DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

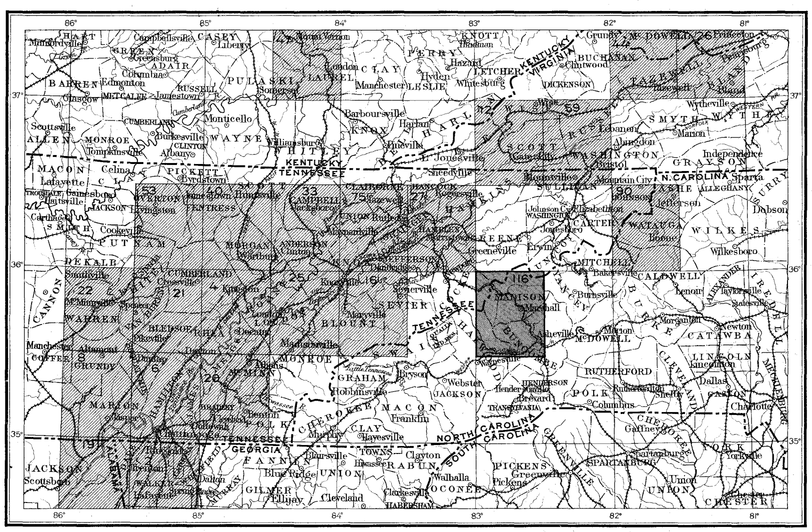
OF THE

UNITED STATES

ASHEVILLE FOLIO

NORTH CAROLINA–TENNESSEE

INDEX MAP



SCALE: 40 MILES-1 INCH

ASHEVILLE FOLIO

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LIBRARY EDITION

ASHEVILLE FOLIO
NO. 116

WASHINGTON, D. C.

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

1904

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

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

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

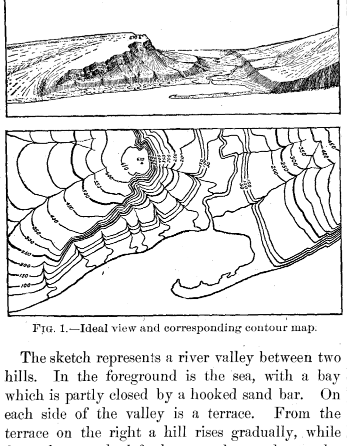


FIG. 1.—Ideal view and corresponding contour map.

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

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found 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 all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles in English inches, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land, and the structure sections show their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. In smaller portion the materials are carried in solution, and the deposits are then called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind; and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

(Continued on third page of cover.)

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

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary...	Recent........ Pleistocene....	Q	Brownish-yellow.
Cenozoic	Tertiary......	Pliocene....... Miocene....... Oligocene...... Eocene........	T	Yellow ocher.
Mesozoic	Cretaceous....	....	K	Olive-green.
Mesozoic	Jurassic	....	J	Blue-green.
Mesozoic	Triassic.......	....	Ћ	Peacock-blue.
Paleozoic	Carboniferous.	Permian....... Pennsylvanian Mississippian..	C	Blue.
Paleozoic	Devonian.....	....	D	Blue-gray.
Paleozoic	Silurian.......	....	S	Blue-purple.
Paleozoic	Ordovician....	....	O	Red-purple.
Paleozoic	Cambrian.....	Saratogan..... Acadian....... Georgian......	Є	Brick-red.
	Algonkian....	....	A	Brownish-red.
	Archean......	....	Æ	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain, is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

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

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

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

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

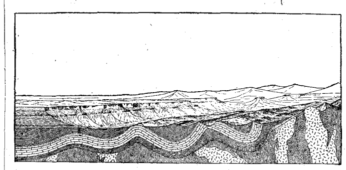


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated 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:

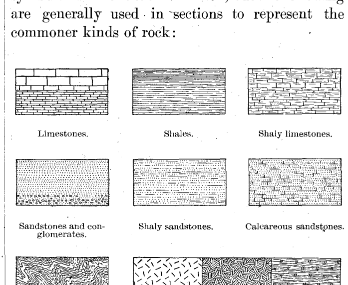


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

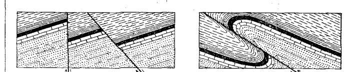


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

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

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

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

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

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

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

DESCRIPTION OF THE ASHEVILLE QUADRANGLE.

By Arthur Keith.

GEOGRAPHY.

GENERAL RELATIONS.

Location.—The Asheville quadrangle lies chiefly in North Carolina, but includes also a portion of Tennessee. It is situated between parallels 35° 30′ and 36° and meridians 82° 30′ and 83°, and contains 968.70 square miles, divided between Madison, Buncombe, and Haywood counties in North Carolina and Greene, Cocke, and Unicoi counties in Tennessee.

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

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

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

The eastern division of the province embraces the Appalachian Mountains, a system which is made up of many minor ranges and which, under various local names, extends from southern New York to central Alabama. Some of its prominent parts are the South Mountain of Pennsylvania, the Blue Ridge and Catoctin Mountain of Maryland and Virginia, the Great Smoky Mountains of Tennessee and North Carolina, and the Cohutta Mountains of Georgia. Also embraced in the eastern division is the Piedmont Plateau, a vast upland which, as its name implies, lies at the foot of the Appalachian Mountains. It stretches eastward and southward from their foot from New York to Alabama, and passes into the Coastal Plain, which borders the Atlantic Ocean. The Mountains and the Plateau are separated by no sharp boundary, but merge into each other. The same rocks and the same structures appear in each, and the form of the surface varies largely in accordance with the ability of the different streams to wear down the rocks. Most of the rocks of this division are more or less crystalline, being either sediments which have been changed to slates, schists, or similar rocks by varying degrees of metamorphism, or igneous rocks, such as granite and diabase, which have solidified from a molten condition.

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

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

Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1000 feet in Alabama to more than 6700 feet in western North Carolina. From this culminating point they decrease to 4000 or 3000 feet in southern Virginia, rise to 4000 feet in central Virginia, and descend to 2000 or 1500 feet on the Maryland-Pennsylvania line.

The Appalachian Valley shows a uniform increase in altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2000 feet at the Tennessee-Virginia line, and 2600 or 2700 feet at its culminating point, on the divide between New and Tennessee rivers. From this point northward it descends to 2200 feet in the valley of New River, 1500 to 1000 feet in the James River basin and 1000 to 500 feet in the Potomac River basin, remaining about the same through Pennsylvania. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2000 feet.

The Plateau or western division increases in altitude from 500 feet at the southern edge of the province to 1500 feet in northern Alabama, 2000 feet in central Tennessee, and 3500 feet in southeastern Kentucky. It is between 3000 and 4000 feet in West Virginia, and decreases to about 2000 feet in Pennsylvania. From its greatest altitude, along the eastern edge, the Plateau slopes gradually westward, although it is generally separated from the interior lowlands by an abrupt escarpment.

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

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

GEOGRAPHY OF THE ASHEVILLE QUADRANGLE.

Geographic divisions.—The area of the Asheville quadrangle is nearly all included in the Mountain division of the Appalachian province. A few square miles in the extreme northwest corner are situated in the Great Valley. The topography of this corner is of the kind which prevails in the Great Valley, and consists of low, rounded hills and shallow valleys. Practically all of the area of the quadrangle is occupied by a number of mountain chains with broad plateaus and deep, narrow intervening valleys. The most prominent of these chains is the Newfound Mountains, which extend in a general northerly direction between the valleys of Pigeon and French Broad rivers. In the northeast portion of the quadrangle rise the Bald Mountains, a group of disconnected ridges and peaks. The highest point in these, Big Bald (5530 feet), lies about half a mile east of this quadrangle. The foothills of the Craggy Mountains extend westward from the Mount Mitchell quadrangle nearly to French Broad River, just north of Asheville. The sides of these mountains are steep and made up of smooth, flowing slopes. The intervening valleys are sharp and narrow at their heads and descend rapidly to the altitudes of the different plateaus. At about these levels they quickly widen out into rounded valleys and plateaus.

The most striking single feature in the region is the plateau of French Broad River, which stands at elevations between 2100 and 2200 feet. Similar in every respect, but smaller and about 500 feet higher, is the plateau of Pigeon River. These plateaus extend from the main streams up the larger tributaries with gradually greater elevations. The plateaus consist of a series of gently rolling and smoothly rounded summits, but slightly varied by shallow valleys near the stream heads. The summits rise to heights which are remarkably uniform over large areas. The plain which they form may be readily seen from any of the summits. Into the plateaus the rivers and larger creeks have sunk canyons during different periods of erosion. These have steep and rocky borders and are so narrow as to be easily overlooked except when close at hand.

Drainage.—The drainage of the quadrangle is mainly into French Broad River, but a considerable area is tributary to Pigeon River, and several small creeks along the northern edge of the quadrangle flow into Nolichucky River. All, however, unite in the Valley of Tennessee, about 20 miles northwest of this quadrangle. From their heads high up in the mountains the streams fall with heavy grades down to the levels of the two plateaus. For considerable distances after those levels are reached the grades are very light, until the heads of the secondary canyons are reached. Thence downward the streams descend swiftly, with many small waterfalls and rapids. Thus, French Broad River descends from an elevation of 1975 feet at Asheville to less than 1200 feet at the point where it passes out of the quadrangle.

GEOLOGY.

GENERAL GEOLOGIC RECORD.

Nature of the formations.—The formations which appear at the surface of the Asheville quadrangle and adjoining portions of the Appalachian province comprise igneous, ancient metamorphic, and sedimentary bodies, all more or less altered since their materials were first brought together. Some of them are very ancient, going back to the earliest known period. They consist mainly of two groups, of widely different age and character. These are (1) igneous and metamorphic rocks, including gneiss, schist, granite, diorite, and similar formations; and (2) sedimentary strata, of lower Cambrian age, including conglomerate, sandstone, shale, limestone, and their metamorphosed equivalents. Ordovician rocks are also found in a small and unimportant area. The oldest of these groups occupies the greatest area, and the youngest the least. The materials of which the sedimentary rocks are composed were originally gravel, sand, and mud, derived from the waste of older rocks, and the remains of plants and animals. All have been greatly changed since their deposition, the alteration being so profound in some of the older gneisses and schists as to destroy their original nature.

From the relations of the formations to one another and from their internal structures many events in their history can be deduced. Whether the crystalline rocks were formed at great depth or at the surface is shown by their structures and textures. The amount and the nature of the pressure sustained by the rocks are indicated in a measure by their folding and metamorphism. The composition and coarseness of the sediments show the depth of water and the distance from shore at which they were produced. Cross bedding and ripple marks in sandstones indicate strong and variable currents. Mud cracks in shales show that their areas were at times above and at times below water. Red sandstones and shales like those of the Watauga formation were produced when erosion was revived on a land surface that had been long subject to decay and had become covered with a deep residual soil. Limestones show that the currents were too weak to carry sediment or that the land was low and furnished only fine clay and substances in solution. Coarse strata like those of the Cochran conglomerate indicate strong currents and wave action during their formation.

Principal geologic events.—The rocks themselves thus yield records of widely separated epochs ranging from the earliest age of geologic history through the Paleozoic. The entire record may be summarized as follows, from the oldest formation to the latest:

Earliest of all are the great bodies of Carolina gneiss. Its mode of origin, whether igneous or sedimentary, is buried in obscurity. It represents a complex development and many processes of change, in the course of which the original characters have been largely obliterated. The gneiss is, however, distinct from and much older than any other formation yet identified in the province, and the time of its production is the earliest of which we have record.

During succeeding epochs masses of igneous rock were forced into the gneiss. The lapse of time was great; igneous rocks of many different kinds were intruded, and later intrusive masses were forced into the earlier. The granitic texture of some of the formations and the lamination and schistosity of others were produced at great depths below the surface.

Upon these once deep-seated rocks now rest lavas which poured forth upon the surface in pre-Cambrian time. Thus there are in contact two extremes of igneous rocks—those which consolidated at a considerable depth, and those which cooled at the surface. The more ancient crystalline complex had therefore undergone uplift and long-continued erosion before the period of volcanic activity began. The complex may safely be referred to the Archean period, being unmeasurably older than any rocks of known age. Whether these ancient lavas represent a late portion of the Archean or are of Algonkian age is not certain. The latter is more probable, for they are closely associated with the Cambrian rocks. Yet they are separated from the Cambrian strata by an unconformity, and fragments of the lavas form basal conglomerates in the Cambrian.

Next, after a period of erosion, the land was submerged, and sandstones, shales, and limestones were laid down upon the older rocks. In these sediments are to be seen fragments and waste from the igneous and metamorphic rocks. The different sedimentary formations are classified as being of Cambrian or later age, according to the fossils which they contain. Remnants of these strata are now infolded in the igneous rocks, and the portions thus preserved from erosion cover large areas of the mountains. The submergence which caused their deposition began at least as early as the beginning of Cambrian and extended at least into Silurian time. It is possible that the beginning was earlier and the end not until the close of Carboniferous time; the precise limits are not yet known.

These strata comprise conglomerate, sandstone, slate, shale, limestone, and allied rocks in great variety. They were far from being a continuous series, for the land was at times uplifted and areas of fresh deposits were exposed to erosion. The sea gradually advanced eastward, however, and land areas which furnished sediment during the early Cambrian were covered by later Paleozoic deposits. The sea occupied most of the Appalachian province and the Mississippi basin. The area of the Asheville quadrangle at first formed part of the eastern margin of the sea, and the materials of which the rocks are composed were derived largely from the land to the southeast. The exact position of the eastern shore line of this ancient sea is not known except here and there, and it probably varied from time to time within rather wide limits. In the earliest Cambrian time it lay just northwest of the position of Crabtree Bald, in the southwest quarter of the quadrangle.

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

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

DESCRIPTION OF THE FORMATIONS.

Rocks of the Asheville quadrangle.—The rocks exposed at the surface in the Asheville quadrangle comprise three great classes—metamorphic, igneous, and sedimentary. The latter are found in the northwest portion of the quadrangle over a large area, from which a number of narrow belts pass into the adjoining areas of igneous rocks. Along Pigeon River also, in the southwestern part of the quadrangle, are found two considerable areas of sedimentary rocks separated from the main bodies. In all, these sediments cover about one-fifth of the area of the quadrangle. They consist of conglomerates, sandstones, shales, and limestones of considerable variety and rocks into which these have been metamorphosed, including quartzites, graywacke, slates, and schists. They are almost entirely of Cambrian age, ranging from the Snowbird formation, the oldest sedimentary deposit known in this region, to the Knox dolomite, of Cambrian and Ordovician age. At the border of the Valley, on the north slope of Meadow Creek Mountains, is found a narrow area of the Athens shale, of Ordovician age, the youngest rock exposed in this quadrangle. The representation of the lower Cambrian strata is very full and complete.

The remainder of the quadrangle is divided about equally between igneous and metamorphic formations. The igneous rocks cover the largest areas along a belt passing through Marshall in a northeasterly course. Around Asheville the surface is entirely occupied by the metamorphic rocks embraced in the Carolina gneiss. This formation occupies a larger area than any other in the quadrangle. In the area of the Asheville Plateau, below Asheville, the Carolina gneiss alternates in a great many narrow bands with the Roan gneiss, of igneous origin.

Practically all of the igneous and metamorphic rocks are of Archean age. There are, however, a few exceptions. In the northern part of the quadrangle, in the drainage of Big Laurel River and Shelton Laurel Creek, are a few areas of metadiabase, which corresponds in all respects to the Linville metadiabase of the Cranberry quadrangle. The latter rock is with little doubt of Algonkian age, and the metadiabase of this region is probably of the same age. This is also true of the small bodies of metarhyolite which traverse the same district.

At many places in the Carolina and Roan gneisses are found dikes and small bodies of a fine-grained granite. These seldom exceed a few feet in thickness and are not of sufficient size to permit their representation on the map. That they are much younger than the other granites of the region is shown by the almost entire absence of the schistosity which characterizes all of the other formations in the mountainous part of the quadrangle. The latest time at which this schistosity was produced was post-Carboniferous, so that these granite dikes are clearly later than Carboniferous, although they may have been produced during the latter part of the period of deformation.

Still a third class of younger igneous rocks is represented by a series of thin sheets and dikes of quartz-diorite. These are to be found at many places in the southwestern portion of the quadrangle. They cut both the ancient metamorphic rocks and the lower Cambrian sedimentary strata, and, accordingly, they are at least as young as the Cambrian. In some places they are seen to have been metamorphosed, though to a less extent than the sedimentary strata, so that it must be inferred that they are older than the Carboniferous deformation. As to their age between these limits, there is no sufficient evidence. It is probable that the difference in age between the quartz-diorite and granite dikes is fully as great as that between the Cranberry granite and the Max Patch granite. Both of these belong to the later portion of the Archean as represented in this region, and both were extensively metamorphosed during the post-Carboniferous deformation. The Max Patch granite is younger than the Cranberry granite and cuts through it at various places. Whether the interval between them is great or not can only be surmised.

The columnar sections show the character and probable age of the different formations, and each will now be described in order of age, as nearly as that can be determined.

ARCHEAN ROCKS.

CAROLINA GNEISS.

Area of the formation.—A wide area in the southern part of this quadrangle is covered entirely by the Carolina gneiss, which is so named because of its extent in North Carolina and South Carolina. Many outliers of the formation are also found alternating with the Cranberry granite and the Roan gneiss north of its principal area. The Carolina gneiss is thus the principal formation of the quadrangle. It is also the oldest formation in this region, since it is cut by the igneous rocks and is overlain by the sediments. Included in it are numerous representatives of the igneous formations, of too small size to be shown on the map. In the gneiss are also found narrow dikes of granite and of quartz-diorite which in no place form areas sufficiently large to be mapped.

Gneiss and schist.—The formation consists of an immense series of interbedded mica-schists, garnet-schists, mica-gneiss, garnet-gneiss, and fine-grained granitoid layers. Most of them are light gray or dark gray in color, weathering to a dull gray and greenish gray. A few thin layers in the mica-schist are bluish gray or black. Toward the northwest the strictly gneissic beds are somewhat more numerous and their banding becomes slightly coarser and better defined. Otherwise the formation is unusually uniform in appearance throughout its areas in this quadrangle. That part of the formation which lies adjacent to the Roan gneiss contains thin interbedded layers of hornblende-schist and gneiss precisely like the Roan gneiss, constituting a transition between the formations. For this reason the boundary between the formations is somewhat indefinite, notably so in the vicinity of Marshall.

The mica-schists are usually fine grained and are composed of quartz, muscovite, a little biotite, and very little feldspar. In many localities these component minerals are segregated into separate layers, producing a gneiss of a marked banded appearance. This result is usually attended by an increase in the amount of feldspar. In a belt 5 or 6 miles wide that passes just northwest of Asheville the schists contain many crystals and flakes of muscovite, which are of coarser grain than the rest of the rock, and thus give it a porphyritic appearance. Associated with the coarse muscovite in a few places are crystals of gray cyanite ranging from one-half to three-fourths of an inch in length. This form of schist is rare in this region, but in the Mount Mitchell quadrangle, adjoining on the east, it occupies large areas and is very prominent. Where these are frequent the schist layers acquire a noticeable silvery appearance.

Southeast of this band of muscovite-schist in the southeast corner of the quadrangle, the schist and gneisses are very frequently garnetiferous. Garnets are also developed, but less prominently, in the muscovite-schists, mica-schists, and mica-gneisses that occur near the contacts of the Roan gneiss, where they appear to be due to the contact with that gneiss. There seems to be no reason of that kind for the occurrence of garnets in the schist around Asheville, although it is possible that their development is connected with the very numerous granite dikes that cut the gneiss in that vicinity. The garnets are small, seldom exceeding a quarter of an inch in dimensions. In the vicinity of Marshall, however, numerous deposits are found with crystals from 1 to 6 inches in diameter. In those portions of the formation that lie near areas of Roan gneiss, biotite is much more conspicuous than elsewhere. Its distribution in this way suggests that it is partly a contact feature of the Roan gneiss intrusion.

