DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

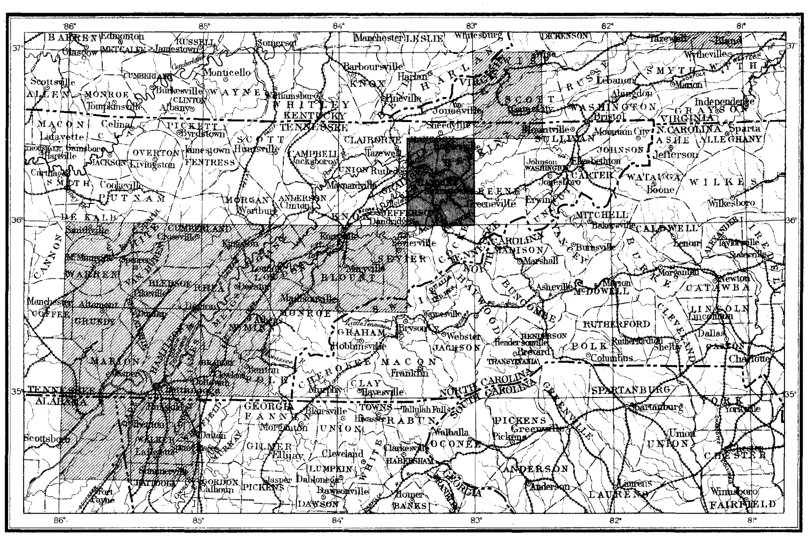
OF THE

UNITED STATES

MORRISTOWN FOLIO

TENNESSEE

INDEX MAP



SCALE: 40 MILES - 1 INCH

AREA OF THE MORRISTOWN FOLIO

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FOLIO 27 | LIBRARY EDITION | MORRISTOWN

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

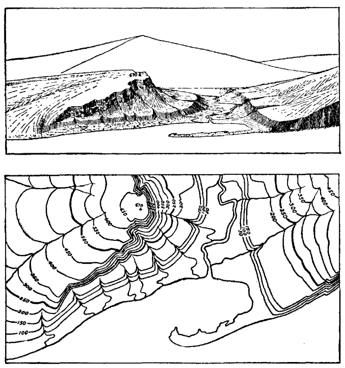

Fig. 1.—Ideal sketch and corresponding contour map.

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

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

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

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

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

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

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

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

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

Atlas sheets.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree; each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. These areas correspond nearly to 4,000, 1,000, and 250 square miles, respectively.

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

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

THE GEOLOGIC MAP.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

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

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

AGES OF ROCKS.

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

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

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

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

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

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

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

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

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

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

period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

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

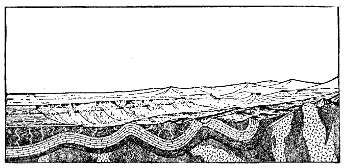

Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape above.

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

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

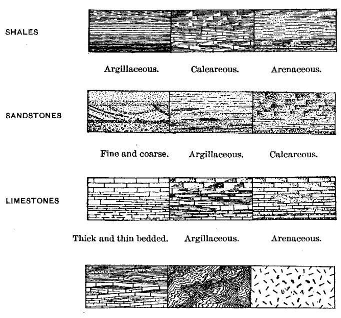

Fig. 3.—Symbols used to represent different kinds of rock.

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

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

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

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

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

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has swelled upward from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,
Director.

DESCRIPTION OF THE MORRISTOWN SHEET.

GEOGRAPHY.

General relations.—The area represented on the Morristown atlas sheet lies entirely in Tennessee, and includes portions of Hancock, Grainger, Hawkins, Hamblen, Jefferson, Cocke, and Greene counties. It is bounded by the parallels 36° and 36° 30′ and the meridians 83° and 83° 30′, and it contains 990 square miles.

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

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

The central division is the Appalachian Valley. It is the best defined and most uniform of the three. In the southern part it coincides with the belt of folded rocks which forms the Coosa Valley of Georgia and Alabama and the Great Valley of East Tennessee and Virginia. Throughout the central and northern portions the eastern side only is marked by great valleys—such as the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and Pennsylvania, and the Lebanon Valley of northeastern Pennsylvania—the western side being a succession of ridges alternating with narrow valleys. This division varies in width from 40 to 125 miles. It is sharply outlined on the southeast by the Appalachian Mountains and on the northwest by the Cumberland Plateau and the Alleghany Mountains. Its rocks are almost wholly sedimentary and in large measure calcareous. The strata, which must originally have been nearly horizontal, now intersect the surface at various angles and in narrow belts. The surface differs with the outcrop of different kinds of rock, so that sharp ridges and narrow valleys of great length follow the narrow belts of hard and soft rock. Owing to the large amount of calcareous rock brought up on the steep folds of this district its surface is more readily worn down by streams and is lower and less broken than the divisions on either side.

The eastern division of the province embraces the Appalachian Mountains, a system which is made up of many minor ranges, and which, under various local names, extends from southern New York to central Alabama. Some of its prominent parts are the South Mountain of Pennsylvania, the Blue Ridge and Catoctin Mountain of Maryland and Virginia, the Great Smoky Mountains of Tennessee and North Carolina, and the Cohutta Mountains of Georgia. Many of the rocks of this division are more or less crystalline, being either sediments which have been changed to slates and schists by varying degrees of metamorphism, or igneous rocks, such as granite and diabase, which have solidified from a molten condition.

The western division of the Appalachian province embraces the Cumberland Plateau and the Alleghany Mountains and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the Mississippi River as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian Valley by the Alleghany front and the Cumberland escarpment. The rocks of this division are almost entirely of sedimentary origin and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely worn down. In the southern half of the province the plateau is sometimes extensive and perfectly flat, but it is oftener much divided by streams into large or small areas with flat tops. In West Virginia and portions of Pennsylvania the plateau is sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the plateau has been completely removed by erosion, and the surface is now comparatively low and level, or rolling.

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

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1,000 feet in Alabama to more than 6,600 feet in western North Carolina. From this culminating point they decrease to 4,000 or 3,000 feet in southern Virginia, rise to 4,000 feet in central Virginia, and descend to 2,000 or 1,500 feet on the Maryland-Pennsylvania line.

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

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

Drainage of the Appalachian province.—The drainage of the province is in part eastward into the Atlantic, in part southward into the Gulf, and in part westward into the Mississippi. All of the western, or plateau, division of the province, except a small portion in Pennsylvania and another in Alabama, is drained by streams flowing westward to the Ohio. The northern portion of the eastern, or Appalachian Mountain, division is drained eastward to the Atlantic, while south of the New River all except the eastern slope is drained westward by tributaries of the Tennessee or southward by tributaries of the Coosa.

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

Geographic divisions of the Morristown area.—The area represented on this atlas sheet divides into three districts, each having quite distinct surface features. These divisions are the ridge district, the Lick Valley, and the knob belt. Beside these, Bays Mountain, in Greene County, is the southwestern end of a group of high ridges lying chiefly in the Greeneville region. The valley south of Parrottsville and Salem, also, is part of the Nolichucky basin of the Greeneville area, but is too small for distinction here.

The ridge district, the most extensive of the three, lies northwest of the line of the two Bays mountains, and consists of a series of long, parallel ridges and lines of hills separated by narrow valleys. Two of the valleys, passing through Mooresburg and Morristown, are broad and level, but few of the others contain much level land. The mountain ridges are long and straight, and vary in height from 2,000 to 2,300 feet, with a few summits attaining 2,500 and 2,700 feet; the lower ridges rise to 1,500 and 1,700 feet. The floors of the valleys range from 1,000 to 1,200 feet, becoming as low as 900 on the lower Holston River. Lick Valley and its continuation, down the Nolichucky and French Broad rivers, consists of flat or slightly rolling plains relieved by low hills and irregular knobs. The most of its surface lies between 1,000 and 1,100 feet, and the hills attain 100 or 200 feet above these elevations. The knob belt lies southeast and east of Leadvale, and consists of a number of short, irregular ridges and conical knobs, in which no definite arrangement exists. The streams of this district flow in deep, narrow cuts, from which the knobs rise with exceedingly sharp slopes. Altitudes along the streams are from 1,000 to 1,100 feet, and the knobs rise from 100 to 400 feet higher.

The entire region is drained by tributaries of the Tennessee River—the Nolichucky, French Broad, Holston, and Clinch rivers. All of them rise far beyond the limits of this area, and they receive here a very small proportion of their water. The Nolichucky falls from 1,100 to 1,000 feet, the French Broad from about 1,000 nearly to 900, the Holston from 1,000 to 850 feet, and the Clinch from nearly 1,100 to 1,000 feet.

