional faults appear. Passing through Virginia and into Tennessee the folds are more and more broken by faults, until, half way through Tennessee, nearly every fold is broken and the strata form a series of narrow, overlapping blocks, all dipping eastward. This condition holds nearly the same southward into Alabama, but the faults become fewer in number and their horizontal displacement much greater, while the folds are somewhat more open.

In the Appalachian mountains the structure is the same as that which marks the great valley; there are the eastward dips, the close folds, the thrust faults, etc. But in addition to these changes of form, which took place mainly by motion on the bedding planes, there were developed a series of minute breaks across the strata, producing cleavage, or a tendency to split readily along these new planes. These planes dip to the east at from 20° to 90°, usually about 60°. This slaty cleavage was somewhat developed in the valley, but not to such an extent as in the mountains. As the breaks became more frequent and greater they were accompanied by growth of new minerals out of the fragments of the old. These consisted chiefly of mica and quartz and were crystallized parallel to the cleavage cracks. The final stage of the process resulted in the squeezing and stretching of hard minerals like quartz, and complete recrystallization of the softer rock particles. All rocks, both those of sedimentary origin and those which were originally crystalline, were subjected to this process, and the final products from the metamorphism of very different rocks are often indistinguishable from each other. Rocks containing the most feldspar were most thoroughly altered, and those with most quartz were least changed. Throughout the entire Appalachian province there is a regular increase of metamorphism toward the southeast, so that a bed quite unaltered at the border of the great valley can be traced through greater and greater changes until it has lost every original character.

The structures above described are manifestly due chiefly to horizontal compression which acted in a northwest-southeast direction, at right angles to the trend of the folds and cleavage planes. The compression apparently began in early Paleozoic time and probably continued at intervals up to its culmination, shortly after the close of the Carboniferous, when the greater portion of the folding was effected.

In addition to the horizontal force of compression, the province has been subjected to other forces, which have repeatedly elevated and depressed its surface. At least two periods of high land near the sea and two longer periods of low land are indicated by the character of the Paleozoic sediments. And in post-Paleozoic time there have been at least three and probably more periods of decided oscillation of the land, due to the action of some vertical force. In every case the movements have resulted in warping the surface, and the greatest uplift has occurred nearly along the line of the great valley.

Structure sections.—The six 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 cannot represent the minute details of structure; they are therefore somewhat generalized from the dips observed near the line of the section in a belt a few miles in width.

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.

It will be seen from the sections that the region is divided by the Cumberland escarpment into two nearly equal divisions having entirely different types of structure. In the northwestern division the strata are horizontal or gently undulating, while in the southeastern they are highly inclined and intersected by numerous faults.

Structure of the plateau.—In the Crab Orchard mountains the strata are bent upward, forming an anticline. If the rocks which have been removed from the top of the arch were restored, the mountains would rise at least 1,500 feet higher than they are at present. But erosion has been more active on the arch than in the adjacent troughs. Thus Sequatchie valley has been eroded along the axis of the anticline toward the southwest, and within the sheet numerous coves have been formed along the same line. West of the Crab Orchard anticline the strata are nearly horizontal, while eastward they dip in a broad shallow syncline, which extends toward the southwest, forming Walden ridge. Along the eastern side of this syncline the strata are rather sharply upturned, forming the Cumberland escarpment. For a short distance north of Emory river they are even overturned, so that they dip steeply toward the east.

Structure of the valley.—The complicated structure of the southeastern half of the area is the result of extreme compression in a northwest-southeast direction. The first effect of this compression must have been to produce a series of narrow, parallel folds similar to the Crab Orchard anticline and Walden ridge syncline, except that they were probably not so broad. The force must have acted very slowly through a long time, so that the tops of the arches were eroded nearly as fast as they rose. When the folding had reached a certain point, further compression resulted in the formation of faults.

The fault planes usually dip toward the southeast, but there are some exceptions along the base of the escarpment. Between Rockwood and Spring City a narrow belt of rocks is bounded by faults, which dip in opposite directions, so that the block of strata has the form of a wedge with the thin edge upward, as shown in sections C and D. On its eastern side the Knox dolomite and on its western side the Rockwood and Chickamauga have been thrust up onto the Lookout sandstone. A similar wedge-shaped mass, bounded by faults with opposing dip, occurs at Post Oak springs, shown in section B, and another at Rhea springs, shown in section E.

