DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

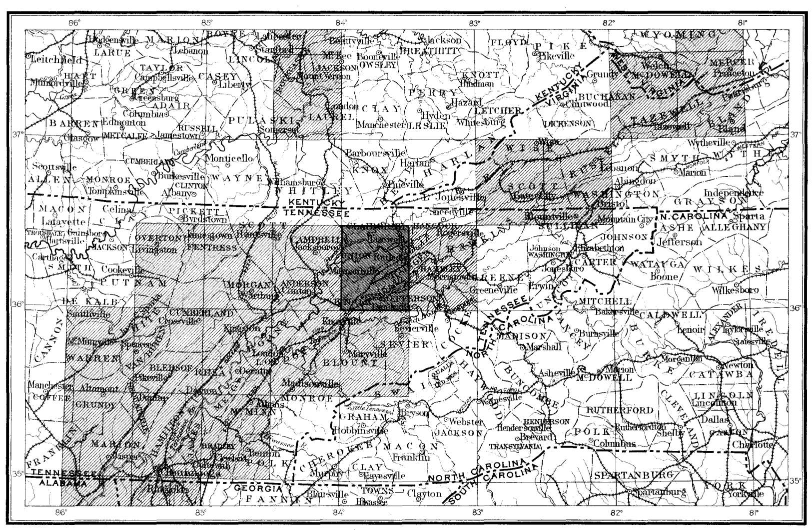
OF THE

UNITED STATES

MAYNARDVILLE FOLIO

TENNESSEE

INDEX MAP



SCALE 40 MILES=1 INCH

AREA OF THE MAYNARDVILLE FOLIO

AREA OF OTHER PUBLISHED FOLIOS

LIST OF SHEETS

DESCRIPTION | TOPOGRAPHY | HISTORICAL GEOLOGY | ECONOMIC GEOLOGY | STRUCTURE SECTIONS

COLUMNAR SECTIONS

FOLIO 75 | LIBRARY EDITION | MAYNARDVILLE

WASHINGTON, D. C.

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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KÜBEL, CHIEF ENGRAVER

1901

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 given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, 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 uniform 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:

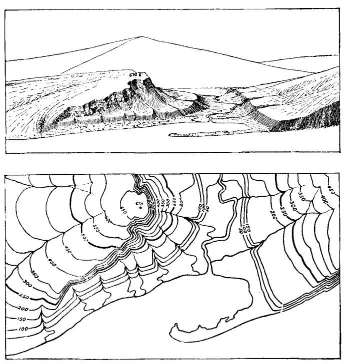


Fig. 1.—Ideal sketch and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the left-hand 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 are drawn 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 similarly with any other contour. In the space between any two contours are found 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 with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be about 240 by 180 feet. 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 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 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 on the ground to an inch on the map. 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 the scale is expressed in three different ways, 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 and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree, i. e., a degree of latitude by a degree of longitude; 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. The areas of the corresponding quadrangles are about 4000, 1000, 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. To each sheet, and to the quadrangle it represents, 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 district 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 maps representing areal geology show 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 map shows 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 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 partially 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 composed are carried as solid particles by 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 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 they 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 guides 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, forming 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 was deposited first.

Fossil remains found in the rocks of different areas, provinces, and 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 in the table in the next column. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period name.

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, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

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	Є	Pinks.
Algonkian	A	Orange-browns.
Archean	Æ	Any colors.

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 and extent of surficial formations of the Pleistocene render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

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. If the metamorphic rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

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.

Historical geology 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. In it the symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology 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 historical geology 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:

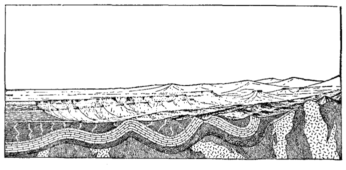


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

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:

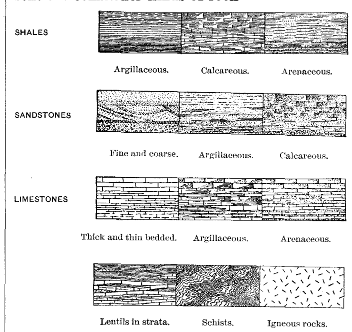


Fig. 3.—Symbols used to represent different kinds of rock.

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 positions, 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 consists 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 occur in the quadrangle. 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 1000 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.

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE MAYNARDVILLE QUADRANGLE.

By Arthur Keith.

GEOGRAPHY.

General relations.—The Maynardville quadrangle lies entirely in Tennessee. It is included between the parallels 36° and 36° 30′ and the meridians 83° 30′ and 84°, and it contains 963 square miles, divided between Knox, Sevier, Anderson, Campbell, Union, Claiborne, Grainger, and Jefferson counties.

Location of quadrangle.

In its geographic and geologic relations this quadrangle 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, which is 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 a single quadrangle; hence it is necessary to consider the individual quadrangle in its relations to the entire province.

Definition of Appalachian 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 longitudinally 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 subdivisions. In its 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 its central and northern portions its 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—its 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 Allegheny 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 features differ with the outcrop of different kinds of rock, sharp ridges and narrow valleys following the belts of hard rock and soft rock, respectively. Owing to the large amount of calcareous rock brought up by steep folds in this division, the surface is more readily worn down by streams and is lower and less broken than that of the divisions on either side.

The Appalachian Valley.

The eastern division of the province embraces the Appalachian Mountains, a system which is made up of many minor ranges under various local names, and which extends from southern New York to central Alabama. Some of its prominent parts are South Mountain of Pennsylvania, Blue Ridge and Catoctin Mountain of Maryland and Virginia, Great Smoky Mountains of Tennessee and North Carolina, and 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 Appalachian Mountains.

The western division of the Appalachian province embraces the Cumberland Plateau and Allegheny 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 Allegheny Front and the Cumberland escarpment. The rocks of this division are almost entirely of sedimentary origin and lie 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 more often divided by streams into large or small hills 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.

The Cumberland Plateau and Allegheny Mountains.

Altitude of the Appalachian province.—The Appalachian province as a whole is broadly dome shaped, the surface rising from an altitude of about 500 feet along its 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 of the subdivisions of the province has one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1000 feet elevation in Alabama to more than 6600 feet in western North Carolina. From this culminating point they decrease to about 3000 feet elevation in southern Virginia, rise to 4000 feet in central Virginia, and descend to 2000 or 1500 feet on the Maryland–Pennsylvania line.

The Appalachian Valley increases uniformly in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2000 feet at the Tennessee–Virginia line, and 2600 or 2700 feet at its culminating point, on the divide between the New and Tennessee rivers. From this point it descends to 2200 feet in the valley of New River, 1500 to 1000 feet in the James River Basin, and 1000 to 500 feet in the Potomac Basin, remaining at about that altitude 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 2000 feet.

The plateau, or western, division increases in altitude from 500 feet at the southern edge of the province to 1500 feet in northern Alabama, 2000 feet in central Tennessee, and 3500 feet in southeastern Kentucky. It is between 3000 and 4000 feet in altitude in West Virginia, and decreases to about 2000 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 to the Atlantic, in part southward to the Gulf, and in part westward to 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 into the Atlantic, while all of the area south of New River, except the eastern slope of the mountains, is drained westward by tributaries of the Tennessee River 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, which pass through the Appalachian Mountains in narrow gaps and flow 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.

Longitudinal streams and transverse trunk rivers.

TOPOGRAPHY OF THE MAYNARDVILLE QUADRANGLE.

Within the limits of this quadrangle parts of two of the geographic divisions of the Appalachian province occur. The edge of the Cumberland Plateau crosses the northwest corner of the quadrangle. The area southeast of this and occupying practically all of the quadrangle is part of the Great Valley of the Appalachians. The quadrangle extends nearly across the Great Valley, the southeast corner being but a few miles from the border of the Unaka Mountains.

The drainage of this district, except the small portion of the Cumberland Plateau where the waters run northward into Cumberland River, has similar features throughout. This portion of the valley of East Tennessee is drained through the Holston, Clinch, and Powell rivers, which pass into the Tennessee River a few miles southwest of this quadrangle. All of these rivers head far beyond the limits of this quadrangle and flow in generally southwest courses along the strike of the upturned strata. Only the smaller creeks are wholly included within this area.

The rivers and larger creeks of this region have a very gradual fall. The rivers range in altitude from 800 to 1000 feet. Their immediate valleys are rather narrow troughs, from 100 to 500 feet below the general level of the surrounding country. Powell River, which flows along a broad arch of Knox dolomite, is sunk the deepest below the surrounding country. The smaller streams flow in open valleys until near the rivers, where they pass through small canyons and deep cuts down to the river levels. Above these valleys the ridges rise in general from 200 to 500 feet. Clinch Mountain, Lone Mountain, and Powell Mountain rise considerably higher, about 1000 feet above the general altitude of the smaller valleys.

GEOLOGY.

STRATIGRAPHY.

The general sedimentary record.—All of the rocks appearing at the surface within the limits of the Maynardville quadrangle are of sedimentary origin—that is, they were deposited from water. They comprise conglomerate, sandstone, shale, coal, limestone, and marble, 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 early 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 cross-bedding indicate swift currents, and shales cracked by drying on mud flats indicate shallow water; while limestones, especially by the fossils they contain, indicate greater depth of water and scarcity of sediment. The character of the adjacent land is shown by the character of the sediments derived from its waste. Coarse sandstones and conglomerates, such as are found in the Coal Measures, may have been derived from high land on which stream grades were steep, or they may have resulted from the wave action of a sea encroaching 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.

Geologic history recorded in the rocks.

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

Four great cycles of sedimentation are recorded in the rocks of this region. Beginning with the first definite record, coarse sandstones and shales were deposited in early Cambrian time along the eastern border of the interior sea as it encroached upon the land. As the land was worn down and still further depressed, the sediment became finer, until in the Knox dolomite, of Cambro-Silurian time, very little trace of shore material is seen. Following this long period of quiet deposition, there was a slight elevation, producing coarser rocks. This elevation became more and more pronounced, until, between the lower and upper Silurian, the land was much expanded and large areas of freshly 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 base-level, affording conditions for the accumulation of the Devonian black carbonaceous shale. After this sandy shales and sandstones of the Devonian 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, containing scarcely any coarse shore waste, was accumulated. 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 in 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.

Geologic history of the Appalachian province.

The rocks of this area.—The rocks range in age from early Cambrian to the end of the Paleozoic, including the Cambrian, Silurian, Devonian, and Carboniferous periods. Carboniferous formations are in part represented here; Devonian rocks have only a small development; while the Cambrian and Silurian formations are fairly complete. The columnar section shows the composition, name, age, and thickness of each formation.

The rocks lie in two distinct areas or groups of widely different age. The valley portion of the quadrangle comprises the formations from lower Cambrian to Carboniferous, but chiefly Cambrian and Silurian. The Cumberland Mountain district contains the Carboniferous formations.

The valley rocks are mainly calcareous and argillaceous; the mountain rocks siliceous, argillaceous, and carbonaceous. In the valley the rocks lie in long, narrow belts and are often repeated by the numerous folds. In the mountains the folds are very slight, so that the belts of rock are more irregular in shape, largely depending upon the location of the stream cuts. The rocks will be described in order of age.

CAMBRIAN ROCKS.

Rome formation.—Six belts of this formation are found in the quadrangle, two being divided into several smaller areas. All of them are in the valley of East Tennessee, principally south and east of Clinch River. The formation includes the oldest strata of this quadrangle and derives its name from Rome, Georgia, where it is well developed. It is composed in the main of red, brown, and green sandy shales and clay shales, with many beds of red, yellow, and brown sandstones, which occur chiefly at the bottom. The beds of sandstone are seldom more than 2 or 3 feet thick and can not be traced any great distance. Occasionally, however, a single bed attains a thickness as great as 30 feet. The sandstones are interbedded with the shale in rapid alternation, and when one bed dies out another begins either higher or lower, so that the general proportion of sandstone to shale remains about the same. The lower portion of the formation in which the sandstones predominate is separately represented upon the map. In the upper shaly portion the layers are very thin and contain many small interbedded sandstone seams. Brilliant colors characterize these strata, especially the thinner, shaly layers.

Layers of blue limestone, attaining a thickness as great as 50 feet, appear to be interbedded with the sandstones; these occur chiefly along the northwestern parts of the areas, or the basal portion of the formation. In the western portion of the quadrangle it can not be determined whether these are interbedded limestones or the Beaver limestone, which elsewhere underlies the Rome formation. In the belt southeast of the eastern Lone Mountain, however, the limestone bed, apparently the same as that farther west, is clearly interbedded with the sandstones. A few of the sandstone beds also contain lime in such amount as almost to become limestones.

