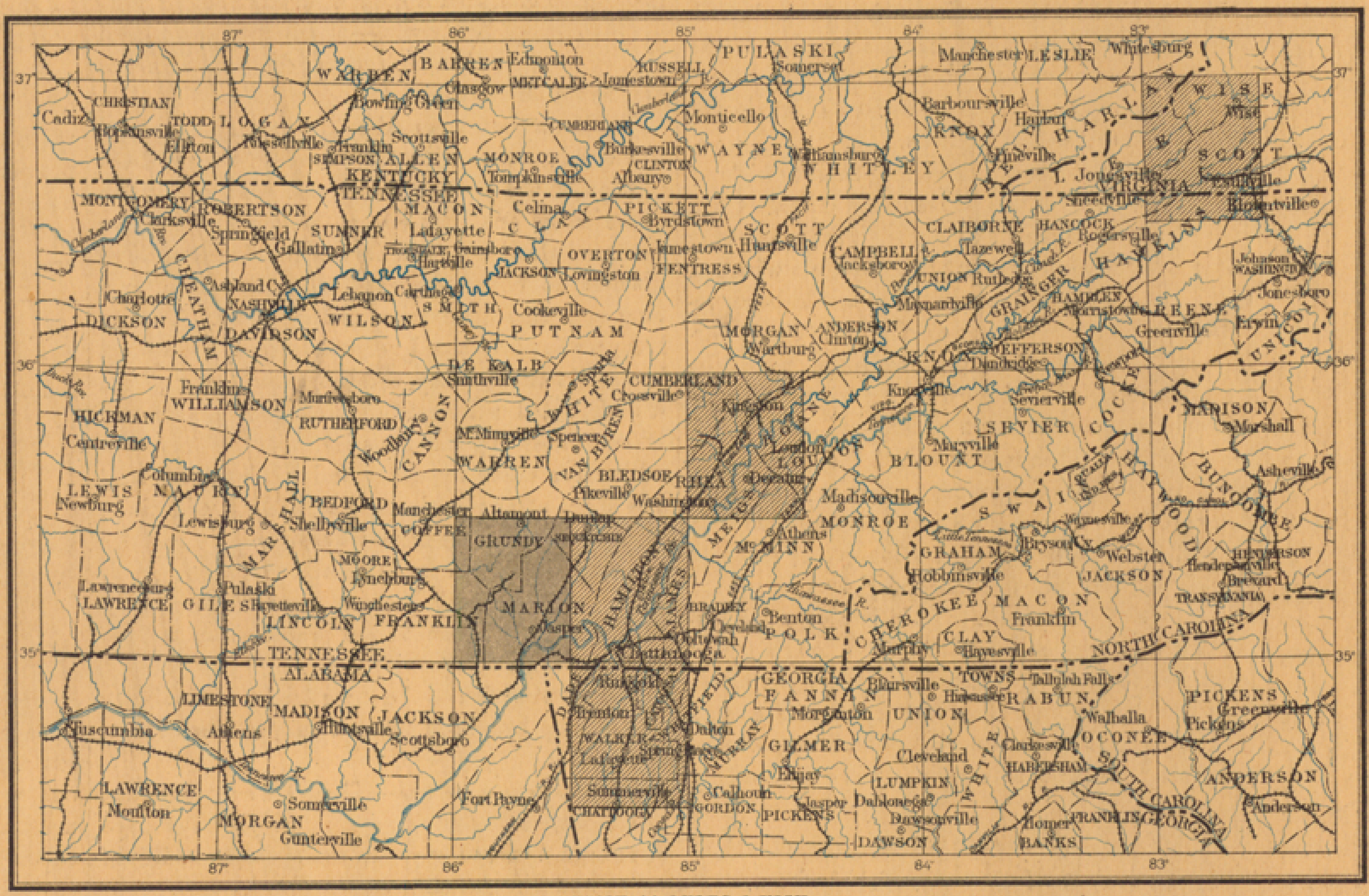
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
J.W. POWELL, DIRECTOR

8

GEOLOGIC ATLAS
OF THE
UNITED STATES

SEWANEE FOLIO
TENNESSEE

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE SEWANEE FOLIO

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FOLIO 8 | LIBRARY EDITION | SEWANEE

WASHINGTON, D. C.

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

1894

EXPLANATION.

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

THE TOPOGRAPHIC MAP.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAP.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they

DESCRIPTION OF THE SEWANEE SHEET.

GEOGRAPHY.

General relations.—The Sewanee atlas sheet is bounded by the parallels 35° and 35° 30′, and the meridians 85° 30′ and 86°. It embraces, therefore, a quarter of a square degree of the earth's surface. Its dimensions are 34.5 miles from north to south and 28.2 miles from east to west, and it contains 974.64 square miles. The adjacent atlas sheets are McMinnville on the north, Chattanooga on the east, and Stevenson on the south, while the country to the west has not yet been surveyed. The sheet lies wholly within the State of Tennessee, the southern limit being within about a mile of the Tennessee-Alabama line. It embraces portions of Grundy, Sequatchie, Marion, Franklin, and Coffee counties.

In its geographical and geological 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. The region thus defined has 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 are long narrow strips of country extending 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. It coincides with the belt of folded rocks, which in the southern part forms the Coosa valley of Georgia and Alabama and the great valley of East Tennessee. Throughout the central and southern portions the eastern side alone is marked by great valleys, such as the Shenandoah valley of Virginia, the Cumberland valley of Maryland and Pennsylvania, and the Lebanon valley of the northeastern part of the State; while the western side is ribbed by a succession of narrow ridges without continuous, intermediate 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. With the outcrop of different kinds of rock, the elevation of the surface differs, so that sharp ridges and narrow valleys of great length follow the upturned edges of hard and soft beds. 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 made up of many minor ranges 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 mountains of Maryland and Virginia, the Great Smoky mountains of Tennessee and North Carolina, and the Cohutta mountains of Georgia, together with many other less important ranges.

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 which have solidified from a molten condition, such as granite and diabase.

The western division of the Appalachian province embraces the Cumberland plateau and the Alleghany mountains, also extending from New York to Alabama, and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as 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 dissected, or elsewhere of a lowland. In the southern half of the province the surface of the plateau is sometimes extensive and perfectly flat, but oftener it is much cut by stream channels into large or small flat-topped hills. In West Virginia and portions of Pennsylvania the plateau is sharply cut by its 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 beyond the central valley 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 6,500 feet in western North Carolina. From this culminating point they decrease to from 3,000 to 4,000 feet in southern Virginia and 1,500 to 2,000 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 it descends to 2,200 feet in the valley of New river, 1,000 to 1,500 feet in the James, from 500 to 1,000 feet on the Potomac, and to about the same throughout 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 division increases in altitude from 500 feet at the southern edge of the province to 1,500 in northern Alabama, 2,000 in central Tennessee and 3,500 in southeastern Kentucky. It is between 3,000 and 4,000 feet in West Virginia and decreases to about 2,000 in Pennsylvania. From its greatest altitude along the eastern edge the plateau slopes gradually westward, although along its western edge 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.

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 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 breaks through the Appalachian mountains by 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. South of New river to northern Georgia the Great valley is drained by tributaries of the Tennessee river, which at Chattanooga turns from the apparently natural course and, entering a gorge through the plateau, runs westward to the Ohio. From Chattanooga southward the streams flow directly to the Gulf. There is abundant evidence that the divide between the Tennessee and Coosa basins is comparatively recent and that formerly the Tennessee river flowed directly south across the present divide and by the present course of the Coosa and Alabama rivers to the Gulf.

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

Topography of the Sewanee sheet.—The country embraced in the atlas sheet lies almost wholly within the western division of the Appalachian province. Crossing its southeastern corner is the Sequatchie valley, located upon the westernmost of the sharp folds which characterize the central or valley division of the province. The larger part of the sheet is occupied by the Cumberland plateau, which has a gradual ascent toward the north, rising from an altitude between 1,700 and 1,800 feet on the south to 1,900 or 2,000 on the north. The plateau is deeply cut by stream channels, especially in the southern portion of the sheet, so that the present table land has only a part of its former extent. The portion that remains, however, is still distinctly a plateau. The surface in general is quite smooth and so densely wooded that one may travel many miles with no intimation that it is not a low as well as level country. Occasional isolated hills or mesas stand from 100 to 400 feet above the plateau surface, appearing as elevations upon a plain. A few of the smallest of these higher elevations appear east of Sewanee; larger ones are found in the vicinity of Tracy; while the most prominent occur between the head of Little Sequatchie and the eastern edge of the sheet. The importance of these heights from an economic standpoint will be pointed out in describing the coal of the region.

