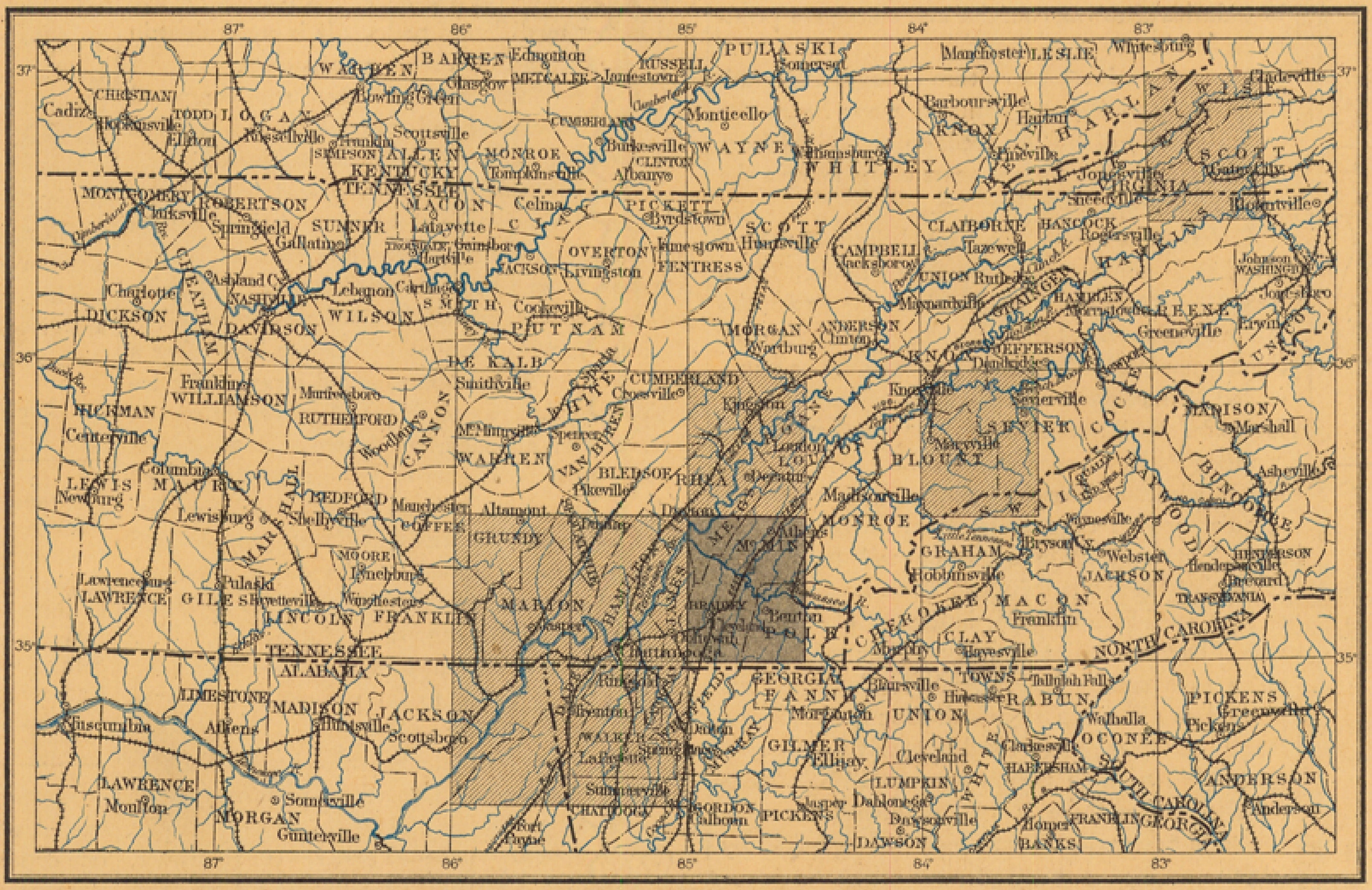
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

CLEVELAND FOLIO
TENNESSEE

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE CLEVELAND FOLIO

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FOLIO 20 | LIBRARY EDITION | CLEVELAND

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS   S. J. KÜBEL, CHIEF ENGRAVER
1895

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

DESCRIPTION OF THE CLEVELAND SHEET.

GEOGRAPHY.

General relations.—The Cleveland atlas sheet is bounded by the parallels of latitude 35° and 35° 30′ and the meridians of longitude 84° 30′ and 85°. The tract embraces, therefore, a quarter of a square degree of the earth's surface. Its dimensions are 34.5 miles from north to south and 28.25 miles from east to west, and it contains 974.64 square miles. The adjacent atlas sheets are Kingston on the north, Murphy on the east, Dalton on the south, and Chattanooga on the west. The tract lies wholly within the State of Tennessee, its southern boundary being about a mile from the Tennessee-Georgia line. It embraces portions of Meigs, McMinn, James, Bradley, and Polk counties.

In its geographic and geologic 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. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as that covered by a single atlas sheet; hence it is necessary to consider the particular tract in its relations to the entire province.

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

The central division is the Appalachian Valley. It is the best defined and most uniform of the three. In the southern part it coincides with the belt of folded rocks which forms the Coosa Valley of Georgia and Alabama and the Great Valley of East Tennessee and Virginia. Throughout the central and northern portions the eastern side only is marked by great valleys—such as the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and Pennsylvania, and the Lebanon Valley of northeastern Pennsylvania—the western side being a succession of ridges alternating with narrow valleys. This division varies in width from 40 to 125 miles. It is sharply outlined on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the 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. The surface differs with the outcrop of different kinds of rock, so that sharp ridges and narrow valleys of great length follow the narrow belts of hard and soft rock. Owing to the large amount of calcareous rock brought up on the steep folds of this 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 which is made up of many minor ranges, and which, under various local names, extends from southern New York to central Alabama. Some of its prominent parts are the South Mountain of Pennsylvania, the Blue Ridge and Catoctin Mountain of Maryland and Virginia, the Great Smoky Mountains of Tennessee and North Carolina, and the Cohutta Mountains of Georgia. Many of the rocks of this division are more or less crystalline, being either sediments which have been changed to slates and schists by varying degrees of metamorphism, or igneous rocks, such as granite and diabase, which have solidified from a molten condition.

The western division of the Appalachian province embraces the Alleghany Mountains and the Cumberland Plateau, 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 a somewhat arbitrary line coinciding with the Tennessee River from the northeastern corner of Mississippi to its mouth, and thence crossing the States of Indiana and Ohio to western New York. 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 oftener it is much cut by stream channels into large or small flat-topped hills. In West Virginia and portions of Pennsylvania the plateau is sharply cut by streams, which have left in relief irregularly rounded knobs and ridges that bear 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 thence descending westward to about the same altitude on the Ohio and Mississippi rivers.

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1,000 feet in Alabama to more than 6,600 feet in western North Carolina. From this culminating point they decrease to 4,000 or 3,000 feet in southern Virginia, rise to 4,000 feet in central Virginia, and descend to 2,000 or 1,500 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 point it descends to 2,200 feet in the valley of New River, 1,500 to 1,000 feet in the James River basin, and 1,000 to 500 feet in the Potomac basin, remaining about the same through Pennsylvania. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2,000 feet.

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

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

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

Topography of the Cleveland area.—The greater portion of the country shown on the Cleveland sheet lies in the Appalachian Valley. The northwest corner of the tract reaches within 2 miles of the Cumberland escarpment, which forms the western limit of the valley district, while its southeastern corner reaches beyond the limit of the valley and includes a small portion of the Appalachian Mountains.

The valley district is characterized by a large number of low ridges and lines of knobs extending in a northeast-southwest direction, parallel among themselves and with the limits of the district on either side. The ridges are formed by narrow strips of rock slightly harder than that on which the intervening valleys are located. The surface has been fashioned by the streams flowing upon it, and the streams have removed the rock partly by solution and partly by carrying off particles of soil. Hence the valleys are upon easily soluble limestone or soft shale, while the ridges are composed of limestone containing a large proportion of insoluble matter or of tough shale and sandstone. The highest of the valley ridges is White Oak Mountain, which extends about 6 miles within the tract and over 50 miles beyond its border toward the southwest. It is formed by beds of hard sandstone in the Rockwood formation. The same beds cap the Texas Knobs, in which they are nearly horizontal, the peculiar circular form of the knobs being due to the accidents of erosion.