The formation is thinnest in the small area 5 miles southeast of New Market, where it comprises 350 feet of sandy shale at the top and about 900 feet of sandstone and shale at the bottom. Its full thickness is not shown here, however, as its base is cut off by a fault. The formation appears to be thickest in the areas which occur near Clinch River, and it there consists of 450 to 500 feet of shale and 1000 or more feet of sandstone and shale. The layers are considerably folded, however, and the thicknesses can not be accurately determined.

From the frequent changes in sediment from sandy to argillaceous mud, and from the abundance of ripple marks on many of the layers, it is evident that the formation was deposited in shallow waters of changeable depth, just as mud flats are now being formed. Fragments and impressions of animals, such as trilobites, which frequented the shallow and muddy waters, have been preserved in the rocks.

The topography of the outcrop of the formation is quite marked and uniform. Decomposition makes its way slowly along the many bedding planes, and the layers break up into small blocks and fragments without much internal weathering. Ledges are rare, except near the stream cuts. The ridges are usually not high, but are particularly noticeable for the regular height to which their crests rise and for frequent stream gaps. The latter feature is especially well shown in the region, and the name "Comby Ridge" is for this reason given to two ridges in the quadrangle. The lower beds, on account of their more sandy nature, produce the ridges.

On the divides the soil is thin and sandy, but 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 away unless protected. In the hollows the timber is large and the vegetation dense.

Rutledge limestone.—The Rutledge formation occurs in four belts in the quadrangle. It is so named because of its fine development in the valley of Rutledge, Grainger County. As a whole, the strata are limestone, but there are beds of green and yellow calcareous shale toward the base, forming a passage into the Rome formation. The limestone is massive and is generally marked by siliceous bands parallel with the stratification. It ranges in color from blue to gray, dark blue, and black. In the valley of Rutledge the formation varies from 500 to 200 feet, and steadily diminishes in thickness farther north and west, so that it is not recognizable in the Cambrian strata of that horizon along the western border of the quadrangle. The sediments laid down at the same time in the western portion of the quadrangle were calcareous shales which are included in the Conasauga shale. The thinning of the limestone and the substitution of shale in its place appears plainly in the southwestern portion of the quadrangle, in the belt which passes southwest through Rutledge. In a general way one finds this shale extending farther and farther east in passing northward from belt to belt of the Cambrian strata.

The highly calcareous nature of the rock causes it to weather easily, and it always forms low valleys or slopes along the ridges of the Rome formation. Underground drainage through sinks is a common feature of this limestone. A deep, dark, rich-red clay covers its areas and outcrops are relatively few. The soil of the formation is very rich and strong and is among the most prized of the soils that are derived directly from rock in place. Its value is somewhat lessened, however, by the frequent wash from the Rome formation.

Rogersville shale.—This shale can be distinguished in the same zones as the preceding limestone. With the replacement of that limestone by shale the means for separating the Rogersville shale are lost, as it can not be distinguished from the similar green shales of the Conasauga formation. The formation consists in the main of bright-green argillaceous shales. The excellent exposures of them near Rogersville, in Hawkins County, give the formation its name. In its chief development south of Clinch Mountain it is usually divided by a layer of massive blue limestone, and its more northern outcrops contain small beds of shaly limestone.

The formation varies in thickness from 250 feet south of Clinch Mountain to 100 feet north of it. It appears to retain a fairly uniform thickness along the strike of the chief belts of outcrop, so that it is probably represented by an equal thickness in the belts of Conasauga shale. Numerous remains of trilobites are found in the shale, which show the formation to be of middle Cambrian age.

Excepting the interbedded limestones, the formation is but little soluble. Decomposition makes its way down the numerous partings, and the thin green flakes thus formed 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 soil is always thin and full of shale flakes, and is rapidly drained by the numerous partings of the shale. When well protected from washing it is fairly productive.

Maryville limestone.—This formation appears in all the belts of Cambrian strata in this quadrangle except the most northern one. This name is given it because of its great development near Maryville, Blount County, Tennessee. Wherever the formation has been distinguished it consists chiefly of massive blue limestone, usually marked by earthy, siliceous bands. In the southeast portion of this area a considerable number of beds of grayish-blue and mottled limestones appear. Toward the north and west the limestone becomes decidedly thinner and its place is taken by beds of shale. Thus, while the Maryville limestone can be traced entirely across the quadrangle in the belt which passes south of Clinch Mountain, it is less and less prominent in each successive belt toward the northwest, until along Clinch River there are no limestone beds of consequence to represent the formation. The shales equivalent to the Maryville limestone are identical in appearance with the Nolichucky shales above it, so that all are classed together under the name Conasauga in areas lying to the west and southwest.

Together with this change from limestone to shale there appears to be a slight diminution in thickness. In the extreme southeastern part of the quadrangle its thickness is about 500 feet; in the vicinity of Rutledge it is probably as great as 600 feet, while north of Clinch Mountain it rapidly diminishes to nothing as it is replaced by the shale. A proper representation upon the map of this change from limestone to shale is very difficult, because the shale gradually makes its appearance between the layers of massive limestone. This is noticeably the case on the lower part of Bull Run Creek, where all that can be done is to give a generalized outline of the limestone. A few fossils can be found in the massive limestone of this formation, chiefly trilobites of middle Cambrian age.

The limestone decays readily by solution and forms a deep, red clay. From this protrude many layers of limestone, especially of the upper beds. In the eastern part of this quadrangle the upper beds of the limestone form a series of hills rising from 100 to 200 feet above the floors of the valleys. Where the formation diminishes and is replaced by shale it usually occupies valleys. Its shale representative in the Conasauga formation also forms valleys. The limestone soil is a deep, strong clay, and forms some of the best farming lands in the State.

Nolichucky shale.—This formation appears in the same belts as the Maryville limestone, and in fact it can be separated from the Conasauga shale only where the Maryville limestone is present. It is named from the Nolichucky River, along whose course in Greene County the formation is well displayed. It is composed of calcareous shale and shaly limestone with beds of massive blue limestone in the upper portion. When fresh, the shale and shaly limestone are of a gray or bluish-gray color, but they weather readily to various shades of gray, yellow, brown, and green. Most of the formation when much weathered is yellow or greenish yellow.

The formation varies in thickness from 550 feet south of New Market to 750 feet near Rutledge. Westward from these points the formation appears to thicken. It is difficult to say, however, whether this is actually the case, because the thin-bedded shales are so frequently crumpled, and also because the thickening is probably in part due to the addition of shales equivalent to the Maryville limestone. This formation is the most fossiliferous of the Cambrian formations, and remains of trilobites and lingulæ especially are very common.

The calcareous parts of the Nolichucky shale dissolve so readily that the rock is seldom seen in fresh condition. After the removal of the soluble constituents, disintegration is slow and proceeds by the direct action of frost and rain. Complete decomposition produces a stiff yellow clay. The covering of soil upon the rock is accordingly thin unless the formation lies upon very gentle slopes, which is seldom the case in this region. In most cases, particularly south of New Market, near Rutledge, and on the north side of Copper Ridge, the shale forms steep slopes to the north of Knox dolomite ridges. In the Cambrian belts lying farther northwest the boundary between the Nolichucky shale and the Knox dolomite lies much lower down the slopes, near the drainage lines, and the shale occupies the valleys. Where the surface has any considerable slope the soil is full of shale fragments and rock outcrops are frequent. The soil is well drained by the frequent partings of the shale, but even at its best it is poor and liable to wash.

Conasauga shale.—This formation appears in the northern and western part of the quadrangle. It consists of calcareous shales, shaly limestones, and thin beds of massive limestone. The thickness of the formation varies from 600 to 750 feet and is greatest in the northwestern areas of the formation. The base of the formation is frequently marked by a thin layer of calcareous sandstone, separating it from the Rome formation. The Conasauga strata accumulated during the deposition of the Rutledge limestone, Rogersville shale, Maryville limestone, and Nolichucky shale in the area to the southeast, representing the more muddy sediments of those times. The manner of the replacement of those formations by the Conasauga shale has been explained. In the Clinch River belt it is equivalent to all four of these formations; in the southwest portion of the belt passing through Rutledge it represents in places only the lower, shaly part of the Rutledge limestone. In the remaining belts it is equivalent to the Rogersville and Rutledge formations. In its characteristics of soil and topography the formation is identical with the Nolichucky shale, and the description of the latter will suffice for both.

SILURIAN ROCKS.

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

The Knox dolomite is the most important and widespread of all the valley rocks. Its name is derived from Knoxville, Tennessee, which is located on one of its areas. The formation consists of a great series of blue, gray, and whitish limestone and dolomite (magnesian limestone), most of which is very fine grained and massive. Many of the beds are banded with thin, brown siliceous streaks. In the lower part of the formation there are also many white and sandy layers. Over large areas, notably near Clinch and Powell rivers and north of New Market, these layers are coarsely crystalline and in fact marble. All varieties are to be found, from slightly siliceous marble to calcareous sandstone. The sandstones outcrop along the rivers in prominent cliffs. Included in the beds of limestone and dolomite are nodules and masses of black chert, locally called "flint," and their variations form the principal changes in the formation. The cherts are most conspicuous in the lower part of the formation, and in places, by the addition of sand grains, grade into thin sandstones. The formation varies from 2600 to 3500 feet in thickness, being thinnest in Copper, Chestnut, and Wallens ridges.

About 2 miles northeast of Luttrell is found an unusual deposit of conglomerate. It occurs in several layers in the uppermost hundred feet of dolomite and consists of pebbles of limestone, calcareous sandstone, and chert in a calcareous matrix. The pebbles are but slightly rounded and give evidence of local erosion at the end of the dolomite deposition.

The amount of earthy matter in the dolomite is very small (from 5 to 15 per cent), the remainder being mainly carbonate of lime and magnesia. It was deposited very slowly, and deposition must have continued for a very long time in order to have accumulated so great a thickness of rock. The dolomite represents a longer epoch than any other Appalachian sedimentary formation.

Disintegration of the dolomite is speedy on account of the solubility of its materials, and outcrops are rare at a distance from the stream cuts. The formation is covered to a great depth by red clay, through which are scattered the insoluble cherts. These are slowly concentrated by the solution of the overlying rock, and where they are most plentiful they constitute so large a part of the soil that cultivation is almost impossible. The cherts are white when weathered and break into sharp, angular fragments. Very cherty areas are always high, broad, rounded ridges, protected by the cover of chert; a good instance of this is Copper Ridge. The soil of the dolomite is strong and of great depth. The objectionable feature is the chert, but when the amount of this is small the soil is very productive. Areas of cherty soil are always subject to drought on account of the easy drainage caused by the chert, and in such localities underground drainage and sinks prevail. Water is obtainable there only from sinks stopped up with mud, from wells, or rarely from springs. Chert ridges are covered by chestnut, hickory, and oak to such an extent as often to be named for those trees.

Chickamauga limestone.—There are many areas of the Chickamauga limestone in this quadrangle. It is so named because of its occurrence on Chickamauga Creek, Hamilton County, Tennessee. It consists of blue and gray massive limestone, shaly and argillaceous limestone, variegated marble, and red slabby limestone. These beds are, as a rule, very fossiliferous, and in the marble especially fragments of corals, crinoids, brachiopods, and gasteropods are so abundant as to make much of the bulk of the rock.

The variation in the Chickamauga, in both thickness and appearance, is greater than in any other formation in the Valley. Along the foot of Cumberland Mountain and of the eastern Lone Mountain the formation consists of 2000 feet of blue and gray limestones, both massive and slabby, with many layers of red, argillaceous limestone near the base. The latter can not be separated as a formation there, but it appears to represent the Moccasin limestone of the sections farther southeast. North of Clinch Mountain many limestone layers at the base of the formation contain nodules of black chert, so that there the distinction between this formation and the Knox dolomite is not so sharp as in most places. Its upper layers also are to some extent interbedded with the red, slabby layers of the Bays formation, which strongly resemble the red Moccasin beds. South of Holston River the limestone is 500 to 700 feet thick and is overlain by 250 to 400 feet of variegated marble; this is overlain by calcareous sandstone and sandy shale (Tellico sandstone), and these in turn by yellow, sandy and calcareous shales with many local beds of argillaceous limestone and marble (Sevier shale). All these beds are regarded as equivalent in age to the Chickamauga in the northwestern part of the Valley.