The plateau is limited by a steep escarpment from 1,100 to 1,500 feet in height on the east and about 1,000 feet high on the west. The form of the escarpment is due to the relation of hard and soft rocks in the plateau. At its surface are hard sandstones which resist erosion, while below are shales and limestones which are readily worn down by the streams or removed by solution. The hard sandstone capping is constantly undermined and breaks off, forming cliffs. Thus the upper part of the escarpment is usually very steep and is frequently composed of vertical cliffs, while the lower portion has gentler slopes covered with fragments of sandstone from the cliffs above. This is the character not only of the escarpment which borders the outer portions of the plateau, but also of that surrounding the numerous coves which penetrate the plateau from either side.

In the extreme southeastern corner of the sheet a small portion of Walden ridge and Sand mountain appear. These are plateaus very similar to the Cumberland plateau farther west.

The Sequatchie valley, a small portion of which appears on this sheet, extends toward the northeast 50 miles and is continued as Browns valley about 70 miles southwest in Alabama. It is almost perfectly straight throughout the whole of this distance, and is bounded either by unbroken escarpments, such as that north of the Little Sequatchie river, or by salient mesas which terminate upon a common line. This linear character is the most striking feature of the valley and is due to the uniform size of the fold on which the valley is located. The rocks formerly arched continuously across from the Cumberland plateau to Walden ridge, forming a ridge where the valley now is. The upper rocks composing the arch have been entirely removed and the underlying easily erodible limestones, being brought higher in the arch than elsewhere, were earlier exposed to erosion. The valley, therefore, was excavated upon them. The rocks in the eastern escarpment dip a few degrees away from the valley, and in some places in the extreme edge of the Cumberland plateau they are found also dipping away from the valley, but more steeply than in Walden ridge. The altitude of the valley is between 600 and 700 feet, with rounded hills rising from 100 to 300 feet above the streams.

The northwestern portion of the sheet is occupied by the highland rim which surrounds the great lowland basin of central Tennessee. The rim here forms a broad terrace between the higher plateau on the east and the low plains on the west. Its altitude is between 1,000 and 1,100 feet, its surface is smooth and in the portion upon this sheet scarcely cut by stream channels.

Stream erosion on the plateau has given rise to many coves which penetrate far within its border. The Tennessee river is 360 feet lower than the streams in the northern part of the sheet upon the highland rim, so that those flowing southeastward from the plateau have more rapid fall than those flowing toward the northwest. Hence the channels have been cut back from the southeast much farther into the plateau and the most extensive coves are tributary to the Sequatchie valley. Battle creek cove is 15 miles in length and reaches nearly across the plateau to within less than three miles of its western side. Crow creek cove, of which only a portion is on this sheet, is 23 miles in length and is separated only by a low, narrow divide from Hawkins cove on the western side. The plateau is here almost entirely cut through, and this line has been utilized by the Nashville, Chattanooga and Saint Louis railroad, only a short tunnel through the upper portion of the divide being necessary. It will be noted that the coves which indent the western side of the plateau are rather broad, while those on the east are long and narrow. This results from the great fall of the streams toward the southeast, by reason of which they tend to deepen their channels rather than to broaden them.

The streams on the northern portion of the sheet are tributaries of Collins river, which flows northward into the Cumberland; those on the western portion are tributaries of Elk river, which flows southwestward to the Tennessee river; while those on the eastern portion empty immediately into the Tennessee.

The foregoing description and an examination of the topographic map show that in this region there are two plains nearly parallel and separated by a vertical distance of about 1,000 feet. The lower plain is apparent in the surface of the highland rim and also, though less clearly, in the hilltops in Sequatchie valley. The upper plain is the general surface of the plateau, below which the stream channels are deeply cut and above which rise a few hills and mesas.

Areas of these two plains have been recognized over nearly the entire Appalachian province, separated by a varying vertical distance, and their relations throw much light upon the history of the province during the later geologic ages. This region formerly stood much lower than now, so that the present plateau, the higher plain, was near sea level. The land was worn down by streams flowing upon its surface till it was reduced to a nearly even plain, with only here and there a low hill remaining where the rocks were unusually hard, or where they were protected from erosion by their position. Since the surface was not perfectly reduced this is called a *peneplain*, and since it was formed near the lowest possible level of erosion it is called a *baselevel peneplain*. After the surface of the land had become reduced nearly to sea level this region was elevated about 1,000 feet and at the same time tilted southward. The streams, which had become sluggish, were at once stimulated to renewed activity and began rapidly to sink their channels into the peneplain. Erosion progressed most rapidly upon soft rocks, so that on the western part of this area, where the sandstone capping was thin, and in the Sequatchie anticline, where limestone formed the surface, the streams quickly sunk their channels down nearly to the new baselevel of erosion and then by broadening their valleys began the formation of a new peneplain. The old peneplain was preserved at the higher level where the hard rocks capped the plateau. After the formation of the second peneplain was well advanced upon areas of soft rocks, the region was again lifted and the streams began cutting their present channels within the last formed peneplain.

GEOLOGY.

STRATIGRAPHY.

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

These rocks afford a record of almost uninterrupted sedimentation from early Cambrian to late Carboniferous time. Their composition and appearance indicate the nearness to shore and the depth of water in which they were deposited. Sandstones marked by ripples and cross bedded by currents, and shales cracked by the sun on mud flats indicate shallow water; while limestones, especially by the fossils they contain, indicate greater or less depth of water and absence of sediment. The character of the adjacent land is also 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. Then the sea received 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 Sewanee sheet was near its eastern margin and the materials of which its rocks are composed were therefore derived largely from the land to the eastward. The exact position of the eastern shore line of this ancient sea is not known, but it probably varied from time to time within rather wide limits.

Two great cycles of sedimentation are recorded in the rocks of this region. Beginning with the first definite record, coarse sandstones and shales were deposited in early Cambrian time along the eastern border of the interior sea as it encroached upon the land. As the land was worn down and still further depressed the sediment became finer, until in the Knox dolomite of the Cambro-Silurian period very little trace of shore material is seen. Following this long period of quiet was a slight elevation producing coarser rocks; this became more and more pronounced until between the lower and upper Silurian the land was much expanded and large areas of recently deposited (Clinch) sandstones were lifted above the sea and eroded. Following this elevation, which completed the first great cycle, came a second period, during which the land was low, probably worn down nearly to baselevel, affording conditions for the accumulation of the Devonian black shale and Carboniferous limestone, which in general show very little trace of shore waste. A second great uplift brought these rocks into shoal water and in some places above the sea, and upon them were deposited, in shallow water and swamps, the sandstones, shales, and coal beds of the Carboniferous. Finally, a further uplift at the close of the Carboniferous stopped the deposition of sediment in the Appalachian province except along its borders in recent times.

SILURIAN ROCKS.

The oldest rocks exposed within the limits of the Sewanee sheet belong to the Silurian or possibly upper Cambrian period. Probably the older Cambrian rocks, which are brought to the surface by the steep folds a few miles eastward, extend beneath the whole of this area and far beyond its western limit, but since they have never been brought to light by natural or artificial means nothing is definitely known as to their character.

Knox dolomite.—This formation consists of massively bedded and somewhat crystalline gray, magnesian limestone. Its base is not exposed upon this sheet, but the formation is probably over 3,000 feet thick. Its lower portion is probably of Cambrian age, but since it is almost entirely devoid of fossils and is homogeneous throughout, the line between the Cambrian and Silurian is very indefinite. This limestone, more properly called dolomite, contains a large amount of silica in the form of nodules or layers of chert or flint. That part of the rock which consists of the carbonates of lime and magnesia is dissolved upon weathering, leaving behind the chert, usually imbedded in red clay. This residual material covers the surface to great depths and the dolomite itself is seldom seen except in the channels of the larger streams.

The Knox dolomite comes to the surface only in a belt about two miles wide through the center of Sequatchie valley. Its outcrops, except near the rivers, are marked by the characteristic low, rounded, chert hills, which rise from 100 to 300 feet above the Tennessee river.

Chickamauga limestone.—The next higher formation, the Chickamauga limestone, occupies a narrow belt on each side of the Knox dolomite, the three belts together forming the greater part of the Sequatchie valley. The formation is mainly a blue, thin bedded, flaggy limestone with some earthy, mottled beds and some which are slightly shaly. It is from 1,100 to 1,300 feet in thickness. The limestone contains many fossils, the most abundant being brachiopods and corals.