The granitoid layers of the gneiss contain quartz and feldspar, with muscovite and biotite in small amounts. In the light-colored layers biotite and muscovite are sparse and the minerals are much less distinctly parallel than in the schists, although usually they are roughly so arranged. The prominence of this foliation depends largely upon the amount of mica in the rock. These granitoid layers and the schists alternate in beds that range from a few inches to a few feet in thickness. Layers similar in composition and from one-tenth of an inch to an inch in thickness compose the banded gneiss.

Pegmatite.—Inclosed within the formation are numerous beds or veins of pegmatite. These occur in the shape of lenses that range in thickness from 1 to 5 feet. They lie for the most part parallel to the foliation of the gneiss, but sometimes cut it abruptly. These pegmatites are most conspicuous near the contacts of the Carolina and Roan gneisses, but are by no means limited to those localities. They are also more prominent in the southern and western portions of the quadrangle. They consist chiefly of very coarsely crystalline feldspar, quartz, biotite, and muscovite. In regions closely adjoining toward the southwest and northeast much merchantable mica is procured from the pegmatites and many rare minerals are found in them. In the Asheville quadrangle, however, the rare minerals are practically absent and the mica does not attain notable size.

Marble.—Associated with the gneiss, but forming an unusual exception to it in character, is a group of marble beds. Two of these are found in Marshall and five are 2 miles west and northwest of Marshall, four of these lying in a nearly straight line southward from French Broad River. Outcrops of the marble are found only in or near the streams, on account of the soluble nature of the rock. At first they seem to be different outcrops of a continuous bed, but it is doubtful if this is the case, because at a few intervening points the marble is plainly absent. It is probable, therefore, that the marble deposits are of lenticular shape. Considerable differences in thickness can be observed, even in the small exposures near the streams, but these may be due to the extreme folding that all of the rocks of the region have undergone. The maximum thickness observed was on Walnut Creek northwest of Marshall, where the outcropping beds are 60 feet thick, with a possibility of as much more concealed. About 200 feet farther north the entire section was occupied by gneisses. South of French Broad River the thicknesses observed range from 10 to 35 feet. The thicknesses shown in Marshall have about the same variations.

The marble is fine grained and is usually white. It contains 84 per cent of carbonate of calcium, 2 per cent of carbonate of magnesium, and 13 per cent of silica. Many portions have a somewhat greenish color, due to tremolite, which forms many small prisms and stubby crystals. Other variations of color are due to small knots of epidote, tremolite, and calcite, and to lenses of fine quartz and hornblende. These seem to be in the nature of secondary segregations and are of frequent occurrence throughout all the marble beds. The most important variation in the marble is seen in the series of thin lenses and sheets of silica that it contains. These are seldom over 2 inches in thickness and are composed of extremely fine-grained quartz. They appear to represent original sedimentary bands, replaced by silica, and have been extremely contorted and folded, like the adjoining gneisses. The value of the marble for building stone is much injured by these various impurities. A few seams of mica-schist found in the marble contain the same minerals and are metamorphosed to the same degree as the adjoining Carolina gneiss. There is, therefore, little doubt that the marbles are of substantially the same age as the gneiss. The gneiss is cut by Cranberry granite at many points within a few feet of the marble, but the granite does not touch the marble at any point. The presence of these marble beds makes it probable that at least part of the Carolina gneiss is of sedimentary origin.

Granite.—Commonly associated with the gneiss and schist are many beds and masses of intrusive granite. These vary in thickness from a few inches up to 100 feet and can be traced sometimes for 200 yards. They cut through the gneisses at every conceivable angle and in masses of extremely variable thickness. On account of these features and their small size it is not practicable to map them as separate formations. The granite is fine grained and very uniform in texture and has a light-gray or whitish appearance. The dikes are somewhat lighter colored where they are smaller, on account of the increasing proportion of quartz and feldspar. The component minerals are quartz, orthoclase and plagioclase feldspar, biotite, and muscovite, the latter being subordinate in amount. As a rule, these beds are massive and very seldom show any of the schistosity which marks all of the adjoining formations. For this reason it is concluded that they were intruded into the gneisses after the principal part of the deformation of the rocks had been accomplished. The very small amount of schistosity which appears, however, must be attributed to that general epoch, so that the age of the granite is closely limited to the close of the period of deformation, which was soon after the Carboniferous.

Quartz-diorite.—Of similar eruptive nature are the beds of quartz-diorite which cut the Carolina gneiss at a number of localities in this quadrangle. These beds are very small, usually only a few inches in thickness. They cut the gneiss and schist at various angles and can not be traced beyond the immediate outcrop in which they are seen. These dikes are found only in the southern part of the quadrangle and are more common toward the west. Diorite dikes of this same series cut the Cambrian strata in this quadrangle and in regions farther southwest, and are therefore among the latest of the eruptive rocks. They are sometimes metamorphosed, though very slightly, so that they were formed nearly at the close of the period of Carboniferous deformation. Thus they are of the same general age as the eruptive granite dikes, though probably somewhat older. The diorite consists of quartz, plagioclase and orthoclase feldspar, and hornblende. The quartz and feldspar are very fine grained, sometimes so fine grained that it is difficult to distinguish them with the unaided eye. Through these are scattered crystals of green hornblende, ranging from one-fourth to three-fourths of an inch in length. An additional constituent is garnet, which occurs in large and small crystals. These are very irregularly distributed and may represent contact reactions of the adjacent formations. The variations in the grain of the diorite are considerable and rapid, being mainly in the size of the hornblende, which, however, is almost invariably porphyritic in appearance, while the other minerals in the rock are never coarse.

Extent and origin of the gneiss.—The Carolina gneiss is much larger than any other formation in this region. On account of the great uniformity of its beds no true measure of their thickness can be obtained; even an estimate would be idle. Their original thickness has been repeated and increased many fold by the enormous deformation to which they have been subjected. Their original nature is equally uncertain. It is possible that most of the mass was once a granite and that it has been metamorphosed into its present condition. Some of the material is granite now, and its local metamorphism to schist can readily be seen. Other and similar material might easily have been altered into the great body of mica-schist. Such an origin can less easily be attributed to the beds of banded gneiss, however, since it fails to account for the parallel layers and banding. The marble beds and the adjoining gneisses are probably of sedimentary origin. One deformation produced a foliation of the rock, whatever its original nature. A subsequent deformation folded and crushed the earlier planes and structures. Before the latter deformation the beds of pegmatite were formed. These were thoroughly mashed by the second deformation and retain in many places only a fraction of their original coarseness. In most of the formation metamorphism has been excessive and has destroyed the original attitudes and most of the original appearance of the rocks.

Decay of the gneiss.—The schistose planes of the various layers afford easy passage for water, and they are deeply decayed. After decomposition has reduced the feldspar, the remaining clay is filled with bits and layers of schist, quartz, mica, and garnet. Solid ledges are seldom found far from the stream cuts and steeper slopes. The cover of clay on the decayed rocks is thin, and the soil is light on account of the large porportion of quartz and mica that it contains; accordingly its natural growths are poorly sustained. The soils are susceptible of great improvement by careful tillage. The greater amount of soluble matter and clay in the gneiss renders its areas slightly more productive than those of the schist. The biotite-gneiss areas are also rather more productive than the others.

ROAN GNEISS.

Extent.—Many areas of Roan gneiss occur in a zone that crosses French Broad River between Marshall and Asheville and that is about 10 miles wide at its widest part. Northeast of the French Broad the Roan gneiss diminishes rapidly in extent, being replaced at the surface by the Cranberry granite. An equal diminution takes place toward the southwest, where the bodies of gneiss become narrower and disappear in the Carolina gneiss. The formation receives its name from Roan Mountain, on the boundary of Tennessee and North Carolina, northeast of this quadrangle.

Character.—The Roan gneiss consists of a great series of beds of hornblende-gneiss, hornblende-schist, and diorite, with some interbedded mica-schist and mica-gneiss. The hornblendic beds are dark greenish or black in color, and the micaceous beds are dark gray. The mica-schist and mica-gneiss beds range in thickness from a few inches to 70 or 80 feet and are most frequent near the Carolina gneiss, into which they form a transition. In many areas of Roan gneiss, especially in Cane River basin, mica-gneiss forms a large proportion of the mass. This interbedding is undoubtedly due in part to the close folding which the formations have undergone, a fact which is visible in many of the smaller beds. It is also probable that part of it was due to the intrusion of a large number of beds near the general line of contact. Later compression of the rocks has made the different beds more or less parallel with one another.

In composition the mica-schist and mica-gneiss are exactly like the micaceous parts of the Carolina gneiss and contain quartz, muscovite, biotite, and more or less feldspar. The hornblende-schists make up most of the formation and are interbedded with hornblende-gneisses throughout. The schist beds consist almost entirely of hornblende, in crystals ranging in length from one-tenth to one-half inch, with a very small amount of biotite, feldspar, and quartz; the gneisses contain layers or seams consisting of quartz or feldspar interbedded with layers of hornblende-schist. In places these are very regularly disposed and give a marked banding to the rock. An accessory mineral frequently seen is garnet. As already stated, this occurs in the Carolina gneiss near the contact of the Roan gneiss, and to a large extent it also occurs in the Roan gneiss in similar positions. In several localities, most of them in the vicinity of Marshall, the garnets are well developed and coarse, attaining dimensions of 2 or 3 inches. In this region many beds of Cranberry granite cut the Roan gneiss, and the garnets may possibly be due to contact action by the granite.

Here and there the hornblende, feldspar, and quartz have the massive structure of diorite or gabbro. Some of these beds are very coarse and massive, as is to be seen at Alexander. Many of the beds of the formation are composed almost entirely of hornblende and are so basic that they appear to have been derived from gabbro. Of this kind are the hornblende-schists and many layers only feebly schistose. So thorough is the alteration, however, that such an origin is not certain. Some masses of this nature have been separately mapped under the name metagabbro. It is also certain that many small areas of similar nature are included within the Roan gneiss.

At many points in the Roan gneiss there are veins and lenses of pegmatite of secondary growth precisely similar to those in the Carolina gneiss. Like those also they are of small size and of slight importance in this region.

The Roan gneiss appears to cut the Carolina gneiss, but the contacts are so much metamorphosed that the fact can not be well proved. Narrow, dike-like beds of the Roan in the Carolina gneiss support this view, as well as the fact that the diorites included in the Roan are less altered than the Carolina gneiss and so appear to be younger. In fact, the shape and continuity of many of the narrower sheets of Roan gneiss can be explained only on the theory that they represent original dikes cutting the Carolina gneiss. Frequent development of garnets in the Carolina gneiss near the borders of the Roan gneiss is evidence of contact metamorphism by the latter.

Metamorphism.—Deformation and recrystallization have extensively changed the rocks of this formation into schists and gneisses. The exact measure of the alteration is usually unknown, because of the uncertainty as to the original character of the rock. It is probable that most of the mass was at first diorite and gabbro, of much the same mineral composition as now. In a few of the coarse masses the original structures can still be seen. The minerals in most of the formation are secondary, however, and are arranged as a whole in parallel layers, causing the schistosity. These minerals and schistose planes are bent and closely folded, to an extent equal in many places to all the folding of the later formations. Thus the Roan gneiss has passed through two deformations, one folding producing the foliation and a second folding the foliation planes. During or before the second deformation the bands of quartz and feldspar appear to have been formed. The total alteration is extreme.

In reducing the surface of the formation the first steps of weathering were taken by decomposition of the hornblende and feldspar, but the more siliceous layers and many of the harder hornblende-schists and mica-schists are extremely slow of disintegration. Their outcrops form cliffs and heavy ledges near the streams, and greatly retard the reduction of the surface. As a whole, the formation is somewhat less resistant than the Carolina gneiss and far weaker than the Cranberry granite. Consequently, its areas are reduced to plateaus in the large stream valleys and form gaps and depressions in the higher ground away from the rivers. The rise of the mountains beyond its areas is in most cases very noticeable. In this respect the formation in this area differs much from its habit in areas farther northeast. The clays accumulating on the Roan gneiss are always deep and have a strong dark-red color; the soils are rich and fertile and well repay the labor of clearing. The hilly surfaces keep the soil well drained, and yet the clayey nature of the soil prevents serious wash; hence they are extensively cultivated, even in situations that are remote from settlements.

METAGABBRO.

Three areas of metagabbro appear in the quadrangle, one in the upper part of Ivy River and two near Alexander. This is a very basic rock of the same general appearance as the massive portions of the Roan gneiss, but is much less schistose and gneissoid. In fact, considerable masses on Ivy River weather into spheroidal form and show practically no schistosity. The minerals of this rock are essentially the same as those of the basic parts of the Roan gneiss, being mainly plagioclase feldspar, dark green or black hornblende, and a very small amount of quartz. In places the rock is specked with garnets. Much the greater part of the rock is made up of the hornblende, the whole mass being dark and glistening, even on weathered surfaces.

Judging from the preponderance of the iron-bearing minerals and the basic nature of the rock, the original formation was probably a gabbro. There is no locality now known at which this origin can be seen. The relative age of the metagabbro and the Roan gneiss can not be determined. The metagabbro is included in the areas of the Roan gneiss and bears a strong resemblance to the massive parts of the latter in all respects. It is probable, indeed, that many small areas of metagabbro are mapped within the Roan gneiss for want of means to distinguish them. Judged by its general crystalline character and associations, the metagabbro was probably formed at about the same age as, or perhaps slightly later than, the Roan gneiss.

The metagabbro is very slow to decompose and leaves many more or less rounded bowlders lying upon the surface. This is especially noticeable in the area west of Alexander, where the formation produces a rocky hill that projects somewhat above the plateau surface. Final decay produces a dark-red clay of no great depth.

SOAPSTONE, DUNITE, AND SERPENTINE.

Many small bodies of these more or less altered igneous rocks are found within this quadrangle, few of them exceeding a quarter of a mile in width and a mile in length. The formation comprises many different rocks, such as soapstone, dunite, and serpentine, and many combinations of minerals derived by metamorphism from the original rocks. The most common variety in this area is an impure soapstone containing many hornblendic minerals. There are, also, many bodies of the dunite composed almost entirely of olivine. These are most common in a belt of soapstone, dunite, and serpentine that runs from Canton northeastward past Weaverville. The soapstones are white and light gray, while the other varieties of the formation have a greenish color, either bright or dull. In a few localities the soapstone consists of little but talc and is pure enough for industrial uses, but as a rule it contains much chlorite and crystals of tremolite, actinolite, or other hornblendic minerals. In the dunites are frequently to be seen veins of pure fibrous talc that range from an inch to a foot in thickness. These are commonest southwest of Alexander and in the vicinity of Marshall. Here and there small veins of chrysotile, called "asbestos," are also found in the dunite. This occurs in the shape both of small veins and of irregular rounded crusts between portions of the dunite. Just east of Jupiter the asbestos fibers have a length across the vein of 3 or 4 inches; usually they are much shorter. The dunite itself is usually more or less altered to serpentine. This is especially the case in the areas 3 miles northeast of Stocksville and 2 to 4 miles southwest of Alexander. All of the varieties of the formation may be present in a single ledge, or one variety may occupy the whole of an area. The latter occurrence is most common where soapstone alone is seen.

In their original form these rocks were peridotite and pyroxenite, composed of olivine with more or less feldspar and pyroxene. The change from these to rocks of the soapstone group is enormous—far greater in appearance than that in any of the other formations. The minerals which now appear, however, are very similar in chemical composition to those of the original rock. The intermediate stages of alteration are obscure or absent in this region, and even the dunite, which is close to the original rock, may itself have been wholly recrystallized. The metamorphism which caused these changes seems to have most easily affected rocks of this mineral composition. Unlike the other metamorphosed rocks, these show only moderate schistosity. Near their borders the soapstones may be schistose by the parallel arrangement of the talc and chlorite scales.

Although these rocks break through and across the beds of Roan gneiss and are thus seen to be distinct from it and of later origin, yet their association with the gneiss is close and marked, especially in regions adjoining the Asheville quadrangle, and they are probably of about the same age. In this quadrangle, however, there are a number of exceptions to this rule. Northeast of Canton, for instance, a few bodies of these basic rocks occur in the Carolina gneiss; even here, however, a very small amount of the Roan gneiss is usually present. Also, a considerable number of soapstone masses are found in the Cranberry granite. These are large fragments that were caught up in the granite at the time of its intrusion. Sometimes masses of Roan gneiss are included with them in the granite and sometimes soapstone alone appears. Thus the soapstone antedates the Cranberry granite. Its alteration is as great as or greater than that of the Roan gneiss and exceeds that of the Cranberry granite, so that it appears to have shared in the earlier metamorphism which involved the Roan and Carolina gneisses. It is therefore classed with the earliest part of the Archean.

Few rocks are slower to decompose than the soapstone, and its areas invariably show many ledges. In extreme cases the entire area is bare rock. Though it is not much affected by solution, it is too soft to stand the direct action of frost and rain, so that it breaks down and occupies low ground. Final decay leaves a cover of stiff yellow clay of little depth and much interrupted with rock. Soils derived from this are of almost no value.

CRANBERRY GRANITE.

The most important member of the Archean rocks in this quadrangle, next to the Carolina gneiss, is the Cranberry granite. This lies in a broad belt that passes diagonally through the quadrangle, from which many tongues run off into the adjoining formations. This general granite mass extends southwestward through the Mount Guyot quadrangle and northeastward through North Carolina and far into Virginia. The formation receives its name from Cranberry, N. C., near which place it is typically developed.

Character.—The formation consists of granite of varying texture and color and of schists and granitoid gneisses derived from granite. The granite is an igneous rock composed of quartz and orthoclase and plagioclase feldspar, with biotite, muscovite, and, in places, hornblende as additional minerals. Minor accessory minerals are magnetite, pyrite, ilmenite, garnet, and epidote. The most notable variation is in the size of the feldspar crystals. As these change the granite changes from a rock of fine, even grain to a rock of porphyritic appearance. The latter variety is more common in the smaller areas of the formation, southwest of French Broad River, while northeast of that river rocks of more uniform grain prevail. Both varieties are to be found in any area, and there seems to be no definite system in their distribution. In the coarse varieties the feldspar is by far the most prominent mineral and gives a prevailing light-gray or white color to the rock. The same is true of many of the narrow dikes penetrating the gneisses. At many places near the areas of Max Patch granite the feldspars of the Cranberry granite are filled with iron oxide, which gives to the rock a marked red appearance. This variety is often characterized by the presence of epidote in small veins and segregated masses. Near the western border of the quadrangle some of the beds of granite are marked by a great development of blue quartz, which appears to be an original constituent. This is also accompanied by secondary veins of blue quartz. A similar development of blue quartz is seen northeast of Sodom Mountain, on the waters of Big Laurel Creek. A noticeable blue color is thus given to the entire rock. In this variety the amount of quartz is considerably in excess of that contained in other forms of the granite. At a number of localities in the Newfound Mountains an equally quartzose granite appears, in which the quartz is colorless. Except for this color, which appears to be an optical effect due to some arrangement of the quartz, the two varieties are alike and are probably of the same origin.

Included rocks.—Included with these are small or local beds of metabasalt, metadiabase, metarhyolite, pegmatite, dikes of fine granite and quartz-diorite, and small bodies of the Roan gneiss, Carolina gneiss, and soapstone, as already stated. The metadiabase and metarhyolite are eruptive in the granite and are undoubtedly of the same age as similar rocks in adjoining quadrangles toward the northeast, which are Algonkian. The metarhyolite occurs in the shape of sheets and dikes ranging in thickness from a few inches to a few feet. These are to be found here and there on the headwaters of Laurel and Ivy rivers and a few have there been mapped. From their very small size it is doubtful whether the beds are continuous for great distances. In this region, moreover, the prevalent metamorphism of the rocks, the heavy forest cover, and the small size of the outcrops usually make it impracticable to trace them and represent them upon the map. The same is true of the dikes of quartz-diorite and of recent granite, such as were described with the Carolina gneiss. In many places it is difficult to decide whether or not to represent the included bodies of Roan and Carolina gneisses. The gneisses are cut repeatedly by the granite dikes, and the beds of each vary from a few inches to many feet in thickness, alternating with great frequency. In only a few cases do the boundaries shown on the map represent a single contact between two large masses; they usually indicate a narrow zone beyond which one rock or the other predominates. Sometimes an area shown as gneiss may contain many small beds of granite, or it may be substantially all gneiss. On the other hand, many of the areas represented as granite include also small bodies of gneiss. These may be continuous with one another or may be disconnected inclusions. Except where these bodies were the prevalent rock over considerable areas they were disregarded in the mapping.

