DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

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GEOLOGIC ATLAS

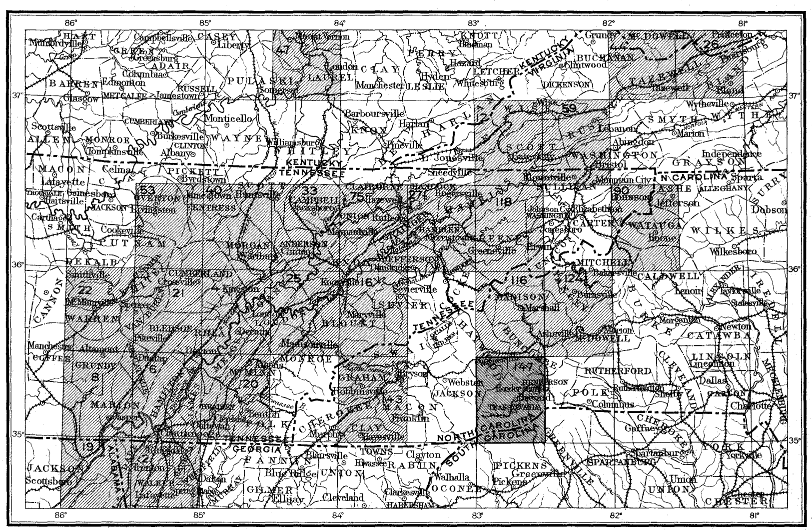
OF THE

UNITED STATES

PISGAH FOLIO

NORTH CAROLINA - SOUTH CAROLINA

INDEX MAP



SCALE: 40 MILES - 1 INCH

PISGAH FOLIO

OTHER PUBLISHED FOLIOS

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

1907

OHIO STATE UNIVERSITY

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).

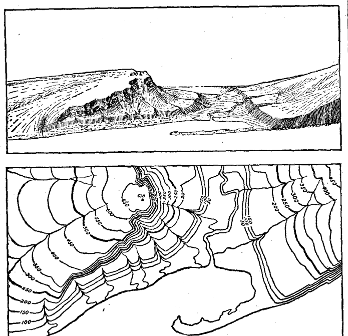


FIG. 1.—Ideal view and corresponding contour map.

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.
	Tertiary......	Pliocene....... Miocene....... Oligocene..... Eocene........	T	Yellow ocher.
Mesozoic	Cretaceous....	....	K	Olive-green.
	Jurassic	....	J	Blue-green.
	Triassic......	....	Ŧ	Peacock-blue.
Paleozoic	Carboniferous.	Permian....... Pennsylvanian Mississippian..	C	Blue.
	Devonian.....	....	D	Blue-gray.
	Silurian......	....	S	Blue-purple.
	Ordovician....	....	O	Red-purple.
	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:

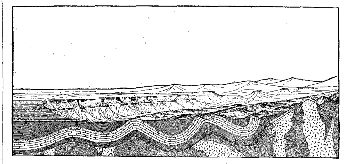


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

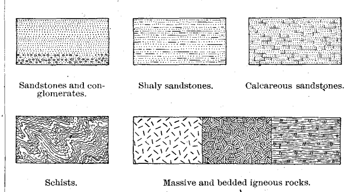


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

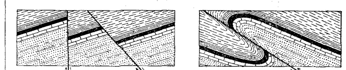


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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 PISGAH QUADRANGLE.

By Arthur Keith.

GEOGRAPHY.

GENERAL RELATIONS.

Location.—The Pisgah quadrangle lies chiefly in North Carolina, but includes in its southeastern portion about 150 square miles of South Carolina. It is situated between parallels 35° and 35° 30′ and meridians 82° 30′ and 83° and contains about 975 square miles, divided between Haywood, Jackson, Transylvania, Henderson, and Buncombe counties in North Carolina and Pickens and Greenville counties in South Carolina.

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 represented on 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 the southern part it coincides with the belt of folded rocks which forms the Coosa Valley of Georgia and Alabama and the Great Valley of East Tennessee and Virginia. Throughout the central and northern portions the eastern side only is marked by great valleys—such as the Shenandoah Valley of Virginia, the Cumberland Valley of Maryland and Pennsylvania, and the Lebanon Valley of 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, which must originally have been nearly horizontal, now intersect the surface at various angles and in narrow belts. The surface features vary with the outcrops of different kinds of rock, so that sharp ridges and narrow valleys of great length follow 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. The eastern division also embraces 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 Cumberland Plateau, Allegheny Mountains, and associated plateaus are called the Appalachian Plateau. 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. Its height is between 3000 and 4000 feet in West Virginia, and decreases to about 2000 feet in Pennsylvania. From its greatest altitude, along its 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 position of the streams in the Appalachian Valley is 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 Cumberland Plateau, runs westward to the Ohio. South of Chattanooga the streams flow directly to the Gulf of Mexico.

DETAILED GEOGRAPHY OF THE QUADRANGLE.

Mountain ranges.—The Pisgah quadrangle is included mainly in the Mountain division of the Appalachian province. In the southeastern part of the quadrangle there is a small area of the Piedmont Plateau, at the foot of the Blue Ridge. The relations of the two are shown in fig. 1 (illustration sheet). Most of the quadrangle consists of mountain ranges, separated here by rolling plateaus and there by deep, narrow valleys. The longest chain is the Blue Ridge, which has a general east-west trend through the southern part of the quadrangle, winding back and forth between the different river basins and dividing the Atlantic from the Mississippi waters. On this is situated Great Hogback, 4790 feet high. The greater portion of the Blue Ridge in this quadrangle is between 3000 and 3300 feet in elevation and forms part of an ancient plateau now deeply cut by the various streams. Most of the mountains between French Broad River and the Blue Ridge and along the upper parts of Toxaway and Horsepasture rivers also form parts of the same plateau. The view in fig. 1 is directly along the heads of all these streams. Another conspicuous range is the Pisgah Ridge, which has a northeasterly-southwesterly course, parallel to the French Broad Valley. On this are situated Big Pisgah Mountain, 5149 feet; Chestnut Bald, 6040 feet; and numerous points of intermediate height. Running northwestward from this are the cross ranges of the Balsams, including Richland Balsam, 6540 feet, the highest point in the quadrangle; Cold Mountain, 6000 feet; and six other points more than 6000 feet in height. In fig. 5 are seen Big Pisgah Mountain, Cold Mountain, and various minor ridges. Pisgah Ridge closely follows the trend of the rock formations. The other mountains have no such relation, however, except here and there for short distances.

The sides of the mountains are steep and usually made up of smooth, flowing slopes. The crests are smooth and rounded, and as a rule are free from cliffs. A typical summit and an exception are seen in fig. 3. The abrupt slope or escarpment along the southerly side of the Blue Ridge (see fig. 1) is one of the notable features of the region. Large cliffs, which are noticeably rare in other parts of the mountains, are common here. The large bodies of mica gneiss which form the Balsam and Pisgah mountains are among the hardest rocks in the quadrangle and cause lines of small cliffs and ledges. In Big Pisgah Mountain and Cold Mountain extensive cliffs appear in the mica gneiss. These are due in large part, however, to the recent removal of the soil cover. On Shining Rock (see fig. 3) is to be seen a rare form of cliff consisting entirely of massive vein quartz.

Similarly the granites make enormous cliffs where they are near drainage lines or along the slopes of the Blue Ridge. The cliffs around Cæsars Head are typical of the latter group, while Dunn Rock, near Brevard, and the many cliffs along Toxaway and Horsepasture rivers illustrate the former class. A third class of cliffs is seen in Panthertail, Cedar Rock, and Lookingglass mountains. (The two last-mentioned cliffs are shown in fig. 2.) These cliffs are situated on divides and owe their great size to the spheroidal weathering of the granite which forms them. With these and similar exceptions, the even slopes of the weathered rocks are seldom broken and the cover of heavy forest is continuous on high and low ground alike. In all the illustrations the extent of the forest is very noticeable.

Valleys and plateaus.—The valleys intervening between the mountain ranges are sharp, narrow, and V-shaped at their heads and have similar grades down to definite levels, at which they widen out into rounded and plateaulike valleys. The plateaus consist near the stream heads of a series of gently rolling and smoothly rounded summits only slightly varied by shallow valleys. These characters are shown in fig. 4. The summits rise to heights which are remarkably uniform over large areas, and the plain which they once formed is readily recognized from any of the summits. Excellent illustrations of this are the views around Brevard and westward from Cæsars Head. (See fig. 1.)

These plateaus are alike in origin and form, but they vary considerably in altitude. They rise gradually toward the heads of the rivers and each major stream has its set of plateau altitudes. The plateau of Pigeon River near Waynesville and Sonoma is between 2700 and 2800 feet above sea; that of French Broad River, about 2200 feet; the Piedmont Plateau surface south of the Blue Ridge, from 1100 to 1300 feet. An exception to this variation from river to river is the plateau of the Blue Ridge, most of which is between 3200 and 3300 feet. Remnants of this pass entirely around the French Broad valley along the heads of the minor streams and continue southwestward across the headwaters of Toxaway and Horsepasture rivers, which flow into the Atlantic. The flat floor of the Pink Beds at the foot of Pisgah Ridge is a fine example of the original surface of the plateau.

The plateaus of Pigeon and French Broad rivers belong to the same period of erosion. The Blue Ridge plateau represents a much earlier and much longer period. Southeast of the Blue Ridge the great Piedmont Plateau was formed at a still later period of erosion, whose action has not yet produced similar features on the streams which drain into the Mississippi. The streams southeast of the Blue Ridge have shorter courses to the Atlantic and have been able to establish lower grades clear to their headwaters. Into all these plateaus the rivers and creeks have sunk their channels in canyons during the later periods of erosion. These have steep and rocky borders and are so narrow as to be easily overlooked from a short distance. The Blue Ridge plateau is most deeply dissected, the streams of the French Broad plateau having cut into it 1000 feet, and those of the Piedmont 2000 feet.

Drainage.—The drainage of the quadrangle is divided between the streams flowing toward the Atlantic and those flowing toward the Gulf, about one-fourth going toward the former. The waters of Davidson, Mills, and Little rivers and other tributaries of the French Broad are joined by those of Pigeon River and flow through the Tennessee into the Ohio and Mississippi. Saluda, Toxaway, and Horsepasture rivers are tributary to Savannah River, which flows into the Atlantic. From their heads, high up on the mountains, the streams fall with heavy grades down to the levels of the plateaus. For considerable distances near those levels the grades are light, until the heads of the secondary canyons are reached. Thence downstream the currents descend swiftly, with many waterfalls and rapids. Thus Mills River, for instance, goes through this cycle twice, as do all the streams which traverse the 3200-foot plateau. Starting at elevations of 5000 to 6000 feet the waters of Mills River descend with rapidly lessening grades to the Pink Beds plateau at 3200 feet. Along this they flow for 2 or 3 miles with very little fall. As the newly cut canyon is entered the river drops rapidly through a narrow gorge to 2200 feet in about 13 miles. Near this level, that of the Asheville plateau, it descends slowly to French Broad River, at a little less than 2100 feet. A similar course is followed by other branches of the French Broad. Toxaway and Whitewater rivers and similar streams have the same characters as Mills River, but the fall from the upper plateau to the Piedmont is nearly twice as great. Accordingly, the country which they traverse is exceedingly steep and rugged and the streams show continuous rapids and falls for miles. The plateau characters at their heads are well preserved and have made possible, by means of a dam about 50 feet in height, the flooding of a large area in Lake Toxaway.

GEOLOGY.

GENERAL GEOLOGIC RECORD.

Nature of the formations.—The formations which appear at the surface of the Pisgah 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 are found mainly in 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 early Cambrian age, including conglomerate, sandstone, shale, limestone, and their metamorphosed equivalents. The older of these groups occupies the greater area, and the younger the lesser. 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 were produced when erosion was revived on a land surface long subject to decay and 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 and conglomerate indicate strong currents and wave action during their formation.

Principal geologic events.—The rocks themselves thus yield records of widely separated epochs 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, as shown in this general region:

Earliest of all was the production of the great bodies of Carolina gneiss. Its 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 immeasurably 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 of Cambrian or later age, according to the fossils which they contain. Remnants of these strata are now infolded in the igneous and metamorphic 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 Pisgah 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 known only here and there, and it probably varied from time to time within rather wide limits.

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, 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. After this long period of quiet came a slight elevation, producing coarser rocks; this uplift 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 exposed in the quadrangle.

DESCRIPTION OF THE FORMATIONS.

ROCKS OF THE QUADRANGLE.

The rocks exposed at the surface in the Pisgah quadrangle comprise three great classes—metamorphic, igneous, and sedimentary. The sediments are found in a narrow band passing up the French Broad Valley and across the heads of Toxaway and Whitewater rivers. They cover barely 3 per cent of the quadrangle. Igneous rocks are very generally distributed throughout the quadrangle, occupying about 50 per cent of its area. Southeast of the sedimentary strata practically all the rocks are of igneous origin. The remaining area, about 45 per cent of the quadrangle, is underlain by the metamorphic rocks of the Carolina gneiss.

The sediments consist of a group of black and gray slates and schists. These contain thin beds of limestone and marble at many points in this quadrangle. The age of the sediments is not well determined, but they are probably Cambrian and are so considered in this discussion.

Of the igneous rocks, granites are found in one large, irregular area in the southeastern part of the quadrangle and in several other and smaller areas west and north of Brevard. Other igneous rocks are diorite, hornblende gneiss, and dunite, which occur in a large number of narrow bands with no definite grouping. The width and frequency of the bands increase somewhat toward the north. The Carolina gneiss, which underlies most of the quadrangle, consists mainly of mica schist and mica gneiss throughout its extent. The gneiss masses which form the Balsam and Pisgah mountains contain much cyanite and garnet, to whose greater resistance to weathering is due much of the height of those mountains. Garnetiferous bands are also numerous in the formation, near the borders of the Roan gneiss areas.

Practically all the igneous and metamorphic rocks are of Archean age. There are, however, a few exceptions to this. The Brevard schist is regarded as Cambrian, for reasons given in the description of the formation. Dikes and small bodies of fine-grained granite are found in the Carolina and Roan gneisses near the northern border of the quadrangle. These seldom exceed a few feet in thickness and are not of sufficient size to be represented 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 appears in the other formations of the mountains. The latest time at which this schistosity was produced was post-Carboniferous. The granite dikes, therefore, are clearly later than Carboniferous, although they may have been produced during the later part of the deformation period.

In the southern half of the quadrangle are found large bodies of granite which are probably younger than the Archean. They show much less metamorphism than the Henderson granite or the Carolina gneiss, through which they cut. Considerable portions of their mass have little or no metamorphism, but retain their original structures. Since the rocks in the same areas which are known to be Archean have very great metamorphism, it is probable that these granites are of considerably later age. It can not be stated from present knowledge how young they are, but the fact that they are altered considerably in places shows that they are Carboniferous or older.