The greater altitude and the rugged surface of the southeastern portion of the area are due wholly to the character of the underlying rocks. Beans and Starr mountains are detached outliers of the Appalachian Mountains. They present an abrupt escarpment to the broad valley on the west and a somewhat less regular face to the dissected plateau along the base of the Appalachian Mountains proper. Big Frog Mountain, reaching an altitude of 4,300 feet, belongs to the Unaka chain, which is the main western range of the Appalachians in their southern portion. It is composed of conglomerate beds with shales which have been hardened by pressure and heat until the whole mass resists erosion nearly uniformly. The forms which result from the erosion of such a homogeneous mass are seen to differ widely from those produced where hard and soft beds alternate. Homogeneous masses give rise to high peaks from which radiate many irregular spurs alternating with deep, rugged gorges. Hard beds alternating with relatively soft ones produce, on the other hand, long, straight, even-crested ridges, such as abound in the Appalachian Valley.

The country lying between Beans Mountain and the Unaka chain, when viewed from an altitude of 1,700 feet or over, appears as an undulating plain. The ridges and hills of which it is composed reach nearly to a common level, while the many narrow stream channels are not seen. It may be regarded as a plain in which the stream channels are deeply incised and on which elevations reaching above the common level are embossed.

In the same way the valley district, seen from an altitude of 1,000 feet or over, appears as a broad, undulating plain, nearly all the ridges and hills rising to a uniform level, a little less than 1,000 feet in altitude. Above this level White Oak Mountain and a few of the minor ridges rise some hundreds of feet; below it the Tennessee and Hiwassee rivers flow in valleys 250 feet in depth, while the valleys of the smaller streams are somewhat shallower. In other words, this portion of the Appalachian Valley may be regarded as a plain on which the higher ridges remain in relief and in which the stream channels have been sunk.

These two plains, at varying altitudes and separated by a varying vertical interval, have been recognized at many points in the Appalachian province, and their relations throw much light on its history during later geologic ages. Only a brief outline of this history can be given here. The region formerly stood much lower than it does now, so that the plateau east of Beans Mountain, which has an altitude of nearly 1,700 feet, was near sea-level. The land was worn down by streams flowing upon its surface until it was reduced to an almost even plain, which stretched continuously westward across the present Appalachian Valley, above the top of White Oak Mountain, coinciding nearly with the present surface of the Cumberland Plateau. The hard rocks of Beans Mountain and of the Unaka chain, then as now, formed the principal elevations, while to the westward only here and there a low hill remained where the rocks were unusually hard or where they were protected from erosion by reason of the remoteness of the main streams. Since it was not perfectly reduced, such a surface is called a *peneplain*; and since it was formed near sea-level, the lowest possible level of erosion, it is called a *baselevel peneplain*. After the surface of the land had become reduced nearly to sea-level, this region was elevated from 700 to 1,000 feet and at the same time tilted southward. The streams, which had become sluggish, were at once stimulated to renewed activity, and began rapidly to sink their channels into the peneplain. Erosion progressed most rapidly upon soft rocks, so that in the portion of this area now occupied by the Appalachian Valley, where limestones and shales form a large proportion of the surface, the streams quickly sunk their channels down nearly to the new baselevel of erosion, and then, by broadening their valleys, began the formation of a new peneplain. Portions of the old peneplain were preserved at the higher level, where hard rocks capped the Cumberland Plateau and where tough slates formed the surface east of Beans Mountain, although even here the streams cut their channels down nearly or quite to the new baselevel. After the formation of the second peneplain was well advanced upon areas of soft rocks, the region was again lifted and the streams began cutting their present channels within the last-formed peneplain.

The greater part of the area is drained by tributaries of the Hiwassee River, which crosses it in a very direct course and joins the Tennessee near the western border. A small part is drained by the Conasauga River, whose waters flow south to the Coosa and thence directly to the Gulf. The tributaries of the Hiwassee and Conasauga interlock at their headwaters, and the divide between the two drainage systems is not a sharp line along the crest of a ridge, but is broad and indistinct. It is, furthermore, a little below the lower of the two baseleveled peneplains above described. From a study of this and the adjoining regions it appears probable that during the formation of that peneplain the drainage was very different from that of the present time. Previous to the uplift which caused the streams to cut their present channels in the peneplain, the Tennessee River did not turn westward, as it now does, but continued southward in the Appalachian Valley, across the present divide, directly to the Gulf.

The arrangement of the streams flowing into the Hiwassee shows a close adjustment to the structure of the region. An inspection of the areal-geology sheet shows that the different kinds of rocks are distributed over the surface in narrow strips extending in a northeast-and-southwest direction; the structure sections also show that the ridges are formed by the outcropping edges of strata which resist erosion. Now the Hiwassee River flows directly across these strips of the various formations, while its tributaries flow in directions closely parallel to them, joining the main stream at right angles. They have adjusted themselves to the character of the rocks, sinking their valleys in the soft rocks and avoiding the hard ones, which are left standing as long, narrow ridges or lines of hills. In the same way, the minute details of the drainage are determined by the character of the rocks. Thus, in the region between Rogers Creek and McMinn Ridge there are many beds of hard sandstone alternating with beds of soft shale, all dipping steeply toward the southeast. The tributaries of Rogers Creek flow across these beds, and are analogous to Hiwassee River, while their smaller branches join them at right angles and have cut narrow valleys between the sandstone ridges. Thus, abrupt alternations in the character of the rocks impose rigid conditions on the distribution of the streams. On the other hand, where there is a broad area of rocks which have the same character, the streams are seen to be irregularly branched, as are South Chestuee and Cooyehuttee creeks.

GEOLOGY.

STRATIGRAPHY.

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

The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin. The area of the Cleveland 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.

OCOEE SERIES (PROBABLY ALGONKIAN).

Probably the oldest rocks in the region represented on the Cleveland sheet occur in its southeastern corner, forming Big Frog Mountain and the plateau along its western base. No fossils have yet been found in these rocks, and they are separated by a great fault from rocks of known age, so that their position in the stratigraphic column can not yet be fixed with certainty. But since they bear all the marks of extreme age, it is best to consider them Algonkian until satisfactory evidence to the contrary is found. These rocks have been most carefully studied in the Knoxville area, 50 miles or more northeast of this region, and although they have been traced across that interval, the correlations of the several formations in the two regions must be regarded as only approximate. The formations have so few constant characteristics and undergo so many variations that even with the most careful work one may go far astray in making correlations.

Wilhite slate.—The lowest of the Ocoee formations, probably equivalent to the Wilhite of the Knoxville sheet, consists in the main of dark-blue or black slate. It also contains lenses of gray, siliceous or argillaceous limestone, which merge gradually into the calcareous slate. Associated with the limestones, and evidently derived from them, are beds of coarse limestone conglomerate. Elsewhere in the formation are beds of sandstone and quartz conglomerate, which attain considerable thickness locally. The slate is seen in its unweathered condition only where streams cut rapidly; elsewhere it is deeply decayed, and appears at the surface as a light greenish-yellow schist, with a greasy feel and with the original bedding often obscured by weathering, which brings out prominently the cleavage planes.

Citico conglomerate.—The correlation of this formation with conglomerate in the Knoxville area is attended by even greater uncertainty than in the case of the Wilhite shale, since a conglomerate bed, from its mode of formation, is necessarily variable in character and position, and great extent at a particular horizon is improbable. Within the area represented on this sheet the formation shows a wide variation in thickness, from 500 feet to 1,100 feet or more; and in character, from a coarse, massive conglomerate to beds of fine sandstone or quartzite in sandy shale.

Pigeon slate.—This resembles the Wilhite rather closely, the chief differences being a frequently observed banding and the abundance of interbedded, gray, schistose sandstones of graywacke, and occasionally also conglomerates. It forms the greater part of the plateau at the base of Big Frog Mountain and an oval area east of Minnewauga Creek. In the latter region it contains one persistent bed of conglomerate, which passes into a quartzite and forms a high ridge south of the Conasauga River, within the area of the Dalton sheet.

Thunderhead conglomerate and slate.—This formation, which toward the northeast is composed in the main of massive conglomerate, can be separated in the Cleveland area into three fairly well-marked divisions. The lowest of these, from 800 to 1,000 feet in thickness, retains the characteristics of the formation in the Knoxville area. It is a massively bedded conglomerate, made up largely of blue quartz and feldspar pebbles, which give it a bluish-gray color. It weathers into large, rounded masses, much like some kinds of granite. The middle division of the formation consists of interbedded black slate and schistose conglomerate or sandstone. The slate appears to predominate, especially on weathered sections, but the great abundance of interbedded conglomerate is seen in the fresh stream cuttings. The upper division is also composed of conglomerate and slate, but the slate is relatively unimportant. The conglomerate of this division is generally quite schistose, and is much less massive than that at the base of the formation. The slate of both these divisions usually shows a fine crimping on the cleavage planes, and is intensely black. Unlike the underlying Wilhite and Pigeon slates, the black color does not disappear on weathering.