The strata lying southeast of Tennessee river are divided into a number of similar belts parallel to the escarpment, each from two and a half to four and a half miles in width. On the western side of each belt are Cambrian rocks, the Apison shale or Rome sandstone, while on the eastern side are Silurian rocks, and the younger strata of one belt dip under the older strata of the belt next eastward. The belts are therefore separated by faults, and the strata of each have been thrust up onto the strata of the zone next westward. Each of these belts represents a syncline in the originally folded strata, while the positions of the intervening anticlines are occupied by the faults. The arches of strata, which formed the anticlines, have usually been entirely removed by erosion, though the anticlinal structure is sometimes preserved next to a fault in the oldest rocks.

Some peculiar faults are shown in sections D and E, just east of Tennessee river. The Chickamauga and Rockwood formations lie in an open syncline, against which the Cambrian rocks are faulted on the eastern side. This is the prevailing structure of the region, but it is further complicated by a nearly horizontal fault, on which the Knox dolomite has been thrust over from the east so that it rests upon the syncline of younger rocks.

MINERAL RESOURCES.

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

Coal.—The productive coal-bearing formations, consisting of the Walden and Lookout sandstones, occupy the entire surface of the sheet west of the Cumberland escarpment, except the head of Sequatchie valley and Grassy and Crab Orchard coves. These formations have an area within the limits of the atlas sheet of about 370 square miles.

The accompanying vertical sections 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 a slight uncertainty is thus introduced into the correlation of coal beds in different parts of the field.

There is always one bed of coal contained in the Lookout, and in some places there are as many as four. One bed immediately below the conglomerate is fairly constant in position, though it varies considerably in thickness. Lying next to the rigid conglomerate, the coal has been much squeezed, especially along the escarpment, where the strata are sharply folded. This bed is worked on the south side of the Emory river at Harriman. It is about ten feet thick at the outcrop, but this is probably only a local swell, produced by the bending of the rocks above and below the coal. Coal beds below the conglomerate have been opened at various points along the escarpment, and also on both sides of the Crab Orchard anticline, but sufficient information for their correlation is not available, though in most cases the first bed below the conglomerate appears to be the one which is generally seen. The lower beds in the Lookout sandstone, though worked on the Chattanooga sheet, appear to be either wanting or so thin as generally to escape notice over much of this region.

The greater part of the workable coal of this area is in the Walden sandstone. About sixty feet above the conglomerate is a bed which seems to be quite uniform in position and character. It is worked at Dayton, just off the southwest corner of the sheet, where it is about five feet thick. It has also been opened on the north bank of the Emory river near Harriman, but by far the most extensive development has been made at Rockwood. The rocks of the escarpment, through which the main entry is driven, there dip northwest about 45°. A short distance back from the escarpment there is a narrow anticline, the axis of which pitches toward the north. In the trough thus formed between the upturned rocks of the escarpment and the anticline, coal is found in irregular masses. The coal yielded most readily as the strata were folded, and it was squeezed out from those parts of the folds where the pressure was greatest, to accumulate where the pressure was relieved. In some places the coal is eighty to one hundred feet thick. Its original structure is almost obliterated, and it occurs in small rhomboidal blocks, whose polished surfaces show that much motion has taken place within the mass.

A second seam, also worked at Rockwood, occurs about 620 feet above the conglomerate. This is called the Richland seam at Dayton, where it is about four feet thick. The strata high enough to contain this coal have been much eroded, but it still remains in the deeper portion of the Walden ridge syncline, a belt three or four miles broad west of the escarpment, and probably also in the plateau west of the Crab Orchard mountains.

Without attempting strict correlations of individual beds it will thus be seen that there are generally three horizons at which workable coal is likely to be found. The first is within 75 feet below the top of the conglomerate, the second within 75 feet, and the third within 650 feet above the top of the conglomerate. Coal beds occur at other horizons, and they may be locally workable, but less generally so than at the three levels mentioned.

All the coals of this region are bituminous, and all, so far as tested, are well suited for coking.