In this region the topography varies much, depending in all cases upon the influence of erosion on the different formations. Such rock-forming minerals as carbonates of lime and magnesia, and to a less extent feldspar, are readily removed by solution in water. Rocks containing these minerals in large proportions are therefore subject to decay by solution, which breaks up the rock and leaves the insoluble matter less firmly united. Frost and rain and streams break up and carry this insoluble residue, and the surface is worn down. According to the nature and amount of the insoluble matter the rocks form high or low ground. Calcareous rocks, leaving the least residue, occupy the low ground. Such are all the formations between the Rome sandstone and the Sevier shale. All of these, except the Knox dolomite, yield a fine clay after solution; the dolomite leaves besides the clay a large quantity of silica in the form of chert, which strews the surface with lumps and protects it from removal. In many regions, where the amount of chert in the dolomite is less, it is reduced to low ground, as the other limestones are. The least soluble rocks are the sandstones, and since most of their mass is left untouched by solution they are the last to be reduced in height. Clinch Mountain is a fine example of this.

Erosion of the valley formations has produced a series of ridges, separated by long valleys, which closely follow the belts of rock. Where the formations spread out at a low dip the valleys or ridges are broad, and where the strata dip steeply the valleys are narrower. Each turn in the course of a formation can be seen by the turn of the ridge or valley that it causes. Each rock produces a uniform type of surface so long as its composition remains the same; with each change in composition the surface changes form.

GEOLOGY.

STRATIGRAPHY.

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

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

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

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

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

The rocks of this area are all sedimentary in origin, and comprise most of the varieties of limestones, shales, and sandstones. They range in age from the earlier sediments of the Appalachians nearly to the end of the Paleozoic, including Cambrian, Silurian, Devonian, and Carboniferous. Carboniferous rocks are but scantily shown; Devonian rocks are as fully represented as anywhere south of Virginia; the Silurian and upper part of the Cambrian are unusually well developed.

The rocks lie in two distinct areas or groups, of different age and composition. Southeast of a line passing through Dandridge, Leadvale, and Whitesburg the rocks consist almost entirely of the shales and sandstones of Silurian age. The Silurian sandstones form Bays Mountain, and the shales underlie the rest of the belt. Northwest of that line all of the formations found in this region appear repeatedly in narrow belts. Thus the knob belt and Lick Valley are seen to be worn from the Silurian shales, while in the ridge district a rapid succession of all formations occurs.

CAMBRIAN ROCKS.

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

The series is thinnest near Dandridge, where it comprises 250 feet of sandy shale at the top and 500 feet of sandstone and sandy shale at the bottom. Its full thickness is not exposed, being cut off by the fault which brings the formation to view. North of Holston River the upper shales are somewhat thicker, and as much as 1,000 feet of sandstone and sandy shale appear.

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

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

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

Rutledge limestone.—The Rutledge formation occurs in all of the areas which show the Rome formation. It is named from its fine development in the valley of Rutledge, in Grainger County. As a whole the strata are limestone, but there are many beds of green and yellow, calcareous shale toward the base, which form a passage into the Rome formation. The limestones are massive, and range in color from blue to dark-blue, black, and gray. In the belt near Dandridge the formation varies from 500 to 350 feet, and, north of the Holston, from 500 to 250 feet, the thickness diminishing toward the southwest ends of the belts.

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

Rogersville shale.—This shale, like the preceding limestone, can be distinguished in all of the zones of Cambrian rocks within the boundaries of this sheet. The excellent showing of the formation near Rogersville gives the formation its name. It consists chiefly of bright-green, argillaceous shales, with occasional beds of thin, red, sandy shale, which occur mainly north of the Holston. In its eastern and southern areas it is divided by a bed of massive blue limestone, and its northwestern outcrops contain many small beds of shaly limestone. The formation varies in thickness from 70 to 250 feet, and is thinnest north of Clinch Mountain. Numerous remains of trilobites are found in the shales, which show the formation to be of middle Cambrian age.

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

Maryville limestone.—This limestone is present in the belts of Cambrian rocks throughout this region. It receives its name from its great development near Maryville, in Blount County, Tennessee. The formation consists of massive, blue limestone, with little change in appearance except frequent earthy, siliceous bands and occasional grayish-blue and mottled beds. In thickness it ranges from 750 feet near Rogersville to 550 feet north of Clinch Mountain and 500 feet on Dumpling Creek. Fossils are rare in these beds, but occasional trilobites are found.

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

Nolichucky shale.—This formation is shown in the same belts as the preceding one, and is the most common of the Cambrian formations. It is named from the Nolichucky River, along whose course in the Greeneville region the shale is well exhibited. The formation is composed of calcareous shales and shaly limestones, with beds of massive, blue limestone in the upper portion. When fresh, the shales and shaly limestones are bluish-gray and gray in color; but they weather readily to various shades of yellow, brown, red, and green. Over much of this region the formation is nearly uniform, and contains only yellow and greenish-yellow shale. Passing northeast along the belts north of Holston River the limestone beds become more prominent and the shales more highly colored and calcareous. The thickness of the formation varies from 400 to 750 feet, being thickest in the belts southwest and northwest of Tates Springs.

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

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

SILURIAN ROCKS.

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

The Knox dolomite is the most important and widespread of all the valley rocks. Its name comes from Knoxville, Tennessee, which rests upon one of its areas. The formation consists of a great series of blue, gray, and whitish limestones and dolomites. Many of the beds are banded with thin, brown, siliceous streaks and are very fine-grained and massive. Within these beds, especially the lower half of the formation, are nodules and masses of black chert, locally called "flint," and their variations are the only changes in the formation. The cherts are least conspicuous in the small areas in the southeastern part of the region. The formation varies in thickness from 3,000 to 3,800 feet, the thicker portions lying near the lower part of Clinch River in Copper and Chestnut ridges.

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

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

Chickamauga limestone.—This formation occurs in many areas throughout the entire region. It is named for its occurrence on Chickamauga Creek, Hamilton County, Tennessee. It consists of massive, blue and gray limestones, shaly and argillaceous limestones, and variegated marbles. These beds are all very fossiliferous, and fragments of corals, crinoids, brachiopods, and gasteropods are so abundant as sometimes to make most of the bulk of the rock. Variations are greater in this formation than in any of the valley rocks, both in thickness and appearance. Northwest of Powell Mountain it consists of 2,400 feet of blue and gray limestone. In the knob belt this formation is represented by a thin belt of blue and gray, shaly and knotty limestone, sometimes 100 feet thick, and often absent entirely. North of Rogersville it is represented by 300 feet of reddish and brown variegated marbles. Between these extremes there is every variation of thickness and composition.

During the accumulation of the Sevier shale, Athens shale, and Moccasin limestone in shallow waters, the limestones of the Chickamauga were deposited in deeper seas. Thus the Chickamauga strata northwest of Clinch Mountain represent a very much longer period than in the other belts, a fact which accounts for the greater thickness in that belt. As the deposition of these beds went on, the land gradually rose and the sea became shallower, thus sending the muddy shore deposits farther and farther northwest.

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

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

Athens shale.—The Athens shale is developed in many areas through the knob belt and Lick Valley and along Clinch and Stone mountains. The shale is named for its occurrence at Athens, McMinn County, Tennessee. It is everywhere composed of blue and black, calcareous shales, which do not vary in appearance. The black shales are found at the bottom of the series and contain lingulæ and numerous graptolites. Their black color is due to the abundance of carbonaceous matter which they contain. The blue shales gradually replace the black shales in passing up through the series, and when fresh consist of thin, light-blue, shaly limestone. As already stated, this formation was deposited at about the same time as the Chickamauga limestone in areas farther northwest, and is the argillaceous sediment accumulated near shore, while the purer calcareous beds gathered farther away. Its thickness is hard to determine on account of the uniformity of its beds, but it is usually about 1,000 or 1,100 feet.

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

Moccasin limestone.—This formation is found in two belts, one northwest of Clinch Mountain, and the other southeast of Stone Mountain. It is named for its occurrence along Moccasin Creek in Scott County, Virginia. The formation consists of red, green, blue, and gray flaggy limestones interbedded with yellow and gray calcareous shales. The red beds are very conspicuous by their color, which is due to the presence of iron oxide in considerable quantity, and they form the chief distinction between this and the Chickamauga limestone. The shaly beds strongly resemble the Sevier shale. In the Stone Mountain area the beds are highly contorted, so that measures of its thickness are seldom precise; good measures on Clouds Creek give 450 to 500 feet. Along Clinch Mountain its thickness becomes slightly less, from 300 to 400 feet, becoming thinner in passing northeast.