The Thunderhead conglomerate and slate occur in the Cleveland area only in Big Frog Mountain. The two lower divisions are well exposed in the Ocoee gorge, where they were described by Safford as the type of the Ocoee series. The upper division forms the summit of Big Frog Mountain.

CAMBRIAN ROCKS.

Beans and Starr mountains are formed by a series of quartzites, sandstones, conglomerates, and shales, separated by faults both from the Ocoee rocks on the east and from the fossiliferous valley rocks on the west. No fossils have yet been found in these rocks by which their age can be determined, but they correspond so closely in character with a series of formations in Chilhowee Mountain in which Cambrian fossils have been found that there can be little doubt that they occupy the same stratigraphic position. This group of formations constitutes the Chilhowee series.

Sandsuck shale and Starr conglomerate.—The Sandsuck shale is dark bluish-gray. In some places it is quite sandy, containing many mica scales, and in others it is calcareous, with beds of impure limestone. It generally contains much iron pyrites, which causes it to weather to a rusty yellow and gives rise to many mineral springs. The conglomerate is usually quite coarse, and contains many large feldspar pebbles. It is thickest at the north end of Starr Mountain and at the south end of Beans Mountain, thinning out between these points and entirely disappearing at the Hiwassee River.

Cochran conglomerate.—This consists in the main of clean quartz sandstone, but passes locally into a coarse conglomerate, notably at the north end of Starr Mountain. Unlike the Starr conglomerate, it increases in thickness from the extreme ends of Starr and Beans mountains, reaching a maximum thickness of 1,500 feet at the Hiwassee River, where it forms bold cliffs on either side of the gorge.

Nichols shale.—The Nichols shale is quite uniform in character, a micaceous, sandy shale, blue when fresh, and weathering to yellowish-brown. It also increases in thickness to a maximum at the Hiwassee River, reaching 1,140 feet in Oswalds Dome, while it is less than 500 feet in thickness near the Ocoee River.

Nebo sandstone.—The Nebo sandstone is a white quartzite or quartzose sandstone, which rarely passes into a conglomerate. It forms the upper cliffs in the Hiwassee gorge, and caps the highest portions of Starr Mountain.

Murray shale.—The Murray shale consists of sandy shale interbedded with thin sandstones. Only a very small area of the formation occurs within the district, and this forms the rounded summit of Oswalds Dome.

These six formations constitute the Chilhowee series. They are probably of lower Cambrian age, older than any of the valley rocks to the westward, and mark a period of rapid sedimentation near a shore-line. The materials of which they are composed appear to have come from a land mass toward the east which was made up largely of crystalline rocks.

Apison shale.—The oldest rocks exposed within the limits of the Cleveland sheet whose age has been determined by the fossils which they contain are slightly sandy or clayey shales. Their most striking peculiarity is the brilliant coloring which they display, in sharply contrasted, alternating bands of red, purple, green, and yellow. The thickness of these shales is not known, since they are always limited on one side by a fault, but at least 1,000 or 1,500 feet are exposed in the western part of the Cleveland tract. The name of the formation is taken from Apison, Tennessee, a town situated in the southeastern part of the area represented on the Chattanooga sheet.

Rome formation.—Next above the Apison shale are the sandstones and shales of the Rome formation. They are probably between 1,600 and 2,600 feet in thickness, but on account of the folding and crumpling which the strata have undergone, it is impossible to obtain accurate measurements. They show a decided thickening toward the west, reaching a maximum of about 4,000 feet in the Chattanooga and Ringgold tracts. From 1,100 to 1,500 feet of the lower portion of the formation are composed of alternating layers of sandstone and shale. Passing upward, the proportion of shale gradually increases, so that toward the top only a few thin, siliceous beds occur, which can scarcely be called sandstone. The shales are usually brown or dark olive-green, while the sandstone beds are reddish brown or purple, with occasional thin layers of white quartzite. The sandstone beds show ripple-marks and other signs of deposition in shallow water, but the water was evidently growing deeper, and the succeeding formation contains limestone and calcareous shales, which must have been formed on a comparatively deep sea-bottom, or perhaps on one which was receiving a smaller amount of mechanical sediment from the adjoining land.

Conasauga[1] shale.—This formation is composed, at the base, of thin limestones interbedded with shales, then of yellow or greenish clay-shales, and at the top, of blue, seamy limestone or calcareous shales. Some of the thin beds of limestone, especially those near the lower part of the formation, have a peculiar oolitic structure, as though made up of rounded or flattened grains about a tenth of an inch in diameter. This oolitic limestone is sometimes wanting, and then the boundary between the Rome and Conasauga becomes very indefinite and their separation difficult. The thickness of the Conasauga varies within rather wide limits, though, on account of the great contortions which its beds have suffered, the same uncertainty attaches to their measurement as in case of the two formations beneath. In the valleys of Rogers Creek and Spring Creek the formation is about 600 feet thick. In South Mouse Creek Valley it is from 1,300 to 1,600 feet thick, the upper half consisting largely of seamy limestone. In the valleys of Cooyehuttee and South Chestuee creeks the formation reaches perhaps 6,000 feet in thickness, though this measurement is somewhat uncertain. The formation takes its name from the Conasauga Valley, Georgia, shown on the Dalton sheet.

In the western half of the area the Cambrian rocks come to the surface in a number of narrow parallel strips. Each strip is limited by a fault along its western edge, and there is generally a regular sequence in the order of occurrence of the formations; the older lie next to the fault and the younger occur in successive narrow bands toward the east. In the valleys of North and South Chestuee and Cooyehuttee creeks are broader belts of Cambrian rocks, less steeply inclined than those to the west.

The Rome sandstone forms ridges, varying in height and continuity with its thickness, while the upper part of the Rome and the overlying Conasauga shale produce level or rolling valleys.

SILURIAN ROCKS.

Knox dolomite.—The lowest division of the Silurian, the Knox dolomite, consists of from 3,800 to 4,100 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. Toward the eastern side of the tract some portions of the formation contain, in place of the chert nodules, beds of coarse, calcareous sandstone. Upon weathering, that part of the rock which consists of the carbonates of lime and magnesia is dissolved, leaving behind the chert or sandstone, usually embedded in red clay. This residual material covers the surface to great depth, and the dolomite itself is seldom seen except in the channels of the larger streams.

The Knox dolomite occupies nearly half the surface of the Cleveland tract west of Beans Mountain. It occurs in a large number of rather narrow parallel belts which extend more or less continuously across the tract, alternating with similar belts of Cambrian rocks. The dolomite outcrops are marked by the characteristic rounded chert hills or ridges, which rise 300 or 400 feet above the adjacent valleys.

Chickamauga limestone.—This formation shows a decided change in character between its exposures on the western side and those on the eastern side of the Appalachian Valley. Along the foot of the Cumberland escarpment in the area of the Chattanooga sheet it is a hard, blue, flaggy limestone about 1,000 feet thick. In the northwest-

[1] In the Ringgold, Chattanooga, and Knoxville folios, and in the legend of the geologic sheets of this folio, this name is spelled "Connasauga," but the United States Board on Geographic Names has recently passed on the term and has adopted the form "Conasauga."

ern portion of the Cleveland tract, along the line of White Oak Mountain, it shows an increase in thickness to 2,100 feet, mainly of blue limestone, but containing some mottled, purple and dove-colored, earthy beds. In the southeastern portion of the tract the formation consists of from 400 to 700 feet of blue and mottled limestone, above which are two formations composed of shales, limestones, and sandstones, which are probably equivalent to the upper beds of Chickamauga limestone farther west. The formation is named from Chickamauga Creek, seen on the Chattanooga and Ringgold sheets.

Athens shale.—In the belt extending from the northeastern corner of the Cleveland tract toward the southwest, across the Hiwassee River, a part of the Chickamauga limestone is replaced by the Athens shale. This is from 850 to 1,100 feet thick, in some places sandy, but generally calcareous, dark-blue when fresh, but weathering yellow. It increases in thickness to 2,500 or 3,000 feet along the eastern side of the valley. In its eastern exposures it also changes its character and includes a bed of calcareous sandstone from 250 to 700 feet thick about 500 feet from the base of the formation.

Tellico sandstone.—The Tellico sandstone consists of a rather coarse sand with calcareous and ferruginous cement. When fresh it is often bluish-gray and might be called a sandy limestone, but it always weathers to a red or purple porous sandstone. There is generally no gradation from the unweathered to the weathered rock, the two phases being separated by a sharp line, up to which the calcareous matter is entirely removed and the iron oxidized. This rock is often referred to as the "iron limestone." The Tellico formation is from 300 to 500 feet in thickness and is not sharply separated from the next formation above.