Metamorphism.—The granite suffered great changes during the deformation of the rocks, both by folding and by metamorphism, the latter being much the more conspicuous. As the rock was folded, planes of fracture and motion were formed in the rock mass, along which metamorphism took place. As the process went on the quartz was broken and recemented, the feldspar developed into mica, quartz, and new feldspar, and chlorite replaced part of the biotite and hornblende. These minerals crystallized in general parallel to planes of motion in the rock and produced schists and gneisses that show a fairly uniform dip over large areas. The results varied in extent from rocks with no change or with mere cleavage to those completely altered into siliceous schists and gneisses, as along the main faults and the southeastern areas. Thin, parallel layers and striations composed of different minerals are of frequent occurrence, and the most extreme schists bear no resemblance to the original rock. The thin sheets of metarhyolite which cut through the granite have been greatly metamorphosed. The original flow banding is now very seldom to be seen. Here and there porphyritic feldspar crystals occur, but much the greater part of the rock is now fine, black schist, composed chiefly of quartz and muscovite with a small amount of black iron oxide.

Under the action of the weather the varieties of granite behave very differently. The coarse granites are very durable and stand out in ledges and bold cliffs; the finer grades, by reason of the decomposition of their feldspars, weaken to a crumbling mass which does not outcrop much except on steep slopes. The schistose portions of the formation break up most readily, the planes of schistosity seeming to afford a ready passage for dissolving waters. In spite of its weathering the formation occupies high ground, on account of the great mass of its insoluble materials. Its heights are frequently rendered less prominent, however, by the superior hardness and greater eminences of the neighboring Max Patch granite or the Cambrian quartzites. It forms round knobs, ridges, and mountains without definite system, whose crests and slopes are usually smooth and rounded. Many parts of its area are cultivated and the soils are light loams of fair depth and strength.

MAX PATCH GRANITE.

The Max Patch granite is displayed in ten or more areas whose longer axes have the same general direction as the Cranberry granite areas. These areas are not so closely connected, however, as are the bodies of Cranberry granite. The largest area is that which surrounds Max Patch Mountain, for which the formation is named. The others are, for the most part, of irregular shape, a mile or less in width, and from 2 to 10 miles long.

Character. — The formation consists almost entirely of coarse granite, in places porphyritic, and in places of uniform grain. The minerals which compose the rock are orthoclase and plagioclase feldspar, quartz, biotite, and a very little muscovite. Accessory minerals are magnetite, pyrite, and epidote, the latter being, for the most part, in secondary veins and patches. Porphyritic crystals of orthoclase feldspar whose lengths exceed one inch are not infrequently to be seen. These are most common north of Big Laurel Creek, where the formations cross the State boundary into Tennessee. The other masses, particularly that around Bluff Mountain, are composed of the uniform, massive variety, which is more characteristic of the formation as a whole. In the porphyritic varieties the feldspars make by far the greatest part of the rock, giving it a light-gray or dull-whitish color. In the massive parts of the formation biotite is prominent and causes a decidedly spotted appearance by the large size of its crystals.

Another variety of great extent is a coarse red granite. This appears to be a modification of the usual massive rock, from which it differs only in having many red or pink feldspars. These give a very marked red color to the whole rock. In the same regions where this red color characterizes the feldspar this mineral is often partially altered into epidote and saussurite. The waxy green tints produced by these minerals may frequently be seen in the same specimen that contains the red feldspar, to which they present a striking contrast in color. Where this process of alteration has been carried to an extreme, the feldspar has been so far replaced by epidote that this mineral composes one-third or one-half the bulk of the rock. This condition is noticeable on Max Patch Mountain and extends northward for a few miles, but it is by no means restricted to that locality. In other places practically all of the feldspars are so altered. The same causes that produced these changes have altered the original biotite more or less completely into chlorite and fibrous hornblende. Besides these processes there was a considerable growth of epidote in small veins and segregated patches. The biotite crystals have also been flattened and elongated so as to make them more than usually prominent.

On the waters of Spring and Hurricane creeks, south of Max Patch Mountain, there is a considerable development of blue quartz in this granite, as is the case in the Cranberry granite. The cause of this variation is not known. This quartz occupies the spaces between the other minerals in a manner that is characteristic of granite, and also appears in small veins an inch or two in thickness. This variety of the granite contains much more quartz than is found in other rocks of the formation.

The Max Patch granite is intrusive in the Cranberry granite and the older gneisses. It rarely comes in contact with the gneisses, however, and is usually surrounded by the Cranberry granite. Contacts between the Max Patch and the Cranberry granites are difficult to find on account of the forest cover and the decay of the formation, but a sufficient number have been discovered to make it clear that the Max Patch cuts the Cranberry. The evidence comprises dikes and included fragments of the Cranberry granite in the Max Patch granite.

Metamorphism. — The formation has suffered great changes by metamorphism. These are especially well shown by the porphyritic portions, where the change in the form of the mineral particles can often be measured. As in the Cranberry granite, the rock has been squeezed and mashed until a pronounced gneissoid structure has been developed at many places. The change is most manifest in the growth of new micas and in the elongation of the porphyritic feldspars. These feldspars have in places increased in length as much as three or four times, assuming pencil-like forms. In other places during the squeezing and slipping under pressure the large crystals were cracked and their fragments rotated until they were nearly parallel with the planes of cleavage. The mica flakes were turned into similar planes and the small grains of quartz and feldspar were broken and recomposed into quartz, feldspar, and mica. This produced a very gneissoid rock, or augen-gneiss, in which porphyritic crystals were cracked and drawn out into separate eyes or strings. In this rock the amount of the distortion can be plainly measured in the less extreme cases by the intervals between the fragments of one crystal. The large feldspars retained their shape better than the finer groundmass, however, and the mica flakes in the groundmass are bent and wrapped around the large feldspars almost as if fluid.

Another result of the deformation is the series of striated and striped surfaces which are common in this formation, as well as in the Cranberry granite. These are due to the linear growths of new minerals, which were arranged parallel to lines of motion in the deformed rock. The dark stripes are composed in the main of fine crystals of biotite and fibrous hornblende, and the light stripes of quartz and feldspar, the new minerals having segregated in this unusual manner. This phenomenon is most common in the vicinity of the fault planes. The entire mass of the granite shows the effect of pressure so extreme as to overcome all the original strength of the rock.

As the formation is attacked by weathering agencies its surface is but slowly reduced. Its siliceous composition, its massive nature, and its great body unite in maintaining the altitude of its areas. In the Asheville quadrangle, where it is best developed, the formation causes such elevations as Bluff Mountain, one of the most conspicuous points of the region. Frequent cliffs mark the course of the more massive beds, and ledges protrude at short intervals. The bowlders and waste from the formation are strewn for considerable distances over the adjoining formations. Upon complete decay the formation produces a reddish or brownish clay of no great depth, mixed with much sand and fragments of rock. Where the soils accumulate on gentle slopes they are strong and fertile, but in this region the formation usually occupies high and steep ground.

ALGONKIAN (?) ROCKS.

METADIABASE.

Outcrops of metadiabase are to be seen on the upper waters of Laurel Creek. A few of these are of sufficient size to be mapped, but most of them are too small to be shown and can not be traced beyond the single outcrops. The formation occurs in a series of dikes cutting the Cranberry granite. The relations and nature of these dikes are well exhibited in the stream cuts near Big Laurel. The bodies of diabase range in thickness from a few inches to 30 or 40 feet, varying rapidly in dimensions. In places these dikes are so numerous that they are greater in bulk than the granite and form rock masses worthy of note. On the weathered sections the waste from the diabase is more conspicuous than the granite, so that the metadiabase is unduly prominent. The area shown on Shelton Laurel Creek seems to be a considerable mass. The metadiabase consists mainly of plagioclase feldspar and hornblende. The feldspar is much altered to chlorite, epidote, and quartz; the hornblende to chlorite and fibrous hornblende. Subordinate minerals are magnetite and epidote, which occur in grains and small knots. The rock is generally of a dull yellowish-green color, due chiefly to the hornblende and chlorite, but varies considerably in its appearance from place to place. The mass on Shelton Laurel Creek shows coarse feldspar crystals, an inch or two in length, arranged in the network that is characteristic of diabase. Most of the other beds are considerably finer, and in the smaller dikes the individual minerals can only with difficulty be seen by the eye.

Metamorphism of the diabase is extensive, and original minerals, such as olivine and augite, are now almost entirely replaced by hornblende, chlorite, and epidote. In the coarser varieties the metamorphism has been much less and has not destroyed the interlocking arrangement of the feldspar crystals. In addition to these alterations of the minerals, which can be readily seen with the eye, a few unaltered portions of the original minerals can be found with the microscope, particularly the augite, surrounded by rims of secondary hornblende and chlorite. As these new minerals formed in a more or less parallel growth considerable schistosity was produced. This is most conspicuous in the small bodies and fine-grained rocks, which were most metamorphosed.

The metadiabase seldom outcrops; weathering quickly reduces it by disintegration of the feldspar and parts of the hornblende, leaving a deep red and brown clay in which are scattered the harder fragments. Consequently the formation occupies depressions, usually lines of drainage if the areas are of large size. The soils are clayey and deep and retain their hold on any slope.

METARHYOLITE.

In the basins of Big Laurel Creek and Ivy River there are many scattered outcrops of this formation. Only a few of them are of sufficient size to be represented on the map. The formation consists of thin beds of metarhyolite, seldom over 5 feet in thickness. It forms sheets and dikes cutting the mass of Cranberry granite. In several places these are so numerous as to compose most of the rock mass, and in those cases are separately mapped. As a rule, however, the areas covered by these beds are not sufficiently large to justify their mapping. In this region, moreover, the heavy forest cover and the small size of the outcrops make it impossible to trace them far.

As the formation is usually seen, it consists of beds of black schist, composed mainly of very fine muscovite, quartz, and black iron oxides. Here and there it has been less metamorphosed and some of the original characteristics of the rock can be seen. These are usually porphyritic crystals of feldspar, more or less flattened. More rarely are to be seen lines of wavy flow banding. The eruptive nature of the metarhyolite in the granite may be easily seen in the larger outcrops. Except that the metarhyolite is later than the Cranberry granite, there is in this region no indication of its age. In the Roan Mountain and Cranberry quadrangles, lying northeast of this, rocks of the same character are probably of Algonkian age, and it is likely that these rocks are of the same age.

The metarhyolite weathers into small flakes and slabs of black schist. The formation is not of sufficient bulk to affect the topography or to produce any considerable amount of soil.

CAMBRIAN ROCKS.

With the deposition of the Cambrian rocks there came a great change in the physical aspect of this region. The sea encroached upon areas which for a long time had been dry land. Erosion of the surface and eruptions of lava ceased and deposition of sediments beneath a sea began. Extensive beds were laid down in some areas before other areas were submerged, and the sediments lapped over lavas and plutonic granites alike. In this quadrangle there are no large bodies of lavas, but they occur a short distance to the northeast, in the Roan Mountain quadrangle. The waste from them all was combined in one sheet of gravel and coarse sand, which now appears as shale, sandstone, conglomerate, and rocks derived from them. The thickness of the first formation varies greatly and abruptly in this region, showing that the surface on which it was laid down was irregular. Subsequent formations of Cambrian age came in a great group of alternating shale and sandstone, followed by an immense thickness of limestone and shale. Fossils of Cambrian age, mainly *Olenellus*, are found as far down as the middle of the sandstone group. The strata lying beneath the fossiliferous beds differ in no material respect from those overlying. All are plainly due to the same causes and form part of one and the same group, and all are closely associated in area and structure.

SNOWBIRD FORMATION.

The principal exposures of the Snowbird formation are found in a belt that passes through the quadrangle just south of Hot Springs. Many smaller areas of the formation, surrounded by Archean rocks, are not far separated from this main body. In Snowbird Mountain, just west of this quadrangle, the formation is conspicuously developed. Throughout this region it rests in its normal position on the Archean rocks and is the first sedimentary deposit thereon. Materials derived from the waste of the granite make up the formation to a large extent. They consist of pebbles and grains of quartz and feldspar, usually more or less rounded. In many places, however, these fragments are angular and show that they have been transported only a short distance from the parent body of granite.

Character.—The formation as displayed in this quadrangle is composed mainly of fine and coarse quartzite. With this are interstratified beds of conglomerate and arkose, as above noted, and subordinate layers of gray and black slate. Some of the quartzites contain much feldspar in small grains, while others contain little but quartz grains. Most of the beds are light colored, white or gray, but there are considerable variations in this respect. Southwest of Max Patch Mountain, for instance, the lower layers are dark bluish gray, a color due to the presence of oxides of iron between the quartz grains. When these beds are considerably weathered oxidation of the iron gives the rock a rusty brown or red color. In the vicinity of Stackhouse they are dark gray, and on the waters of Shelton Laurel Creek the bluish-gray and black layers are of frequent occurrence.

The arkose beds which lie at the base of the formation are either light gray or reddish in color, varying with the color of the feldspar fragments which they contain. Just east of Hot Springs the red color is noticeable, and it becomes conspicuous at the head of Wolf Creek, where it is also much coarser, some of the fragments being an inch in diameter and plainly showing their derivation from the adjacent masses of red Max Patch granite. The arkose layers just west of Allegheny, on Shelton Laurel Creek, are light gray, to which color rock weathering has also changed the red arkose.

In the vicinity of Hot Springs many of the quartzite beds show cross bedding, due to changeable currents during their deposition. Another variety, rather common on the lower part of Spring Creek, is a fine, greenish-gray sandstone or quartzite. In this rock there is considerable fine mica in addition to the usual feldspar and quartz. To this mica, in part chlorite, is due the greenish color.

Northwest of Round Mountain, on the western border of the quadrangle, the top of the formation consists of a massive bed of white sandstone, which is composed of well-rounded grains of quartz sand in a matrix in places siliceous and elsewhere calcareous. Below this follows a thick bed of banded bluish slate, which in turn is underlain by alternating beds of gray sandstone and slate. In that vicinity the amount of slate in the formation is considerably greater than usual. The top of the formation in Rich Mountain is composed of a bed of coarse conglomerate underlain by slates and quartzitic sandstones in alternation. The conglomerate is coarse, many of the pebbles being an inch or more in length. Feldspar, blue and white quartz, and metarhyolite are most prominent in the pebbles.

In the upper portion of the formation the slate beds are most numerous, but they are distributed more or less throughout it. They are best shown in the exposures near Spring Creek and on the north side of Rich Mountain. Their greatest development is in a zone that lies about one-third of the thickness of the formation from the top. The slates are fine grained and argillaceous, sometimes micaceous, and seldom sandy. They are often marked by sedimentary bands of light and dark gray or blue. The slate and quartzite beds are sharply defined from one another in most cases. The abrupt changes in the character of the sediments and the frequent alternations shown thereby indicate extremely variable and unsettled conditions when the formation was deposited. These conditions are such as should be expected, since this was the first sedimentary deposit of the region.

Thickness.—The range in the thickness of the formation is as notable as the variations in its composition, being far greater than that of any other formation in the region. From a minimum of 350 feet on Shelton Laurel Creek it increases rapidly toward the southwest until around Rich Mountain it is nearly 5000 feet thick. As nearly as can be determined this measure is maintained from this point southwestward into the Mount Guyot quadrangle. Owing to the great disturbances which the rocks have passed through, to their poor exposures, and to their heavy cover of timber, it is difficult to arrive at any precise measure of their thickness. An enormous increase in thickness is most obvious, however. From this can be inferred the great inequalities of the sea bottom, inequalities approximately equal to the differences in the thickness of the deposit.

The chief change that has been produced in this rock since it was deposited consists of the silicification of the sandstone into quartzite. In those portions that were feldspathic some of the smaller grains of feldspar have been recrystallized into quartz and mica, giving a somewhat schistose structure. Examples of this structure may be seen in the regions lying southwest of French Broad River. This alteration was effected in the same way as were the similar changes, already described, that occurred in the granite. The interstratified slate beds also received their cleavage at the same time. In places, especially on the upper part of Shelton Laurel Creek, many of them have been thoroughly metamorphosed to black mica-schists. The coarse sandstone and conglomerate were less affected than the fine-grained beds.

The siliceous nature of the formation enables it to resist the attack of weather extremely well. The soils over its areas are thin and much interrupted by rock outcrops. These soils are poor and sandy in all places except in the hollows and coves, where they have accumulated to considerable depths. High, irregular ridges and mountains occupy the areas of the formation. The crests of the ridges are round and the slopes steep, and support but a scanty growth of timber.

HIWASSEE SLATE.

The rocks of this formation occupy three large and very irregular areas lying north and west of Hot Springs. The area on Shelton Laurel Creek is the most important. The name of the formation is derived from Hiwassee River, in Polk County, Tenn., which cuts a fine section through these strata.

Character.—As displayed in this region, the formation consists almost entirely of slate of a bluish-gray or bluish-black color. When the slate is weathered the color becomes greenish, yellowish gray, and yellow. North and northeast of Hot Springs many of the slate beds are somewhat sandy. In the same region they are also a little coarser grained and marked with light-gray, siliceous bands of sedimentary origin. On the other side of French Broad River these rocks are finer grained and more uniform.

In many of the northwestern outcrops the slaty character is less pronounced and some of the layers are almost unaltered shales. A noticeable constituent in some of the beds is mica in fine scales. This was an original deposit in the strata and not a secondary growth, and it is seen in some of the least altered shales. The bulk of the material composing the slates is argillaceous. To this is added here and there the micaceous and sandy material. West of Allen Stand the deposits of sand were considerable enough to make distinct layers 8 to 10 feet in thickness, which locally developed into fine conglomerates.

In the vicinity of Pigeon River and Crabtree Bald the rocks of this formation have a very different aspect, due to metamorphism. They consist almost entirely of schists, of several varieties, with interbedded layers of graywacke. Most of the schists are of dark-gray or black color, varied here and there with lighter gray bands. Sprinkled through these layers are many crystals of ottrelite and garnet. These are frequently arranged in bands along the bedding planes, indicating that certain layers were more favorable than others for the growth of the garnets. The beds of graywacke were probably metamorphosed from rocks similar in character to the feldspathic sandstones seen in the northwestern outcrops of the formation. Except for these layers the schists are fine grained. The schistose planes in that vicinity are usually steep, and as a rule diverge from the bedding. The secondary mica flakes, therefore, do not follow stratification lines unless they have about the same dip as the schistose planes. In the schists lying nearest the base of the formation the metamorphism is greatest and bedding planes are most difficult to distinguish. The banded layers afford no such difficulty.

Limestones.—The most noticeable variation from the slates, and one which most strictly distinguishes this formation from the other slates of the region, is a series of calcareous beds that are interstratified at intervals with the slates. They occur in the shape of more or less interrupted lenticular layers. These are absent from the formation south of Hot Springs, but characterize all of its other areas. In the area lying southwest of this quadrangle they are found in the formation for many miles, but they do not appear to extend northeastward beyond the border of the quadrangle. The limestone varies considerably within short distances. That most commonly found is a blue or dove-colored limestone containing many rounded grains of quartz sand. Beds of this kind are very prominent immediately east of Allen Stand. Associated with these, near the border of the quadrangle, are considerable thicknesses of blue or gray oolitic limestone. The greatest thickness of the calcareous beds in this vicinity is about 300 feet. In places the siliceous material is so prominent that the rock becomes a calcareous conglomerate containing pebbles of quartz and feldspar. This phase is seen around Allen Stand, but is very local and passes within short distances into the more usual kind. The same variety appears 3 miles west of Deep Gap and again on Paint Creek about 3 miles above its mouth. Occasionally beds of limestone conglomerate are found, especially north of Round Mountain. The pebbles in the conglomerate comprise the varieties of limestone which are seen in solid layers, and appear to have been derived from the breaking up of the layers nearly in position. This indicates that the deposit was formed in shallow water, where erosion could affect the newly formed beds.