Weathering produces much the same effect on this as on the Chickamauga limestone, and it does not occupy high ground. The red limestones especially weather out into large flags and slabs, and frequent bare ledges occur. Its soils are red and yellow clays, rarely deep, and are strewn with unweathered fragments. On account of their thinness and steep slopes, the soils are liable to washing and drought, but they are fertile when well situated. Irregular ridges and conical knobs of small height and size cover its areas.

Tellico sandstone.—Thin beds of this sandstone are quite common in the knob belt. The strata consist of bluish-gray and gray calcareous sandstones and sandy shales closely interbedded. These weather by solution of the lime into a porous, sandy rock with a strong-red color. These strata are not extensive enough to be represented upon the map, but they appear in adjoining areas in considerable bodies.

Decay of this rock is rapid, so far as solution goes, and outcrops are few, but the sandy skeleton remains and is sufficiently hard to cause eminences along the boundary of the Sevier and Athens shales.

Sevier shale.—This formation appears in two basins: on each side of the Clinch-Stone Mountain syncline, and in several areas scattered over the knob belt and Lick Valley. It derives its name from its great development in Sevier County, Tennessee, on the continuation of the knob belt. 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 into dull-yellow, greenish-yellow, or gray. The lower portion of the formation in the knob belt contains many small beds of reddish sandstone representing the Tellico sandstone. Above these are thin beds of limestone in the shales, from a few inches to a few feet thick, which weather out in slabs and square blocks. The upper shales are quite sandy and contain beds of calcareous sandstone, so that the whole series forms a transition from the older limestones up into the Bays sandstone. In the Clinch-Stone Mountain basin the whole formation is less sandy, and thus becomes better separated from the Bays sandstone, but less distinct from the Moccasin limestone. The thickness of the formation varies from 900 feet along Clinch Mountain, and 1,300 to 1,500 feet in the Bays Mountains, to 1,800 feet in the knob belt. The latter measure is unsatisfactory on account of the great folding of the strata and the similarity of the beds.

The calcareous parts of the formation readily dissolve, leaving the argillaceous matter sufficiently firm to form slabs or flakes of shale. These strew the surface and retard its wear enough to cause irregular ridges and round knobs of considerable height. Between these the deep, narrow valleys form an irregular network. On complete decay the strata form a thin, yellow clay, which is readily washed down the slopes at which the surface usually lies, leaving much bare rock. Such soils are thin, cold, and subject to drought, and are of very little value. In Lick Valley, and in Holston and French Broad valleys, where the surface is well worn down, the soils accumulate to greater depth and are more mingled with sandy wash. These soils are therefore lighter and more fertile, but are poorly watered. In the coves and hollows receiving the wash from the knobs the soils are deep and rich and support heavy timber. The waters over this formation are scanty and contain much mineral impurity in suspension and solution.

Bays sandstone.—The same areas that contain the Sevier shale contain the Bays sandstone, and it also occurs in Powell Mountain and Walden Ridge. The name is given for its frequent outcrops in the Bays Mountains of Hawkins and Greene counties. It is everywhere a red calcareous and argillaceous sandstone, changes in its appearance being very slight. Near Powell Mountain the lime becomes more important than in other areas, and the rock is an impure limestone. The red color, however, is very marked and persistent. Considerable variations occur in its thickness, which ranges from 200 to 500 feet. The strata are thinnest in Powell Mountain, Walden Ridge, and the southwest end of Bays Mountains, and they increase rapidly toward the southeast and east. Such changes are common in shore deposits, where the volume of sediment increases as the source becomes less remote.

Owing to the amount of calcareous matter that it contains, the Bays sandstone, although so thick, never stands at great altitudes. Its outcrops form low ridges, or steep slopes on the Clinch sandstone mountains. Decay is never deep, but the sandy residue is loose and crumbling and does not resist wear. Soils are invariably thin on this rock, and it outcrops more than any other calcareous formation. On account of their shallow and sandy nature these soils are of very little value except in the small hollows where the waste has collected. These support some fairly good timber, but are very limited in extent.

Clinch sandstone.—This formation forms all of the mountains in the ridge district except Newman Ridge, and is especially prominent in Clinch Mountain, for which it is named. The formation is composed mainly of massive white sandstones, in which are included, in the Bays Mountains, a few beds of red sandstone similar to the Bays sandstone. The white sandstone is formed of rounded quartz grains of even size and fine to medium grain. Some of the layers contain scolithus borings, and occasionally cross-bedded strata are found. Its thickness varies from 300 to 350 feet in the Bays Mountains, and thins from 500 feet in the Clinch Mountain syncline to 200 feet in the Powell Mountain basin.

Solution affects the formation but little, owing to its very siliceous composition, so that it invariably makes conspicuous ridges. To its hardness Clinch and the other mountains of the ridge district owe their prominence. When its beds are much tilted they cause mountains with steep flanks and narrow, regular crests, like Clinch Mountain. Its flat-lying beds produce broad-topped summits, like Short Mountain. Many cliffs and ledges are produced by this rock, and its fragments strew the surrounding slopes and choke the streams. Its soils are sandy and sterile, and support but a scanty vegetation.

Rockwood formation.—Strata of this formation are found in the Bays Mountain syncline and in the Powell syncline; in the Clinch basin they are absent and the Devonian black shale rests upon the Clinch sandstone. The formation derives its name from its outcrops at Rockwood, Roane County, Georgia. It consists mainly of shales, usually calcareous and slightly sandy. In the Powell syncline many layers of white and reddish-brown sandstone, from 3 inches to 3 feet thick, are interbedded with the shale. Bright colors abound in the shales, varying from red and yellow to green, and endure until the rock is badly weathered. Its total thickness is not seen in the Bays syncline; what is left by erosion measures 400 feet. In the Powell basin it is from 400 to 500 feet thick. Various fossils, chiefly brachiopods, are found in the formation, which show it to be of upper Silurian age.

The formation weathers readily into open, rolling valleys or slopes along the Clinch sandstone mountains. The sandstone beds in the Powell basin outcrops resist erosion rather better and form low hills and ridges. Its soils are not very deep or fertile, and are also impaired by sandstone wash from the mountains. They are, however, well situated and well drained, and in the Bays syncline are fairly productive.

Hancock limestone.—In the Powell syncline are found the only areas of this formation in the valley of East Tennessee, and from its occurrence here in Hancock County it derives its name. The formation consists entirely of interbedded, massive and shaly limestones of a blue, gray, or dove color. The thickness of these strata is 450 feet. Massive beds are more frequent at the bottom and top of the formation and attain a thickness of 20 feet. Great numbers of fossils, largely brachiopods, corals, and crinoids, are found throughout the formation, and show it to be of upper Silurian age. In general appearance this formation strongly resembles the Chickamauga limestone.

Under the attacks of weather the formation readily loses its calcareous matter and forms valleys. Outcrops are not rare, and consist usually of the massive beds. The cover of red clay is generally deep, and from it are derived soils of great strength and fertility. By the sandy wash from adjacent formations their clayey nature is modified until they are often light and well drained.

DEVONIAN ROCKS.

Chattanooga shale. — This formation, whose name is taken from its occurrence in Chattanooga, Tennessee, is found in many belts in the Clinch basin and in the Powell syncline. In this region it is a bed of black, carbonaceous shale, with no variations of composition. Its upper layers for a few feet are interbedded with the Grainger shale, and it is unconformably deposited on the Silurian Hancock, Rockwood, and Clinch formations. It maintains a constant thickness of 400 to 450 feet. Frequently the surfaces of the shale are covered with yellowish-red crusts of alum and iron ore, which have been dissolved out of the body of the rock. Small, rounded lumps and nodules of iron ore also occur in some layers of the shale. On account of its fine grain and softness, the formation lies either in deep valleys or on steep slopes protected by harder formations. Its valleys, except between Sharp Mountain and Newman Ridge, are narrow and cold and shut in between high ridges. Decay is rapid in this rock, so that outcrops are very rare; the residual yellow clay is dense and cold, and so much covered with sandstone wash that it is of little agricultural value.

Grainger shale.—Areas of this formation are found in the same districts as the Chattanooga shale. Its name is derived from Grainger County, where it is well displayed. It comprises sandy shales and shaly and flaggy sandstones, the latter being more numerous in the upper layers. Two miles northwest of Mooresburg a thin bed of quartz conglomerate lies at the very top of the series. All beds are bluish-gray when fresh, and weather out green and greenish-gray. In the bottom flags are many impressions of the supposed seaweed, *Spirophyton cauda-galli.* These beds vary from a thickness of 1,200 feet in the Clinch basin to 400 feet in the Powell basin, indicating that the shore lay toward the southeast.

Decay proceeds slowly in the argillaceous materials of this rock, and the sandy layers remain unaffected. Its areas stand out in ridges, but only for 400 to 500 feet above the valleys on either side, because the rock gradually crumbles under the wear of rain and frost. These ridges are very regular in height, and are gapped by frequent streams from the valleys of Chattanooga shale. Its soils are sandy and full of bits of rock, and lie at right angles, so that they are sterile and nearly valueless for agriculture.

CARBONIFEROUS ROCKS.

Newman limestone.—The same basins that hold the two preceding formations contain this also, and it is named for its occurrence here in Newman Ridge. Massive and shaly limestones make up the entire formation. In the Clinch basin the massive bed, 100 feet thick, lies at the base and is overlain by thin and shaly limestones over 1,400 feet thick. Erosion has here removed the top of the formation, so that its full thickness is not seen. In the Powell basin the entire formation consists of massive limestone 700 feet thick, thus showing a diminution away from the muddy shore sediment. All of the limestones are blue or grayish-blue when fresh, and the shaly layers weather out greenish-yellow. The lower massive limestones contain many layers and nodules of black chert; these, and the limestone itself, are full of fossil crinoids, corals, and brachiopods. This chert weathers white, like the Knox dolomite chert, and can be distinguished from the latter by the fossils that it contains. It does not affect the topography, for it breaks into small fragments and is relatively small in amount.

The massive limestone in the Clinch basin weathers readily and forms low ground; the upper shaly beds resist erosion to a considerable degree and form broad, rounded knobs and hills as high as the Grainger shale. This upland position keeps the soils well drained, and they are fairly deep; they are filled with flakes and shales of limestone, but are productive and strong. Deep, rich clays of great fertility are formed on the lower beds. In the Powell basin the massive limestones are slower to dissolve on account of their close texture and the amount of silica in the rock besides the chert. Their position on the slopes of ridges keeps the covering of soil thin, and frequent cliffs and ledges mark the course of the formation. Little land of agricultural value is found on these strata on account of the abruptness of the slopes.

Pennington shale.—This is the latest of the formations which occur in the valley of East Tennessee, and is found here in a small area on Newman Ridge. Its exposures in Virginia, at Pennington Gap in Clinch Mountain, give the formation its name. The formation consists here of whitish, sandy shales and thin sandstones. Erosion has removed the upper strata, but 250 feet yet remain. It shows no variation in the region and no marked characters. Decay penetrates along the bedding planes, working mainly by rain and frost, and the rock slowly breaks up into small fragments. Few outcrops appear, but the soils are thin, sandy, and poor.

STRUCTURE.

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

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

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

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

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

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

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

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

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

Faults are represented on the map by a heavy, solid or broken line, and in the section by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have been moved on its opposite sides.

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

Two regions exist in this area in which the types of deformation differ materially,—on either side of a line passing northeast through Dandridge, Witt Foundry, and Russellville. These are nearly the same as the topographic and geologic divisions,—the ridge district, and the knob belt and Lick Valley. Both of these districts lie wholly in the great Appalachian Valley.

The rocks of the ridge district have been thrown out of their original position by folds and by faults. These are distributed over the whole area, and are of the same type. The folds are long and straight, are usually closely folded, and are as a rule squeezed so far that the rocks on the western side of the anticlines were bent up until vertical and then pushed beyond the vertical. The dips vary from flat to vertical and thence to 50° overturned; the sides of the average fold dip 40° to the southeast and 80° or 90° to the northwest. The arch 2 miles southwest of Mooresburg (Section C) and the basin south of Richland Knobs (Sections D and E) illustrate the open folds. Close folds appear in the Clinch syncline (Section A), and close folds broken by faults appear northwest of Dandridge (Sections E and F). The rocks varied greatly in their manner of yielding to pressure. Massive rocks with few bedding planes, such as Knox dolomite and the Clinch sandstone, bent in great curves. Thin-bedded shales and sandstones, like Athens shale and Rome sandstone, were puckered and contorted, because their thin beds bent and slipped easily on their bedding planes. The stream-cuts in Rome sandstone everywhere show such complex folds, and the anticline 2 miles southeast of Russellville (Sections D, E, and F) shows the gradual replacement of the easy curves in the dolomite by the close folds in thinner Cambrian beds. Two chief synclinal areas are present: one in Powell and Sharp mountains and Newman Ridge, the other southeast of Clinch Mountain. Two corresponding anticlinal areas occur: one between Newman Ridge and Clinch Mountain, and the other passing near Rogersville, Mooresburg, and there dividing into two. A third anticlinal region begins east of Whitesburg and passes south of Morristown and Mossy Creek in the Cambrian rocks.

Associated with the anticlinal uplifts are the faults, seven of great range and twelve lesser or branch faults. Like the broken arches from which they are formed, the faults are long and straight. They are situated on the northwestern side of the anticlines; at that point the horizontal pressure was square across the beds, so that they were least able to resist it, and broke there, if anywhere. The planes of the faults are nearly parallel to the beds on the southeast side of the folds, so that, when erosion along the break has been so great as to wear away the upper parts of the fold, only rocks with the southeastern dip remain. This is illustrated in Section D in Comby and War ridges and north of Tate Springs. The planes of the faults dip from 5° to 60° southeast, most of them being about 35°. The amount of displacement varies from nothing to 4 miles, the latter being the least measure of the fault immediately northwest of Tate Springs. On most of the faults the displacement is from 1 to 3 miles. The arch 2 miles southeast of Russellville (Sections D and E) illustrates the formation of a fault from a fold by the gradual overturning and final breaking of the western beds. Similar developments are shown in the faults in the Cambrian rocks along the lower Holston. The Mossy Creek fault (Section F) illustrates a fault whose plane at the surface is nearly flat.

The second structural province of this region lies southeast of a line passing through Russellville, as already described. In this province the rocks have been deformed almost entirely by folding, since the formations at the surface are for the most part thin-bedded and easily bent. The province is a great synclinal area, or synclinorium, in which are many minor synclines and anticlines. The axes of these folds are much less regular than in the ridge district, both in direction and height, and rise or pitch downward in a marked manner. An instance of this is the anticline underlying Warrensburg, and the sudden rise of the anticlines along the northwest border of the basin. To the latter feature is due the separation of this basin from the ridge district. The line of rise crosses the strike of the folds at an angle of 20°. In Sections D and E is shown the substitution of the larger folds of the Knox dolomite for the little folds and crumples in the Athens and Sevier shales. Few outcrops of the latter formations show the same dip for 50 feet, and in the railroad cuts the vast number of folds are well exposed. The majority of the folds are overturned, often so far that the beds on each side are parallel. East of Parrottsville, in the corner of this area, lies a small portion of the anticlinal district which is prominent in the Greeneville and Mount Guyot districts. One of the anticlines here is slightly broken in the manner usual to that district.

The latest form in which yielding to pressure is displayed in this region is vertical uplift or depression. Evidence of such movements can be found at various intervals during the deposition of the sediments, as at both beginning and end of the epochs of deposition of the Knox dolomite, the Athens shale, the Clinch sandstone, and the Newman limestone. After the great period of Appalachian folding, already described, such uplifts took place again, and are recorded in surface forms. While the land stood at one altitude for a long time, most of the rocks were worn down nearly to a level surface, or peneplain. One such surface was developed over the greater part of this region, and its more or less worn remnants are now seen in the hills and ridges, the most of which rise 1,600 or 1,800 feet. Traces of an older peneplain remain in Clinch, Powell, and Stone mountains and Newman Ridge, at elevations of from 2,000 to 2,200 feet. The early stages of a younger peneplain are seen, at elevations of from 1,000 to 1,100 feet, in Mooresburg and other valleys of the ridge district and in the terraces and floors of the Holston, French Broad, Nolichucky, and Lick valleys. Large areas of this peneplain were formed in the Knoxville region, and others farther down the streams. Still more recent elevation gave the streams fresh power to wear, and the Holston is now reducing its lower portions in a narrow cut. It is known that there were other such uplifts in this region, but their records have been entirely removed by later erosion. Doubtless still others occurred which were not of sufficient length to allow peneplains to form and record the movement.

MINERAL RESOURCES.

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

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

The total thickness of the marble beds, in places as great as 300 feet, is by no means available for commercial use. The rock must be of desirable color, must quarry in blocks of large size free from cracks or impure layers, and must be of fine, close texture.

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

These changes are illustrated by the disappearance of red marble northeast of Thorn Hill in the belt running north of Clinch Mountain, its place being taken by blue and gray marbles. These latter beds are of good body, but lack the most prized color. Workable beds are rarely over 50 feet thick, and usually in that thickness there is a combination of several varieties. Quarries far separated from one another have quite distinct series of beds, and each quarry has its special variety of marble. All marbles of this region are free from any siliceous impurity, and all of reasonable purity take a good polish and are unaffected by weather.