Sevier shale.—This consists mainly of calcareous shale, which is rarely seen in its fresh condition, being generally weathered red or yellow. It contains numerous thin beds of iron limestone resembling the Tellico sandstone, and also considerable beds of marble. The latter is either gray or red, and is highly fossiliferous, while the shales contain comparatively few fossils.

These two formations, the Tellico and the Sevier, generally give rise to a type of country known as the "red knobs." In the region south of Athens they occupy a long, narrow basin or trough whose rim is formed by the iron limestone of the Tellico formation and the central portion by the Sevier shales. The unweathered rocks are very hard, so that erosion depends on the solution of their calcareous cement. This proceeds more rapidly in most of the beds than the residual material can be removed by the streams, and deep, red soil covers the sharp knobs which mark the surface of the trough and particularly its rim.

Rockwood formation.—The Rockwood formation, the highest division of the Silurian, is confined to the western portion of the tract, chiefly to White Oak Mountain and Texas Knobs. It is about 1,200 feet thick in White Oak Mountain. The lower portion consists of purple, calcareous shales and sandstones, which form transition beds from the blue Chickamauga limestone upward into the hard, brown sandstones composing the central part of the Rockwood. Above the latter are sandy shales and a few calcareous beds, with which is associated the iron that gives the formation such great economic importance. Its name is taken from Rockwood, Tennessee.

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 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, 3 or 4 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 it 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.

In middle Tennessee valuable beds of lime phosphate are associated with the Chattanooga black shale, but no phosphate in sufficient quantity to be of commercial importance has been found in East Tennessee. It seems probable that the peculiar conditions favorable for the accumulation of the phosphate were quite local and were entirely absent from the region of the Cleveland sheet.

CARBONIFEROUS ROCKS.

Fort Payne chert.—The Fort Payne chert consists of about 350 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 or shale increases toward the top and gradually replaces the chert. The chert of this formation is readily distinguished from that of the Knox dolomite by the abundant fossils which it contains. It is often made up almost entirely of crinoid stems embedded in a siliceous cement; on weathering, the cement remains as a porous chert filled with fossil impressions.

The formation takes its name from Fort Payne, Alabama. Like the Chattanooga black shale, it is confined, in the Cleveland tract, to a small area on White Oak Mountain. How much farther eastward these formations may have been deposited is not known, but it is possible that they originally extended nearly to the eastern side of the Appalachian Valley.

The Carboniferous formations which are found above the Fort Payne within the area of the next sheet westward probably at one time extended over a portion of the Cleveland tract, but they have been entirely removed by erosion. During the Carboniferous period, or at its close, this region was elevated permanently above sea-level, so that the constructive process of deposition stopped and the 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 the term *anticline* to the upward-bending arches.

A synclinal axis is a line running lengthwise of the synclinal trough, at every point occupying its lowest part, toward which the rocks dip on either side. An anticlinal axis is a line which occupies at every point the highest portion of the anticlinal arch, and away from which the rocks dip on either side. These axes may be horizontal or inclined. Their departure from the horizontal is called the *pitch* of the axis, and is usually but a few degrees. In addition to the folding, and as a result of the continued action of the same forces which produced it, the strata along certain lines have been fractured and the rocks have been thrust in different directions on opposite sides of the fracture; this is termed a *fault*. The rocks are also altered by production of new minerals from the old, a change termed *metamorphism*.

Structure of the Appalachian province.—Three distinct types of structure occur in the Appalachian province, each one prevailing in a separate area corresponding to one of the three geographic divisions.

In the plateau region and westward the rocks are but little tilted from their original horizontal positions and are almost entirely unchanged; in the valley the rocks have been steeply tilted, bent into folds, broken by faults, and to some extent altered to 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 crest of each anticline is very uniform in height, so that for long distances it contains the same formations. The anticline are also approximately equal to one another 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 toward 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 6 or 8 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, halfway 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 becomes 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. The new minerals 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 one another. Rocks containing the most feldspar were most thoroughly altered, and those with most quartz were least changed. Throughout the greater part of the Appalachian Mountains there is a regular increase of metamorphism toward the southeast, so that a bed quite unaltered at the border of the Great Valley can sometimes 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 five sections on the structure sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank strip. The vertical and horizontal scales are the same, so that the elevations represented in the profile are not exaggerated, but show the actual form and slope of the land. These sections represent the structure as it is inferred from the position of the strata observed at the surface. On the scale of the map they can not represent the minute details of structure; they are therefore somewhat generalized from the dips observed 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.

Structure of the Cleveland area.—The complicated structure of this area, shown by the structure sections, 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 folds. 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 sections show five well-marked synclines west of the Ocoee rocks, with a larger number which are less distinct. These are all nearly parallel, crossing the tract in a northeast-southwest direction with slightly curved axes. The White Oak Mountain syncline extends through Texas Knobs and beyond the northern border of the tract. Its western side has a gentle dip eastward, while its eastern side has been overturned, so that it also dips eastward, but much more steeply. In the same way the western side of the Eastanaula syncline has a gentle eastward dip, while the eastern side is vertical (Section C) or overturned (Section A).

The syncline forming Starr and Beans mountains is admirably displayed in the gorge of the Hiwassee River, which cuts directly across it. The massive beds of Chilhowee sandstone making cliffs on either side of the river are seen to dip gently downward from the northwest and southeast sides of the mountain toward the center, the main sandstone bed coming down to the level of the river from a height of 700 feet above it.

The structure of the Ocoee rocks is somewhat obscured by the development of slaty cleavage, which has in some places quite obliterated the original bedding. These rocks have evidently been subjected to horizontal compression similar to that which folded the valley rocks, but the more massive beds have offered greater resistance to the formation of narrow folds. Two rather broad synclines occupy the Ocoee area on either side of Sylco Creek, which is itself located on a narrow anticline.

The anticlines which should occur between the synclines are not so well preserved as the latter, and are seen only in some of the belts of Cambrian rocks.

As shown in the sections, the faults are most numerous between the White Oak Mountain and Eastanaula synclines. The strata within this belt are cut into a large number of narrow blocks which overlap each other, the fault planes all dipping southeastward. Each fault doubtless corresponds in position to an anticline in the original folds, while the overlapping blocks of strata are the western sides of the original synclines, the steep eastern sides having been sheared off by the faults and subsequently eroded.

The Chilhowee formations are separated from the valley rocks by a fault whose plane dips eastward at a low angle. At the north end of Starr Mountain, on the Murphy sheet, it is very nearly horizontal. In the same manner the Ocoee formations are separated from the Chilhowee and valley rocks by a fault plane on which the former have been thrust an unknown distance over the latter.

A fault of very exceptional type for this region is seen in Section B. It extends for a short distance parallel to the axis of the Starr Mountain syncline, and the western side of the syncline has dropped about 1,200 feet vertically.

MINERAL RESOURCES.

The mineral resources of the Cleveland tract consist of iron ore, lead ore, limestone, building and road stone, and brick and tile clay.

Iron ore.—Two varieties of iron ore, which differ widely in appearance and in their mode of occurrence, are found in this area. They are (1) hematite or red fossil ore, and (2) limonite or brown ore.

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

The proportion of iron in the ore usually decreases with distance from the surface, and at considerable depths it becomes simply a more or less ferruginous limestone. 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.

The upper part of the Rockwood formation, which carries the ore, occurs within the Cleveland area only in White Oak Mountain. Its outcrops occupy a narrow strip along the overturned eastern edge of the syncline and a somewhat broader strip along the western edge. The ore has not been worked in the Cleveland area, but a few miles to the southwest, in the Chattanooga area, it has been mined to some extent.

(2) The limonite ore does not occur in this region as a regularly stratified bed, but in irregular surface deposits; hence the limits within which it may occur can not be indicated with the same certainty as in case of the red ore. These deposits, however, are found to be associated with certain groups of strata or with certain structural lines, so that in a general way their distribution may be indicated.

Although iron oxide is very widely distributed throughout the rocks and soil, it is only when it becomes segregated in large quantities and in a comparatively pure condition that it is commercially valuable as an ore. The agency by which the segregation is effected is the percolating surface water, which contains small quantities of weak acids derived from the atmosphere and from decaying vegetation. These acids dissolve the iron disseminated through the rocks. When the solution is exposed to air, either at the surface or in cavities under ground, the iron becomes insoluble and is precipitated as the slimy, yellowish substance often seen about mineral springs. This substance gradually hardens, and where it collects in sufficient quantity, forms a bed of limonite iron ore.