In the columnar sections are shown the character and probable age of the different formations, and these will be described in order of age as nearly as it is known.

ARCHEAN ROCKS.

CAROLINA GNEISS.

Distribution.—The northwestern half of the quadrangle is nearly covered by the Carolina gneiss, which is so named because of its extent in North and South Carolina. Most of the large areas of this formation are connected with one another and in reality form one large mass penetrated by many bodies of the different igneous rocks. In addition to being the principal formation of this quadrangle, it is also the oldest, since it is cut by the igneous rocks and overlain by the sediments. Inclosed within its areas are numerous igneous and secondary rocks. Although these are too small to be shown on the map, they can readily be assigned to formations which are elsewhere mapped in larger bodies.

General character.—The formation consists of an immense series of interbedded mica schist, garnet schist, mica gneiss, garnet gneiss, cyanite gneiss, and fine granitoid layers. Most of them are light or dark gray in color, weathering to dull gray and greenish gray. Layers of white granitic material are not uncommon, and lenses and veins of pegmatite are frequent. Much the greater part of the formation consists of mica gneiss and mica schist. In most of the formation the minerals are segregated into layers, either singly or in combinations, thus producing rocks with a marked banded appearance. These rocks usually have more feldspar than the schists. The granitoid layers contain quartz and feldspar, with muscovite and biotite in small amounts; in the light-colored layers the biotite and most of the muscovite are wanting. The schists are composed of quartz, muscovite, a little biotite, and a very little feldspar. They have a fine grain and a strong schistosity, but their texture is even and the minerals are uniformly distributed.

A few thin layers in the mica schist have a bluish-gray or black color, largely due to grains of iron oxides. These are most numerous in those portions of the formation near the Brevard schist. They strongly resemble the coarser portions of the Brevard schist; the component minerals are about the same, and the dark color given by the iron oxides is the most prominent characteristic of each. The similarity in appearance near the contacts suggests that part of the Carolina is of sedimentary origin. The possible origin of the Carolina is discussed under the heading "Metamorphism."

The gneisses and schists alternate in beds from a few inches to 50 feet thick. Layers similar in composition and from one-tenth to 1 inch in thickness compose the banded gneisses. That part of the formation which is adjacent to the Roan gneiss contains some thin interbedded layers of hornblende schist and hornblende gneiss precisely like the Roan gneiss. The areas of the formations thus merge somewhat, so that the boundary between them is seldom definite.

Cyanite gneiss.—In the Balsam and Pisgah mountains and the area drained by West Fork of Pigeon River, the gneiss shows a marked increase in cyanite. This mineral is distributed along distinct layers of the gneiss and occurs in crystals an inch or less in length, giving the rock a decided porphyritic appearance. These are usually parallel with the foliation and the other minerals of the inclosing gneiss. In areas northeast of this quadrangle the cyanite is seen to be of a later age than most of the other minerals composing the gneiss. The cyanite forms stubby, flat crystals or blades of a light-gray or dark-gray color. On weathered surfaces these stand out prominently from the rest of the rock. Associated with these cyanite layers in many places are prominent large patchy crystals of muscovite. These are distributed through the rocks just as the cyanite crystals are, and, like them, probably have a secondary origin. Where they are frequent they give a noticeable silvery appearance to the schist or gneiss. Small garnets are often found in the same layers with the cyanite and coarse muscovite.

Garnet gneiss.—Garnet schist and garnet gneiss are a conspicuous part of the Carolina gneiss. The garnets are small, seldom exceeding one-fourth of an inch in diameter. They are rather evenly distributed through the rock and but seldom restricted to bands in the gneiss. These rocks are most prominent in the northwestern portion of the quadrangle, in the Balsam and Pisgah mountains, and extend as far northeast as Skyland. Thus in this quadrangle they characterize bodies of gneiss from 1 to 4 miles in width and 25 miles in length, and extend far into the adjoining quadrangles. Some occurrences accompany the contacts of the Roan gneiss and are apparently due to them. In most of the large areas, however, there is no apparent connection between eruptive beds and the production of garnets, many of the garnets being miles from any outcrop of the Roan gneiss. If the igneous rocks caused the growth of all the garnets, it must have been by inducing an extensive circulation of mineralizing waters.

Granite gneiss.—The granitoid layers of the gneiss contain quartz and feldspar, with small amounts of muscovite and biotite. In the light-colored layers the biotite and the muscovite are sparse. The granitoid layers and the schists alternate in beds ranging in thickness from a few inches to a foot or two. Beds of such size are rather rare in this quadrangle. Layers similar in arrangement, varying in thickness from one-tenth of an inch to an inch, compose the banded gneiss. Toward the north and east in this quadrangle the granitoid layers increase in amount. In them the minerals are much less distinctly parallel than in the schists and gneisses. The parallel arrangement is usually seen more or less roughly, however, and its prominence depends largely on the amount of mica in the rock.

Pegmatite.—Included in the area of the formation are numerous veins and dikes of pegmatite. One group of these occurs in the shape of lenses ranging from 1 foot to 25 feet in thickness. Some of the largest of the lenses can be readily followed for 2 or 3 miles. The smaller ones, however, can not be traced surely beyond the immediate outcrops. For the most part, they lie parallel to the foliation of the gneiss. In places they have the form of veins or dikes and cut the gneisses abruptly, with nearly parallel walls. The pegmatites are most conspicuous near the contacts of the Carolina and Roan gneisses, but are not closely limited to those localities. They are also found in great numbers near the Whiteside granite mass, which itself has pegmatitic portions. These latter pegmatites are closely associated with that granite, cut the foliation of the gneisses, and are of the nature of dikes. They vary greatly in form, from narrow masses to irregular patches, or even scattered crystals. Many of the smaller lenses can be seen to be surrounded on all sides by mica gneiss, and apparently were deposited from aqueous solutions.

The pegmatites consist chiefly of very coarsely crystalline feldspar, quartz, biotite, and muscovite; crystals of orthoclase feldspar rarely attain dimensions of 2 feet, and mica 2 feet. In them are also found many rare or valuable minerals, including beryl, emerald, tourmaline, garnet, and cyanite. The pegmatites associated with the granite contain fewer minerals than the others and are more feldspathic. Much merchantable mica is procured from the pegmatites of lenticular and veinlike shape, and the Balsam and Pisgah mountains form one of the best mica districts of the State.

Many of the minerals of the pegmatite have been crushed and folded by the second deformation which folded the gneisses. The pegmatites, therefore, are older than this deformation. Their connection with the contacts of the Roan and Carolina gneisses is not sufficiently marked to prove that contact action caused the pegmatites. The smaller lenses appear to have been formed by deposition from mineralized waters, after the manner of veins. Those of veinlike form also show a banded arrangement in places. Owing to the considerable alteration of the pegmatite contacts, however, it is difficult to determine their origin with precision. As stated above, much of the pegmatite is plainly igneous.

Intrusive granites.—Inclosed within the gneiss and schist areas are many bodies of intrusive granite. These vary in thickness from a few inches up to a few feet, and, on account of their small size and the difficulty in tracing them, they are not represented on the map. They cut the gneisses at every conceivable angle. The granite is fine grained and very uniform in texture, and has a light-gray or whitish appearance. The smaller dikes are somewhat lighter colored than the large ones on account of the larger proportion of quartz and feldspar. The component minerals are quartz, orthoclase and plagioclase feldspar, biotite, and muscovite, the micas being subordinate in amount. As a rule these beds are massive and fairly free from the schistosity which marks all of the adjoining formation. For this reason it is concluded that they were intruded into the gneisses after the principal part of the deformation of the region had been accomplished. They are accordingly later than the Carboniferous in age. In approaching the Whiteside granite areas, these dikes are found more often. Since both dikes and granite masses have the same relations and composition, it is probable that they came from the same magma.

Metamorphism.—The Carolina gneiss covers greater areas than any other formation in this region. On account of the uniform aspect of its beds over large areas, no true measure of its thickness can be obtained; even an estimate is idle. The apparent thickness is enormous, having been increased many times by the folding and the enormous metamorphism to which the gneiss has been subjected. The original nature of this gneiss is uncertain. It is possible that much of the mass was once a granite. Some of the material has a granitic character now, and its local metamorphism to schist can be readily 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. Many parts of the formation in areas adjoining on both the northeast and the southwest are doubtless of sedimentary origin. The apparent transition of the Carolina into the sedimentary Brevard schist indicates that other parts of the Carolina are sedimentary. It is very likely that still other sedimentary masses have not been distinguished from the Carolina because of their total metamorphism and similarity to the latter.

Whatever their original nature, one deformation produced a foliation of these rocks. A subsequent deformation folded and crushed the earlier planes and structures. Before the latter period pegmatites 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 excessive metamorphism has destroyed the original attitudes and most of the original appearance of the rocks. The rocks of the formation are now composed entirely of the metamorphic minerals. These are usually arranged with their longer dimensions nearly parallel to one another and to the different layers. Where the layers have been bent by the later deformation the minerals are bent into corresponding curves. In places where by the second deformation a second schistosity was produced, this schistosity cuts in parallel planes across the older schistose layers. Since the schistosity is evidenced more strongly by the micas than other minerals, the coarse and granitoid layers are least schistose and the mica schists most so.

Decomposition.—The schistose planes of the various layers afford easy passage for water and are deeply decayed. After decomposition has destroyed the feldspar the resultant clay is filled with bits and layers of schist, quartz, and mica. Solid ledges are seldom found far from the stream cuts and the steeper slopes. Near the Blue Ridge many large ledges and cliffs appear. The cyanite gneiss and garnet gneiss of the Balsam and Pisgah mountains, especially, form big cliffs and rocky slopes. In fact, these mountains owe their height to the superior resistance of these gneisses. The cover of clay on the decayed rocks is thin, and the soil is light on account of the large proportion of quartz and mica that it contains. Accordingly, its natural growths are poorly sustained, even in the areas of gentle slope where the formation has been well decomposed. These soils, however, are susceptible of great improvement by careful tillage. In the mountain areas, where slopes are steep and fresh rock is nearer the surface, the soils are richer and stronger and produce good crops and fine timber. The greater amount of soluble matter and clay in the gneiss renders its areas somewhat more productive than those of the schist. The garnet and cyanite gneiss areas are somewhat less productive than those of the ordinary gneiss.

ROAN GNEISS.

Distribution.—Areas of this formation are found generally throughout the quadrangle, usually in long, narrow bands. In the northwestern half of the quadrangle the Roan forms dikelike bands in the Carolina gneiss. In the southeastern half, however, the Roan lies in very irregular bodies inclosed by the eruptive masses of Henderson or Whiteside granite. The formation receives its name from Roan Mountain, on the boundary of Tennessee and North Carolina, north of this quadrangle.

Relation to Carolina gneiss.—The Roan gneiss appears to cut the Carolina gneiss, but the contacts are so much metamorphosed that the fact can not well be proved. Moreover, the rocks included in the Carolina are entirely metamorphosed; some of the Roan is less altered, however, and thus appears to be younger. Narrow, dikelike bodies of Roan in the Carolina support this view, for some of these narrow beds are plainly of an igneous nature. In fact, the shape and continuity of many of the narrow sheets of Roan gneiss can be explained only on the theory that they represent original dikes cutting the Carolina gneiss. In still other areas the Roan gneiss consists of large numbers of lumps or lenses of hornblende gneiss surrounded by mica gneiss. These undoubtedly represent original dikes of the Roan disconnected by folding and faulting. The frequent development of garnets in the Carolina near the borders of the Roan gneiss seems to indicate contact metamorphism.

Character.—The Roan gneiss consists of a great series of beds of hornblende gneiss, hornblende schist, and diorite, with some interbedded mica schist, garnet schist, and gneiss. The hornblendic beds are dark greenish or black in color and the micaceous beds are dark gray. The mica schist and gneiss beds range in thickness from a few inches to 100 feet, and are numerous only near the Carolina gneiss, into the areas of which they merge. In composition the mica schist and gneiss are exactly like the micaceous parts of the Carolina gneiss, and are composed of quartz, muscovite, a little 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 from one-tenth to one-half inch long, with a very small amount of biotite, feldspar, and quartz; the gneisses contain layers or seams consisting of quartz and feldspar interbedded with layers of hornblende schist. In places these are regularly disposed and give a marked banding to the rock. Here and there the hornblende, feldspar, and quartz appear with the massive structure of diorite. Some of these beds are very coarse and massive, with crystals half an inch long. Many of the beds of this formation consist almost entirely of hornblende and are so basic that they appear to have been derived from gabbro. So thorough is the alteration, however, that such an origin is not certain. In many localities the diorites contain large crystals of garnet, due to alteration induced by intrusive granite.

In composition the mica schist and the mica gneiss beds 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 a large share of the formation and are interbedded with hornblende gneiss throughout. The schists are most prominent north and west of Burnsville, near the Cranberry granite masses. The schist beds consist almost entirely of hornblende, in crystals from one-tenth to one-half an inch long, with a very small amount of biotite, feldspar, and quartz. The gneiss is composed of layers or sheets of quartz or feldspar interbedded with sheets 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 contacts of the Roan gneiss, and it is common also in the Roan gneiss in similar positions. The garnets are seldom larger than a quarter of an inch in diameter and as a rule are much smaller.

In the northeastern part of the quadrangle many lenses and patches of epidote, hornblende, and quartz are to be seen in the gneiss. These are of late origin and replace the older hornblende more or less thoroughly. They are associated with veins of epidote, and neither variety has been deformed. Seldom are they more than 3 feet long or over a few inches thick.

Here and there the hornblende, feldspar, and quartz are found with the structure of diorite or gabbro. A few of these beds are very coarse and massive. About 3 miles west of Sitton is a small body of massive diorite with crystals of feldspar and hornblende nearly an inch long. Massive rocks of medium grain are found here and there in the Roan gneiss with no special geographic distribution. Many of the beds of the formation which consist almost entirely of hornblende are so basic that they appear to have been derived from gabbro. Of this kind are the hornblende schist and many layers less strongly schistose. So thorough is the alteration, however, that such an origin is not certain. At many points in the Roan gneiss there are found veins and lenses of pegmatite of secondary growth, precisely similar to those described under "Carolina gneiss." They seldom, however, equal the latter in size and importance. Dikes and small masses of granite like the Whiteside granite are found in the Roan gneiss, just as in the Carolina, too small to be mapped.

Metamorphism.—Deformation and recrystallization have extensively changed the original rocks of this formation into schist and gneiss. The exact measure of the alteration is usually unknown because the original character of the rock is uncertain. It is probable that most of the mass was originally diorite and gabbro of much the same mineral composition as now. A few of the coarse masses still retain much of their original texture. 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 were afterward bent and closely folded in many places to an extent equal to all the folding of the later formations. Thus the Roan gneiss has passed through two deformations, one producing the foliation, and a second folding the foliation planes and minerals. During or before the second deformation the bands of quartz and feldspar of the gneiss appear to have been formed. The total alteration is extreme.