The available localities for quarrying are partly limited by the attitude of the marble beds. The best situations are those in the belt north of Rogersville, where the strata dip at a high angle and there is little stripping to be done. Here the location of the marble, well above drainage, is an added advantage. In the areas north of Clinch Mountain the dip is such as to carry the marble beneath the surface with narrow outcrops, but is not steep enough to avoid considerable stripping. Good marble abounds in these areas, however, and will become available in time as more favorable localities are exhausted, or as the fashionable color changes.

Owing to the soluble nature of the pure marble, it is either completely unaltered and fresh or is 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; when these are sawed and exposed to 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 is thereby lost.

Building stone.—Besides marble, which is used for ornamental building, the Knox dolomite, Chickamauga limestone, and Clinch sandstone are in use. Most of the Clinch sandstone makes building stone of great strength and durability, but it lacks variety or beauty of color. Fresh rock can be obtained with ease, and it can be opened readily along its bedding planes in layers from 1 to 5 feet thick. The brown, calcareous Sevier sandstone in Bays Mountains affords an admirable building stone. Its layers are from 2 to 6 feet thick; it is readily opened and worked into any shape. Massive ledges indicate its resistance to weather, and its brown, red, and bluish colors are very pleasing. Quarry sites are available for both Clinch and Sevier strata near the railroad at Bulls Gap. Building stone and flags of good quality can be obtained from the Grainger shale at most of the stream gaps through its areas. Beds of suitable sizes for most uses can be opened along the numerous shale partings. Its colors are dark-blue and grayish-blue, and its hardness is sufficient to make large ridges and considerable ledges. The Knox dolomite has long been used for chimneys, bridge abutments, and, occasionally, stone houses. It is very hard and firm and thoroughly satisfactory in its wear. Its beds average from 6 inches to 2 feet in thickness, and it is not adapted for larger work on that account. The formation is so widespread that no quarrying center has been established, and rock has been secured only for local use. The more massive blue limestones of the Chickamauga formation are occasionally used, and have the same characters for building material as the Knox dolomite.

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

The Rogersville shale has long found local use for road metal, and in some regions roads are built along its outcrop. It secures a smooth surface and good drainage for the road, but is not especially durable. The Rome sandy shales are used near their outcrops with great success. The material is abundant, easily worked, and fairly lasting, and it secures excellent drainage. Roads built on the Grainger sandstone outcrops are much like the Rome formation roads; their surfaces are smooth and well drained, and the material is abundant and readily broken.

Other formations which could be used for road building are the various limestones and the Clinch sandstone. The latter is worked on the roads across Clinch Mountain with fair success. The road-bed formed of this rock is very hard, but is liable to wash when broken fine enough to have a smooth surface, because the rock contains no cementing material.

Lead.—Ores of this metal are found 3 miles southwest of Leadvale. No mining has been done of any consequence, and the developments are small. The ore is cerussite, and is mingled with calamine and blende. These occur as incrustations and fillings in irregular cavities which take up a large portion of the rock.

Zinc.—In two localities in this region zinc ores are found: one, just mentioned, near Leadvale, and another at Mossy Creek. The ore at Mossy Creek has been mined for years and the output is now large. It consists mainly of blende, with a small amount of calamine and cerussite; these occur in a zone of brecciated dolomite, filling the crevices in the mass and replacing some of the dolomite. The ore appears to be a replacement of the usual calcareous cement of the breccia. This breccia zone runs nearly north and south, and marks the plane of a considerable fault.

Lime and cement.—Many beds in the Knox dolomite and Chickamauga limestone have been burned into excellent lime. The greater part of the dolomite has too small a proportion of calcareous matter for such a purpose, but available beds occur both at the top and bottom of the formation. Of the Chickamauga beds the marble would supply the best of lime, but it is more valuable for ornamental uses. Various Cambrian limestones are of sufficient purity to produce good lime, but are practically untried. The massive beds of the Newman limestone also would furnish good material. In the Chickamauga limestone some reddish-brown argillaceous beds, low down in the formation, are adapted by composition to produce hydraulic cement. Of all these materials little use has been made, and the various rocks have been burned near at hand when wanted, so that no industry has been established.

Brick clay.—Clays suitable for the manufacture of brick are abundant throughout the region. They are derived from the wash of various formations, chiefly the Knox dolomite, the Cambrian limestones and Nolichucky shale, and the Athens and Sevier shales. They collect in depressions of the surface upon or near these formations, and are very widely distributed. The suitability of the clay is largely determined by the slopes of the surface; the finer and purer deposits are found in the basins surrounded by gentle slopes. On the low ground of Lick Creek and the Nolichucky and French Broad valleys good clays are widespread and deep, and no tract of any considerable size is without a deposit. Only local use has been made of these clays, and bricks have been burned in the immediate neighborhood of their use.

Timber.—Many formations produce timber of value, and usually there is a distinct association of certain trees with one formation. All of the formations are timber-covered in suitable localities. The Knox dolomite is always marked by a good growth of oak, chestnut, and hickory. In the hollows of the Athens, Sevier, Rockwood, and Rome formations grow poplar, chestnut, oak, and pine. Areas of Chickamauga limestone are covered by a cedar growth, of no great value. The most valuable bodies of timber in this region have been cut, especially the finer varieties of wood like walnut and poplar. By far the greater part of the region is still timber-covered, however, and the less fancied trees, such as oak and chestnut, are both numerous and valuable. They are in small, scattered bodies, except on a few of the larger dolomite ridges, and this renders them best adapted to local consumption.

Water-power.—A natural resource of this region which is thus far little used is the water-power. The supply of water in the streams is abundant and fairly constant; cherty districts and Sevier shale areas are poorly watered, but others are fed by countless springs and by rivers rising in mountainous regions. Over most of this region the stream grades are light, particularly so in the rivers. Two districts of considerable size, however, possess systems of falls. Where Holston River approaches the Knox dolomite area, which underlies Rogersville, Morristown, and Mossy Creek, the smaller streams regularly have heavy grades for a short distance back from the river. Similar sets of steeply falling streams descend from Copper and Chestnut ridges into Clinch River. In these localities high grades are maintained against the wear of the streams by the hardness of the Knox dolomite, and actual falls are common. The supply of water is not great, but it is steady except in the driest seasons, being fed chiefly by springs. Other falls of small size, but great in number, descend over the hard beds in the water-gaps of the Rome and Grainger formations. At present only occasional saw-mills and grist-mills utilize this power, but in the future it may become of value for manufacturing purposes.

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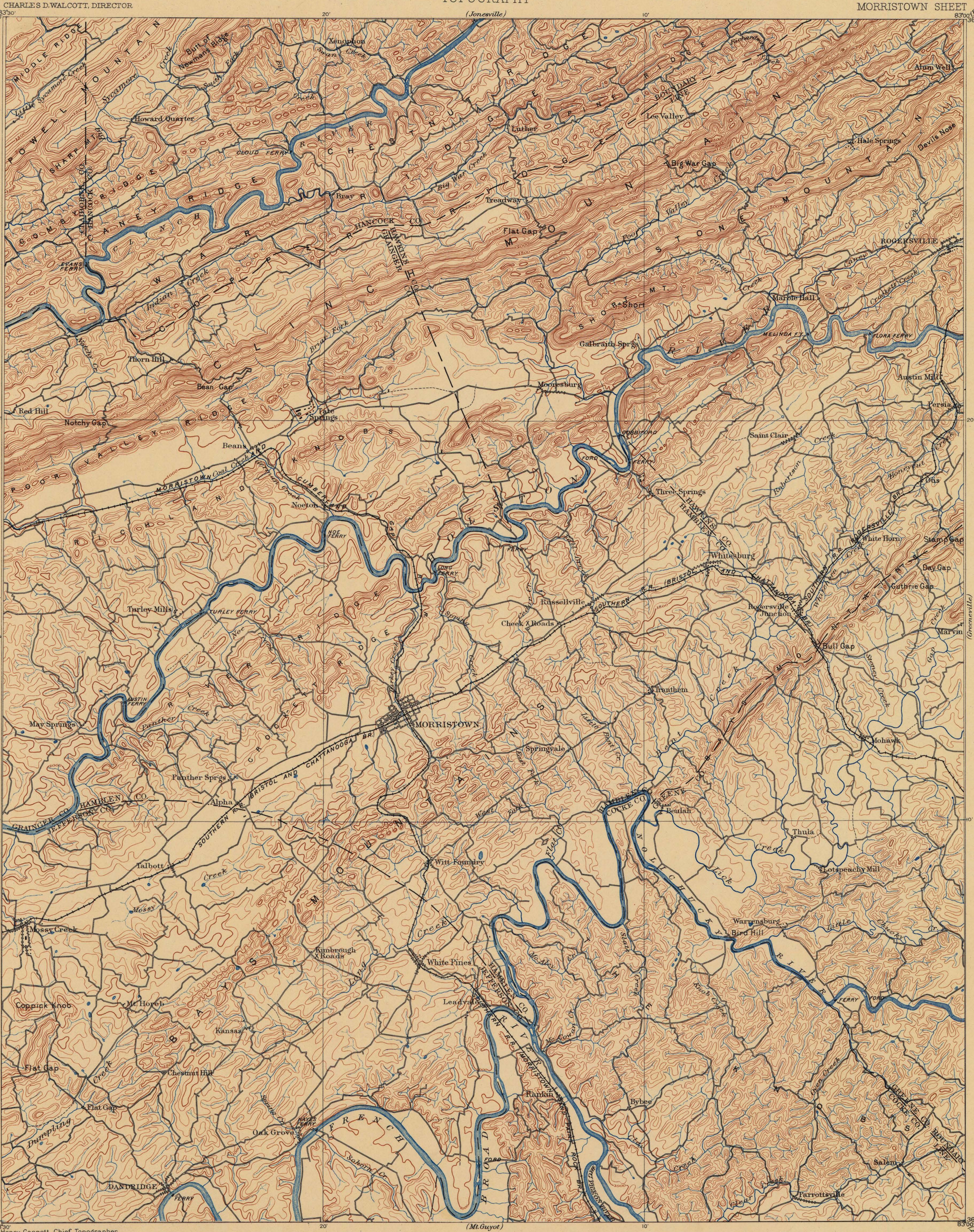
TENNESSEE
MORRISTOWN SHEET