The formation takes its name from the valley of Chickamauga creek, on the Chattanooga and Ringgold atlas sheets, where it is typically developed.

Rockwood formation.—The last described formation passes without abrupt transition into this higher division of the Silurian strata. The base of the Rockwood consists of calcareous shales together with thin beds of hard blue limestone. The upper portion is made up of green clay shales, quite calcareous where they are unweathered, with a few beds of limestone. The formation is from 200 to 350 feet thick and its outcrop forms a narrow band along the eastern side of Sequatchie valley. The corresponding outcrop, which would normally occur along the western side of the valley, is absent by reason of the fault on that side of the Sequatchie anticline. The formation is of great economic importance on account of the red fossil iron ore which it contains. This will be described under the head of Mineral Resources. The formation is named from Rockwood, Tennessee, on the Kingston sheet.

DEVONIAN ROCKS.

Chattanooga black shale.—Overlying the Rockwood formation is a thin stratum of shale which appears to represent the whole of the deposition which took place in this region during the Devonian period. Typical exposures of this shale appear in the north end of Cameron hill, within the city limits of Chattanooga, from which locality it takes its name.

The Chattanooga black shale has a remarkably uniform character wherever seen within the limits of the atlas sheet, and for a long distance on either side north and south. It varies in thickness from 12 to 25 feet. The upper portion of the shale, three or four feet thick, is usually dark gray in color and often carries a layer of round phosphatic concretions about an inch in diameter. The remainder of the formation is jet black, from an abundance of carbonaceous matter, and, when freshly broken, it emits a strong odor like that of petroleum.

This shale, on account of its distinctive and striking appearance, has attracted much attention from miners, and has been prospected in many places for coal and various ores, especially silver and copper. Such exploitation, however, has always been attended by failure. Although it contains a large proportion of carbonaceous matter, which burns when it is placed in a hot fire, the amount is not sufficient to constitute a fuel, and no true coal is ever found associated with the shale. Small concretions of iron pyrites, which it often carries, have given rise to the commonly accepted but wholly erroneous belief that the shale contains valuable ores. The formation is of economic importance as a starting point in prospecting for the red fossil iron ore, which occurs at a uniform depth, over considerable areas below it.

CARBONIFEROUS ROCKS.

Fort Payne chert.—This formation consists of from 50 to 200 feet of very siliceous limestone. At the base, resting on the Chattanooga black shale, are usually heavy beds of chert, with only a small amount of limestone or greenish calcareous shale. The lime increases toward the top of the formation and, gradually replacing the chert, it passes without abrupt transition into the Bangor limestone above. The chert of this formation is readily distinguished from that of the Knox dolomite by the great number of fossils which it contains. It is often made up of a mass of crinoid stems imbedded in a siliceous cement. On weathering, the cement remains as a porous chert filled with fossil impressions. In some cases the fossils alone are silicified, so that they remain in the soil after the solution of the calcareous cement. The formation occurs in a narrow strip on the eastern side of the Sequatchie valley, usually forming, with the Rockwood shale, a narrow ridge or line of knobs parallel to the mountain escarpment. It maintains a ridge on the western side of the valley south of Jasper, but north of this point it is cut out by the Sequatchie fault, as are the underlying Chattanooga black shale and the Rockwood formation.

The chert is also exposed on the western edge of the sheet in much broader areas. These beds are nearly horizontal, but rise gradually westward, appearing first in the stream channels and then forming a broad belt of country known as "the Barrens."

The name of the formation is taken from Fort Payne, Alabama.

Bangor limestone.—This consists of 800 or 900 feet of limestone, which everywhere forms the lower slopes of the escarpments, the floors of all the coves, and the inner portion of the highland rim. In general it is a massive, blue, crinoidal limestone, although it presents many local variations from this type. Nodules of chert are more or less abundant throughout the formation, though not evenly distributed. In the southeastern portion of the sheet black, nodular chert is generally abundant about 150 feet below the top of the formation, while along the western escarpment a bed of shaly limestone, 45 feet thick, in a corresponding position, contains large numbers of quartz geodes from one to ten inches in diameter. Beds of white, porous chert are somewhat abundant in the limestone at the base of the western escarpment, and the same chert occurs imbedded in patches of deep red soil at some distance from the escarpment. Some beds of very fine grained, oolitic limestone occur in the lower half of the formation, especially on the southern portion of the sheet. The upper beds of the Bangor generally weather to bright colored, red, green, and purple clay shales.

Lookout sandstone.—The calcareous shales at the top of the Bangor indicate a change in the conditions of sedimentation, shoaling water and an increase in quantity of sediment. During the deposition of the succeeding formation the sea bottom was lifted, so that the water became shallow over a wide area, while an abundant supply of mud and sand was washed in from the adjoining land. These conditions were unfavorable for the animals whose remains are so abundant in the preceding formation, and instead of limestone a great mass of shale and sandstone was deposited. The surface also stood above sea level at various times, long enough at least for the growth of the luxuriant vegetation which formed the coal beds.

The Lookout sandstone includes from 120 to 510 feet of conglomerate, sandstone, sandy shale and clay shale, and coal. Its upper limit is at the top of a heavy bed of conglomerate or coarse sandstone from 25 to 75 feet in thickness, which forms the upper cliff in the plateau escarpments. The hard, cross bedded sandstone, which lies below the conglomerate and is separated from it by from 5 to 50 feet of sandy shale, usually forms the most prominent cliff, especially in the southeastern portion of the sheet. The Lookout formation decreases in thickness toward the west. The conglomerate usually remains, while the underlying shales and sandstones become thinner or disappear.

Walden sandstone.—Above the Lookout conglomerate is another series—sandstone and sandy clay shale and coal—with a bed of conglomerate at the top. This series is included in the term Walden sandstone. The rocks were deposited under conditions very similar to those which prevailed during the deposition of the preceding formation, but the conditions changed less frequently and were somewhat more favorable for the accumulation of coal.

The thickness of the Walden is about 550 feet at the head of Mill creek, south of Tatesville, 475 at the old Victoria mines, and a little over 300 at Tracy city. It thus thins out westward even more rapidly than the Lookout sandstone. The Walden sandstone doubtless once extended over the entire area of the Sewanee sheet, but is at present confined to a few isolated areas which have escaped erosion, upon the summit of the plateau.

These two formations, the Lookout and Walden sandstones, constitute the productive coal measures of the region. The position and thickness of the various beds of coal will be described under the head of Mineral Resources.

At the close of the Carboniferous period this region was elevated permanently above sea level, so that the constructive process of deposition was stopped and the destructive process of erosion was begun.

STRUCTURE.

Definition of terms.—As the materials forming the rocks of this region were deposited upon the sea bottom, they must originally have been in nearly horizontal layers. At present, however, the beds are not usually horizontal, but are inclined at various angles. When any particular bed is followed for a considerable distance it is often found forming a series of arches and troughs. In describing these folded strata the term *syncline* is applied to the downward bending troughs and *anticline* to the upward bending arches.

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

Structure of the Appalachian province.—These three methods of change which the rocks of the province have suffered are grouped very distinctly along the three geographical divisions.

In the plateau region and westward the rocks are but little tilted from their original horizontal positions and are almost entirely unchanged; in the valley the rocks have been steeply tilted, bent into anticlines and synclines, broken by faults and to some extent altered into slates; in the mountain district faults and folds are prominent, but the rocks have been changed to a greater extent by the minute breaks of cleavage and by the growth of new minerals.

In the valley the folds, and the faults developed from them, are parallel among themselves and to the old land body, extending in a northeast-southwest direction for great distances. Some faults have been traced for 300 miles and some folds have even greater length. The crests of the anticlines are very uniform in height, so that for long distances they contain the same formations. They are also approximately equal to each other in height, so that many parallel folds bring to the surface the same formations. Most of the rocks dip at angles greater than 10°, and frequently the sides of the folds are compressed till they are parallel. The folding is greater in thin bedded rocks, such as shale and shaly limestone, because the thin layers were most readily bent and slipped along their bedding planes. Perhaps the most striking feature of the folds is the prevalence of southeastward dips. In some sections across the southern portion of the Appalachian valley scarcely a bed can be found which dips towards the northwest.