Weathering.—In reducing the surface of the formation, the first stage is the decomposition of the hornblende and feldspar. The more siliceous layers and many of the harder hornblende schists and mica schists are extremely slow of disintegration, however. 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 or Henderson granites. Consequently its areas are reduced to plateaus in the large stream valleys and form gaps and depressions in the high ground away from the rivers. The rise of the mountains beyond its areas is very noticeable in most cases. In this respect the formation differs much from its habit farther northeast in the Roan and Cranberry quadrangles. The clays accumulating on this formation 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 latter prevents serious wash. Hence, the soils are extensively cultivated in situations remote from the principal settlements.

SOAPSTONE, DUNITE, AND SERPENTINE.

Distribution.—Many areas of these rocks are found within the quadrangle. While most of them are less than half a mile in length, one exceeds that considerably. The largest area is on Pigeon River at Three Forks, with a length of about a mile. Here most of the masses are lens shaped and three or more times as long as they are wide. This area is nearly all in contact with Carolina gneiss, but there is a small body of Roan gneiss at its eastern end. In this respect this area differs considerably from most others of the formation, the association of which with the Roan gneiss is usually close and marked. There are in this quadrangle only six exceptions to this rule, out of sixty-two areas of the formation.

Relations.—The rocks of this group break through and across the beds of Roan gneiss and are thus seen to be distinct from and later than the gneiss. From the constant association of the two formations, however, and the rarity of the soapstone group in other situations, the difference in age can not be considered great. Its alteration is as great as or greater than that of the Roan gneiss, so that it appears to have shared in that earlier period of metamorphism which involved the Roan and Carolina gneisses.

Character.—The group comprises many different rocks, such as soapstone, dunite, and serpentine, and many other combinations of minerals derived from the original rocks by metamorphism. The variety most common in this quadrangle is an impure soapstone containing chlorite, hornblende, and silicates of magnesia. There are also two or three bodies of dunite composed almost entirely of olivine. These are found in the basins of Wolf and Tennessee creeks. The soapstones are white and light gray, while the other varieties of the formation have a greenish color, either bright or dull. In some localities the soapstone contains little but talc and is fit for industrial uses, but, as a rule, it contains much chlorite and crystals of enstatite, tremolite, actinolite, or magnesian silicates. The bodies of talc and pure soapstone are usually found around the borders of the formation, but the large mass at Three Forks is nearly all made up of schistose talc. All the varieties of the formation may be present in a single ledge, or one variety may occupy the whole of an area. The latter relation is most common where soapstone alone is seen. The dunite is usually more or less altered to serpentine. This change may appear in considerable masses of the rock, or in small patches or seams, and is very irregular in its distribution.

Many minor mineral deposits of later origin are found in the formation. Nickel ores form thin seams and coatings between portions of the dunite, and corundum occupies small veins and patches in dunite and soapstone. Here and there small veins of asbestos are found in the dunite. They occur in the shape both of small veins and of irregular rounded crusts between portions of the dunite. Small veins of this kind are found near Tennessee and Wolf creeks, but are of no importance. The alteration proceeds along cracks into the mass of the rock, replacing the dunite more and more near the surface.

Metamorphism.— 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 the soapstone group is enormous—far greater in appearance than that of any of the other formations. The minerals which now appear, however, are closely related in chemical composition to those of the original rock. The intermediate stages of alteration are obscure or absent in this region. These changes seem to have easily affected the peridotites and pyroxenites. Unlike the other metamorphosed rocks, these show only moderate schistosity. Near their borders the soapstones are often schistose in consequence of the parallel arrangement of the talc and chorite scales. This condition prevails throughout many of the smaller bodies and even of the large mass at Three Forks. In a few places in this quadrangle a schistose nature is given to the rock by parallel crystals of tremolite. This result, although common in adjoining regions on the west, is rare in this quadrangle, for the usual alteration is to soapstone. Entirely different is the arrangement of the actinolite and enstatite crystals in many localities, for they form bunches and radiating clusters in the soapstone.

An exception to the general altered aspect of these rocks is the dunite, for it appears to be one of the least metamorphosed rocks of the region. The serpentine, which is a common alteration product of the dunite, is not due to such metamorphism as the schistose rocks, but to hydration. In this process the water worked in through the cracks and joints of the original dunite and united chemically with the olivine to form serpentine.

Weathering.—Few rocks are slower to disintegrate than those of this formation, and its areas invariably show many ledges. Wherever the formation contains much tremolite or enstatite huge ledges come to the surface and large bowlders are scattered everywhere. The rock is not much affected by solution, but breaks down under the direct action of frost and usually occupies low ground. Final decay leaves a cover of stiff yellow clay of little depth and much interrupted by rock. Soils derived from this are of almost no value.

HENDERSON GRANITE.

Distribution.—The rocks of this formation lie in a band 6 or 8 miles wide running diagonally through the quadrangle. Northwest of this granite lies the Brevard schist and southeast of it the Whiteside granite. The extensive areas and exposures of the granite in Henderson County give the formation its name.

Relations.—This granite is intrusive in all the Archean rocks with which it comes into contact. Northeast of this quadrangle the ends of some of the granite bodies pass under the surrounding gneiss with shapes like anticlines. The schistose planes of the gneiss arch over and dip away from the granite as if pushed up by the granite from below. In this quadrangle the contacts with the Carolina gneiss are much obscured by metamorphism. The granite cuts the Roan gneiss and carries large included masses of gneiss near the Blue Ridge. The granite passes out of this quadrangle into the adjoining quadrangles for 50 miles both northeastward and southwestward.

Character.—The granite is composed mainly of orthoclase and plagioclase feldspar, quartz, muscovite, and biotite, enumerated in order of their importance. The latter mica varies a great deal in amount, but is usually subordinate. The usual color of the rock is gray, becoming lighter after weathering. The general aspect of the rock is strikingly uniform through this area. Porphyritic crystals of orthoclase feldspar are a prominent feature of the rock. The porphyritic varieties are not limited to any particular position in the granite mass, but are irregularly distributed through it. The porphyries grade into granites of uniform grain, and the two varieties may be present in a single ledge. In this quadrangle the porphyritic feldspars are a decided characteristic of the rock and the massive variety is rather uncommon. This is most strikingly to be seen near French Broad River, in numerous cliffs and ledges. The rock has a general gneissoid aspect and most of the phenocrysts are drawn out into lenses (or augen) more than twice their original length. Where they retain their original shape they are seldom over an inch in length.

Northeast of Brevard and near the Carolina gneiss the granite is finer grained and the porphyritic feldspars are fewer and smaller. Many finer beds have there been metamorphosed into dark schists resembling the Carolina schists.

The massive granite which appears here and there in small bodies is usually of fine or medium grain and contains very little biotite. The feldspars make up a large portion of the rock and give it a much lighter color than that usual in the porphyries.

Metamorphism.—The formation has been greatly affected by metamorphism. This is best shown by the porphyritic portions, where the change in the form of the mineral particles can often be measured. The rock has been squeezed and mashed until large portions have a pronounced gneissoid structure. Results of this kind are prominent throughout this area and especially near the French Broad Valley. The change is manifest in the growth of the new micas and in the elongation of the porphyritic feldspars. The latter have increased in places to two or three times their original length. During the squeezing and slipping under pressure large crystals were cracked and their fragments rotated until they were nearly parallel with the schistose planes. 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. Large bodies of a very gneissoid rock (or augen gneiss) were thus produced, in which many porphyritic crystals were cracked and pressed out into eyes or strings. The amount of distortion can be plainly measured in the least extreme cases by the interval between the fragments of one crystal. The large feldspars retain their shape better than the finer groundmass, however, and the mica flakes in the latter are bent and wrapped around the large feldspars almost as if fluid.

Weathering.—As the formation is attacked by weathering agencies its surface is slowly lowered. Its siliceous composition and its great mass unite in maintaining the relative altitude of its areas. It forms a high plateau south of the French Broad, deeply cut by the smaller creeks. The summits of this are broad and rounded, with steep faces toward the streams. The granite causes many ledges and cliffs, which are conspicuous features of the landscape near French Broad River. The bowlders and waste from the formation are carried for long distances over the adjoining formations. Upon complete decay the formation produces a yellowish or reddish clay, which is frequently leached out nearly white. This is mixed with sand and fragments of rock on the mountain sides and is of no great depth. In the valleys the rock is often decomposed and soft to depths as great as 30 feet, and the overlying clay is 6 or 8 feet in thickness. Except in coves and hollows the soil is infertile and is subject to drought.

CAMBRIAN ROCKS.

BREVARD SCHIST.

Age, name, and relations.—The strata of this formation are the only sedimentary rocks recognized within the quadrangle. They are named from their occurrence near Brevard, in Transylvania County. The evidence thus far obtained is insufficient to determine their age. They form the first sedimentary deposit upon the Archean rocks, holding a position which is occupied in this region only by Cambrian strata. The rock types found in this formation can be precisely duplicated in the Cambrian rocks farther north and northwest. In fact, the resemblance between this and the Hiwassee slate is very marked. Each consists in the main of bluish-black and dark banded slates or schists, the color varying according to the degree of metamorphism. Interbedded with these are sandy layers and lentils of blue limestone. The Hiwassee formation, which is a slate in its northwestern outcrops, is metamorphosed toward the southeast into schists which are identical in varieties and in appearance with the Brevard schist. The frequency of limestone lenses in the Hiwassee slate and the absence of limestone from thousands of feet of strata above and below it give added interest to the presence of these limestone lenses in the Brevard schist. The latter is not now known to be connected in area with the Cambrian strata lying farther northwest, so that there is no definite proof that the Brevard and the Hiwassee formations are equivalent.

Character.—As it is displayed in this quadrangle the formation consists mainly of schist and slate. Most of it is schist, of a dark bluish-black, black, or dark-gray color. At several points considerable bodies of marble are interbedded with the schist. In some of the lower layers of the formation along Boylston Creek the schistose character is less pronounced and the rock is a banded mica slate. All the strata are fine grained except a few siliceous layers, which represent original sandy strata, and some thin layers of quartzite and fine conglomerate. The rocks are composed mainly of very fine quartz and muscovite, through which are scattered countless minute grains of the iron oxides, producing the dark color. Another constituent commonly found is graphite. This is disseminated in minute grains through large masses of the rock and is only here and there concentrated in some layers. Graphite is also found associated with quartz in small secondary lenses. In the adjoining Mount Mitchell quadrangle the graphite is so abundant as to have led to mining operations. The base of the formation is the most regularly graphitic and has many strikingly black beds. In a few localities garnets are found in these rocks. They are disseminated through the schist in small crystals, usually less than one-tenth of an inch in diameter. They are more numerous in the northeastern parts of the formation, but are nowhere conspicuous. Where the garnets are present it is sometimes difficult to distinguish the schist from garnet schists in the Carolina gneiss. This is particularly true where they are much weathered. The schists of this formation, however, are usually finer grained. The garnets are of secondary origin, and probably were developed by the same agencies in each of the formations during their metamorphism.

The most unusual part of the formation in this quadrangle is the series of limestone lentils which are found at intervals throughout its extent. They are most numerous and largest northeast of Brevard, and consist of finely crystalline limestone or marble. This is usually white, but contains also beds of blue, buff, and banded blue and white colors. Southeast of Lake Toxaway the carbonate of lime is largely replaced by silica and the rock has a cherty aspect. In the quarries near Fletcher the total thickness of the marble lentil is about 250 feet and its length over a mile. The quarries at the head of Boylston Creek show about 50 feet of marble, with a probable length of 1½ miles. The other lentils are both thinner and shorter. Owing to the soluble nature of the limestone, outcrops of it are very scarce, and it is possible that it extends considerably farther than shown on the map. The contacts of the limestone and the adjoining black schist are sharp wherever they are visible, and there is no interbedding. The materials composing the limestone are entirely different from those of the black schist, except for a little silica, which is probably of secondary origin. The change in the conditions which produced limestone instead of the black schist must, therefore, have been abrupt and complete. The limestone deposits extend only about 4 miles northeast of Fletcher, but they are found southwestward at intervals through South Carolina and far into Georgia; so the conditions which they represent were widespread.

An exception to the usual fine grain of the Brevard schist is to be seen in the thin beds of quartzite found in the schist near Cherryfield and Rosman. These occur interbedded with the black schist 700 or 800 feet above the base of the formation. They consist of feldspathic quartzite, usually fine, but in places conglomeratic. They are only a few feet thick and seldom outcrop. By their waste they can be traced for considerable distances, but they are too small to be indicated separately on the map. They represent local activity in erosion, in contrast with the uniformity which preceded and followed them.

Metamorphism.—While the effects of metamorphism are not conspicuous in this formation on account of its fine grain, they are in reality profound. Only near the base of the formation and in a few districts can the original sedimentary bands be seen; usually they are entirely destroyed by the secondary minerals. The original argillaceous or feldspathic materials of the slate developed new quartz and muscovite. It is probable that some of the latter seen in the less-altered slates is an original mineral. The quartz is in very small grains, sometimes lenticular in shape. The muscovite occurs in extremely small scales and flakes, which lie nearly parallel to one another and cause the schistosity of the rock. The iron oxides and garnet are undoubtedly secondary.

Weathering.—The rocks of the formation disintegrate more readily than most of the others of the region, but the formation occupies ground only slightly lower than the Carolina gneiss. Decay makes its way down the schistose partings, and the rock breaks up into slabs and flakes, largely by the action of frost. Red and brown clay soils are left when the rock is completely disintegrated. These are shallow and contain many flakes of the black schist. Ledges are usually near the surface, but seldom outcrop far from the stream cuts. The soils are light and fairly productive on the lowlands, but on the slopes and summits of the mountains support only a scanty growth of timber.

POST-CAMBRIAN (?) INTRUSIVE ROCKS.

WHITESIDE GRANITE.

The Whiteside granite lies in two general areas in this quadrangle. The principal mass occupies the southeast corner of the quadrangle and is part of a much larger body to the south and east. Also, in a wedge-shaped area running southwestward from the Pink Beds there are many irregular bodies of the granite. They do not extend far northeast of the Pink Beds, but pass southwestward considerable distances into Georgia and South Carolina. In the southeastern area the granite contains many enormous inclusions of the older gneisses, which lie with various positions and directions. In the northwestern area the granite appears for the most part in dome-shaped masses uplifting the gneisses, and from them many sheets and dikes are sent off. The formation is named from Whiteside Mountain, in the Cowee quadrangle, where it forms a series of enormous cliffs.