Iron ore.—The only iron ore sufficiently abundant to be commercially important is the red fossil ore of the Rockwood formation. This ore is very similar in appearance to that occurring at the same horizon in such widely separated localities as Wisconsin, New York, and Alabama. It is a stratified bed of constant thickness and with definite relations 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. This 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. Considerable quantities of this soft ore are frequently obtained by trenching along the outcrops of the bed where it is not of sufficient thickness to make mining profitable at present.

Along the foot of the Cumberland escarpment a narrow strip of the Rockwood shale extends across the sheet, except at points where a number of short breaks are caused by faulting. The ore occurs in workable quantity along this whole strip, though it is thicker in the northern than the southern half. It has been worked at numerous points near Spring City, Sheffield, and Evansville, but only by surface trenching. Between Rockwood and Emory gap there are two beds of ore, one about 200 feet and the other 500 feet below the Chattanooga black shale. Only the upper bed is worked at present, its thickness varying from three and a half to five feet. The workings have reached about 100 feet below the surface, and, while the ore shows an increase in the proportion of lime, it can probably be worked with profit to much greater depths.

The Rockwood formation thickens toward the east, but the calcareous beds with which the iron ore is associated are confined to its upper portion. In the Tennessee valley, near the center of the sheet, it forms a strip about nine miles in length, which is crossed four times by the Tennessee river, so that a large part of the area is not available for mining. Notwithstanding the unfavorable conditions, considerable mining has been done in this area, generally by surface trenching.

A third belt of the ore-bearing rocks occupies the top of the syncline which extends from near Kingston to Ten Mile Stand. There are two areas, separated by erosion, each about five miles in length, and from a quarter to a half mile in width. The ore has been worked only in the northern of these areas. On the western edge the strata dip eastward at an angle of ten degrees, and on the eastern edge they are nearly vertical. The ore all lies above the level of the Tennessee river, so that the lime has been thoroughly leached out. The bed is from four to seven feet in thickness, with a few thin shale partings.

In the same line with these two areas of iron-bearing rocks, a third occurs near the southern edge of the sheet. The ore is not so thick as further north, though it has been worked to some extent.

Limestone.—Limestone suitable for blast furnace flux and for lime is abundant and convenient of access. The Bangor limestone is used at Rockwood on account of its freedom from impurities and its close proximity to the furnace. No lime is burned within the limits of the sheet.

Building stone.—Stone adapted to architectural uses occurs in nearly all the formations of this region. That which has been most largely used is from the Chickamauga limestone. Sandstones especially well adapted for foundations occur in the Lookout and Walden formations, but these have as yet been quarried only in a small way for local use.

Road material.—The hard blue Bangor and Chickamauga limestones offer an abundant supply of macadam, and the residual chert of the Fort Payne and Knox dolomite formations is an ideal surfacing material.

Clays.—The residual red or blue clays of the Bangor and Chickamauga limestones are generally well adapted for making bricks. These clays, as well as some from the Cambrian shales, are quite extensively used in adjacent areas for making drain tile.

The beds of fire clay which are usually associated with the coal probably contain material well adapted for making fire brick, but they are yet wholly undeveloped.

SOILS.

Throughout this region there is a very close relation between the character of soils and that of underlying geologic formations. Except in limited areas along the rivers and the steep slopes of the Cumberland escarpment, the soils are derived directly from the decay and disintegration of surface rocks. Where these are sandstones or sandy shales the resulting soil is sandy, where they are clay shales or limestones 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. The attitude of the strata and the consequent breadth of outcrop of each formation determine the area of the derived soil. Where a formation is nearly horizontal at the surface, as the Walden sandstone of the plateau, the corresponding soil covers a broad area, but where its outcrop is nearly vertical, as the Connasauga shale, its resulting soil covers only a narrow strip. The character of the soils derived from the various geologic formations being known, their distribution may be determined from the map showing the areal geology, which thus serves also as a soil map.

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 Rockwood formation, and the Rome sandstone; (2) clay soils, derived from the Bangor and Chickamauga limestones and the Connasauga and Apison shales; (3) cherty soils, derived from the Fort Payne chert and Knox dolomite; and (4) alluvial soils, deposited by the rivers upon their flood plains.