Between these sections showing the extremes are various intermediate sections. In the Clinch syncline the position of the Tellico sandstone is apparently occupied by the Moccasin limestone, although some beds, like the Tellico, are present in the overlying Sevier shale. North of this basin the Sevier shale consists of about 50 feet of yellow shale and sandy layers, too thin to show on the map, and the remainder of the interval between the Bays sandstone and the Knox dolomite is occupied by the Chickamauga limestone.

The Moccasin limestone in the Clinch Mountain syncline is a portion of the Chickamauga modified by the introduction of red coloring matter. This is so striking in appearance as to merit separate representation on the map. The Moccasin appears to represent about the same period of time as the Tellico sandstone, and resembles it by the presence of much ferruginous matter. Similar beds are to be found in all areas of the formation north of Holston River, but only in the Clinch Mountain syncline are they sufficiently prominent or distinct to be separated as a formation.

The explanation of these differences in deposits formed at the same time is that the shore from which the material was largely derived lay toward the east or southeast, and that the formations in that vicinity received more shore material. Thus the sand in the Tellico, which directly implies a neighboring shore, disappears toward the west in receding from the shore. The same is true of the finer shore materials or muddy sediment forming the shales of the Sevier, which extends for a considerable distance farther west than the sand grains because of its greater fineness. Along Cumberland Mountain only an extremely small portion of the formation is composed of calcareous shale. Along the intermediate areas in the vicinity of the eastern Lone Mountain the shales are more frequent, especially in the upper part of the formation, and are repeatedly interbedded with the limestones. Thus, the Chickamauga strata northwest of Clinch Mountain represent a much longer period than those of the same name in the other belts, a fact which accounts for the greater thickness of the formation toward the northwest. As deposition of these beds went on, the land gradually rose and the sea became shallower, thus causing the muddy shore deposits to extend farther and farther northwest.

The Chickamauga limestone always occupies low ground, as would be expected from the amount of lime that it contains. This is most noticeable north of Clinch Mountain, where it is situated practically in the bottom of the valleys. Decomposition proceeds by solution, but varies greatly in the different varieties of the rock. The marbles and purer limestones weather deeply into a dark-red clay, through which occasional outcrops appear. Many of the massive blue limestones invariably make ledges and are a characteristic feature of the surface of the formation. Over the shaly varieties the soil is less deep and strong, and many lumps and slabs of rock remain. This particularly characterizes those areas lying northwest of Clinch Mountain. In the extreme southeast part of the quadrangle a variety of weathering is seen, which is very common farther south and east. It consists of irregular, rolling surfaces with many broad outcrops; small knots and lens-shaped lumps of weathered limestone are frequent in the soil of this type of rock. Natural growths of cedar are the usual accompaniment of the limestone portions of this formation. The soil of the marble and heavy limestones is deep and very fertile and forms some of the best lands of the Great Valley. That derived from the shaly limestones is also very rich wherever it attains any depth, but it needs careful tillage to prevent washing, and is apt to be poorly watered.

Holston marble.— In the lower part of the Chickamauga formation are many beds of more or less coarsely crystalline marble. These do not appear northwest of the Clinch syncline, except in a most local way. In that syncline and southward, however, marble is usually well developed in all the areas of the formation. On account of its distinctive appearance and economic importance it is shown on the map under the name "Holston marble." It is from 600 to 650 feet thick near Clinch Mountain and thins in all directions from that area. The position of the marble beds in the limestone varies much from place to place. Usually there is a considerable thickness of blue and gray limestone below the marble; north of Clinch Mountain, however, this is not the case, whereas the marble beds are thicker and rest directly upon the Knox dolomite. The same condition was observed on the south side of Black Oak Ridge.

The marble differs from most of the rocks of the formation in being coarsely crystalline. It may have been altered after its formation by the passage of water through the rock, dissolving and recrystallizing the carbonate of lime, or it may have been deposited in its present form. The shaly parts containing less lime are not crystalline. The forms of the fossils inclosed in marble are plainly visible, although wholly recrystallized. The marble varies considerably in color, most of the rock, however, being of two types, a dark bluish gray and a variegated reddish brown or chocolate. Of these two varieties the latter, or reddish marble, is considerably more common; both are extensively quarried for ornamental stone.

Moccasin limestone.—This formation is represented on the map only in the Clinch syncline, although beds of the same character appear farther north and west in the same relative position. They usually are so interbedded with the limestones of the Chickamauga that it is impracticable to separate them. South of Clinch Mountain they do not appear at all, their place being occupied by the Tellico sandstone. It is therefore probable that the Moccasin limestone and Tellico sandstone represent deposits formed at the same time under different conditions. The marked red color in both formations, due to iron oxide upon weathering, distinguishes them from the adjacent formations. Some of the layers of the Moccasin contain so much sand as to resemble the Tellico strongly, the usual difference between the two being the presence in the Moccasin of argillaceous matter, instead of the sandy matter which characterizes the Tellico. This difference is probably due to the greater distance of the Moccasin from the shore, and is of the same class as other differences in the sediments of that time.

The formation is named because of its occurrence along Moccasin Creek in Scott County, Virginia. It consists of red, green, blue, and gray flaggy limestones in alternation, and contains a little red and gray calcareous shale. The red beds are the most numerous and are made conspicuous by their color, which forms the chief distinction between this formation and the Chickamauga. The shaly beds can not be distinguished from those of the Sevier formation. Some of the red layers contain a considerable amount of sand, becoming in places argillaceous sandstones. These are, however, comparatively uncommon. In thickness the formation ranges from 600 to 800 feet, including all the varieties.

The Moccasin formation is affected by weathering much as is the blue Chickamauga limestone, and forms smaller knobs in the lower parts of the valleys. The red limestones, in particular, weather into large flags and slabs and show frequent bare ledges. The soil of the Moccasin is yellow, red, or purplish clay, rarely deep, and is strewn with unweathered fragments. On account of its thinness the soil is subject to washing and drought, but is fertile when well situated.

Tellico sandstone.—Two areas of this formation are found in this quadrangle, both lying south of Holston River. These strata consist of bluish-gray and gray, calcareous sandstones and sandy shales, closely interbedded. By solution of the lime they weather into a porous sandy rock with a strong red or brown color. Their thickness in this region varies widely, from 100 to 350 feet, and they represent the edge of the formation as it thins out northwestward. Toward the south they thicken rapidly and become an important formation.

Decomposition of the Tellico sandstone is rapid, so far as solution goes, and outcrops are few, but the sandy skeleton remains and is hard enough to cause lines of knobs from 100 to 200 feet in height. In fact, the formation is more conspicuous in its effect upon topography than in any other way. Its soil is thin and sandy. As it usually lies upon hill slopes, its liability to wash is considerable, and it is not extensively cultivated.

Sevier shale.—This formation appears in this quadrangle in four separate areas, the largest being in the Clinch Mountain syncline. The name of the formation is taken from its great development in Sevier County, Tennessee, immediately south of this quadrangle. As a whole, the formation consists of argillaceous and calcareous shales, most of them being thick bedded and slabby. These are gray, bluish gray, and brown when fresh, and weather out a dull yellow, greenish yellow, or gray. Beds of limestone from a few inches to a few feet in thickness are common, particularly in the lower part of the formation. Some of these layers contain great quantities of fossils, especially corals, crinoids, and brachiopods of the same general age as the Chickamauga fossils. The upper shales are frequently sandy and contain thin seams of sandstone, so that the formation shows a transition from the older limestones up into the Bays sandstone.

As stated in the description of the Chickamauga limestone, in the synclines northwest of Clinch Mountain, limestone was laid down at the same time that the Sevier shale was deposited at other points, and the limestone is there included in the Chickamauga. In the Powell Mountain syncline and in eastern Lone Mountain there are 50 feet or less of sandy shales and limestones immediately underlying the Bays sandstone which appear to represent the Sevier. They are too thin and too indefinite, however, to represent upon the map. The thickness of the formation is from 1100 to 1300 feet in the Clinch Mountain limestone. It is possibly thicker toward the south, while toward the north it very rapidly diminishes, being represented on eastern Lone Mountain, as before stated, by only a few feet of shale with the same characteristics. The limestones deposited there at the same time as the shales along Clinch Mountain can not be separated from the earlier Chickamauga limestones.

The calcareous parts of the formation readily dissolve, leaving the argillaceous matter firm enough to form slabs or flakes of shale. These strew the surface and retard its wear enough to cause rounded knobs and spurs of considerable height. On complete disintegration the strata form a thin, yellow clay, which is readily washed down the slopes of the surface, leaving much bare rock. Such soils are thin, cold, and subject to drought. Where the layers of limestone are more frequent the soil is more like that of the Chickamauga limestone and is more valuable. The water in areas of this formation is scanty and contains much mineral impurity in suspension and solution.

Bays formation.—The strata of this formation traverse this quadrangle in four belts more or less interrupted. The name is given because of its extensive outcrops in the Bays Mountains of Hawkins and Greene counties. The formation consists mainly of red, calcareous and argillaceous sandstone and changes very little in its appearance. In the northern portion of this quadrangle the calcareous element is more prominent, and beds of sandy limestone characterize the formation; the dark-red color is persistent throughout, however. The thickness of the formation ranges from 150 feet in Cumberland Mountain to 500 feet in Clinch Mountain. Considering its thickness, this formation is one of the most persistent in the southern Appalachians.

Owing to the amount of calcareous matter that it contains, the Bays sandstone does not stand at great altitudes, even when thick, unless it is protected by the harder strata of the Clinch or Rockwood formations. Decomposition is never deep, but the residue is loose and crumbling and does not resist wear. The formation outcrops more than any other, except similar beds of the Moccasin and Chickamauga limestones, and is conspicuous on the surface by its red color. The soil is thin on this rock and is full of slabby fragments. On account of its shallow and sandy nature, the soil is of very little value, except in the small hollows where the wash has collected.

Clinch sandstone.—This formation is found in three interrupted belts in this region, and is especially prominent in Clinch Mountain, from which it is named. The formation is composed mainly of massive white sandstone. In this are included a few layers of sandy shale in the western outcrops of the formation. One bed in Clinch Mountain is coarse enough to be called conglomerate. The rock is formed of rounded quartz fragments of even size and fine grain. Most of the layers are massive, from 6 inches up to 2 feet in thickness, and in places cross-bedded and ripple-marked strata are found.

The formation is about 500 feet thick in Clinch Mountain, but it thins rapidly toward the northwest, so that only 200 feet shows in Powell Mountain and about 150 feet in the eastern Lone Mountain. In that Lone Mountain which lies northwest of Maynardville the formation is entirely absent, and the same is true along the front of Cumberland Mountain. This rapid thinning of the formation within such narrow limits would seem to indicate that the shore from which it was derived lay at no great distance to the southeast. Few fossils are preserved in these strata, although casts of annelid trails and scolithus borings are very common in the upper beds.

Solution affects the formation but little, owing to its siliceous composition, so that where it is present in any body it makes conspicuous heights. To its hardness Clinch Mountain and the other high mountains of the vicinity, except Cumberland Mountain, owe their prominence; and where the formation is cut off by faults, there the mountains terminate abruptly. Many cliffs and ledges are produced by this rock and its fragments strew the adjoining slopes and choke the streams. Its soil is sandy and sterile and supports only light vegetation.

Rockwood formation.—Strata of this formation are found in all but one of the basins which contain the preceding formation, and also in Cumberland Mountain and in Lone Mountain north of Maynardville. It is absent, however, in the Clinch Mountain syncline, although later formations appear. The formation derives its name from Rockwood, Rome County, Georgia. It consists in the main of shales, both calcareous and sandy, but contains many beds of massive sandstone from 1 to 10 feet in thickness. These are most prominent in the two Lone Mountains. Along Cumberland Mountain the shales are finer grained and more calcareous, containing but little sandstone. The greatest thickness of the formation, about 700 feet, is in Lone Mountain northwest of Maynardville; 400 to 450 feet appear near Cumberland Mountain.

Bright colors abound in the shales, varying from red and brown to yellow and green, and continue even when the rock is badly weathered. In this, as in most other respects, the formation is strikingly like the Rome formation. Beds of fossiliferous iron ore occur in it, chiefly in the western portion, in layers from a few inches up to 3 feet in thickness. Many fossils, chiefly brachiopods, are found in the formation, and especially in the iron ores, showing the rocks to be of upper Silurian age.

The formation weathers readily where it consists mainly of shales, as along Cumberland Mountain, and forms low knolls and knobs. In the western Lone Mountain the interbedded sandstones are sufficiently hard and heavy to cause a considerable ridge, which rises 400 or 500 feet above the surrounding valley. Its soil is not very deep or fertile and is also impaired by the sandstone wash from this and adjoining formations. Along Cumberland Mountain, however, the soil is well situated and well drained and is fairly productive.