As nearly as can be determined the formation has an average thickness of from 1200 to 1500 feet. In the area passing south of Hot Springs its thickness is approximately 1300 feet; in Meadow Creek and Paint mountains, from 700 to 900 feet, thus becoming thinner in a northwest direction.

The strata of this formation have not been excessively modified by deformation. Its principal result has been the production of slaty cleavage. This has not entirely obliterated the bedding in most cases where that was originally well marked. In the finer portions, where the grain was at first uniform throughout, it is now very difficult to detect the bedding planes. Only in a few rare cases on the upper parts of Shelton Laurel Creek and along Pigeon River, as above stated, has the deformation been sufficiently extreme to produce mica-schists. These are very fine grained and are dark bluish, gray, or black in color.

The rocks of this formation do not withstand the action of weather as well as those of the other Cambrian formations. Decomposition makes its way down the partings of bedding and cleavage and the rock is broken up in small fragments and flakes. On the steep slopes, where the areas of the formation are upheld by the adjoining harder quartzites, there are frequent ledges and outcrops, and the soil is thin and scanty. In most areas the slates spread out considerably and cause low ground. This is more commonly the case where the calcareous beds come in toward the southwest. In these situations considerable soil accumulates and affords fair farming ground.

COCHRAN CONGLOMERATE.

North and west of Hot Springs several areas of the Cochran conglomerate are found in the same general localities as the Hiwassee slate, just described. This formation is so named from its occurrence around Cochran Creek, on Chilhowee Mountain, in the Knoxville quadrangle.

Character and extent.—In the Asheville quadrangle the formation consists chiefly of coarse and fine conglomerates, sandstones, and quartzites. White or light-gray colors characterize the sandstones and quartzites, while the conglomerates are frequently dark gray and bluish gray. The dark colors prevail in the vicinity of Paint Rock. The conglomerate beds are distributed generally throughout all the areas of the formation. They are coarsest 2 miles northwest of Deep Gap, where many of the pebbles exceed 2 inches in length. Conglomerates with pebbles an inch in length are found on the north slope of Paint Mountain; also 2 miles south of Deep Gap, 3 miles southeast of Paint Rock, and in the area lying southwest of Hot Springs. Elsewhere the formation consists mainly of fine conglomerates, coarse sandstones, and quartzites. The individual beds of conglomerate can not be traced for great distances and are more properly coarse sandstones containing variable quantities of large pebbles. In nearly all cases the materials of the conglomerate are well worn. This is noticeably true of the coarse pebbles, some of which are most perfectly rounded. Far the greater number of the pebbles are of white quartz. With these are associated pebbles and grains of feldspar, which are less rounded than the quartz pebbles. Characteristic of the formation are pebbles of black slate, apparently derived from the underlying Hiwassee slate. These appear in practically all parts of the formation, but are least common in the coarse, well-rounded conglomerates. Of frequent occurrence, also, are pebbles of black metarhyolite, apparently the same rock that appears in the Algonkian formations. These pebbles are most conspicuous in the coarsest conglomerates, and their well-rounded shapes plainly show that they have traveled great distances.

The matrix of the conglomerate is substantially the same as the body of the coarse sandstones and consists of coarse and fine grains of quartz and feldspar. The feldspar grains are frequently angular on account of the cleavage of the mineral. The quartzites consist almost entirely of fine quartz grains, more or less cemented by secondary quartz. Quartz of this character is also present, though to a less extent, in all of the sandstones and conglomerates. In some of the more feldspathic layers secondary mica has been developed, as well as the quartz, and the rocks have the aspect of graywacke. This is more common south of French Broad River than elsewhere.

Interstratified with the siliceous beds in practically all parts of the formation are unimportant beds of slate. These are most numerous in the vicinity of Paint Rock and Allen Stand. The slates are dark bluish and gray and resemble the Hiwassee slate in all particulars.

From the coarseness of the fragments in this formation it is inferred that the formation was deposited by strong currents. Some of the well-rounded material was evidently derived from far distant sources, while much was as plainly of local origin, especially the feldspar and slate pebbles. The variations in the conglomerates and the alternation of conglomerate and fine shale indicate that the conditions under which they were deposited varied rapidly. In these respects the Cochran conglomerate closely resembles the Snowbird formation. Areas of metarhyolite are found only in regions northeast and east of this, so that some of the material, at least, came from those directions.

Great variations are seen in the thickness of the formation. Southwest of Hot Springs it attains its greatest thickness, 2500 feet, while southeast of Hot Springs it is less than half as thick. In Paint Mountain it is 1100 to 1200 feet thick, but its thickness appears to be considerably less in the vicinity of Paint Rock and Deep Gap. In the latter localities, however, it is highly contorted and measurements of its thickness are unsatisfactory.

Alterations.—There are no striking changes in the formation due to metamorphism. Secondary quartz, as already stated, has converted many of the sandstones and fine conglomerates into quartzites, especially in the southern and eastern exposures. In the coarse conglomerates, however, such results are very rare; the feldspathic matrix has been affected most of all. Alterations in this matrix proceeded in the same manner as in the similar minerals of the granites; secondary quartz, feldspar, and mica were developed and a limited amount of schistosity was produced. The fine secondary mica plates lap around the coarse pebbles where the latter are of considerable size. Some of the pebbles are cracked and dented by other pebbles, and the fragments are somewhat dislocated. These are usually recemented by secondary quartz. The general appearance of the rock, however, is seldom greatly altered.

The siliceous nature of the formation enables it to withstand erosion successfully. This is especially the case in the region north of French

Broad River, where bold bluffs and ridges follow the course of the formation. Along the main divides the conglomerate maintains great elevations, which are in some measure due to the weakened power of the streams. Sharp-topped ridges and steep slopes are found in all places. The soils are thin, sandy, and full of bowlders, and are of practically no value for agriculture or timber. Many ledges and cliffs jut through the cover of soil, especially where the finer quartzites predominate. The waste from these spreads far over the adjoining slates.

GREAT SMOKY CONGLOMERATE.

In Crabtree Bald and the surrounding regions two areas of the Great Smoky conglomerate are to be seen. This formation is so named from its notable development in the Great Smoky Mountains, southwest of Pigeon River. In this quadrangle it corresponds in position and in general character to the Cochran conglomerate. As the formations are traced southwestward, however, though each remains a conglomerate, substantial differences appear in bulk and in associated sediments, so that it is advisable to distinguish the two. It is possible that in regions lying farther southwest the Great Smoky represents a greater lapse of time than the Cochran conglomerate.

Character.—The formation contains a considerable variety of strata, comprising conglomerate, quartzite, graywacke, mica-schist, and slate. The original character of the beds is plainest in the conglomerate, whose layers range in thickness from 1 to 50 feet. The pebbles are finer in this than in the Cochran conglomerate and seldom exceed one-half inch in length. From this they grade into coarse and fine quartzites and graywackes. All of these rocks are of a decided gray color, becoming whitish on exposure, by the weathering of the feldspar that they contain. This change is most noticeable in the conglomerates whose feldspars are the coarsest and least metamorphosed. Most of the pebbles are of white quartz. Near Pigeon River there are many pebbles of blue quartz, derived from the blue-quartz granites of that region. Feldspar pebbles characterize the conglomerates throughout their areas, and in places there are found pebbles of schist like the underlying Hiwassee schist. Interbedded with these coarse rocks are numerous seams and beds of mica-schist and slate.

Alterations.—The beds of graywacke are most altered and in many places can be distinguished from the gneisses of the Archean only with great difficulty. In Crabtree Bald they are most metamorphosed. On the lower part of Pigeon River they are less so, however, and are seen to be derived from coarse feldspathic sandstones. Some of the pebbles retain their original rounded form, while many have been crushed and squeezed. In Crabtree Bald and Oak Mountain many pebbles are flattened to one-fifth of their original thickness. Much secondary mica was developed at the same time, in coarse and fine flakes. The feldspar grains recrystallized into quartz and mica during metamorphism. As was the case in the Hiwassee slate, the planes of these secondary minerals dip at high angles. They may be parallel to the stratification planes or may diverge from them, according to the folding of the strata.

In most of the areas the original shales have been metamorphosed to schists. On the lower part of Pigeon River they are somewhat less altered, and seams of slate are found. The schists are of a light- or dark-gray color, while the slates are considerably darker and are indistinguishable from the strata of the Hiwassee. Most of the beds of slate and schist are less than a foot in thickness. Occasionally, however, they are as much as 25 to 30 feet thick. The best measure of the thickness of the formation places it at 750 feet. The metamorphism is so great, however, that this measure is not very certain.

The rocks of this formation are very resistant to erosion. The quartz and mica are very slowly soluble, and the feldspathic material is not sufficient in the more altered varieties to cause ready disintegration. Decay begins along the planes of schistosity and the rock breaks up into many slabs and fragments. These are left in the soils, which are thin and sandy and in the most altered varieties are very micaceous. High mountains and peaks mark the Great Smoky conglomerate throughout, and on their slopes and crests are many ledges and cliffs. On the broader summits west of Pigeon River the formation bears thick and fairly fertile soil.

NICHOLS SLATE.

Character.—This formation is named from Nichols Branch of Walden Creek in Chilhowee Mountain, Knoxville quadrangle, Tennessee, where it occurs in typical form. The Nichols slate in this quadrangle consists largely of fine-grained rocks that vary from slates to shales, according to the degree of their metamorphism. The slates are dark gray and bluish gray, and are sometimes marked with light-gray bands like the layers of the Hiwassee slate. The shales are usually micaceous, fine scales of mica having been deposited when the rock was formed. A very small amount of secondary mica was also developed as the strata were folded. Many of the layers of the formation are sandy as well as argillaceous, the clayey character being, however, the predominant one. There are no notable variations in the formation except for the included quartzite mass.

Thickness.—There are considerable variations in the thickness of the formation. The slates vary from 300 to 1300 feet, the greatest development being in Paint Mountain and the least in the vicinity of Hot Springs. There appears to be no system in the variations. It is possible that the changes in thickness are only apparent and are due, in part at least, to the close folding of the beds. Except for the quartzites, the layers of the formation are very similar to one another, and it is impossible to tell whether or not any part has been repeated.

Alterations.—Few obvious changes have been made in these strata by metamorphism. The chief result has been a slaty cleavage, and in no case has the rock been transformed into a schist.

The action of weather on the beds of this formation is similar to that on the Hiwassee slate. The beds are not especially soluble, but their argillaceous materials decompose. The disintegrated mass is comparatively soft and crumbling and is worn down with relative ease. The areas of the formation are usually upheld by the adjoining quartzites and conglomerates, but form depressions between the ridges and knobs of the latter. The soils are thin and dry and of small value except here and there in the coves, where timber flourishes.

Quartzite lentil.—Included in the formation are several layers of quartzite, one of which develops into a considerable mass. In this quadrangle it is of sufficient size to be mapped, but has not been recognized in the adjoining quadrangles. These beds strongly resemble the succeeding quartzite formations. They are fine or medium grained and consist almost entirely of rolled quartz sand, recemented by secondary quartz. The quartzite lentil ranges in thickness from 350 to 750 feet, the thickest measures being in Paint and Meadow Creek mountains, where the slates also are thickest. The effects of these strata on the topography and the soils are precisely the same as those of the other quartzites.

NANTAHALA SLATE.

Several areas of Nantahala slate are found in the same region as the Great Smoky conglomerate. The strata of this formation correspond in general position to those of the Nichols slate. The different layers are also of the character which would be produced in the Nichols slate by sufficient metamorphism. In this region no formation is seen overlying the Nantahala slate, and only 700 feet are left in the synclines. The thicknesses seen where the formation is entire, in quadrangles lying southwest of this, are much greater and considerably exceed those of the Nichols slate.

The greater part of the formation is composed of black and gray mica-schists and ottrelite-schists. These strongly resemble the schists of the Hiwassee formation. The mica-schists are, as a rule, somewhat darker, the color being due to very minute grains of iron oxides. Many of the layers are composed of light-gray, dark-gray, and bluish-gray bands, and these layers in particular can not be distinguished from the Hiwassee schists. These are derived from banded slates like those which occur in the Nichols slate.

Many of the layers are sprinkled with crystals of garnet, and ottrelite is a universal constituent of the formation. The crystals of the ottrelite are arranged with their cleavage at right angles to the planes of schistosity, a relation characteristic of this mineral throughout the region. The garnet crystals are frequently grouped in bands that follow the stratification, as in the Hiwassee slate. This feature also characterizes the staurolite-schists that are common at the base of the formation. A band of the schist a few inches wide may be full of staurolite and the adjoining band may contain none. The garnet and ottrelite crystals are seldom more than one-tenth of an inch in diameter, while the staurolite crystals are from 2 to 4 inches in length. There appears to be no special arrangement of the axes of the staurolite crystals. At the base of the formation there is considerable interbedding with the Great Smoky conglomerate, and many unimportant layers of graywacke are found here and there in the Nantahala slate.

The formation weathers very slowly, because it has few soluble constituents. The rocks gradually crumble, however, and the disintegrated portions are not hard enough to withstand great wear. Solid rock is seldom far from the surface, and many broad, rounded ledges characterize the formation. Its soils are thin and sandy and full of mica and of slabs of schist. The formation occupies lower ground than the Great Smoky conglomerate and forms low spurs and depressions between the mountains of the latter.

NEBO QUARTZITE.

The strata of this formation that occur in this quadrangle are found chiefly north and west of Hot Springs. The formation is named from Nebo Springs, on Chilhowee Mountain, Tennessee, where it is conspicuously exposed. Most of the areas are irregular on account of the complicated folding of the strata. The formation is composed almost entirely of quartzites and sandstones. Interbedded with these are minor layers of shale and slate, which are visible only near streams on which the sections are clean cut. It is possible that the amount of these layers is greater than it would seem, the weaker beds being covered by soil and heavy vegetation.

The quartzites and sandstones are practically all light gray or white and all become white on exposure. Most of the beds are fine grained, although a few are coarse enough to be considered conglomerates. This is the case in the upper part of the formation on Meadow Creek Mountain. The slate and shale beds are gray and bluish gray, argillaceous, and sandy. Usually they are much weathered and of a dull-yellow color. There is practically no material in the siliceous strata except quartz. Originally this was all in the form of rounded grains of sand. Now, in many places, owing to the deposition of secondary silica during metamorphism, the original grains are closely cemented. Frequently they break with a clean, conchoidal fracture entirely irrespective of the bedding planes and the granular structure. Except for this silicification little change was produced in the formation by metamorphism.

The thickness of the formation varies greatly, ranging from 350 feet in Meadow Creek Mountain to about 1600 feet around Hot Springs. In Paint Mountain the formation is about twice as thick as in Meadow Creek Mountain. Thus, in this formation, as in those just described, the thicknesses show a general increase to the southeast.

The Nebo quartzite resists the weather better than any other of the Cambrian strata, for its purely siliceous composition makes it nearly free from the effects of solution. This is most apparent near French Broad River, in Paint Rock and many other cliffs. The slaty beds gradually decompose and crumble and the siliceous beds break up along the bedding and joint planes, chiefly by the action of frost. Slowly the fragments slide down the slopes and are removed by the streams, being carried to great distances before disintegration is complete. The soils covering the formation are very thin and sandy and support only the scantiest growth of timber.

MURRAY SLATE.

Outcrops of Murray slate are limited to narrow belts at Hot Springs and in Paint and Meadow Creek mountains. The name of the formation is taken from Murray Branch of Walden Creek, new Chilhowee Mountain, Tennessee. The formation consists of shales and slates, and is practically indistinguishable from the Nichols slate. The strata are argillaceous or micaceous, and in places sandy. The micaceous character is most apparent in those shales that are least altered. These strata, like those of the Nichols slate, are occasionally marked with light-gray and dark-gray bands due to sedimentation. In the more slaty portions of the formation south of Hot Springs the prominence of these bands has been greatly reduced by the cleavage.

Measurements of the thickness of the formation are very hard to obtain. The beds are often contorted, and their areas are covered with wash from the adjoining quartzite formations. As nearly as it can be estimated, the thickness of the formation varies from 300 to 450 feet.

The Murray slate withstands erosion to about the same extent as the Nichols slate. It breaks down slowly into flags and small flakes, chiefly through the action of frost. Outcrops are very rare except along stream courses and divides. The softness of the formation as compared with the adjoining quartzites causes it to occupy depressions and slopes between the quartzite ridges and spurs. Soils are thin and light upon the ridges and accumulate to considerable depths in the hollows, where a good growth of timber is found.

HESSE QUARTZITE.

The Hesse quartzite occupies three areas of considerable size adjoining those of the Murray slate. The formation has been so named because it occurs in typical form on Hesse Creek near Chilhowee Mountain, Tennessee. Its strata can not be distinguished from those of many of the older quartzites. They are composed almost entirely of white quartzite, in which are included a few minor layers of argillaceous and sandy shale of the same character as the preceding shale formations. The quartzites are fine or medium grained in this quadrangle and the variations in its appearance are very slight. In the vicinity of Hot Springs the grains of the original sandstone are most thoroughly recemented by secondary silica. The rock there is a fine-grained, glassy quartzite of exceeding hardness. At the end of Meadow Creek Mountain it passes upward into the Shady limestone through 25 to 30 feet of yellow, sandy shale and calcareous sandstone. In a few localities scolithus borings are found in the quartzite layers, such as characterize the uppermost Cambrian quartzites throughout this region.

The formation is about 700 feet thick in Meadow Creek Mountain and somewhat thicker in Paint Mountain. In the vicinity of Hot Springs the thickness appears to vary from 700 to 1200 feet. Owing to the great deformation of the rocks in that region, however, these measurements are of very doubtful value.

The strata of this formation resist the weather in the same manner as those of the Nebo quartzite. Ledges are frequent, but there are few cliffs. The soils are poor and sandy and, except those formed by the topmost sandy shales, are of little use for any purpose.

SHADY LIMESTONE.

Three areas of this formation are found within the limits of this quadrangle. The formation is named for its occurrence in Shady Valley, Johnson County, Tenn. It consists almost entirely of limestone and dolomite of various kinds, more or less crystalline. With the advent of this formation there was a change in the distribution of land and sea—one of the most marked changes in Appalachian history. Sediments deposited previous to this time had been coarse and siliceous and plainly derived from neighboring land masses where erosion was active. In this formation the amount of shore material is inconspicuous and far the greater proportion of the rock is carbonate of calcium. The rock is fine grained and uniform in composition over very large areas. The amount of erosion was, therefore, abruptly reduced at this time, probably by submergence of the land and recession of the shore toward the east and south. The general conditions which then prevailed continued far into Ordovician time with no great modification.

Varieties—Several kinds of limestone are seen in the formation. In color they are in general bluish gray or gray and are apt to weather dull gray or black. Some of the layers are mottled gray, blue, or white, and often seamed with calcite. The formation is nearly 1000 feet thick in this vicinity. In the area southeast of Meadow Creek Mountain beds of white limestone or marble occur in considerable thickness near the bottom of the formation. These are less prominent around Hot Springs. On these layers the black surface of weathered outcrops is most noticeable. A considerable percentage of carbonate of magnesium is contained in these layers. Thin seams of blue and gray shale occur in a few parts of the formation, and a few beds of red shale in its upper layers make a transition into the overlying Watauga shale. Siliceous impurities in the form of sand grains are found in a few beds in the limestone, and chert is somewhat more common. This mineral usually forms small, round nodules with gray surfaces and concentric gray and black bands inside. Another variety has the structure of chalcedony and occurs in lumps a foot or more in diameter.