Sandy soils.—The Cumberland escarpment has already been described as separating the area of the Kingston sheet into two nearly equal divisions, which differ widely in topographic features and geologic structure. The difference in soils is also marked. Northwest of the escarpment the rocks are sandstones and sandy shales, and, except in the coves which are underlain by limestone, the soil is a sandy loam. At the surface it is gray, while the subsoil is generally light yellow, but varies to deep red. It usually contains sufficient clay to give the subsoil such coherence that a cut bank will remain vertical for some years. The depth of the soil on the plateau varies from a few inches to a dozen feet, depending chiefly on proximity to streams and the consequent activity of erosion. Almost the whole 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 an appreciation of the agricultural possibilities of this region.

The sandy soils southeast of the escarpment are confined to a few narrow strips coinciding with the outcrop of the Rockwood and Rome sandstones. These formations, however, produce sharp ridges, so that their soils are not agriculturally important.

Since the sandstones of this region occupy the highest land, the sandy soil is often washed down to lower levels and covers up the clay soil of adjacent valleys. This happens along the Cumberland escarpment, so that the strip of Bangor limestone at its base is covered by sandy soil instead of clay soil.

Clay soils.—In the coves of the Crab Orchard mountains the surface of the Bangor limestone is covered by a thin mantle of bluish gray clay soil, formed from its insoluble portions. Southeast of the escarpment the many parallel valleys are due to the presence of narrow belts of soluble limestones or easily eroded shales, which form clay soils. The most productive of these are derived from the Chickamauga limestone, and their distribution coincides with that of the formation as shown on the geologic map. They have generally a deep red color, but where the mantle of residual material is thin, the soil is often dark bluish gray. The clay soils derived from the Cambrian shales are somewhat less productive. The Connasauga and upper part of the Rome make stiff, bluish gray soils, thinner than that covering the limestone, the shaly structure often appearing a few inches below the surface.

Cherty soils.—About half the area southeast of the escarpment 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 the Fort Payne chert is similar to that from the Knox dolomite, but the areas of the Fort Payne outcrops are so small that their soil is relatively unimportant.

Alluvial soils.—These are confined to the flood plains or bottoms of the Tennessee and Clinch rivers. Their areas are small, as the rivers are usually bordered on one side or the other by steep bluffs. The soil is a rich, sandy loam, containing a considerable proportion of fine mica scales derived from the crystalline rocks far to the east.

C. WILLARD HAYES,
Geologist.

May, 1894.

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

TOPOGRAPHY

TENNESSEE.
KINGSTON SHEET

Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in charge.
Triangulation by S.S. Gannett.
Topography by F. M. Pearson. Surveyed in 1884-5.
Topography by C. E. Cooke. Surveyed in 1891.

Scale 1/125000

Contour Interval 100 feet.

Edition of July 1893.