DEVONIAN ROCKS.

Chattanooga shale.—This formation, named from its occurrence at Chattanooga, Tennessee, is found in three belts in this region. The belts at the foot of Cumberland and Clinch mountains are the largest and extend far beyond the limits of this quadrangle. The two small areas at the foot of the western Lone Mountain are small fragments cut off along fault planes. The formation is practically the same in appearance throughout this region, and indeed for great distances northeast and southwest. It consists almost entirely of black carbonaceous shale. In places along the foot of Cumberland Mountain beds of fine red clay shales are interbedded with the lower portion of the black shales. In the Clinch syncline the black shales include thin layers of dark, sandy shale, and the upper layers of black shale are interbedded for a few feet with the sandy shales of the Grainger formation. The basal beds appear to be unconformably deposited on the Rockwood and Clinch formations of Silurian age, the Rockwood being absent in the Clinch Mountain area. The usual thickness of the Chattanooga shale is from 400 to 450 feet, but along Lone Mountain this measure is reduced to 100 feet. Whether or not this is due to compression or to an original thinning can not be discovered.

On account of its fine grain and softness the formation lies in deep valleys shut in by ridges of the harder formations. Its long, narrow valley at the foot of Clinch Mountain is a striking example of this. On Cumberland Mountain it occupies the steep slope beneath the Newman limestone and thus forms the border of the valley of the Silurian formations. Frequently the surface of the shale is covered with a yellowish-red crust of alum and iron oxide, derived from pyrite in the body of the rock. Small lumps and nodules of iron oxide are present in some of the layers. Many sulphur springs issue from the upper layers of the formation, derived from the decomposition of the pyrite. Disintegration is thorough in this shale, so that outcrops are rare except close to the streams. The residual yellow clay is dense and so much covered with wash from the sandstone formations that it is of little agricultural value.

Grainger shale.—The area of this formation lying south of Clinch Mountain is the only one which occurs in this quadrangle. Its name is derived from Grainger County, where it is very well exposed. The formation comprises sandy and calcareous shales and shaly and flaggy sandstones, the latter being perhaps more numerous in the upper layers. The sandstone beds are from a few inches to 3 or 4 feet in thickness. Shales and sandstones alike are bluish gray when fresh and weather out to a dull green or greenish gray. Many of the flaggy beds in the lower part of the formation contain impressions of the supposed sea-weed, *Spirophyton cauda-galli.*

The formation has a thickness of 900 to 1000 feet along the Clinch Mountain area and is entirely absent toward the west. At the south end of Clinch Mountain it appears to be much thinner. Whether or not this is the result of faulting, it is difficult to say. Such is probable, however, from the abrupt and local nature of the change. The upper shales of the formation there become quite calcareous and form a transition upward into the Newman limestone.

Fossils which have been found in the Grainger formation in regions to the northeast indicate that its upper part is Carboniferous, while a Devonian age for its lower portion is indicated by its interbedding with the Chattanooga shale. The formation thus constitutes a transition between the Devonian and Carboniferous. Just how much of the formation to consider Devonian it is not at present possible to say. There do not appear to be any notable changes in the strata accompanying the passage from one age to the other.

Disintegration proceeds slowly in the argillaceous and calcareous strata, while the sandy layers are but little affected. They gradually crumble, however, under rain and frost. The formation stands out in ridges rising 400 to 500 feet above the valleys on either side. These ridges are very regular in height and are frequently cut through by streams from the valleys in the Chattanooga shale. The Grainger soil is sandy and full of bits of rock and lies at high angles, so that it is sterile and practically valueless for farming.

CARBONIFEROUS ROCKS.

As was stated in the description of the Devonian rocks, the upper part of the Grainger shale is probably of Carboniferous age. Because it is impracticable to divide this formation the whole of it is shown on the map as Devonian.

Newman limestone.—This formation is found in three belts lying on the south sides of Clinch, the western Lone, and Cumberland mountains. Of these the only important one is that along Cumberland Mountain, the formation in the other two belts appearing only locally along faults. It is so named because of its occurrence in Newman Ridge, immediately east of this quadrangle. In the Clinch Mountain syncline the base of the formation, about 100 feet thick, consists of massive cherty limestone overlain by thin and shaly limestones. In all of the other areas the formation consists almost entirely of massive limestone, usually containing nodules and beds of black chert. The lower layers are usually more cherty than the upper, and in places the chert makes massive beds in the limestone. All of the limestones of this formation are blue or grayish blue when fresh; the shaly layers weather to greenish yellow. Layers and nodules of black chert weather to a delicate white. These, and the limestone itself, are full of fossil crinoid stems, corals, and brachiopods. This chert is very much like the Knox dolomite chert, but can be distinguished from the latter by the abundant fossil crinoid stems which it contains. In the Newman limestone of Cumberland Mountain are seen several seams of fine limestone conglomerate, a few feet in thickness.

Along Cumberland Mountain, where the full thickness of the formation is exposed, it varies from 300 feet to about 600. These variations do not seem to be attributable to faulting or compression, but are probably due to the deposition of the formation upon an irregular surface of erosion. These conditions were absent in the Clinch Mountain area where the Grainger formation is interbedded with the Newman limestone and the Chattanooga shale with the Grainger. It is perhaps on account of this erosion that the Grainger shale does not appear outside of the Clinch Mountain syncline.

The chert in the Newman limestone does not affect the topography, for it breaks into small fragments and does not accumulate in such great quantities as the Knox chert. The massive limestones form many outcrops, and, along Cumberland Mountain in particular, frequent cliffs and ledges mark the course of the formation. The rock finally decomposes to a deep, red clay of great fertility. On Cumberland Mountain, however, because of its position on the steep slopes, the covering of soil is thin, and it is also much covered with sandstone wash. Only small areas of land on this formation are of agricultural value in this region.

Pennington shale.—This is the latest of the calcareous formations that occur in the valley of East Tennessee. Its exposures in Virginia at Pennington Gap, Lee County, give the formation its name. It is seen in this quadrangle only in the face of Cumberland Mountain. The formation consists of calcareous and sandy shales with thin beds of either flaggy or massive sandstone and of either shaly or massive limestone. The shales have a prevailing grayish or greenish color, but are usually much weathered to a dull yellow. There are few outcrops to be found except of the heavier sandstone and limestone beds. The formation ranges from 150 to 220 feet in thickness, but it is difficult to give precise measures on account of the scarcity of outcrops. The beds of massive sandstone are light grayish white or yellowish, and lithologically can not be distinguished from those of the overlying Lee conglomerate. Thus there is more or less of a transition between the two formations and it is very difficult to make an exact separation. In passing westward the sandstone beds diminish and soon disappear, so that the two formations are readily distinguished. The calcareous layers weather readily, and, except for the heavier sandstones, the formation makes no impression upon the topography. It produces no soil of value, for its natural soil is covered by wash from the overlying Lee conglomerate.

Lee conglomerate.—In Cumberland Mountain appears the only area of this formation within the quadrangle, this being but the edge of an extensive basin to the northwest. The formation takes its name from Lee County, Virginia. It consists in the main of massive sandstone. Near the base is a thick bed of quartz conglomerate, and higher in the formation are two other beds of conglomerate. Some of the pebbles in these strata are an inch in length. Near the base of the formation are a few thin beds of shale, and at the top there are about 40 feet of sandstone underlain by an equal amount of shale. Much the greater part of the formation consists of massive sandstone. Some of the layers, especially the upper beds, are cross bedded. The formation as here shown is 1000 to 1100 feet thick. Its thickness diminishes rapidly westward and increases eastward.

The strata of this formation, on account of their very siliceous nature, are comparatively insoluble and make high, prominent mountains. Lines of cliffs accompany its course, the lowest conglomerate being particularly prominent in this respect. On the north side of Cumberland Mountain the slopes are more gentle, owing to the slight northward dip of the strata, and thin sandy soil collects. This is of very little value, however, except for a small amount of good timber that grows in the hollows.

Briceville shale.—Two very small areas of this formation, the latest sedimentary deposit within this quadrangle, appear on the north side of Cumberland Mountain. They are parts of a continuous belt lying just outside of this quadrangle. The name of the formation is taken from Briceville, Anderson County, where the shale is prominently exposed. The formation here consists mainly of bluish-gray, argillaceous, and sandy shales. Interstratified with these are workable seams of coal and small beds of sandstone. The sandstones are usually massive, from 1 to 10 feet in thickness, and have much the same appearance as the sandstones of the Lee conglomerate. About 100 feet of the formation is shown in this quadrangle.

The shales afford little resistance to weather, owing to their fine grain, and the formation occupies low ground. The sandstone beds are hard enough to cause ledges and small knobs, but are not of sufficient size to maintain great elevations. The lowest beds are almost invariably followed by streams. The soil is thin and poor and usually covered with waste from the sandstone beds and from the Lee conglomerate. The chief soil of value in this formation is on the small bottoms developed along the stream courses.

STRUCTURE.

Definition of terms.—As the materials forming the rocks of this region were deposited upon the sea bottom, they must originally have lain in nearly horizontal sheets or layers. At present, however, the beds are usually not horizontal, but are inclined at various angles, their edges appearing at the surface. The *strike* of a bed is the course which its intersection with a horizontal surface would take. The angle at which it is 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. In a simple fold a *synclinal axis* is that portion of a syncline along which any individual bed is lowest, and toward which the rocks dip from each side. An *anticlinal axis* is that portion of an anticline which throughout includes the highest portions of a stratum of the arch, and away from which the rocks dip on each side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and is usually very much less than the dip of the beds. 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 *thrust 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 thrust faults of the ordinary type, rocks change their relative position mainly by motion on the bedding planes. In the more minute dislocations, however, the individual fragments of the rocks are bent, broken, compressed, and slipped past each other, causing a tendency to break along parallel planes, called *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.

In the Valley region the folds and faults are parallel to each other and to the western shore of the ancient continent. They extend northeast and 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 at the surface. 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 have been so far compressed that 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.

General character of folds and faults of the valley region.

Faults were developed in the northwestern sides of anticlines, and vary in extent and frequency with 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 thousands of feet thick, and in places the upper strata have been 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. Through Pennsylvania and Maryland they become more numerous and steeper. In southern Virginia they are closely compressed and often closed, while occasional faults appear. In passing from Virginia into Tennessee the folds are more and more broken by faults. In the central part of the valley of Tennessee folds are generally so obscured by faults that the strata form a series of narrow, overlapping blocks all dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

In the Appalachian Mountains the southeastward dips, close folds, and faults that characterize the Great Valley are repeated. The strata are also traversed by the minute breaks of cleavage and metamorphosed by the growth of new minerals. The cleavage planes dip to the east at from 20° to 90°, usually about 60°. This form of alteration is somewhat developed in the valley as slaty cleavage, but in the mountains it becomes important and often destroys all other structures. All rocks in the mountains were subjected to this process, and the final products of the metamorphism of very different rocks are frequently 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.

Cleavage and metamorphism in the Appalachian Mountains.

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.

Rock structures due to northwest-southeast compression.

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.

Vertical movements of the surface.

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 Section 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.

Underground relations of strata.

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 lines of the sections.

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 relative direction in which the strata have moved.

Structure of the Maynardville quadrangle.—The rocks of this quadrangle have been disturbed from the horizontal position in which they were deposited, and have been bent and broken to a great extent. The lines along which the changes took place run, as a rule, in a northeast-southwest direction, and the individual folds or faults extend for great distances in rather straight lines. On the Structure Section sheet the extent of these deformations is shown. The position of the rocks underground is calculated from dips observed at the surface and from the known thickness of the formations.

Within this quadrangle there are two structural districts in which the types of deformation differ materially. One of these is very small and limited to the area north of Cumberland Mountain. This is a portion of the great Plateau district, in which the rocks lie nearly flat. The structure is far different in the greater portion of the quadrangle, the rocks having been forced out of their original position into folds and faults. This is a portion of the Valley district of the Appalachian province. Powell anticline, the great arch along whose axis runs Powell River, forms an intermediate type of structure which is comparatively local.