Weathering proceeds faster in this formation than in most others of the region. The rock dissolves, leaving a dark-red clay which contains many lumps of chert. As these lumps are seldom abundant enough to protect the surface entirely from removal, the formation makes valleys and low hills. Its clays and soils are deep and strong and afford excellent farming land wherever they are not too much encumbered with wash from the siliceous formations. As a rule, however, the natural soils are very much altered and impoverished by this waste. In the red clays of this formation occur extensive deposits of brown hematite and manganese oxide.

WATAUGA SHALE.

Character—Two narrow areas of Watauga shale appear next above the Shady limestone. The name of the shale is derived from Watauga River, in Carter County, Tenn., along which it is finely exposed. The formation consists of a series of interbedded red, brown, yellow, green, and variegated shales, shaly sandstones, and impure limestones. Much the greater part of the formation is made up of highly colored shales, in places calcareous, in places sandy, and usually argillaceous. When perfectly fresh many layers appear as blue or drab limestone. Slight exposure produces in them reddish colors and shaly partings. The limestone beds are blue and blue-gray in color and show all grades of transition from limestone to red shale. The thickness of the limestone layers in this vicinity seldom exceeds 3 feet and usually is considerably less. The beds of red sandstone are local and argillaceous and differ from the sandy shale chiefly in being more massive. They reach in places a thickness of 6 feet and are closely interbedded with the shale.

The thickness of the formation in the vicinity of Meadow Creek Mountain is between 1000 and 1100 feet. Both there and near Hot Springs the top of the shale has been removed by erosion and the full thickness is not shown.

A great many of the layers, of both shale and sandstone, are covered with trails left by crawling animals. Both shales and sandstones are also ripple marked in many places, and a few of the sandstones are cross-bedded. These features and the alternation of the sediments show that the conditions which controlled their deposition had not quite attained the balance and quiet which characterized subsequent deposition. The red and highly colored muds from which these strata were formed were probably derived from a land mass which had long been subject to disintegration and decay.

Chert—A widespread part of the calcareous strata is chert, which is more prominent in the lower beds of the formation. In the vicinity of Hot Springs, however, the amount of chert in the formation is very small. It occurs in nodules and masses that sometimes reach a diameter of 1 foot and are of a very tough and durable nature. The iron oxide which colors the shale so strongly is in places combined with the chert to such an extent that the mass becomes an ore. In this region, however, the proportion of chert is far too great and the term ore is not applicable. Small deposits of brown hematite free from siliceous impurity also occur in the beds of shale, but are of no economic importance.

None of the beds of the formation withstand weathering successfully. The calcareous beds are speedily dissolved, leaving the shales and sandstones to crumble and break down. The chert is very durable, but is not sufficient in amount to protect the other beds. The sandy material is able only to form low ridges and rounded knobs, which are brought into small relief by the Shady limestone valleys. Soils are deep only over the calcareous strata and are kept loose by the sand and bits of shale. While seldom very fertile, they are fairly productive, and are all accessible and easily cultivated.

HONAKER LIMESTONE.

This is the next younger formation after the Watauga shale, but in this region the two do not come into contact. One very small area of the Honaker is seen in the northwest corner of the quadrangle, where the formation is brought up along a fault. This area and another just north of the quadrangle are the ends of somewhat larger masses in the Greeneville quadrangle. The formation in this quadrangle is less than 100 feet thick. The strata are composed of massive limestone of a bluish or gray color and are of the same character throughout these limited exposures. That part of the limestone which normally rests on the Watauga shale is not visible, nor is the upper portion of the Watauga shale. The character of their contact can not be stated, therefore. The limestone passes up into the Nolichucky shale with but a few feet of interbedded limestone. The upper part of the Honaker consists of dark-gray limestones, which weather into small lumps with black surfaces. The soils and topography of the formation in this quadrangle are unimportant on account of the limited size of the area.

NOLICHUCKY SHALE.

The Nolichucky shale is seen in the same region as the formation just described, but in slightly larger areas. It is named from Nolichucky River, along whose course in the Greeneville quadrangle the shale is well exhibited. The formation is composed of calcareous shales and shaly limestones, with beds of massive blue limestone in its upper portion. The included limestones are unimportant in this region, but are developed toward the northeast. When fresh the shales and shaly limestones are bluish gray and gray in color, but they weather readily to various shades of yellow, brown, red, and green. Most of the shale here consists of yellow and greenish-yellow beds. Over this region the formation shows no variations. Its thickness is between 450 and 500 feet. These are the most fossiliferous of the Cambrian rocks, and remains of animals, especially trilobites and lingulas, are very common.

Solution of the calcareous parts is so rapid that the rock is seldom seen in a fresh condition. After removal of the soluble constituents decomposition is slow. Complete weathering produces a stiff yellow clay. Weathered rock lies near the surface and the covering of soil is accordingly thin, except where the formation presents very gentle slopes, which are covered by a deep clay. The soils are well drained by the frequent partings of the shale, but at their best they are light and poor and liable to wash. The shale forms valleys and slopes along the Knox dolomite ridges.

ORDOVICIAN ROCKS.

KNOX DOLOMITE.

Age.—While the Knox dolomite does not belong entirely in the Ordovician, a large part of it is of that age, and as the formation can not be divided it is all described with the Ordovician rocks. The lower portion in adjoining regions contains a few middle Cambrian fossils, and in this and other quadrangles the upper portion carries many Ordovician fossils, largely gasteropods. It is impossible, however, to draw any boundary between the parts of the formation. The Knox dolomite is the most important and widespread of the Valley rocks. Its name is derived from Knoxville, Tenn., which is located on one of its areas.

Character.—The formation contains a great series of blue-gray or whitish limestone and dolomite (magnesian limestone), usually very fine grained and massive. Many of the beds are banded with thin, brown, siliceous streaks. Interbedded with the dolomite are beds of white, calcareous sandstone a few feet thick. These are poorly exposed in this region, but are well developed a little farther north and west. They are made up of fine, rounded sand grains lying in a calcareous cement, and are most noticeable a little above the Nolichucky shale. These grade from calcareous sandstone into slightly siliceous marble, in places coarsely crystalline.

Included in the beds of limestone and dolomite are nodules and masses of black chert, locally called "flint." In this region the cherts are less conspicuous than in areas of the dolomite farther north. They are commonest in the lower part of the formation, and in places, by the addition of sand grains, they grade into thin sandstones. The formation is about 3500 feet thick in this region.

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

Weathering.—The dolomite weathers speedily on account of the solubility of its materials, and outcrops are rare at a distance from the stream cuts. The formation is covered to a great depth by red clay; through this are scattered the cherts, which are very slowly soluble. These are gradually concentrated by the solution of the overlying rock, and where they are most plentiful they constitute so large a part of the soil that cultivation is almost impossible. This condition is not attained in areas shown in this quadrangle. The cherts are all white when weathered and break into sharp, angular fragments. The formation causes broad, rounded ridges more or less protected from erosion by the covering of chert. Such soils are always subject to drought on account of the easy drainage caused by the chert, and sinks and underground drainage channels are common in them. In many places water is obtainable only from stopped-up sink holes, from wells, or, rarely, from springs.

ATHENS SHALE.

One narrow belt of Athens shale is seen in this quadrangle, on the north side of Meadow Creek Mountain. It there lies against a fault plane, on which are brought up the Cambrian quartzites. The shale is named for its occurrence at Athens, McMinn County, Tenn. It is composed of black and bluish-black shales and is the latest formation shown in this quadrangle. The shales are all calcareous and, especially at the bottom, are carbonaceous and full of remains of graptolites. All of the strata here shown are very fine grained and thin bedded, and sedimentary banding is seldom visible. On account of the obscurity of the bedding planes and the presence of the cleavage in the formation its thickness is difficult to measure. The strata here exhibited are probably 300 feet thick. The transition from the Athens shale to the underlying Knox dolomite is rather sharp and indicates a sudden change in the relations of land and sea at that time. This change compares in magnitude and extent with that which immediately preceded the deposition of the Shady limestone.

The rock weathers rapidly at first by solution of its calcium carbonate, so that ledges are found only near stream cuts. The lumps and flakes of argillaceous matter left behind are very slow to decompose and crumble, and turn yellow only after long exposure. The soils on the formation are unimportant in this region and are overspread with wash from the Cambrian quartzites.

STRUCTURE.

INTRODUCTION.

Those rocks of the Asheville quadrangle that were deposited upon the sea bottom must originally have extended in nearly horizontal layers. At present, however, the beds of strata are seldom horizontal, but are inclined at various angles, their edges appearing at the surface. Folds and faults of great magnitude occur in the Appalachian region, their dimensions being measured by miles, but they also occur on a very small, even a microscopic scale. Many typical Appalachian folds are to be seen in the Asheville region. In these folds the rocks have changed their forms mainly by adjustment and motion on planes of bedding and schistosity. There are also countless planes of dislocation independent of the original layers of the rocks. These are best developed in rocks of an originally massive structure and are usually much nearer together and smaller than the planes on which the deformation of the stratified rocks proceeded. In these more minute dislocations the individual particles of the rocks were bent, broken, and slipped past one another or were recrystallized.

Explanation of structure sections.—The sections on the structure-section sheet represent the strata as they would appear in the sides of a deep trench cut across the country. Their position with reference to the map is on the line at the upper edge of the blank space. The vertical and horizontal scales are the same, so that the actual form and slope of the land and the actual dips of the layers are shown. These sections represent the structure as it is inferred from the position of the layers observed at the surface. The minute details of structure can not be represented on the scale of the map, and they are, therefore, somewhat generalized from the dips observed in a belt a few miles in width along the line of the section. Faults are represented on the map by a heavy solid or broken line, and in the section by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the direction in which the strata have been moved on its opposite sides.

GENERAL STRUCTURE OF THE APPALACHIAN PROVINCE.

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

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

Faults.—Faults appear on the northwestern sides of anticlines, varying in extent and frequency with the changes in the strata. Almost every fault plane dips toward the southeast and is approximately parallel to the beds of the upthrust mass. The fractures extend across beds many thousand feet thick, and sometimes the upper strata are pushed over the lower as far as 10 or 15 miles. There is a progressive change in the results of deformation from northeast to southwest, and different kinds prevail in different places. In southern New York folds and faults are rare and small. Through Pennsylvania toward Virginia folds become more numerous and steeper. In Virginia they are more and more closely compressed and often closed, while occasional faults appear. In passing through Virginia into Tennessee the folds are more broken by faults. In the central part of the valley of Tennessee folds are generally so obscured by faults that the strata form a series of narrow overlapping blocks of beds dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

Metamorphism.—In the Appalachian Mountains the southeastward dips, close folds, and faults that characterize the Great Valley are repeated. The strata are also traversed by minute breaks along cleavage lines and metamorphosed by the growth of new minerals. The cleavage planes dip eastward at angles ranging from 20° to 90°, usually about 60°. This phase of alteration is somewhat developed in the Valley as slaty cleavage, but in the Mountains it becomes important and frequently obscures all other structures. All rocks were subjected to this process, and the final products of the metamorphism of very different rocks are often indistinguishable from one another. Throughout the southeastern part of the Appalachian province there is a great increase of metamorphism toward the southeast, until the resultant schistosity becomes the most prominent of the Mountain structures. Formations in that region whose original condition is unchanged are extremely rare, and frequently the alteration has obliterated all the original characters of the rock. Many beds that are scarcely altered at the border of the Valley show greater and greater changes as they are traced southeastward, until every original feature is lost.

In most of the sedimentary rocks the bedding planes have been destroyed by metamorphic action, and even where they are distinct they are usually less prominent than the schistosity. In the igneous rocks planes of fracture and motion were developed, which, in a measure, made easier the deformation of the rocks. Along these planes or zones of extreme motion the original texture of the rock was largely destroyed by the fractures and by the growth of new minerals, and in many cases this alteration extends through the entire mass of the rock. The extreme development of this process is seen in the mica-schists and mica-gneisses, the original textures of which have been entirely replaced by the schistose structure and parallel flakes of new minerals. The planes of fracture and schistosity are inclined toward the southeast through most of the Mountains, although in certain belts, chiefly along the southeastern and southern portions, northwesterly dips prevail. The range of the southeasterly dips is from 10° to 90°; that of the northwesterly dips, from 30° to 90°.

Earth movements.—The structures above described are chiefly the result of compression which acted most effectively in a northwest-southeast direction, at right angles to the general trend of the folds and of the planes of schistosity. Compression was also exerted, but to a much less extent, in a direction about at right angles to that of the main force. To this are due the cross folds and faults that appear here and there throughout the Appalachians. The earliest-known period of compression and deformation occurred during Archean time, and resulted in much of the metamorphism of the present Carolina gneiss. In is possible that later movements took place in Archean time, producing a portion of the metamorphism that appears in the other Archean rocks. In the course of time, early in the Paleozoic era, compression became effective again, and a series of movements took place that culminated soon after the close of the Carboniferous period. The latest of this series was probably the greatest and to it is chiefly due the well-known Appalachian folding and metamorphism. This force was exerted at two distinct periods, the first deformation producing great overthrust faults and some metamorphism, the second extending farther northwest and deforming previous structures as well as the unfolded rocks. The various deformations combined have greatly changed the aspects of the rocks—so much so, in fact, that the original nature of some of the oldest formations can be at present only surmised.

In addition to the force that acted in a horizontal direction, this region has been affected by forces that acted vertically and repeatedly raised or depressed the surface. The compressive forces were tremendous, but were limited in effect to a relatively narrow zone. Less intense at any point, but broader in their results, were the vertical movements that extended throughout this and other provinces. It is likely that these two kinds of movement were combined during the same epochs of deformation. In most cases the movements have resulted in a warping of the surface as well as in uplift. One result of this appears in overlaps and unconformities of the sedimentary formations.

As was stated under the heading "General geologic record" (p. 1), depression of this kind took place at the beginning of the Paleozoic, with several repetitions later in the same era. They alternated with uplifts of varying importance, the last of which closed Paleozoic deposition. Since Paleozoic time there have been at least four, and probably more, periods of decided uplift. How many minor uplifts or depressions have taken place can not be ascertained from this region.

STRUCTURE OF THE ASHEVILLE QUADRANGLE.

Larger features.—The rocks of this quadrangle have undergone many alterations since they were formed, having been bent, broken, and metamorphosed to a high degree. The structures which resulted from these changes trend in general northeast and southwest. In this quadrangle, however, there is much less regularity than is usual in the Appalachians. The Asheville quadrangle can be divided into two areas in which the geological structures differ widely from each other. They correspond closely with the areas covered by the Cambrian and Archean rocks, and the differences in structure are due in large measure to differences in the character of the rocks. The structures in the sedimentary rocks are readily deciphered. In the igneous and metamorphic rocks, however, though it is easy to see that they have been greatly disturbed and though the details of the smaller structures are apparent, yet it is difficult to discover the larger features of their deformation.

Folds and faults.—In the Cambrian area the rocks are involved in large folds and broken by immense thrust faults. Both the faults and the folds vary widely in direction, especially east of Hot Springs, where they change within short distances from nearly east-west to nearly north-south courses. The axes of the folds are neither straight nor continuous for long distances, but the pitch in many places is as great as the dip upon the flanks of the folds. This is notably the case in the vicinity of Stackhouse; also on the headwaters of Paint Creek, and at several points along Paint Mountain. Most of the faults dip toward the southeast, as do the majority of Appalachian structures. An unusual number of exceptions to this rule are found in this region, however. The fault that passes through Deep Gap (shown in section C–C) and a small one 2 miles south of Wolf Creek (section D–D) illustrate these exceptions.

Most of the faults of the region are not extreme in dip or amount of throw. Their courses exhibit many different directions, but are fairly constant for each individual fault. Thus the fault planes intersect one another, producing a series of branching faults and cutting the crust of the earth into a most irregular series of blocks. The planes of the different faults vary in dip from 20° to 60°, being usually between 30° and 40°. It is difficult to obtain measures of the throw on these fault planes, the minimum thrust being from 1 to 2 miles, much less than the great Hot Springs fault. They partake somewhat of the character of the latter, in that their planes do not follow the stratification very closely. Their origin in and connection with anticlines is apparent in many places, as, for instance, at the east ends of Paint Mountain and Meadow Creek Mountain. In Paint Mountain the pitch of the associated fold persists throughout the entire length of the mountain and thus brings eight of the Cambrian formations against the fault plane in turn.

Curved faults.—The great fault which passes just north of Hot Springs is one of the most unusual in the Appalachians. Its outcrop forms a nearly complete oval and its planes, if extended upward, would almost unite in a dome. Starting in an overturned fold southeast of Stackhouse, its plane dips successively toward all points of the compass and dies away in another fold parallel to and 2 miles northwest of its starting place. In its production are exhibited compression and shortening, not only in the usual northwest-southeast direction but in all others. The area inclosed by the fault plane thus represents a downthrown mass upon which the adjoining rocks were piled high from all sides. The plane cuts abruptly across the edges of the strata at many points, particularly where the mass of Max Patch granite is thrust forward upon them, and the usual connection of anticlinal fold and fault is not obvious here. The features of this fault are indicated in sections C–C and D–D. The dip of the plane varies from nearly flat at the foot of Bluff Mountain up to 50° or 60° east of Hot Springs. The evidence needed for measuring its maximum throw is not sufficient. It has, however, a displacement of at least 3 miles.

The north-south fault which passes 2 miles east of Stackhouse is similar to the foregoing fault in all its features except that its plane is not so curved. This, too, gives evidence of a considerable shortening of the earth's crust in an east-west direction. To account for the features which faults of this kind exhibit, they must be considered as planes of shearing that pass through the granites and sedimentary rocks and are little influenced by the attitudes of the stratification planes. In this respect they differ widely from the prevailing Appalachian faults, which lie for the most part parallel to the stratification.

Structures in Archean rocks.—The second area with distinctive structures appears in the Archean rocks, covering the greater part of the quadrangle. In this the effects of deformation are chiefly seen in the schistosity and foliation of the igneous and crystalline formations. Folds are also to be seen, but they are subordinate to other structures. They are best defined in the basin of Pigeon River, where bodies of sedimentary rocks are folded in with the Archean granites and gneisses. Folds of considerable importance are also seen near Clyde, in the contorted Roan and Carolina gneisses. Similar results appear in the vicinity of Alexander and a few miles northeast of Marshall. If the original attitudes of the Archean formations were known, as in the case of the sediments, many other folds could undoubtedly be determined. The formations are so much larger, however, and distinctive beds that can be followed are so few, that it is difficult to trace connections between one part of the gneisses and another. For the same reasons it is practically impossible to determine fault planes except where they involve the sedimentary strata. In many cases they are highly probable, as for instance along the west foot of Crabtree Bald.

Repeated folding.—As was stated in the description of the Carolina and Roan gneisses, the foliation evident in them was produced at an exceedingly early date. In the later or post-Carboniferous compression, these foliation planes were deformed by folding. Thus were produced the larger folds, such as those near Clyde, and the minor folds and wrinkles which are seen by scores in every large outcrop. The conditions of deformation were such as to fold and mash rather than break the layers, and the bands of gneiss are variously twisted and grow thicker and thinner from place to place. Bending of the beds was largely accommodated by motion along the foliation planes.

Mashing.—In the granites during the same period of folding there were no existent foliation planes. Under the great stress, however, planes and zones of shear and mashing were produced and change of form took place on them. The dips of these planes are almost altogether toward the southeast and are nearly uniform over large areas. They vary in amount from 20° up to vertical, averaging 50° or 60°. Along the contacts of the formations the planes of schistosity are roughly parallel to the contact, in both dip and direction. Within the body of each formation, however, there are considerable divergences from the direction of the contact. Around the more massive and resistant portions of the rocks, also, the schistose planes swing gradually. In places where the motion was especially localized, as in the vicinity of fault planes, the minerals of the granite were elongated into thin sheets and strings or striated forms. In many other places in the body of the granite similar results are to be seen and may be due to the same conditions.

