DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J.W. POWELL, DIRECTOR

GEOLOGIC ATLAS

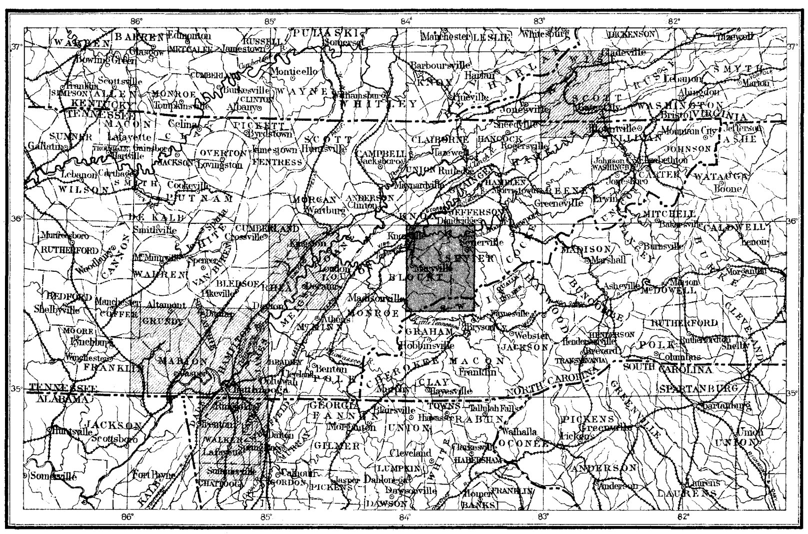
OF THE

UNITED STATES

KNOXVILLE FOLIO

TENNESSEE - NORTH CAROLINA

INDEX MAP



SCALE: 40 MILES - 1 INCH

AREA OF THE KNOXVILLE FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION   TOPOGRAPHY   AREAL GEOLOGY   ECONOMIC GEOLOGY   STRUCTURE SECTIONS

COLUMNAR SECTIONS

FOLIO 16   LIBRARY EDITION   KNOXVILLE

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

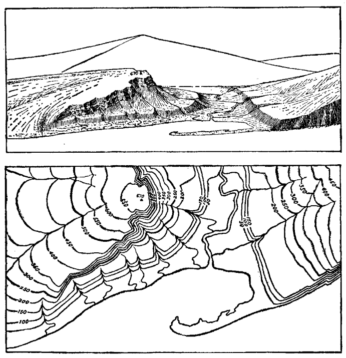


Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAP.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

USES OF THE MAPS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

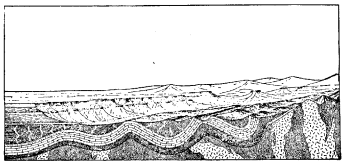


Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

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

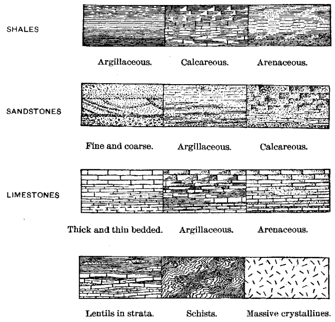


Fig. 3. Symbols used to represent different kinds of rocks.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

J. W. POWELL,
Director.

DESCRIPTION OF THE KNOXVILLE SHEET.

GEOGRAPHY.

General relations.—The region represented by the Knoxville atlas sheet lies chiefly in Tennessee, but includes also a portion of North Carolina. It is included between the parallels 36° and 35° 30′ and the meridians 84° and 83° 30′, and it contains 1,000 square miles, divided between Knox, Sevier, and Blount counties in Tennessee and Swain County in North Carolina.

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 individual sheet in its relations to the entire province.

Subdivisions of the Appalachian province.—The Appalachian province may be subdivided into three well-marked physiographic divisions, throughout each of which certain forces have produced similar results in sedimentation, in geologic structure, and in topography. These divisions 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 Cumberland Plateau and the Alleghany Mountains and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the Mississippi River as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian Valley by the 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 worn down. In the southern half of the province the plateau is sometimes extensive and perfectly flat, but it is oftener much divided by streams into large or small areas with flat tops. In West Virginia and portions of Pennsylvania the plateau is sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion, and the surface is now comparatively low and level, or rolling.

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. It 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.

Geographic divisions of the Knoxville area.—Within the limits of the Knoxville sheet two geographic divisions appear, dividing the area into equal parts. The division northwest of Chilhowee Mountain is part of the Great Valley of East Tennessee; the division southeast of that ridge is part of the mountain belt of North Carolina and Tennessee. The entire region is drained by the Tennessee River and its tributaries—the Holston, French Broad, Little Tennessee, Little Pigeon, and Little rivers. With the junction of the French Broad and Holston rivers above Knoxville the Tennessee River begins. Little Pigeon and Little rivers are wholly within the area of this sheet; the others extend far beyond it.

The streams of the mountain district fall rapidly from their source down to about 1,000 feet above sea, at which level they emerge into the valley. Their valleys are deep, and the slopes rise continuously from narrow bottoms to the divides. The streams of the valley fall from 1,000 feet at the valley border to 760 feet at Knoxville. The larger streams are sunk in sharp, narrow troughs 100 to 200 feet below the adjacent country. Most of the surface of the valley stands at an altitude of 1,000 to 1,100 feet; above this various ridges project from 100 to 500 feet.

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

Erosion of the valley formations has produced a series of long ridges, separated by long valleys, which closely follow the belts of rock. Where the formations spread out at a low dip the valleys or ridges are broad, and where the strata dip steeply the valleys are narrower. Each turn in the course of a formation can be seen by the turn of the ridge or valley which it causes. Each rock produces a uniform type of surface so long as its composition remains the same; with each change in composition the surface changes form. The Knox dolomite illustrates this feature well. Near Maryville it has little chert and lies at nearly the same altitude as the Nolichucky shale and Maryville limestone. The amount of chert in the dolomite steadily increases northeastward and the cherty ridges become more and more prominent, until southeast of Dumpling Creek they stand from 300 to 400 feet above the valley of Nolichucky shale and Maryville limestone. Ridges of the Citico conglomerate show similar but more rapid changes, and, from an elevation of 2,800 feet where the formation is thickest, drop to 1,500 feet in a few miles as the formation thins out.

The topography of the mountain district is as unlike that of the valley as its rocks are unlike those of the latter. None of the regularity of the valley ridges appears, and only the Knox dolomite, the Citico conglomerate, and the Chilhowee formations produce the same surface forms in all places. This is due partly to the more irregular folding of the rocks and partly to the less definite separation of the soluble and insoluble rocks into thin beds. The northwestern part of the district consists of the long, straight ridge of Chilhowee and four open valleys or "coves" hemmed in by irregular ridges and mountains. The coves were produced by erosion of the Wilhite slate and Knox dolomite, while the harder rocks around them were not reduced. The effect of solubility is well shown in Cades Cove. The floor of this consists largely of limestone, yet scarcely an outcrop appears, while in the less soluble rocks around it the streams flow over innumerable ledges.

The southeastern part of the district is composed of the crest of the Smoky Mountains, from 4,500 to 6,500 feet in height, with a series of outliers and spurs gradually descending in all directions. The hard conglomerates which maintain these elevations are thick and not divided into narrow belts, so that they do not control the directions of the streams and the divides wander very irregularly. The divides of the mountains and ridges are usually smooth and round; many of them have large areas of easy slopes, which are called "balds" when bare of trees. The easy arch of the crests soon gives place, however, to steep ravines and narrow v-shaped valleys. From the crests the spurs branch and fall rapidly to the streams, being here and there studded with knobs and with frequent cross spurs in both directions. The height and steep slopes of these mountains have proved very effectual barriers to their settlement. Their great width has also aided in keeping the peoples on either side quite distinct and independent of each other.

GEOLOGY.

STRATIGRAPHY.

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

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

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

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

A different period of depression, of unknown age, left its record in the rocks of the mountain district. During their deposition the sea encroached farther on the land than at any other period, and the activity of erosion and deposition then is shown in the coarseness and frequent changes of the deposits.

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

The rocks of this area are all sedimentary in origin, and comprise most of the varieties of limestones, shales, slates, sandstones, and conglomerates. They range in age from the earliest known sediment of the Appalachians nearly to the end of the Paleozoic, including the Cambrian, Silurian, Devonian, and Carboniferous periods. Carboniferous rocks are but scantily represented here; Devonian rocks have as good a representation as in any region south of Virginia; while the Cambrian and lower part of the Silurian are better developed than in almost any other area.

The rocks lie in three distinct areas or groups of widely different age. The valley half of the sheet comprises the formations from lower Cambrian to Carboniferous, most of them being of later age than the Chilhowee series. The Chilhowee strata appear only in Chilhowee Mountain; they are lower Cambrian. The mountain district is covered, excepting the four coves, by the Ocoee formation, the age of which has not been finally determined.

The valley rocks are mainly calcareous, the Chilhowee rocks mainly siliceous, and the mountain rocks siliceous and feldspathic. In the valley the rocks lie in long narrow belts and are often repeated by the different folds. In the mountains the folds are less continuous, so that the belts of rock are more irregular in shape. The greater size of the formations also gives less complex and narrow belts. The rocks will be described in order of age.

ROCKS OF UNKNOWN AGE.

The "Ocoee" group of rocks, forming the mountain areas, are indicated upon the map as of unknown age. In earlier publications they have been considered to be Cambrian and to lie under the Chilhowee rocks, but there is ample evidence which separates them from the Cambrian series, though not sufficient to fix their age; they are therefore mapped as unknown. From the base upward the series is divided into the following formations: the Wilhite slate, the Citico conglomerate, the Pigeon slate, the Cades conglomerate, the Thunderhead conglomerate, the Hazel slate, and the Clingman conglomerate.

Wilhite slate.—This formation is the lowest bed of the Ocoee series, and is a bluish-gray or black argillaceous slate. Its upper portion becomes calcareous and contains frequent beds of limestone and limestone conglomerate. The formation is well shown on Wilhite Creek, in the area of the Mount Guyot sheet, and is named from that occurrence. Its thickness varies from nothing on the south side of Wears Cove to 800 feet on the south side of Tuckaleeche Cove; ordinarily it is from 300 to 400 feet thick. It is confined for the most part to the lower portions of the mountain district, forming bands about the limestone coves and being especially prominent on the Little Pigeon River. A number of small patches occur along the Little Tennessee River also.

The formation varies little in character from place to place except in its upper 100 feet, the chief change being the addition of a little calcareous matter to the argillaceous mud forming the slate in its southwestern areas. Within the Little Pigeon basin thin sandy seams give the rock a banded appearance. In the upper beds there is the greatest variety, and beds of limestone and limestone conglomerate appear and disappear. These deposits are local in nature and form lenses in the slate. In Tuckaleeche Cove some of the lenses are only 6 inches thick and a foot long; on the Little Tennessee they are at least 50 feet thick and several miles long. Usually they are distinct from the slates, but sometimes the slate and limestone grade into each other gradually, with no sharp boundary. Rarely the pebbles of the limestone conglomerate are embedded directly in the slate. The limestones and conglomerates are plentiful only near the Little Tennessee River, but along the Little Pigeon a few occurrences are known.

The limestones are usually massive blue beds, and, excepting occasional round sand grains, are quite pure. In some areas, for instance, near the mouth of Abram Creek, considerable siliceous impurity occurs besides the sand. Other beds are gray, dove, whitish-gray, black, and mottled blue.

The conglomerate is composed of fragments of limestone of every variety shown in the massive beds. Most of the pebbles are rounded, others are sharp and angular and can be traced step by step from a solid bed which becomes more and more broken until the fragments are entirely separate and scattered. They vary in size from mere grains to pebbles 6 or 8 inches in diameter. Fragments of the conglomerate, broken in its turn, are also found in the conglomerate. The production of these conglomerates from the limestone where it lay shows that the limestone was exposed to erosion after its formation, and continued so for some time during the deposition of the conglomerate.

The matrix of the conglomerate is calcareous, rarely slaty, and consists of the fine waste of the massive limestone, just as the pebbles are its coarse waste. Considerable numbers of round sand grains and a few sandstone and quartz pebbles are found locally.

Slight alterations have taken place in the Wilhite slate, more particularly around Wears and Tuckaleeche coves. The change consists of schistosity and cleavage, produced in the slate by squeezing and stretching. These changes are quite widespread but do not materially alter the appearance of the rock.

Owing to the slightly calcareous nature and fine grain of the Wilhite formation it invariably yields to erosion and occupies low ground. Soils formed by its decay are deep and strong, and consist of yellow and brown clays and loams with a few slate bits scattered through them. Nearly their whole extent is available for agriculture, and is the more valuable on account of the scarcity of tillable land in the mountain district. They are loose and well drained in spite of their gentle slopes.

Citico conglomerate.—This formation has about the same range as the preceding one, around the coves and near the Little Tennessee and Little Pigeon rivers. It is entirely siliceous, and varies from fine white sandstone to coarse quartz conglomerate, with a few thin beds of sandy slate. Its name is given on account of the good development of the formation on Citico Creek, Monroe County, Tennessee. The changes from fine to coarse sediment are very sudden and are accompanied by changes in thickness from 50 to 800 feet, the coarse beds being the thickest. The coarse deposits are not limited to one area, but are quite generally distributed. Along the northwestern edge of the belt they are more common than on the southeastern side. At the eastern end of Millers Cove the quartz pebbles are coarse, the largest being an inch and a half in diameter. From that size they diminish to minute sand grains. The average thickness is about one-third of an inch. Near Gatlinburg, Sevier County, the gray sandstone is occasionally cross-bedded.

Nine-tenths of the pebbles of the conglomerate are white quartz, and to them is due the gray or white color of the rock. Pebbles of fine black quartz-porphyry and of Wilhite slate are widely spread in small numbers, and a few pebbles of feldspar also occur. On the Little Tennessee River and on Caney Creek (a branch of Little Pigeon River) the conglomerate contains pebbles of blue limestone. In the latter place there are found also pebbles of a granite such as covers large areas in the Smoky Mountains, shown on the Mount Guyot sheet.

There was little assortment of the pebbles according to size when the formation was deposited, and coarse and fine were buried alike in a gray siliceous matrix of sand grains. They represent the gravel deposits along the shores of that time, where rivers and waves moved the large pebbles and slower currents carried off the fine mud. The cross-bedded sediments give additional evidence of shallow water at that time, and the pebbles of Wilhite slate show that formation to have been out of water in places. Since its deposition the conglomerate has suffered scarcely any change of form except in folding, although in occasional areas the rock has been squeezed and a small amount of mica has been developed.

Decay of this formation is very slow, as might be expected from the insolubility of its materials. Lines of sharp ridges and frequent ledges mark its course. Its soil is thin and full of sand, quartz pebbles, and fragments of the rock, and supports but a scanty growth of timber and underbrush. When cleared and exposed to the weather the soil loses what little clay it has and becomes worthless.

Pigeon slate.—This slate occurs in the same general area as the preceding formations, but is more extensive on account of its greater thickness. It forms one large area south and west of the coves and a smaller, nearly continuous one north of Wears Cove. Its name is derived from Little Pigeon River, in Sevier County, which drains much of the area of the formation.

The formation consists of a thick mass of slate of great uniformity. When fresh the rock is bluish-gray, when weathered it becomes a dull-yellow. It is mainly argillaceous, occasionally banded by thin seams of coarser, siliceous material. A few thin beds of fine white sandstone occur at various parts of the formation, notably toward the top, but they are not at all prominent. Its uniformity is as pronounced along its range as it is from top to bottom, and no differences can be seen from one area to another. In thickness it varies from 1,300 to 1,700 feet. On account of the lack of distinctive beds it is difficult to give precise figures, but many sections in separate areas fall between those limits.

Little alteration has taken place in the materials of this slate since its formation. During the production of the folds there was a general development of cleavage, the planes of which dip from 20° to 60° southeast. It has not altered the composition of the rock materially, and its chief effect is to obscure the partings along the bedding and to supplant them by cleavage partings.

Of the materials of the slate—quartz, feldspar, mica, and argillaceous matter—only the feldspar is subject to ready solution. Its particles are frequent, but are so small that even when decayed the texture of the rock is not so much impaired that it can not resist further wear. Consequently, the formation makes high ground in all cases. Owing to the great thickness of the formation and the width of its areas, it has produced no definite system of topography, but occurs in a network of interlacing ridges and knobs. The crests are always rounded, but narrow, and the streams lie in deep, steep-sided cuts.

The soils of this formation are always thin and are interrupted by frequent outcrops along the divides. On the flanks of the ridges the wash from the higher ground produces excellent soil, where the slopes are not too steep for cultivation, and the small creek bottoms are supplied with a deep and rich soil. Natural growths of timber are very light and scrubby except in the hollows and bottoms.

Cades conglomerate.—This formation appears in a belt forming high spurs and outlying mountains along the northwest side of the Smoky Mountains. It consists of thick beds of slate, sandstone, graywacke, and conglomerate, and is named for its prominence in the high butts around Cades Cove. The apparent thickness of the formation is approximately 2,400 feet. This may be an overestimate, because there are no well-marked beds by which faults or folds can be detected with certainty, and the formation may possibly be repeated. The deep cover of soil and waste also makes it more difficult to determine the order and thickness of the beds.

The materials of the formation are of nearly the same nature in all its beds, and consist of quartz, feldspar, and argillaceous matter. These minerals make conglomerates, sandstones, or slates, according to their coarseness. The beds of fine slate are black and grayish-black; the other beds are of various shades of gray. Few of the beds are over 50 feet in thickness, that of most being from 6 inches to 3 feet. Their rapid alternation shows many changes in currents and supply of sediment at the time of their deposition.

The formation has undergone some alteration since its deposition. This is most noticeable in the slaty beds, and consists of the growth of a small amount of very fine mica, usually parallel to the bedding. Various thin beds of sandstone and conglomerate have also been squeezed and a small amount of new mica has grown from the broken feldspar. In the massive beds this alteration has been sufficient to obliterate the faint bedding and render it difficult to determine the true dip.

Considerable elevations are caused by this formation, owing to its bulk and hardness, but they are dwarfed by the greater heights of the Smoky Mountains. The crests of its divides are broad and round, and the slopes are steep on account of their height above the streams. Soils of the formation are brown and black loams of good depth, especially on the side slopes and bottoms of ravines, and support a heavy growth of timber and underbrush. Along the divides soils are more scanty and interrupted by rock; nevertheless, they support a good growth of timber. The fertility of the soil is due partly to the potash from decay of the feldspathic material, and partly to the lightness caused by the large percentage of quartz grains.

Thunderhead conglomerate.—This formation underlies the greater part of the mountains. It consists of a heavy series of conglomerate, graywacke, and sandstone, with many small partings of slate. The name is taken from Thunderhead, on the North Carolina-Tennessee boundary. The general color of the rocks is gray; the slate beds are black or dark-gray when fresh, but are too small to affect the color of the mass materially. On account of the scarcity of outcrops and the similarity of the beds, it is difficult to determine the thickness of the formation, but it is believed to be about 3,000 feet.

There is little variety in this formation, and no division into beds of distinct character can be discovered. All the slate beds are the same in composition; the coarse beds vary only in proportion of quartz and feldspar. Many of the coarser beds contain fragments of blue quartz in addition to the usual white quartz and feldspar, and small fragments and patches of black slate very often occur in the mass of the conglomerate.

During the deposition of this formation currents were strong and sediment plentiful. Many changes of both currents and sediments occurred, yet their general character persisted for a very long time and resulted in the accumulation of the heaviest conglomerate bed in the Appalachian province.

This conglomerate has been somewhat altered, in the same manner as the Cades conglomerate. Schistosity has been developed by squeezing during folding, and mica has grown from the material of the feldspar. The amount of new mica increases toward the east to such an extent that on the south side of the Smoky Mountains the slates become fine mica-schists.

The extremely siliceous nature of the formation, and its coarseness and great thickness, enable it to resist erosion so well that few of its summits fall below 4,000 feet. In the Smoky Mountains, seen on the Mount Guyot sheet, it forms several summits of 6,600 feet. Its divides are broad and smooth and contain large areas of fairly level ground, which are celebrated as cattle ranges. These, when bare of trees, are clothed with thick grass, and, under the name of "balds," are widely known. The side slopes steepen gradually in approaching the ravines, but are never precipitous. The woods are usually open and free from underbrush. On the main summits the trees are often stunted by the wind, and resemble orchards in their regularity; in ravines and on occasional summits patches of nearly impassable underbrush occur.

The soils are deep and strong even on the divides, while in the ravines and bottoms ledges are extremely rare. The soils are brown and black loamy clays and loams, and support a strong growth of plants able to stand the cold due to the altitude. On the soils washed from this formation the heaviest growths of timber in these mountains are supported. The feldspathic beds decay soonest and cause the fertility of the soil; the more siliceous beds remain almost unweathered, and their large blocks strew the adjacent slopes and clog the streams for many miles.

Hazel slate.—This formation occurs in two basins in the southeastern part of the area, mainly in North Carolina. Its name is chosen because of the frequent occurrence of the slate on Hazel Creek, in Swain County, North Carolina.

The formation is chiefly black slate; many beds of thin sandstone and conglomerate also occur in the slate, but they are far inferior to the slate in amount. The thickness appears to be about 700 feet, but most of the sections are so poorly exposed and so much folded that the exact thickness can not be ascertained. Many sections appear to show less than 700 feet, and variations may occur. In some of the outcrops near the State boundary the original sedimentary banding can be seen, but ordinarily the bedding is obliterated by the later squeezing and the development of mica. In the more eastern areas the rock is always a fine black schist, consisting of parallel flakes and grains of quartz, feldspar, mica, and iron oxide. Its outcrops usually show little effect of weather, but long exposure reduces it to a yellow micaceous schist or slate. On account of its insoluble and compact nature it forms some of the sharpest divides in the entire mountain region. Several occur along the State boundary which are too narrow to allow the passage even of a trail. Where it does not form the divide its influence on topography is masked by the heavy conglomerates on either side, and it appears only as a steeper slope.

On divides its soil is a strong black clay of great fertility, but it is very scant and unimportant. Elsewhere its surfaces are covered with wash from the adjacent conglomerates.

Clingman conglomerate.—This conglomerate is developed only in the southeastern part of the mountain district. It is named for its occurrence on Clingman Dome, seen on the Mount Guyot sheet. In this point it forms the second highest peak in the Appalachian province. It is precisely the same in composition as the Thunderhead conglomerate, and none of its beds can be distinguished from those of the former. The only noticeable difference is the smaller development of slate beds in the Clingman conglomerate. This formation occurs only in the deepest synclines, and the thickness left from erosion is 1,000 feet. Of its original thickness no estimate can be formed, nor can it be said what beds, if any, followed it.

Like the Thunderhead conglomerate, its crests are broad, smooth arches, and its soils support a heavy growth of timber.

CAMBRIAN ROCKS.

Sandsuck shale.—This shale is the lowest bed occurring in the group of Chilhowee Mountain, and is of lower Cambrian age. It occurs chiefly at the eastern end of Chilhowee Mountain, and forms many small areas. Its name is given on account of its occurrence on Sandsuck branch of Walden Creek, in Sevier County. Since it appears only on the crests of anticlines and along faults, its total thickness is not known, but it is at least 1,000 feet thick. There are no variations in the formation, and it consists of bluish-gray shales with lighter-gray bands; when weathered the shales are dull-yellow in color. Owing to their softness they invariably occupy valleys or steep slopes protected from erosion by other, harder beds. The areas of the Sandsuck shale are small, so that its soils are usually modified by sandy wash from the adjacent formations. They are, however, of fair depth and are well drained and light. Like all of the other formations occurring in Chilhowee Mountain, this shale is unaltered.

Cochran conglomerate.—This formation is a massive bed of conglomerate, the heaviest of this series. It is mainly shown at the northeast end of the mountain, but occurs also in a small strip southwest of Montvale Springs. There are three parts to this formation in most places: an upper sandstone, 600 to 900 feet thick; a bed of bluish-gray shale, ranging from 100 feet to nothing at the end of the mountain; and a bed of coarse conglomerate, from 500 to 700 feet thick. These beds are of the same character throughout, and the only variation is the increase in thickness toward the southwest. The sandstone is composed of round grains of white quartz; the shale is argillaceous, micaceous, and slightly sandy; and the conglomerate is composed of quartz and feldspar embedded in a matrix of argillaceous sand. A small bed of reddish-brown sandstone occurs near the base of the white sandstone. The pebbles of the conglomerate are well rounded and worn, and range in size from three-fourths of an inch down to mere grains. There is little assortment of the fragments, and coarse and fine are alike embedded in a fine matrix. The general color of the rock is a greenish-white, which, as well as the large proportion of feldspar, distinguishes the rock from the Citico conglomerate. These irregularities of material are typical of beach deposits, but the hypothesis of such an origin is hardly borne out by the regularity of sequence and thickness over the whole length of the mountain.

Weather attacks the feldspathic portions of the conglomerate, but the coarse quartzose material resists decay so well that the formation always occupies high ground. Two types of crest are formed: the sharp divide of the upper sandstone, shown in the high bench at the end of the mountain, with the interrupted knobs lying immediately northwest; and the rounded summits of the conglomerate lying along Waldens Creek, together with the buttes southwest of Montvale. The course of the formation is marked by extensive cliffs, and ledges are very frequent. Soils are poor and thin and are filled with coarse quartz pebbles, so that only a scanty growth of timber and vegetation is supported.

Nichols shale.—This shale occupies a belt usually on the northwest face of the mountain, but it is interrupted for a few miles near Montvale Springs. It is named from its occurrence on Nichols branch of Walden Creek. The formation consists of grayish-blue shales, sandy, micaceous, argillaceous, and slightly calcareous, and is uniform in composition from top to bottom and from end to end. It ranges in thickness from 550 to 800 feet, thinning toward the southwest.

Surfaces formed by this shale are of little value. They are usually steep slopes leading up to sandstone divides, and the soils are impoverished by the wash from the sandstone. Occasionally the shale for a short distance forms a divide which is nearly bare of soil. It lies upon the prominent bench at the northeast end of Chilhowee Mountain and affords fair farming land.

Nebo sandstone.—This bed occurs in the nearly continuous areas along the top of the mountain, and is named from Mount Nebo Springs, which are situated upon it. It is a uniform bed of fine white sandstone, which contains only grains of fine white sand and small quartz pebbles. In appearance and thickness it is constant throughout the area of the mountain. Its massive beds and close grain make it very slow to decay, and it forms the highest summits of the mountains. Soils produced by the sandstone are very thin and sandy and support only the scantiest vegetation. Frequent cliffs and ledges follow its course, and its fragments are scattered far down the mountain side, clogging every stream for miles.

Murray shale.—This bed is the last shale of the series, and differs from the preceding Nichols shale in no respect save that of thickness. Its name is derived from good exposures on Murray branch of Walden Creek. It measures 300 feet in all places where fully exposed, and uniformly consists of sandy micaceous and calcareous shale. The bed is of little account either as a soil producer or in affecting the topography. Small depressions between sandstone crests or steep slopes mark its course. This bed contains the only fossils discovered in this series, which were found on the east side of Little River Gap and on the crest of the mountain above Montvale Springs. These fossils are lingulellæ and trilobites.

Hesse sandstone.—Two areas are occupied by this formation: one an isolated knob south of the end of Chilhowee, the other extending from the southwest end of Millers Cove past the boundary of the sheet. In this latter area it forms a high table-land known as the "Flats." South from Montvale Springs it forms a notched line of sharp peaks on the southeast side of the mountain. Everywhere it is a fine white sandstone, formed of round quartz grains. Its thickness is unknown, for it lies only in synclines whose upper portions have long since disappeared; upwards of 500 feet yet remain. Like the Nebo sandstone, its crests are sharp and rugged, marked by many ledges and bounded by cliffs. Its soils are usually thin and poor, though where they are flat for considerable areas, as in the "Flats," there is an accumulation of good soil. Even this, however, is readily exhausted unless carefully used.

This sandstone is the last of the series in this mountain. Each formation is sharply distinguished from the adjacent formations, and the stratigraphic relations are continuous throughout the mountain. In no other place in the Appalachians is the lower Cambrian series so thick or so clearly defined. The Chilhowee series is separated from the lower Cambrian strata of the valley by faults, which prevent any observation of the relations originally existing between the two groups of beds. In Chilhowee the middle and upper Cambrian strata up to the Knox dolomite are wanting. The Knox dolomite is represented partly by shales. But in the valley a great thickness of middle and upper Cambrian strata occurs. The oldest of the strata in the valley are, however, probably younger than those of Chilhowee, although they are of lower Cambrian age.

Apison shale.—The Apison formation and the Chilhowee series never come in contact. This formation is a series of brightly colored red, green, and brown sandy shales, deposited in thin beds with rapidly changing colors. It occurs in a belt along the northwest side of Bays Mountain, and it is named from its occurrence at Apison, James County, Tennessee. Its general aspect is the same throughout this belt, and no special beds can be detected. Its measurement is therefore difficult, especially since it is very much folded and contorted, but a probable thickness of 900 to 1,000 feet can be given.

Its surface consists of knobs, here and there rising sharply above the neighboring limestones for several hundred feet. Since the materials composing it—argillaceous mud and quartz sand—are not readily soluble, it forms but shallow soils, and frequent rock outcrops appear. Little use is made of its surfaces, and the growth of timber is poor and thin.

Beaver limestone.—This formation is limited to a single narrow belt on the northwest side of Bays Mountains. It is a bed of massive blue limestone about 300 feet thick and shows no variations in this small area. It is named from its occurrence in Beaver Ridge, north of Knoxville.

The carbonate of lime which it contains causes it to dissolve readily, and it forms a small depression next to Bays Mountain. Its soil is a deep-red clay, but it is covered and modified by Rome sandstone wash and is of little importance.

Rome formation.—Two areas of this formation occur in this region: a small one north of Bays Mountain, and a long one forming Bays Mountain. The formation is named from its good development at Rome, Georgia. It is made up of red, yellow, and brown sandstones and red, brown, and green sandy shales, most of the sandstones being at the bottom. Few of the beds of sandstone are over 2 or 3 feet thick, and none are continuous for any great distance. They are repeatedly interbedded with shale, and when one dies out another begins, higher or lower, so that the result is the same as if the beds were continuous. The shales are very thin, and small seams of sandstone are interbedded with the shale. Brilliant colors are as common in these as in the Apison shale. A few of the sandstone beds contain lime in such amounts as almost to become limestones.

The series is thinnest in Bays Mountain, where it comprises 250 feet of sandy shale at the top and 550 to 700 feet of sandstone and sandy shale at the bottom.

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

The topography of the formation is quite marked and uniform. Decay makes its way slowly along the frequent bedding planes, and the rock breaks up into small bits and blocks without much internal decay. Ledges are rare on the divides, and its ridges are rarely very high. They are especially noticeable for their even crests and for frequent stream gaps. In some areas this latter feature is so prominent as to secure for them the name of "comby" ridges. The lower beds, on account of their more sandy nature, are most evident in the topography.

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

Rutledge limestone.—The Rutledge formation occurs in a belt passing south of Bays Mountain and north of Maryville. It is named from its fine development in the valley of Rutledge, in Grainger County, Tennessee. As a whole the strata are limestone, but there are many beds of green and yellow calcareous shale toward the base, which form a passage into the Rome formation. The limestones are massive, and range in color from blue to dark-blue, black, and gray. In the belt of Cambrian strata north of Knoxville the formation is not present as a limestone but as calcareous shale which can not be distinguished from the Connasauga and Rogersville shales. The thickness of 450 feet diminishes to 350 feet toward the southwest end of the belt.

The highly calcareous nature of the rock causes it to weather easily, and it invariably forms low valleys or slopes along Rome sandstone ridges. Underground drainage through sinks is a common feature of this limestone. Deep, rich, red clay covers its areas, and outcrops are very few. The soils of the formation are very rich and strong and are among the most valuable of the soils that are derived directly from rock in place. It is somewhat injured, however, by the rather frequent wash from the Rome sandstone.

Rogersville shale.—This shale, like the preceding limestone, can be distinguished in only one zone within the boundaries of this sheet. In the area north of Knoxville it can not be separated from the Rutledge shale. It consists chiefly of bright-green, argillaceous shales, with occasional beds of thin, red, sandy shale, which occur mainly north of Maryville; northeast of Bays Mountain it is divided by a bed of massive blue limestone. It ranges from 180 to 220 feet in thickness.

Numerous remains of trilobites are found in the shales, which show the formation to be of middle Cambrian age.

Excepting the middle bed of limestone, the formation is little soluble. It decays down the numerous partings into thin green scales and flakes, which are gradually broken up by rain and frost. Outcrops are frequent, but the rock is soft and forms only small knolls in the limestone valleys. Its soils are always thin and full of flakes of shale, and are rapidly drained by the numerous partings of the shale. When carefully protected from washing they are fairly productive.

Maryville limestone.—This limestone is present in the belts north of Knoxville and southeast of Bays Mountain. It receives its name from its great development near Maryville, in Blount County. The formation consists of massive blue limestone, with little change in appearance except frequent earthy, siliceous bands and occasional grayish-blue and mottled beds. In thickness it ranges from 150 feet north of Knoxville to 350–400 feet near Maryville and 500–550 feet on

Dumpling Creek. Fossils are rare in these beds, but occasional trilobites are found. During the early part of the deposition of this limestone in the Bays Mountain belt shales were deposited north of Knoxville that can not be separated from the shales of the Rogersville epoch.

The limestone decays readily by solution and forms a deep, red clay. From this many ledges of limestone, especially of the upper beds, protrude. Along Dumpling Creek the upper beds of the limestone make a series of hills between narrow valleys; elsewhere the whole formation lies in valleys. Its soils are clayey and are deep and strong, forming some of the best farming lands in the State.

Nolichucky shale.—This formation is shown in the same belts as the preceding one, and is the most common of the Cambrian formations. It is named from the Nolichucky River, along whose course in Greene County the shale is well exhibited. The formation is composed of calcareous shales and shaly limestones, with beds of massive blue limestone in the upper portion. When fresh, the shales and shaly limestones are bluish-gray and gray in color; but they weather readily to various shades of yellow, brown, red, and green. Over the greater part of this region the formation is most nearly uniform and contains only yellow and greenish-yellow shale. Passing northeast along Bays Mountain, the beds of limestone begin to be more prominent and the shales more highly colored. The thickness of the formation remains quite constant at 450–500 feet.

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

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

SILURIAN ROCKS.

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

The Knox dolomite is the most important and widespread of all the valley rocks. Its name comes from Knoxville, which rests upon one of its areas. The formation consists of a great series of blue, gray, and whitish limestones and dolomites. Many of the beds are banded with thin, brown, siliceous streaks and are very fine-grained and massive. Within these beds are nodules and masses of black chert, locally called "flint," and their variations are the only changes in the formation. The cherts are most conspicuous in an east-and-west belt across the northern part of the area. The formation is 3,500 feet thick, and varies but little from this.

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

While in most places limestone was forming during the middle of this epoch, a different deposit was accumulating in the region now forming Millers Cove, in Chilhowee Mountain. This consists of sandy shales and thin sandstones of bright-red, green, and yellow colors, which are about 1,500 feet thick, are interbedded with dolomite at their contact, and lie in synclines upon the dolomite. These beds are varieties of the formation near shore, where a large amount of sand and mud was deposited instead of calcareous matter. They weather deeply, but their siliceous nature enables them to form knobs of considerable height.

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

Chickamauga limestone.—This formation occurs in many areas in the northwestern part of the sheet. It is named for its occurrence on Chickamauga Creek, Hamilton County, Tennessee. It consists of massive blue and gray limestones, shaly and argillaceous limestones, and variegated marbles. These beds are all very fossiliferous, and fragments of corals, crinoids, brachiopods, and gasteropods are so abundant as sometimes to make most of the bulk of the rock. Variations are greater in this formation than in any of the valley rocks, both in thickness and appearance. Northwest of Knoxville it consists of 500–700 feet of blue limestone and gray argillaceous limestone beneath 250–500 feet of marble. East and south of Bays Mountain this formation is represented by a thin belt of blue and gray argillaceous limestone, sometimes 50 feet thick and often absent entirely. Between these extremes there is every variation of thickness and composition.

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

As would be expected from the amount of lime that it contains, the formation always occupies low ground. Decay is rapid by solution, but varies greatly in the different varieties of rock. The marbles and poorer limestones weather deeply into a rich, red clay, through which occasional ledges appear. Many of the massive blue limestones invariably make ledges, and are regular features of the surface of the formation upon slopes protected from weather by the overlying Tellico sandstone. Over the shaly varieties the soil is less deep and strong, and frequent outcrops occur. This is especially the case in the broad areas of the formation southeast and east of Knoxville, where the limestone is quite argillaceous. There the rock is very scantily covered with clay, and on many hills most of the surface is bare rock. Curious knots and eye-shaped lumps of weathered limestone are very characteristic of this type of rock, which is covered by natural growths of cedar. Soils of the marble and heavy limestones are deep and very fertile, forming some of the best lands in the Great Valley. Those derived from the shaly limestones are also very rich whenever they attain any depth, but they need careful tillage to prevent washing.

Athens shale.—The Athens shale is developed in a long belt southeast of Bays Mountain and a smaller area near Sevierville. The shale is named for its occurrence at Athens, McMinn County, Tennessee. It is everywhere composed of blue and black shales, which do not vary in appearance. The black shales are found at the bottom of the series and contain lingulæ and numerous graptolites. The blue shales gradually replace the black shales in passing up through the series, and when fresh consist of thin, light-blue, shaly limestone. This formation was deposited at about the same time as the Chickamauga limestone in areas farther northwest, and is the argillaceous sediment accumulated near shore, while the purer calcareous beds gathered farther away.

Exposure to weather soon removes the lime and reduces the rock first to bluish-gray, then to dull-yellow and grayish-yellow, shale. The fine grain and soluble nature of the shale cause it to form valleys throughout this area. Its soils are thin on hillsides, but wash down and accumulate to considerable depths on the low ground. They consist of yellow and brown clays and are too compact and cold to be of great value. When they are mingled in the lower ground with sand from the adjacent Tellico sandstone they become more open and light and produce better crops.

Tellico sandstone.—Areas of this sandstone are quite common, the principal one lying a few miles northwest of Chilhowee Mountain. The excellent section cut by Tellico River, in Monroe County, Tennessee, gives the formation its name. The strata consist of bluish-gray and gray calcareous sandstones and sandy shales closely interbedded. These weather by solution of the lime into a porous sandy rock with a strong-red color, so pronounced as to give the name "red knobs" to many of its areas. The beds vary considerably in thickness and in the amount of sandy material. Northwest of Knoxville the formation consists mainly of 250 feet of calcareous and sandy shales, with one bed of sandstone. In the high knobs south of Knoxville it is about 500 feet thick and is composed of calcareous sandy shales with many interbedded sandstones; a few small beds of marble are included here and there. This character is maintained over all the areas except in the "slate knobs," or northeast part of the main belt, where the sandy element is less pronounced and the rock is uniformly gray in color. In the southwestern part of this belt beds of red sandstone again appear, and become more prominent toward the southwest.

Decay of this formation is rapid, so far as solution goes, and outcrops are few, but the sandy skeleton remains and is sufficiently hard to cause considerable eminences. Its areas are marked by rounded knobs and ridges, which are deep-red where the soil is exposed, and are repeatedly traversed by streams. The large proportion of sand and the general steepness of slopes render the soil liable to wash. Only the lower portions of the slopes are much tilled, therefore, although the soils are everywhere deep, light, and fairly fertile.

Sevier shale.—This formation appears in three basins: one passing through the city of Knoxville, one about 7 miles southeast of Knoxville, and another immediately northwest of Chilhowee Mountain. It derives its name from its great development in the last-named area, in Sevier County. As a whole it is a thick series of calcareous yellow shales, weathered from light-blue shaly limestone. It is similar to the Athens shale, and with it occur occasional beds of gray limestone or variegated marble and beds of sandy shale and calcareous sandstone. In the Knoxville belt the series is thin, but it has the typical sequence of strata. Southeast of Knoxville the formation has at the base 200–300 feet of gray argillaceous limestone, gray and variegated marble, and shaly limestone, followed by 1,000–1,200 feet of calcareous yellow shales with occasional thin limestone beds and sandy shales. North of Montvale Springs there are two heavy beds of sandy shale and calcareous sandstone interbedded with light-blue shaly limestone, as shown in the columnar section. The shales are precisely like the Athens shale, and the sandstones are very similar to the Tellico sandstone. Passing northeast the sandstones diminish in thickness and are more interbedded with shales; so the sequence, which is evident near Montvale Springs, is very indefinite near Little Pigeon River. Fossils similar to those of the Chickamauga limestone are common in the limestones and marbles of this formation.

These different beds produce surfaces and soils similar to those of the Athens shale and Tellico sandstone, but are slightly less well defined. The description of the latter formations, therefore, applies to these beds.

Bays sandstone.—The same areas that contain the Sevier shale contain also the Bays sandstone. The name is given for its frequent outcrops in the Bays Mountains of Hawkins and Greene counties, Tennessee. It is everywhere a red calcareous and argillaceous sandstone, changes in its composition being very slight. In the Knoxville area the lime becomes more important than in the others, and the rock is often an impure limestone. Near Montvale feldspathic grains appear in the rock, and not far toward the southwest they are quite an important element. The red color, however, is very marked and persistent. Great variations occur in its thickness, which in the northeastern areas ranges from 300 to 500 feet, and in the southeastern from 1,100 feet near Montvale Springs to 300 feet near Little River, the latter measure including a central bed of shale. This change is common in shore deposits, where the volume of sediment diminishes rapidly as the source becomes more remote.

Owing to the amount of calcareous matter that it contains, the Bays sandstone, although so thick, never stands at great altitudes. Its surfaces are low knobs of no definite shape or arrangement Decay is never deep, but the sandy residue is loose and crumbling and does not resist wear. Soils are invariably thin on this rock, and it outcrops more than any other except part of the Chickamauga limestone. On account of their shallow and sandy nature these soils are of very little value except in the small hollows where the waste has collected. These support some fairly good timber, but are very limited in extent.

Clinch sandstone.—This formation is represented by 6 feet of white sandstone in a locality 5 miles southwest of Little River, near Chilhowee Mountain. The outcrop is the only occurrence of the formation within the area of the atlas sheet, and is too small to be shown upon the map. It is of interest solely as the representative of a great formation in Clinch Mountain, whence it takes its name.

DEVONIAN ROCKS.

Chattanooga black shale.—This formation, whose name is taken from its occurrence in Chattanooga, Tennessee, is found within the Knoxville area in a single narrow belt along Chilhowee Mountain. This belt is its only occurrence on the east side of the Great Valley in Tennessee or Virginia, and is notable on that account. Some of its outcrops contain fossil lingulæ. In this region it is a bed of black carbonaceous shale, with no variations of composition. Its upper layers for a few feet are interbedded with the Grainger shale, and it is unconformably deposited on the Silurian rocks. On account of its softness it is usually much covered with wash from adjacent formations and its thickness is hard to determine, but it ranges from 30 to 50 feet, being thinnest west of Montvale. It is not extensive, and neither its surface forms nor its soils are of importance.

Grainger shale.—Only one area of Grainger shale, that along Chilhowee Mountain, occurs in this area. Its name is derived from Grainger County, Tennessee, where it is well displayed. It comprises gray shales and shaly and flaggy sandstones, with white sandstone and red and brown sandy shales at the top; and this series is everywhere present. All beds below the white sandstone are bluish-gray when fresh, and weather out green and greenish-gray. Among the lower sandy shales are fossils such as fenestellæ, lingulæ, and brachiopods; in the bottom flags are many impressions of the supposed seaweed, *Spirophyton cauda galli*. These beds retain their thickness of 1,100 feet with great regularity.

The siliceous matter in these rocks causes them to make a ridge of considerable height, which has a straight, even top. The crest is composed of the white sandstone bed, and its flanks are composed of the sandy shales. Owing to the hardness of the white sandstone, the slopes of the formation are steep and strewn with sandstone fragments. These features, added to the poverty of the soil, on account of its thin and sandy nature, make this formation of little agricultural value.

CARBONIFEROUS ROCKS.

Newman limestone.—This formation, which derives its name from the great outcrops in Newmans Ridge, Hancock County, Tennessee, is the latest of the valley rocks occurring in this region, and it lies in the same basin that holds the Grainger shale. Here the formation has 100 feet of massive blue limestone at the base, followed by 500 feet of gray calcareous shale and shaly limestone. No variations are observable in this area. The bottom limestone is largely made up of fragments of crinoids, corals, and brachiopods, of Carboniferous age. The soluble nature of the formation causes it to form the valleys of this district, where it maintains a slightly rolling surface; elsewhere it makes high ridges. It forms a red clay when decayed, but this is rarely seen on account of the wash of Chilhowee sandstone and Grainger sandstone. Its soils, which are naturally good, are thus made nearly worthless.

STRUCTURE.

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

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

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

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

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

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

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

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

Structure sections.—The sections on the structure sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual dips of the strata are shown. These sections represent the structure as it is inferred from the position of the strata observed at the surface. On the scale of the map they can not represent the minute details of structure, and they are therefore somewhat generalized from the dips observed in a belt a few miles in width along the line of the section.

Faults are represented on the map by a heavy, solid or broken line, and in the section 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 Knoxville area.—The rocks of this area have been disturbed from the horizontal position in which they were deposited, and bent and broken to a high degree. The lines along which the changes took place run in a northeast-southwest direction, and the individual folds or faults run for great distances in quite straight lines. On the accompanying sheet of sections the extent of these deformations is shown. The position of the rocks under ground is calculated from the dips observed at the surface and the known thickness of the formations.

Two regions exist in this area in which the types of deformation differ materially. These are nearly the same as the topographic and geologic divisions, the mountain district and the valley district, dividing along the synclinal axis passing north of Sevierville and Chilhowee.

The rocks of the valley have been thrown out of their original position by folds and by faults. These are distributed over the whole area and are of the same type. The folds are long and straight, are usually closely folded, and are often squeezed so far that the rocks on the western side of the anticlines were bent up until vertical and then pushed beyond the vertical. The dips vary from flat to vertical and thence to 50° overturned; the sides of the average fold dip 40° to the southeast and 80° or 90° to the northwest. The arch 8 miles east of Knoxville (Section B) and the basin north of Sevierville (Section A) illustrate the open folds. Close folds appear near Maryville (Section F), and close folds broken by faults appear northwest of Knoxville (Section D). The rocks varied greatly in their manner of yielding to pressure. Massive rocks with few bedding planes, such as Knox dolomite and the sandstones of Chilhowee Mountain, bent in great curves. Thin bedded shales and sandstones, like Athens shale and Rome sandstone, were puckered and contorted, because their thin beds bent and slipped easily on their bedding planes. The railroad cuts in Tellico sandstone south of Knoxville show such complex folds, and the anticline 6 miles southeast of Knoxville (Sections B and D) shows the gradual replacement of the easy curves in the dolomite by the close folds in thinner beds. Two general anticlinal areas are present: one in the Cambrian belt 2 miles northwest of Knoxville, the other along the line of Bays Mountain. Two corresponding synclinal areas occur: one between Knoxville and Bays Mountain, and the other in the Silurian and Carboniferous rocks passing northwest of Chilhowee Mountain.

Associated with the anticlinal uplifts are the faults, eight in number. Like the broken arches from which they are formed, the faults are long and straight. They are situated on the northwestern side of the anticlines; at that point the horizontal pressure is square across the beds, so that they were least able to resist it, and broke there, if anywhere. The planes of the faults are nearly parallel to the beds on the southeast side of the folds, so that, when erosion along the break has been so great as to wear away the upper parts of the fold, only rocks with the southeastern dip remain. This is illustrated in Section B, north of Dumpling Creek. The planes of the faults dip from 20° to 60° southeast, most of them being about 45°. The amount of displacement varies from nothing to 5 miles, the latter being the least measure of the fault immediately southeast of Montvale Springs. On most of the faults the displacement is from 1 to 3 miles. The arch 8 miles east of Knoxville (Sections B and D) illustrates the formation of a fault from a fold by the gradual overturning and final breaking of the western beds. Similar developments are shown in the two faults in the Silurian rocks northwest of Bays Mountain.

The second structural province of this region lies southeast of a line along Chilhowee Mountain, passing entirely through the area of the sheet. In this province the rocks have been deformed not only by folding and faulting, as in the valley, but also by metamorphism, or alteration of their minerals. The folds and faults themselves have many features not shown in the valley. Only three faults occur: two along Chilhowee Mountain and one in the southwest corner of the area. These faults dip at a much less angle than those of the valley, and sometimes are nearly flat; their planes are parallel to the strata, as in the valley. The large fault passing east of Millers Cove is unlike the valley faults in having no direct connection with an anticline. It grows less in passing northeast and dies out in the area of the Mount Guyot sheet in a series of small folds. Its plane is in the Wilhite slate, over its northern portion, and it returns to that bed near the Little Tennessee River. It appears to be a great slip along the thin Wilhite strata, rather than a break in a close anticline.

Folds are as common in the mountains as in the valley, but the mountain folds lack the great regularity characteristic of the valley folds. Since the beds are more massive in the mountains, the folds are also rather larger. The unusual features of the folds are the extent to which their crests rise and fall where transverse folds cross the longitudinal folds. A prominent example of this is the general uplift along which the coves are situated, and the cross-uplifts which bring the dolomite to view in the coves. The transverse folds have dips fully as steep as the longitudinal folds, and in some cases, as in the southwest end of Tuckaleeche Cove, are the more prominent of the two. This zone of irregular anticlines extends entirely through the Knoxville area, and is matched by the irregular synclinal basin of the Smoky Mountains.