Folds and faults are distributed over the entire area of the Great Valley and are almost wholly of one kind. The folds are long and straight; they are usually so closely squeezed that the rocks on the western side of the anticlines are vertical, and even overturned. The dips range from flat to vertical and to 50° overturned. The usual dip on the southeast side of a fold is from 30° to 45° to the southeast. Nearly all of the folds in this quadrangle have been compressed until broken. The anticline which brings up the Cambrian strata immediately northeast of New Market, however, is open and unbroken in this area, and has nearly equal dips upon opposite sides. The great Powell anticline is also unbroken, and the beds, with dips ranging from 20° to 30° on the southeast side, pass over a broad, flat crest into steep or vertical dips upon the northwest. Sections A–A and C–C illustrate the chief changes in this fold. Folds which were tightly squeezed without breaking appear in the Rome formation south and west of Maynardville and in the Sevier shale south of Luttrell, but they are of minor dimensions. The syncline just north of Strawberry Plains is very unusual in that it is about as broad as it is long, has steep dips on all sides, and plainly shows compression from all directions.

Associated with the anticlinal uplifts are the faults, eleven in number without counting minor faults and branches. Like the broken arches from which they are formed, the faults are long and straight. The breaks occurred on the northwestern sides of the anticlines, at which point the horizontal strain is directly across the beds, so they are least able to resist it. The fault immediately south of New Market, sections C–C and E–E, exhibits this perhaps better than any fault known in the southern Appalachians. The development of a fault from an anticline is finely shown between Corryton and Beaver Ridge, sections E–E and F–F, and also near the point where Holston River leaves this quadrangle. The lower parts of the fault planes are nearly parallel to the beds on the southeast sides of the anticlines, 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 southeast dips remain. This is best illustrated in section C–C. As would be expected, the anticlinal part of the broken fold is commonly worn away, because it is uplifted the highest. In section D–D is shown an intermediate stage in the removal of the upthrust strata, which now lie on hilltops disconnected from the main mass. The synclinal portions of the broken folds are shown in this quadrangle much more frequently than in other and similar portions of the Appalachian Valley. In fact, the synclinal axis is well defined for considerable distances in each of the different folds in this region, except that which passes through Maynardville. Even in this the axis is defined at one point 3 miles east of Maynardville.

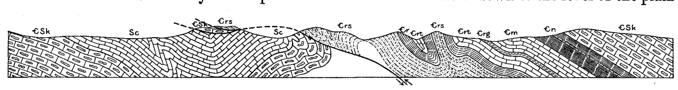


Fig. 1.—Section along the line D–D on the geologic map. Outlying masses of Knox dolomite and Rome formation are shown, which were thrust over on younger rocks and are left in isolated patches by erosion.
Scale: 1 inch=3000 feet.

The planes of the faults usually dip from 30° to 50° southeast, most of them being about 45°. The fault 3 miles east of Maynardville has an average dip of less than 10° to the south, and the fault south of New Market is for considerable areas nearly flat. Each of these fault planes has been somewhat folded since its formation. The amount of displacement varies in the different faults of this quadrangle from a few feet up to nearly 3 miles, the latter being the lowest computation of the fault which passes southeast of Clinch Mountain. The faults which pass southeast of New Market and of both Lone mountains have minimum displacements of 2 and 2½ miles. It is probable that most of the others have similarly large displacements.

In the Plateau district of this quadrangle the rocks have not been deformed by folds and faults as in the Valley district, but have changed their attitudes by a slight tilting toward the northwest. In Cumberland Mountain due north of Well Spring the dips are from 10° to 20°, but become steeper as the strata extend northeast and southwest. At the northern foot of the mountain, just at the edge of the quadrangle, the rocks are flat, and they maintain that position for a considerable distance toward the northwest.

Another 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 the beginning and end of the epoch of deposition of the Knox dolomite, during the deposition of the Tellico sandstone, and following the deposition of the Pennington shale. 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 to a nearly level surface. One such surface was developed over all the Valley district, and its more or less worn remnants can now be seen in the hills and ridges of the harder formations, at elevations from 1500 to 1700 feet. Since the production of that surface, uplift of the land has given the streams greater slope and greater power to wear. They have worn down into the old surface to varying depths, according to their size, and have begun the formation of similar new surfaces at elevations between 1000 and 1100 feet. These are furthest developed along the course of Holston River and its larger tributaries, where considerable areas have been reduced to rolling plains. To a less extent the process has gone on in the smaller valleys of Clinch and Powell rivers, where the plains have not reached far back from the main streams. Naturally, they show best in the softer or the more soluble beds, usually the Chickamauga limestone or strata of that age. Still later uplift has started the process again and has produced the present narrow stream cuts. Since the streams are still wearing their channels downward and but little along the sides, they have not yet attained the low grade at which the older plains were formed.

The remains of another and still older plain are to be seen in the higher mountains of this region. This plain was almost entirely removed during the formation of the later ones, and is preserved in only a few places by the hard sandstones of the Clinch and Lee formations. It is best shown in Clinch Mountain, a large portion of which stands at an altitude of 2000 to 2200 feet. Above this small areas project, which probably had not been worn down to the level of the plain; for instance, Retts View, at the southwest end of Clinch Mountain. The same general altitudes appear in House Mountain, the eastern Lone Mountain, and the mountains east of Tazewell. A portion of Cumberland Mountain also stands at this height, but most of it is considerably higher, probably not having been reduced.

It is likely that there were many such pauses as these plains denote in the upward movement of this region, but their records have been for the most part removed. Doubtless still others occurred which were not of sufficient length to permit plains to be formed and record the movement. Movements of depression as well as uplift may have taken place, but of that there is no evidence in the surfaces of this region.

MINERAL RESOURCES.

The rocks of this district which are valuable for use in the natural state are marble, building stone, and road material. Other materials derived from the rocks are iron, lead, zinc, lime, cement, and clay. Through their soils the formations are valuable for crops and timber, and by the grades which they establish on the streams they produce water power.

Coal.—Bituminous coal occurs in the Carboniferous rocks in the northwest corner of this quadrangle. The formation which contains the coal seams is the Briceville shale. The coal has not been commercially developed in the small areas of the formation within this quadrangle, although some of the seams have been opened. Both northeast and southwest from this region the coal seams in this formation are extensively worked and are in fact the chief coal beds of this portion of Tennessee. Their small area within this quadrangle, however, renders them of little importance.

Marble.—Marble is found in great quantity in three belts of the Chickamauga limestone lying southeast of Copper Ridge. The distribution of the marble and quarries is shown on the Economic Geology sheet. The chief developments along these belts are adjacent to the railroads.

The total thickness of the marble beds, which is in places as great as 300 feet, is by no means available for commercial use. The rocks 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 sediments at the time of their deposition. Carbonate of lime, iron oxide or hydrate, and clay were deposited together with calcareous shells of animals. The firmness of the rock is due to its having a large proportion of lime, while its rich, dark colors are produced by oxide of iron; but when clay is present in large proportions the rock becomes a worthless shale. The colors vary from white to cream, yellow, brown, chocolate, red, pink, gray, and blue, in endless variety. Absence of iron oxide results in gray, grayish white, and white. The colors are either scattered uniformly through the rock or are grouped 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 this marble. Most of the marble in this region has a distinct reddish or chocolate color. The blue and gray marble is more common in the northern belts of the formation.

Like the shaly matter, the iron oxide is an impurity, and the two are apt to accompany each other. The most prized rock, therefore, is a mean between the pure and impure carbonate of lime, and slight changes in the form of the components result in deterioration or improvement in 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. Workable beds are rarely as thick as 50 feet, and usually in that thickness there is a combination of several varieties. Quarries separated from one another have quite distinct series of beds and each quarry has its special varieties. All of the marble is free from siliceous impurity and, when otherwise reasonably pure, takes a good polish and is not affected by weather.

The foregoing changes are better illustrated by the disappearance of the massive marble and the increase of shale in the belt passing southwest from Luttrell. Similar changes are seen east and south of McMillan and Strawberry Plains. The position of the marble in the Chickamauga limestone also varies. Near the northeast end of Black Oak Ridge, and also northeast from Luttrell, the Chickamauga limestone appears only above the marble. Along Holston River, however, the limestone appears only below the marble. In other places the marble occupies an intermediate position. In the next basin north of the Clinch syncline no marble appears except northeast of Maynardville, where some unimportant beds of gray marble occur, not shown on the map. North and west of this no marble has been observed, nor does any of consequence occur along the southern border of the quadrangle.

The marble above the Tellico sandstone in the base of the Sevier shale is comparatively thin and shaly. Occasionally, however, a local thickening takes place and the beds resemble the Holston marble in all respects. The Sevier marble beds are much more variable than those of the Chickamauga, and there is a smaller amount of workable material in them; consequently they have not been successfully quarried.

Available localities for quarrying are limited in part by the dip of the marble beds. The dip is usually steep in this region, so that the amount of earth to be stripped is not great. Near Holston River, owing to the recent cutting of the streams, the marble is usually at some distance above the water level. In the more northern areas, where the streams have not cut their valley deeply, the marble usually occupies the lowest portions of the valleys, being the most soluble of the formations, and the drainage of the quarry becomes an important problem. This is also the case even in areas well above drainage level, when springs and underground streams are encountered, as frequently happens.

Owing to the soluble nature of the pure marble, it is either completely unaltered and fresh or it is entirely reduced to red clay. The best marbles, therefore, are nearly as solid at the surface as at great depths. Marbles which are shaly at the surface become less weathered in going down, and appear solid; but when these are sawed and exposed to the weather, their inferiority appears in splits along the argillaceous seams and in cracks through the thicker masses. Solution of the pure beds has produced holes and caves down to the adjacent stream levels. Through these openings the quarrymen attack the rock more easily, but much valuable stone has been lost by solution.

Tests for absorption of water show a high resistance in the better grades of marble, and the rock is very well fitted for withstanding weather. Its crushing strength is also very high in the purer layers. Tests of a number of samples gave an average strength of 16,000 pounds per square inch.

Iron.—Iron ore is found in the form of red hematite in the Rockwood formation. It occurs interbedded with the variegated shales in layers ranging from a few inches up to 3 or 4 feet in thickness. The usual thickness is about one foot in this region. No developments have been made of the ore in this quadrangle, although much ore has been mined both to the northeast and southwest, especially along Cumberland Mountain. The ore is the product of the replacement by iron oxide of the carbonates in an original limestone bed. The fossils that were embedded in the limestone retain their forms perfectly and make up so much of the mass that the ore has long been known as the "fossil iron ore." When the fossil ores are worked down to the water level of the adjacent country the percentage of iron is so much less that they are practically limestones and are valueless as ores. Here the amount of ore is strictly limited by the water level, and, as the layers which contain the ore always occupy low ground, the amount of ore is much less than would be supposed.

Brown hematite and limonite are also found in this region. They occur in irregular masses in the residual clays of the Knox dolomite. These deposits are irregular and of small amount and have not been mined in this area.

Zinc and lead.—Ores of zinc and lead occur at many localities within this area and are found in quantity at seven points, viz.: New Prospect on Powell River, 2 miles northeast of New Prospect, 6 miles southwest of Tazewell, $1\frac{1}{2}$ miles southeast of New Market, 1 mile west of Mascot station, at McMillan station, and 1 mile west of Caswell station. These ores are grouped in two distinct belts, one lying chiefly near Powell River and one lying near Holston River. In the Powell belt ores of both metals are present, but they vary widely in relative proportions. In the Holston belt ores of lead are practically absent.

At New Prospect the lead ore is prominent and the locality was formerly known as "Lead Mine Bend." The ore consists principally of galena and blende, with smithsonite, calamine, cerussite, calcite, and a very little pyrite, and is found in the lower layers of the Knox dolomite. The cerussite and calamine are found near the surface in the more or less decomposed strata, and result from alteration of the blende and galena. The ore-bearing area is a narrow zone running about N. 50° E., in which the rocks are crushed and broken. It lies just south of the crest of the Powell anticline at the point where the latter reaches its greatest height and exposes the Conasauga shale. The ore occurs in east-west vertical veins which send out thin veins parallels to the limestone layers. Much ore is also found scattered through the broken and recemented rock in pockets and crystals. The ore is secured chiefly by mining the rocks in an open quarry; from this tunnels have been run down the gently dipping strata for 300 feet. This locality is one of the oldest in the State. In the last few years mining operations have been resumed by the John Weir Lead and Zinc Company, but are now at a standstill.

Two miles northeast of New Prospect the zinc and lead ores are found again in considerable body on both sides of Powell River, along the same line of disturbance and also in the lower layers of the Knox dolomite. In this locality the zinc is more prominent than the lead, the chief minerals being smithsonite and calamine, with a little galena and blende. These are in small pockets and irregular veins in a calcareous and siliceous gangue. Outcrops of ore can be traced for several miles to the southwest, and form part of a belt of similar deposits near the bottom of the Knox dolomite along the crest of the Powell anticline. No developments have been made here. For 9 miles S. 70° W. of New Prospect, zinc and lead ores are found here and there, but are undeveloped.