Out of the close folds, the faults were developed and with extremely few exceptions the fault planes dip toward the southeast. The planes on which the rocks broke and moved are parallel to the bedding planes, just as the rocks slipped on their beds in folding. Along these planes of fracture the rocks moved to distances sometimes as great as six and eight miles. There is a progressive increase in degree of deformation from northeast to southwest, resulting in different types in different places. In northern Pennsylvania folds are inconspicuous. Passing through Pennsylvania towards Virginia they rapidly become more numerous and dips grow steeper. In southern Virginia the folds are closely compressed and often closed, while occasional faults appear. Passing through Virginia and into Tennessee the folds are more and more broken by faults, until, half way through Tennessee, nearly every fold is broken and the strata form a series of narrow, overlapping blocks, all dipping eastward. This condition holds nearly the same southward into Alabama, but the faults become fewer in number and their horizontal displacement much greater, while the folds are somewhat more open.

In the Appalachian mountains the structure is the same as that which marks the great valley; there are the eastward dips, the close folds, the thrust faults, etc. But in addition to these changes of form, which took place mainly by motion on the bedding planes, there were developed a series of minute breaks across the strata, producing cleavage, or a tendency to split readily along these new planes. These planes dip to the east at from 20° to 90°, usually about 60°. This slaty cleavage was somewhat developed in the valley, but not to such an extent as in the mountains. As the breaks became more frequent and greater they were accompanied by growth of new minerals out of the fragments of the old. These consisted chiefly of mica and quartz and were crystallized parallel to the cleavage cracks. The final stage of the process resulted in the squeezing and stretching of hard minerals like quartz, and complete recrystallization of the softer rock particles. All rocks, both those of sedimentary origin and those which were originally crystalline, were subjected to this process, and the final products from the metamorphism of very different rocks are often indistinguishable from each other. Rocks containing the most feldspar were most thoroughly altered, and those with most quartz were least changed. Throughout the entire Appalachian province there is a regular increase of metamorphism towards 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 manifestly due chiefly to horizontal compression which acted in a northwest-southeast direction at right angles to the trend of the folds and cleavage planes. The compression apparently began in early Paleozoic time and probably continued at intervals up to its culmination shortly after the close of the Carboniferous, when the greater portion of the folding was effected.

In addition to the horizontal force of compression the province has been subjected to other forces which have repeatedly elevated and depressed its surface. At least two periods of high land near the sea and two longer periods of low land are indicated by the character of the Paleozoic sediments. And in post-Paleozoic time there have been at least three and probably more periods of decided oscillation of the land due to the action of some vertical force. In every case the movements have resulted in warping the surface, and the greatest uplift has occurred nearly along the line of the great valley.

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

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

Structure of the Sewanee sheet.—The area embraced within this sheet shows but little diversity in its geologic structure. There are no crystalline rocks and no traces of metamorphism. Over the greater portion of the area the strata are nearly horizontal, dipping but a few feet to the mile, so that their inclination can be detected only by determining the altitude of some particular bed at several widely separated points. The southeastern corner of the sheet belongs to the central division of the Appalachian province, which is characterized by steep narrow folds.

The Sequatchie anticline is typical of the Appalachian folds. In length it is somewhat greater than the Sequatchie valley, for at its ends the upper rocks have not been removed by erosion but remain as a high arch. This arch forms the Crab Orchard mountains on the Kingston sheet. On the southeastern side of the anticline the rocks dip at low angles, from 8° to 12°, while on the northwestern side they are much more steeply inclined, being in some places vertical or overturned. Upon the northwestern side of the anticline the strata are broken by a fault and older rocks are thrust across the broken edges of the younger. Thus north of Jasper the Bangor limestone west of the fault comes in contact with the Chickamauga limestone, the three intermediate formations which normally occur being entirely concealed. South of Jasper the displacement of the strata on the fault plane is not so great and only the Chattanooga and Rockwood shales are concealed. The presence of this fault thus explains the absence on the western side of the valley of the iron ore bearing Rockwood formation.

West of the Sequatchie valley the rocks are not folded but have a gentle eastward dip. As shown in section CC, the top of the Bangor limestone has a gradual rise from an altitude of 1,070 feet near the valley to 1,600 feet at Sewanee and 1,830 feet at the western edge of the plateau, which is an average of about 35 feet per mile. The top of the Lookout sandstone rises in the same distance only about 500 feet, or about 25 feet per mile, since that formation is 250 feet thinner at the western escarpment than at Sequatchie valley. While no considerable folds have been formed in these rocks they bear evidence of having been subjected to great horizontal pressure. In many places thin beds, especially of coal and argillaceous shale or fire clay, have been intensely plicated and folded between the layers of massive, rigid sandstone, which show no change from their original position. This folding of the easily yielding strata is much more common in the Lookout strata than in the Walden and sometimes offers serious obstacles to mining the lower coals.

MINERAL RESOURCES.

The mineral resources of the Sewanee sheet consist of *coal*, *iron ore*, *limestone*, *building* and *road stone* and *brick clay*.

Coal.—The productive coal-bearing formations, consisting of the Lookout and Walden sandstones, occupy the surface of the Cumberland plateau and Sand mountain. Within the atlas sheet they have an area of about 500 square miles. Not all of this area, however, contains workable coal.

The accompanying vertical sections show the position and thickness of the various coal beds. These sections are not generalized, but each represents the actual measurements made at a single locality. It will be seen that the beds vary considerably in number, position, and thickness from one part of the field to another. The datum plane from which their position is measured up or down in the section is the top of the Lookout conglomerate. It is not always possible to determine this point exactly, so that some uncertainty is thus introduced into the correlation of coal beds in the different parts of the field.

The coal beneath the Lookout conglomerate has been worked at various places upon the sheet, especially in the vicinity of South Pittsburg and Sewanee, and it is shown in many places by natural and artificial exposures. While the coal is generally of excellent quality, the beds are extremely variable in thickness, and calculations based upon them are therefore uncertain.

A seam has been opened at the head of Hubbard cove, on the western side of the plateau, something less than 100 feet below the top of the conglomerate. It lies almost immediately beneath a heavy ledge of sandstone which forms the cliff at the top of the escarpment. The coal is from 16 to 24 inches thick. Below is a bed of fire clay which passes downward into 40 feet of bluish gray, micaceous shales resting upon the Bangor limestone.

At the University mines, a mile north of Sewanee, two seams appear. The upper one is very thin but is of interest, as it occupies a position analogous to that seen in Hubbard cove immediately beneath the heavy cliff sandstone. The seam worked is about 40 feet below, with bluish, sandy shales intervening. It averages 30 inches in thickness. About a mile and a half northeast of Sewanee, at the Shake Rag mines, the section is nearly the same, but is better exposed and shows three seams, of which the upper and lower are thin. At the head of Lost creek cove, just east of Sewanee, a continuous section is exposed from the Bangor limestone to the top of the conglomerate, and no trace of coal is seen. Hence it appears that over some areas, which are probably small, the Lookout sandstone is barren of coal.

At Tracy City a drilling showed three horizons corresponding to the three seams at the Shake Rag mines, each being marked by one or more thin seams of coal. But none of them were of workable thickness.

On the east side of Crow creek, at the southern edge of the sheet, two seams have been opened and worked to some extent. The upper bed is from 24 to 42 inches thick and probably corresponds to the upper horizon marked by thin seams in the Tracy and Sewanee sections. The lower seam is from 7 to 18 inches in thickness; it increases eastward with the increasing thickness of the formation and is worked at a number of mines on both sides of Haley cove, near South Pittsburg. It varies from 12 to 24 inches, sometimes reaching a thickness of 3 feet. Above it is a ledge of sandstone about 50 feet thick, which forms the main cliff. The coal has been removed from the greater portion of Point Chester and at present the pillars are being drawn. This seam contains a clean block coal and has a high reputation, especially as a domestic fuel. It is known as the Battle creek coal. Fifty feet below is another bed, generally about 7 inches thick, but varying from 1 inch to 6 or 7 feet within a few rods. It is too uncertain for profitable working.

At the Needmore mine, on the south side of Sweden cove, the Battle creek seam is 3.5 feet thick, with a thin shale parting. The lower bed also shows here from 8 to 13 inches thick. At King point, north of Battle creek, three beds are shown, of which two may be workable. The upper is about 24 inches thick and apparently corresponds to the upper bed in the Crow creek section and to the upper horizon shown in the Sewanee and Tracy sections. The lower bed is from 6 to 24 inches thick; it may correspond to the Battle creek seam, or, more probably, to the one below it.

Several seams appear north of the Little Sequatchie river, as shown on the Victoria and Whitwell sections, but they are generally too thin to be worked. A seam has been opened about a mile north of Sequatchie, probably the lowest of the three shown on the Victoria section, which is 14 inches thick at the outcrop and is said to increase 30 yards from the surface to 6 feet. This is probably a local swell.