The rocks of the Tellico formation contain a large amount of iron disseminated through their mass. In some places this has been segregated by the action of percolating surface waters so as to form deposits of limonite. This is the case in the area of Tellico rocks a few miles south of Cleveland. The ore occurs as nodules embedded in the deep, red soil. More thorough examination would be necessary to determine its quantity and commercial value.

Along the western face of Starr and Beans mountains, and also along Gee Creek, are deposits of limonite associated with faults. The fractured condition of the rocks along the faults appears to have favored the deposition of the ore, probably by affording an easy passage to the percolating waters which held the iron in solution after it was leached out of the surrounding rocks.

Lead ore.—Small quantities of galena, or lead sulphide, are generally found disseminated through the Cambrian and the Silurian limestones of this region, and in a few places this mineral occurs in sufficient quantity to make mining profitable. It is most abundant near the base of the Knox dolomite or in heavy blue limestones at the top of the Conasauga shale. It occurs in irregular veins penetrating the limestone, which is here much fractured. The ore is mined and smelted at Blue Springs, about 6 miles south of Cleveland.

Conditions similar to those occurring at Blue Springs are found at many points in the area, and it is probable that the ore will be found elsewhere in paying quantities. The areas within which the deposits may be looked for are along the lines marking the base of the Knox dolomite and the top of the Conasauga shale. The positions of these possibly productive lines are easily determined from the sheet showing the areal geology.

Limestone.—The Tellico, Chickamauga, and Knox formations afford an abundance of limestone suitable for lime or flux. A high grade of lime is made from the beds of marble which occur in the Tellico area south of Cleveland.

Building stone.—Stone adapted to architectural uses occurs in nearly all the formations of this region. Sandstones suitable for foundations occur in White Oak and Starr mountains. The latter are quarried in the Hiwassee gorge. At present only those blocks are worked which have become detached from the cliffs above and cover the lower slopes. The stone has a very even grain, and contains enough feldspar to make it work easily. Although it appears quite massive, it splits with remarkable evenness and is particularly well adapted for curbing. A variety of ornamental stones might be obtained from the Tellico and Chickamauga formations, such as brown sandstone and purple or dove-colored mottled limestone.

Clays.—The residual red, blue, or gray clays of the Conasauga, Knox, and Chickamauga are generally well adapted for making brick. These clays, especially those from the Cambrian shales, are quite extensively used in adjacent areas for making drain tile. Some of the highly siliceous clays from the Knox dolomite are well suited for refractory fire-brick, and the manufacture of such brick is carried on near Cleveland.

SOILS.

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

When derived in this way from the disintegration of the underlying rock, soils are called *sedentary*. If the rock is a sandstone or sandy shale the soil is sandy, and if it is a clay-shale or limestone the soil is clay. As there are abrupt changes in the character of the rocks, sandstones and shales alternating with limestones, so there are abrupt transitions in the character of the soil, and soils differing widely in composition and agricultural qualities often occur side by side; and as the attitude of the strata determines the breadth of outcrop of each formation in different places, it also determines the area of the particular soil derived from each.

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

Classification.—The soils of this region may conveniently be classed as follows: (1) Sandy soils; derived from the Rockwood formation, some portions of the Tellico sandstone, the Sevier shale and the Knox dolomite, the Rome sandstone, and the sandy members of the Chilhowee and Ocoee series. (2) Clay soils; derived from the Athens shale, the Chickamauga limestone, and the Conasauga and Rome shale. (3) Cherty soils; derived from the Fort Payne chert and the Knox dolomite. (4) Alluvial soils; deposited by the larger streams upon their flood plains.

(1) Considerable diversity in appearance and quality is found in the soils here classed together as sandy. Those from the Rockwood and Rome sandstones are usually rather thin and rocky, and, occurring on steep ridges, they have little agricultural importance. The soils from the "iron limestone" of the Tellico are deep and rich, but as they occur on the steep slopes of the red knobs, they are deeply gullied as soon as the protecting forest is removed, and in many places the soil has been entirely washed away. The largest area of sandy soil is in the southeastern part of the tract, and is derived from the Chilhowee and the Ocoee rocks. The surface is so much cut up by narrow valleys and ravines that but little tillable land is found. The country is well adapted for grazing, but the practice of burning off the leaves each fall prevents the accumulation of vegetable mold in the soil and also kills all except the coarser grasses.

Since the sandstones occupy the highest land, the overplaced soils — those washed down the steep slopes to lower levels — are mostly sandy. They are especially abundant along the western base of Beans and Starr mountains, where the clay soil of the valley rocks is often wholly concealed by sand derived from the sandstone and shale which form the mountains.

(2) The valleys of this region are due to the presence of narrow belts of soluble limestone or easily eroded shale, and hence, except immediately along the larger streams, they are always occupied by clay soils. The most productive of these are derived from the Conasauga and the Chickamauga limestones and the Athens shale; their distribution coincides with the outcrops of those formations as shown on the geologic map. They have generally a deep-red color, but where the mantle of residual material covering the rock is thin the color is often dark bluish-gray. This is its character in Georgetown Valley, where the largest area of the limestone occurs. The clay soils derived from the Cambrian shales are somewhat less productive. The Conasauga shales and those in the upper part of the Rome make stiff, bluish-gray soils, which are usually thinner than those covering the limestones, the shaly structure often appearing a few inches below the surface.

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

(3) Nearly half the area west of Beans Mountain is underlain by the Knox dolomite. The soil derived from this formation consists of clay, in which the chert is embedded. 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 where 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 are much smaller and are usually on steep slopes, so that its soil is relatively unimportant.

(4) These are confined to the flood plains or bottoms of the Tennessee, Hiwassee, Ocoee, and Conasauga rivers. As these streams are usually bordered on one side by bluffs, their bottoms are comparatively narrow. The soil is a rich, sandy loam, containing a considerable proportion of fine mica scales, derived from the crystalline rocks to the eastward.

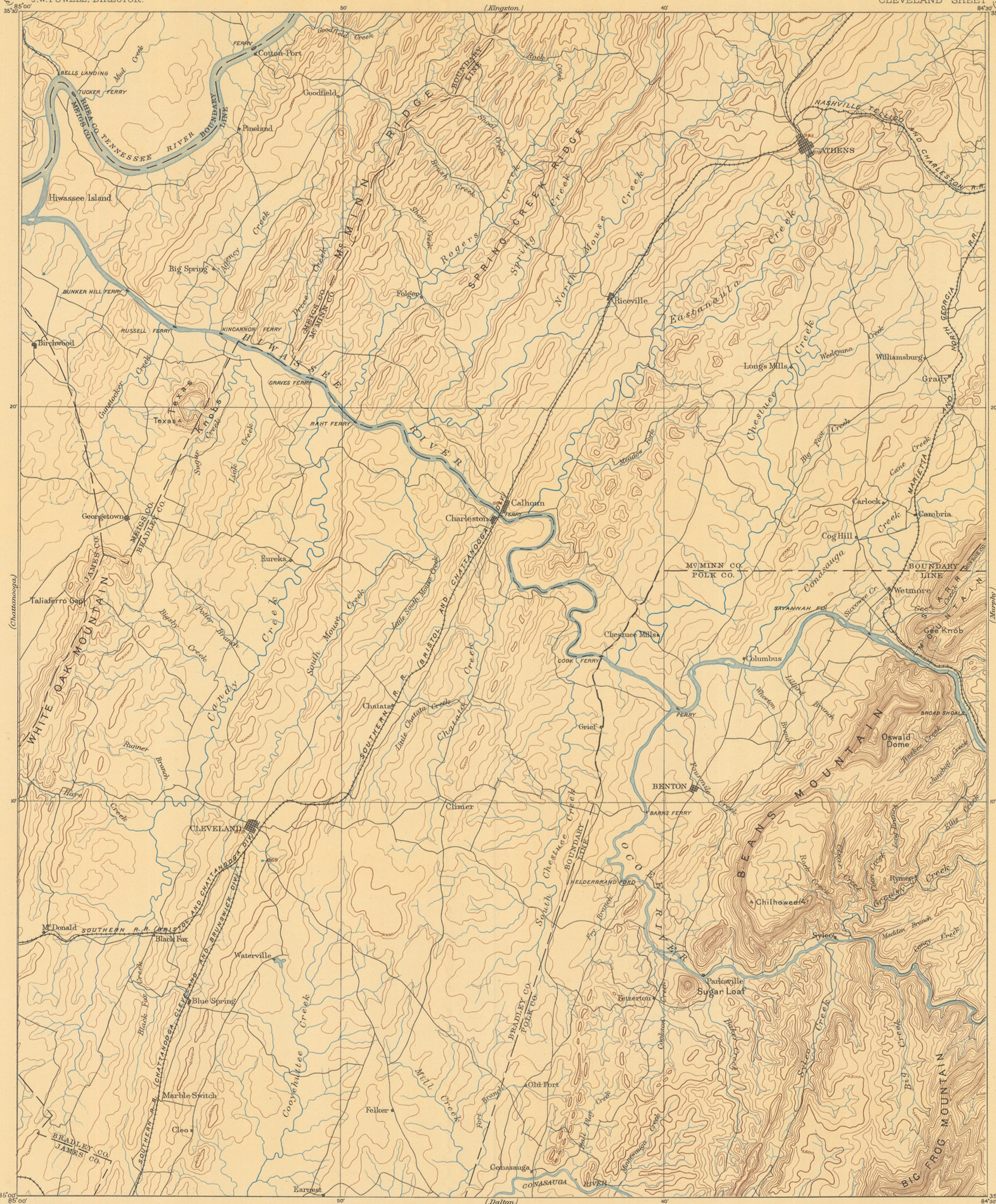
CHARLES WILLARD HAYES,
Geologist.