Six miles southwest of Tazewell is found a small deposit of calamine and smithsonite with a little galena, but it is undeveloped. The ore lies in the lower part of the Knox dolomite, in the disturbed area near a fault.

One and one half miles southeast of New Market, 1 mile west of Mascot station, at McMillan station, and 1 mile west of Caswell station, ores of zinc are found in the upper part of the Knox dolomite and constitute the Holston zinc belt. The deposits at the two former localities are in broken strata along small anticlines, and all are nearly in line, apparently on the same zone of disturbance.

No mining has been done near Mascot except to take out the carbonate ore from the clay. Near New Market the New Market mine is now being developed. The ore is mainly blende, with some smithsonite and calamine near the surface. It is distributed in large irregular veins in a gangue of broken limestone, dipping with or slightly steeper than the strata, which form a gentle anticline. The ore is obtained in an open quarry.

At McMillan, the Seven Day Zinc Mining Company has its mining operations well under way. The ore is chiefly blende, with smithsonite and calamine, and is found in irregular pockets and vein-like seams scattered through the limestone beds. The mine is an open quarry, showing a width of ore-bearing rock of 30 feet, the layers being much broken. Near Caswell the Knoxville Zinc Mining Company has a deposit of zinc ore, consisting of blende, which is altered near the surface to calamine and smithsonite. The inclosing limestone is much shattered and recemented with calcite. The extent of this is being tested by a shaft and by drilling.

Building stone.—Besides marble, whose chief use is for ornamental work, building material of great strength and durability can be secured from the Knox dolomite, the Chickamauga limestone, and the Clinch sandstone. These lack the variety and beauty of color found in the marble. Fresh rock can be obtained with ease and can be opened readily along the bedding planes in layers from 1 to 5 feet thick. The usual situation of the outcrops above the water level makes drainage easy. Up to the present time no quarries have been opened in this area and only the loose surface blocks have been utilized. The Knox dolomite has the widest use, and is built into chimneys, bridge abutments, and stone houses. It is very hard and firm and nearly impervious to water. Its beds are thin, ranging from 6 inches to 2 feet in thickness, and its uses on that account are somewhat limited. No quarrying centers have been established, because the formation is so widespread, and rock has been secured for merely local use.

The massive blue limestones of the Chickamauga formation are also used in the same manner as the Knox dolomite. The thin layers which weather out into loose slabs are also extensively used in building stone fences. Material for flagstones and curbstones is found in the Tellico sandstone. Most of the layers are less than a foot thick and are not suited for heavy building work. The stone is very easily quarried and is fairly strong and durable. Sites for quarries are readily to be found, especially on the hillsides near Holston River.

Besides the foregoing there are many kinds of material, of which practically no use has been made. These consist of the limestone beds in the various Cambrian formations, notably in the southeast part of the quadrangle, and of the sandstones in the Rome, Rockwood, Grainger, and Lee formations. Few layers in the Rome attain a thickness greater than 5 feet, but not infrequently the sandstones of the Grainger and Rockwood formations are as thick as 20 feet, thus furnishing material for the heaviest kind of construction. Beds of sandstone and conglomerate in the Lee are even thicker and harder, but are impracticable because of their inaccessible situations. None of these sandstones have any considerable range of color, the Rome sandstone being red or yellow, the Rockwood yellow or yellowish white, the Grainger bluish or greenish gray, and the Lee white or grayish white. Quarry sites can be established to advantage in the many stream gaps through the formations, and the position of the rock in ridges makes drainage easy. The Rome and Grainger sandstones are not so hard as the Clinch and Lee, but all form natural ledges and cliffs, showing that they will resist water and frost sufficiently well.

Road material.—There are two classes of road materials to be found in this quadrangle—those which depend upon their cementing powers for their durability, and those which depend upon their hardness. Among the former are the various limestone formations and the Tellico sandstone; and among the latter are the various sandstones and sandy shales. The formations that have been most used are the Knox dolomite, Chickamauga limestone, Tellico sandstone, and the various marbles. Only in Knox County has any systematic use been made of these materials. Elsewhere they have been employed in the most irregular way. The sandstone formations have been widely used in repairing the roads, but not for any considerable building. Most of them are well adapted to the repair of roads because they are readily secured from their weathered outcrops and broken into small, angular fragments. The same is true of the cherts of the Knox dolomite, which are widespread and frequently so abundant as to form natural roadways. Good drainage can be secured by the use of any of these strata. The softer formations, such as the calcareous and argillaceous shales, have been much used locally. Roads frequently follow the outcrop of the Rogersville shale and are well drained and fairly durable.

Lime and cement.—Many beds in the Knox dolomite and Chickamauga limestone have been burned into lime. Most of the dolomite has not enough calcareous matter for such purposes, but available beds are to be found both at the top and bottom of the formation. Most of the heavier beds of the Chickamauga are suitable for lime burning. The same is true of the marbles, which contain as high as 98 per cent of lime, but they are more valuable for ornamental uses. Good material may also be obtained from the massive beds of the Newman limestone, and many of the Cambrian limestones are sufficiently pure for the purpose. In the Chickamauga formation many beds have the right composition to produce cement. Some of the reddish limestones of the same type as the Moccasin limestone have been utilized for that purpose. No considerable use has been made of these materials, and the various rocks have been burned near the points where they were wanted, so that no general industry has been established.

Brick clays.—Clays suitable for the manufacture of bricks are abundant throughout this quadrangle, particularly in the southern portion. They are derived for the most part from the wash of various formations, chiefly the limestones and calcareous shales. They collect in depressions of the surface on or near these formations and are very widely distributed. The suitability of the clay is largely determined by the slopes of the adjacent surfaces; the finer and purer deposits are found in those basins which are surrounded by gentle slopes. On the low grounds of the large creeks tributary to Holston River good clays are widespread and deep, and in fact no tract of considerable size is without deposits large enough for local uses. Clays are also found closely associated with the rivers in bottom lands and terraces. These are derived from the waste of many formations and are usually fine and well assorted. These deposits are usually of less extent than those of the creek valleys, and are of much less importance. Only local use has been made of these clays, and bricks have been burned only near the point of use.

Timber.—Many formations produce timber of value, and usually there is a definite association of certain trees on one formation. Most of the formations are timber covered in suitable localities, but some, particularly the cliff-making sandstones, have only a scattered growth. The Knox dolomite is accompanied by a good growth of oak, chestnut, and hickory. In the sheltered hollows, particularly those on the Sevier, Rockwood, and Rome formations, are found poplar, chestnut, oak, and pine. Areas of Chickamauga limestone produce many cedars, of no special value. The most available timber in this region has been cut, especially the finer varieties suitable for export, like walnut and poplar. Much the greater portion of the region is timber covered, however, and while it furnishes an abundant supply for all local uses, the amount exported is small.

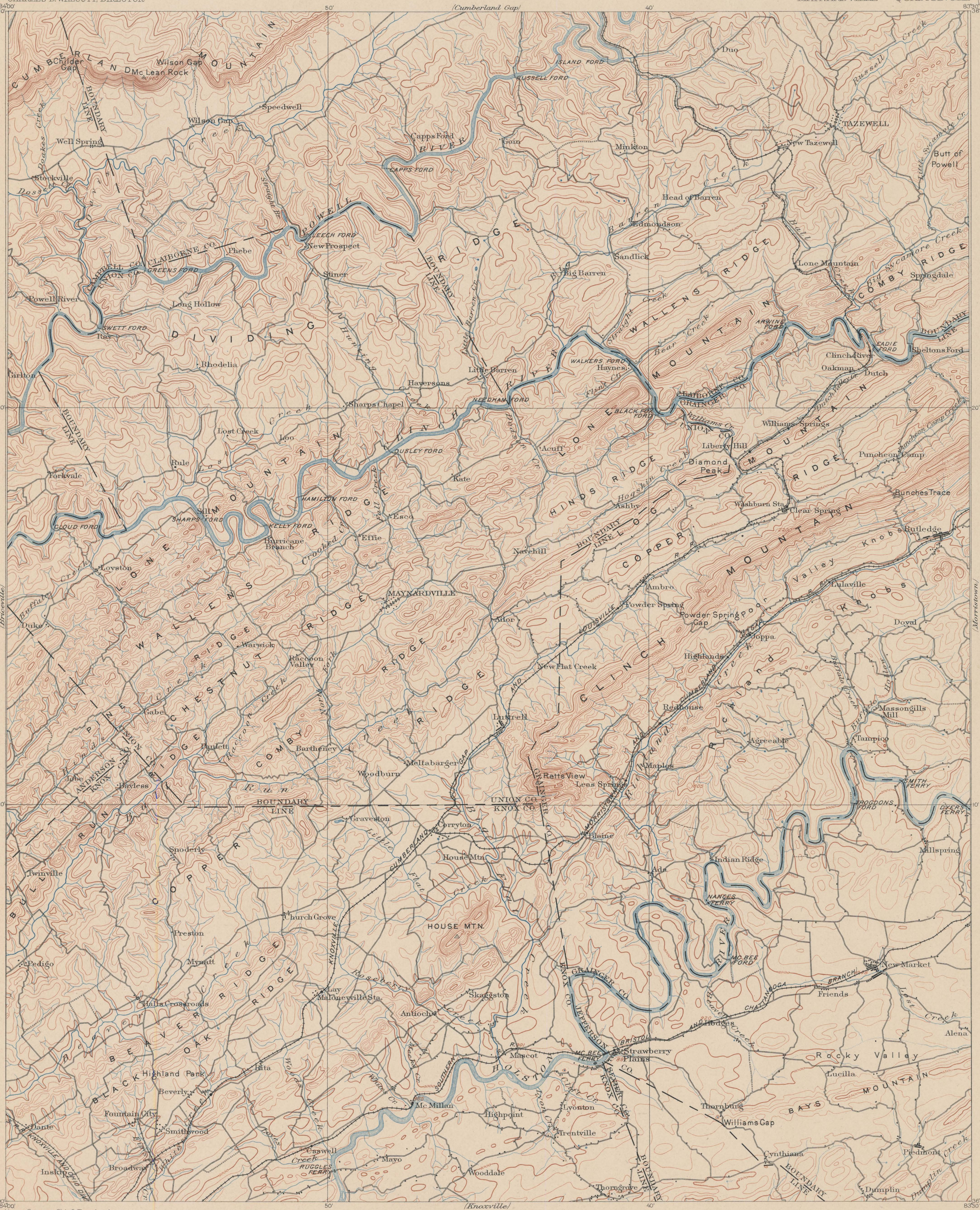
Water power.—A natural resource of this region which is far from developed is the water power. The supply of water in the streams is abundant and fairly constant. The cherty dolomite districts are poorly watered, but other areas are fed by springs and creeks, and by rivers rising in distant mountain regions. The grades of the rivers are steady and low and are seldom adapted for power sites. The small streams, particularly the tributaries of Clinch and Powell rivers, furnish small water power in many places. In general their valleys are high and their grades small, except in the immediate vicinity of the rivers, where they rapidly descend into the canyon-like channels of the latter. This is especially true of the streams which flow across the strike of the formations. None of these streams furnish a notably great body of water, but the fall is considerable, and for certain purposes it is extremely valuable. In many locations natural mill sites are developed by the fall of the streams over hard beds in the Rome, Knox, Rockwood, and Grainger formations. These sites are suited only for small local purposes, inasmuch as the fall is small and the body of water is not great. At present this power has been utilized only by sawmills and gristmills and has not been applied to manufacturing.

February, 1901.

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

TOPOGRAPHIC SHEET

TENNESSEE
MAYNARDVILLE QUADRANGLE



LEGEND

RELIEF *(printed in brown)*

Figures *(showing heights above mean sea level instrumentally determined)*

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

Depression contours

DRAINAGE *(printed in blue)*

Streams

Intermittent streams

Ponds

Sinks

CULTURE *(printed in black)*

Roads and buildings

Private and secondary roads

Trails

Railroads

Tunnels

Bridges

Ferries

Fords

County boundary lines

Triangulation stations

Henry Gannett, Chief Topographer.
H. M. Wilson, Chief Geographer in charge.
Triangulation by S. S. Gannett.
Topography by C. G. Van Hook and J. H. Wheat.
Surveyed in 1892-95.

Scale $\frac{1}{125000}$

Miles

Kilometers

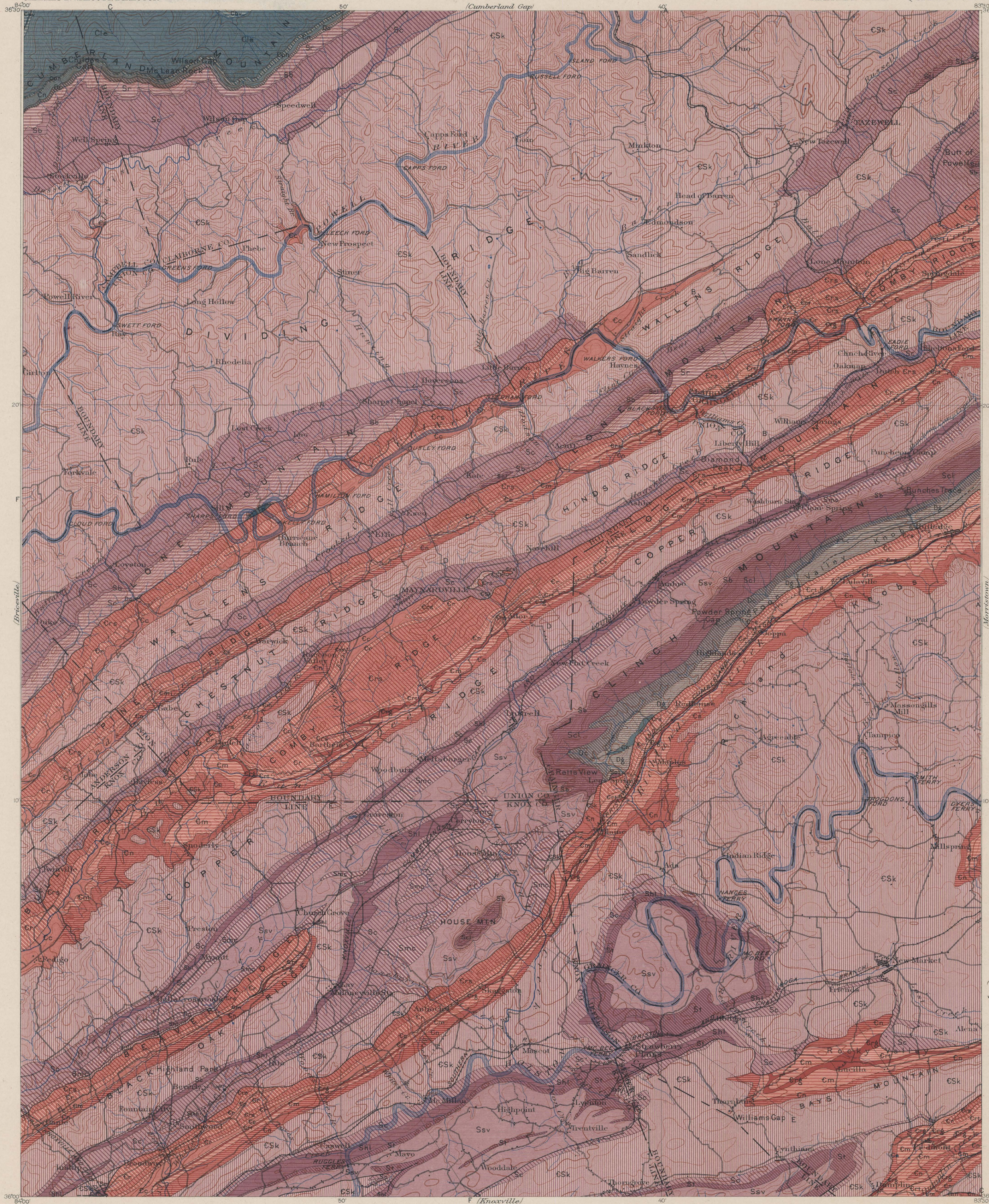
Contour interval 100 feet.
Datum is mean sea level.

Edition of Dec. 1900.

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

HISTORICAL GEOLOGY SHEET

TENNESSEE
MAYNARDVILLE QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

CARBONIFEROUS

- Cbv — Briceville shale *(dark-gray argillaceous shale with sandy beds and thick coal beds)*
- Cle — Lee conglomerate *(massive sandstone and conglomerate with thin coal seams)*
- Cpn — Pennington shale *(calcareous shale, sandstone, and limestone)*
- Cn — Newman limestone *(massive blue limestone, cherty near the base)*

DEVONIAN

- Dg — Grainger shale *(grayish sandstones and sandy shale)*
- Dc — Chattanooga shale *(carbonaceous black shale)*

SILURIAN

- Sr — Rockwood formation *(reddish calcareous shale with shaly sandstone and iron beds near the top)*
- Scl — Clinch sandstone *(massive white sandstone)*
- Sb — Bays formation *(red argillaceous sandstone and red, sandy, argillaceous limestone)*
- Ssv — Sevier shale *(light-colored sandy shale, calcareous shale, and thin limestones, with local beds of marble near the base)*
- Smc — Moccasin limestone *(red, green, and blue argillaceous limestone)*
- St — Tellico sandstone *(bluish-gray calcareous sandstone and shale)*
- Sc — Chickamauga limestone *(blue and gray shaly limestone and massive limestone with marble beds)*
- Shl — Holston marble in Chickamauga limestone *(variegated marble lentils, chiefly reddish or gray)*

SILURIAN / CAMBRIAN

- ЄSk — Knox dolomite *(light and dark magnesian limestone with chert nodules)*

CAMBRIAN

- Єc — Conasauga shale *(reddish calcareous shale with thin beds of limestone)* *(The Conasauga shale is divided into two or more parts by the development of limestone formations toward the northeast)*
  - Єn — Nolichucky shale *(variegated calcareous shales and thin limestones)*
  - Єm — Maryville limestone *(massive blue limestone)*
  - Єrg — Rogersville shale *(greenish clay shale with limestone layers)*
  - Єrt — Rutledge limestone *(massive dark-blue limestone)*
- Єr — Rome formation *(red, green, and brown sandy shale)*
- Єrs — Sandstone lentils in Rome formation *(red, white, and brown sandstone)*

Faults

Sections

Henry Gannett, Chief Topographer.
H. M. Wilson, Chief Geographer in charge.
Triangulation by S. S. Gannett.
Topography by C. G. Van Hook and J. H. Wheat.
Surveyed in 1892-95.

Van Hook 1892 / Wheat 1895

Scale 1/125000

Contour interval 100 feet.
Datum is mean sea level.

Edition of May 1901.

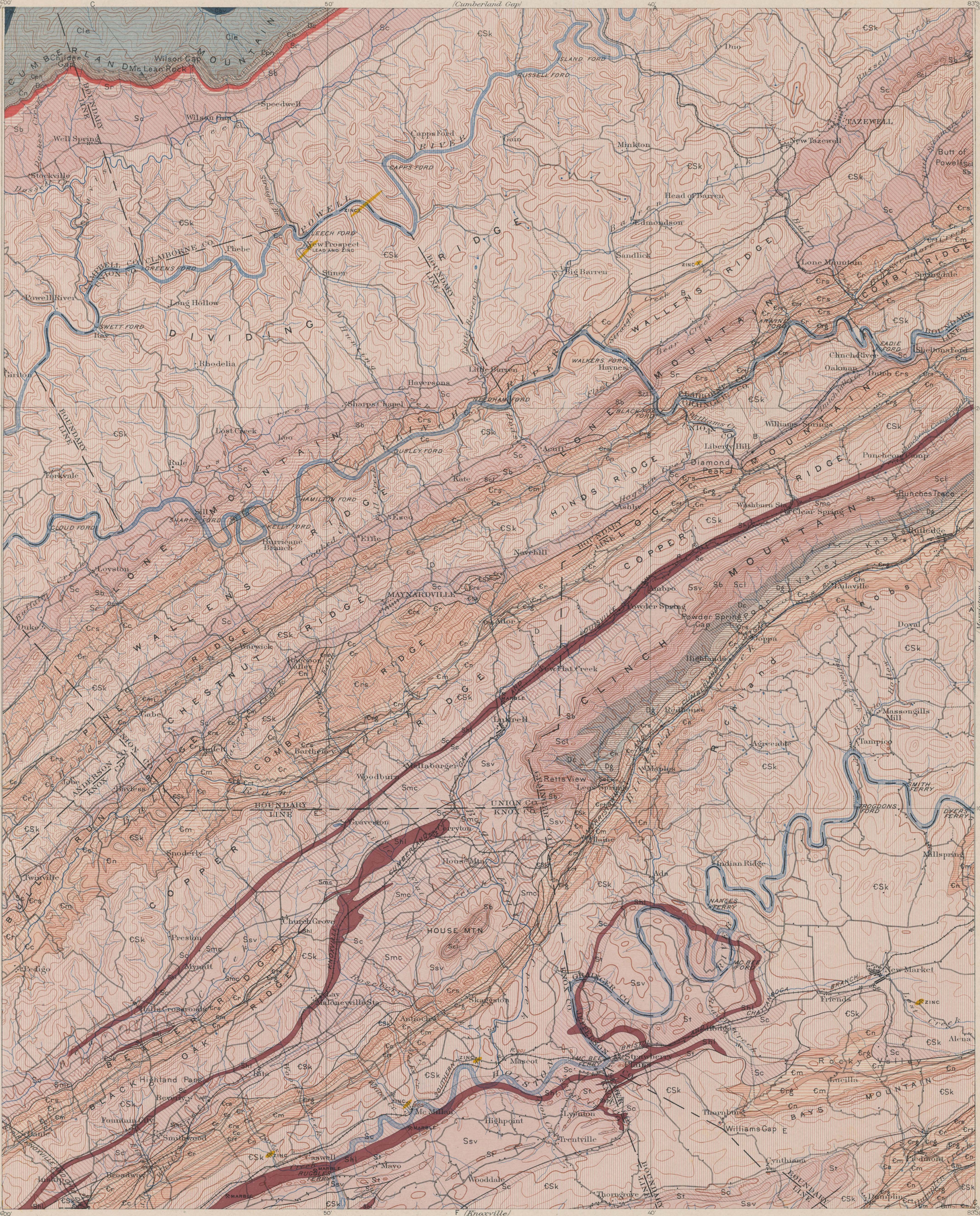
Geology by Arthur Keith.
Assisted by Marius R. Campbell.
Surveyed in 1889 and 1899.

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

ECONOMIC GEOLOGY SHEET

TENNESSEE
MAYNARDVILLE QUADRANGLE

(Williamsburg) (Cumberland Gap) (Jonesville)



(Briceville) (Morristown) (Loudon) (Knoxville) (Mt. Guyot)

LEGEND
(continued)

⚒ Mines and quarries
× Prospects

Known productive formations

Shl — *Marble* (*Holston marble, chiefly red or gray, in the Chickamauga limestone*)

Lead and zinc

Cbv — *Coal* (*Briceville shale contains thick coal beds in adjoining areas*)

Iron (*Rockwood formation contains beds of hematite iron ore in its upper portion*)

LEGEND

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

CARBONIFEROUS

Cbv — Briceville shale (*dark-gray argillaceous shale with sandy beds and thick coal beds*)

Cle — Lee conglomerate (*massive sandstone and conglomerate with thin coal seams*)

Cpn — Pennington shale (*calcareous shale, sandstone, and limestone*)

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

DEVONIAN

Dg — Grainger shale (*grayish sandstones and sandy shale*)

Dc — Chattanooga shale (*carbonaceous black shale*)

SILURIAN

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

Scl — Clinch sandstone (*massive white sandstone*)

Sb — Bays formation (*red argillaceous sandstone and red, sandy, argillaceous limestone*)

Ssv — Sevier shale (*light-colored sandy shale, calcareous shale, and thin limestones, with local beds of marble near the base*)

Smc — Moccasin limestone (*red, green, and blue argillaceous limestone*)

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

Sc — Chickamauga limestone (*blue and gray shaly limestone and massive limestone with marble beds*)

Shl — Holston marble in Chickamauga limestone (*variegated marble lentils, chiefly reddish or gray*)

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

CAMBRIAN

Cn — Nolichucky shale (*variegated calcareous shales and thin limestones*)

Cm — Maryville limestone (*massive blue limestone*)

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

(*The Conasauga shale is divided into two or more parts by the development of limestone formations toward the northeast*)

Crg — Rogersville shale (*greenish clay shale with limestone layers*)

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

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

Crs — Sandstone lentils in Rome formation (*red, white, and brown sandstone*)

Faults

Sections

Legend is continued on the left margin.

Henry Gannett, Chief Topographer.
H. M. Wilson, Chief Geographer in charge.
Triangulation by S. S. Gannett.
Topography by C. G. Van Hook and J. H. Wheat.
Surveyed in 1892-95.