The Walden sandstone in this region contains from two to four seams of coal, only one of which is of workable thickness. This is the second above the Lookout conglomerate, the well known Sewanee seam. It has been worked near Sewanee, at Tracy city, and at the Victoria and Whitwell mines near the Sequatchie valley, and has been opened at various points about the head of Collins river and on Griffith creek. The areas within which the Sewanee coal may be expected to occur are shown approximately on the Economic sheet. There may be a few other small patches of productive territory on the sheet, but if so they are very inconsiderable in extent. The westernmost of these areas are the three in the vicinity of Sewanee. Mines have been worked here for many years and most of the coal has been removed. The good coal is covered by from 40 to 70 feet of sandy shale and soil. Where the covering is of less thickness the coal is apt to be deeply weathered. The thickness of the seam is from 2 to 3.5 feet and was 5 feet in some of the portions which have been removed. It is 38 or 40 feet above the top of the Lookout conglomerate. A thin seam is reported to occur below it, but this was not seen by the writer.

At Tracy city two seams are exposed, the first 25 and the second 70 feet above the top of the conglomerate. The lower bed is called the "Little Sewanee" or "Coke oven" seam. Its thickness is about 12 inches and it is overlain by a ten-foot ledge of coarse sandstone. The upper seam or "Main Sewanee" is from 3 to 6 feet thick, averaging about 3.5. In a few places it has been found decreasing to two inches, but in general it is very uniform. It is overlain by hard, blue, sandy shale, in which are many plant impressions. The impressions of large tree trunks are to be seen in the roof of the mines. Many of these are from 18 to 24 inches in diameter. Blue shale of similar character to the roof shale, but containing more clay, occurs beneath the seam. This coal has been mined two miles west of Tracy by the Nashville, Chattanooga, and St. Louis Railway company, but chiefly at two groups of mines north and northeast of the town by the East Tennessee Coal, Iron and Railroad Company. These two groups of mines cover an area of nearly two square miles, from which most of the coal has been removed. The structure of the coal is not "block" but "gnarley," and it readily crumbles in handling. The coarse portions are shipped for steam fuel, while the screenings, in some cases after passing through a washer, are coked for use in the company's furnace at South Pittsburg.

The largest area of the Sewanee coal within the sheet is on its eastern edge north of the Little Sequatchie. It was mined for a number of years at the extreme southern point of the productive area, at the Victoria mines. These have been abandoned for the Whitwell mines, two miles further northeast, where the coal is of better quality and more accessible. Openings have been made at several points on the south side of Griffith creek, showing a seam of good coal from 3 to 4.5 feet thick. It is here 90 feet above the conglomerate, or about 40 feet higher in the section than at Whitwell. At the head of Mill creek, two miles and a half south of Tatesville, several openings show a seam from 3.5 to 5 feet thick only 30 feet above the conglomerate. East of Tatesville the coal shows in the road, 64 feet above the conglomerate. It is impossible to say definitely whether or not it is the same seam showing at these different localities at such a variable distance above the conglomerate, but it is safe to say that the area indicated on the map contains at least one coal seam from 3 to 5 feet thick, which if it is not the Sewanee is equally good.

Iron ore.—Two varieties of iron ore occur on the Sewanee sheet. They are *hematite* or *red fossil ore* and *carbonate* or *spathic ore*.

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

The proportion of iron in the ore usually decreases with distance from the surface; at considerable depths it becomes simply a more or less ferruginous limestone. The decrease downward in the proportion of iron is due to the fact that near the surface the lime has been largely removed by percolating surface waters, leaving behind the insoluble iron oxide as the soft ore. The presence of lime in the ore is not objectionable, except as it renders mining more difficult, for it removes the necessity of adding limestone as a flux in the furnace.

The outcrop of the Rockwood formation occupies a narrow strip along the eastern side of the Sequatchie valley, the strata dipping at low angles, from 8° to 15°, toward the east, beneath Walden ridge. The corresponding outcrop of the formation on the western side of Sequatchie valley is concealed by a fault, as already explained, and as shown in the structure sections.

The ore is extensively worked at Inman, where the bed is 5.5 feet thick. It is separated from the overlying Chattanooga black shale by 60 feet of bluish, calcareous shale. A bed of blue limestone 3.5 feet thick occurs immediately above the ore. At the outcrop the soft ore is mined by stripping, from 20 to 30 feet of overlying rock being removed. In some places the amount of lime increases gradually from the outcrops downward, while in others a sharp line separates the soft from the hard ore. The workings have reached over 500 feet from the surface with no important change in thickness or quality of the ore. Taking the average of many analyses the hard ore contains 24.5 per cent. of metallic iron and about 30.7 per cent. of lime. The Inman ore is used at the South Pittsburg furnace, generally being mixed with limonite from Alabama.

Carbonate.—The spathic or black band iron ore has not yet been utilized in this region, though considerable quantities probably exist. It is not generally so uniform in quantity or quality as the hematite, although, like that ore, it occurs in a regularly stratified deposit. It is found almost exactly at the contact of the Bangor limestone and Lookout sandstone. The bed has been observed at various points on Crow creek, in Lost creek cove, in the boring at Tracy, at Beersheba springs, and at the head of Hubbard cove. At the last named locality it has been opened and is about 3.5 feet thick. The change which the ore undergoes from carbonate to limonite may there be observed in all its phases. At the outcrop it consists almost wholly of limonite shells. A short distance from the surface it is composed of nodules coated with limonite, but containing a core of unchanged carbonate within. Still further from the surface the bed is unchanged carbonate. The latter is light yellow and resembles in appearance a fine grained, earthy limestone. The limonite shells are partially filled with clay, which is the earthy matter originally disseminated through the carbonate, together with some unchanged carbonate.

An analysis of different portions of the ore shows the following composition: (1) is the unchanged carbonate, (2) is the completely oxidized limonite shell, and (3) is the residual material partially filling the latter.

	(1)	(2)	(3)
Fe	35.19	47.21	24.28
SiO_2	5.53	8.00	24.37
CO_2	34.29	——	20.27
P_2O_5	.14	.20	.07

It is thus seen to compare favorably with other spathic ores, being comparatively low in silica and phosphorus.

Although this ore may not at present compete successfully with the more abundant and easily accessible hematite, it will probably be utilized in the near future.

Limestone.—The supply of limestone on the Sewanee sheet suitable for blast furnace flux and for lime is abundant and convenient of access. At the South Pittsburg furnace Bangor limestone is used from a quarry on the mountain side above the furnace. It contains from 3 to 9 per cent. of magnesia.

The Bangor limestone is also extensively burned for lime at Sherwood.

Building stone.—Stone adapted to architectural uses occurs in nearly every formation on the sheet. That which has been most largely used is in the upper part of the Lookout sandstone. Quarries in the vicinity of Sewanee furnished the beautiful buff and pink sandstone of which some of the imposing university buildings were constructed. Considerable stone has also been shipped from the same quarries. Some beds of light gray oolitic limestone in the Bangor seem admirably adapted for building purposes, closely resembling the well known Indiana oolitic or Bedford stone. Limestone of this character forms a high bluff along the Nashville, Chattanooga and St. Louis Railway east of Shellmound and also occurs along the same road in Crow creek valley.

Road material.—The hard blue Bangor and Chickamauga limestones furnish an abundant supply of macadam material, requiring but little transportation. The residual chert or flint of the Fort Payne and Knox dolomite formations is an ideal road material and might be used to excellent advantage for surfacing in macadam roads.

Clays.—The residual deposits resulting from the solution of the Chickamauga limestone are red or blue clays, and are generally well adapted for making brick. Some portions of the Bangor limestone leave a residual clay suitable for brickmaking and also for drain tile. Several beds of fire clay which are associated with the coal probably contain material well adapted for making fire brick, but they are as yet wholly undeveloped.

SOILS.

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

When derived in this way from the disintegration of the underlying rock, soils are called sedentary. If the rock is a sandstone or sandy shale the soil is sandy, and if it is a clay shale or limestone the soil is clay. As there are abrupt changes in the character of the rocks, sandstones and shales alternating with limestones, so there are abrupt transitions in the character of the soil, and soils differing widely in composition and agricultural qualities often occur side by side.

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

Classification.—The soils of this region may conveniently be classed as (1) sandy soils, derived from the Walden and Lookout sandstones; (2) clay soils, derived from the Bangor and Chickamauga limestones and Rockwood shale; (3) cherty soils, derived from the Fort Payne chert and Knox dolomite; (4) alluvial soils, deposited by the larger streams upon their flood plains.

Sandy soils.—The Cumberland plateau is formed of sandstones and sandy shales, and its soil is a sandy loam. At the surface it is gray, while the subsoil is generally light yellow, but varies to deep red. In some places it consists largely of sand, but in others it contains sufficient clay to give the subsoil considerable coherence, so that a cut bank will remain vertical for some years. The depth of soil on the plateau varies from a few inches to ten feet or more, diminishing in proximity to streams, where erosion is most active. A large part of the plateau retains its original forest growth, chiefly of oak, chestnut and hickory, while pines clothe the steep sides of the stream channels. The practice of burning off the leaves each fall prevents the accumulation of vegetable mold and has delayed a just appreciation of the agricultural possibilities of this region. It has been found well adapted for fruit-raising, particularly for grapes, and the Swiss colonists at Gruetli make considerable quantities of wine.

The soil of the "Barrens," on the extreme northwestern portion of the sheet, is a light gray, sandy silt. It resembles the soil of the plateau, but is even less productive. It is not wholly a residual soil derived from the underlying rocks, but was deposited either in standing water or on a low land surface near the mouths of streams, when this region stood nearly at sea level.

Since the sandstones of this region occupy the highest land, the overplaced soils, or those washed down to lower levels, are mostly sandy. They are especially abundant at the foot of the escarpment surrounding the plateaus, where the Bangor limestone and its clay soil are often wholly concealed. The delta deposits formed by streams emerging from gorges cut in the plateaus also give considerable area of sandy soil, overlying rocks which would themselves produce clay or cherty soils.

Clay soils.—These are derived chiefly from the Bangor and Chickamauga limestones, and their distribution coincides with the outcrops of these formations, as shown on the geologic map. They sometimes have a deep red color, but where the mantle of residual material covering the rock is thin it is often dark bluish gray. The rocks generally weather more rapidly where they have a steep dip than where they are nearly horizontal. Hence the soil is deeper and more highly colored on the narrow belt of Chickamauga limestone on the western side of Sequatchie valley than in the broader belt of the same rocks on the eastern side.

The soil in the many coves which penetrate the Cumberland plateau is derived chiefly from the Bangor limestone. It is a bluish clay with a slight admixture of sand from the rocks capping the plateau, and is exceptionally fertile. It is especially adapted to clover and grain. Considerable areas of red clay land occur on the highland rim between the foot of the plateau and the inner edge of the Barrens.

Cherty soils.—More than a third of the area of Sequatchie valley is underlain by the Knox dolomite. The soil derived from this formation consists of clay, in which chert is imbedded. The proportion of chert to clay is variable; in some places only occasional fragments occur, while in others the residual material is made up almost wholly of chert. Where the clay predominates the soil is deep red, but becomes lighter with the increase in amount of chert, and in extreme cases is light gray or white. Even when the proportion of chert is very large this is a strong, productive soil, especially adapted to fruit raising. The soil derived from the Fort Payne chert is similar to that from the Knox dolomite, but the areas of the Fort Payne are much smaller and usually on steep slopes, so that its soil is relatively unimportant.

Alluvial soils.—The Sequatchie, Elk, and Tennessee rivers are bordered by moderately broad flood plains or bottoms covered with alluvial soil. A strip of such soil from a quarter to a half a mile wide usually occurs along one side of these streams, with a bluff upon the opposite side. The soil of these bottoms is a rich sandy loam, in the case of the Tennessee containing a considerable proportion of fine mica scales derived from the crystalline rocks far to the eastward. These alluvial soils constitute the most continuously productive land of this region.

CHARLES WILLARD HAYES,
Geologist.

June, 1894.

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

TOPOGRAPHY

TENNESSEE
SEWANEE SHEET

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Control Line and Topography by L. Nell and M. Hackett.
Surveyed in 1886 and 1890-93-94.

ENGRAVED BY EVANS & BARTLE, WASH. D.C.

Scale 1:125000

Contour Interval 100 feet

Edition of July 1894.

U.S.GEOLOGICAL SURVEY
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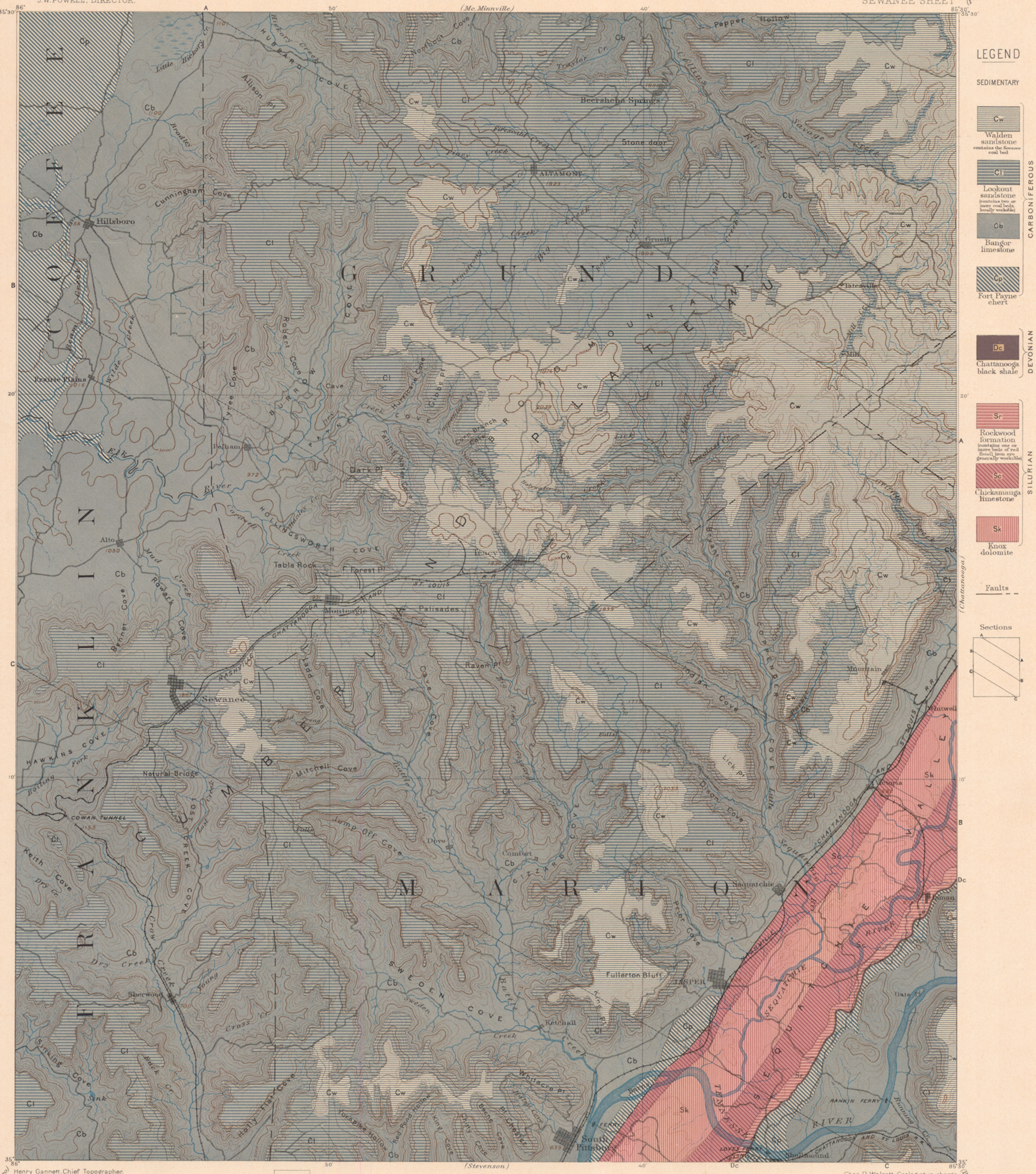
AREAL GEOLOGY

TENNESSEE
SEWANEE SHEET



Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Control Line and Topography by L.Nell and M.Hackett.
Surveyed in 1886 and 1890-93-94.