U.S. GEOLOGICAL SURVEY.
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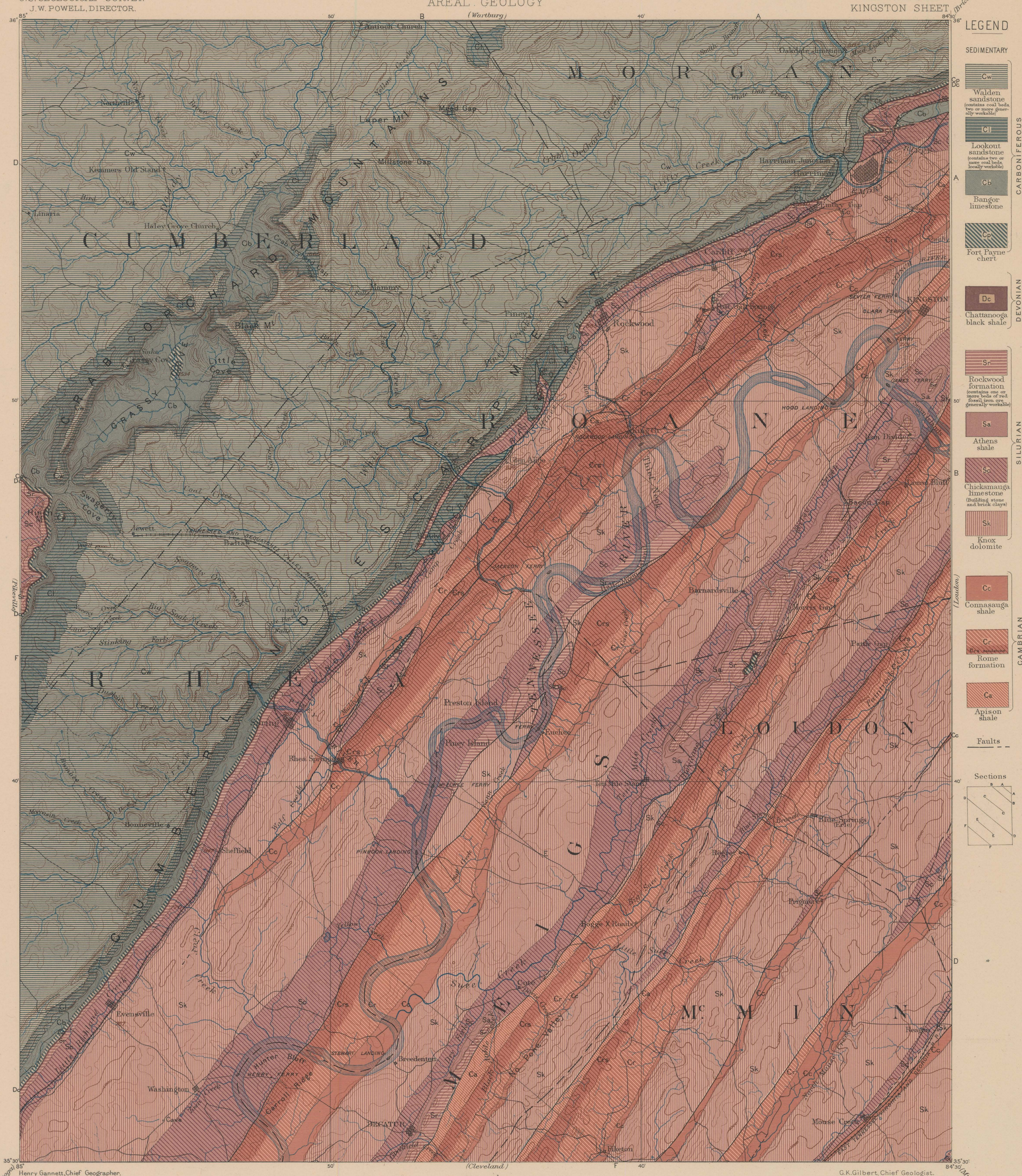
AREAL GEOLOGY

TENNESSEE.
KINGSTON SHEET



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G. K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in Charge.
Geology by C. Willard Hayes.
Assisted by M. R. Campbell.
Surveyed in 1883-90.