LEGEND

RELIEF
(printed in brown.)

1632
Figures
(showing exact heights above mean sea-level.)

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

DRAINAGE
(printed in blue.)

Rivers
Creeks
Intermittent streams
Ponds
Sinks
Springs

CULTURE
(printed in black.)

Towns and cities
Houses
Churches
Railroads
Roads
Bridges
Ferries
Fords
Trails
County lines
Triangulation stations

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by R.L. Longstreet.
Surveyed in 1890.

Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles

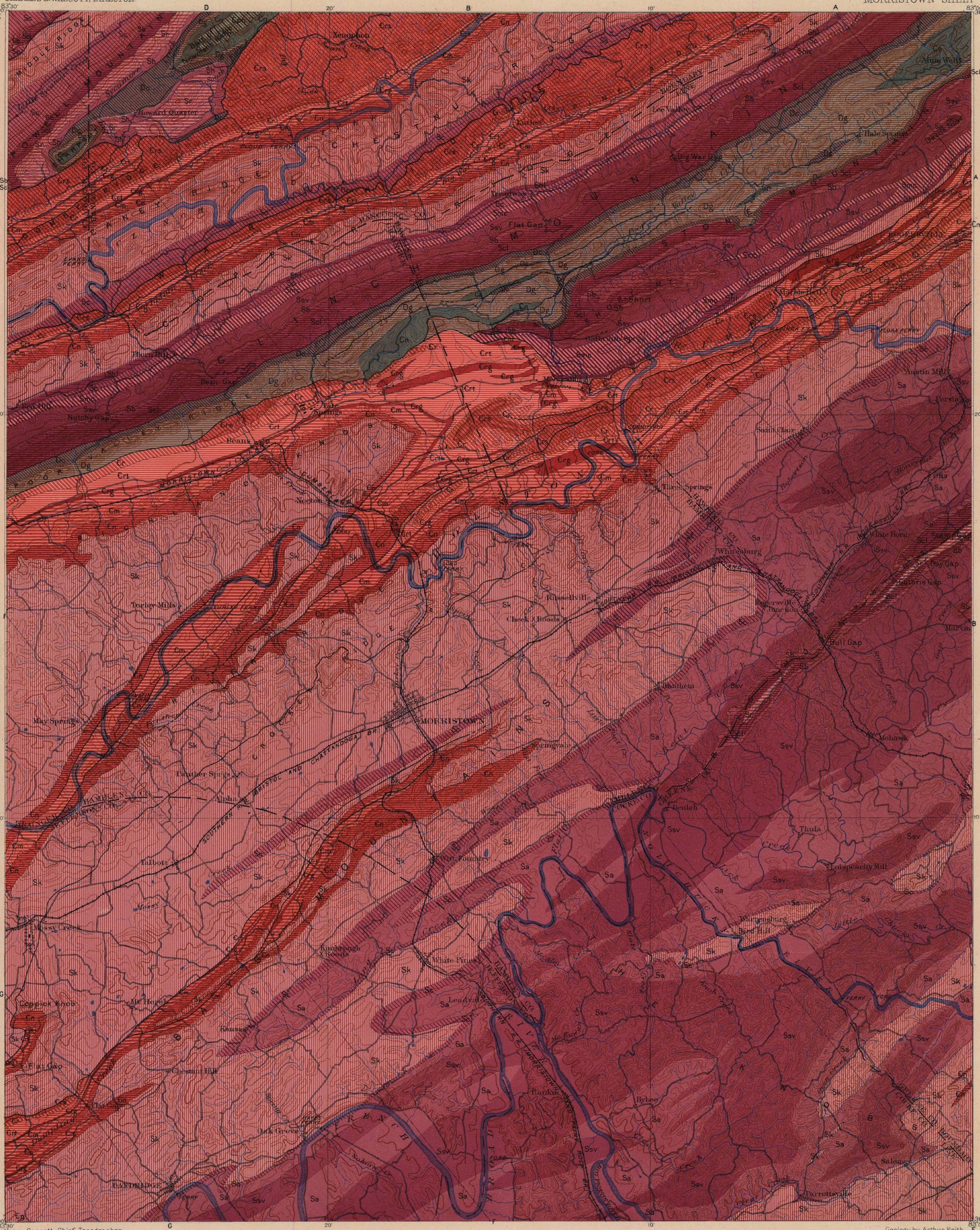
1 ½ 0 1 2 3 4 5 Kilometers

Contour Interval 100 feet
Datum is mean Sea level.
Edition of Jan. 1896.

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

AREAL GEOLOGY

TENNESSEE
MORRISTOWN SHEET



LEGEND

SEDIMENTARY ROCKS

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

CARBONIFEROUS

- Cpn — Pennington shale *(sandstones with sandy and calcareous shales)*
- Cn — Newman limestone *(bluish, shaly and massive limestone)*

DEVONIAN

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

SILURIAN

- Sh — Hancock limestone *(massive and shaly, blue limestone)*
- Sr — Rockwood formation *(variegated, sandy shales and thin sandstones)*
- Scl — Clinch sandstone *(massive, white sandstone)*
- Sb — Bays sandstone *(red, calcareous and argillaceous sandstone)*
- Ssv — Sevier shale *(calcareous sandstone, sandy shale, calcareous shale, and limestone)*
- Sa — Athens shale *(light-blue, calcareous shale, with black shale at the base)*
- Smc — Moccasin limestone *(red and green, argillaceous limestone)*
- Sc — Chickamauga limestone *(blue and gray limestone with marble layers)*
- Shl — Holston marble
- Sk — Knox dolomite *(magnesian limestone with chert nodules)*

CAMBRIAN

- Ꞓn — Nolichucky shale *(variegated, calcareous shales and thin limestones)*
- Ꞓm — Maryville limestone *(massive, blue limestone)*
- Ꞓrg — Rogersville shale *(greenish clay-shale with limestone layers)*
- Ꞓrt — Rutledge limestone *(massive, dark-blue limestone)*
- Ꞓr — Rome formation *(red, green, and brown sandy shale)*
- Ꞓrs — Lentils in Rome formation *(red, white, and brown sandstone)*

SPECIAL SYMBOLS

Faults

Sections

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by R.L. Longstreet.
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Edition of Jan. 1896.

Geology by Arthur Keith.
Assisted by A.C. Lane.
Surveyed in 1888-89-90-91.