The sedimentary rocks of the Pigeon River basin also show effects of mashing, such as were seen in the igneous rocks. The strata were compressed and loaded far beyond their strength; and recrystallization of the rock minerals took place, sometimes along minute breaks and slip planes and also throughout the strata as a whole. The growth of these minerals was in places sufficient to transform the strata entirely. Thus, a formation which appears as slate and shale west of Wolf Creek has become a garnet- and staurolite-schist near Pigeon River. The feldspathic sandstone and conglomerate south of Hot Springs are metamorphosed into a coarse and fine graywacke on Crabtree Bald. Banded slates and shales have become black mica- and ottrelite-schists, and the entire series of rocks plainly shows the most intense pressure. However, the change in form by folding which accompanies this is no greater than that seen in the folded and faulted areas farther north.

In the structure section it is not possible, on account of the small scale, as has already been stated, to show the minor folds and wrinkles, so that the structure is necessarily generalized and represented as comparatively simple. In sections D–D and F–F some of the larger folds in the gneisses are represented. To control the representation of the form of bodies of granite and gneiss beneath the surface there are no known laws such as justify the representations of underground strata. In many places the granite bodies can be seen protruding through the gneisses from below. In other places the same relation can be deduced from a study of the topography. There are also many places in which the bodies of Roan and Carolina gneisses and soapstone plainly rest at various discordant angles within and upon the bodies of the granite. As a general principle, moreover, it is evident that the granites were intruded into the gneisses from larger bodies of granite lying deeper in the earth. For these reasons the granite masses have been represented as growing larger downward.

MINERAL RESOURCES.

The rocks of this region are of use in their natural state, as soapstone, talc, barite, marble, corundum, garnet, building stone, and road material, and in the materials that may be developed from them, such as iron, lime, and clay.

Besides the deposits which are generally known to be valuable, there are numerous others which are interesting and which may in future have a more decided value. Most noticeable of these are the nickel, chrome, and asbestos deposits associated with the dunite masses.

SOAPSTONE.

Soapstone and allied rocks are found here and there in the Archean formations at frequent intervals throughout the entire length of the Appalachians. Although the material is thus very widespread, few of the areas are over a mile in length. Some of the bodies measure but a few feet, and not many of them cover more than an acre. The soapstone and talc are derived by metamorphism from very basic intrusive rocks and are usually associated with dunite, serpentine, chlorite, schist, and other products of metamorphism. These metamorphic products are often found together in each area. In the French Broad Valley soapstone is by far the most common, more than eighty separate areas being known below Asheville.

In places the soapstone is sufficiently pure for economic use. As a rule, however, talc, the hydrous silicate of magnesia forming the soapstone, is too much mixed with other silicates, especially those of the hornblende family, to be valuable. The special uses of soapstone demand a rock which is readily cut and sawed and which contains no material that is affected by fire. Some of the hornblendic minerals fuse readily, and others which fuse less easily are hard and injure the texture and interfere with the working of the stone. The igneous rocks from which the soapstones were formed vary much in composition, so that the beds of soapstone are equally variable in quality. Metamorphism of the original rock was not always complete and did not always produce a soapstone even when complete. Accordingly, in this quadrangle large bodies of soapstone are rare. It usually occurs in seams or layers between or around serpentine and dunite. On the economic geology map are indicated those areas where soapstone is found in sufficient body to be valuable. Thus far, however, only loose blocks and bowlders have been sawed and used in building fireplaces. In no place has the rock been quarried to any extent.

TALC.

The talc deposits of this region are connected with the bodies of soapstone already described. The bodies of workable talc are concentrated in a belt 4 or 5 miles wide, lying along French Broad River, on both sides of the stream, between Marshall and Alexander. The talc, or hydrous silicate of magnesia, was formed by alteration of basic rock which contained originally an abundance of magnesian silicates. In most cases, however, there were formed in addition to the talc a number of other silicates containing magnesia, such as chlorite, tremolite, actinolite, and hornblende. As a rule, the talc is equaled or exceeded in amount by the other silicates. Why the talc predominates in one locality and the other silicates in another is a matter of doubt. In many places a portion of the mass is mainly talc or very pure soapstone, while other portions may be filled with the silicate minerals. Where there are differences of this kind in a single soapstone body the purer soapstone and talc are usually at the borders of the mass, having been influenced in some manner by the contact of the adjoining rocks.

Besides the talc of this form, pure talc is found also in veins a few inches in width that pass here and there through the mass of the rock. This form of the mineral is usually fibrous or foliated and free from the objectionable silicates. Talc veins of this character seem to be of later formation than the large bodies of talc and the soapstones. These veins are found also in the serpentine and dunite masses, together with veins of chlorite. The talc so far mined has been taken from the veins and from the purer portions at the borders of the soapstone masses. Although the amount of talc disseminated through the soapstone is vastly greater, it is not practicable to separate it from the chlorite and other minerals which are intermingled with it. In following the vein talc there is a fair amount of certainty as to the product, both in quality and in quantity. In the bordering bodies of talc the quantity is much greater and can be determined fairly well. The quality is quite uncertain, however, and the value of the talc is liable to be much lessened by the presence of the other silicates. It is impossible to say in advance where the quality of the talc will be thus depreciated.

The talc is almost entirely white, sometimes translucent, but usually opaque. It is probable that if work were pushed into the solid rock the translucent material would be found predominant. Thus far mining has been confined to pits in clay and decomposed rock. In this material stains of earth and iron oxide are common. The talc thus far produced varies from massive to fibrous, the latter being the most common, and it is fitted only for grinding into powder. Although the available amount of talc of this class is considerable, practically none is produced now, and the industry is at a standstill.

ASBESTOS.

At many points in the various dunite bodies asbestos is found. It occurs in veins that intersect the dunite at various angles and apparently fill the spaces between broken blocks of the dunite. The thickness of the veins varies greatly within short distances, ranging from 8 inches down to fractions of an inch. Most of the veins are less than 2 inches thick. The principal exposures are in the dunite body 3 miles northeast of Stockville. A small amount of prospecting has been done in this place, but there is no development of note. Many of the other dunite masses contain small veins and seams of asbestos, which are, however, of no body or importance. The quality of the mineral is excellent. The fibers run from wall to wall across the vein, and their length is thus measured by the thickness of the vein. Most of the material now visible is weathered, but it is fairly tough, and that in the fresh rock promises to be of good quality.

This asbestos is a silicate of magnesia with a little alumina, and is properly called chrysotile. As is indicated by its occurrence in veins that intersect the dunite, it is clearly a secondary mineral. It shows no traces of mechanical deformation or alteration, and is thus one of the latest minerals in the dunite. It is therefore of later origin than most of the silicates in the adjoining formations, for their positions were determined by pressure during deformation. The unaltered dunite consists mainly of olivine, a silicate of magnesia alone. To form the asbestos the addition of alumina and more silica was necessary. These might readily have come from the minerals of the adjacent formations, which contain them in abundance. The cracks between the dunite blocks would have furnished this material ready access to the interior of the dunite.

BARITE.

Barite is found in a narrow area about 5 miles long running a little north of east from Bluff, on Spring Creek, to and across French Broad River. It occurs mainly in the granite masses and to a less extent in the feldspathic quartzites of the Cambrian. It usually lies near the contacts of the two formations. The barite occupies irregular veins and gashes in the country rock, and one body can seldom be followed for any considerable distance. The veins are rarely over a foot in thickness and are usually only a few inches. Accordingly, much useless rock has to be handled in getting out the ore. The barite is well separated from the inclosing rock. There are practically no other minerals associated with the barite.

The country rock was much broken and shattered before the formation of the barite, and the spaces were filled with the ore. From the arrangement and crystalline condition of the barite, it is evident that it was deposited from aqueous solutions. As to the derivation of the material in solution there is no evidence; probably it came from the great mass of granite within which it is now found. All of these barite areas occur in a belt near and parallel to one of the principal thrust faults of the region. The rocks were greatly disturbed during the production of the original fault plane, and later, to a less extent, during its secondary deformation. It appears most likely that the crushing of the quartzites seen in the barite deposits was associated with this later deformation. In the old workings on Spring Creek, near the level of the creek, the barite-bearing quartzites are very close to the thrust fault and there seems to be a distinct connection between the fault and the barite. The barite occurs in large crystals and crystalline masses which have not been deformed, as were the minerals of the inclosing rocks. From this it is clear that the barite was deposited after the period of faulting and folding, and although the shattering of the rock may have been due to the folding, the barite must have been introduced later. The crevices in the shattered granite afforded comparatively easy access to the solutions that carried the barite, but no direct connection in origin can be traced between the faults and the barite deposits.

At present only the deposits on Spring Creek are being mined. A considerable amount of barite was taken from the veins a mile southeast of Stackhouse, but the deposits on Doe Branch were never developed to any extent. Southeast of Stackhouse small open cuts were made and short shafts and tunnels were driven. These were nearly on the crest of a ridge, and penetrated for some distances the more or less weathered granites. On Spring Creek the mining has been done chiefly through open cuts. These are now of considerable size and much material has been removed. The openings lie on ridges which are about 500 feet above water level and which slope steeply toward Spring Creek. The surroundings are thus favorable for extensive operations, and the quantity of barite appears to be large.

CORUNDUM.

Five areas are known within this quadrangle where corundum occurs. This mineral is an oxide of aluminum and is found in association with masses of dunite or serpentine, or rocks which are closely allied to them. In two of the areas at the head of Hominy Creek the accompanying rock is dunite and serpentine. In the remaining areas it is mainly amphibolite. The corundum is found near the contacts of these rocks with the adjoining formations, which in all cases here include the Roan gneiss. Wherever the corundum can be found in place it occurs in vein-like masses associated with chlorite, usually near the borders of the dunite masses. The chlorite and corundum lie in more or less distinct layers, in which the crystals have no definite arrangement. The corundum is crystalline in form and varies in size from mere grains up to poorly formed crystals an inch or two in diameter. It is usually of a dull-gray or bluish-gray color.

The origin of the corundum is a matter of considerable doubt. From its close connection with the borders of the dunite and inclosing formations there is little doubt that its deposition was related to that contact. The idea has been advanced that it was formed by the eruptive contact of the dunite with the inclosing rocks, and was among the earliest minerals so produced. The associated chlorite and hornblendic minerals are all silicates of magnesia, much the same in composition as the minerals of the dunite and allied masses at places where there is no corundum. There is little or no alumina in the minerals of the dunite except the corundum. In the adjoining formations, however, it is present in great quantities in the form of silicates, and chemical reactions between the two masses may have led to its deposition near the places of contact. In the formation of the hornblendic minerals, which was the chief change from the olivine of the original rock, there was a large addition of silica. This necessarily came from the adjoining more siliceous formations. It is therefore possible that the alumina was set free by the absorption of the silica into the dunite and crystallized as the oxide in the zone where the reactions took place. The vein-like form of the deposits is in favor of this view and is strongly against an origin of the corundum earlier than the deformation of the rocks.

The rocks which inclose the corundum are extremely old, and during their metamorphism, as has already been stated, most of the minerals which now compose them were formed. The crystals of these minerals lie with their major axes in definite positions, usually about parallel to one another. The various magnesian silicates which accompany the corundum, chlorite and tremolite in particular, most obviously lack this arrangement, although the same minerals in other parts of the dunite and adjoining formations are strongly marked in that way. Hence it is clear that where these minerals are grouped with the corundum they are of secondary origin. Therefore, two classes of secondary minerals must be recognized—those formed by metamorphism under pressure, and those of vein-like form, including chlorite, corundum, and feldspar. From the close association of the corundum with the vein-like minerals it is probable that the corundum also is secondary. Moreover, there is in the corundum itself no evidence of metamorphism by pressure, although evidence of pressure is distinctly seen in the inclosing rocks. It shows no rearrangement of the cleavage planes or major axes in one general direction, as is the case in most minerals acted upon in that way. Yet the corundum could not have escaped the deforming influences if they were in operation in the rock. Nor is there any change of the crystalline form of the corundum, although its prominent cleavage would have made a change easy. For these reasons, accordingly, it is highly probable that the corundum was not an original part of the rock.

While corundum has been noted at only five localities in this quadrangle, the same relations of the dunite to other formations are repeated in seventy-five other places. Thus it is more than likely that corundum may be found at many other localities. The work thus far done in developing the extent of the corundum consists of shallow shafts and pits. These have scarcely tested the amount in any place, so that definite statements in that connection can not be made.

GARNET.

Garnet is found in large amounts west and northwest of Marshall in crystals thickly scattered through the mica-schist. The crystals range in size from 6 inches down and are usually well formed dodecahedrons. The inclosing mica-schist is part of the Carolina gneiss and is near small bodies of the intrusive Cranberry granite and the Roan gneiss. It is not, however, strictly a contact deposit. Four miles S. 60° W. of Marshall and 1 mile south of Little Pine Creek the garnet is now mined for use as an abrasive. The ore consists of the garnet crystals, which are taken from the schist by hammer and pick. A tunnel follows the "vein" a short distance into the hard rock, where it is from 8 to 10 feet thick, and numerous test pits have developed the garnet over a length of one-fourth mile. Like the inclosing schist, the vein dips from 30° to 50° toward the southeast. Its strike is 30° east of north and it appears to continue northeastward 2 miles, to French Broad River, one-fourth of a mile above Little Pine Creek. One-eighth of a mile northeast of the river the large garnets appear again, but the farther extent of the vein is not known.

NICKEL.

Ores of nickel are found 3 miles northeast of Canton, 2 miles southeast of Leicester, and 3 miles northeast of Stocksville, the three points being nearly in line with one another. The nickel occurs in the form of a hydrous silicate, probably genthite, filling tiny veins and cracks and coating the surfaces of the dunite. Occurring with the nickel silicate, and in the same manner, is found much chalcedony, or amorphous silica, in thin sheets and veins. These intersect the rock at various angles and strew the surface of the ground with lumps of silica like honeycomb.

The dunite is reported to show a trace of nickel in all analyses; this may be combined with the chromite. The concentration of the nickel into the silicate coatings is made possible by the crevices and joints that penetrate the dunite in all directions. So numerous are they that the dunite is in many places a breccia. Some of the fragments have separated half an inch and the cracks filled with nickel ore. Such a condition is probable only near the surface of the earth. Accordingly, the nickel ore is inferred to be a secondary deposit—one of the most recent in the dunite. This conclusion is supported by the freedom of the nickel ore and accompanying quartz from deformation. All occurrences thus far seen are above drainage level and appear to be due to hydration processes near the surface of the ground. From this region the depth of the deposits can not be ascertained, but it is not likely to be great. Northeast of Stocksville considerable material was exposed in the search for chromic iron and corundum, but no notable developments have been made. Extensive tests of similar deposits have recently been made near Webster, about 40 miles southwest of Canton. The best ore there is stated to contain as high as 7 per cent of nickel, and the quantity in sight is large. In that case it has been difficult to find a suitable commercial process for reducing the ore.

CHROMITE.

Chromite is found in the dunite area 3 miles northeast of Stocksville and on the border of this quadrangle. It forms small grains disseminated through the mass of the dunite. Just east of this point many test pits were dug and considerable rock was blasted, but no chromite deposit of importance was found. In many other places chromic iron is seen in the dunite in the same form, and, in fact, it appears to be a constant accompaniment of that formation. In no part of this quadrangle has a noteworthy deposit been discovered.

IRON ORES.

Magnetite.—Magnetic iron ore is found in five general localities in this quadrangle, viz: 5 miles nearly west and 6 miles nearly north of Alexander, 3 miles west of Barnard, 1 mile about east of Jupiter, and in Haywood County at the head of Hurricane Creek. In the latter three of these localities the magnetite is inclosed in granite. West of Alexander it is in mica-gneiss. In the latter region, however, many dikes of granite cut the mica-gneiss, so that the situation is not widely different. Besides these principal localities there are many others in which magnetite float ore is found. These lie in a belt which crosses the basin of French Broad River in a general northeast direction just a little below Marshall.

At the locality north of Alexander known as the Big Ivy mine, on the south bank of Big Ivy River, magnetite was developed in two open cuts and a number of pits. These exposed the ore for a length of several hundred feet in a northeast-southwest course. It is many years since work has been done on this deposit. The magnetite has been traced both to the southwest and to the northeast by means of the float ore and the dip needle. Across Big Ivy River it extends northeastward for nearly 3 miles. The ore occurs in a vein that dips steeply toward the northwest about parallel to the inclosing walls of hornblende-gneiss. The thickness of the vein is as great as 50 feet, but its depth has not been developed. The magnetite is hard and granular and is associated with a gangue of hornblende, epidote, and quartz.

Five miles west of Alexander magnetite outcrops on a smaller scale. The ore consists of compact magnetite and is found in a vein from 2 to 3 feet thick. It is inclosed in walls of hornblende-mica-gneiss and dips southeastward with them at an angle of about 70°. The actual exposure of the ore is insufficient to show the amount of the deposit. By means of the float the deposit can be traced for several miles toward the southwest.

At other points indicated on the economic map magnetite is found in considerable quantities, but it has not been exploited to any notable extent. From many other localities small quantities of magnetite float ore are reported.

Specular hematite.—On Wolf Creek, 2 miles northwest of Bluff Mountain, is found a deposit of specular hematite. This occurs in irregular veins cutting the red Max Patch granite. The veins are small and without definite trend or dip and they may be better described as a group of fissures in the more or less shattered granite. The ore incloses and is mixed with many fragments of the granite. Little work has been done to develop the extent of the ore, and its value is problematic.

Brown hematite.—Ores of this nature are abundant in the northwestern part of the district and include limonite and various combinations of the hydrate and oxide of iron. They occur as lumps and masses in the residual clays of the Shady limestone and are most plentiful on Shut-in Creek and along the south slope of Meadow Creek Mountains. These ores are usually very pure and were worked in the old forges at Hayesville Furnace, just north of the border of this quadrangle. In recent years considerable ore has been taken out for shipment from the deposits on Shut-in Creek.

Small bodies of brown hematite are found here and there along the various fault planes in the areas covered by the Cambrian quartzites. These ores are usually siliceous and grade into ferruginous breccias of no value. Other small deposits are found at various situations in the Cambrian shales, but these are never of any great extent. Brown hematites are also found in very limited quantities throughout the areas underlain by Carolina gneiss and Roan gneiss, especially the latter. None of these seem to be extensive and they have not been at all developed.

Ores in the Shady limestone, like most of the ores of this class in the Appalachians, are very pure and have furnished most of the ore mined. The amount of ore in the clay varies much. On Shut-in Creek it is most abundant at the west end of the belt of limestone, where that rock lies in a synclinal basin surrounded by ridges of harder quartzite. The same structure is seen south of Meadow Creek Mountains, most of the area of the limestone, however, appearing only on the north side of the fold. The hematite is most abundant near the contact of the limestone and the underlying quartzite, and is found here and there along practically the entire contact. The upper portions of the limestone contain very little ore. Its presence in the lower layers near the quartzite appears to be due to downward concentration into those layers. The limestone itself contains little or no ferruginous material, so that the hematite is probably derived from the quartzite series, in which are found small accumulations of pyrite. The depth of the ore has not been tested except in shallow pits and open cuts. It is probable that in this region, as in other places where there are similar occurrences, the clays containing the ore are not much more than 30 feet deep.

LIME.

There are three general situations in this quadrangle in which limestone is found suitable for making lime. These are all in the northwest portion of the quadrangle and below Hot Springs. Most important is the Knox dolomite, lying northwest of Meadow Creek Mountains. Many of its beds are very pure limestone, especially in the upper part of the formation. This material was used in the old iron works at Hayesville Furnace. The second general group of lime rocks is found in the Shady limestone. Near the east end of Meadow Creek Mountains these have been burned on a small scale. The same formation at Hot Springs has furnished much lime. Prominent outcrops in an excellent situation on French Broad River, a mile below Hot Springs, yielded abundant material. In the Hiwassee slate limestone is found in lenticular deposits in an irregular belt running northeast-southwest through Paint Rock. Some of these are of considerable length, for instance, one lying on Little Laurel Creek just south of Allen Stand, where the limestone body has a thickness of over 100 feet and a length of over 4 miles. On the headwaters of Big Creek, also, near the west edge of the quadrangle, there are many outcrops of the same kind of limestone. They are all more or less siliceous, but are sufficiently pure to furnish material for any local needs.

