DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

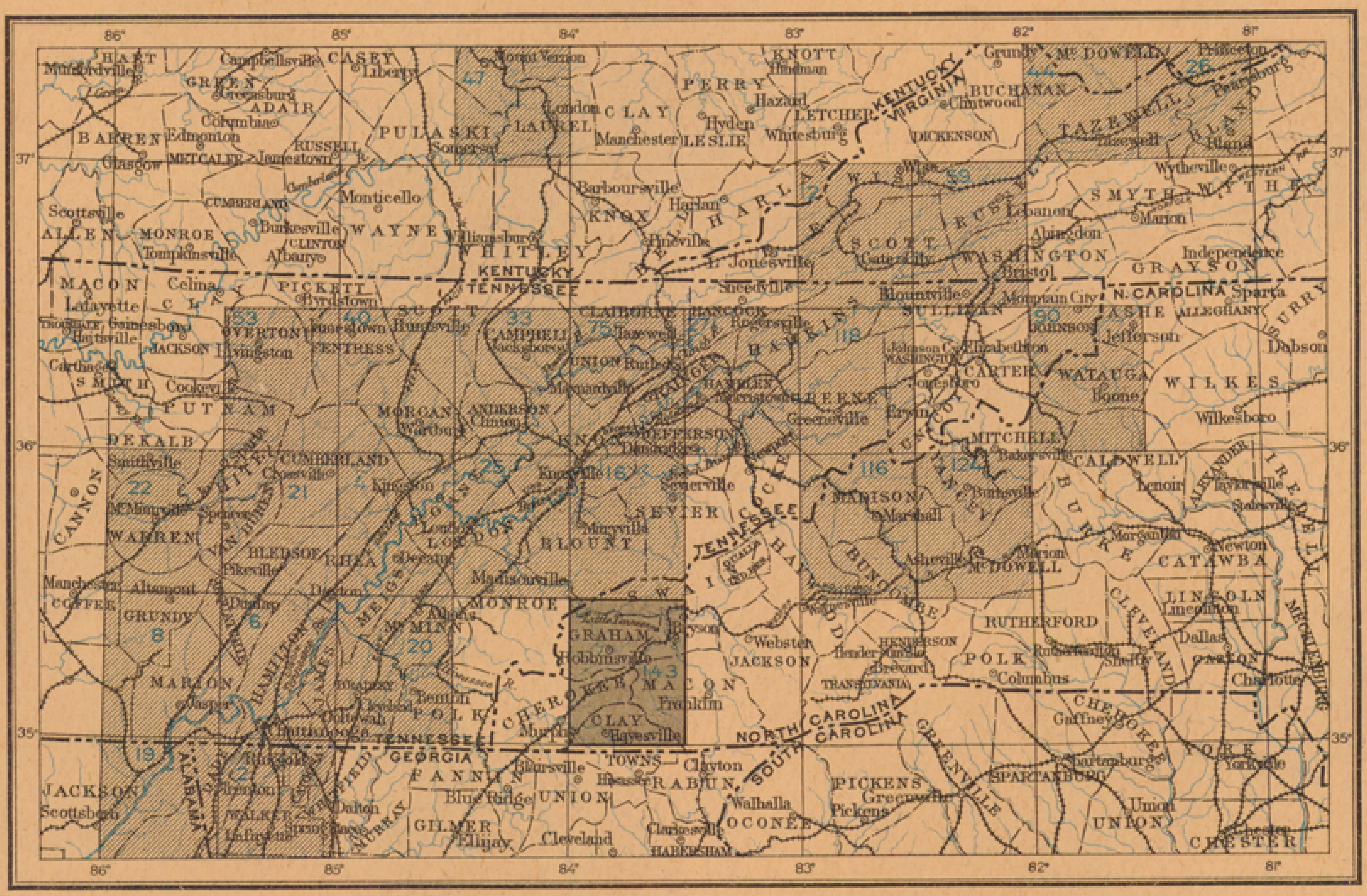
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS OF THE UNITED STATES

NANTAHALA FOLIO

NORTH CAROLINA – TENNESSEE

INDEX MAP



SCALE: 40 MILES = 1 INCH

NANTAHALA FOLIO

OTHER PUBLISHED FOLIOS

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WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER
1907

EOLOGIC 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).

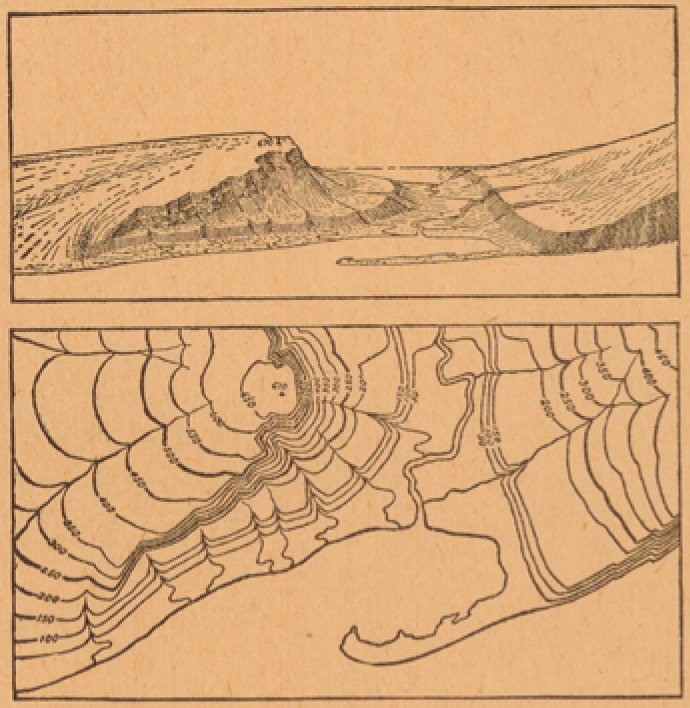

Fig. 1.—Ideal view and corresponding contour map.

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.)

DESCRIPTION OF THE NANTAHALA QUADRANGLE.

By Arthur Keith.

GEOGRAPHY.

GENERAL RELATIONS.

Location.—The Nantahala quadrangle lies mainly in North Carolina, but in its northwest corner includes also a few square miles of Tennessee. It is bounded by parallels 35° and 35° 30' and meridians 83° 30' and 84°, and contains 985 square miles, in Graham, Swain, Macon, Clay, and Cherokee counties, North Carolina, and Monroe and Blount counties, Tennessee.

In its geographic and geologic relations this quadrangle forms part of the Appalachian province, which extends from the Atlantic Coastal Plain on the east to the Mississippi lowlands on the west, and from central Alabama to southern New York. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. Only a part of this history can be read from an area so small as that 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 and Allegheny Mountains and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the eastern boundary of the Mississippi embayment as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian Valley by the Allegheny Front and the Cumberland escarpment. The rocks of this division are almost entirely of sedimentary origin and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely worn down. In the southern half of the province the Plateau is sometimes extensive and perfectly flat, but it is oftener much divided by streams into large or small areas with flat tops. In West Virginia and portions of Pennsylvania the Plateau is sharply cut by streams, leaving in relief irregularly rounded knobs and ridges which bear but little resemblance to the original surface. The western portion of the Plateau has been completely removed by erosion, and the surface is now comparatively low and level, or rolling.

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

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

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

The Plateau or western division increases in altitude from 500 feet at the southern edge of the province to 1500 feet in northern Alabama, 2000 feet in central Tennessee, and 3500 feet in southeastern Kentucky. 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 Plateau, runs westward to the Ohio. South of Chattanooga the streams flow directly to the Gulf of Mexico.

DETAILED GEOGRAPHY OF THE QUADRANGLE.

Geographic divisions.—The Nantahala quadrangle is included entirely in the Mountain division of the Appalachian province. The quadrangle includes the Great Smoky Mountains on the north, the Blue Ridge on the southeast, and various cross ranges in the center. In this region there is less correspondence than usual between the forms of the surface and the underlying strata. This is true of the details of the formations as well as of the broad geologic divisions. The surface of the region is that of a number of mountain ranges running in various directions, separated by narrow stream valleys and small plateaus. The area which lies in Tennessee is very small and differs in no respect from the North Carolina portion.

Drainage.—The region is drained by six rivers. One of these, the Tallulah, flows south from the Blue Ridge at Standing Indian and finds its way into the Atlantic. Of the others, the Nantahala and Cheoah join the Little Tennessee within this quadrangle; Valley and Hiwassee rivers unite just west of the quadrangle and also join Tennessee River on the western side of the Great Valley. Thus practically all of the water of this region flows into the Ohio and the Gulf of Mexico.

All the rivers in this region have heavy grades. Valley River has the least fall—from 2700 feet at Red Marble Gap to about 1500 feet at the border of the quadrangle. Nantahala River has by far the greatest descent, falling from 4100 feet on the Blue Ridge to a little less than 1600 feet at the point where it joins the Little Tennessee, an average grade of about 65 feet per mile, the greater part of it coming in the upper 25 miles. A similarly rapid fall characterizes the lower portion of Cheoah River. Originally the Nantahala flowed in a direct course down the Cheoah Valley. It was diverted about midway in its course by a branch of Little Tennessee River, working back along the soluble Murphy marble. Its old elevation of 2800 feet is marked by pebble deposits on summits $1\frac{1}{2}$ miles nearly west and 3 miles nearly southeast of Nantahala. On the upper reaches of both of these streams small plateaus and terraces, rarely over a mile in width, accompany the watercourses. Below Aquone, on the Nantahala, and Buffalo Creek, on the Cheoah, the channels of the rivers descend in narrow and rapidly deepening canyons (see fig. 1 on columnar section sheet). Similar plateaus, from 2 to 4 miles wide, border the upper parts of the Little Tennessee and Tuckasegee. The river channels have cut their way 200 to 500 feet below the surface of these plateaus. Not far beyond the junction of these two rivers the valley is hemmed in by steep mountains and becomes a narrow and rocky gorge. The descent of 4000 feet from Hangover to the mouth of Cheoah River is accomplished in a trifle over 4 miles.

Hiwassee River below Hayesville is bordered by plateaus of the same character as those on the Little Tennessee. A short distance above that point the river is nearly at the level of the plateau. Valley River, although a smaller stream, has cut its channel wider than the Hiwassee, because much of its course is on the marble beds (see fig. 3 on columnar section sheet). The ready solubility of these beds has resulted in broad and open valleys along the river, from 200 to 300 feet below the plateau level. Both these rivers have broad terraces covered with waterworn pebbles from 25 to 50 feet above the stream level. Each river in this quadrangle has worn its basin down to its particular local base-level, and the plateaus thus produced have different heights, varying according to the difficulty of erosion. All of the stream valleys except the Nantahala were reduced to substantially the same level—2000 to 2100 feet. The plateaus which now appear on the Nantahala were produced at a considerably earlier date than those of the other streams and are about 1000 feet higher. Above the levels of the different plateaus the valleys are wild and rocky V-shaped ravines, with slopes steadily increasing nearly to the divides.

Topography.—The variations in the topography of this region depend very largely upon the influence of erosion on the different formations. Such rock-forming minerals as carbonates of lime and magnesia, and to a less extent feldspar, are removed by solution in water. Rocks containing these minerals in large proportions are, therefore, subject to decay by solution, which breaks up the rock and leaves the insoluble matter less firmly united. Frost, rain, and streams break up and carry off this remainder, and the surface is thus worn down. According to the nature and amount of the insoluble matter the rocks form high or low ground. Calcareous rocks, leaving the least residue, make the low ground. Such are the Nottely marble and the Andrews schist; these leave a fine clay after solution. The least soluble rocks are the quartzites and the more siliceous portions of the Great Smoky conglomerate. Since most of their mass is left untouched by solution they are among the last to be reduced in height. The quartzite formations in this quadrangle, however, seldom have bulk sufficient to maintain very great heights. Teyahali Bald, 4708 feet, and Tusquitee Bald, 5291 feet, are exceptional heights for the quartzite. Apparently much of the Great Smoky conglomerate forms an exception to the rule, for it contains much soluble matter in feldspar and yet maintains great heights, such as Hooper Bald, 5485 feet; Hangover, 5147; Cheoah Bald, 5065; and Tellico Bald, 5200 feet. For this result the immense mass of the formation and the insolubility of the quartz it contains are largely responsible. Many portions of the Roan gneiss areas also attain great altitudes, although much of the hornblende and feldspar occurring in them is comparatively soluble. The Carolina gneiss forms much high ground, including Standing Indian, 5495 feet, one of the highest points on the Blue Ridge. Many other summits formed by the gneiss are over 5000 feet.

Erosion of the sedimentary formations has tended to produce a series of ridges and valleys which follow the belts of rock, but only where the formations differ from one another considerably in solubility is this result attained to any great degree. In the basin of Valley River and in the vicinity of Peachtree Creek the results of this process are marked. Where the formations spread out with a low dip the valleys and ridges are broad, and where the strata dips steeply the valleys are narrow. Each turn in the course of a formation is reflected in the turn of the ridge or valley which it causes. Each rock produces a uniform type of surface so long as its composition remains the same; with each change in composition the surface changes form. Conspicuous examples of the control of the topography by the character of the rock are afforded by the areas of the Nottely quartzite and the Murphy marble. The limestones have disappeared through solution from the valley floors which they underlie, and the clays which they left have been swept over with waste from the adjacent mountains. This material forms the terraces and bottoms which follow the streams, even far up toward their heads. In the basins of Valley and Hiwassee rivers these are conspicuous. In most of the quadrangle, however, the rock belts are broad and differences in solubility are not great, consequently the valleys and ridges do not follow the rock belts at all closely. In the streams which drain the Great Smoky conglomerate areas there is no such relation apparent. Even where there is some difference in solubility—for instance, between the Great Smoky conglomerate and the Nantahala slate—the streams are not yet adjusted to the rock belts, but are forced by their high grades into the most direct channels.

GEOLOGY.

GENERAL GEOLOGIC RECORD.

Nature of the formations.—The formations which appear at the surface of the Nantahala 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 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 Nantahala 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 FORMATIONS.

ROCKS OF THE QUADRANGLE.

The rocks of this district are sedimentary, igneous, and metamorphic; most of the varieties of sedimentary rock are present, and a few of the igneous and crystalline. They range in age from the earliest known formation of the Archean well into the Cambrian. Rocks of still later age are found in dikes cutting the Archean and Cambrian beds, but the dikes are too small to be shown on the map. The strata of Cambrian age are those which constitute the Ocoee group. Until recently the age of these strata was not definitely settled. They are now assigned to Cambrian, upon evidence gathered within this quadrangle and in those situated farther north and east, particularly the Knoxville, Mount Guyot, