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UNITED ICAL SURVEY

LES D. WALC RECTOR

GEOLOGIC ATLAS

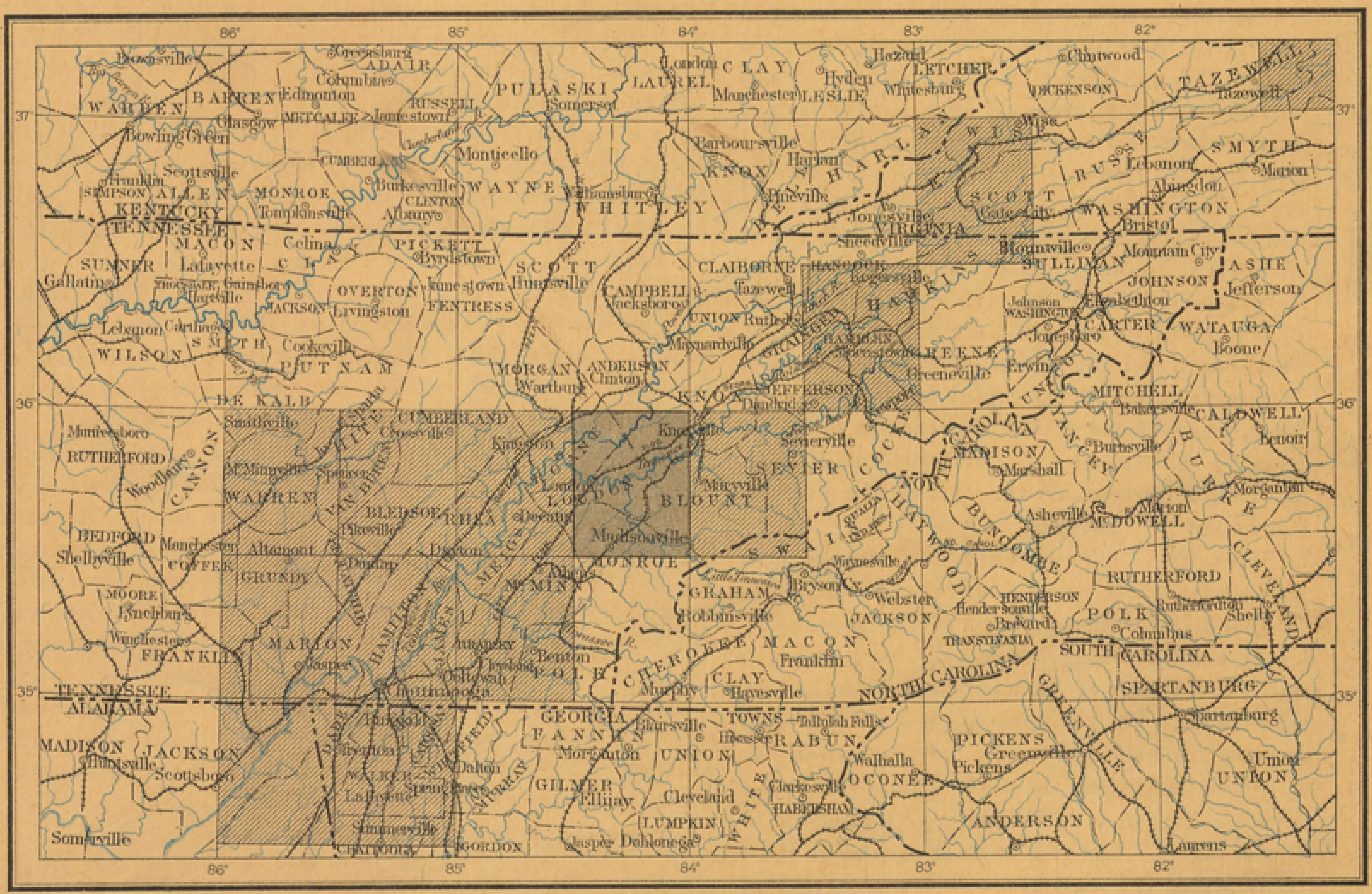
OF THE

UNITED STATES

LOUDON FOLIO

TENNESSEE

INDEX MAP



SCALE: 40 MILES = 1 INCH

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FOLIO 25 LIBRARY EDITION LOUDON

WASHINGTON, D. C.

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

1896

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

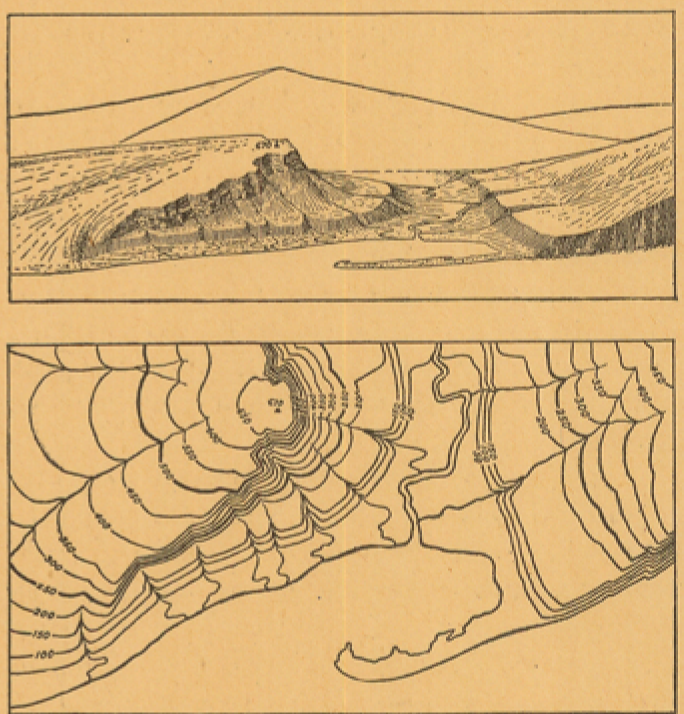

Fig. 1.—Ideal sketch and corresponding contour map.

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

1. A contour indicates approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours 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 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—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

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

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

Atlas sheets.—The map is being published in 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; 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 4,000, 1,000, and 250 square miles, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. 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, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

DESCRIPTION OF THE LOUDON SHEET.

GEOGRAPHY.

General relations.—The region represented by the Loudon atlas sheet lies entirely in Tennessee. It is included between the parallels 36° and 35° 30′ and the meridians 84° and 84° 30′, and it contains 968.7 square miles, divided between Knox, Roane, Loudon, Monroe, and Blount counties.

In its geographic and geologic relations this area forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west, and from central Alabama to southern New York. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as that covered by a single atlas sheet; hence it is necessary to consider the 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 constant 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. Thence 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 high 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 Loudon area.—Three geographic divisions appear within the limits of the sheet. The northwestern corner includes 5 square miles of Walden Ridge and the Cumberland Plateau; the southeastern corner contains 33 square miles of the outliers of the Great Smoky Mountains; and the remainder, 930 square miles, lies in the East Tennessee Valley.

The entire region is drained by the Tennessee River and its tributaries, the Emory, Clinch, Tellico, and Little Tennessee rivers. By the junction of the Clinch and Tennessee, a few miles beyond the border of this area, the drainage is united in a single stream. None of these rivers rise within the limits of this area, and only a small part of their water is derived from the creeks which are so contained. The rivers rise from 650 to 760 feet above the sea on the northwestern edge of the valley, and to 850 feet on its southeastern edge. The larger streams are sunk in sharp, narrow basins from 100 to 200 feet below the adjacent country, according to their size, and the smaller ones rise nearly to the level of the ridges. The ridges of the valley are strikingly uniform in height, ranging from 1,000 to 1,300 feet above sea-level. Walden Ridge has here its usual elevation, from 1,500 to 1,700 feet, and the Great Smoky outliers rise to 2,700 feet in Chilhowee Mountain.

In this region the topography is quite varied, and in all cases depends upon the effects of erosion on the different formations. Such rock-forming minerals as carbonates of lime and magnesia, and to a less extent feldspar, are entirely removed by solution in water. Rocks containing these minerals are therefore subject to decay by solution, which breaks up the rock and leaves the insoluble matter less firmly united. Frost and rain and streams break up and carry off this insoluble residue, and the surface is worn down. The rocks form high or low ground according to the condition of the insoluble matter. Calcareous rocks, which leave the least and finest 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 leave 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 also is reduced to low ground. The least soluble rocks are the sandstones, and since most of their mass is left untouched by solution, surfaces formed by these are the last to be reduced in height.

Erosion of the valley formations has produced a series of long ridges separated by narrow valleys which closely follow the belts of rock. Where the formations spread out at a low dip the valleys or ridges are broader, and where the strata dip steeply the valleys are narrower. Every turn in the coarse of a formation can be told at a distance by the turn of the ridge or valley which it causes. Every rock produces the same type of surface as long as its composition remains the same; every change in composition produces a change in form of surface. The Knox dolomite illustrates this fact well. Southeast of Brick Mill, Blount County, 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 northward and westward, and the cherty ridges become more and more prominent until, in Black Oak, Chestnut, and Copper ridges, they stand from 300 to 400 feet above the shale valleys.

The topography of the mountain district is as unlike that of the valley as the rocks of the one are unlike those of the other. None of the regularity of the valley ridges appears, and the streams wind in narrow, v-shaped valleys to and fro across the different formations. Only the end of the long, sharp crest of Chilhowee Mountain lies in this area; and the other summits are the merest foothills of the Great Smoky Mountains.

GEOLOGY.

STRATIGRAPHY.

The general sedimentary record.—All of the rocks appearing at the surface within the limits of the Loudon atlas 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 nature 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 Loudon 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 shoreline 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 developed better than in almost any other area.

The rocks lie in four distinct areas or groups of widely different age. The coal-bearing rocks of the Carboniferous lie in and north of Walden Ridge. The valley part of the tract comprises the formations from lower Cambrian to Carboniferous, all of them being of later age than the Chilhowee series. The Chilhowee strata appear only in Chilhowee Mountain, and are of lower Cambrian age. The mountain district is covered by the Ocoee formation, the age of which has not yet been 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 to justify their separation from the Cambrian series, though not sufficient to fix their age; they are therefore mapped as unknown. The series is divided into the following formations, beginning with the base: 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 southeast of Tallassee Ford to 500 feet west of Chilhowee; ordinarily it is from 300 to 400 feet thick.

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. 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. Northeast of Little Tennessee River some of the lenses are only a few inches thick and a few feet long; near the river 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 near the Little Tennessee River, but are less prominent southwest of that stream.

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 separated 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 near Chilhowee Mountain. The change consists of schistosity and cleavage, produced in the slate by squeezing and stretching. These changes are not widespread and do not materially alter the appearance of the rock.

Owing to the slightly calcareous nature and fine grain of the Wilhite formation it yields to erosion and invariably 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. They are loose and well drained in spite of their gentle slopes. Their outcrops are narrow in this area and are not important agriculturally.

Citico conglomerate.—This formation has about the same range as the preceding one, near the Little Tennessee River. 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 100 to 500 feet, the coarse beds being the thickest. The coarse deposits are not limited to one area, but are quite widely distributed. In the northwestern areas they are more common than in the southeastern. The quartz pebbles are very coarse, the largest being 4 and 5 inches in diameter. From that size they diminish to minute sand grains. The average thickness is about one-third of an inch.

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 the conglomerate contains pebbles of blue limestone and of earthy siliceous limestone derived from the Wilhite slate.

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 southwest of Chilhowee Mountain and a smaller one in the southeastern corner of the district mapped. 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 adjoining areas fall between those limits. The full thickness of the formation is not presented here, the upper beds having been removed by erosion.

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.

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 scarcely altered.

Cochran conglomerate.—This formation is a massive bed of conglomerate, the heaviest of the series. It is mainly shown at the northeastern end of the mountain, but it occurs also in two small strips at the southwestern end. 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. 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 born 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, and the rounded summits of the conglomerate near the end of the mountain. 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 which usually lies on the northwestern face of the mountain; but southeast of Alleghany Springs it crosses the crest. It is named from its occurrence on Nichols branch of Walden Creek, in Sevier County. 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 is about 500 feet in thickness in this area.

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. In a narrow valley south of the end of Chilhowee Mountain this formation affords fair farming land.

Nebo sandstone.—This bed occurs in nearly continuous areas along the top of the mountain, and is named from Mount Nebo Springs, in Blount County, 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 particular save that of thickness. Its name is derived from good exposures on Murray branch of Walden Creek in Sevier County. 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. This formation occupies the highest part of the mountain, and forms a notched line of sharp peaks on its southeast side. 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 the surface is flat for considerable areas 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. 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.

Rome formation.—Four areas of this formation occur in the northwestern part of the valley area and one south of Morganton. 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 a common feature of these beds. A few of the sandstone beds contain lime in such amounts as almost to become limestones.

The series comprises 250 to 300 feet of sandy shale at the top and 550 to 700 feet of sandstone and sandy shale at the bottom. It is thinnest in the southeastern area.

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 seldom 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 two areas southeast of Morganton. 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 belts of Cambrian strata north of Morganton the formation is not present as a limestone, but as calcareous shale, which can not be distinguished from the Conasauga and Rogersville shales. The thickness of the formation, where it can be distinguished, is 200 feet.

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 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.

Rogersville shale.—This shale, like the preceding limestone, can be distinguished in only one zone within the boundaries of this sheet. In the areas north of Morganton 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 and blue limestone. It ranges from 200 to 225 feet in thickness.

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

Excepting the small beds of limestone, the formation is but 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 zone running south of Morganton and in a narrow belt southeast of Beaver Ridge. Its name is taken 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 to nothing in the Beaver Ridge belt, and from 350 to 400 feet south of Morganton. Fossils are rare in these beds, but occasional trilobites are found. During the early part of the deposition of this limestone in the Morganton belt, shales were deposited in the Beaver Ridge belt 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, but the whole formation occupies 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. 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 very nearly uniform, and contains only yellow and greenish-yellow shale. Where the Maryville formation was deposited as shale it is impossible to separate it from this formation. The thickness of the formation remains quite constant at 450 to 500 feet.

This formation is the most fossiliferous of the Cambrian strata, 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 on the southeast side of the valley, 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.

Conasauga shale.—This is the commonest Cambrian formation in this region. It consists of calcareous shales, shaly limestones, and thin beds of massive limestone. In the belt passing north of Copper Ridge the base of the formation is marked by a thin bed of limestone conglomerate, and in many other localities by a bed of oolitic limestone. This formation was accumulated during the deposition of the Rutledge limestone, Rogersville shale, and Maryville limestone, and represents the near-shore, muddier sediment of those times. These limestones gradually thin out and are replaced by the Conasauga shale, as shown south of Beaver Ridge. In characteristics of soil and topography it is identical with the Nolichucky shale. The thickness of the formation ranges from 600 to 850 feet.

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, in Knox County, 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 over the northwestern part of this area. The formation is usually 3,500 feet thick, and varies from this to 2,500 and 3,800 feet.

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 must have lasted for a very long time in order to accumulate so great a thickness of this kind of rock. The dolomite, on this account, represents a longer epoch than any of the other Appalachian formations.

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 Black Oak and Copper ridges. Regions of little chert form rolling ground rising but little above the surrounding rocks; this is the nature of the southeastern portion of the area. 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 district mapped. 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. On Poplar Creek it comprises 1,200 feet of blue, red, and gray limestones and flaggy limestones. In the northeast part of the area mapped it consists of 500 to 700 feet of blue limestone and gray, argillaceous limestone beneath 250 to 500 feet of marble. Along the southeastern side of the valley this formation is represented by a thin belt of blue and gray, argillaceous limestone, sometimes 50 feet thick and usually absent entirely. Between these extremes there is every variation of thickness and composition.

The upper beds of the formation often 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. These more crystalline beds, while usually at the top, vary somewhat in position, especially west of Loudon, where they are developed at the very bottom of the formation.

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 purer limestone 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 large areas of the formation passing through Loudon and Louisville, 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 near the southeastern border of the valley. 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. In the northeastern part of the district mapped the formation consists of 250 feet of calcareous and sandy shales, with one small bed of sandstone. In the high knobs around Louisville 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. At Houk, in the southeastern belt, there are 900 feet of reddish sandstone and sandy shale. The amount of sand in the formation decreases northwestward, so that the formation can not be recognized northwest of the Loudon belt, its place being taken by shales and limestones. The sandy material represents the coarser shore sediment of that time.

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 two basins, one passing southeast of Louisville and the other immediately northwest of Chilhowee Mountain. It is so named because of its great development in the latter area, in Sevier County. As a whole it is a thick series of calcareous, yellow shales, weathered from light-blue, shaly limestone, and similar to the Athens shale; to these are added in places beds of gray limestone or variegated marble and beds of sandy shale and calcareous sandstone. Southeast of Louisville the formation has 200 to 300 feet of gray argillaceous limestone, gray and variegated marble, and shaly limestone, followed by 1,000 to 1,200 feet of calcareous, yellow shales with occasional thin limestone beds and sandy shales. Between Houk and Alleghany 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. Southwestward the sandstones increase, until they become more prominent than the shales southwest of Tellico River, and many small beds of pure white sandstone occur. Toward the northwest the sandy sediment rapidly lessens, and does not appear beyond Loudon. 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 soils and topography of the latter formation, therefore, applies to these beds.

Bays sandstone.—This formation occurs in this region in the basin just northwest of Chilhowee Mountain and in a small area north of Clinch River. It is so named because of its frequent outcrops in the Bays Mountains of Hawkins and Greene counties, Tennessee. Changes in its composition are very small, and it is generally a red, calcareous sandstone. There is a small amount of feldspathic matter in the rock, slightly greater toward the southwest. The red color is very marked and persistent. Great variations occur in its thickness. Along Poplar Creek the amount of sand is so small that the formation is nearly a limestone, and runs from 100 feet in thickness down to nothing. Near Emory River it is absent altogether. In the belt next to Chilhowee Mountain it increases from 1,100 feet to 1,500 feet toward the southwest, and some small beds of white sandstone appear. This is the change common in shore deposits, where the amount of sediment diminishes rapidly from the point of supply.

Owing to the amount of calcareous matter that it contains, the Bays sandstone never stands at great altitudes, even where it is thick. 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 its surfaces are more often bare than those of any other valley formation except the Chickamauga limestone.

Clinch sandstone.—The same basin along Chilhowee Mountain that contains the Bays sandstone has three small areas of Clinch sandstone. This formation consists entirely of white sandstone, and varies in thickness from 130 feet to nothing. Southwest of Little Tennessee River it is usually from 4 to 10 feet thick, and rapidly increases northeast of the river. At a point northeast of Alleghany Springs the formation was eroded after its deposition, so that the next formation, the Devonian shale, was laid down directly upon the Bays sandstone. The formation is inconspicuous in its effect upon topography and soil, and is of interest chiefly because it represents a formation important in Clinch Mountain, whence it takes its name.

Rockwood formation.—North of Clinch River four small areas of this formation occur. It consists of red and yellow calcareous shales and reddish and blue shaly limestones. The beds in the upper part of the formation are somewhat sandy, and in the Bear Creek area are sufficiently hard to have produced a high ridge. Deposits of fossiliferous iron ore are found in the calcareous shales, especially in the vicinity of Oakdale Furnace. The division between the Chickamauga limestone and this formation is not sharp in this region, and the two grade into each other to some extent. The formation probably represents a large part of the waste of the Clinch sandstone during its erosion, for, in the regions where the latter was eroded, no Rockwood shale appears to have been deposited and the Devonian shale lies directly upon the Bays sandstone.

The amount of sand in the rock causes it to resist solution and wear and to occupy high ground, usually a sharp, even ridge with numerous stream gaps. Its soils are thin and sandy, and, situated as they usually are on the slopes of ridges, are but little used. 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.

DEVONIAN ROCKS.

Chattanooga black shale.—This formation occurs in a single narrow belt, parallel to Chilhowee Mountain, and in three smaller areas in the northwestern part of the district mapped. It is so named because of its occurrence at Chattanooga, Tennessee. This belt is its only occurrence in Tennessee or Virginia on the eastern side of the Great Valley, and is notable on that account. Some of its outcrops contain fossil lingulæ. In this region it is a bed of black, calcareous and carbonaceous shale with no variations of composition. It is in many places unconformably deposited on the Silurian rocks, and its upper layers for a few feet are interbedded with the Grainger shale when that formation is present. On account of its softness it is usually much covered with wash from adjacent formations, and its thickness is hard to determine. Near Chilhowee Mountain it ranges in thickness from 6 to 30 feet, being thinnest west of Little Tennessee River; north of Clinch River it is 80 feet thick. It occupies depressions of small size, and neither its surface forms nor its soils are of importance.

Grainger shale.—Two areas of Grainger shale occur in this district: that along Chilhowee Mountain, and its continuation southwestward. Its name is derived from Grainger County, Tennessee, where it is well displayed. It comprises flaggy sandstones, sandy shales, and sandstones, with white sandstone and red and brown sandy shales at the top; and this series is present throughout. 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; and in the bottom flags are many impressions of the supposed seaweed, *Spirophyton cauda-galli*. These beds retain their thickness of 1,100 feet with the greatest regularity.

The siliceous matter in these rocks causes them to make a ridge of considerable height and of straight, even top. The crest of this is composed of the white sandstone bed, and its flanks 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 is the latest of the valley rocks that occur in this region, and lies in the same basins that hold the Grainger shale. It is so named because of its great outcrops in Newman Ridge, Hancock County, Tennessee. Near Chilhowee Mountain the formation has 100 feet of massive blue limestone at the base, followed by 500 feet or more 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. North of Clinch River it consists entirely of 700 feet of massive blue limestone, and lies directly upon the Chattanooga shale. A considerable number of chert nodules are contained in the base of this limestone, and their white fragments strew the surface when weathered. These, like the limestone itself, are full of fossils, chiefly crinoids.

The soluble nature of the formation consigns it to the valleys, where it forms a slightly rolling surface. Rarely its cherty portions are hard enough to cause high ground and rounded ridges. It forms a red clay when decayed, but this is seldom seen in its natural condition, on account of the wash from the adjacent formations. Its soils, which are naturally good, are thus rendered of small value for agriculture.

Lee conglomerate.—The only area of this formation occurring in the district mapped is found in Walden Ridge. It consists of a bed of massive sandstone, 900 feet thick; near the base is a small bed of quartz conglomerate, and several of the sandstone layers are coarse and conglomeratic. A bed of shale, about 20 feet thick, lies 100 feet above the base of the formation, and contains a bed of coal, which has been worked northeast of Oakdale Furnace. A similar and thicker shale bed near the top of the formation also carries a thin bed of coal. At the middle of the formation there is an unconformity by erosion, extending through at least 20 feet of the sandstone.

By reason of their very siliceous nature the sandstones of this formation are almost insoluble, and make sharp, prominent mountains. Lines of cliffs accompany its course, and the stream gaps are narrow, rocky gorges. Its soils are so thin and are so blocked with sandstone fragments as to be worthless except for the occasional good timber on the lower slopes.

Briceville shale.—A small belt of this shale lies immediately northwest of Walden Ridge. The formation is composed mainly of bluish-gray and black shale, and contains many small beds of sandstone and workable seams of coal. Three hundred feet of the formation appear in this area, but it is possible that the thickness is slightly reduced by a fault near Walden Ridge. Only one coal bed has been worked in this vicinity, and that shows an average of 42 inches of good coal.

The shales, owing to their fine grain, offer little resistance to weather, and the formation always occupies low ground. The sandstone beds are hard enough to cause the formation of small knobs, but are too thin to produce prominent ridges. The lowest beds are almost invariably occupied by streams in narrow valleys. The soils are thin and poor, and are much encumbered with waste from the sandstone beds and from the Lee conglomerate. Where the valleys widen much they contain bottoms with a fairly good, sandy soil.

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 axes may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and is usually but a few degrees. In districts where strata are folded they are also frequently broken across, and the arch is thrust over upon the trough. Such a break is called a *fault*. If the arch is worn away and the syncline is buried beneath the overthrust mass, the strata at the surface may all dip in one direction. They then appear to have been deposited in a continuous series. Folds and faults are often of great magnitude, their dimensions being measured by miles, but they also occur on a very small, even a microscopic, scale. In folds and faults of the ordinary type, rocks change their form mainly by motion on the bedding planes. In the more minute dislocations, however, the individual fragments of the rocks are bent, broken, and slipped past each other, causing *cleavage*. Extreme development of these minute dislocations is attended by the growth of new minerals out of the fragments of the old—a process which is called *metamorphism*.

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

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 were developed in the northwestern sides of anticlines, varying in extent and frequency with the changes in the strata. Almost every fault plane dips toward the southeast and is approximately parallel to the bedding planes of the rocks lying southeast of the fault. The fractures extend across beds many 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, they become more numerous and steeper. In southern Virginia they are closely compressed and often closed, while occasional faults appear. The folds, in passing through Virginia into Tennessee, are more and more broken by faults. In the central part of the valley of Tennessee, folds are generally so obscured by faults that the strata form a series of narrow, overlapping blocks, all dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

In the Appalachian Mountains the southeastward dips, close folds, and faults that characterize the Great Valley are repeated. The strata are also traversed by the minute breaks of cleavage and metamorphosed by the growth of new minerals. The cleavage planes dip to the east at from 20° to 90°, usually about 60°. This form of alteration is somewhat developed in the valley as slaty cleavage, but in the mountains it becomes important and 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 sections by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have been moved on its opposite sides.

Structure of the Loudon area.—The rocks of this area have been disturbed from the horizontal position in which they were deposited, and have been 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 dips observed at the surface and from the known thickness of the formations.

Three districts exist in the area mapped, in which the types of deformation differ materially. These are nearly coincident with the topographic and geologic divisions: the valley district, the mountain district, and the plateau district.

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, and are usually closely squeezed, often 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 range from flat to vertical and thence to 50° overturned; the average fold dips 40° on the southeast and 70° to 90° on the overturned side.

The rocks in this region have been compressed so far that the folds are almost universally overturned; in section D, running completely across the valley belt, only five limited areas show northwest dips. The folded belt, owing to this great compression, is narrower than at any point toward the northeast. Sections B, D, and E illustrate the only open fold of the region, passing southeast of Loudon. The same sections also illustrate the closed folds passing through Madisonville. Overturned folds appear in section D, near Lenoir, and in section F near Sweetwater.

Associated with the anticlinal uplifts are the faults, fifteen 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 are least able to resist it, and break there if anywhere. The planes of the faults are nearly parallel to the beds on the southeast side of the folds; so that, when motion along the break has been great or when the upper parts of the fold have been worn away, only rocks with the same dip remain. This is illustrated especially well in section D, northwest of Lenoir. Few of the principal folds remain unbroken, and no other section across the valley districts shows as many faults as this. The planes of the faults dip from 20° to 60° southeast, most of them about 45°. The amount of displacement varies from nothing up to 5 miles, the latter being the least measure of the fault immediately northwest of Chilhowee Mountain. On most of the faults the displacement is from 1 to 3 miles. The arch and corresponding basin northwest of Madisonville (sections D, E, and F) illustrate the formation of a fault from a fold, by the overturning and final breaking of the northwestern beds. Similar developments are shown in the fault passing southeast of Sweetwater (sections D, E, and F).

The second structural province of this region lies southeast of a line along Chilhowee Mountain, passing through the corner of the district mapped. In this province the rocks have not only been deformed by folds and faults, as in the valley, but also by change of their minerals, or metamorphism. The folds and faults themselves have many features not shown in the valley. Two large faults occur, one on either side of Chilhowee Mountain, and four minor ones closely adjoining. The fault southeast of Chilhowee dips at a much less angle than do the faults in the valley, and sometimes is nearly flat; its plane is parallel to the adjoining strata, as in the valley faults, but it is unlike them in having no apparent connection with an anticline. Over most of its course its plane lies in the Wilhite slate, and it appears to be a great slip along the thin Wilhite strata rather than a break in a close anticline. One short fault, southeast of Chilhowee Mountain, shows the very rare feature of a northwest dip. This, too, is nearly parallel to the strata on either side.

Folds are as common in the mountains as in the valley, but the mountain folds lack the great regularity of those in the valley. Since the beds are more massive in the mountains, the folds are also rather larger. They are also less closely compressed than in the valley district. The unusual feature of the folds is the extent to which their crests rise and fall where transverse folds cross the longitudinal ones. These transverse uplifts sometimes have dips as steep as the longitudinal folds.

The details of metamorphism, the third mode of change in the mountain rocks, have been given under the different formations. The process was in general as follows: The minerals first changed position during the folding of the rock, fracturing more and more, 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, characterized by 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 of form increases in a southeast direction, beginning with mere cleavage without change of minerals near Chilhowee Mountain, but the alteration is not conspicuous within the limits of this area. Rocks of fine grain and feldspathic nature have been altered most.

The latest form in which yielding to pressure is displayed in this region is vertical uplift or depression. Evidence can be found of such movements at various intervals during the deposition of the sediments, as at both beginning and end of the epochs of deposition of the Knox dolomite, the Athens shale, and following the deposition of the Clinch sandstone and 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 all of the valley district, and its more or less worn remnants are now seen in the hills and ridges, at elevations of 1,000 to 1,200 feet. Since its formation, uplift of the land gave the streams greater slope and greater power to wear; they have therefore worn down into the old surface to varying depth, according to their size, and have produced the narrow, deep cuts in which the streams now flow. As they are still wearing their channels downward, and but little laterally, they have not reached the grade to which the old peneplain was worn. The amount of uplift was possibly 500 to 600 feet, much more than the depth of the present stream-cuts. Traces of another and earlier peneplain can be found in Walden Ridge, at 1,600 feet, and in various ridges forming the lower portion of the mountain district. These are quite obscure, and the plains were almost removed during the formation of the later ones. It is probable that there were many such pauses and uplifts in this region, but their records have been almost entirely removed. Doubtless still others occurred which were not of sufficient length to permit peneplains to form and to record the movement.

MINERAL RESOURCES.

The rocks of this region which are valuable for use in the natural state are coal, marble, slate, building stone, and road material. Other materials derived from the rocks are iron, 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.

Coal.—Bituminous coal occurs in many seams in the Carboniferous rocks in the northwestern part of this region. The coal-bearing area included in the district mapped is small and is a portion of the large field extending northeast and southwest for many miles. Seams have been mined north of Oakdale Furnace and on Little Emory River. The bed near Oakdale averages about 4 feet in thickness, but dips at a very high angle, owing to its location near a line of folding. Operations are now carried on along the branches of Little Emory River, where the rocks are slightly rolling and nearly flat. The seam worked varies from 2 to 5 feet in thickness, with occasional thicker pockets, and lies in the lower part of the Briceville shale, like the seam worked in the same formation at Big Mountain, Briceville, and Coal Creek, shown on the Briceville sheet. Other thin seams of varying thickness lie near the top of the conglomerate and in the Briceville shale, but these are of no practical value.

These coals are all of good quality for shop and steam use, but have not been worked to great depths. They are well above water-level and much cut into by the minor drainage lines. Their proximity to the line of change from vertical to flat strata has rendered them somewhat irregular in thickness.

Marble.—Marbles are found in great quantity in the Chickamauga limestone in most of its eastern outcrops, and also in the Sevier shale. The distribution of the marbles and quarries is shown on the economic sheet. Their chief development is in the belts passing near Loudon and Louisville, and is due as much to superior means of transportation as to the quality of the rock.

The total thickness of marble, 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 was present with clay in large proportion the rock is a worthless shale. The color is due to the presence of very fine grains of iron oxide, either limonite or hematite, and varies from cream, yellow, brown, chocolate, red, and pink to blue, in endless variety. Absence of iron oxides 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 the marbles. Like the shaly matter, the iron oxide is an impurity, and the two are apt to accompany each other. The most highly prized rock, therefore, is a balance between the pure and the impure, and slight changes in the form of sediment result in poorer 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 marble in the belt northwest of Madisonville and by the shifting of the marble into the beds next to the Knox dolomite at Marble Bluff, west of Loudon. As a rule, however, the marble remains very constantly in the upper part of the Chickamauga limestone. The marbles of the Seveir shale are prominent at the bottom of the formation, but occasionally occur in the upper strata as well. They are similar to the Chickamauga marbles, but usually have not such rich colors, being oftenest of a gray color; and they contain more shaly beds. The belts passing south of Loudon and Louisville have this marble more highly developed than the other belts. It has been quarried only in the southeastern belt, near Mountainville, and farther southward at the Tellico River, and its beds are not now worked for want of transportation.

Workable beds are rarely over 50 feet thick, and usually in that thickness there is a combination of several varieties. Quarries far separated from each other have quite distinct series of beds, and each quarry has its special variety of marble. All marbles of this region are free from any siliceous 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 northeastern portions of the belts, where the strata dip at small angles and cover a greater surface. In most of the other areas of marble the beds are more folded and dip at greater angles, so that prolonged quarrying will necessitate a great deal of stripping. Good marble abounds in these areas, however, and will be quarried in course of 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 its particles are not wholly crystalline. The irregular forms and the different colors of its fragments give a very pleasing effect, although the colors are quiet and subdued. The small body of this rock discourages its development, and the frequent sand grains materially injure its polish.

Slate.—Two formations in this region contain beds of slate, the Wilhite and the Pigeon slates. The Wilhite slate is too calcareous and soft for practical use. 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 in the area of the Knoxville sheet 2 miles from the river and 3 miles southeast of Chilhowee, and much good material has been taken out for shipment. The slates are of fine, even grain, and split into slabs of any desirable size an inch thick, or into roofing slates one-quarter of an inch thick. In this particular quarry the cleavage crosses the bedding and produces ribbons on 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 through the formation.

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 in adjacent areas near Knoxville and used in that 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 for stone houses. It is very hard and firm and thoroughly satisfactory in wear, but its beds average only from 6 inches to 2 feet in thickness, and on that account it is not adapted for larger work. 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 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 Lee conglomerate. Little use has been made of them thus far because of their inaccessibility and extreme hardness in working.

Various formations are in use for road building. The Knox dolomite, the marbles, 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 recements the mass firmly. The cherts of the Knox dolomite have long been used, and form natural roads on chert ridges like Black Oak Ridge. Their fragments are angular, pack very firmly, and are almost indestructible. The open structure secured by them to the road-bed keeps it well drained. The rapid wear of iron tires and shoes by the sharp edges of the chert is the only objection to its use.

The Rogersville shale has long found local use for road material, 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 and smoothness.

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 of two kinds occur in this region, red hematite and brown hematite. In adjacent areas, near Knoxville, brown hematite results from the decomposition and concentration of the ferruginous matter in the Tellico sandstone, and the ores are of good quality. In this area no ores have been developed in this formation. Another class of ores occurs along the fault southeast of Chilhowee Mountain. They appear at several 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 the southeastern belt of dolomite numerous small outcrops of ore appear, but none have been mined, and the amount of ore is small. The quality of the ore is good, and it has produced good iron when worked in similar banks in other areas. Near Oakdale fossiliferous red hematite bedded in the Rockwood formation has been mined extensively, but the ores, which were of excellent quality, appear to have been almost entirely worked out.

Lime and cement.—Many beds in the Knox dolomite and Chickamauga limestone have been burned for lime and excellent results obtained. The marbles also would furnish the best of lime, but 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 such beds immediately northwest of Knoxville has been burned, giving a good cement.

Brick clay.—Clays suitable for making bricks are very abundant in this region. They are found in the several formations, principally Knox dolomite, Chickamauga limestone, and Athens shale, and consist of wash from the residual clays into the neighboring hollows. The deposits usually are not deep, but are of large area and frequent occurrence. Much of the wash from the slate formations of the mountains contains clay, in places where the hollows do not have steep slopes, and this will eventually be of value. Local use has long been made of the clays of the valley, and bricks have been burned for building near at hand. At no place in this area have systematic operations been carried on.

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 supplied with better or more abundant water than the district which includes the Smoky Mountains, a portion of which is included in the area here mapped. 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 often be used for power. The small streams fall rapidly to the deeper channels of the large rivers and furnish abundant power. Thousands of falls are produced in the smaller creeks by hard beds of rock, such as the upper sandstone of the 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 of great value.

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 oaks, 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 and Sevier shale 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. The choicest of the timber of this region has been cut, but an immense amount yet remains; the mountain timbers have only been touched in the most accessible places, and are for the most part virgin forest.

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

TOPOGRAPHY

TENNESSEE
LOUDON SHEET

LEGEND

RELIEF
(printed in brown)

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

Depression contours

DRAINAGE
(printed in blue)

Rivers

Creeks

Intermittent streams

Ponds

Springs

Sinks

CULTURE
(printed in black)

Towns and cities

Houses

Railroads

Roads

Ferries

Fords

County lines

Triangulation stations

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

Scale 1:125000

Contour Interval 100 feet
Datum is mean Sea level

Edition of Oct. 1895.

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

AREAL GEOLOGY

TENNESSEE
LOUDON SHEET

LEGEND
(continued)

CAMBRIAN

Ch — Hesse sandstone *(fine, massive, white sandstone)*

Cmr — Murray shale *(blue-gray, sandy shale)*

Cnb — Nebo sandstone *(fine and coarse, massive, white sandstone)*

Cnc — Nichols shale *(bluish-gray, sandy shale)*

Cch — Cochran conglomerate *(massive, white sandstone and coarse, feldspathic conglomerate)*

Cs — Sandsuck shale *(bluish-gray, argillaceous shale)*

AGE UNKNOWN

Pg — Pigeon slate *(gray argillaceous slate with sandy layers)*

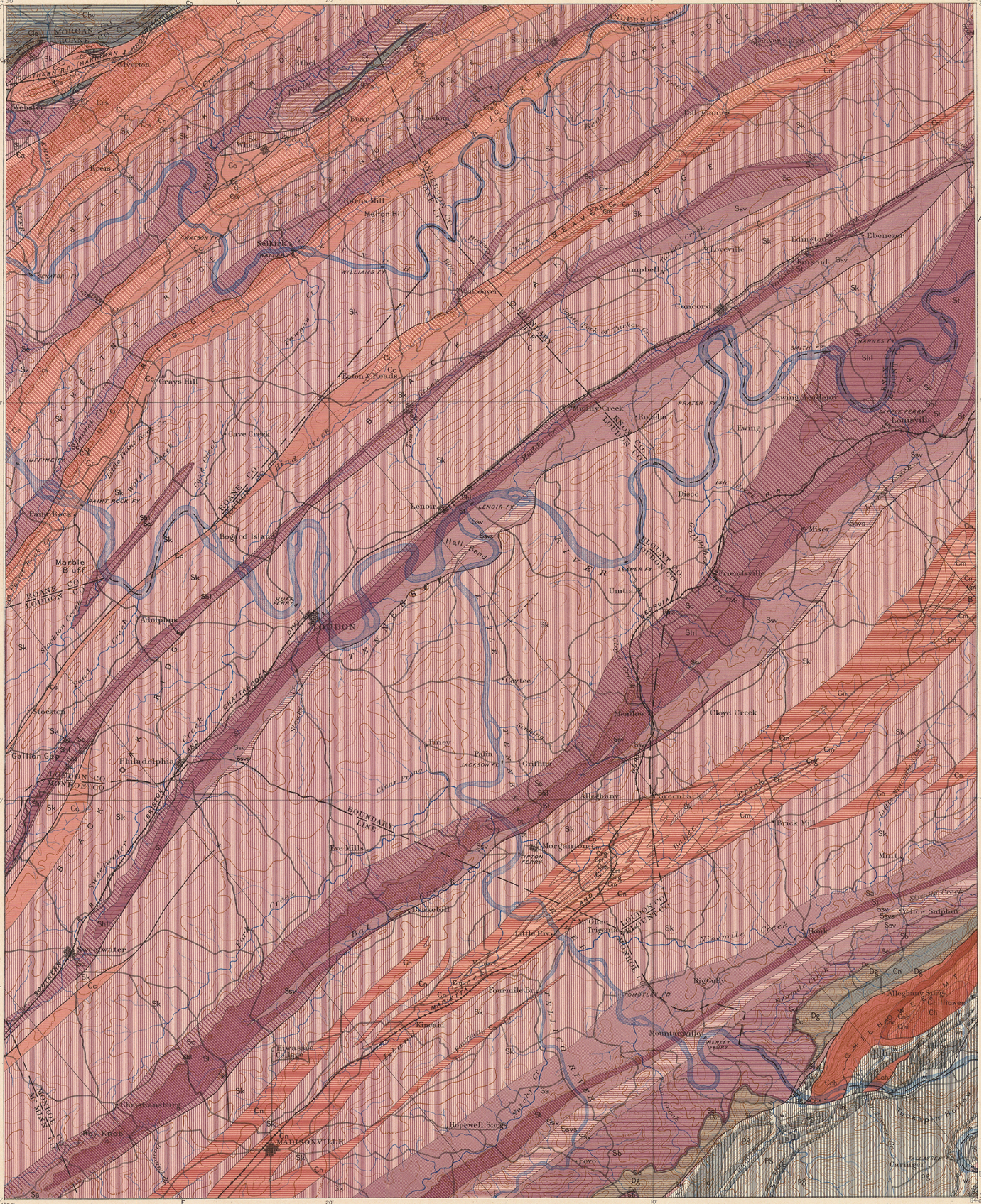
c — Citico conglomerate *(fine, white sandstone and coarse conglomerate)*

Wl — Wilhite slate *(limestone conglomerate and black slate)*

SPECIAL SYMBOLS

Faults

Sections



35°30' 84°30' F 20' 10' 84°00' 35°30'

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by S.S. Gannett.
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" " C.E. Cooke. 1891.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour Interval 100 feet
Datum is mean Sea level

Edition of Oct. 1895.

G.K. Gilbert, Chief Geologist.
Bailey Willis, Geologist in charge.
Geology by Arthur Keith.
Assisted by R.E. Edes.
Surveyed in 1889-90.

LEGEND

SEDIMENTARY ROCKS

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

CARBONIFEROUS

Cbv — Briceville shale *(dark-gray, argillaceous shale with sandstone beds and coal seams)*

Cle — Lee conglomerate *(massive, white sandstone and conglomerate)*

Cpn — Pennington shale *(sandy and calcareous shales interbedded)*

Cn — Newman limestone *(massive blue limestone, cherty at the base)*

DEVONIAN

Dg — Grainger shale *(bluish-gray, sandy shale and sandstone)*

Dc — Chattanooga shale *(black, calcareous and carbonaceous shale)*

SILURIAN

Sr — Rockwood formation *(reddish, calcareous shale with white sandstone and iron beds near the top)*

Scl — Clinch sandstone *(massive, white sandstone)*

Sb — Bays sandstone *(red sandstone and sandy limestone)*

Ssvs — Sevier sandstone *(lentils of gray, calcareous sandstone in Sevier shale)*

Ssv — Sevier shale *(bluish, calcareous shale)*

St — Tellico sandstone *(bluish-gray sandstone and sandy shale)*

Sa — Athens shale *(blue, calcareous shale with black, carbonaceous shale at the base)*

Shl — Holston marble *(lentils of variegated marble in Chickamauga limestone)*

Sc — Chickamauga limestone *(massive, blue limestone and gray, shaly limestone)*

Sk — Knox dolomite *(light and dark, magnesian limestone with chert nodules)*

CAMBRIAN

Subdivisions of the Connasauga shale

Cn — Nolichucky shale *(brown, calcareous shale with thin limestone beds)*

Cm — Maryville limestone *(massive, dark-blue limestone)*

Crg — Rogersville shale *(green clay-shale with a bed of limestone)*

Crt — Rutledge limestone *(massive, dark-blue limestone)*

Cc — Connasauga shale *(reddish, calcareous shale with thin beds of limestone)*

Cr — Rome formation *(reddish and green, sandy shale)*

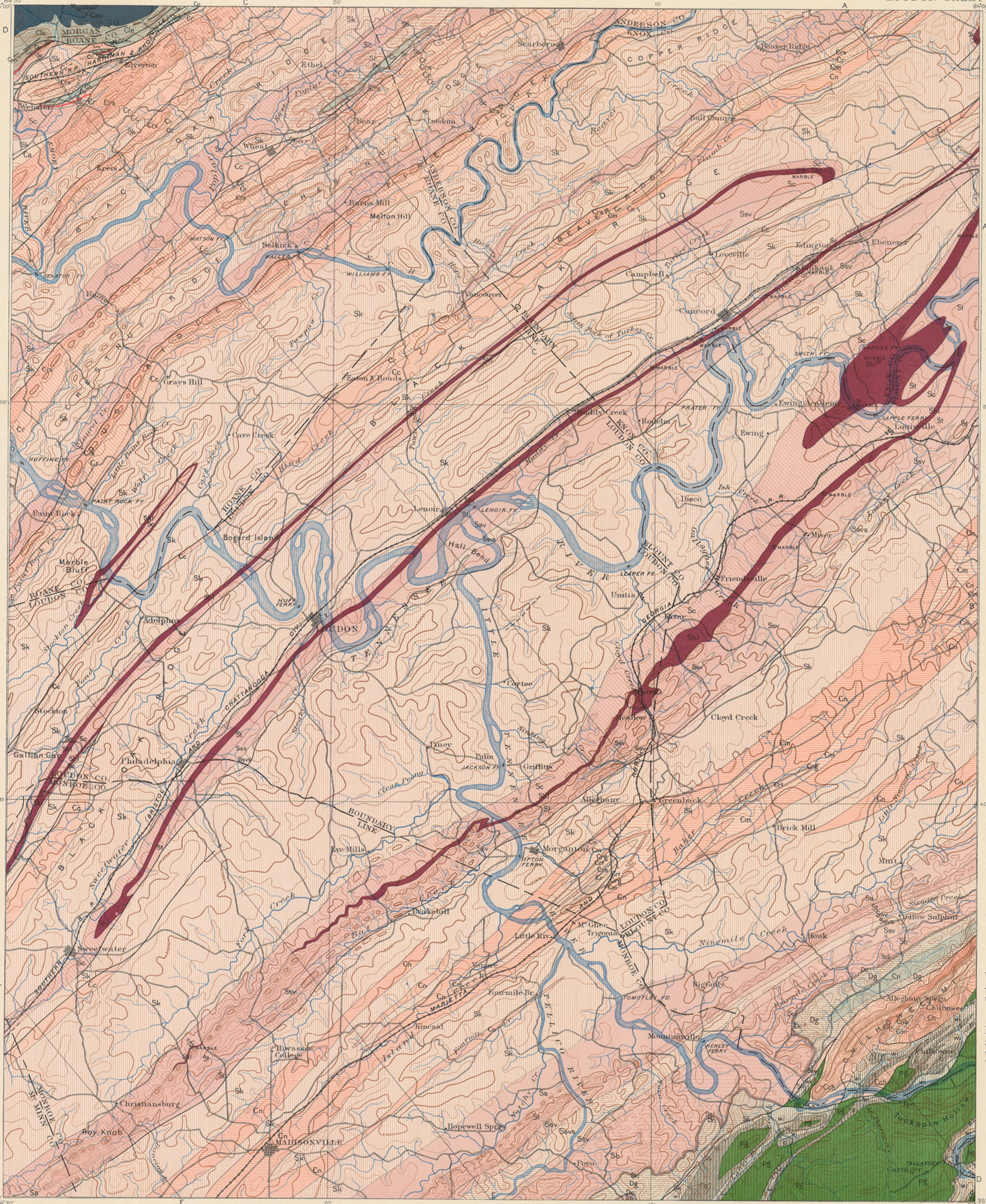
Crs — Rome sandstone *(lentils of reddish sandstone in Rome formation)*

Ca — Apison shale *(red, green, and brown, sandy shale)*

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

ECONOMIC GEOLOGY

TENNESSEE
LOUDON SHEET



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Scale $\frac{1}{125000}$
Miles
Kilometers
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- Crt — Rutledge limestone (massive, dark-blue limestone)

- Cc — Connasauga shale (reddish, calcareous shale with thin beds of limestone)
- Cr — Rome formation (reddish and green, sandy shale)
- Crs — Rome sandstone (lentils of reddish sandstone in Rome formation)
- Ca — Apison shale (red, green, and brown, sandy shale)

LEGEND (continued)

CAMBRIAN
- Ch — Hesse sandstone (fine, massive, white sandstone)
- Cmr — Murray shale (blue-gray, sandy shale)
- Cnb — Nebo sandstone (fine and coarse, massive, white sandstone)
- Cnc — Nichols shale (bluish-gray, sandy shale)
- Cch — Cochran conglomerate (massive, white sandstone and coarse, feldspathic conglomerate)
- Cs — Sandsuck shale (bluish-gray, argillaceous shale)

AGE UNKNOWN
- Pg — Pigeon slate (gray argillaceous slate with sandy layers)
- c — Citico conglomerate (fine, white sandstone and coarse conglomerate)
- wi — Wilhite slate (limestone conglomerate and black slate)

Known productive formations
- Coal
- Red hematite iron ore
- Variegated marble
- Slate

SPECIAL SYMBOLS

Faults

Sections

⚒ Mines and Quarries

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

STRUCTURE SECTIONS

TENNESSEE
LOUDON SHEET

LEGEND
(continued)

CAMBRIAN

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Cmr — Murray shale *(blue-gray, sandy shale)*

Cnb — Nebo sandstone *(fine and coarse, massive, white sandstone)*

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SEDIMENTARY ROCKS

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DEVONIAN

Dg — Grainger shale *(bluish-gray sandy shale and sandstone)*

Dc — Chattanooga shale *(black, calcareous and carbonaceous shale)*

SILURIAN

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Crt — Rutledge limestone *(massive, dark-blue limestone)*

Cc — Connasauga shale *(reddish, calcareous shale with thin beds of limestone)*

Cr — Rome formation *(reddish and green, sandy shale)*

Crs — Rome sandstone *(lentils of reddish sandstone in Rome formation)*

Ca — Apison shale *(red, green, and brown, sandy shale)*

Henry Gannett, Chief Topographer.
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Scale $\frac{1}{125000}$
5 Miles
5 Kilometers

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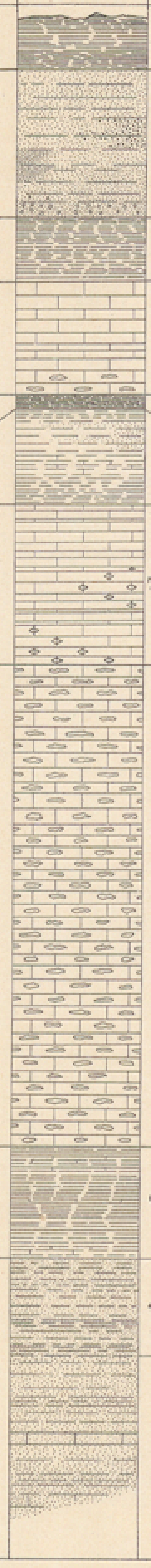
COLUMNAR SECTIONS

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

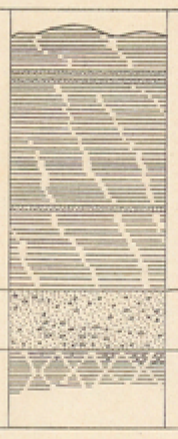
TENNESSEE
LOUDON SHEET

GENERALIZED SECTION NORTH AND WEST OF LOUDON.

SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
CARBONIFEROUS	Briceville shale.	Cbv		300+	Blue, gray, and black, argillaceous shales, with sandstone beds and coal seams.	Valleys.
	Lee conglomerate.	Cle		900	Massive, white sandstone, locally cross-bedded, with conglomerate layers near the bottom.	High, rocky mountains and ridges.
	Pennington shale.	Cpn		400±	Sandy and calcareous shales interbedded, with small beds of sandstone.	Slopes of mountains of Lee conglomerate.
	Newman limestone.	Cn		700	Massive, blue and dove limestone, cherty near the base.	Steep slopes and cliffs, and small ridges.
DEV.	Chattanooga shale.	Dc		80	Black, calcareous and carbonaceous shale.	Narrow valleys.
SILURIAN	Rockwood formation.	Sr		600	Red, yellow, and brown, calcareous shales and sandy shale; white sandstone and iron ore near the top.	Sharp, straight ridges.
	Chickamauga limestone.	Sc		700–1400	Massive, blue limestone; red, flaggy limestone; gray, argillaceous and shaly limestone.	Low, round hills and rolling valleys.
	Holston marble.	Shl			Variegated, reddish, brownish, and gray marbles, shaly marble, and shale.	Smooth, rounded hills.
	Knox dolomite.	Sk		2500–3500	Magnesian limestone, white, gray, light- and dark-blue, with nodules of chert	Broad, cherty ridges and high, rounded hills.
CAMBRIAN	Conasauga shale.	€c		600–850	Yellow, red, and brown, calcareous shale, with thin beds of limestone and shaly limestone.	Valley and slopes of Knox dolomite ridges.
				400–850	Brilliant red, yellow, green, and brown, sandy and argillaceous shales.	Slopes of Rome sandstone ridges.
	Rome formation. (Rome sandstone) Apison shale.	€r (€rs) €a		1000+	Red, yellow, and brown sandstones and sandy shale.	Sharp ridges with notches and gaps.

GENERALIZED SECTION SOUTHEAST OF CHILHOWEE MOUNTAIN.

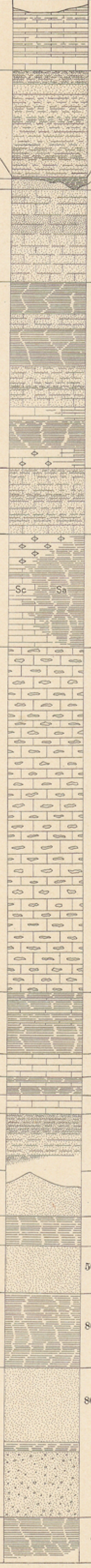
Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
AGE UNKNOWN	Pigeon slate.	pg		1300+	Banded, gray and bluish-gray clay-slate and sandy slate, with a few sandstone beds.	Irregular ridges and knobs, with steep slopes.
	Citico conglomerate.	c		100–300	Coarse and fine quartz-conglomerate; coarse and fine, white sandstone.	High, sharp ridges.
	Wilhite slate.	wi		100–200	Bluish-black slate, with limestone conglomerate and limestone at the top.	Narrow valleys and slopes of Citico conglomerate ridges.

NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		Safford: Geology of Tennessee, 1869.
Carb.	Briceville shale. Lee conglomerate. Pennington shale.	Cbv Cle Cpn	Coal measures.
	Newman limestone.	Cn	Mountain limestone.
Dev.	Grainger shale.	Dg	Siliceous group.
	Chattanooga shale.	Dc	Black shale.
Silurian	Rockwood formation.	Sr	Dyestone group.
	Clinch sandstone. Bays sandstone.	Scl Sb	Clinch Mountain sandstone.
	Sevier shale. Tellico sandstone. Athens shale.	Ssv St Sa	Trenton and Nashville series.
	Holston marble. Chickamauga limestone.	Shl Sc	Trenton, Lebanon, or Maclurea limestone.
	Knox dolomite.	Sk	Knox dolomite.
Cambrian	Nolichucky shale. Maryville limestone. Rogersville shale. Rutledge limestone. } Conasauga shale.	€n €m €rg €rt } €c	Knox shale.
	Rome formation. Apison shale.	€r €a	Knox sandstone.
	Hesse sandstone. Murray shale. Nebo sandstone. Nichols shale. Cochran conglomerate. Sandsuck shale.	€h €mr €nb €nc €ch €s	Chilhowee sandstone.
	Pigeon slate. Citico conglomerate. Wilhite slate.	pg c wi	Ocoee group.

GENERALIZED SECTION SOUTH AND EAST OF LOUDON.

SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
CARB.	Newman limestone.	Cn		650+	Bluish-gray shale and shaly limestone. Massive, blue limestone.	Low, open valleys.
DEVONIAN	Grainger shale.	Dg		1100–1200	Red and yellow, sandy shale. Massive, white sandstone. Greenish- and bluish-gray, sandy shale and sandstone.	Slopes of high ridges and lines of low knobs.
	Chattanooga shale.	Dc		6–50	Black, calcareous and carbonaceous shale.	Narrow valleys.
SILURIAN	Clinch sandstone.	Scl		0–100	Massive, white sandstone.	Small ridges and benches.
	Bays sandstone.	Sb		1100–1300	Red sandstone, calcareous sandstone, and sandy limestone.	Irregular hills and knobs.
	Sevier shale.	Ssv Ssvs Ssv		300–400 100–200 400	Bluish, calcareous shale and shaly limestone, with lentils of calcareous sandstone.	Low valleys with uneven surfaces.
		Ssvs		350–550	Bluish-gray, calcareous sandstone and sandy shale.	Ridges and lines of hills.
		Ssv		450–750	Bluish, calcareous shale and limestone Variegated marble.	Low valleys with uneven surfaces.
	Tellico sandstone.	St		350–900	Bluish-gray and reddish, calcareous sandstone and sandy shale interbedded.	Ridges and lines of high hills.
	Holston marble. } Athens shale. Chickamauga limestone.	Shl Sa Sc		1000–1200	Variegated marble, blue, calcareous shale, and limestone, grading eastward into blue, calcareous shale, carbonaceous at the base.	Low valleys with slightly uneven surfaces.
	Knox dolomite.	Sk		3500–3800	Magnesian limestone, white, gray, light- and dark-blue, with nodules of chert.	Broad, cherty ridges and high, rounded hills.
CAMBRIAN	Nolichucky shale.	€n		650	Yellow and brown, calcareous shale, with limestone beds.	Flat, open valleys.
	Maryville limestone.	€m		0–250	Massive, dark-blue limestone.	Open valleys and lines of low knobs.
	Rogersville shale.	€rg		180	Bright-green clay-shale, with a bed of limestone.	Lines of low knobs.
	Rutledge limestone.	€rt		0–200	Massive, dark-blue limestone.	Open valleys.
	Rome formation. (Rome sandstone.)	€r (€rs)		500+	Brilliant red, yellow, green, and brown, sandy and argillaceous shale. Red, yellow, and brown sandstone and sandy shale.	Slopes of Rome sandstone ridges. Sharp ridges with notches and gaps.
	Hesse sandstone.	€h		500+	Fine, massive, white sandstone.	High, sharp-crested mountains.
	Murray shale.	€mr		300	Bluish-gray, sandy shale.	Steep slopes and depressions.
	Nebo sandstone.	€nb		500–650	Fine and coarse, massive, white sandstone.	High, sharp-crested mountains.
	Nichols shale.	€nc		800–900	Bluish-gray, sandy shale.	Steep slopes and narrow valleys.
	Cochran conglomerate.	€ch		800–900	Massive, white sandstone, coarse and fine.	High, sharp-crested mountains.
				100	Red sandstone and gray, sandy shale.	Small depressions.
				700	Coarse conglomerate, with quartz and feldspar pebbles.	High, round-topped mountains and ridges.
	Sandsuck shale.	€s		500+	Bluish-gray, argillaceous shale.	Slopes of Cochran conglomerate mountains.

ARTHUR KEITH,
Geologist.

in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be discovered by observing their relative positions. This relationship holds except in regions of intense disturbance; sometimes in such regions the disturbance of the beds has been so great that their position is reversed, and it is often difficult to determine the relative ages of the beds from their positions; then *fossils*, or the remains of plants and animals, are a guide to show which of two or more formations is the oldest.

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are characteristic types, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together and formed a chain of life from the time of the oldest fossiliferous rocks to the present.

When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which one was deposited first.

Fossil remains found in the rocks of different areas, of different provinces, and of different continents, afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the color or colors and symbol assigned to each, are given below. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, with the exception of Pleistocene and Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the

Period.	Symbol.	Color.
Pleistocene	P	Any colors.
Neocene { Pliocene / Miocene }	N	Buffs.
Eocene { including Oligocene }	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic / Triassic }	J	Blue-greens.
Carboniferous { including Permian }	C	Blues.
Devonian	D	Blue-purples.
Silurian { including Ordovician }	S	Red-purples.
Cambrian	€	Pinks.
Algonkian	A	Orange-browns.
Archean	Æ	Any colors.

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

The number of surficial formations of the Pleistocene is so great that, to distinguish its formations from those of other periods and from the igneous rocks, the entire series of colors is used in patterns of dots and circles.

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

The legend is also a partial statement of the geologic history. The formations are arranged according to origin into surficial, sedimentary, and igneous, and within each class are placed in the order of age, so far as known, the youngest at the top.

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

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface.

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

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

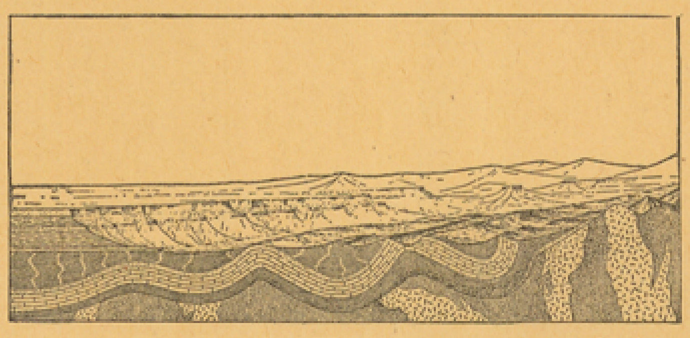


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape above.

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

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

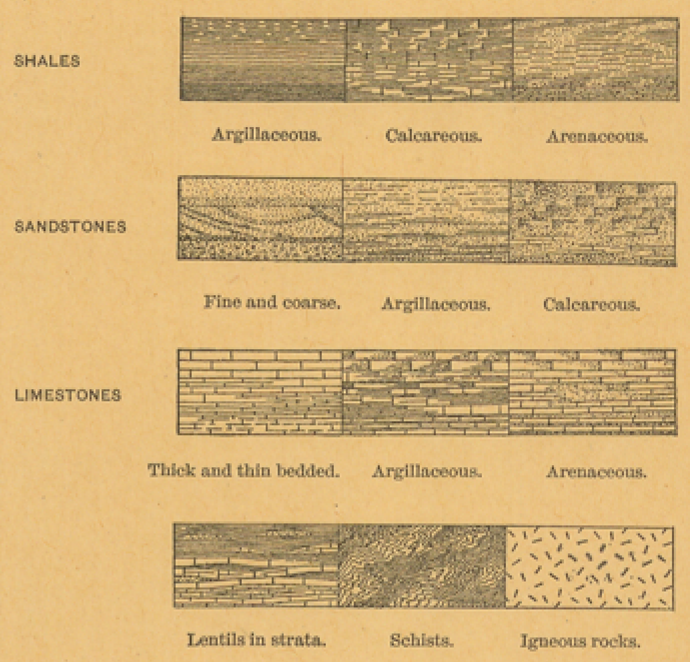


Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

In fig. 2 there are three sets of formations, distinguished by their underground relations.

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

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

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their 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 the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

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

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

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

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

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

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

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

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