Van Hook 1892 — Wheat 1895

Scale $\frac{1}{125000}$

Miles — Kilometers

Contour interval 100 feet.
Datum is mean sea level.
Edition of May 1901.

Geology by Arthur Keith.
Assisted by Marius R. Campbell.
Surveyed in 1889 and 1899.

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

STRUCTURE-SECTION SHEET

TENNESSEE
MAYNARDVILLE QUADRANGLE

Henry Gannett, Chief Topographer.
H. M. Wilson, Chief Geographer in charge.
Triangulation by S. S. Gannett.
Topography by C. G. Van Hook and J. H. Wheat.
Surveyed in 1892-95.

Van Hook 1892 — Wheat 1895

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of July 1901.

Geology by Arthur Keith.
Assisted by Marius R. Campbell.
Surveyed in 1889 and 1899.

LEGEND
(continued)

Known productive formations

Shl — *Marble* (Holston marble, chiefly red or gray, in the Chickamauga limestone)

Lead and zinc

Cbv — *Coal* (Briceville shale contains thick coal beds in adjoining areas)

Iron (Rockwood formation contains beds of hematite iron ore in its upper portion)

Section D-D on an enlarged scale is shown in the text

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

CARBONIFEROUS

Cbv — Briceville shale (dark-gray argillaceous shale with sandy beds and thick coal beds)

Cle / Cle — Lee conglomerate (massive sandstone and conglomerate with thin coal seams)

Cpn / Cpn — Pennington shale (calcareous shale, sandstone, and limestone)

Cn / Cn — Newman limestone (massive blue limestone, cherty near the base)

DEVONIAN

Dg / Dg — Grainger shale (grayish sandstones and sandy shale)

Dc / Dc — Chattanooga shale (carbonaceous black shale)

SILURIAN

Sr / Sr — Rockwood formation (reddish calcareous shale with shaly sandstone and iron beds near the top)

Scl / Scl — Clinch sandstone (massive white sandstone)

Sb / Sb — Bays formation (red argillaceous sandstone and red, sandy, argillaceous limestone)

Ssv / Ssv — Sevier shale (light-colored sandy shale, calcareous shale, and thin limestones, with local beds of marble near the base)

Smc / Smc — Moccasin limestone (red, green, and blue argillaceous limestone)

St / St — Tellico sandstone (bluish-gray calcareous sandstone and shale)

Sc / Sc — Chickamauga limestone (blue and gray shaly limestone and massive limestone with marble beds)

Shl / Shl — Holston marble in Chickamauga limestone (variegated marble lentils, chiefly reddish or gray)

CAMBRIAN

€Sk / €Sk — Knox dolomite (light and dark magnesian limestone with chert nodules)

€n / €n — Nolichucky shale (variegated calcareous shales and thin limestones)

€m / €m — Maryville limestone (massive blue limestone)

€c / €c — Conasauga shale (reddish calcareous shale with thin beds of limestone)

(The Conasauga shale is divided into two or more parts by the development of limestone formations toward the northeast)

€rg / €rg — Rogersville shale (greenish clay shale with limestone layers)

€rt / €rt — Rutledge limestone (massive dark-blue limestone)

€r / €r — Rome formation (red, green, and brown sandy shale)

€rs / €rs — Sandstone lentils in Rome formation (red, white, and brown sandstone)

Faults

Legend is continued on the left margin.

COLUMNAR SECTION SHEET

GENERALIZED SECTION FOR MAYNARDVILLE QUADRANGLE NORTHWEST OF WALLENS RIDGE.

SCALE: 1 INCH = 1000 FEET.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	Briceville shale.	Cbv		200+	Black, bluish-gray, and gray, argillaceous shale with small beds of sandy shale and sandstone, and thick coal beds.	Flat valleys with small hills and spurs. Thin clay soil with sandy wash.
	Lee conglomerate.	Cle		1000–1100	Massive sandstone, in part cross bedded, with conglomerate, a few thin shale beds, and thin coal seams.	Sharp, rugged ridges and mountains with many cliffs and ledges. Thin, sandy and rocky soil with much sandstone waste.
	Pennington shale.	Cpn		150–220	Calcareous shale, sandstone, and limestone.	Small hollows. Sandy clay soil.
	Newman limestone.	Cn		300–600	Massive and cherty, blue limestones with a few shale beds.	Rolling ground, small ridges, and a few cliffs on the mountain slopes. Cherty, red clay soil.
DEV.	Chattanooga shale.	Dc		100–400	Black, carbonaceous shale.	Narrow depressions.
SILURIAN	Rockwood formation.	Sr		400–700	Red and brown, calcareous and sandy shales with local beds of white sandstone and fossiliferous red hematite.	Valleys and sharp, even-topped ridges. Thin, sandy soil.
	Bays formation.	Sb		150–250	Red, argillaceous and sandy limestone.	Valleys and low slopes. Thin, sandy clay soil.
	Chickamauga limestone.	Sc		1500–2000	Blue and gray limestone, argillaceous limestone, flaggy limestone, and calcareous shale. Blue and gray, massive limestone with a few nodules of black chert.	Smooth, open valleys. Red and yellow clay soil. Low, rounded hills. Red, clayey soil with chert fragments.
?	Knox dolomite.	ꞒSk		2800–3500	Magnesian limestone, white, gray, light blue, and dark blue, with nodules of chert. Beds of white, calcareous sandstone and sandy marble.	Broad, cherty ridges and high, rounded hills. Deep, red clay soil with many fragments of chert and sandstone.
CAMBRIAN	Conasauga shale.	Ꞓc		600–750	Yellow, red, and brown, calcareous shale with thin beds of limestone.	Valleys, and slopes of Knox dolomite ridges. Thin, yellow clay soil.
	Rome formation.	Ꞓr		450–600	Bright-red, green, and brown, sandy shale with layers of thin sandstone.	Slopes of sandstone ridges. Thin, brown clay soil with much sandstone wash.
	Rome sandstone lentils.	Ꞓrs		1000+	Red, yellow, and brown, sandy shale and massive sandstone with layers of blue and sandy limestones.	Sharp ridges with notches and gaps. Thin, sandy soil with ledges and fragments of sandstone.

NAMES OF FORMATIONS.

Period.	Arthur Keith: Briceville Folio, U. S. Geological Survey, 1896.	Names and Symbols used in this Folio.			Arthur Keith: Morristown Folio, U. S. Geological Survey, 1896.	Safford: Geology of Tennessee, 1869.
CARB.	Briceville shale.	Briceville shale.		Cbv		
	Lee conglomerate.	Lee conglomerate.		Cle		
	Pennington shale.	Pennington shale.		Cpn	Pennington shale.	Mountain limestone.
	Newman limestone.	Newman limestone.		Cn	Newman limestone.	
DEV.		Grainger shale.		Dg	Grainger shale.	Siliceous group.
	Chattanooga shale.	Chattanooga shale.		Dc	Chattanooga shale.	Black shale.
SILURIAN					Hancock limestone.	Meniscus limestone.
	Rockwood formation.	Rockwood formation.		Sr	Rockwood formation.	Dyestone group.
		Clinch sandstone.		Scl	Clinch sandstone.	Clinch Mountain sandstone.
	Bays limestone.	Bays formation.		Sb	Bays sandstone.	
	Chickamauga limestone.	Sevier shale.		Ssv	Sevier shale.	Trenton and Nashville series.
		Tellico sandstone.		St		
					Athens shale.	
		Moccasin limestone.		Smc	Moccasin limestone.	
		Chickamauga limestone.		Sc	Chickamauga limestone.	Trenton, Lebanon, or Maclurea limestone.
		Holston marble.		Shl	Holston marble.	
	Knox dolomite.	Knox dolomite.		ꞒSk	Knox dolomite.	Knox dolomite.
CAMBRIAN	Conasauga shale.	Conasauga shale. Ꞓc	Nolichucky shale.	Ꞓn	Nolichucky shale.	Knox shale.
			Maryville limestone.	Ꞓm	Maryville limestone.	
			Rogersville shale.	Ꞓrg	Rogersville shale.	
			Rutledge limestone.	Ꞓrt	Rutledge limestone.	
	Rome formation.	Rome formation.		Ꞓr	Rome formation.	Knox sandstone.
	Rome sandstone lentil.	Rome sandstone lentils.		Ꞓrs	Rome sandstone lentil.	

GENERALIZED SECTION FOR MAYNARDVILLE QUADRANGLE SOUTHEAST OF WALLENS RIDGE.

SCALE: 1 INCH = 1000 FEET.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARB.	Newman limestone.	Cn		300+	Massive and cherty, blue limestone.	Flat, open valleys. Cherty, red clay soil.
DEVONIAN	Grainger shale.	Dg		900–1000	Greenish-gray and bluish-gray, sandy shale and sandstone.	High ridges and lines of knobs with many water gaps. Thin, sandy soil.
	Chattanooga shale.	Dc		400–450	Black, carbonaceous shale.	Deep, narrow valleys. Yellow clay soil.
SILURIAN	Rockwood formation.	Sr		0–300+	Red, yellow, and brown, sandy shales and thin sandstones with thin beds of red hematite.	Sharp, even-topped ridges. Thin, sandy soil.
	Clinch sandstone.	Scl		150–500	Massive, white sandstone.	High, sharp mountains.
	Bays formation.	Sb		200–500	Red, calcareous and argillaceous sandstones.	Steep slopes of Clinch sandstone mountains.
	Sevier shale.	Ssv		1100–1300	Light-blue, sandy and calcareous shales with beds of shaly limestone.	Irregular ridges and steep knobs. Yellow and red clay soil.
	Moccasin limestone.	Smc		600–800	Red and gray, flaggy limestone and calcareous shale.	Low ground with irregular ridges and knobs. Red and yellow clay soil.
	Chickamauga limestone. (Holston marble.)	Sc (Shl)		500–1800	Blue and gray limestone, argillaceous limestone, flaggy limestone, and calcareous shale. Variegated marble, red, brown, gray, and pink.	Smooth, open valleys. Red and yellow clay soil.
?	Knox dolomite.	ꞒSk		2600–3500	Magnesian limestone, light blue, dark blue, and white, with nodules of chert. Beds of white, calcareous sandstone and sandy marble.	Broad ridges and irregular, rounded hills. Deep, red clay soil with many fragments of chert and sandstone.
CAMBRIAN	Nolichucky shale.	Ꞓn		500–600	Yellow, red, and brown, calcareous shale with a few limestone beds.	Narrow valleys, and steep slopes of Knox dolomite ridges. Thin, shaly soil.
	Maryville limestone.	Ꞓm		300–600	Massive, blue limestone, becoming shaly toward the west.	Lines of knobs. Red clay soil.
	Rogersville shale.	Ꞓrg		100–225	Bright-green clay shale, with a limestone bed.	Valleys and low knolls. Thin, shaly soil.
	Rutledge limestone.	Ꞓrt		180–500	Massive, blue limestone, becoming shaly toward the west.	Open valleys. Red clay soil.
	Rome formation.	Ꞓr		350–400	Red, green, yellow, and brown shale and sandy shale.	Slopes of Rome sandstone ridges. Thin, sandy soil.
	Rome sandstone lentils.	Ꞓrs		1100+	Red, yellow, and brown, sandy shale and massive sandstone with layers of blue, sandy limestone.	Sharp ridges with many notches and water gaps. Thin, sandy soil with fragments of sandstone.

GENERALIZED SECTION FOR MAYNARDVILLE QUADRANGLE NEAR HOLSTON RIVER.

SCALE: 1 INCH = 1000 FEET.

Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
SILURIAN	Sevier shale.	Ssv		700+	Light-blue, sandy and calcareous shales with beds of limestone and argillaceous marble near the base.	Flat, open valleys with low knobs. Yellow and red clay soil.
	Tellico sandstone.	St		100–350	Bluish-gray, calcareous sand stone and sandy shale.	High, rounded knobs and ridges. Red, sandy soil.
	Holston marble.	Shl		200–400	Variegated marble, red, brown, gray, and white.	Rounded hills and slopes. Deep, red clay soil.
	Chickamauga limestone.	Sc		500–700	Blue limestones and gray, argillaceous limestones.	Low and rolling valleys. Red clay soil.
	Knox dolomite.	ꞒSk		3500	Magnesian limestone with nodules of chert.	Broad ridges and irregular rounded hills. Deep, red clay soil with many fragments of chert and sandstone.

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Information Concerning

Topographic and Geologic Maps and Folios

and Other Publications of the Geological Survey

can be had on application to

The Director, U. S. Geological Survey,

Washington, D. C.