Relations.—This granite is intrusive in all the rocks of this quadrangle with which it comes into contact except the Triassic diabase. The ends of some of the granite bodies pass under the surrounding gneisses and are shaped like anticlines. The schistose planes of the gneiss arch over and dip away from the granite as if pushed up by the granite from below. This is excellently shown east of Lake Toxaway and around the Pink Beds. This relation is characteristic of those masses of the granite which lie northwest of the Brevard schist. The smaller granite bodies in that region appear to lie between the layers of gneiss, both formations having moderate dips in the same direction. The great granite mass in the southeastern part of the quadrangle shows none of the anticlinal arrangement. Within this general granite area are many extremely irregular inclusions of the gneisses. These extend in many directions and dip at all angles. The general position of these included masses is monoclinal between the different parts of the granite, and they appear to represent the remnants of the original gneiss cover. The large granite mass extends both southeastward and southwestward for considerable distances into the adjoining quadrangles, and the rocks now at the surface evidently were once deep down within the granite body. The granite domes represent the upper portions of a similar great mass.

Only a small amount of metamorphism is to be seen in this granite, some of its masses appearing to be entirely free from it. For this reason it is concluded that the granite was forced into the gneisses after most of the deformation of the region had been accomplished. Accordingly the granite may be as late as the Carboniferous in age.

Included within the areas mapped as Whiteside granite are numerous outcrops and small bodies of the older formations. There are also many dikes of the granite beyond the borders of the principal masses. Near the contacts of the formations the beds vary from a few inches up to many feet in thickness and alternate with great frequency. In comparatively few cases do the boundaries shown on the map represent a single contact between two large masses, but rather they indicate a narrow zone beyond which one rock or the other predominates. Unless the included bodies of other formations were found to prevail over considerable areas they were disregarded in the mapping.

Character.—The granite is composed mainly of orthoclase and plagioclase feldspar, quartz, muscovite, and biotite, enumerated in order of importance. Minor accessory minerals are magnetite, ilmenite, pyrite, and garnet. Most of the rock is made up of the feldspars. The biotite varies a great deal in amount and is sometimes entirely absent. The granite has least biotite in the dikes and small bodies, and they are nearly white. There is also little biotite in the granites of the southeastern mass. The Toxaway granite mass contains the most biotite and its color is, accordingly, darker than any of the others. All the rocks of the formation, however, have a generally light color, varying from white to gray.

Most of the granite is of fine or medium grain. This is especially true of the dikes and small bodies and of the great southeastern mass. At various places near the borders of the granite, porphyritic feldspar crystals are found. These are most prominent near Lake Toxaway and east of Brevard. At the latter place it is difficult to distinguish between the porphyritic forms of the Whiteside and Henderson granites. In the Whiteside granite, however, the massive form is much more common and the porphyritic phase is usually localized near its borders. In those parts of the formation which are much metamorphosed the phenocrysts are somewhat drawn out into lenses or augen of slightly more than their original length. Where they retain their original shape they are from a half to three-fourths of an inch in length. Akin to this are the small dikes and patches of pegmatite found at many points in the granite. Some of these are massive and others porphyritic, and the varieties grade into one another. The pegmatite patches grade into the granite and range in size from single crystals of feldspar up to bodies 2 or 3 feet across.

Another variety of the Whiteside granite is marked by a decided flow banding. This is due to the arrangement of the minerals in rudely parallel layers when the granite was forced in a molten condition into the other rocks. This can be seen at many points in the various granite bodies, but is best shown near Lake Toxaway, Lookingglass Mountain, and along Saluda River east of Cæsars Head. The rock marked by wavy flow bands merges into the massive variety in the same ledge.

Metamorphism.—During the deformation of the rocks the granite suffered changes both by folding and by metamorphism. The folding is the most prominent and is best shown in the dome-shaped masses north of the Blue Ridge. It is probable that some of the folding and upheaval of the surrounding gneiss was accomplished during the intrusion of the granite. Similar folding is shown near Marietta, in the southeastern part of the quadrangle, where the granite and gneiss bodies describe a semicircle. Metamorphism is comparatively small in most of the granite, but locally is of importance. Its chief development is near Lake Toxaway, where schistose and gneissoid granites are common. Some of these are as much deformed as the Henderson granite. The coarse varieties and those containing most biotite show the alteration best, while the fine-grained and light-colored granites have practically no metamorphism throughout large masses. When the rock was folded planes of fracture and motion were found 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. These minerals crystallized in general parallel to planes of motion in the rock; inasmuch as these were the result of broad general stresses the planes of schistosity are fairly uniform in position over large areas. The change is most manifest in the porphyritic feldspars, which have increased somewhat in length. They were cracked and broken and their fragments were rotated until nearly parallel. The mica flakes were turned into similar planes and thus was produced a gneissoid rock or augen gneiss with many porphyritic crystals pressed out into eyes. The large feldspars retained their shape better than the finer groundmass, and the mica flakes in the latter are bent and wrapped around the large crystals. Other results effected by the deformation are the stripes and striated surfaces which mark the granite here and there. These are due to linear growths of new minerals with parallel arrangement. The dark stripes are composed in the main of fine biotite and fibrous hornblende and the light stripes of quartz and feldspar. This phenomenon is well shown along the southern border of the quadrangle and in the fresh sections along Toxaway and Horsepasture rivers.

Weathering.—The surface of the formation is slowly lowered as it is attacked by weathering agencies. There is considerable variety in the topographic forms caused by the granite. All varieties give rise to ledges and great cliffs, and all are found worn down into plains. The cliffs of Whiteside Mountain, in the adjoining Cowee quadrangle, are the largest in the Appalachians, and the same granite forms similar cliffs in Lookingglass Mountain, Table Rock (see figs. 1 and 2), and many other localities. In these positions the granite also forms plateaus adjoining the cliffs. The difference seems to be due to the action of the acids in the soils, by which the feldspars are decomposed wherever soil is allowed to accumulate. A ledge once bare of soil is kept so by rain and frost and if situated on a steep slope becomes a cliff. Decay works down into the granite by the decomposition of the feldspars, leaving the quartz and mica grains free. The final product is a light-red or yellowish clay often strewn with fine white sand. In coves and hollows the soil is fairly fertile, but elsewhere is thin, easily worn out, and subject to drought.

TRIASSIC (?) ROCKS.

DIABASE.

Distribution and relations.—In the southeastern part of the quadrangle are found three areas of this rock. They form practically one narrow dike, being but slightly separated and lying in a single line. Their most distinctive feature is the absence of dynamic metamorphism, although the adjoining rocks are all metamorphosed, in places extremely. Rocks of the character of diabase and gabbro are especially subject to metamorphism, so that its absence here indicates that the diabase was formed after the general period of metamorphic action. Inasmuch as rocks of precisely this character are of frequent occurrence among the rocks of the Triassic period and are found at intervals in the older rocks of other areas, and as there are no other formations of this character known in the Appalachians, this rock is considered to be of Triassic age.

Character.—The diabase is a dense, hard rock of prevailing black or dark color, and on weathered surfaces has a reddish-brown or rusty appearance. It is composed chiefly of plagioclase feldspar, hornblende, and pyroxene, in crystals of medium size. Additional constituents are magnetite and pyrite in small grains and crystals. The texture of the rock is sometimes massive and granular like gabbro, but usually has the ophitic structure of diabase. Near the contacts with other formations the grain of the rock grows perceptibly finer, but it is seldom coarse in this quadrangle. In places the contact variety is an extremely fine whitish or gray rock without visible grain and resembling chert.

Weathering.—This rock withstands weathering most effectively. Decay works gradually in along joints, and spheroidal masses and bowlders are formed, which are characteristic of the surface of the formation. Ledges are seldom far from the surface and the cover of brown clay is usually thin. The rounded bowlders readily find their way downhill and block the stream channels.

STRUCTURE.

INTRODUCTION.

The rocks of this quadrangle that were deposited upon the sea bottom must originally have extended in nearly horizontal layers. At present, however, the beds or 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 region. In the 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 texture 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. On the scale of the map they can not represent the minute details of structure, and they are therefore somewhat generalized from the dips observed in a belt a few miles in width along the line of the section. Faults are represented on the map by a heavy solid or broken line, and in the section by a line whose inclination shows the probable dip of the fault plane, the arrows indicating the relative direction in which the strata have been moved.

GENERAL STRUCTURE OF THE APPALACHIAN PROVINCE.

Types of structure.—Three distinct kinds of structure occur in the Appalachian province, each one prevailing in a separate area corresponding to one of the geographic divisions. In the Cumberland 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 from northeast to southwest in the results of deformation, 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 here and there faults appear. Through Virginia into Tennessee the folds are more broken by faults. In the central part of the Valley of East 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 the minute breaks of cleavage and are 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 Mountain region 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 southern 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 there 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 can be traced southeastward through greater and greater changes 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 localized motion the original texture of the rock was largely destroyed by the fractures and by the growth of the 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. It 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 northwestward 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, the vertical movements 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. 2), depressions of this kind took place at the beginning of Paleozoic time, 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.

LOCAL STRUCTURES.

General features.—The rocks of this area have undergone many alterations in texture and position since they were formed, having been bent, broken, and metamorphosed in a high degree. The structures which resulted from these changes extend in a general northeast direction. Exceptions to this are seen south and east of Cæsars Head and in the basin of Pigeon River. In these areas the structure planes swing into a northwest course, nearly at right angles to their prevailing direction. Many minor changes of this kind are to be found at various localities in the quadrangle.

Structures in the sedimentary rocks are readily deciphered. In the igneous and metamorphic formations, however, while it is easy to see that the rocks have been greatly disturbed and the details of the smaller structures are apparent, it is difficult to discover the larger features of their deformation. One reason for this is that the original shape of most of the formations is unknown, because they are intrusive and consequently irregular. Another reason is that the masses of one kind of rock are so great and distinctive beds are so rare that structures of large size can seldom be detected.

While folds are numerous throughout the quadrangle, especially where they are defined by the sedimentary rocks and the uplifted granite masses, their importance is much less than that of the multitude of slips that accompany the metamorphism, which combined equal the larger structures. It is possible, also, that other faults occur in addition to the few faults that are shown, but for lack of distinctive or regular beds they can not be determined. By far the greater part of the deformation of the rocks in the region has taken place through metamorphism. It is very probable that the folds are complicated with faults along their borders; for instance, in the synclines of Brevard schist. No sharp line can be drawn, however, between the dislocation shown in faults and in metamorphism without displacement.

In the structure sections it is not possible, on account of the small scale, to show the minor folds and wrinkles, so that the structure is generalized and represented as comparatively simple. Nor is it possible to represent the granite and gneiss occurring beneath the surface, since they have no known methods of disposition or occurrence, such as characterize the sediments. 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 instances in which the bodies of Roan and Carolina gneiss and soapstone 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. From a similar course of reasoning, the bodies of Roan gneiss, being probably eruptive in the Carolina gneiss, have been treated as enlarging beneath the surface.

Folds.—In a broad way the structure of the rocks of the Pisgah quadrangle is that of a synclinal basin between two broad areas of uplift. The basin, which is marked by infolded sedimentary rocks, the Brevard schist, has a nearly straight course from northeast to southwest, almost from corner to corner of the quadrangle. The principal syncline is composed of from two to five minor synclines, along which in places the underlying granites are exposed. This fold, which begins in the adjoining Mount Mitchell quadrangle, extends with a singularly straight course southwestward through South Carolina and far into northern Georgia. Its extent and straightness make it one of the most striking folds in this part of the country. Toward it the structure planes of the gneisses on the north approach in succession. Local twists and turns in the individual beds can be found in almost any large outcrop. These are accommodated to one another, however, so that the average course of the formations is very regular for long distances.

The synclines in other portions of the quadrangle are recognized as such chiefly because they separate definite anticlines. Minor exceptions to this are seen in the contorted gneisses northwest of Pisgah Mountain.

The two areas of uplift are marked both by the foliation planes and by the masses of granite which have forced the gneiss upward from below. Of the two uplifts the southeastern is far the simpler and compares in this respect with the principal syncline. This is especially true of a belt 5 or 6 miles wide adjoining the syncline. The southeastern portion of this uplift, however, is very irregular in the direction of the foliation planes. Just west of Marietta, in particular, the included masses of gneiss and the foliation planes describe a semicircle.

The northwestern uplift is composed of many axes, the most conspicuous being those which expose the Henderson granite. At four places—near Lake Toxaway, around Panthertail Mountain, Lookingglass Mountain, and the Pink Beds—the doming of these masses and their anticlinal arrangement is very well shown. The same attitudes are to be seen in the rocks overlying the main granite masses, comprising the Roan and Carolina gneisses and smaller sheets and masses of the granite. All these axes pitch toward the northeast, so that the granite disappears in that direction and higher rocks form the surface. The crescent-shaped outlines of the various formations on the pitching folds are very striking. Around Lake Toxaway the anticlinal arrangement of the foliation planes is finely shown well down into the granite mass. Similarly, the sections northeast of Lookingglass Mountain show the arching of the overlying gneisses. The remainder of the great anticlinal uplift is characterized by very steep dips. Enormous bodies of the rocks stand on edge and are very highly contorted. This condition is brought out somewhat by the thin bands of Roan gneiss northwest of Big Pisgah Mountain.

The folds, both anticlines and synclines, range in size from mere wrinkles up to arches and basins with breadths of miles. Folds of all intermediate dimensions are to be observed. A few of them are open, especially near the ends of the granite domes. Sections C–C and D–D exhibit these moderately folded rocks. The majority of the folds, however, are nearly or quite closed. Thin beds, like those of the Brevard schist and portions of the Carolina gneiss, are bent and crumpled in an extreme degree without breaking. This is best seen in sections A–A and B–B. Sections B–B and C–C also cross masses of highly contorted gneisses with closed folds. Other large masses of gneiss with steep or vertical dips undoubtedly contain many closed folds which can not be detected.

Faults.—Faults are very rare in this quadrangle, and the only situation in which they are probable is along the southeast side of the Brevard syncline. It is difficult to explain the change from Carolina gneiss to Henderson granite on the opposite sides of the syncline without faulting. Usually there is perfect conformity of all the formations in dip, so that a fault can not be detected by that means. At Davidson River the granite near the schist is highly brecciated and undoubtedly faulted. It is not probable, however, that the contact between the Henderson granite and the schist is usually one of faulting. Except in that situation no faults of any note have been determined. Small faults of a few inches throw are to be seen at many points in the gneisses, especially where large ledges have been swept bare by streams, but such displacements are local and unimportant.

Metamorphism.—Metamorphism of the rocks was extreme, as well as the folding. In the description of the individual formations its detailed effects on the rocks were described. In general it consisted of a mashing of the rocks under the overwhelming pressure and a production of planes of fracture and motion through the body of the rock as well as along the sedimentary planes. Along these planes of fracture and to a less extent in other parts of the rock new minerals were developed, lying about parallel to planes of motion. To this arrangement is due the schistosity of the rocks. For the most part the new minerals were quartz and muscovite developed from the recrystallization of the old quartzose, feldspathic, and argillaceous material. These results are such as characterize metamorphism throughout the Appalachian Mountains. In this region there is also seen an enormous development of secondary garnet and cyanite during metamorphism. Similar metamorphic products are found in tracing these structures southwestward into Georgia. Northeastward the garnet-cyanite phases extend for 40 or 50 miles and southwestward for 10 to 25 miles, while the other products continue throughout the Appalachians.