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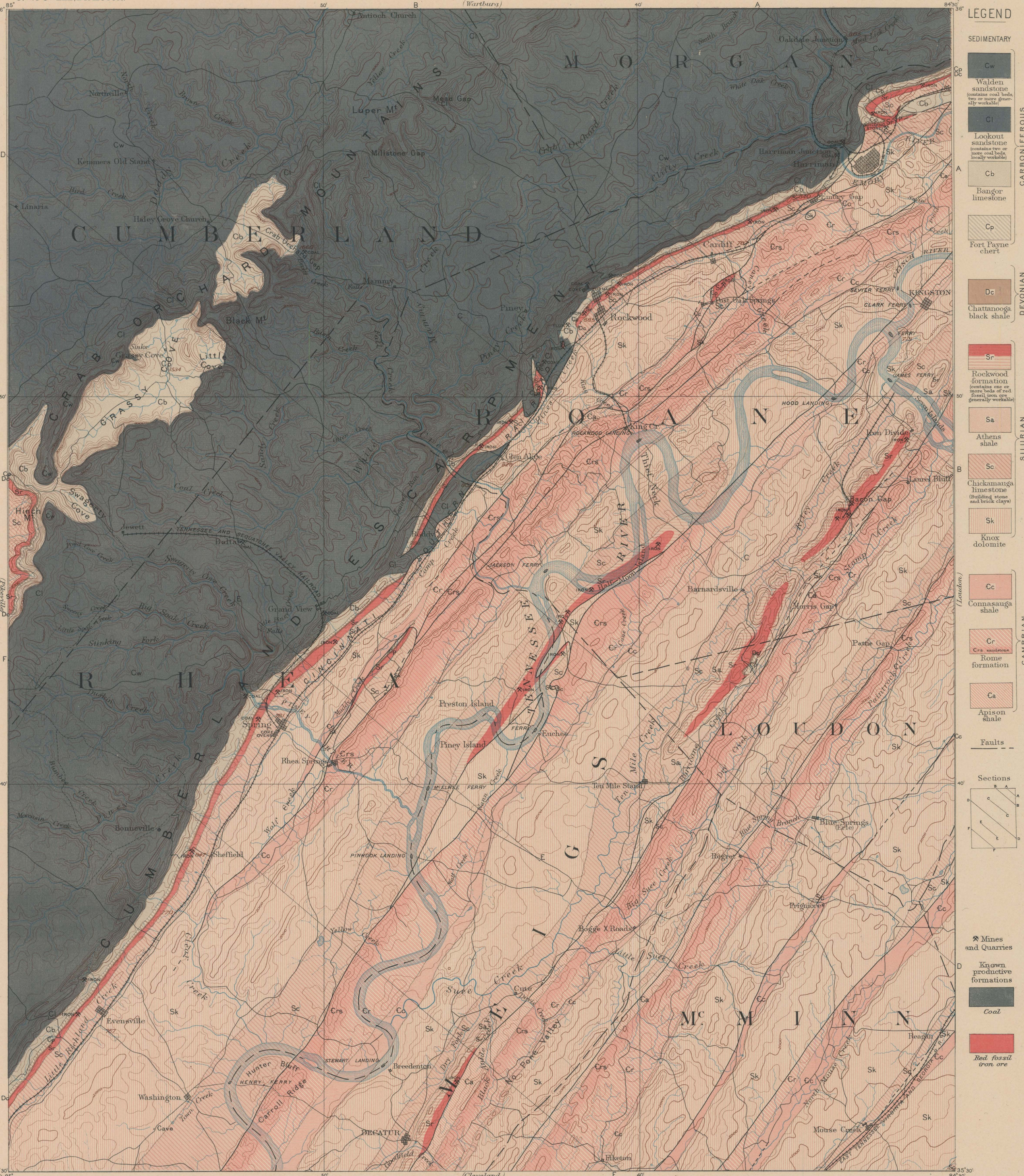
ECONOMIC GEOLOGY