Outcrops of these different limestones are common near the stream courses, but on the intervening hill slopes are comparatively rare. This is especially true of the Shady limestone, which shows in body only on the lower portion of Cove Creek, on Shut-in Creek, and near Hot Springs, although its areas are large.

MARBLE.

Among the strata of the Shady limestone are many beds which are suitable for use as marble. These occur in the lower layers of the formation near the Hesse quartzite. In the areas of this formation just west of Hot Springs and also at the east end of Meadow Creek Mountains these beds appear. In other areas they are concealed from view, although they probably underlie the surface.

The marble occurs in massive beds from 1 to 5 feet thick showing very little stratification. The marble beds are white and are interbedded with dark-blue crystalline limestones. The grain of the marble is fine, but is coarser than that of the blue limestones of the Shady or that of the strata of the Knox dolomite. On weathered surfaces the outcrops of the marble have a decidedly black color. This color does not extend into the rock, nor does it appear on surfaces which have been artificially broken and exposed for years. From the natural outcrops of the marble its durability can be inferred, and its strength is assured by the hardness of the rock. None of its other qualities have been tested, nor has the stone been used at all as marble. The best situations for developing it are west of Hot Springs, where it has been burned for lime. At that point the marble occupies bluffs and cliffs that rise directly from French Broad River, so that good rock could easily be procured and water and waste material disposed of. Transportation would be furnished by the railroad which passes by the deposit.

BUILDING STONE.

Stone of value for building purposes is found in many of the formations in this quadrangle, especially the Archean. Both the Max Patch and the Cranberry granites are conspicuous in this respect. Those portions of the Max Patch in particular that are marked by red feldspar and epidote are very ornamental. The porphyritic masses in the Max Patch granite also present a striking appearance. The beds of these are heavy, and large blocks can be cut in many places, although this, like all of the rocks in the region, is more or less schistose. The Cranberry granite has no special features of color or marking, but its light color and fairly uniform texture make it adaptable to many purposes. Opportunities for quarrying this rock are abundant near the French Broad and its tributary streams, especially Spring Creek and Laurel Creek.

The best granite of the region is found in the small bodies and dikes which cut the Carolina gneiss and the other granites. These are very common in the southeastern half of the quadrangle, but are best shown between Alexander and Asheville. On the uplands they rarely outcrop, but near the streams they are fresh and easily reached. Small openings have been made on them in many places, but these have hardly more than tested the quality of the rock. The stone is fine grained and massive and has practically no schistosity. Its color is light gray to nearly white, and it may be worked readily into any shape desired. Many of these granite bodies are of sufficient size for quarrying, although most of them are measured by only a few feet. Thus far this granite has been used chiefly for road material. A number of the macadamized roads north of Asheville have been constructed of this rock and have been found very satisfactory.

The various Cambrian quartzites have also furnished building material to a very limited extent from loose bowlders, which have been utilized in chimneys, bridge abutments, and in the old iron furnaces. The rock parts readily into beds from 6 inches to 2 feet in thickness, but is extremely tough and is hard to drill and dress. Along French Broad River below Paint Rock, and just above Hot Springs, are large outcrops of quartzite in suitable locations for quarrying. Many of the thin sandstone and quartzite layers in the Cambrian formations can be quarried readily into flagstones. They are from 2 inches upward in thickness and come out in slabs of large size.

Another class of building stone, one which has been much used, is the Knox dolomite. The area of this rock in the quadrangle is small. Its beds are from 6 inches to 2 feet in thickness and part readily along the bedding planes. It is readily cut and dressed and will support great weights. It has been used in many of the railroad bridge abutments, having been brought from Tennessee by rail.

The dams that have been built across Hominy Creek and French Broad River for the purpose of developing power were constructed of rock obtained from the heavier beds of the Carolina gneiss. Only strength and durability are required for this work, and the material was found near at hand. The same material has been largely used in the city of Asheville for foundations and similar work.

BRICK CLAYS.

All of the formations in this region except the Cambrian quartzites form clays on decomposition. These are of various kinds—argillaceous, sandy, or micaceous—and they extend over nearly the whole quadrangle. On the slopes of the mountains and ridges and the steep borders of the canyons along the main streams the amount of clay is very small. Over the remaining plateau areas, composing somewhat less than half of the quadrangle, the cover of clay and decayed material is often 50 feet deep. The best clays occur along the flood plains of the larger rivers and creeks and in the small valleys and hollows on the plateaus which have not been reached by the later cutting of the streams.

The flood-plain clays are limited in amount and are not found all along the river courses. Below Hot Springs and in the vicinity of Asheville on French Broad River clay is commonly found, but between those points the stream flows too rapidly to lay down clays and only sandy deposits appear. The few clay deposits on Pigeon River are above Clyde, almost all of the flood plain being sandy and gravelly.

The chief sources of clay are the small hollows and stream heads on the old plateau surfaces. Into these the finest portions of the decomposed rock were washed and formed excellent clay deposits. There are thousands of these within the quadrangle, and the total amount of material of that kind is very great. These clays are from 1 to 6 feet deep, being thickest in the bottoms of the hollows and thinner on the hill slopes. These have been burned into bricks at a great number of places for local use, and the material is so generally distributed that no special developments have been made.

ROAD MATERIAL.

Material for constructing roads is abundant throughout the quadrangle. Along the uplands of the French Broad and Pigeon plateaus it is comparatively scarce, but rock is available near most of the watercourses, which cut the region with a network of channels. In the vicinity of Asheville many macadamized roads have been built, the material used being obtained from the granite dikes above mentioned and the Carolina gneiss. These crush into sharply angular forms, pack well, and contain so much silica that they stand a great deal of wear. Except on these roads practically no use has been made of the abundant road materials, and rock along the course of a road has been regarded as a drawback or hindrance.

The other granites of the region all furnish abundant road material, and usually enough can be picked up from the ground adjoining to macadamize the roads wherever necessary. The same is true of the Cambrian quartzites in the regions occupied by them. They crush into angular fragments, are extremely durable, and give good drainage. Good natural roads are found along the areas of the Cambrian shales. They are well drained and smooth, but are not very durable. The best materials for road building in the quadrangle are the different calcareous beds, the Knox dolomite, and the Shady limestone. They are easily crushed; their fragments pack together firmly and become recemented by the lime which they contain. No practical use has yet been made of these materials in the quadrangle. Excellent material of a different kind is to be had from the metagabbro and many portions of the Roan gneiss. These rocks are hard and tough and consist largely of hornblende. By decomposition of the hornblende iron is set free, which recements the mass in a measure, as is the case with the calcareous rocks. The two largest bodies of this material are found near Alexander, on the French Broad, and Grantville, on Ivy River. In the Roan gneiss scattered over the Asheville Plateau are thousands of beds of similar composition.

WATER POWER.

The resources of this quadrangle in the form of water power are very great. The streams, both great and small, fall rapidly in nine-tenths of the area. Their flow is very steady from season to season, since they are fed from multitudes of springs and drain well-forested areas. The stream grades are divided into three general groups according to their relations to the large topographic features. These are below, above, or on the old plateau surfaces. As explained under "Geography," the Pigeon and French Broad plateaus were once well developed and covered about half the area of the quadrangle. Above them were large areas of mountains that were never reduced to the level of the plateaus.

Since the formation of the plateaus the streams have acquired fresh power and have recut their channels to greater depths. The new cuts are greatest in the lower portions of the main streams and are progressively shallower toward their heads. Down the slopes of the mountains the small streams descend with very heavy grades, usually from 100 to 300 feet per mile. As they pass through the margins of the plateaus they descend slowly, usually much less than 30 feet per mile. When they reach the heads of the newer cut channels they descend rapidly again at grades from 20 to 100 feet per mile. The newer cutting of the French Broad extends entirely through this quadrangle, but the upper part of the Pigeon has not yet seriously cut into the old plateau. The cutting on the larger tributaries extends back 5 to 10 miles from the French Broad and much less from the Pigeon.

The total descent of the French Broad in this quadrangle is a little over 800 feet in a distance of about 45 miles. The descent is accomplished by a large number of rapids and abrupt descents of a few feet each. In the smaller streams the total fall is much less, but is concentrated into shorter distances. In 30 miles of the French Broad above Hot Springs there are not more than five or six smooth stretches a quarter of a mile long. Below Hot Springs there are a number of these. The smaller streams have practically nothing of the kind, except Pigeon River, which flows smoothly near its plateau surface for 7 or 8 miles in this quadrangle.

The water power developed in this region is thus attained primarily by the elevation and recutting of the old plateau. Since the large streams are nearly all below the plateau level, those water powers which are above it are in most cases on small streams and are of no great amount. Practically the only exceptions to this are Crabtree and Fines creeks, which descend to Pigeon River with many small falls. While the existence of heavy grades is in general determined by these geographic features, they are localized by the harder beds of rock. The differences of grade caused in this manner are most conspicuous on the small streams. Where the French Broad cuts through the Carolina and Roan gneisses the rock is uniform and causes little variation in the grade. Where the river enters the granite areas its channel is more contracted and the grade is locally somewhat greater. The quartzite beds still farther down the river produce the most distinct falls, such as are seen a mile above Hot Springs, where there is a direct drop of about 6 feet.

The water power thus at hand has been used for many years in only the most limited ways. Gristmills and sawmills have been turned by the small streams, but nothing more. Within the last few years, and especially in the vicinity of Asheville, extensive dams have been built and power has been taken from Hominy Creek and Ivy River. This has been transformed into electrical energy and carried to Asheville. The French Broad at Marshall and Big Pine Creek opposite Barnard have been dammed for manufacturing purposes. An extensive plant is now being constructed immediately below Asheville to dam and utilize the French Broad. As a whole, however, development has barely begun, and scores of similar plants might be put on the rivers in their courses through this quadrangle.

October, 1903.

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

TOPOGRAPHY

NORTH CAROLINA - TENNESSEE
ASHEVILLE QUADRANGLE

(Morristown) (Greeneville) (Roan Mt.) (Mt. Guyot) (Mt. Mitchell)

ENGRAVED FEB. 1901 BY U.S.G.S.

LEGEND

RELIEF
(printed in brown)

2082 Figures (showing heights above mean sea level instrumentally determined)

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

DRAINAGE
(printed in blue)

Streams

CULTURE
(printed in black)

Roads and buildings

Churches and school houses

Private and secondary roads

Trails

Railroads

Bridges

Ferries

State lines

County lines

Triangulation stations

Bench marks

(Cowee) (Pisgah) (Saluda)

H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr and S. S. Gannett.
Topography by W. L. Miller.
Surveyed in 1898-99.

MAGNETIC NORTH
TRUE NORTH
APPROXIMATE MEAN DECLINATION 1904.

Scale $\frac{1}{125000}$

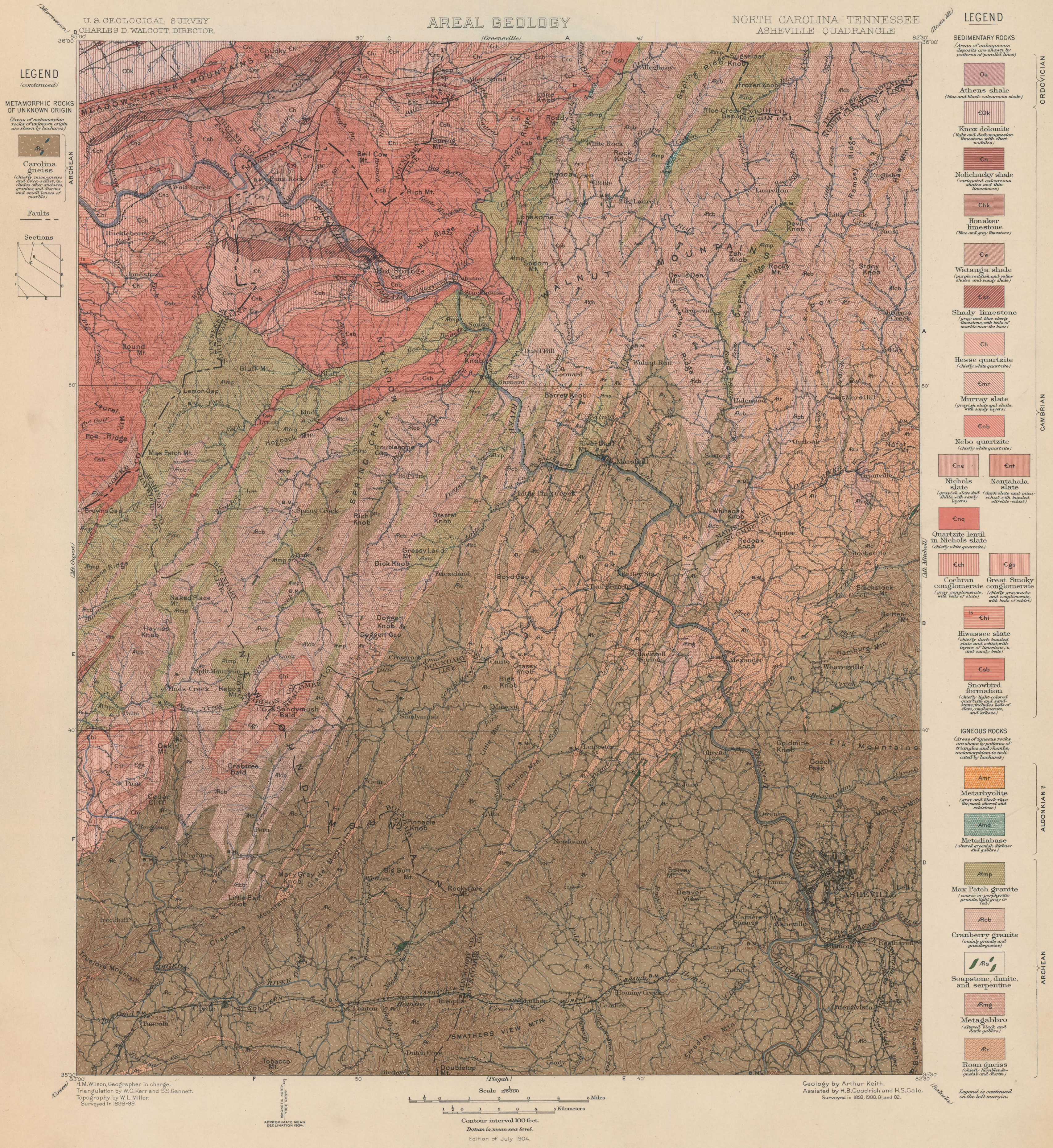
1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

Edition of June 1904.


U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR
AREAL GEOLOGY
NORTH CAROLINA-TENNESSEE
ASHEVILLE QUADRANGLE
(Morristown)
(Greeneville)
(Roan Mt.)
(Mt. Guyot)
(Mt. Mitchell)
(Cowee)
(Pisgah)
(Saluda)
LEGEND
(continued)
METAMORPHIC ROCKS OF UNKNOWN ORIGIN
(Areas of metamorphic rocks of unknown origin are shown by hachures)
ARc
Carolina gneiss
(chiefly mica-gneiss and mica-schist; includes other gneisses, granites, and diorites and small lenses of marble)
ARCHEAN
Faults
Sections
LEGEND
SEDIMENTARY ROCKS
(Areas of subaqueous deposits are shown by patterns of parallel lines)
Oa
Athens shale
(blue and black calcareous shale)
ORDOVICIAN
€Ok
Knox dolomite
(light and dark magnesian limestone with chert nodules)
€n
Nolichucky shale
(variegated calcareous shales and thin limestones)
€hk
Honaker limestone
(blue and gray limestone)
€w
Watauga shale
(purple, reddish, and yellow shales and sandy shale)
€sh
Shady limestone
(gray and blue cherty limestone, with beds of marble near the base)
€h
Hesse quartzite
(chiefly white quartzite)
€mr
Murray slate
(grayish slate and shale, with sandy layers)
€nb
Nebo quartzite
(chiefly white quartzite)
€nc
Nichols slate
(grayish slate and shale, with sandy layers)
€nt
Nantahala slate
(dark slate and mica-schist, with banded ottrelite-schist)
€nq
Quartzite lentil in Nichols slate
(chiefly white quartzite)
€ch
Cochran conglomerate
(gray conglomerate, with beds of slate)
€gs
Great Smoky conglomerate
(chiefly graywacke and conglomerate, with beds of schist)
ls
€hi
Hiwassee slate
(chiefly dark banded slate and schist, with layers of limestone, ls, and sandy beds)
€sb
Snowbird formation
(chiefly light-colored quartzite and sandstone; includes beds of slate, conglomerate, and arkose)
CAMBRIAN
IGNEOUS ROCKS
(Areas of igneous rocks are shown by patterns of triangles and rhombs; metamorphism is indicated by hachures)
Amr
Metarhyolite
(gray and black rhyolite, much altered and schistose)
Amd
Metadiabase
(altered greenish diabase and gabbro)
ALGONKIAN ?
ARmp
Max Patch granite
(coarse or porphyritic granite, light gray or red)
ARcb
Cranberry granite
(mainly granite and granite-gneiss)
ARs
Soapstone, dunite, and serpentine
ARmg
Metagabbro
(altered black and dark gabbro)
ARr
Roan gneiss
(chiefly hornblende-gneiss and diorite)
ARCHEAN
Legend is continued on the left margin.
MEADOW CREEK MOUNTAINS
WALNUT MOUNTAINS
SPRING CREEK MTN.
SMATHERS VIEW MTN.
Elk Mountains
Hot Springs
Wolf Creek
Jonestown
Round Mt.
Bluff Mt.
Max Patch Mt.
Marshall
Weaverville
ASHEVILLE
Biltmore
Tobacco Mt.
Doubletop Mt.
Canton
Candler
Clyde
Tuscola
Pinnacle Knob
Big Butt Mt.
Crabtree Bald
Sandymush Bald
H.M. Wilson, Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by W.L. Miller.
Surveyed in 1898-99.
MAGNETIC NORTH
TRUE NORTH
APPROXIMATE MEAN DECLINATION 1904.
Scale 1/125000
1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometers
Contour interval 100 feet.
Datum is mean sea level.
Edition of July 1904.
Geology by Arthur Keith.
Assisted by H.B. Goodrich and H.S. Gale.
Surveyed in 1893, 1900, 01, and 02.