April, 1895.

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

TOPOGRAPHY

TENNESSEE
CLEVELAND SHEET



LEGEND

RELIEF
(printed in brown)

Figures
(showing exact heights above mean sea-level)

Contours
(showing height above sea, horizontal form and steepness of slopes of the surface)

DRAINAGE
(printed in blue)

Rivers

Creeks

Intermittent streams

Ponds

CULTURE
(printed in black)

Towns and cities

Houses

Railroads

Roads

Bridges

Ferries

Fords

County lines

Triangulation stations

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

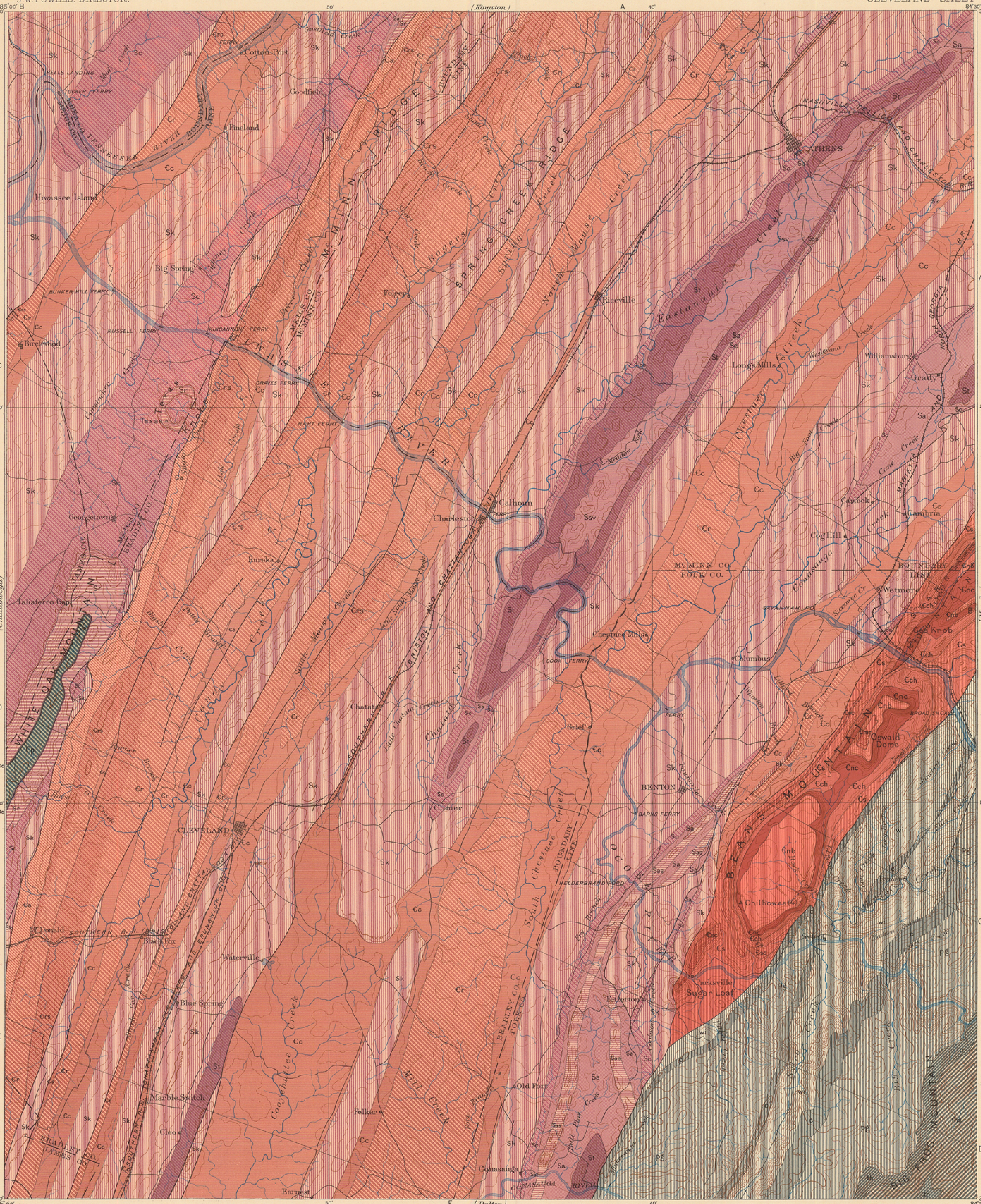
Contour Interval 100 feet
Datum is mean Sea-level

Edition of July 1895.

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

AREAL GEOLOGY

TENNESSEE.
CLEVELAND SHEET



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Triangulation by S.S. Gannett.
Topography by F.M. Pearson. Surveyed in 1884-5.
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Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour Interval 100 feet

Datum is mean Sea level

Edition of July 1895.

G.K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in Charge.
Geology by C. Willard Hayes.
Assisted by M.R. Campbell.
Surveyed in 1889-90.

LEGEND

SEDIMENTARY ROCKS

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

CARBONIFEROUS

- Cp — Fort Payne chert *(interbedded chert and limestone)*

DEVONIAN

- Dc — Chattanooga black shale *(carbonaceous)*

SILURIAN

- Sr — Rockwood formation *(brown sandstone and shale)*
- Ssv — Sevier shale *(blue, calcareous and sandy shale)*
- St — Tellico sandstone *(gray or red, calcareous, ferruginous sandstone)*
- Sa — Athens shale *(blue calcareous shale)*
- Sas — Lentil in Athens shale *(coarse, white sandstone)*
- Sc — Chickamauga limestone *(blue, flaggy or mottled, argillaceous limestone)*

CAMBRIAN

- Sk — Knox dolomite *(magnesian limestone with nodules of chert)*
- Cc — Connasauga shale *(greenish clay-shale with beds of limestone)*
- Cr — Rome formation *(brown or purple shale)*
- Crs — Rome sandstone *(purple, brown, or white sandstone in sandy shale)*
- Ca — Apison shale

CHILHOWEE SERIES

- Cmr — Murray shale *(yellow sandy shale)*
- Cnb — Nebo sandstone *(white quartzitic sandstone)*
- Cnc — Nichols shale *(micaceous sandy shale)*
- Cch — Cochran conglomerate *(quartzite, sandstone, and conglomerate)*
- Cs — Sandsuck shale *(blue, calcareous shale)*
- Csc — Starrs conglomerate *(lentil in Sandsuck shale)*

AGE UNKNOWN

OCOEE SERIES

- th — Thunderhead conglomerate *(containing blue quartz and feldspar; the mass is schistose)*
- ths — Thunderhead slate *(interbedded in the conglomerate)*
- Pg — Pigeon slate *(blue or black slate with beds of conglomerate, showing slaty cleavage)*
- c — Citico conglomerate *(ferruginous conglomerate, sandstone, and sandy shale, showing slaty cleavage)*
- w — Wilhite slate *(blue slate with lentils of sandy limestone and conglomerate, showing slaty cleavage)*