Nell
Hackett

Scale $\frac{1}{125000}$

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet

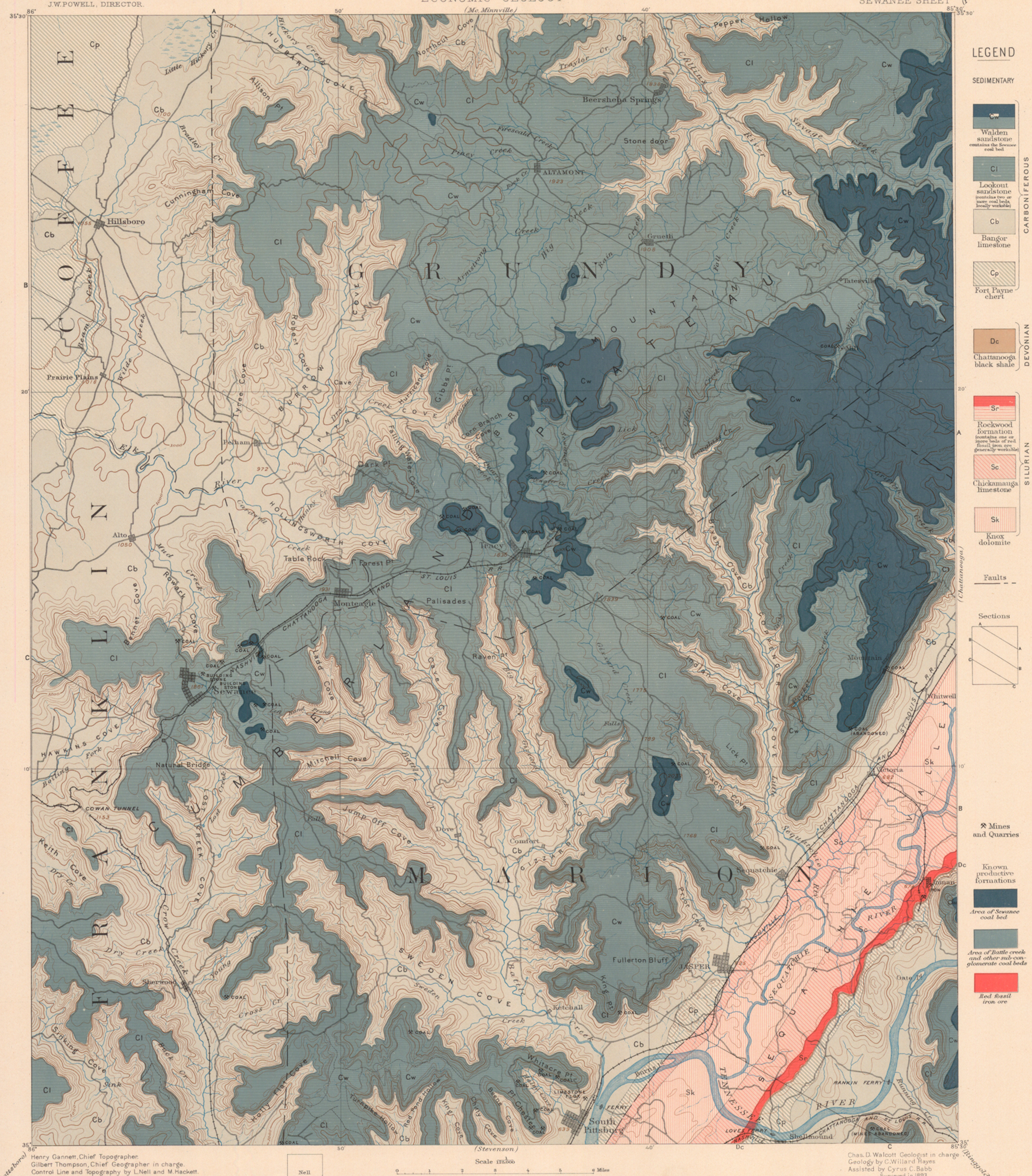
Edition of July 1894.

Chas. D. Walcott Geologist in charge
Geology by C.Willard Hayes
Assisted by Cyrus C.Babb
Surveyed in 1893.

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

ECONOMIC GEOLOGY

TENNESSEE
SEWANEE SHEET



Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer in charge.
Control Line and Topography by L. Nell and M. Hackett.
Surveyed in 1886 and 1890-93-94.

Scale $\frac{1}{125000}$
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Edition of July 1894.

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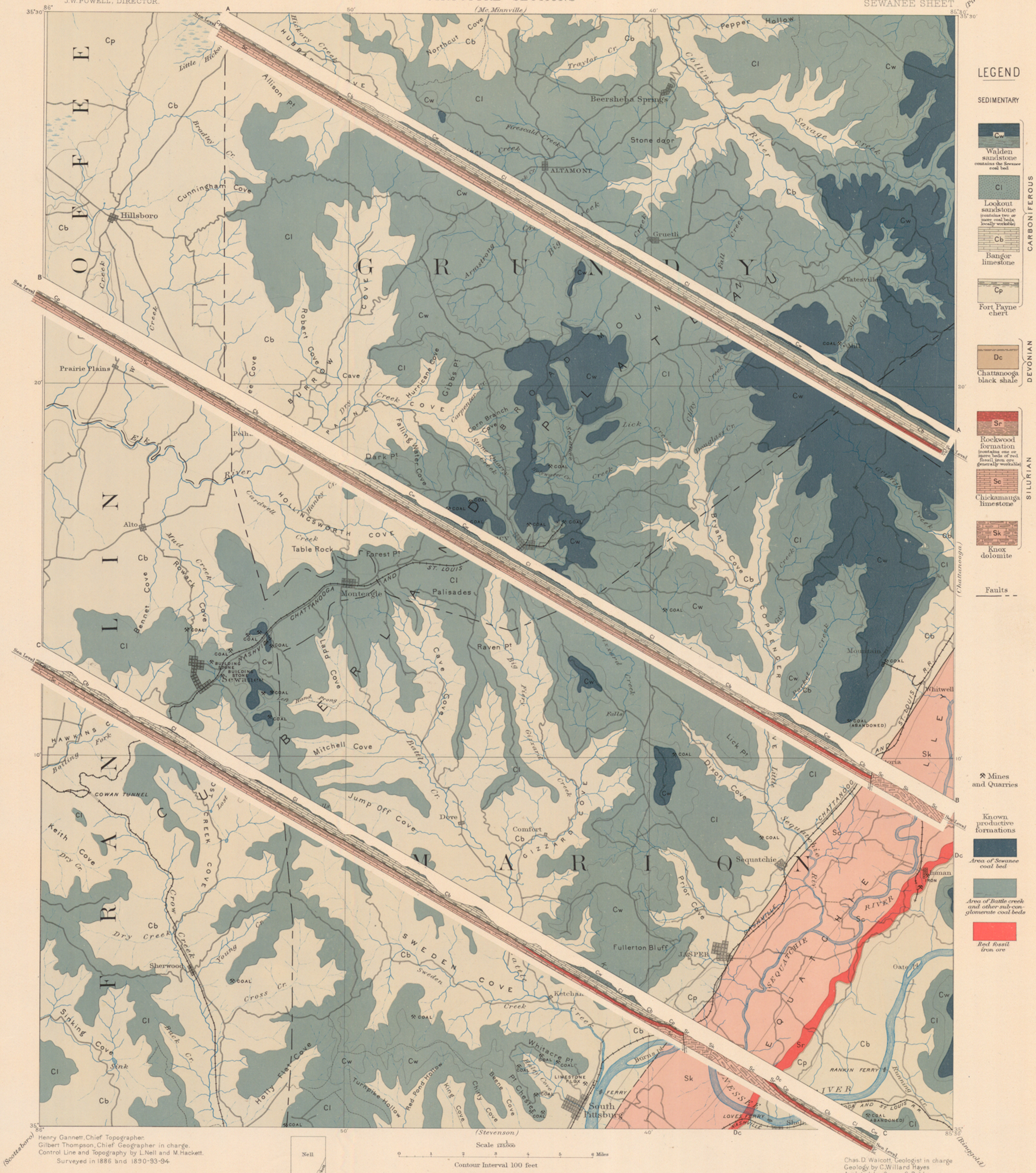
Surveyed in 1893.

STRUCTURE SECTIONS



Henry Gannett, Chief Topographer.
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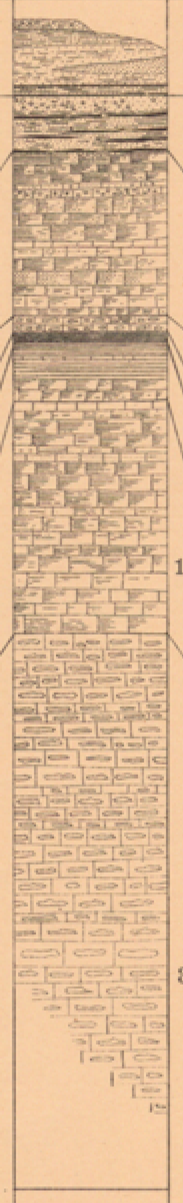
COLUMNAR SECTIONS

GENERALIZED SECTION FOR THE SEWANEE SHEET.