The processes of metamorphism were along the same lines in both sediments and crystallines. The mineral particles were changed in position and broken during the folding of the rock. In folding, the differential motion in the sedimentary strata was to a large extent along bedding planes. As deformation became extreme, however, other planes of motion were formed through the individual layers, as in the case of the massive igneous rocks. In rocks which had already become gneissoid or schistose as the result of previous metamorphism the existent schistose planes served to facilitate flexure, as did the bedding planes of the sediments. In the massive igneous rocks there were no planes already formed, but these were developed by fracture and mashing, and the change of form expressed in folds was less than in the laminated rocks. These schistose partings are in a general way parallel to one another for long distances and over large areas. This is conspicuously true of the gneissoid portions of the Henderson granite. They sometimes diverge considerably for short distances around harder portions of the rock, which have yielded less under compression, but the influence of these portions is only local. Near the boundaries of formations, also, the schistose partings are usually about parallel to the general contact of the formations, the yielding to pressure having been directed by differences in strength between the formations. Thus, while the strike of the different formations may vary considerably in adjoining areas, yet the schistose planes swing gradually from one direction to another, and there is seldom an abrupt change.

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 appear in the Balsam and Pisgah mountains, the minor folds, and the wrinkles which are seen in 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 the gneisses are twisted and grow thicker and thinner in the greatest variety. Bending of the beds was largely accommodated by motion along the foliation planes.

In the granites during the same period of folding there were no existing foliation planes. Under the great stresses, however, planes and zones of shearing and mashing were produced and changes of form took place on them. These planes dip for the most part toward the southeast and are nearly uniform over large areas. They vary in amount from 5° or 10° up to vertical, averaging about 40°. 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 more massive and resistant portions of the rocks, also, the schistose planes swing gradually. In places where the motion was especially localized the minerals of the granites were elongated into thin sheets and strings or striated forms. In the porphyritic granites, like the Henderson, the large feldspar crystals were cracked, rotated, flattened, and elongated into eyes. Around these harder portions the secondary micas of the granite are closely bent.

There is great variety in the direction of the structure planes in the region. Their average trend is between N. 30° E. and N. 45° E. Locally there are groups running north and south, and also northwest and southeast. Some of the latter are brought out by the Roan gneiss bands in the Pigeon River basin. Local curves due to anticlinal structures are to be seen around the ends of the Whiteside granite areas north of the French Broad Valley, both in the granite and in the surrounding gneisses. Similar curves without trace of anticlinal origin are seen in the southeast corner of the quadrangle, where the schistose planes describe a semicircle in both gneisses and granite. In practically every case where the pitch of a large fold can be determined it is toward the northeast.

In the dips of the schistose planes of this quadrangle there is great variation. Throughout most of the area the dip of the schistose planes and sedimentary beds is toward the southeast at angles ranging from 10° to 90°. In certain belts there are usually distinct groups of dips. An exceptional feature in this respect is the series of northwestward-dipping beds and schistose planes seen along the headwaters of French Broad River. This is best defined in the region lying south of Tennessee Bald, in which locality most of the dips are northerly at angles of 20° to 60°. These northwesterly dips are caused by the anticlinal domes of Whiteside granite, which run from the Pink Beds in a southwest course. The anticlinal form taken by the granite masses is followed also by the schistosity, where it is developed, and by the foliation of the gneiss. An exceptional area of another character is found in the Henderson granite. In this rock the dip of the schistosity as a rule is very small—from 10° to 20° toward the southeast. Similarly light dips prevail in the adjoining Whiteside granite around and northeast of Cæsars Head. Strongly in contrast with these are the dips in the gneisses of the Pigeon River basin, where for mile after mile the rocks scarcely diverge from the vertical, even in spite of extreme crumpling.

Vertical movements.—The latest form in which yielding to pressure is displayed in this region is vertical uplift or depression. Evidence of such movements during the deposition of the sediments can be found in this quadrangle, as at the beginning of the deposition of the Brevard schist. In post-Carboniferous time, after the great period of Appalachian folding just described, such uplifts took place again and are recorded in surface forms. While the land stood at one altitude for a long time, most of the rocks were worn down to a nearly level surface. Over a large part of this region one such surface was developed, but only its worn remnants are now to be seen, at the heads of the main streams, where secondary cutting has not yet reached. Along the Blue Ridge are found the largest areas of this plateau, from 3000 to 3200 feet above sea. There are many smaller remnants here and there in the high mountains, the most perfectly preserved being the Pink Beds. Over much of this region another such surface was developed, which is still visible in the plateaus along French Broad River at elevations of 2200 to 2300 feet. Actual profiles of small parts of these plateaus are shown in sections A–A, B–B, and C–C. Southeast of the Blue Ridge another plain was extensively developed after further uplift and erosion had taken place. This, the Piedmont Plateau, now stands at heights of 1100 to 1200 feet above sea.

After the formation of each of these plains, uplifts of the land gave the streams greater slope and greater power to wear; they have therefore cut into the old surfaces to varying depths and produced canyons or later plains, according to their power and the nature of the waste they carried. The amounts of the uplift can be estimated, from the vertical intervals between the plateaus, at nearly 1000 feet after the first period of reduction, 1100 feet after the second, and perhaps 1000 feet after the last period. Other uplifts and pauses undoubtedly occurred in this region, but their traces are obscure; and probably there were still others which were not of sufficient length to allow plains to be formed and record the movement.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The rocks of this region yield materials of value, such as soapstone, talc, mica, corundum, kaolin, gold, graphite, copper, lime, building stone, and brick clay. The soils they form produce timber and crops, and the grades they cause furnish abundant water power.

SOAPSTONE.

Soapstone is found here and there through the Archean formations. With allied rocks it occurs at frequent intervals through the entire length of the Appalachians. Although soapstone is thus very widespread, few of its areas are over a mile in length. Some of the bodies are to be measured by a few feet, and most of them cover only a few acres. Soapstone is derived from the metamorphism of very basic igneous rocks and is associated with dunite, serpentine, chlorite schist, and other products of that metamorphism. It is customary to find several of the metamorphic varieties together in each area. South of the Blue Ridge only one soapstone body is known and practically all of it is found in the district north of Brevard and Lake Toxaway. More than twenty areas of the formation show a considerable amount of soapstone, in addition to those bodies pure enough to be classed as talc.

In places the soapstone is sufficiently pure for economic use. As a rule, however, the talc, the hydrous silicate of magnesia forming the basis of soapstone, is too much mixed with other silicates, especially 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 the working of the stone. The igneous rocks from which the soapstone was formed vary much in composition, so that the bodies 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, the mass at Three Forks of Pigeon River being much the greatest. The soapstone usually occurs in seams or layers in serpentine and dunite, a few inches or a few feet thick, and in larger bodies at the ends and borders of their inclosing masses. In this quadrangle an unusual number of bodies of the formation are entirely made up of soapstone or talc. On the economic geology map are indicated twenty-one areas of the formation where soapstone is found in sufficient purity and body to be valuable. The most promising localities are at Three Forks, 5 miles west of Fletcher, and 2 miles southeasterly from Lake Toxaway. At Three Forks the soapstone body is about a mile long, much of it being nearly pure talc, while at the other two localities its bands are from 100 to 1500 feet long. Thus far, however, only loose blocks and bowlders have been sawed and used for building fireplaces, and nowhere has the rock been quarried to any extent.

TALC.

Deposits of pure talc are found in connection with the dunite-soapstone rocks. The talc has the same origin as the soapstone bodies, both being derived from the metamorphism of peridotite, and is, in fact, only the purest form of those deposits.

On the economic geology map ten talc localities are shown. The principal ones are 4 miles northeast of Lake Toxaway, at Three Forks of Pigeon, and just south of Waynesville. In these three localities the talc forms substantially the entire outcrop of the formation. No tests have been made of the depth of the talc bodies. Since, however, they replace the dunite the depth of the talc is probably similar to that of the dunite. The shape of the dunite bodies is lenticular and their depth is doubtless as great as their length on the surface. At Three Forks the talc crops out in an irregular area about a mile long. Near Waynesville and east of Lake Toxaway the talc forms small lenses 10 to 50 feet thick and from 50 to 150 feet long.

Some uses of talc demand that the product shall be absolutely free from grit; others, that it shall contain no fusible minerals; still others, that the minerals shall be massive and capable of being sawed into small sections. All of the talc shown here is sufficiently free from grit and fusible substances. A few small grains of iron oxides are found in most of the talc, but these can readily be separated when the rock is pulverized. Except for these oxides there are no fusible impurities. All of the talc, however, is schistose to some degree. This structure renders it unfit for the manufacture of pencils, on account of the easy splitting which it produces; but it does not affect the use of the talc in larger forms, such as linings for fireplaces and furnaces. In this way considerable use has been made of the material from these localities. None of the talc is translucent or massive. The portions now available are the surface materials, however, and the deeper rock would doubtless be better. In no case would the schistose character be absent.

MICA.

In the pegmatites of the Archean rocks, mica occurs in crystals large enough to be of commercial value. Pegmatites are found in the various granites and gneisses throughout a large portion of their areas, but they contain mica of workable size chiefly in a belt about 8 miles wide and running 20 miles southward from Waynesville. The largest mica has been produced from the Big Ridge mine, on the southwestern side of Lickstone Bald. All of the mines are in the Carolina gneiss, as are most of the good mica mines of this region. The principal developments in mica mining have been in the Big Ridge mine and also within a distance of 4 miles from Tennessee Bald. The mica region also extends westward into the Cowee quadrangle.

The group of mica-bearing pegmatites passes northward into the Asheville quadrangle, but does not there contain mica of workable size. In general, however, outside of the mica district above described the crystals of mica in the pegmatites either were not originally of workable size or have been crushed or distorted during the deformation of the rock. In this quadrangle the pegmatites which carry large mica are usually of lenticular shape and lie in general parallel to the inclosing gneisses. Some can be traced for miles, while others extend only a few rods or a few feet. In some places the pegmatite has the form of a vein or dike, with nearly parallel walls; this variety cuts across the schistosity of the gneiss at high angles. Still other pegmatites are replacements of the Whiteside granite and are entirely inclosed in it. These are more feldspathic than the other forms and are closely connected with the granite in origin; they seldom or never carry merchantable mica. Pegmatite in the Henderson granite is comparatively rare and the mica is small.

The mica which is mined is the variety muscovite, and it is crystallized with quartz and feldspar, forming the pegmatite. In many localities biotite also occurs, and beryl, garnet, chlorite, and numerous other minerals are found. From a texture like that of granite the coarseness of the pegmatite varies until the mica crystals attain a diameter as great as 20 inches. Crystals of this size are rare, having been found only in the mine at the head of Pigeon River. The average crystals mined are from 3 to 8 inches in diameter.

In places the mica apparently follows rather irregular planes, which are termed the "vein." The distribution in the vein of the crystals or "blocks" of good mica is very irregular. They can not be predicted or traced far with a definite position in the pegmatite. Consequently, the success of any mica mine is uncertain at the start. Large mica may be found at once or barren rock may continue throughout. Large mica at one point may become smaller in a few feet, or the crystals may be crushed and cut into ribbons. Even when the mica is large, most of it may be "A" mica with poor cleavage. Generally, however, one class of mica prevails for considerable distances.

Many of the crystals do not furnish sheets across their entire diameter, for seams and cuts divide them into strips and angular pieces. Such crystals, however, are suitable for ground mica. Impurities in the form of dendrite figures, stains, and spots render much of the mica worthless for any purpose, and clay penetrates between the sheets where the rock is decayed near the surface. Clayey impurities can be, for the most part, taken out by careful washing, but the spots of dendrite can not be wholly removed, existing as they do between the thinnest sheets. These spots are unimportant in mica where transparency is not required, or where used for insulation of low-tension electric currents.

Pits and shallow openings have been made at scores of places in this region during many years, but they have usually been sunk in the decayed rock and soon exhausted. Later work in the solid rock is difficult, on account of the hardness of the quartz and feldspar.

At present the only work carried on is at the Big Ridge mine and 2 miles north of Balsam Grove on the head of French Broad River. The Big Ridge mine is the most important and has been worked for many years. At that point inclines go down for 70 or 80 feet, at angles of 10° to 30° to the northeast, following the pitch of the pegmatite and the inclosing mica gneiss. The mine lies just on a small anticlinal fold in the mica gneiss which pitches northeast. The pegmatite is composed of feldspar, quartz, muscovite, and biotite, with a little beryl, apatite, garnet, and chlorite. The amount of biotite is unusually large in this pegmatite. The feldspar is mainly plagioclase, some of which is clear and glassy. Its crystals are large, occasionally exceeding a foot in length. The largest mica "blocks" are nearly a foot across the sheets, but most of them are much smaller. Most of the mica has good cleavage and but little figuring. The product is used chiefly for insulating work in electric construction.

CORUNDUM.

Corundum is an aluminum oxide and is found in association with the Archean rocks. Within this area three localities where it occurs are known and it is reported to have been found in numerous others. There are two distinct kinds of occurrence: Near Great Hogback, a mile northeast, and also about a mile southwest, corundum is found in connection with the dunite formation. At Retreat it also occurs in mica gneiss.

At Retreat corundum was first found in the gravel bed of a small stream. During later search for its source a small amount of corundum was encountered in a small tunnel in the mica schist a few rods northeast of the stream. It was evident, however, that the main source of the corundum was not discovered, because the corundum was found in the gravels above the tunnel. The corundum float was traced for perhaps 200 yards. Most of the corundum was of a light-grayish color. Small fragments of a clear sapphire blue were found, and some of the light-colored pieces contained sapphire streaks. Some of the larger pieces are deeply pitted, as if the corundum had filled in spaces between other minerals. In the tunnel the corundum crystals were reported to be embedded directly in the mica schist. Small veins of vermiculite, usually associated with corundum, are found in the schist. These schists are somewhat garnetiferous and are just northeast of a narrow dike of the hornblende gneiss which lies in the Carolina gneiss. Aside from this suggestion of a contact relation between the corundum and the igneous rock, there is no evidence in this region as to the origin of the corundum. No deposit of note was developed in the hard rock, nor is the amount of corundum in the gravels or the amount of gravel itself sufficient to justify much work to recover it.

The deposits near Great Hogback are typical of most of the southern Appalachian corundum. They are closely associated with the dunite formation. The principal occurrence here is at the Burnt Rock mine, a mile northeast of Great Hogback. The dunite there forms a lenticular mass at the contact of the hornblende gneiss and mica gneiss. There is a minor lens of the dunite formation below the principal one and separated from it by a thin band of mica gneiss and pegmatite. The main body of the mica gneiss is above the dunite, while below it is chiefly hornblende gneiss. The rocks as a whole have a dip of about 30° NW. The dunite formation here consists of a rock characterized by large amounts of enstatite and chlorite. These are secondary replacements of the minerals of an original peridotite or pyroxenite.

Corundum is found there in two situations. A little is embedded in the kaolin of the pegmatite lenses; the major part, however, is derived from veins along the border of the dunite and filling small cracks between its blocks. These veins or seams are seldom more than a foot or two thick, and consist mainly of chlorite, actinolite, vermiculite, and corundum. The corundum occurs in nodules and small lumps in the other minerals. They form a closely felted mass in which most of the crystals are arranged at right angles to the walls of the vein. The corundum has for the most part a dull gray color, but now and then sapphire-blue or ruby-pink crystals were found. Corundum also occurs sparingly in the pegmatite lenses cutting the gneisses. It there forms crystals inclosed in feldspars and is not of commercial importance. About 10 tons of corundum was taken out from this locality in 1892, but the work was discontinued the following year. Several times since then the deposits have been prospected. The work consists only of open cuts and pits following the contacts and irregularities of the veins, and no systematic exploration has been made.

At the Brockton mine, about a mile southwest of Great Hogback, the associations are practically the same as at Burnt Rock. A much larger amount of corundum was taken out, however, at the same time that operations were carried on at Burnt Rock.

The origin of the corundum is doubtful. All the rocks in which it is inclosed are marked by schistosity which results from metamorphism. The corundum and associated minerals in the veins do not display this feature. It is most probable, therefore, that the corundum-bearing veins were formed later than the inclosing rock.

KAOLIN.

There are two localities in the quadrangle at which kaolin has been found in quantity—at Retreat and near Sonoma, 2½ miles nearly northeast of Retreat. The kaolin has resulted from disintegration of pegmatite lenses, which are very common in that region. Those which contain a large proportion of feldspar have decomposed most and form workable deposits. Rock decay has been most thorough and deepest near the old plateau surfaces, and in those regions also it is most difficult to determine the nature of the underlying rock on account of the thick cover of soil. It is certain that there are many other deposits not discovered, of equal or greater value than those mentioned here. The pegmatite bodies are universally found in this region, and on the uplands are frequently seen to be of large size.

The two instances cited are scarcely developed at all and barely more than their presence is known. Near Retreat the kaolin has been exposed in three small pits on opposite sides of a little ridge, and it is probable that it is a single body. One pit is nearly north from the other, a direction which crosses the foliation of the mica gneiss. The kaolin near Sonoma appears to have a similar north-south direction, which is there more nearly coincident with the strike of the inclosing mica gneiss. At this locality a single pit about 15 feet deep has been sunk on the top of a hill. In each case the kaolin has a clear white color and is very little surface stained. It is mixed with a moderate amount of fine quartz and but little mica. Although no considerable deposit has been revealed, the prospects are worth further testing; owing to the steep dips of the country rocks, they would probably descend to considerable depths. Near Retreat the kaolin deposit has a length of about 200 feet, and may be much longer; the length of the other deposit is unknown.

GOLD.

Vein gold is found at only one place within the Pisgah quadrangle, at the Boylston mine, on the southeast slope of Forge Mountain. In addition to this occurrence of gold in the ledge, gold has been washed from the gravels along the head of Toxaway River, now occupied by Lake Toxaway. Similar gravels at the western foot of Great Hogback were washed for gold with considerable success before they were covered by the present lake at Fairfield. The gravels occupy valleys of streams which head within 2 miles of the deposit. The basins above the gravels are mainly underlain by granite with narrow bands of hornblende and mica gneiss. These gravels at Lake Toxaway are associated closely with the plateau of the Blue Ridge, and are a little over 3000 feet above sea. Similar gravels derived from the same group of rocks are found in a narrow belt running northeastward across the headwaters of French Broad River near Balsam Grove, of Davidson River, and of Mills River in the Pink Beds. While it is not known that these gravels are auriferous, there is reason to suppose that they are.

At the Boylston mine operations have been carried on at several times during a period of thirty years. The deposits are quartz veins carrying gold and pyrite. The country rock is bluish-gray and gray mica schist and mica gneiss, cut by narrow beds of white biotite granite. There are four or five quartz veins in the property with a general strike of N. 30° E., the same as the country rock. The one on which the most work has been done lies near the foot of the mountain. This varies in thickness from 2 to 8 feet. It is lenticular in character, but in places the lentil is so long as to resemble a fissure vein. The dip of the lentils and of the containing rocks is the same. Along the surface in shallow cuts they all dip toward the northwest, while in the hard rock of the tunnel the dip is steep toward the southeast. Inasmuch as all the rocks of that region dip toward the southeast when in place, it is probable that the northwestward dips are due to creeping of the decayed rock down the mountain. Some of the quartz is very rich in pyrite, while the greater part of it carries a very little. It is probable that the great range in reported values is due to very unequal distribution of pay ore. Most of the quartz is vitreous, but a considerable part is saccharoidal. The principal developments consist of a long line of open cuts in the weathered rock and quartz. These extend along the foot of the mountain for half a mile. Below these openings a tunnel has been driven to a reported length of 700 feet. The original developments included a 10-stamp mill, which remains; the last work was done by a 40-stamp mill, which has been removed.

GRAPHITE.

Graphite is found here and there in many of the layers of the Brevard schist, disseminated through the body of the schist in extremely fine particles. While the deposits of this mineral have been mined on the extension of the schist in the Mount Mitchell quadrangle, no work has been attempted in this quadrangle. The black schists are graphitic in many parts of the formation, especially near its base. In fact, graphite might be said to be a regular constituent of the schist in some areas. As to the cause of the presence of the graphite in some places and its absence in others there is no good evidence, nor is it known whether the graphitic material was introduced into the schists as an original or as a secondary constituent. Its presence in the Mount Mitchell quadrangle in veins, the quartz of which is secondary, indicates a secondary origin for the graphite. The schist itself is composed of very fine quartz and muscovite scales with black iron oxides in extremely minute grains. These various minerals are distributed uniformly through the schist. Another mineral sometimes found in the graphitic schists is garnet.

In some respects the outlook for successful recovery of the graphite is better in this than in the Mount Mitchell quadrangle, where both cyanite and garnet were abundant in the graphitic schist and were a serious hindrance to the separation of the graphite. In this quadrangle the schists appear to be as graphitic, while cyanite is absent and garnet uncommon.

COPPER.

Copper ore is known to exist along the western border of the quadrangle at a number of places shown on the economic geology map. The copper occurs as chalcopyrite mixed with pyrite and pyrrhotite. These minerals are found in three forms —as concentrations in layers of mica schist and mica gneiss, as vein deposits with quartz, and as vein deposits with epidote and quartz. No deposits of value have been discovered where minerals were disseminated in mica gneiss. In this form, however, when weathered, they cause a great deal of iron-ore float and limonite stains, forming small gossans. These have led to considerable prospecting work, but without success. Of this character are the localities near Lavinia. On Dick Creek about east of Retreat and on Pigeon River a mile south of Retreat small openings have been made in quartz veins cutting the mica gneiss. These strike about N. 30° W. and dip at steep angles toward the southwest. Small amounts of pyrrhotite and pyrite and traces of chalcopyrite were found, but no deposit of any value. On Wolf Creek a few miles west of Pinhook Gap chalcopyrite occurs in an epidote-quartz vein associated with pyrite, plagioclase feldspar, and lime garnet. The vein, about 20 feet wide, cuts the mica gneiss and runs northeasterly for a considerable distance. Numerous other occurrences of the epidote-quartz rock are found in that region, but in no case does it constitute an ore. About a mile northeast of Tennessee Gap lies a considerable series of gossans. In one pit 2 feet of iron ore were found, which is the greatest thickness shown at any point. Several prospects extend the gossan lead northeastward about a mile, mainly in the Roan gneiss. Although almost no work has been done on this deposit, the indications are better than anywhere else in the quadrangle.

BUILDING AND ORNAMENTAL STONE.

Most of the formations of this quadrangle yield stone suited for building. The best is found in the Henderson granite, Whiteside granite, and Brevard schist.

Granite.—The two granite formations contain by far the best and most abundant building stone. Neither is very variable in texture, and large quantities of massive, uniform stone can be procured. The Henderson granite yields the most workable and accessible stone in this region. Extensive outcrops of the formation are common throughout its course, especially near French Broad River. The formation consists mainly of the porphyritic granite, which is usually schistose or gneissoid. The rock is gray for the most part, either light or dark. The porphyritic feldspar crystals give a striking aspect to the rock and render it suitable for ornamental work. The stone can readily be opened along the schistose planes, and split into beds of any desired thickness. It dresses well, and is exceedingly hard and durable. The best localities for quarrying are along and near French Broad River. In these situations many large outcrops and cliffs of granite reach the surface and the slopes are steep. Considerable stone has been quarried at three places shown on the economic map and local use made of it in bridges and buildings.

The Whiteside granite yields excellent stone of a more massive texture than the Henderson. Its color is light gray or white, and its grain is medium and very uniform through large bodies. It splits out in thick sheets and dresses very well. Its durability is shown by its enormous cliffs in Table Rock and Lookingglass Mountain. Along the Blue Ridge are found the best natural outcrops, but quarries could be developed readily at nearly any locality in its areas. The cover of soil is seldom heavy over the rock and weathering is not deep. The stone has been used for dams, chimneys, and abutments.

Marble.—Beds of marble are found in the Brevard formation at several points. While the areas underlain by the marble are large, outcrops of the rock itself are very scarce. The marble is much more rapidly dissolved by circulating waters than the adjoining rocks, so that its surface is low and overspread with wash from the harder formations. Most of it is white or light colored, but associated with this variety are beds of white marble with blue bands and numerous dark-blue beds. An analysis of the marble near Fletcher gives 95 per cent of carbonate of calcium and 5 per cent of carbonate of magnesium. The marble is finely crystalline, and some of it has almost the texture of limestone. The lower beds of marble shown near Fletcher are not suitable for ornamental use, since silica is present in the form of small grains which impair the polish of the stone. The upper 200 feet, however, are suitable for ornamental stone. The greatest thickness of the marble shown in this region is near Fletcher, about 250 feet. At all other points the thickness is much less.

No attempts have been made to utilize the marble for building stone, but large amounts have been taken out for burning into lime. The locality near Fletcher affords the most available places for quarrying. The marble there lies along the bottom lands of a small stream, and hard rock comes within 4 or 5 feet of the surface. This would necessitate considerable pumping. The dip of the strata at that point is southeastward at angles ranging from 65° to 75°. At this angle the quarrying of definite beds of marble would not involve handling a great deal of rock. The rock is usually massive and fairly free from joints, so that large blocks could be quarried.

LIME.

Lime for building and agricultural purposes can be obtained in this quadrangle only from the marble beds in the Brevard schist. For many years this lime was used, even before the advent of railroads. Large quantities have been burned and the product has been found excellent. The kilns on Boylston Creek furnish material for local use, while those at Fletcher ship their product by railroad. Outcrops of the marble are scarce and are usually found near streams, so that disposal of waste material and water requires extra expense.

BRICK CLAYS.

All of the formations in this region form clays on decomposition. These are of various kinds—pure, sandy, or micaceous—and they extend over most of the valleys and lower portions of the quadrangle. In the mountains the amount of clay on the slopes is very small. In the smaller valleys throughout the area, however, more or less clay is always found. In the more level portions of the region the cover of clay and decomposed rock is from 3 to 50 feet thick. The best clay is found in two situations—on the flood plains and terraces of the larger rivers and in the small valleys and hollows on the various plateaus. On the small streams of this quadrangle, except those some distance southeast of the Blue Ridge, the grades are too heavy to permit the accumulation of clay. Along the rivers and larger creeks there are extensive deposits in flood plains and terraces. These clays have been used principally near Waynesville, Brevard, and Fletcher. At the latter point a good-sized plant is using the clays along the bottom lands of Cane Creek. The deposit is 8 or more feet in thickness and covers many square miles. Its size is even exceeded by similar deposits along Mud Creek and French Broad and Saluda rivers. Into the small hollows of the old plateau surfaces, also, the finest portions of the decomposed rock were washed and there excellent clay beds were formed. The total amount of this kind of material in the quadrangle is enormous. These clays are from 1 to 6 feet deep, being thickest in the bottoms of the hollows and thinner on the hill slopes. In many places these have been burned into bricks for local use.

WATER RESOURCES.

WATER POWER.

Within this quadrangle there are abundant resources in the form of water power. In nine-tenths of the area the streams, both great and small, flow rapidly. Since they are fed from multitudes of springs and drain well-forested areas, their flow is very steady from season to season. The stream grades are divided into three general groups, according to their relations to the large topographic features. These are above, below, or on the old plateau surfaces. As was explained under the heading "Geography," plateaus now are found at three heights above sea level and cover about two-thirds of the quadrangle. Above them stand large mountain masses never reduced to the levels of the plateaus.

Since the formation of the plateaus as plains the streams have acquired fresh power and recut their channels to greater depths. The new cuts are deepest in the lower portions of the main streams and are progressively shallower toward their heads. The streams are only beginning their work in recutting the Piedmont Plateau, and their channels are less than 200 feet below the plateau tops. The French Broad plateau is only from 2 to 6 miles wide in this quadrangle. On this the channels of the streams still flow for 5 or 6 miles below Brevard, at which point recent cutting is well under way. Where the stream leaves the quadrangle it is about 200 feet below the plateau surface. The plateau of Pigeon River extends only a few miles into the quadrangle and has not been appreciably lowered by recent cutting. The Blue Ridge plateau was the most extensive of all in this region. Its height is from 3100 to 3200 feet above sea and it was principally developed in the basin of French Broad River, and the basins of Saluda, Toxaway, and Whitewater rivers on the south side of the Blue Ridge.

During the formation of the French Broad plateau the streams cut down into the Blue Ridge plateau about 1000 feet and formed a network of deep canyons. Stream grades in these are usually heavy and small waterfalls are common. Typical of this is the course of Mills River. This heads on Pisgah Ridge over 5000 feet above sea, descends rapidly to the plateau of the Pink Beds at 3200 feet, and descends in a narrow canyon to the French Broad plateau at 2200 feet in about 8 miles. Southward from the Blue Ridge plateau the streams descend a little more than 2000 feet to the Piedmont Plateau. The fall from the upper to the lower plateau is extremely heavy in most of the streams, many of the smaller creeks accomplishing it in 4 or 5 miles. Typical of this is South Saluda Creek. Horsepasture and Toxaway rivers flow 5 or 6 miles along the upper plateau surface and descend with many waterfalls and rapids to the lower plateau in 8 or 9 miles, an average grade of considerably more than 200 feet per mile. The streams of the Piedmont Plateau are comparatively sluggish and descend in this quadrangle only about 200 feet in 10 miles.

The streams which flow northward from Pisgah Ridge and Balsam Mountains start at heights of 5000 and 6000 feet above sea and fall with great rapidity to about 3000 feet, where the beginnings of the Pigeon plateau are to be seen. The courses of these streams lie in V-shaped gorges and the amount of water is considerable in each, although the drainage areas are small.

Thus, there are two situations in which extremely high grades are typical of all the streams. These are the unreduced masses of the Balsam and Pisgah mountains and the canyons intersecting the Blue Ridge plateau. Most of the streams thus located are small, but they drain heavily forested and well-watered regions, so that their flow is considerable and steady. Their extremely high grades concentrate the water power within narrow limits and render it available at little expense.

The water power developed in this region is thus obtained, for the most part, by the elevation and cutting of the Blue Ridge plateau. Since the large streams are nearly all below the plateau level those water powers which are above the plateau are in most cases on small streams and of no great amount. The heavy grades are due to the backward cutting of the streams, here and there concentrated into falls and rapids by hard beds of rock. This is notably the case in the Whiteside granite areas near the Blue Ridge, where its hard and massive character causes enormous cliffs and ledges. Similar but smaller falls are made by the Henderson granite. The various gneisses are not widely different in their influence upon the immediate stream grades.

The enormous water powers thus at hand in the quadrangle have received scarcely any development. A few sawmills and gristmills have been turned by the small streams, but nothing more. With the coming of railroads and the possibilities of electric transmission the energy of the various streams should prove very valuable.

WATER SUPPLIES.

The various sources of water in the Pisgah quadrangle furnish an unusually large supply. The region is covered, for the most part, with heavy timber growth and is almost altogether mountainous, no part of it being more than 8 miles distant from high mountains. The fall of rain and snow is heavy and the natural advantages for storage are very great. The rocks of the mountain district, particularly the gneisses in the northwestern part of the quadrangle, have large numbers of schistose planes and are not dense. Accordingly, they are able to hold large quantities of water. The granites are less schistose and more compact, and thus are able to store up less water. The result is seen in the more frequent droughts which affect the granite regions. In the granites, also, the schistose planes over large areas dip at small angles and do not conduct the rainfall readily into the interior of the rock. The gneisses, on the other hand, stand at very steep angles over nearly all the areas, and thus the water is carried into the earth most readily. Ample time is allowed for this transfer, for evaporation is checked by the forest growth and by the lower temperatures due to the height of the mountains. In times of flood the streams rise and fall quickly, but the usual flow is steady and full. Innumerable springs maintain this flow in spite of occasional droughts. In the mountains, where rock comes close to the surface, most of the springs issue directly from the rock. In the valleys and plateaus the residual soils are from 6 to 50 feet thick. The water of the springs is largely absorbed by this and seeps out from the clay into hollows. Actual springs are very much fewer on surfaces of this kind, which are practically limited to the remnants of the plateaus. As was stated under the heading "Geography," these plateaus are found chiefly around French Broad River and the streams which flow southward from the Blue Ridge.

The only use made of the enormous outflow of water from this region is for domestic purposes. The houses were built within easy reach of springs, which was usually possible. On the uplands of the plateaus and on the flood plains of streams shallow wells were sunk in the clay and gravel. A few wells have been cut in decomposed and solid rock for depths of 50 or 60 feet, but none have been bored to any considerable depth. The town of Waynesville secures its water by damming a small creek about 3 miles northwest of the town. A far better supply can be secured from the head of Allen Creek, distant about 6 miles, while from West Fork of Pigeon River, 13 miles distant, an ample supply of the best quality can be obtained. The latter could be taken through Davis Gap and delivered to the town under a head of about 200 feet. These supplies are of the very best quality. The water is seldom turbid, even after the heaviest rain, and a good flow is maintained by the stream, however severe the drought. The situation of each catchment basin is excellent, since it includes a compact area of mountains from 5000 to 6500 feet in height, where the forest cover is very heavy and the precipitation unusually great. Similar supplies are to be found in East Fork of Pigeon River, West Fork of French Broad River, Mills River, and Davidson River, all flowing from the Pisgah Ridge. For example, the town of Brevard is now supplied from Kings Creek, a small branch dammed 2 miles from the town. A much better supply could be secured from the head of Davidson River, at a distance of about 11 miles. Similar supplies are to be had from Toxaway and Horsepasture and various creeks flowing southward and eastward from the Blue Ridge.

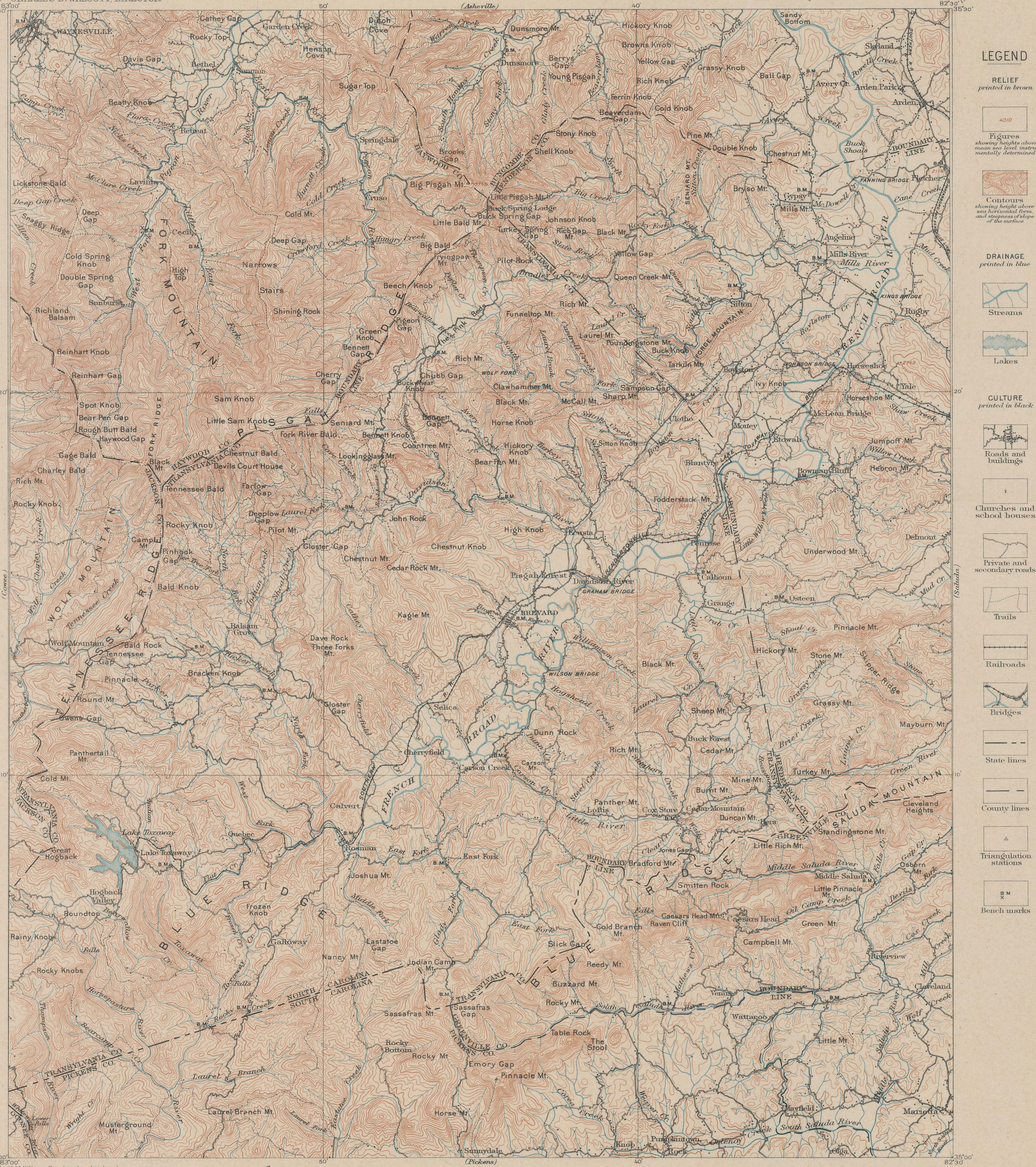
July, 1906.

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

TOPOGRAPHY

NORTH CAROLINA—SOUTH CAROLINA
PISGAH QUADRANGLE

(Mt. Guyot) (Mt. Mitchell)



H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr and S. S. Gannett.
Topography by R. D. Cummin, J. H. Wheat, W. L. Miller and E. McL. Long.
Surveyed in 1886-88 and 1895-96.
Revised by Arthur Keith and H. S. Gale in 1904-1905.

APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{125000}$

Miles

Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of June 1906, reprinted Feb. 1907.

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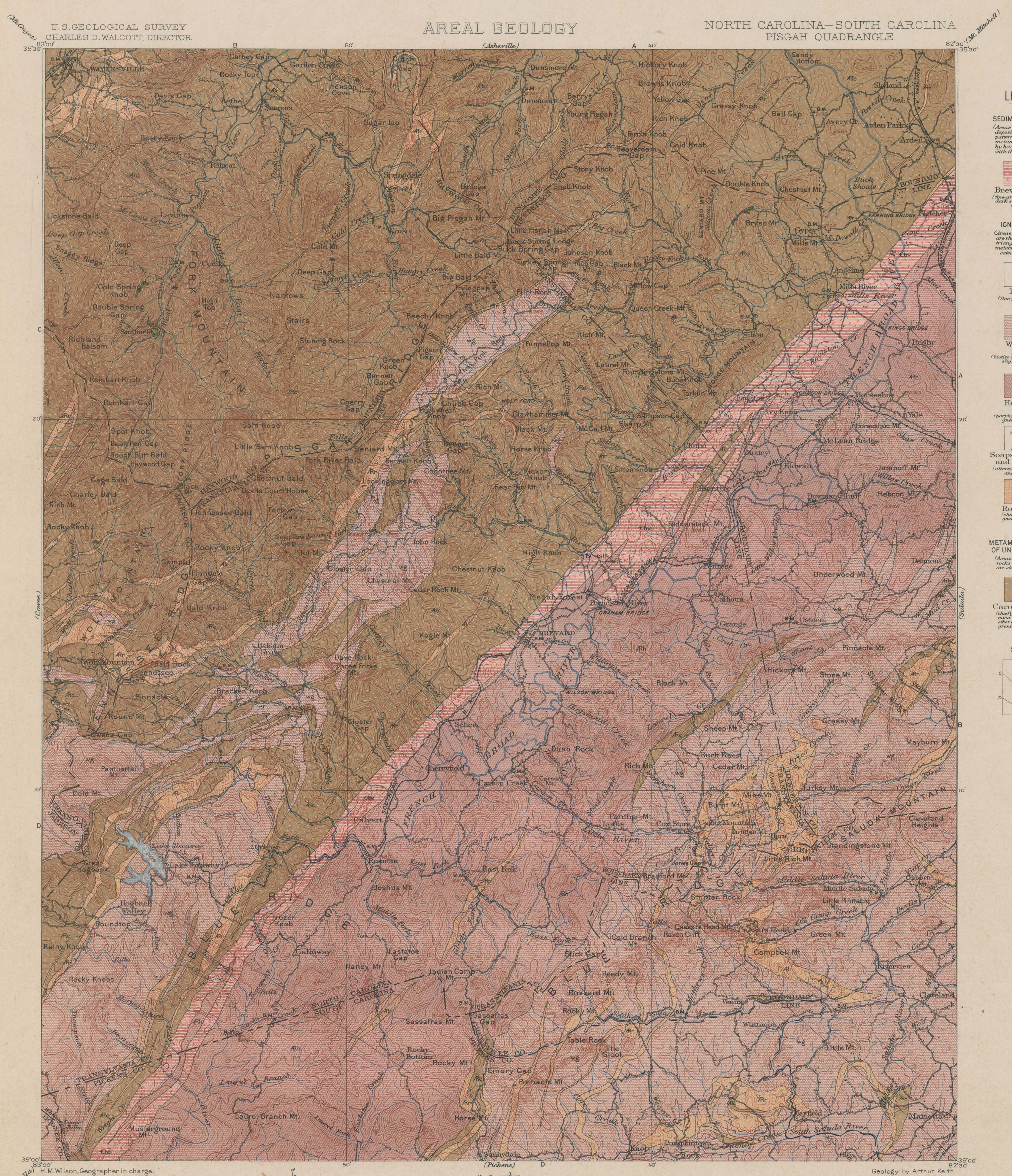
AREAL GEOLOGY

NORTH CAROLINA—SOUTH CAROLINA
PISGAH QUADRANGLE



LEGEND

SEDIMENTARY ROCKS
(Areas of subaqueous deposits are shown by patterns of parallel lines; metamorphism is indicated by hachures combined with the line patterns)

Ꞓbv — Brevard schist *(fine-grained, black and dark schist, with lentils of limestone)* — CAMBRIAN

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

Diabase *(fine-grained massive diabase)* — TRIASSIC

wg — Whiteside granite *(biotite-muscovite granite, slightly schistose)* — AGE UNDETERMINED

Ꜳh — Henderson granite *(porphyritic granite and gneissoid granite)* — ARCHEAN

Ꜳs — Soapstone, dunite, and serpentine *(altered from peridotite and pyroxenite)* — ARCHEAN

Ꜳr — Roan gneiss *(chiefly hornblende gneiss and schist)* — ARCHEAN

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

Ꜳc — Carolina gneiss *(chiefly mica gneiss and mica schist, includes other gneisses, schists, granite, and diorite)* — ARCHEAN

Sections

H. M. Wilson, Geographer in charge.
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APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{125000}$
Contour interval 100 feet.
Datum is mean sea level.
Edition of Jan. 1907

Geology by Arthur Keith, assisted by Hoyt S. Gale.
Surveyed in 1900-1905.

U. S. GEOLOGICAL SURVEY
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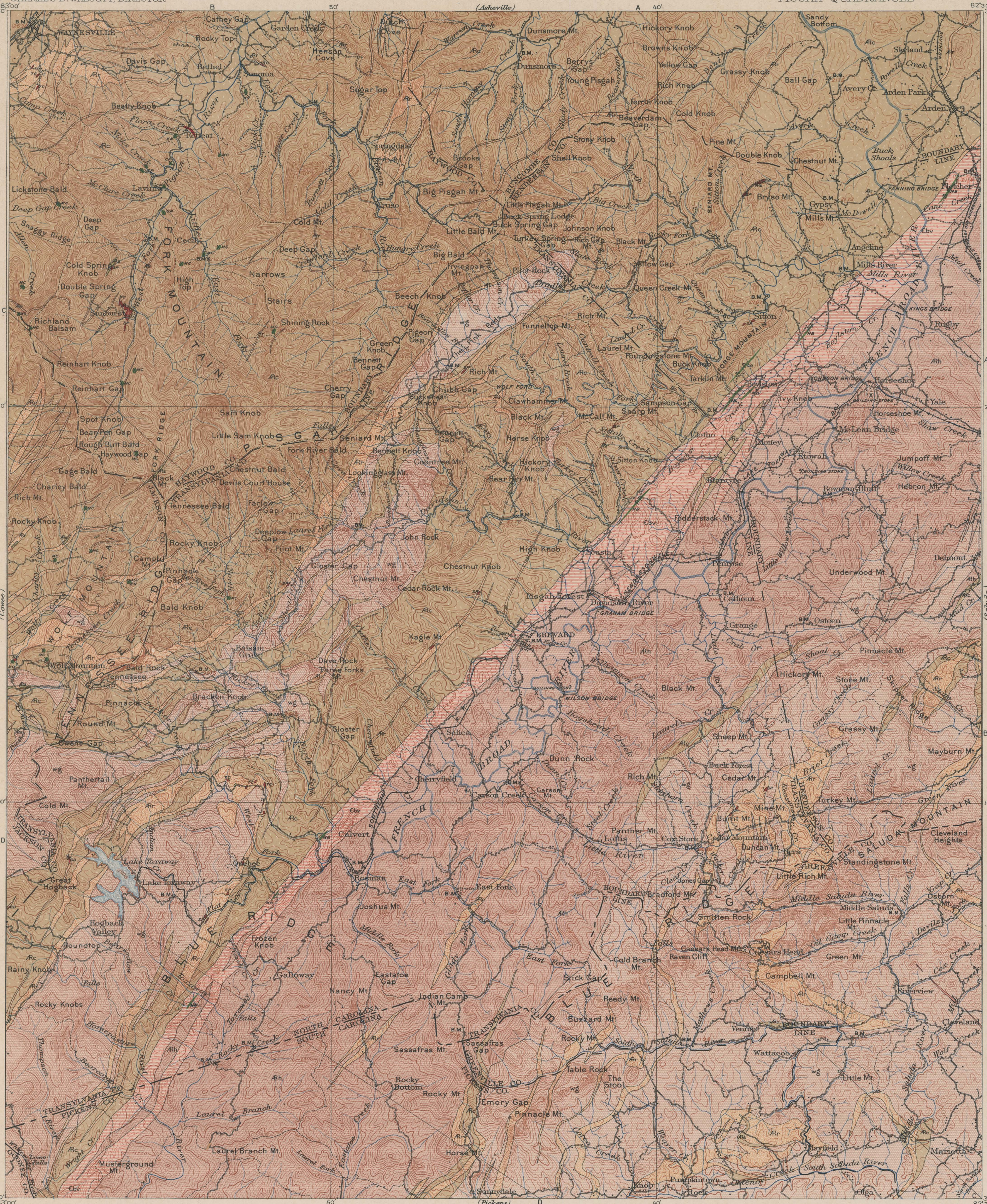
ECONOMIC GEOLOGY

NORTH CAROLINA–SOUTH CAROLINA
PISGAH QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; metamorphism is indicated by hachures combined with the line patterns)

Єbv — **Brevard schist** *(fine-grained, black and dark schist, with lentils of limestone)* — CAMBRIAN

IGNEOUS ROCKS

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

Diabase *(fine-grained massive diabase)* — TRIASSIC

wg — **Whiteside granite** *(biotite-muscovite granite, slightly schistose)* — AGE UNDETERMINED

Ꜳh — **Henderson granite** *(porphyritic granite and gneissoid granite)* — ARCHEAN

Ꜳs — **Soapstone, dunite, and serpentine** *(altered from peridotite and pyroxenite)* — ARCHEAN

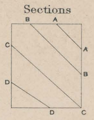
Ꜳr — **Roan gneiss** *(chiefly hornblende gneiss and schist)* — ARCHEAN

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

(Areas of metamorphic rocks of unknown origin are shown by hachures)

Ꜳc — **Carolina gneiss** *(chiefly mica gneiss and mica schist; includes other gneisses, schists, granite, and diorite)* — ARCHEAN

Sections



⚒ *Mines and quarries*
x *Prospects*

Known mineral deposits

GD — *Gold* *(auriferous quartz veins)*

CP — *Copper*

CD — *Corundum-bearing veins*

MC — *Mica-bearing veins*

TC — *Talc*

SP — *Soapstone*

KN — *Kaolin* *(decomposed pegmatite veins)*

MB — *Marble* *(lentils in Brevard schist suitable for building stone and for lime)*

H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr and S. S. Gannett.
Topography by R. D. Cummin, J. H. Wheat, W. L. Miller, and E. McL. Long.
Surveyed in 1886-88 and 1895-96.
Revised by Arthur Keith and H. S. Gale in 1904-1905.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1906.

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.

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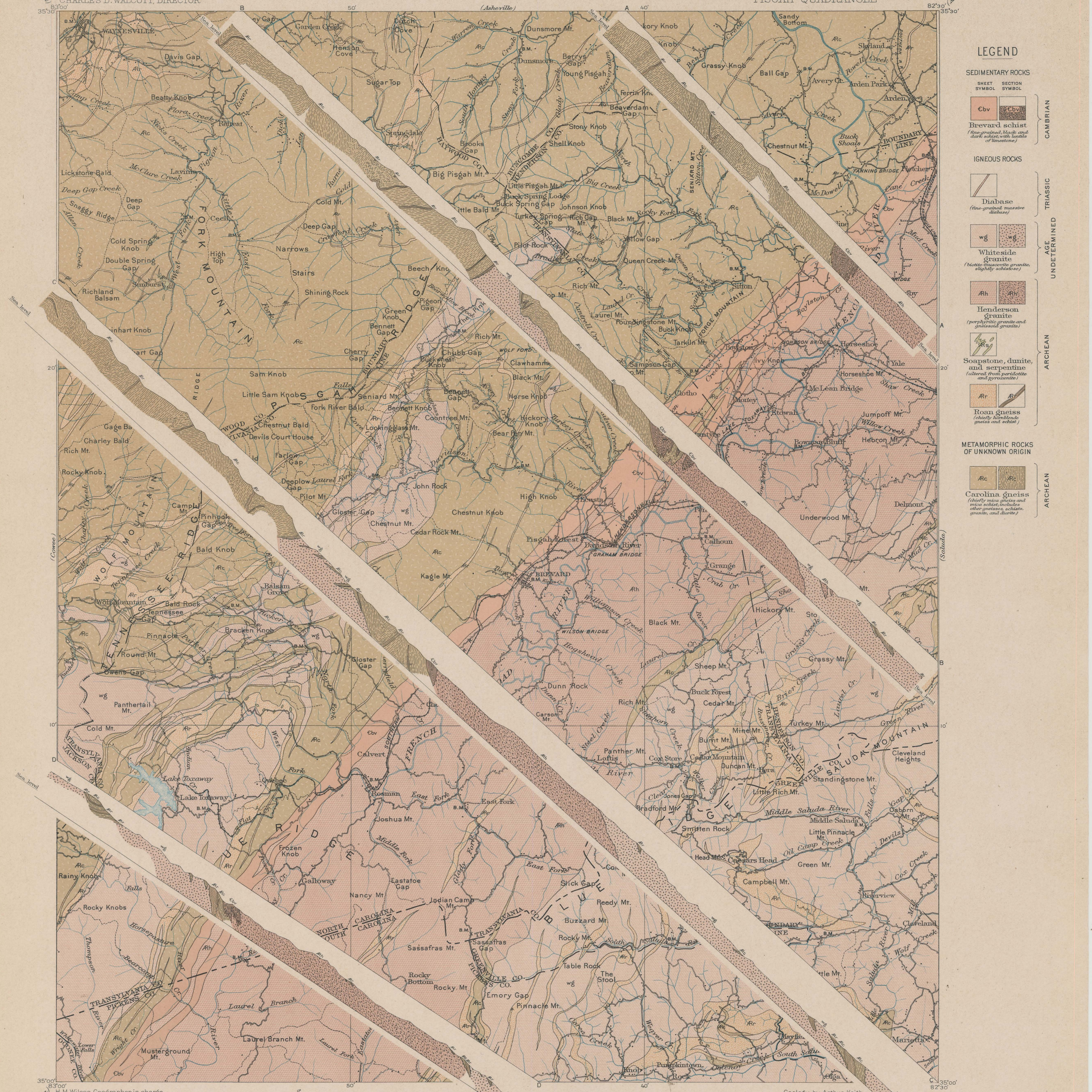
STRUCTURE SECTIONS

NORTH CAROLINA–SOUTH CAROLINA
PISGAH QUADRANGLE



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Scale 1/125000

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ILLUSTRATIONS

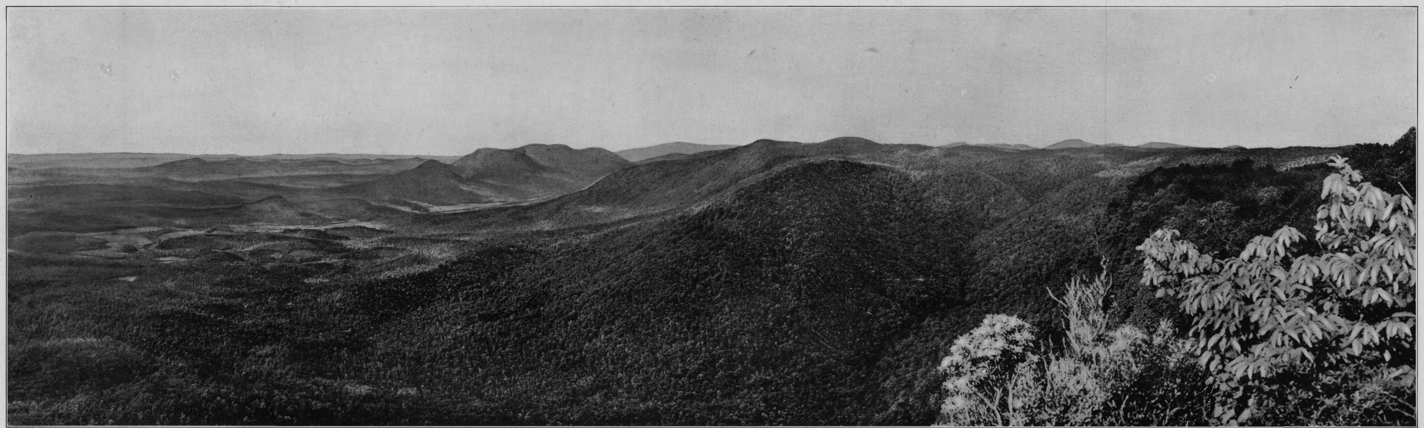

FIG. 1.—PLATEAU AND ESCARPMENT OF THE BLUE RIDGE FROM CÆSARS HEAD, SOUTH CAROLINA; LOOKING S. 30° W. TO N. 80° W.

The plateau extends westward to the foot of Great Hogback, in the distance on the right, 20 miles away. Table Rock and the Piedmont are seen on the left, the latter 2,000 feet below the viewpoint.

FIG. 2.—LOOKINGLASS MOUNTAIN FROM BENNETT GAP, 1½ MILES DISTANT; LOOKING S. 30° W.

Dome structure is strongly developed in the granite at the northern end of the mountain. Cedar Rock, another dome, is seen at the left, and part of Pisgah Ridge on the right. The mass of granite is anticlinal and pitches northeastward, disappearing near Bennett Gap.

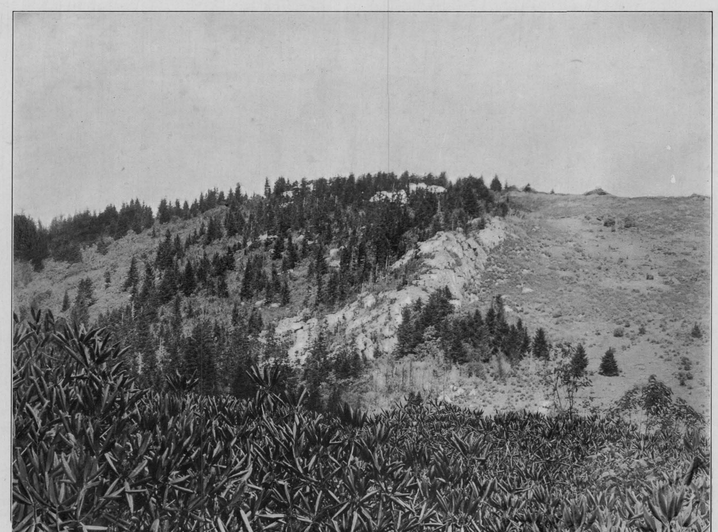

FIG. 3.—SHINING ROCK ON PISGAH MOUNTAIN; LOOKING N. 20° W.

The rock is a mass of white sugary quartz, 30 to 60 feet thick. It is more than one-eighth of a mile long and terminates beyond the summit of the mountain. Offsets in its course can be seen, which are probably due to displacement along the vertical joint planes that cut the quartz in great numbers.

FIG. 4.—PLATEAU OF PIGEON RIVER, 2 MILES SOUTHEAST OF WAYNESVILLE, N. C.; LOOKING NEARLY NORTH.

Chambers Mountain is seen in the distance. The point of view is on a pebble-covered terrace, other remnants of which can be seen curving upward in their usual relation to the plateau summits. This view is typical of the details of all the plateaus, where they are not deeply dissected.

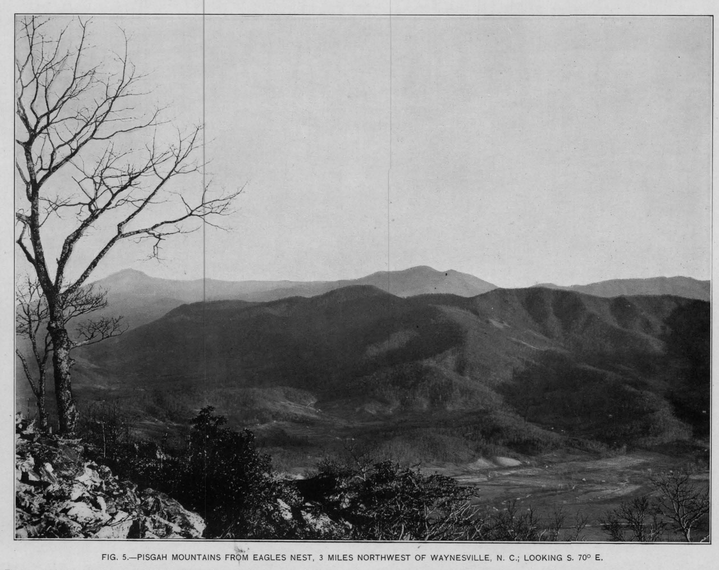

FIG. 5.—PISGAH MOUNTAINS FROM EAGLES NEST, 3 MILES NORTHWEST OF WAYNESVILLE, N. C.; LOOKING S. 70° E.

The valley of Richland Creek and part of Waynesville, N. C., are in the foreground, 2,000 feet below the point of view. Beatty Knob, beyond the valley, shows the details of ridges and spurs characteristic of these mountains. Cold Mountain, 6,000 feet in altitude, and Big Pisgah Mountain, 5,749 feet, form the sky line.

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