Faults

Sections

B A A B C C D D E E

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

ECONOMIC GEOLOGY

TENNESSEE.
CLEVELAND SHEET

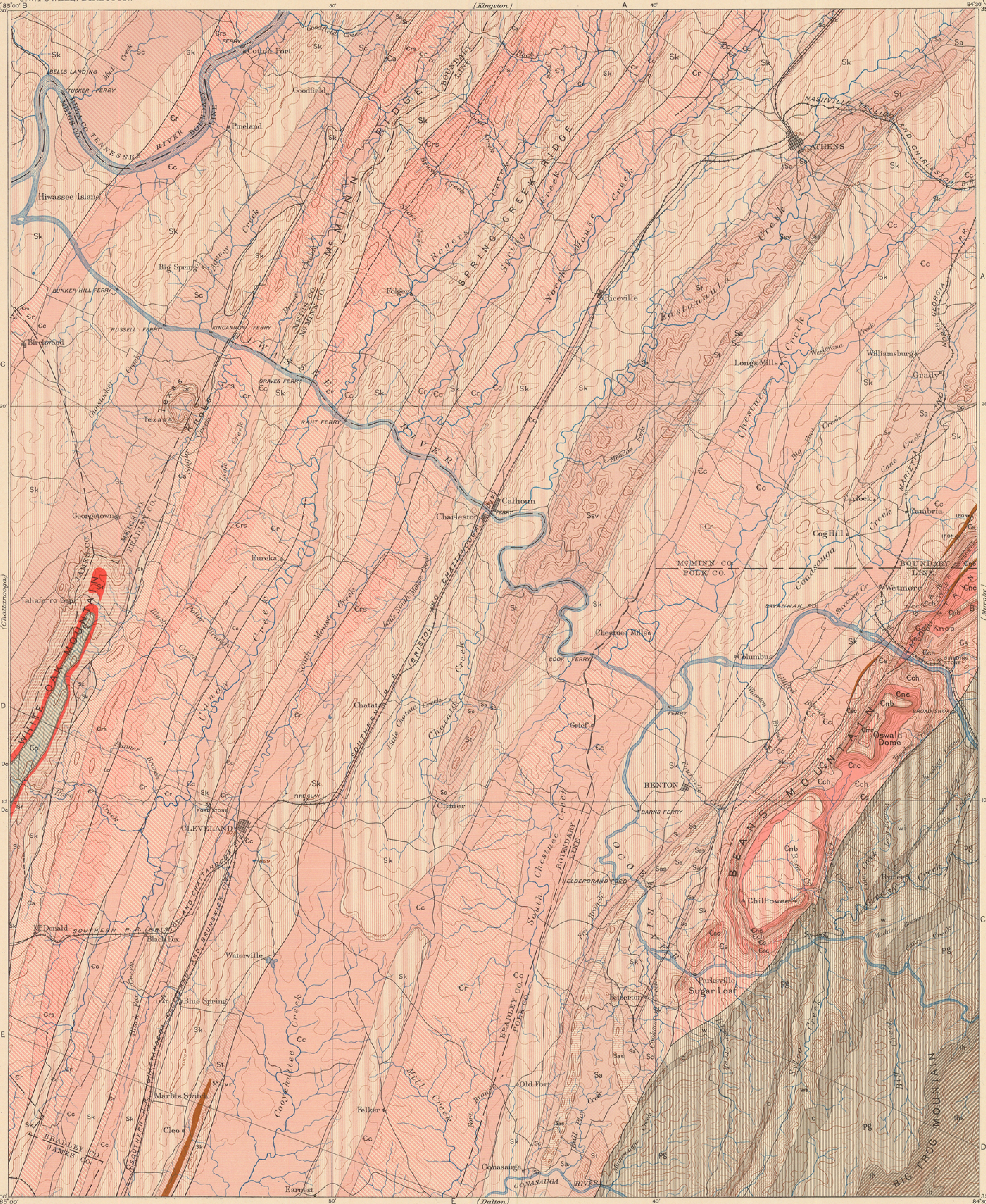
Known productive formations

Red fossil iron ore

Limonite iron ore

SPECIAL SYMBOLS

⚒ Mines and Quarries



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Scale 1:125000

Contour Interval 100 feet

Datum is mean Sea level

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Bailey Willis, Geologist in Charge.
Geology by C. Willard Hayes.
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LEGEND

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- Sas — Lentil in Athens shale (coarse, white sandstone)
- Sc — Chickamauga limestone (blue flaggy or mottled, argillaceous limestone)
- Sk — Knox dolomite (magnesian limestone with nodules of chert)

CAMBRIAN

- Cc — Connasauga shale (greenish clay shale with beds of limestone)
- Cr — Rome formation (brown or purple shale)
- Crs — Rome sandstone (purple, brown, or white sandstone in sandy shale)
- Ca — Apison shale

CHILHOWEE SERIES

- Cmr — Murray shale (yellow sandy shale)
- Cnb — Nebo sandstone (white quartzitic sandstone)
- Cnc — Nichols shale (micaceous sandy shale)
- Cch — Cochran conglomerate (quartzite, sandstone, and conglomerate)
- Cs — Sandsuck shale (blue calcareous shale)
- Csc — Starrs conglomerate (sand or sandy shale)

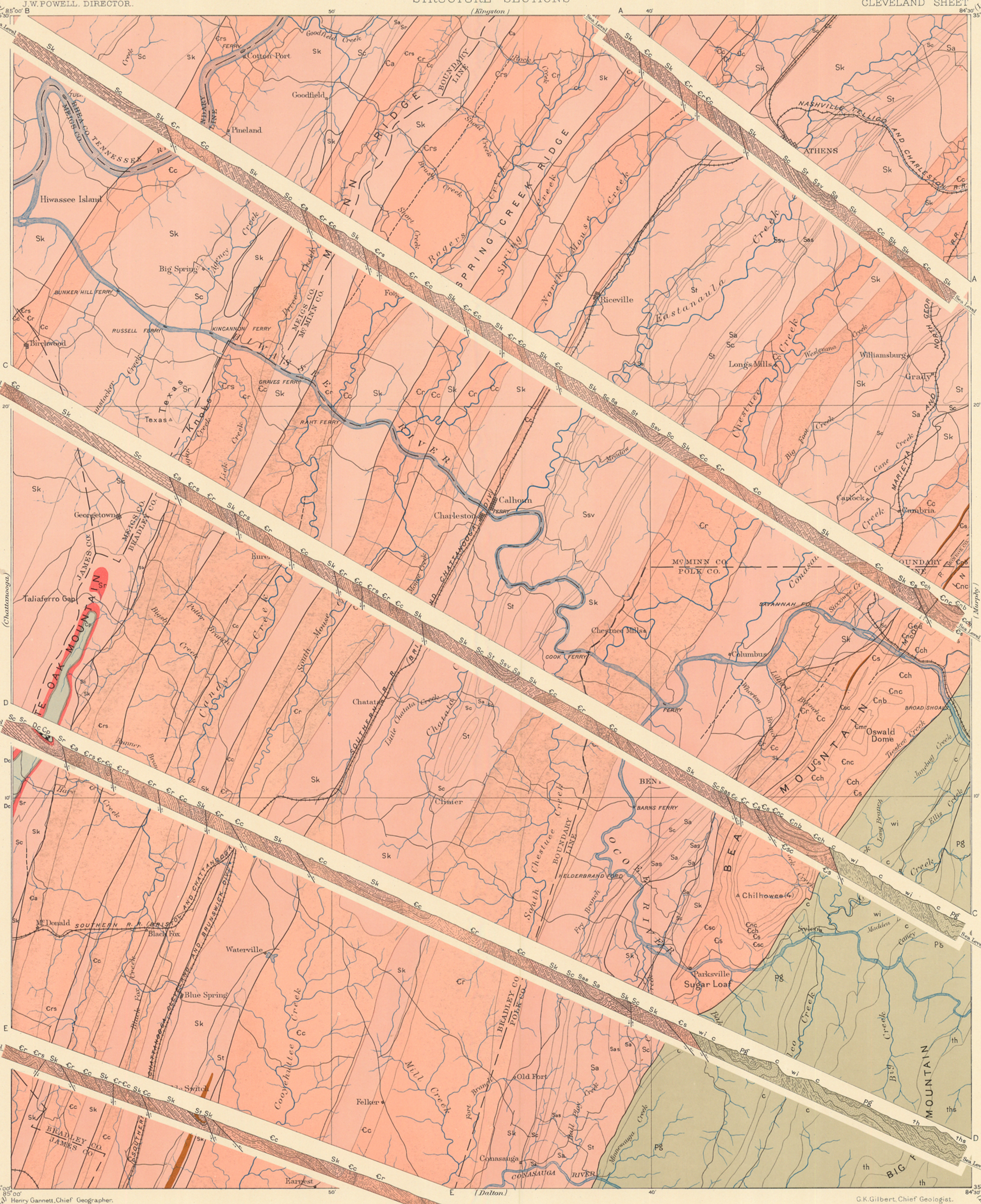
AGE UNKNOWN — OCOEE SERIES

- th — Thunderhead conglomerate
- Th — Thunderhead slate (interbedded in the conglomerate)
- Pg — Pigeon slate
- C — Citico conglomerate
- W — Wilhite slate

Faults

Sections

STRUCTURE SECTIONS



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- Cs — Sandsuck shale *(blue, calcareous shale)*
- Csc — Starrs conglomerate *(lentil in Sandsuck shale)*

AGE UNKNOWN

OCOEE SERIES
- th — Thunderhead conglomerate *(containing blue quartz and feldspar; the mass is schistose)*
- ths — Thunderhead slate *(interbedded in the conglomerate)*
- Pg — Pigeon slate *(blue or black slate with beds of conglomerate, showing slaty cleavage)*
- c — Citico conglomerate *(ferruginous conglomerate, sandstone and sandy shale, showing slaty cleavage)*
- wi — Wilhite slate *(blue slate with lentils of sandy limestone and conglomerate, showing slaty cleavage)*

Faults

Known productive formations

- *Red fossil iron ore*
- *Limonite iron ore*

COLUMNAR SECTIONS.