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

ECONOMIC GEOLOGY

TENNESSEE
MORRISTOWN SHEET

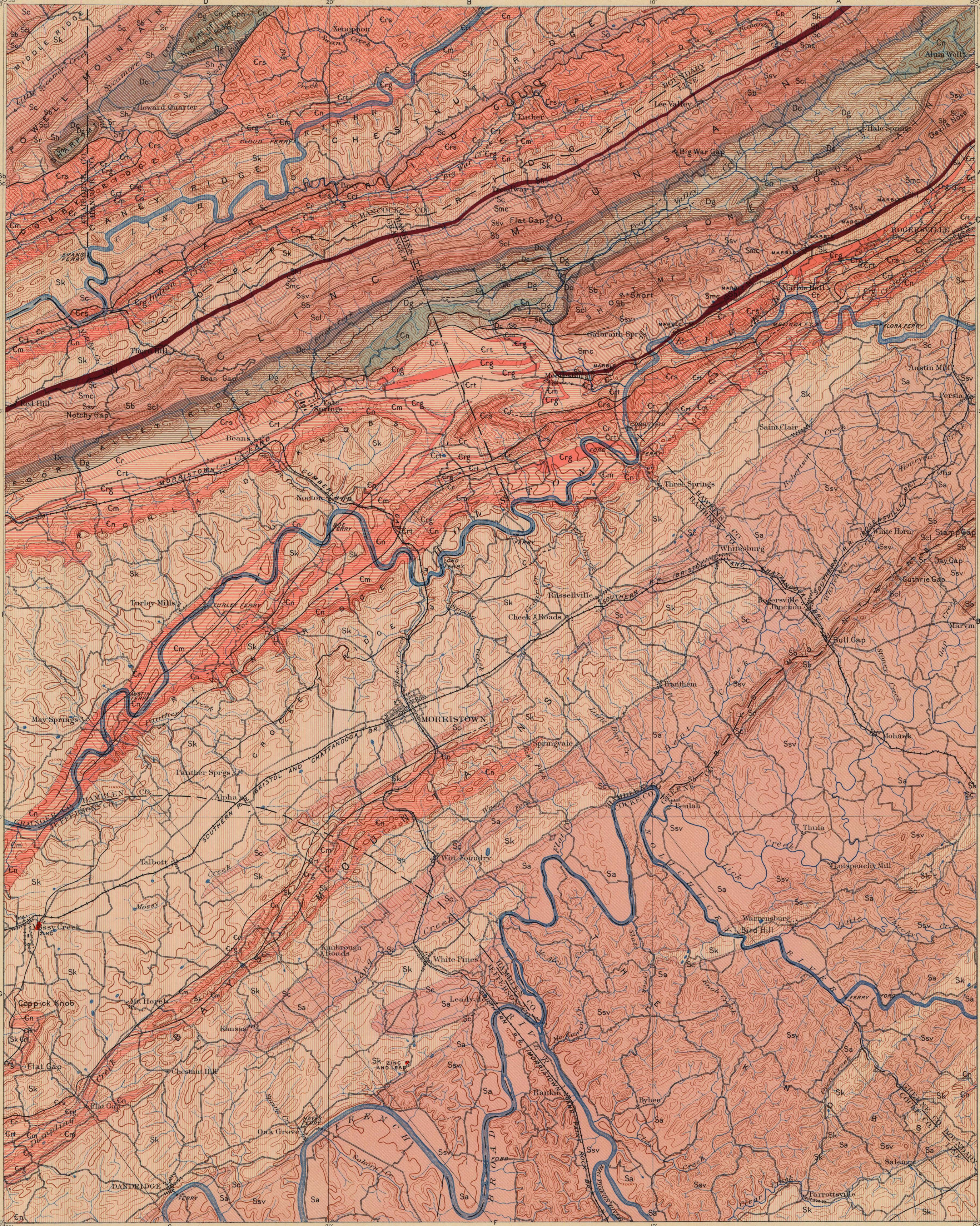
LEGEND
(continued)

⚒ Mines and quarries

Known productive formations

Variegated marble

Zinc and lead



LEGEND

SEDIMENTARY ROCKS

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

CARBONIFEROUS

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Sh — Hancock limestone *(massive and shaly blue limestone)*

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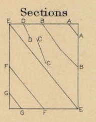
SPECIAL SYMBOLS

Faults

Sections



Legend is continued on the left margin

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by W.C. Kerr and S.S. Gannett.
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Scale $\frac{1}{125000}$

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Contour Interval 100 feet

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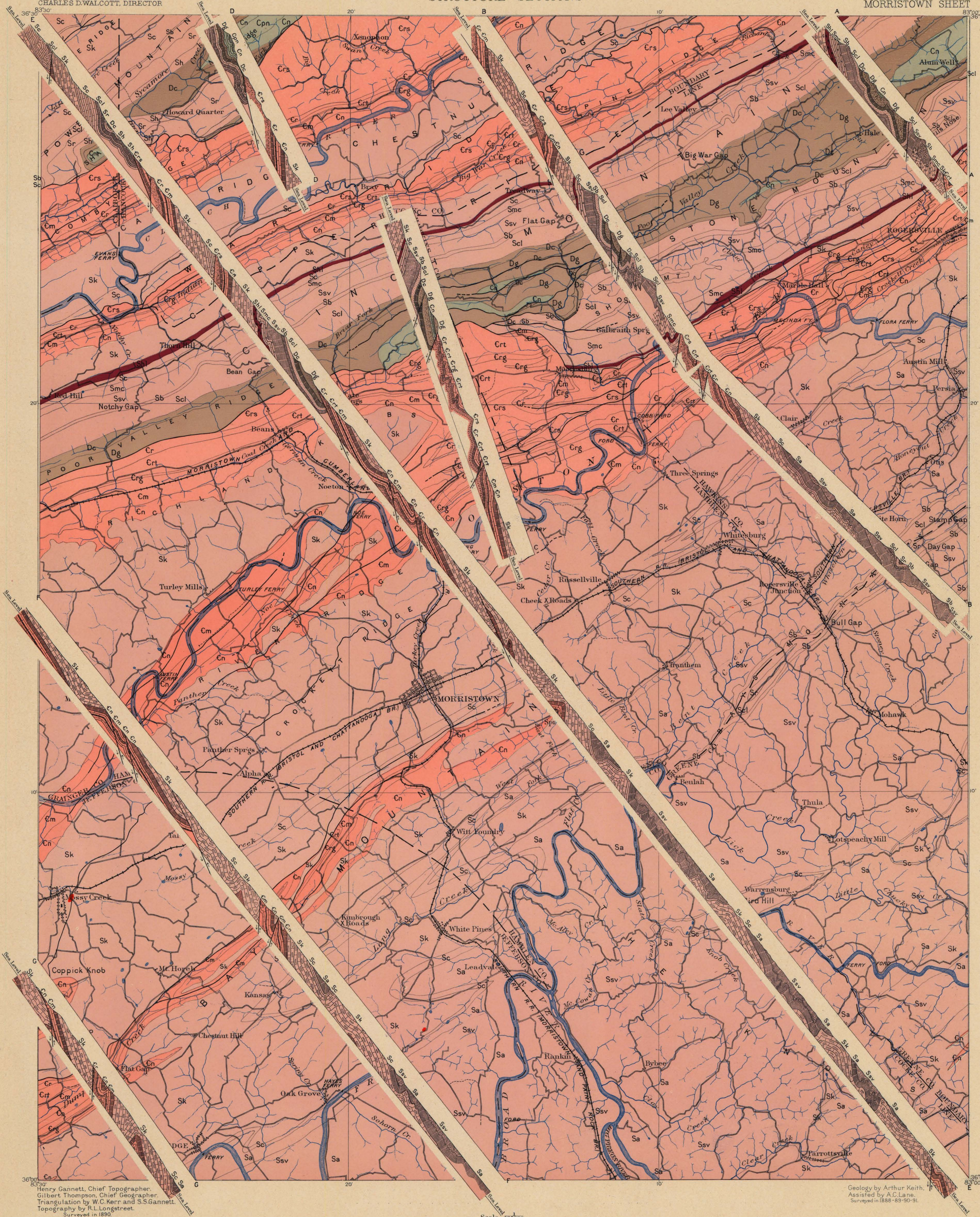
U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

STRUCTURE SECTIONS

TENNESSEE
MORRISTOWN SHEET



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LEGEND

SEDIMENTARY ROCKS

CARBONIFEROUS

- Cpn — Pennington shale (sandstones with sandy and calcareous shales)
- Cn — Newman limestone (bluish shaly and massive limestone)

DEVONIAN

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

SILURIAN

- Sh — Hancock limestone (massive and shaly blue limestone)
- Sr — Rockwood formation (variegated, sandy shales and thin sandstones)
- Scl — Clinch sandstone (massive, white sandstone)
- Sb — Bays sandstone (red calcareous and argillaceous sandstone)
- Ssv — Sevier shale (calcareous sandstone, sandy shale, calcareous shale, and limestone)
- Sa — Athens shale (light blue, calcareous shale, with black shale at the base)
- Smc — Moccasin limestone (red and green, argillaceous limestone)
- Sc — Chickamauga limestone (blue and gray limestone with marble layers)
- Shl — Holston marble
- Sk — Knox dolomite (magnesian limestone with chert nodules)