The results of metamorphism, the third mode of change in the mountain rocks, have been given in describing the different formations. The process was in general this: The minerals were changed in their positions during the folding of the rock, were fractured more and more as the folding continued, while new minerals, especially quartz and mica, grew out of the fragments of the feldspar. These new minerals were arranged parallel to the planes along which the rocks moved, and caused planes of schistosity by the easy splitting parallel to the mica. The planes of motion and fracture dip to the east, usually from 50° to 60°; when the rocks lie at similar angles the bedding and schistosity coincide; when the rocks dip at widely different angles the bedding is apt to be obliterated by the schistosity, especially in weathered rocks. This change in form increases in a southeast direction, from mere cleavage near Chilhowee Mountain to nearly complete alteration into new minerals in the southeast corner of the area. Rocks of fine grain and feldspathic nature were altered most.

The latest form in which yielding to pressure is displayed in this region, is vertical uplift or depression. Evidence of such movements can be found at various intervals during the deposition of the sediments, as at both beginning and end of the epochs of deposition of the Knox dolomite, the Athens shale, the Clinch sandstone, and the Newman limestone. After the great period of Appalachian folding, already described, such uplifts took place again, and are recorded in surface forms. While the land stood at one altitude for a long time, most of the rocks were worn down nearly to a level surface, or peneplain. One such surface was developed over much of the valley district, and its more or less worn remnants are now seen in the hills and ridges, at elevations from 1,100 to 1,200 feet. Since its formation, uplift of the land gave the streams greater slope and greater power to wear; they have accordingly worn down into the old surface to varying depths, according to their size, and have produced the deep, narrow cuts in which the streams now flow. As they are still wearing their channels downward and but little from side to side, they have not reached the grade at which the old peneplain was worn. The amount of elevation was possibly 500–600 feet, much more than the depth of the present stream-cuts. Traces of another peneplain can be found in the center of Chilhowee Mountain and on various ridges forming the lower portion of the mountain district, at elevations ranging around 2,200 feet. These are quite obscure, and this plain was nearly removed in the formation of the later one just described. It is certain that there were other such uplifts and pauses in this region, but their records have been almost entirely removed by later erosion. Doubtless still others occurred which were not of sufficient length to allow peneplains to form and record the movement.

MINERAL RESOURCES.

The rocks of this region are of use in the natural state, as marble, slate, building stone, and road material, and in the materials developed from them, such as iron, gold, lime, cement, and clay. Through their soils they are valuable for crops and timber, and in the grades which they establish on the streams they cause abundant water-power.

Marble.—Marbles are found in great quantity in the Chickamauga limestone in nearly all of its occurrences. The distribution of the marbles and quarries is shown on the economic sheet. Their chief development is in the belts passing near

Knoxville, and is due as much to superior means of transportation as to quality of the rock.

The total thickness of the marble beds, in places as great as 400 feet, is by no means available for commercial use. The rock must be of desirable color, must quarry in blocks of large size free from cracks or impure layers, and must be of fine, close texture.

The variations in all of these characters are due to differences in the sediment at the time of its deposition. Carbonate of lime, iron oxide, and clay were deposited together with shells of large and small mollusks. The firmness of the rock depends upon a large proportion of the lime, while the dark, rich colors are due to the oxide of iron; but if the latter be present with clay in large proportion the rock becomes a worthless shale. The colors vary from cream, yellow, brown, chocolate, red, and pink to blue, in endless variety. Absence of iron oxide results in gray, grayish-white, and white. The colors are either scattered uniformly through the rock or are collected into separate crystals or patches of crystals; forms such as fossils are usually of pure, white calcite. The curious and fantastic arrangement of the colors is one of the chief beauties of these marbles. Like the shaly matter, the iron oxide is an impurity, and the two are apt to accompany each other. The most prized rock, therefore, is a balance between the pure and impure, and slight changes in the form of sediment result in deterioration or better quality. Such changes are common in most sediments and must be expected in quarrying the marble. Not only may a good bed become poor, but a poor bed may develop into good marble.

These changes are illustrated by the disappearance of good marble for a few miles in the belt running through the northern portion of Knoxville. The belt which is productive south of Knoxville becomes of minor importance 8 miles northeast of Knoxville; and the bed at the bottom of the Sevier shale is the productive one in that locality. These latter marbles in the region of Knoxville are usually shaly and of less value, although they contain many beds of good body and color. Workable beds are rarely over 50 feet thick, and usually in that thickness there is a combination of several varieties. Quarries far separated from one another have quite distinct series of beds, and each quarry has its special variety of marble. All marbles of this region are free from any except argillaceous impurity, and all of reasonable purity take a good polish and are unaffected by weather.

The available localities for quarrying are limited by the attitude of the marble beds. The best situations are those in the belt immediately south of Knoxville, where the strata dip at small angles and cover a greater surface. Similar advantages favor the belt 5 miles northwest of Knoxville. In most of the southeastern areas of marbles the beds are more folded and dip at greater angles, so that prolonged quarrying will necessitate a great deal of stripping and deep cutting. Good marble abounds in these areas, however, and will become available in time as more favorable localities are exhausted.

Another rock of considerable beauty is the limestone conglomerate along the Little Tennessee River, south of Chilhowee Mountain. This rock is not strictly a marble, because it is not wholly crystalline. The irregular forms of its fragments and their different colors give a very pleasing effect, although the colors are quiet and dark. The small body of this rock discourages its development, and the frequent sand grains in the matrix injure its polish materially.

Slate.—Two formations in this region contain beds of slate, the Wilhite and Pigeon slates. The Wilhite slate is too calcareous and soft for such use in the vicinity of Little Tennessee River, but has the necessary hardness, evenness, and cleavage along the Little Pigeon River. Along the latter stream the slate is well exposed over great areas, but has never been developed. Quarries have been opened in the Pigeon slate along the Little Tennessee River at many points, and slates and flags taken out for local use. Recently a quarry has been opened on a small creek 2 miles from the river and much good material taken out for shipment. The slates are of fine, even grain, and split into slabs an inch thick, of any desirable size, or into roofing slates. In this particular quarry the cleavage crosses the bedding and produces ribbons in much of the slate. An old quarry about 2 miles north of this shows the cleavage and bedding coincident, and flags of great size are readily loosened. Some of the slate layers contain pyrite, necessitating selection of the material for use. There are a great number of available places for quarrying in the bluffs along the river and the adjacent small streams on either side. That this slate resists weathering is amply proved by the high, sharp slate cliffs that border the river along most of its course.

Building stone.—Besides marble, which is used for ornamental building, the Knox dolomite, Chickamauga limestone, and Tellico sandstone are in use. The sandstone has been quarried south of Knoxville and used in the city for curbstones and foundations. It is readily worked on account of its frequent bedding planes, and is dressed with ease into any shape. The amount of silica that it contains ensures its hardness, and judging from its occasional natural bluffs, it resists weather well. The Knox dolomite has long been used for chimneys, bridge abutments, and, occasionally, stone houses. It is very hard and firm and thoroughly satisfactory in its wear. Its beds average from 6 inches to 2 feet in thickness, and it is not adapted for larger work on that account. The formation is so widespread that no quarrying center has been established, and rock has been secured only for local use. The more massive blue limestones of the Chickamauga formation are occasionally used, and have the same characters for building material as the Knox dolomite. Excellent building rock can be found in all of the sandstones of Chilhowee Mountain and in the massive beds of the Cades and Thunderhead conglomerates. The inaccessibility of the latter bars their use to any extent in this region. One use for them is the manufacture of millstones, for which they are suited by reason of their extreme hardness and their uniform grain.

Various formations are in use in building roads. The Knox dolomite, the marble, and the Tellico sandstone have been used in the pike system of Knox County, and have proved satisfactory. Their success is largely due to the readiness with which they are broken and to the lime in their composition, which cements the mass firmly. The cherts of the Knox dolomite have long been used, and form natural roads on chert ridges, like Black Oak Ridge north of Knoxville. Their fragments are sharp, pack very firmly, and are almost indestructible. The open structure secured to the road-bed by their use keeps it well drained. An objection to their use is the rapid wear of iron shoes and tires by their sharp edges.

The Rogersville shale has long found local use for road metal, and in some regions roads are built along its outcrop. It secures good drainage for the road, but is not especially durable. Of late years the Pigeon slate has been built into roads with great success. The material is abundant, easily broken, and durable, and secures excellent drainage.

Other formations, which could be used for roads with success are the various Cambrian limestones and the sandstones of the Sevier shale.

Iron ore.—Iron ores occur in this region, most of them being brown hematite. On Tuckahoe Creek east of Knoxville brown hematite results from the decomposition and concentration of the ferruginous matter in the Tellico sandstone. These ores have been extensively prospected and are of good quality. They are not, however, of great body, although their surface indications are extensive; no mining of importance has been done. Many other outcrops of red and brown hematite occur in the form of veins and irregular deposits in the Tellico sandstone, but they are not of large quantity. Red and brown hematite also occur as a small vein in the shaly Newman limestone southeast of Montvale Springs. These have not been developed and are of doubtful quantity and quality.

Another class of ores occurs along the fault southeast of Chilhowee Mountain. They appear at many places in the slate and sandstone wash near the fault, in the form of a lean and siliceous brown hematite. They are of considerable body but irregular distribution, and are of small value. The third class of ore is developed over the Knox dolomite at many points, and consists of lumps and masses of brown hematite scattered through the clay. In Millers Cove, at the contact of the Knox dolomite and Nebo sandstone, are many outcrops of lean and brecciated ore, often so filled with sandstone as to be worthless. Their body is considerable, but the quality is inferior. At other points—6 miles south of Maryville, 5 miles northeast of Maryville, and 2 and 4 miles southwest of Boyd Creek, all in the upper part of the dolomite—iron ore has been mined and considerable good ore taken out. These deposits and others of similar occurrence are local and irregular, and the amount of ore must be determined separately for each bank. The ores are usually of good quality, and result from the oxidation of masses of pyrite in the clay.

Gold.—Gold has never been discovered in the rock in this region. It occurs in the gravels of the mountain streams, especially of Little River, in small particles rarely attaining the size of wheat grains. Undoubtedly it is derived from the quartz veins, which are common in the slates and conglomerates on the head of Little River. Much prospecting has failed to disclose productive ledges, and the gold is probably too small in amount to be preceived until concentrated in the streams. No systematic washing has been done, and ordinary laborers have secured only fair day's wages at panning.

Lime and cement.—Many beds in the Knox dolomite and Chickamauga limestone have been burned for lime and excellent results obtained. The purer marbles also would furnish lime, but they have been worked for ornamental stone to more profit. Many of the Cambrian limestones are also of sufficient purity to furnish lime, but are yet untried. Certain reddish-brown argillaceous beds at the bottom of the Chickamauga limestone are adapted by composition to make hydraulic cement. Rock from these beds immediately northwest of Knoxville has been burned, forming a good cement.

Brick clay.—Clays suitable for making bricks are very abundant in this region. They are found in several formations, principally Knox dolomite, Chickamauga limestone, and Athens shale, and consist of wash from the residual clays into the neighboring hollows. The deposits are not usually deep, but are of large area and very frequent occurrence. Much of the wash from the slate formations of the mountains forms beds of clay in places where the hollows do not have steep slopes, and these will be of local value in brickmaking. Local use has long been made of the clays of the valley, the bricks being burned near the point of use. As material can usually be found near at hand, it has such great advantage that only at Knoxville and Maryville have systematic operations been undertaken. At Maryville the clay is the residual clay of the dolomite only a little worked over. At Knoxville the clays chiefly worked are situated on the Chickamauga limestone and consist of wash from that limestone, the marble, and the Tellico sandstone. Bricks of excellent quality are made, and the deposit of clay is extensive.

Water-power.—One of the chief natural resources of this region, and one but little used thus far, is the water-power. There is no portion of the Appalachian province with better or more abundant water than the district including the Smoky Mountains. The streams are fed by multitudes of springs and are clear and steady during most of the year. Their grades are steep and long, and countless falls and rapids give natural sites for the development of power. The steepness of grade is such that sudden showers often swell the streams to great height and volume; but these freshets die away as quickly as they come and are not a serious obstacle to the utilization of the streams.

Streams in the valley are less plentiful and steady than those of the mountains. The large streams have regular grades and can not well be used for power. The streams of size similar to Little Pigeon and Little rivers and smaller fall rapidly to the deeper channels of the large rivers and furnish abnndant power. Thousands of falls are produced in the smaller creeks by hard beds of rock, such as the upper sandstone of Grainger shale, the Rome sandstones, the Tellico sandstone, and the more siliceous beds of the Knox dolomite. Thus far the only use of this vast amount of power has been in grist mills and occasional saw mills; ultimately it will prove valuable.

Timber.—Many of the formations produce timber of great value, and usually there is a distinct association of certain trees with some one formation. Every formation is timber-covered in favorable localities, but only the valuable groups need be enumerated. The Knox dolomite is invariably marked by a good growth of oak, chestnut, and hickory. In the hollows of the Athens shale and Rome sandstone are found poplar, chestnut, oak, and pine. The shaly parts of the Chickamauga limestone are always covered by red cedars and a few oaks. Hollows and valleys of the Pigeon and Wilhite slates have a fine growth of poplar, linn, oak, buckeye, chestnut, ash, and hemlock. On the slopes of these beds grow oaks, chestnuts, and occasional pines. By far the best timber grows upon the soils of the conglomerates, Cades, Thunderhead, and Clingman. In their hollows and sheltered slopes are found enormous poplar, ash, hemlock, linn, buckeye, oak, maple, chestnut, and walnut trees; on their upper slopes and summits, cherry, oak, maple, birch, and beech. Certain areas of conglomerate, notably Clingmans Dome, are covered by a dense growth of balsam fir and rhododendron. The walnut timber has been cut in all but the most remote places. The choicest of the valley timber has been cut, but an immense amount yet remains; the mountain timber has been touched only in the most accessible places, and is for the most part virgin forest.

ARTHUR KEITH,

Geologist.

May, 1895.

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

TOPOGRAPHY

TENNESSEE-NORTH CAROLINA
KNOXVILLE SHEET

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by S.S. Gannett.
Topography by F.M. Pearson and C.G. Van Hook.
Surveyed in 1884-85-90.

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

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet.

Datum is mean Sea level

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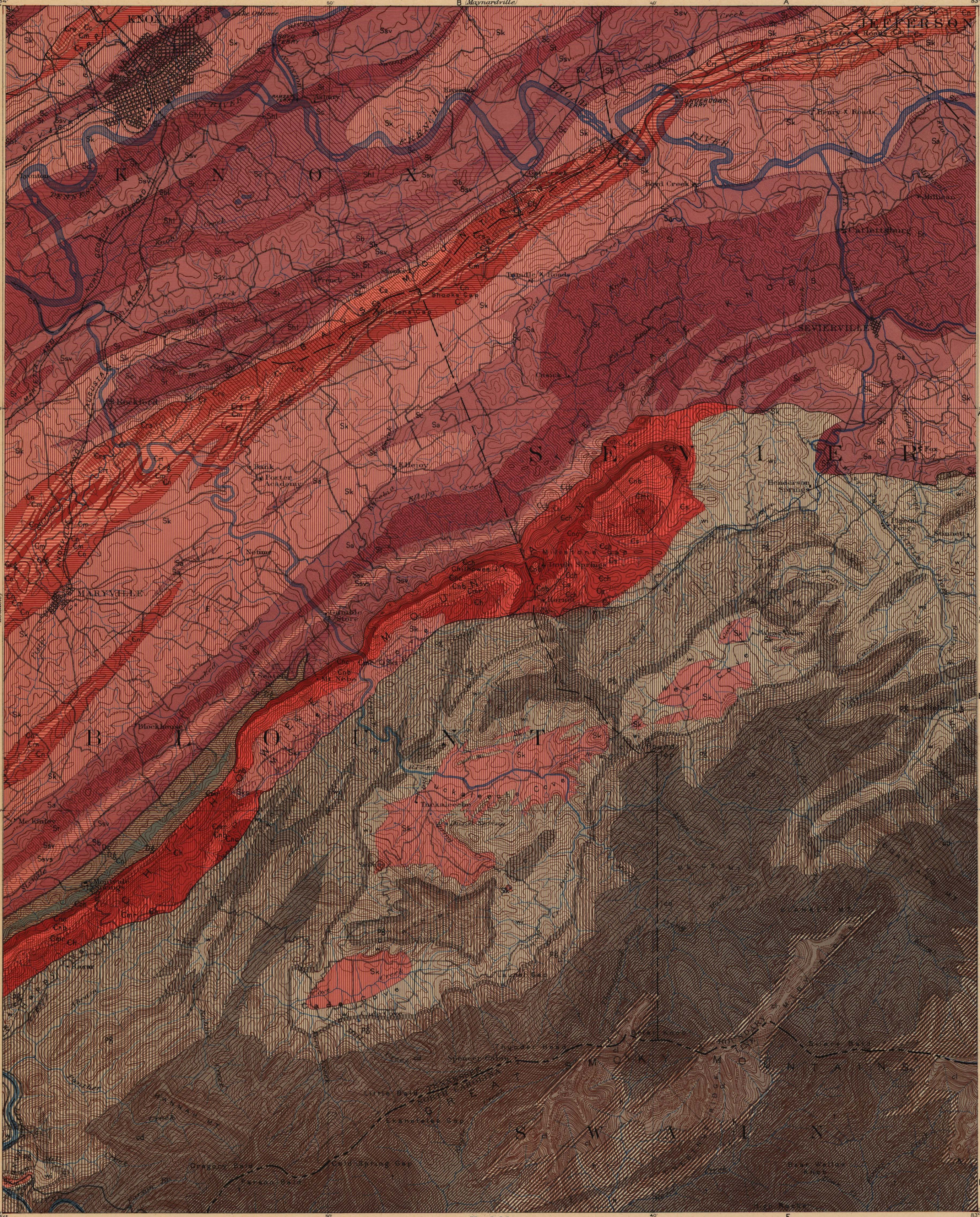
AREAL GEOLOGY

TENNESSEE-NORTH CAROLINA
KNOXVILLE SHEET



LEGEND
(continued)

AGE UNKNOWN

- cl — Clingman conglomerate *(Gray sandstone and coarse and fine conglomerate)*
- h — Hazel slate *(Black slate with sandstone and conglomerate layers)*
- t — Thunderhead conglomerate *(Gray sandstone and fine conglomerate with sandy slate)*
- cd — Cades conglomerate *(Interbedded, gray sandstone, sandy slate, and fine conglomerate)*
- pg — Pigeon slate *(Bluish gray, argillaceous slate with sandy upper layers)*
- c — Citico conglomerate *(Coarse and fine quartz conglomerate and sandstone)*
- wi — Wilhite slate *(Bluish black, argillaceous and calcareous slate with lenses of limestone and limestone-conglomerate near the top)*

Faults

Sections

LEGEND

SEDIMENTARY

CARBONIFEROUS

- Cn — Newman limestone *(Bluish, shaley and massive limestone)*

DEVONIAN

- Dg — Grainger shale *(Greenish and bluish gray, sandy shale)*
- Dc — Chattanooga black shale *(Black, calcareous shale)*

SILURIAN

- Sb — Bays sandstone *(Red, calcareous sandstone)*
- Ssv — Sevier shale *(Bluish, calcareous shale)*
- Ssvs — Lentil in Sevier shale *(Gray, calcareous sandstone and sandy shale)*
- St — Tellico sandstone *(Bluish gray, calcareous sandstone and shale)*
- Sa — Athens shale *(Light blue, calcareous shale, with black shale at the base)*
- Shl — Holston marble *(Lentils of variegated marbles of many colors in blue and gray limestone)*
- Sc — Chickamauga limestone *(Blue and gray, argillaceous limestone)*
- Sk — Knox dolomite *(Magnesian limestone with chert nodules)*

CAMBRIAN

- Sks — Knox formation. Shore deposit of Knox dolomite *(Red, yellow, and brown shale and thin sandstone)*
- Ꞓn — Nolichucky shale *(Calcareous shale with thin limestone beds)*
- Ꞓm — Maryville limestone *(Massive, blue limestone)*
- Ꞓrg — Rogersville shale *(Greenish clay shale with limestone layers)*
- Ꞓc — Connasauga shale *(Brown, green, & yellow calcareous shale with thin limestone beds)*
- Ꞓrt — Rutledge limestone *(Massive, dark blue limestone)*
- Ꞓr — Rome formation *(Red, green, and brown sandy shale)*
- Ꞓrs — Lentils in Rome formation *(Red, white, and brown sandstone)*
- Ꞓb — Beaver limestone *(Massive, blue limestone)*
- Ꞓa — Apison shale *(Red, green, and brown, sandy shale)*
- Ꞓh — Hesse sandstone *(Fine, white, massive sandstone)*
- Ꞓmr — Murray shale *(Grayish blue, sandy shale)*
- Ꞓnb — Nebo sandstone *(Massive, white sandstone, coarse and fine)*
- Ꞓnc — Nichols shale *(Grayish blue, sandy shale)*
- Ꞓch — Cochran conglomerate *(Massive sandstone and conglomerate)*
- Ꞓs — Sandsuck shale *(Grayish blue, argillaceous shale)*

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

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet.

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G.K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in charge.
Geology by Arthur Keith.
Surveyed in 1889-90-91.

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ECONOMIC GEOLOGY

TENNESSEE-NORTH CAROLINA
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- wi — Wilhite slate *(Bluish black, argillaceous and calcareous slate with lenses of limestone and limestone-conglomerate near the top)*

Faults

Sections

D B A C A E C B F F E D

⚒ Mines and Quarries

Known productive formations

Marble

Slate

Brown hematite iron ore.

LEGEND

SEDIMENTARY

CARBONIFEROUS

- Cn — Newman limestone *(Bluish, shaley and massive limestone)*

DEVONIAN

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- Ssv — Sevier shale *(Bluish, calcareous shale)*
- Ssvs — Lentil in Sevier shale *(Gray, calcareous sandstone and sandy shale)*
- St — Tellico sandstone *(Bluish gray, calcareous sandstone and shale)*
- Sa — Athens shale *(Light blue, calcareous shale, with black shale at the base)*
- Shl — Holston marble *(Lentils of variegated marbles of many colors in blue and gray limestone)*
- Sc — Chickamauga limestone *(Blue and gray, argillaceous limestone)*
- Sk — Knox dolomite *(Magnesian limestone with chert nodules)*
- Sks — Knox formation. Shore deposit of Knox dolomite *(Red, yellow, and brown shale and thin sandstone)*

CAMBRIAN

- Ꞓn — Nolichucky shale *(Calcareous shale with thin limestone beds)*
- Ꞓm — Maryville limestone *(Massive, blue limestone)*
- Ꞓrg — Rogersville shale *(Greenish clay shale with limestone layers)*
- Ꞓc — Connasauga shale *(Brown, green, & yellow calcareous shale with thin limestone beds)*
- Ꞓrt — Rutledge limestone *(Massive, dark blue limestone)*
- Ꞓr — Rome formation *(Red, green, and brown sandy shale)*
- Ꞓrs — Lentils in Rome formation *(Red, white, and brown sandstone)*
- Ꞓb — Beaver limestone *(Massive, blue limestone)*
- Ꞓa — Apison shale *(Red, green, and brown, sandy shale)*
- Ꞓh — Hesse sandstone *(Fine, white, massive sandstone)*
- Ꞓmr — Murray shale *(Grayish blue, sandy shale)*
- Ꞓnb — Nebo sandstone *(Massive, white sandstone, coarse and fine)*
- Ꞓnc — Nichols shale *(Grayish blue, sandy shale)*
- Ꞓch — Cochran conglomerate *(Massive sandstone and conglomerate)*
- Ꞓs — Sandsuck shale *(Grayish blue, argillaceous shale)*

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

STRUCTURE SECTIONS

TENNESSEE-NORTH CAROLINA
KNOXVILLE SHEET

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by S.S.Gannett.
Topography by F.M.Pearson and C.G.Van Hook.
Surveyed in 1884-85-90.

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

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet.

Datum is mean Sea level

Edition of Jan. 1895.

G.K.Gilbert, Chief Geologist.
Bailey Willis, Geologist in charge.
Geology by Arthur Keith.
Surveyed in 1889-90-91.

COLUMNAR SECTIONS.

GENERALIZED SECTION NORTHWEST OF BAYS MOUNTAIN.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
SILURIAN	Bays sandstone.	Sb		800— —500		
	Sevier shale.	Ssv		1000— —1200 200— —300	Light-blue sandy and calcareous shales, with beds of limestone and argillaceous marble.	Open, flat valley.
	Tellico sandstone.	St		250— —500	Bluish-gray calcareous sandstone.	High rounded knobs and ridges.
	Chickamauga limestone.	Sc		200— —400 500— —700	Variegated marble, red, brown, gray, and white. Blue limestones and gray argillaceous limestones.	Round hills, and slopes of Tellico sandstone knobs. Level and rolling valleys.
	Knox dolomite.	Sk		3500	Magnesian limestone, white, gray, light and dark blue, with nodules of chert.	Broad ridges and irregular rounded hills.
CAMBRIAN	Nolichucky shale.	Ꞓn		700— —800	Yellow, red, and brown calcareous shales, with a few limestone beds.	Narrow valleys; steep slopes of Knox dolomite ridges.
	Maryville limestone.	Ꞓm		150	Massive blue limestone.	Valleys.
	Rome formation shale.	Ꞓr		700— —900	Red, green, yellow, and brown shales and sandy shales.	Slopes of Rome sandstone ridges.
	Rome formation sandstone.	Crs		800+	Red, yellow, and brown sandstones and sandy shales.	Sharp ridges with notches and gaps.

GENERALIZED SECTION SOUTHEAST OF CHILHOWEE MOUNTAIN.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
AGE UNKNOWN	Clingman conglomerate.	cl		1000+	Gray sandstone and coarse and fine conglomerate, with blue quartz and feldspar.	High mountains and broad domes.
	Hazel slate.	h		600— —800	Black slate with small beds of sandstone and fine conglomerate.	Very sharp irregular divides and peaks.
	Thunder Head conglomerate.	th		3000+	Gray sandstone and coarse and fine conglomerate, with blue quartz and feldspar.	High domes and irregular mountains with broad rounded tops and steep slopes.
	Cades conglomerate.	cd		2400+	Gray sandstone and fine conglomerate, with many beds of sandy slate.	Mountains and irregular ridges with rounded tops and steep slopes.
	Pigeon slate.	pg		1300— —1700	Banded gray and bluish-gray slate and sandy slate; a few gray sandstone beds.	Irregular ridges and knobs with steep slopes.
	Citico conglomerate.	c		50— —800	Coarse quartz conglomerate. Fine quartz conglomerate. Coarse white sandstone. Fine white sandstone.	High, sharp ridges.
	Wilhite slate.	wi		0— —1000	Limestone conglomerates and sandy limestone.	Open valleys; steep slopes of Citico conglomerate ridges.

GENERALIZED SECTION SOUTHEAST OF BAYS MOUNTAIN.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
CARB.	Newman limestone.	Cn		600+	Bluish-gray shale and shaly limestone. Massive blue limestone.	Low, open valleys.
DEVONIAN	Grainger shale.	Dg		1200	Red and yellow sandy shale. Massive white sandstone. Greenish and bluish-gray sandy shales and sandstones.	Slopes, high sharp ridges.
	Chattanooga black shale.	Dc		30-50	Black calcareous shale.	Narrow valleys.
SILURIAN	Bays sandstone.	Sb		800— —1100	Red calcareous sandstone.	Belts of low irregular knobs
	Sevier shale.	Ssv		500— —600 200— —400 500— —600 500— 650 500— —750	Light-blue calcareous shale. Bluish-gray and red calcareous sandstones and shales. Light-blue calcareous slates. Bluish-gray and gray calcareous sandstones and shales. Light-blue calcareous shale.	Open, rolling valleys. Lines of low knobs. Open, rolling valleys. Lines of high knobs. Open, rolling valleys and small knobs.
	Tellico sandstone.	St		800— —900	Bluish-gray and gray calcareous sandstones and shales.	Lines of high knobs.
	Athens shale.	Sa		1000— —1200	Light-blue calcareous shale. Black calcareous shale.	Belts of low knobs. Open valleys.
	Chickamauga limestone.	Sc		50-0	Gray argillaceous limestone.	
	Knox dolomite.	Sk		3500	Magnesian limestone; white, gray, light and dark blue, with nodules of chert.	Broad ridges and irregular rounded hills.
CAMBRIAN	Nolichucky shale.	Ꞓn		450— —550	Yellow and brown calcareous shale and limestone beds.	Flat, open valleys.
	Maryville limestone.	Ꞓm		350— —550	Massive dark-blue limestone.	Open valleys; lines of low knobs.
	Rogersville shale.	Ꞓrg		180— —220	Bright-green clay-shales, with a limestone bed.	Lines of low knobs.
	Rutledge limestone.	Ꞓrt		350— —450	Massive dark-blue limestone.	Open valleys.
	Rome formation.	Ꞓr		250	Red, green, yellow, and brown shales and sandy shales.	Slopes of Rome sandstone ridges.
	Rome formation sandstone.	Ꞓrs		500— —700	Red, white, and brown sandstones and sandy shales.	Sharp ridges with notches and gaps.
	Beaver limestone.	Ꞓb		300	Massive blue limestone.	Narrow valleys
	Apison shale.	Ꞓa		200 900+	Green argillaceous shale. Bright-red, green, and brown sandy shales.	Belts of irregular knobs and ridges.
	Hesse sandstone.	Ꞓh		500+	Fine, white massive sandstone.	High, sharp-crested mountains.
	Murray shale.	Ꞓmr		300	Grayish-blue sandy shale.	Steep slopes and depressions.
	Nebo sandstone.	Ꞓnb		500	Massive white sandstone, coarse and fine.	High, sharp-crested mountains.
	Nichols shale.	Ꞓnc		550— —800	Grayish-blue sandy shale.	Steep slopes of Nebo sandstone mountains; narrow valleys.
	Cochran conglomerate.	Ꞓch		600— —900 100-0 500— —700	Massive white sandstone, coarse and fine. Red sandstone, gray sandy shale. Coarse conglomerate, quartz, and feldspar pebbles.	High, sharp-crested mountains. Mountains and ridges with rounded crests.
	Sandsuck shale.	Ꞓs		1000+	Grayish-blue argillaceous shale.	Flat, narrow valleys.