TENNESSEE
KINGSTON SHEET



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

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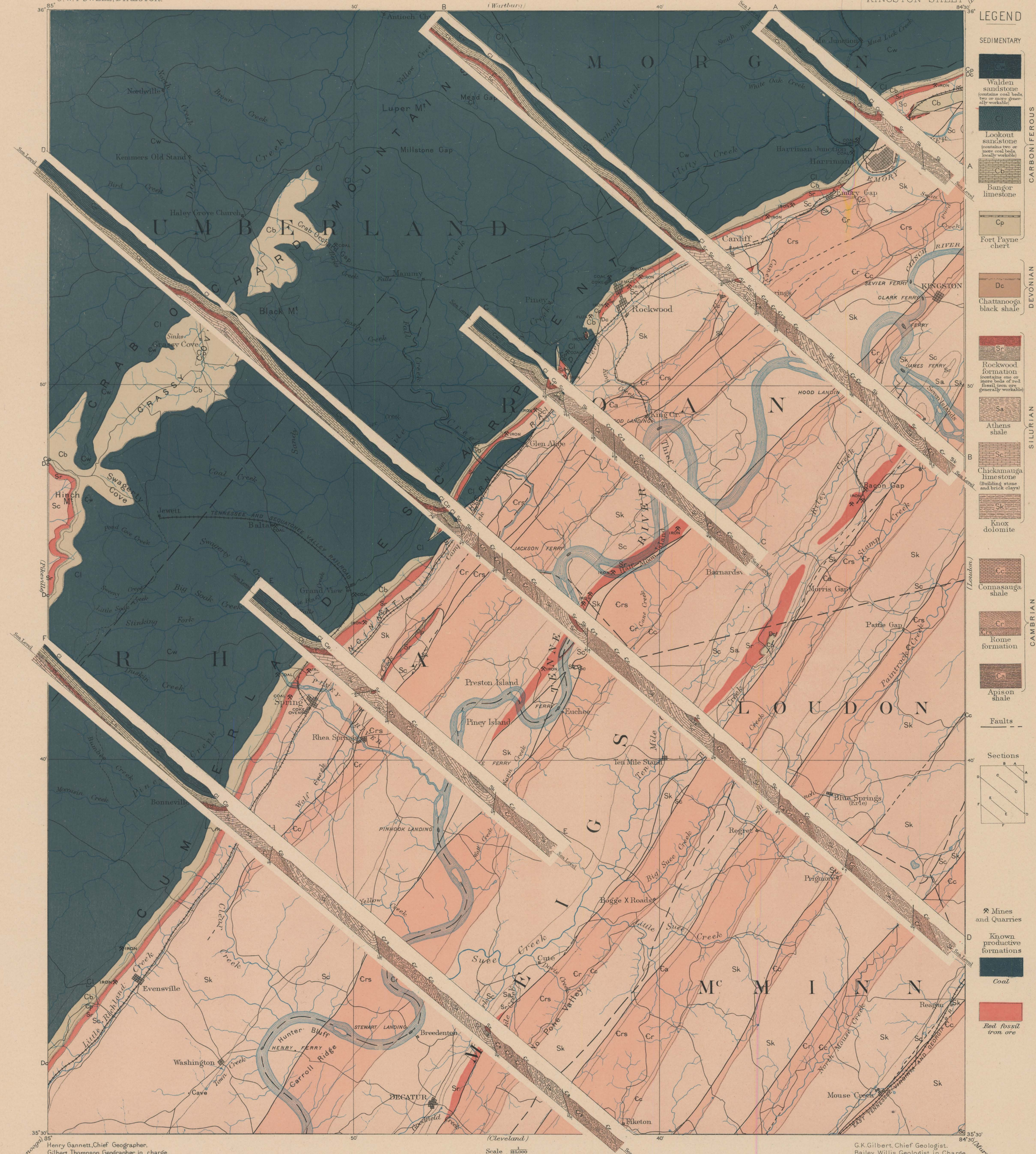
Assisted by M.R. Campbell.
Surveyed in 1889-90.

STRUCTURE SECTIONS



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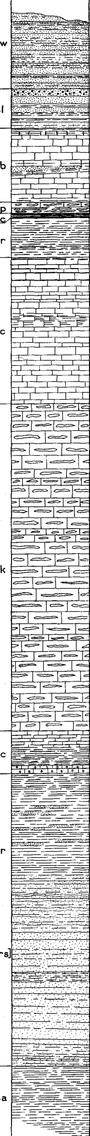
Surveyed in 1889-90.

COLUMNAR SECTIONS

GENERALIZED SECTION WEST OF THE CLINCH AND TENNESSEE RIVERS.

SCALE 1000 FEET = 1 INCH.

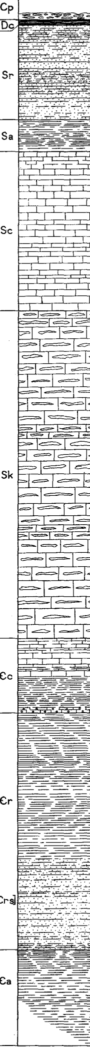
Period.	Formation Names.	Formation Symbols.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	Walden sandstone.	Cw		1300	Coarse sandstone and sandy shale with beds of coal and fire clay.	Flat topped, plateau-like mountains, intersected by narrow rocky gorges. Gray, yellow or red sandy loam.
	Lookout sandstone.	Cl		260—510	Conglomerate and massive sandstone; sandy shale with beds of coal and fire clay.	Cliffs; abrupt plateau escarpments. Scanty soil, rocky and sandy.
	Bangor limestone.	Cb		750—850	Shaly limestone. Massive, blue, crinoidal limestone. Sandy and shaly limestone.	Steep mountain slopes and coves. Black clay soil with more or less sand from rocks above. Narrow valleys. Red clay, with sand and chert from adjacent slopes.
	Fort Payne chert.	Cp		75—150	Cherty limestone.	Sharp, narrow ridges parallel to plateau escarpments. Sandy clay soil with abundant fragments of chert.
DEV.	Chattanooga black shale.	Dc		15—30	Carbonaceous shale.	
SILURIAN	Rockwood formation.	Sr		165—650	Greenish clay shale with beds of fossil iron ore.	
	Chickamauga limestone.	Sc		1300—1700	Blue flaggy limestone.	Level valleys; shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestones are nearly horizontal and deeper red clay where they are steeply inclined.
	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.	Ꞓc		300—500	Blue seamy limestone. Greenish clay shales. Thin beds of oolitic limestone.	Narrow level valleys. Stiff yellow or bluish gray clay soil.
	Rome formation.	Ꞓr		2800—3400	Greenish or brown shales with thin siliceous layers.	
	[Rome sandstone.]	[Ꞓrs]		[1800—2200]	Purple or brown sandstones interbedded with sandy shales.	Comby ridges. Rocky sandy soil.
	Apison shale.	Ꞓa		1000 +	-	Narrow, rolling valleys. Stiff clay soil.