GENERALIZED SECTION WEST OF SOUTHERN RAILROAD.

SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARB.	Fort Payne chert.	Cp		350+	Cherty limestone and heavy beds of chert.	Knobs parallel with Rockwood ridges. Sandy soil with fragments of chert.
DEV.	Chattanooga black shale.	Dc		20	Carbonaceous shale.	
SILURIAN	Rockwood formation.	Sr		1100–1300	Calcareous sandstone and shale. Hard, brown sandstone. Purple, calcareous sandstone and shale.	High, steep ridges. Rocky, sandy soil.
SILURIAN	Chickamauga limestone.	Sc		1800–2100	Blue, flaggy limestone with some mottled, earthy beds.	Level valleys; shallow residual deposits of red or blue clay. Scanty, blue clay-soil where the limestone is nearly horizontal, and deeper, red clay where it is steeply inclined.
SILURIAN	Knox dolomite.	Sk		3800–4200	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.	€c		500–1600	Blue, seamy limestone. Greenish clay-shale. Thin beds of oolitic limestone.	Level or rolling valleys. Stiff, yellow or bluish-gray clay-soil.
CAMBRIAN	Rome formation. [Rome sandstone.]	€r [€rs]		1800–2600	Greenish or brown shale with thin siliceous layers. Purple, brown, and white sandstone interbedded with sandy shale.	Comby ridges. Rocky, sandy soil.
CAMBRIAN	Apison shale.	€a		1500+	Sandy shale or clay-shale in brightly colored bands.	Rolling valleys. Stiff clay-soil.

GENERALIZED SECTION EAST OF BEANS MOUNTAIN.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
OCOEE SERIES—AGE UNKNOWN.	Thunderhead conglomerate.	th		300±	Massive conglomerate interbedded with black slate.	Top of Frog Mountain. Rich, black soil.
OCOEE SERIES—AGE UNKNOWN.	Thunderhead slate.	ths		1500±	Black slate with beds of conglomerate and sandstone, generally schistose.	Steep slopes. Thin, sandy soil.
OCOEE SERIES—AGE UNKNOWN.	Thunderhead conglomerate.	th		800–1000	Massive conglomerate of blue quartz and feldspar.	Ridges. Rocky soil.
OCOEE SERIES—AGE UNKNOWN.	Pigeon slate.	pg		?	Blue or black slate with local beds of sandstone and conglomerate, generally schistose.	Plateau of erosion deeply dissected by stream channels. Thin, sandy soil.
OCOEE SERIES—AGE UNKNOWN.	Citico conglomerate.	c		500–1100	Conglomerate and sandstone with beds of sandy shale.	
OCOEE SERIES—AGE UNKNOWN.	Wilhite slate.	wi		?	Blue slate with lenses of quartz-conglomerate, sandy limestone, and limestone conglomerate.	

GENERALIZED SECTION EAST OF SOUTHERN RAILROAD.

SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
SILURIAN	Sevier shale.	Ssv		850+	Calcareous shale and sandstone with beds of marble.	The "Red Knobs." Deep-red, sandy clay.
SILURIAN	Tellico sandstone.	St		300–500	Ferruginous and calcareous sandstone; "iron limestone."	
SILURIAN	Athens shale.	Sa		850–2500	Calcareous shale with local beds of sandstone and limestone.	Valleys.
SILURIAN	Athens sandstone.	Sas				Short, sandstone ridges with sandy soil.
SILURIAN	Athens shale.	Sa				Valleys. Scanty, blue clay-soil where the limestone beds have low dips, and deeper, red clay where they are steeply inclined.
SILURIAN	Chickamauga limestone.	Sc		300–650	Blue, flaggy limestone.	
SILURIAN	Knox dolomite.	Sk		4200–4400	Magnesian limestone, white, gray, or light-blue; generally granular and massively bedded, containing nodules, layers of chert, and beds of coarse sand.	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.	€c		1100–6000	Blue, seamy limestone. Greenish, calcareous clay-shale and beds of limestone. Thin beds of oolitic limestone in shale.	Level or rolling valleys. Stiff, yellow or bluish-gray clay-soil. Valleys with low ridges. Thin, sandy clay-soil.
CAMBRIAN	Rome formation. [Rome sandstone.]	€r [€rs]		1600 [1100]	Brownish shale. Purple, brown, or white sandstone interbedded with sandy shale.	Comby ridges. Rocky, sandy soil.
CAMBRIAN	Murray shale.	€mr		200+	Sandy shale.	High, steep ridges; western outliers of Great Smoky Mountains. Rocky, sandy soil.
CAMBRIAN	Nebo sandstone.	€nb		250–600	White quartzite or quartzose sandstone.	
CAMBRIAN	Nichols shale.	€nc		440–1140	Micaceous, sandy shale.	
CAMBRIAN	Cochran conglomerate.	€ch		200–1500	Quartzite, quartzose sandstone, and conglomerate.	
CAMBRIAN	Sandsuck shale.	€s		750–1900	Blue shale, locally calcareous.	Steep mountain-slopes. Thin, sandy soil.
CAMBRIAN	Starrs conglomerale.	€sc		0–660	Conglomerate, generally feldspathic.	
CAMBRIAN	Sandsuck shale.	€s		?	Blue shale.	

CHARLES WILLARD HAYES,
Geologist.

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:

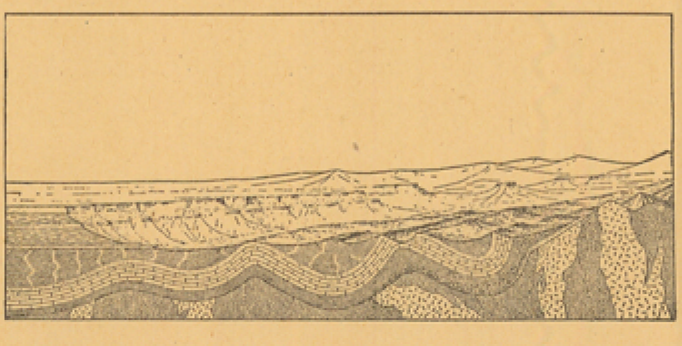

Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

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:

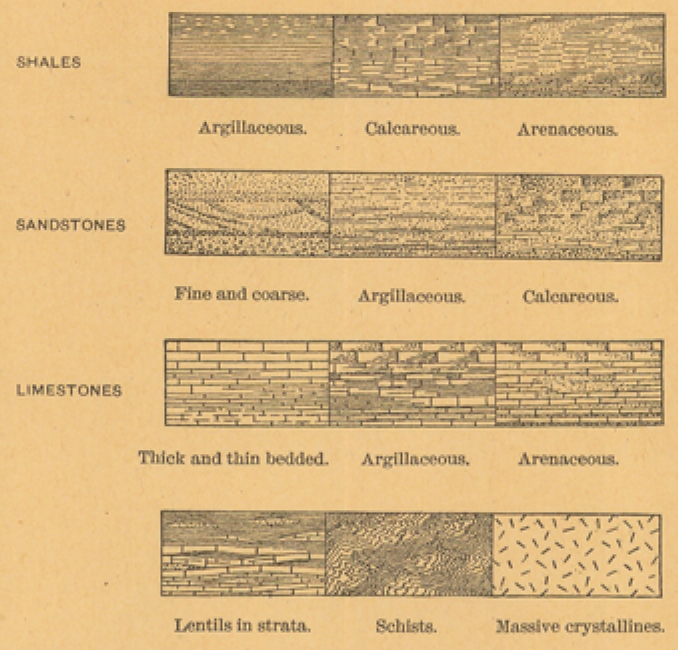

Fig. 3. Symbols used to represent different kinds of rocks.

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.