SCALE 1000 FEET = 1 INCH.

Period.	Formation Name.	Formation Symbols.	Columnar Section	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARBONIFEROUS	Walden sandstone.	Cw		300–500	Conglomerate. Coarse sandstone and sandy shale with beds of coal and fire clay.	Plateau and mesas, bounded by cliffs and steep talus slopes. Gray, yellow, or red, sandy loam.
	Lookout sandstone.	Cl		120–510	Conglomerate. Sandstone and shale with beds of coal, fire clay, and iron ore.	
	Bangor limestone.	Cb		800–900	Shaly limestone, containing nodules of chert geodes. Massive, blue, crinoidal limestone, some beds oolitic. Arenaceous limestone.	Steep plateau slopes and coves. Level plain west of Cumberland plateau. Black or red clay soil.
	Fort Payne chert.	Cp		60–80	Cherty limestone and heavy beds of chert.	Steep ridges in Sequatchie valley. "Barrens" west of Cumberland plateau, sandy and cherty soil.
DEV.	Chattanooga black shale.	Dc		12–25	Carbonaceous shale.	
SILURIAN	Rockwood formation.	Sr		200–350	Greenish clay shale with beds of fossil iron ore. Calcareous shale.	
	Chickamauga limestone.	Sc		1100–1300	Blue, flaggy limestone with some mottled, earthy and shaly beds	Level valleys; shallow residual deposits of red or blue clay. Scanty blue clay soil where the limestone is nearly horizontal, and deeper red clay where the beds are steeply inclined.
CAMBRIAN	Knox dolomite.	Sk		3000 +	Magnesian limestone; white, gray, or light blue; generally granular and massively bedded; containing nodules and layers of chert.	Low ridges and irregular rounded hills; deep residual deposits of red clay and chert. Red clay soil with a few fragments of chert, grading into white or gray soil, composed almost entirely of chert

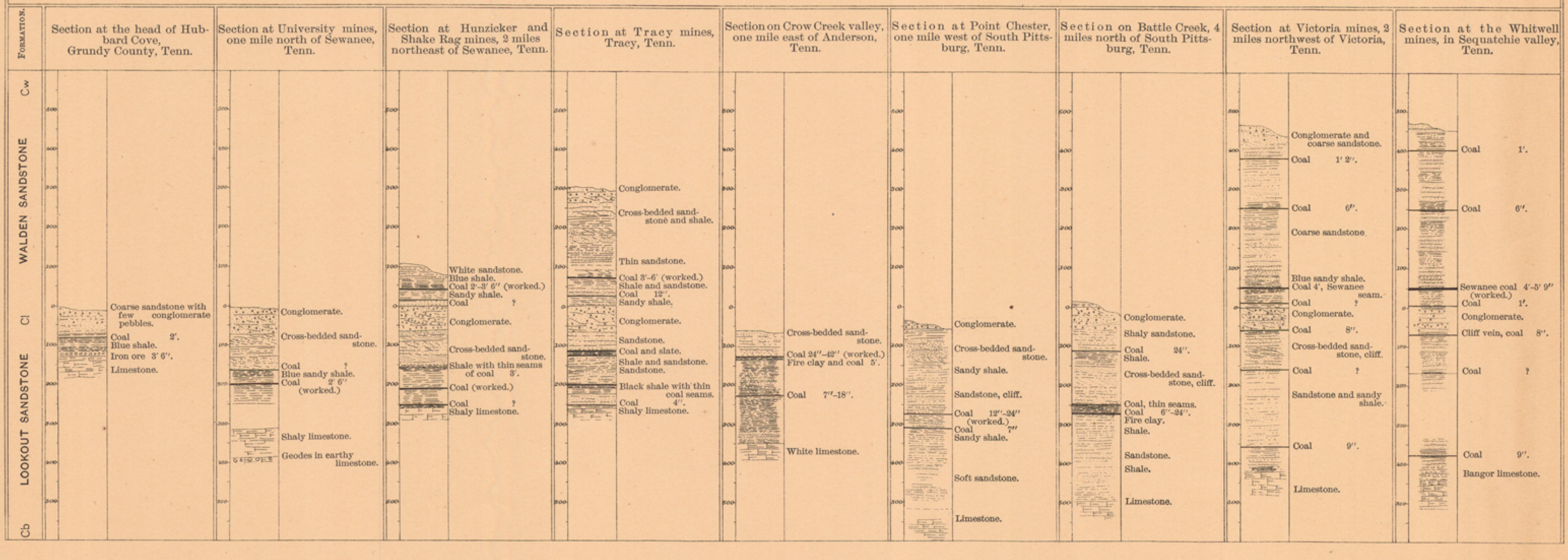
NAMES OF FORMATIONS.

		Names and symbols used in this sheet.	Stafford; Geology of Tennessee, 1869.	Smith: Geology of the valley region adjacent to the Cahaba coal field, Alabama, 1890.	Smith; Outline of the Geology of Alabama, 1878.
Carboniferous	Cw Cl	Walden sandstone. Lookout sandstone.	Coal measures.	Coal measures.	Upper coal measures. Lower coal measures. Millstone grit; conglom.
	Cb	Bangor limestone.	Mountain limestone.	Bangor limestone.	Upper sub-carboniferous or mountain limestone.
	Cp	Fort Payne chert.	Siliceous group.	Fort Payne chert.	Lower sub-carboniferous.
Dev.	Dc	Chattanooga black shale.	Black shale.	Black shale.	Genesee or black shale.
Silurian.	Sr	Rockwood formation.	Dyestone group: White Oak mountain sandst.	Red mountain or Clinton.	Clinton or Dyestone.
	Sc	Chickamauga limestone.	Trenton, Lebanon or Maclurea limestone.	Trenton or Pelham limestone.	Trenton, Chazy or Maclurea.
	Sk	Knox dolomite.	Knox dolomite.	Knox dolomite.	Quebec or Knox dolomite.

VERTICAL SECTIONS; SHOWING THE POSITION AND THICKNESS OF COAL BEDS.

SCALE 250 FEET = 1 INCH.

VERTICAL DISTANCES ARE MEASURED FROM THE TOP OF THE LOOKOUT CONGLOMERATE.



C. WILLARD HAYES,
Geologist.

pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

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

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

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

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

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

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

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

USES OF THE MAPS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

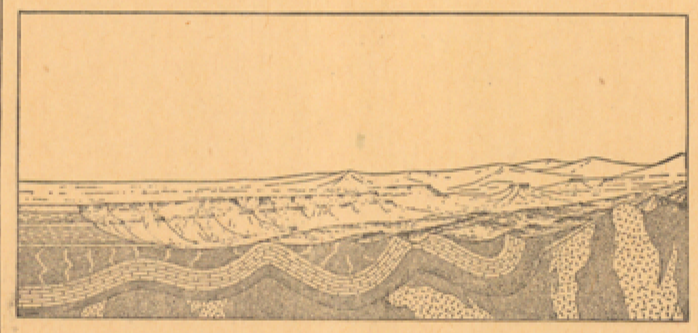


Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

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

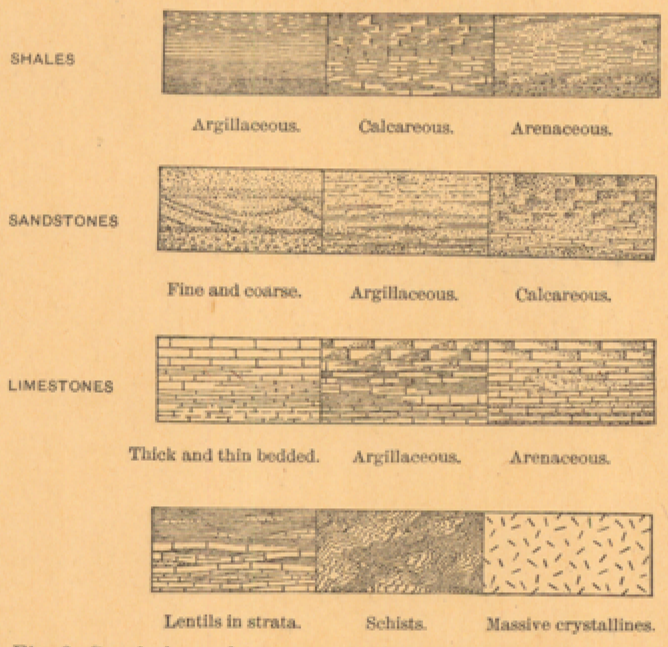


Fig. 3. Symbols used to represent different kinds of rocks.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

J. W. POWELL,
Director.