GENERALIZED SECTION EAST OF CLINCH AND TENNESSEE RIVERS.

SCALE 1000 FEET = 1 INCH.

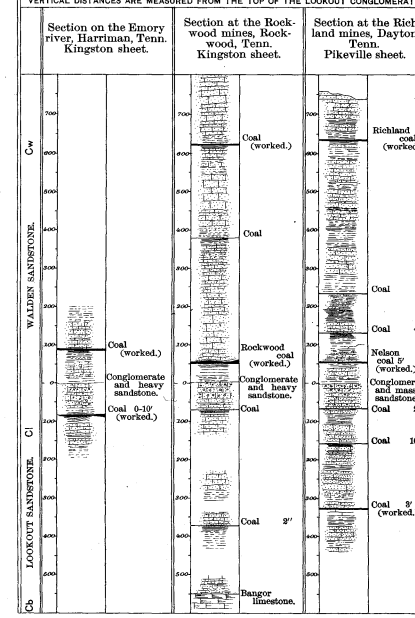
Period.	Formation Names.	Formation Symbols.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
C.	Fort Payne chert.	Cp		75 +	Beds of chert and cherty limestone.	Knobs parallel with Rockwood ridges; sandy soil with fragments of chert.
D.	Chattanooga black shale.	Dc		35	Carbonaceous shale.	
SILURIAN	Rockwood formation.	Sr		850—1000	Calcareous sandy shale and beds of iron ore. Coarse porous sandstone. Thin bedded sandstone and shale.	High ridges with undulating or rounded summits. Rocky, sandy soil.
	Athens shale.	Sa		250—400	Calcareous shale weathering yellow.	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.
	Chickamauga limestone.	Sc		1500—1800	Earthy limestones; mottled, purple and gray. Blue flaggy limestone.	
	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.	Ꞓc		0–1500	Blue seamy limestone. Greenish clay shales. Thin beds of oolitic limestone.	Level or rolling valleys. Stiff yellow or bluish gray clay soil.
	Rome formation.	Ꞓr		2100—3000	Greenish or brown shales with thin siliceous layers.	Valleys with low ridges. Thin sandy clay soil.
	[Rome sandstone.]	[Ꞓrs]		[700—1000]	Purple and brown sandstones interbedded with sandy shales.	Comby ridges. Rocky, sandy soil.
	Apison shale.	Ꞓa		1000 +	Highly colored calcareous shales; red, purple, green and yellow.	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 THE LOOKOUT CONGLOMERATE.



NAMES OF FORMATIONS.

		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 sub-carbonifer's.	Mountain limestone. Siliceous group.
Dev.	Dc	Chattanooga black shale.	Black shale.	Genesee or Black shale.	Black shale.
Silurian	Sr Sa Sc Sk	Rockwood formation. Athens shale. Chickamauga limestone. Knox dolomite.	Red mountain or Clinton. Trenton or Pelham limestone. Knox dolomite.	Clinton or Dyestone. Trenton, Chazy or Maclurea. Quebec or Knox dolom.	Dyestone group: White Oak mountain sandst. Trenton, Lebanon or Maclurea limestone. Knox dolomite.
Camb.	Ꞓc Ꞓr Ꞓrs Ꞓa	Connasauga shale. Rome formation. Rome sandstone. Apison shale.	Choccolocco or Montevallo shales.	Knox shales. Calciferous or Knox s. s.	Knox shale. Knox sandstone.

C. WILLARD HAYES,
Geologist.