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

ECONOMIC GEOLOGY

NORTH CAROLINA–TENNESSEE
ASHEVILLE QUADRANGLE

LEGEND
(continued)

METAMORPHIC ROCKS OF UNKNOWN ORIGIN
(Areas of metamorphic rocks of unknown origin are shown by hachures)

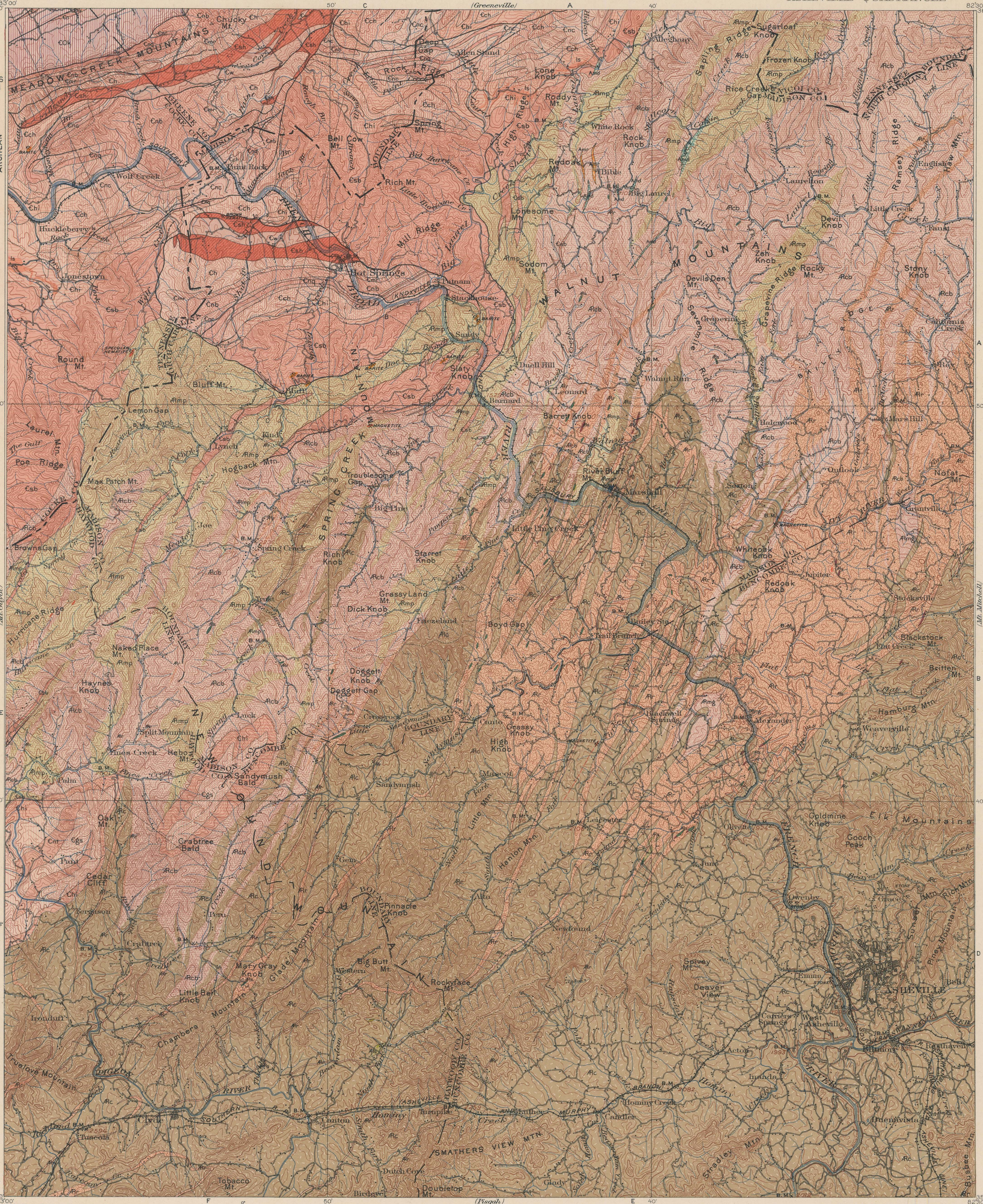
ARCHEAN
- ARc — Carolina gneiss *(chiefly mica-gneiss and mica-schist; includes other gneisses, granites, and diorites and small lenses of marble)*

Faults

Sections

⚒ Mines
X Prospects

Known productive formations
- *Talc veins and bodies*
- *Soapstone*
- *Barite veins and bodies*
- *Corundum (basic rocks bearing corundum)*
- *Magnetite and specular hematite (bodies and lenses)*
- *Brown hematite (residual clay of Shady limestone contains irregular deposits of limonite or brown hematite)*
- *Marble (lenses in Carolina gneiss)*



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Surveyed in 1893, 1900, 01, and 02.

LEGEND

SEDIMENTARY ROCKS
(Areas of subaqueous deposits are shown by patterns of parallel lines)

ORDOVICIAN
- Oa — Athens shale *(blue and black calcareous shale)*
- €Ok — Knox dolomite *(light and dark magnesian limestone with chert nodules)*

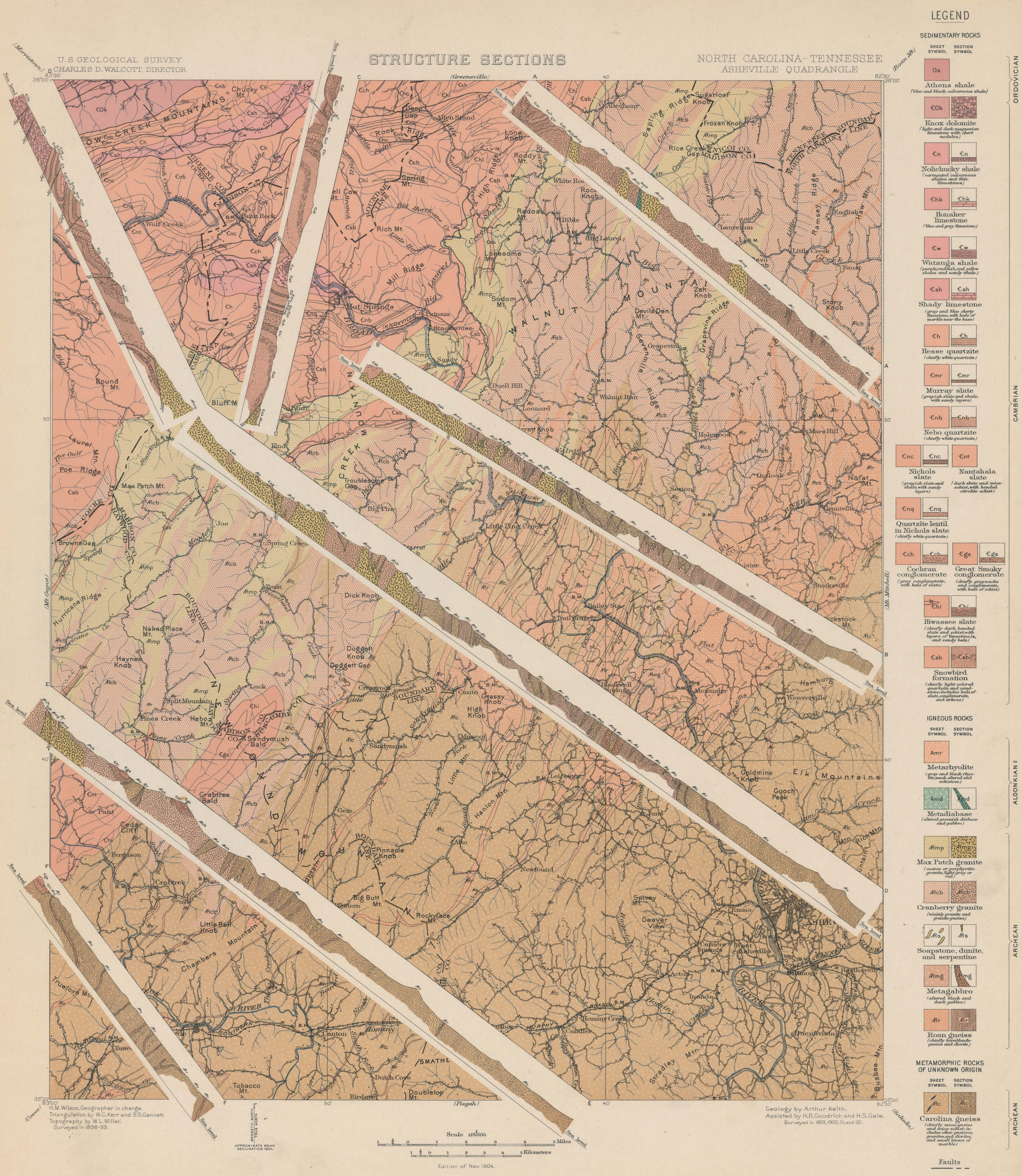
CAMBRIAN
- €n — Nolichucky shale *(variegated calcareous shales and thin limestones)*
- €hk — Honaker limestone *(blue and gray limestone)*
- €w — Watauga shale *(purple, reddish, and yellow shales and sandy shale)*
- €sh — Shady limestone *(gray and blue cherty limestone, with beds of marble near the base)*
- €h — Hesse quartzite *(chiefly white quartzite)*
- €mr — Murray slate *(grayish slate and shale, with sandy layers)*
- €nb — Nebo quartzite *(chiefly white quartzite)*
- €nc — Nichols slate *(grayish slate and shale, with sandy layers)*
- €nt — Nantahala slate *(dark slate and mica-schist, with banded ottrelite-schist)*
- €nq — Quartzite lentil in Nichols slate *(chiefly white quartzite)*
- €ch — Cochran conglomerate *(gray conglomerate, with beds of slate)*
- €gs — Great Smoky conglomerate *(chiefly graywacke and conglomerate, with beds of schist)*
- €hi, ls — Hiwassee slate *(chiefly dark banded slate and schist, with layers of limestone, ls, and sandy beds)*
- €sb — Snowbird formation *(chiefly light-colored quartzite and sandstone; includes beds of slate, conglomerate, and arkose)*

IGNEOUS ROCKS
(Areas of igneous rocks are shown by patterns of triangles and rhombs; metamorphism is indicated by hachures)

ALGONKIAN ?
- Amr — Metarhyolite *(gray and black rhyolite, much altered and schistose)*
- Amd — Metadiabase *(altered greenish diabase and gabbro)*

ARCHEAN
- ARmp — Max Patch granite *(coarse or porphyritic granite, light gray or red)*
- ARcb — Cranberry granite *(mainly granite and granite-gneiss)*
- ARs — Soapstone, dunite, and serpentine
- ARmg — Metagabbro *(altered black and dark gabbro)*
- ARr — Roan gneiss *(chiefly hornblende-gneiss and diorite)*

Legend is continued on the left margin.



U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR
STRUCTURE SECTIONS
NORTH CAROLINA-TENNESSEE
ASHEVILLE QUADRANGLE
LEGEND
SEDIMENTARY ROCKS
SHEET SYMBOL
SECTION SYMBOL
ORDOVICIAN
Athens shale
(blue and black calcareous shale)
Knox dolomite
Nolichucky shale
Honaker limestone
(blue and gray limestone)
Watauga shale
Shady limestone
Hesse quartzite
(chiefly white quartzite)
Murray slate
Nebo quartzite
(chiefly white quartzite)
Nichols slate
Nantahala slate
Quartzite lentil in Nichols slate
(chiefly white quartzite)
Cochran conglomerate
Great Smoky conglomerate
Hiwassee slate
Snowbird formation
CAMBRIAN
IGNEOUS ROCKS
Metarhyolite
Metadiabase
(altered greenish diabase and gabbro)
ALGONKIAN?
Max Patch granite
Cranberry granite
Soapstone, dunite, and serpentine
Metagabbro
(altered black and dark gabbro)
Roan gneiss
ARCHEAN
METAMORPHIC ROCKS OF UNKNOWN ORIGIN
Carolina gneiss
ARCHEAN
Faults
H.M. Wilson, Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by W.L. Miller.
Surveyed in 1888-89.
APPROXIMATE MEAN DECLINATION 1904.
Scale 1/125000
Miles
Kilometers
Edition of Nov. 1904.
Geology by Arthur Keith.
Assisted by H.B. Goodrich and H.S. Gale.
Surveyed in 1893, 1900, 01, and 02.
(Greeneville)
(Pisgah)
(Mt. Mitchell)
(Mt. Guyot)
(Morristown)
(Roan Mt.)
(Cowee)
(Saluda)
Sea level
WALNUT MOUNTAINS
Hot Springs
Mars Hill
Weaverville
Asheville
Canton
Max Patch Mt.
Sandymush Bald
Elk Mountains

COLUMNAR SECTIONS

GENERALIZED SECTION FOR ASHEVILLE QUADRANGLE NORTH AND WEST OF HOT SPRINGS.

SCALE: 1 INCH = 1000 FEET.

System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Soils and Surface.
ORDOVICIAN	Athens shale.	Oa		300+	Light-blue calcareous shale. Black carbonaceous shale.	Belts of low knobs. Open valleys.
ORDOVICIAN — ? —	Knox dolomite.	€Ok		3500±	Magnesian limestone — light blue, dark blue, and white — with nodules of chert.	Broad ridges and irregular, rounded hills.
CAMBRIAN	Nolichucky shale.	€n		450–500	Yellow, red, and brown calcareous shale, with a few limestone beds.	Narrow valleys and steep slopes of Knox dolomite ridges.
CAMBRIAN	Honaker limestone.	€hk	SEQUENCE BROKEN	100+	Massive blue and gray limestone and banded limestone.	Narrow valleys.
CAMBRIAN	Watauga shale.	€w		600+	Purplish, reddish-brown, and yellow shales, sandy shales, and thin sandstones.	Lines of round hills and knobs. Sandy and clayey soils, reddish and purplish.
CAMBRIAN	Shady limestone.	€sh		800–950	Gray, bluish-gray, mottled gray and white limestones, with nodules and masses of chert.	Valleys and low hills. Deep clay soils, dark red and cherty.
CAMBRIAN	Hesse quartzite.	€h		700–1200	Massive white quartzite and sandstone.	High, sharp mountains and peaks. Thin, sandy, and rocky soils.
CAMBRIAN	Murray slate.	€mr		300–450	Bluish-gray and gray, argillaceous and sandy shales and slates, with thin sandstones.	Depressions and slopes of quartzite mountains. Light, sandy soils.
CAMBRIAN	Nebo quartzite.	€nb		350–1700	Massive white quartzite and sandstone.	High, sharp mountains, with many cliffs. Thin, sandy, and rocky soils.
CAMBRIAN	Nichols slate with quartzite lentil.	€nc		200–600	Bluish-gray and gray argillaceous and sandy shales and slates, with thin sandstone layers.	Depression between quartzite crests. Light, sandy soils.
				250–700	Massive white quartzite and sandstone.	Sharp mountains and knobs. Thin, sandy, and rocky soils.
				300–800	Bluish-gray and gray argillaceous and sandy shales and slates, with thin sandstone layers.	Depressions between quartzite crests. Light, sandy soils.
CAMBRIAN	Cochran conglomerate.	€ch		300–2500	Massive quartz conglomerate, light gray and dark gray, with seams of dark slate.	High mountains and ridges. Thin, rocky, and sandy soils.
CAMBRIAN	Hiwassee slate.	€hi		900–1500	Blue, black, gray, and banded slates and a little ottrelite- and mica-schist. Includes layers of coarse sandstone and quartzite, and beds of limestone, calcareous sandstone, and conglomerate.	Slopes of conglomerate mountains, and low, hilly ground. Thin, clayey or sandy soils.
CAMBRIAN	Snowbird formation.	€sb		350–5000	Gray and white feldspathic quartzite and sandstone, with many layers of dark slate, especially near the middle, and numerous cross-bedded layers throughout. Includes some quartz conglomerate at the top, and coarse quartz conglomerate and red or gray arkose at the base.	High, irregular mountains, ridges, and knobs, with round summits. Thin, sandy, and rocky soils.
	UNCONFORMITY					
ARCHEAN	Gneisses, granites, and ancient volcanic rocks.				Descriptions given in accompanying table.	Descriptions given in accompanying table.

GENERALIZED SECTION FOR ASHEVILLE QUADRANGLE IN VICINITY OF CRABTREE.

SCALE: 1 INCH = 1000 FEET.

System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Soils and Surface.
CAMBRIAN	Nantahala slate.	€nt		700+	Black and gray slate and mica-schist and black-banded ottrelite- and garnet-schist, with some staurolite-schist.	Depressions and low spurs of graywacke and conglomerate mountains. Thin, micaceous and sandy soils.
CAMBRIAN	Great Smoky conglomerate.	€gs		750±	Gray feldspathic quartzite, graywacke, and some conglomerate, with beds of gray mica-schist and slate.	High mountains and peaks, with cliffs. Thin, rocky, micaceous and sandy soils.
CAMBRIAN	Hiwassee slate.	€hi		450–1000	Gray and black mica-schist, garnet-schist, and ottrelite-schist, with interbedded layers of graywacke.	Depressions and low hills. Thin sandy and micaceous soils.
CAMBRIAN	Snowbird formation.	€sb		0–50	White feldspathic quartzite.	Low hills.
	UNCONFORMITY					
ARCHEAN	Gneisses and granites.				Descriptions given in table below.	Descriptions given in table below.

GENERALIZED TABLE OF IGNEOUS AND METAMORPHIC ROCKS, ACCORDING TO AGE.

System.	Formation Name.	Symbol.	Columnar Section.	Character of Rocks.	Character of Soils and Surface.
ALGONKIAN	Metarhyolite.	Amr		Black metarhyolite-schists.	Effect on topography and soil not appreciable.
ALGONKIAN	Metadiabase.	Amd		Dull yellowish-green altered diabase, in part coarsely crystalline.	Minor depressions. Deep clay soils.
ARCHEAN	Max Patch granite.	ARmp		Very coarse biotite-granite, usually massive, but in places porphyritic and altered to augen-gneiss. Colors usually light gray in the eastern areas and reddish in the western.	High, irregular mountains with steep slopes and broad, round summits. Red and brown clayey soils, with many ledges.
ARCHEAN	Cranberry granite.	ARcb		Biotite granite and granite-gneiss, coarse and fine; colors, light gray, dark gray, and white. Includes dikes of schistose and unaltered diabase, fragments of hornblende-gneiss, and dikes of unaltered, fine biotite-granite.	High, irregular mountains, peaks, and spurs, with round summits. Red and brown clayey soils, with many ledges.
ARCHEAN	Soapstone, dunite, and serpentine.	ARs		Dunite, in part serpentinized. Soapstone contains talc and tremolite.	Yellow clay soils, with many ledges and fragments of rocks.
ARCHEAN	Metagabbro.	ARmg		Dark-green and black, massive metagabbro.	Broad, round hills. Dark-red and brown clay soils.
ARCHEAN	Roan gneiss.	ARr		Hornblende-gneiss and schist, with some massive and schistose diorite. Includes many beds of mica-gneiss, mica-schist, and hornblende-mica-gneiss, and dikes of altered and unaltered biotite-granite.	Broad plateau surfaces or depressions in Carolina gneiss ridges. Dark-red and brown clay soils.
ARCHEAN	Carolina gneiss.	ARc		Interbedded mica-gneiss and mica-schist, coarse and fine, bluish gray and gray. Contains many small beds of hornblende-gneiss, large bodies of garnet-schist and kyanite-schist, and dikes of biotite-granite, both altered and unaltered.	Ridges, peaks, spurs, and high mountains with irregular crests. Red and brown micaceous and clayey soils.

NAMES OF FORMATIONS.

System.	Arthur Keith: Knoxville Folio, U. S. Geological Survey, 1895.	Names and Symbols used in this Folio.		Arthur Keith: Cranberry Folio, U. S. Geological Survey, 1903.
Ordovician	Athens shale.	Athens shale.	Oa	
Ordovician	Knox dolomite.	Knox dolomite.	€Ok	
Cambrian	Nolichucky shale.	Nolichucky shale.	€n	
Cambrian	Maryville limestone.	Honaker limestone.	€hk	
Cambrian	Rogersville shale.			
Cambrian	Rutledge limestone.			
Cambrian	Rome, Beaver, Apison formations.	Watauga shale	€w	Watauga shale.
Cambrian		Shady limestone.	€sh	Shady limestone.
Cambrian	Hesse sandstone.	Hesse quartzite.	€h	Erwin quartzite.
Cambrian	Murray shale.	Murray slate.	€mr	Hampton shale.
Cambrian	Nebo sandstone.	Nebo quartzite.	€nb	
Cambrian	Nichols shale.	Nichols slate. Nantahala slate.	€nc €nt	
Cambrian	Cochran conglomerate.	Cochran conglomerate. Great Smoky conglomerate.	€ch €gs	Unicoi formation.
Cambrian	Sandsuck shale.	Hiwassee slate.	€hi	
Cambrian		Snowbird formation.	€sb	
Archean		Max Patch granite.	ARmp	Beech granite.
Archean		Cranberry granite.	ARcb	Cranberry granite.
Archean		Metagabbro.	ARmg	
Archean		Roan gneiss.	ARr	Roan gneiss.
Archean		Carolina gneiss.	ARc	Carolina gneiss.

ARTHUR KEITH,
Geologist.

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