CAMBRIAN

- Ɛn — Nolichucky shale (variegated, calcareous shales and thin limestones)
- Ɛm — Maryville limestone (massive, blue limestone)
- Ɛrg — Rogersville shale (greenish clay-shale with limestone layers)
- Ɛrt — Rutledge limestone (massive, dark-blue limestone)
- Ɛr — Rome formation (red, green, and brown sandy shale)
- Ɛrs — Lentils in Rome formation (red, white, and brown sandstone)

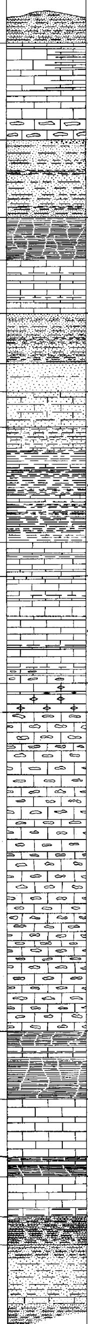
Faults

Known productive formations

- *Variegated marble*
- *Zinc and lead*

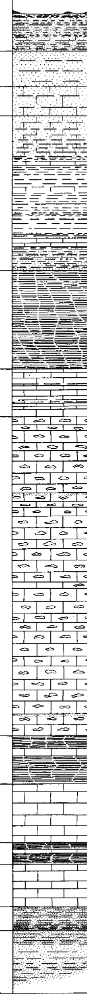
COLUMNAR SECTIONS

GENERALIZED SECTION NORTHWEST OF HOLSTON RIVER.



Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
CARBONIFEROUS	Pennington shale.	Cpn		250+	Gray and white sandstone and sandy shale.	High ground and ridges with rounded crests.
	Newman limestone.	Cn		700–1500	Bluish-gray and blue shale and shaly limestone. Massive, blue cherty limestone.	Large rounded knobs and ridges. Low, open valleys.
DEVONIAN	Grainger shale.	Dg		400–1200	Greenish- and bluish-gray sandy shale and sandstone.	High ridges and lines of knobs with many water gaps.
	Chattanooga shale.	Dc		400–450	Black, carbonaceous shale.	Deep, narrow valleys.
SILURIAN	Hancock limestone.	Sh		0–450	Massive, blue limestone and bluish-gray shaly limestone.	Low, rolling valleys.
	Rockwood formation.	Sr		400–500	Red, yellow, and brown, calcareous and sandy shales and thin sandstone.	Low knobs, and slopes of Clinch sandstone mountains.
	Clinch sandstone.	Scl		200–500	Massive, white sandstone.	Steep, sharp mountains.
	Bays sandstone.	Sb		200–500	Red, calcareous and argillaceous sandstone.	Steep slopes on Clinch sandstone mountains.
	Sevier shale.	Ssv		900–1500	Light-blue, sandy and calcareous shales with beds of shaly limestone.	Irregular ridges and steep, sharp knobs.
	Moccasin limestone.	Smc		300–500	Red and gray flaggy limestone and calcareous shale.	Low ground with irregular ridges and conical knobs.
	Chickamauga limestone.	Sc		900–2400	Blue and gray limestone, shaly limestone, and marble.	Open, rolling valleys.
	Holston marble.	Shl		0–300	Variegated marble, red, brown, gray, and white.	Valleys and slopes of Knox dolomite ridges.
SILURIAN / CAMBRIAN	Knox dolomite.	Sk		3000–3800	Magnesian limestone, light- and dark-blue, and white, with nodules of chert.	Broad ridges and irregular, rounded hills.
CAMBRIAN	Nolichucky shale.	€n		650–750	Yellow, red, and brown, calcareous shale with a few limestone beds.	Narrow valleys and steep slopes of Knox dolomite ridges.
	Maryville limestone.	€m		550–650	Massive, blue limestone.	Lines of knobs and open valleys.
	Rogersville shale.	€rg		70–250	Bright-green clay-shale with a limestone bed.	Lines of low knolls.
	Rutledge limestone.	€rt		200–500	Massive, blue limestone with a few shale beds at the base.	Open valleys.
	Rome formation.	€r		250–300	Red, green, yellow, and brown shale and sandy shale.	Slopes of Rome sandstone ridges.
	Rome sandstone-lentil.	€rs		600–1000+	Red, yellow, and brown sandstone and sandy shale with a bed of sandy limestone.	Sharp ridges with notches and water gaps.

GENERALIZED SECTION SOUTHEAST OF HOLSTON RIVER.



Period.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography.
SILURIAN	Rockwood formation.	Sr		400+	Red, yellow, and green, calcareous and sandy shales.	Low, rolling valleys.
	Clinch sandstone.	Scl		300–350	Massive, white sandstone.	Steep, sharp mountains.
	Bays sandstone.	Sb		200–500	Red, argillaceous and calcareous sandstone.	Steep slopes of Clinch sandstone mountains.
	Sevier shale.	Ssv		1300–1800	Brown and gray calcareous sandstone and shale. Light-blue calcareous and sandy shales with beds of gray limestone.	High knobs and steep slopes. Irregular, low knobs and rolling valleys.
	Athens shale.	Sa		1000–1100	Light-blue calcareous shale. Black, carbonaceous shale.	Belts of low knobs. Open valleys.
	Chickamauga limestone.	Sc		0–900	Massive, blue limestone, gray argillaceous limestone, and shale.	Open valleys.
SILURIAN / CAMBRIAN	Knox dolomite.	Sk		3000–3500	Magnesian limestone, light- and dark-blue, and white, with nodules of chert and a few thin, white sandstone beds.	Broad ridges and irregular, rounded hills.
CAMBRIAN	Nolichucky shale.	€n		400–600	Yellow, red, and brown calcareous shale with a few limestone beds.	Narrow valleys and steep slopes of Knox dolomite ridges.
	Maryville limestone.	€m		500–750	Massive, blue limestone.	Lines of knobs and open valleys.
	Rogersville shale.	€rg		200–230	Bright-green clay-shale with a limestone bed.	Lines of low knolls.
	Rutledge limestone.	€rt		350–500	Massive, blue limestone with a few shale beds at the base.	Open valleys.
	Rome formation.	€r		250	Red, green, yellow, and brown shale and sandy shale.	Slopes of Rome sandstone ridges.
	Rome sandstone-lentil.	€rs		500+	Red, yellow, and brown sandstone and sandy shale with a bed of sandy limestone.	Sharp ridges with notches and water-gaps.

NAMES OF FORMATIONS.

Period.	Names and Symbols used in this Folio.		Arthur Keith: Knoxville Folio, U. S. Geological Survey. 1895.	M. R. Campbell: Estillville Folio, U. S. Geological Survey. 1894.	Safford: Geology of Tennessee, 1869.
Carb.	Pennington shale.	Cpn		Pennington shale.	Mountain limestone.
	Newman limestone.	Cn	Newman limestone.	Newman limestone.	Siliceous group.
Dev.	Grainger shale.	Dg	Grainger shale.	Grainger shale.	Black shale.
	Chattanooga shale.	Dc	Chattanooga black shale.	Chattanooga black shale.	
Silurian	Hancock limestone.	Sh		Hancock limestone.	Meniscus limestone.
	Rockwood formation.	Sr		Rockwood formation.	Dyestone group.
	Clinch sandstone.	Scl		Clinch sandstone.	Clinch Mountain sandstone.
	Bays sandstone.	Sb	Bays sandstone.	Bays sandstone.	
	Sevier shale.	Ssv	Sevier shale.	Sevier shale.	Trenton and Nashville series.
	Athens shale.	Sa	Athens shale.		
	Moccasin limestone.	Smc		Moccasin limestone.	
	Chickamauga limestone.	Sc	Chickamauga limestone.	Chickamauga limestone.	Trenton, Lebanon, or Maclurea limestone.
	Holston marble.	Shl	Holston marble.		
	Knox dolomite.	Sk	Knox dolomite.	Knox dolomite.	Knox dolomite.
Cambrian	Nolichucky shale.	€n	Nolichucky shale.	Nolichucky shale.	Knox shale.
	Maryville limestone.	€m	Maryville limestone.	Maryville limestone.	
	Rogersville shale.	€rg	Rogersville shale.	Rogersville shale.	
	Rutledge limestone.	€rt	Rutledge limestone.	Rutledge limestone.	
	Rome formation.	€r	Rome formation.	Russell formation.	Knox sandstone.
	Rome sandstone-lentil.	€rs	Rome sandstone-lentil.		

ARTHUR KEITH,
Geologist.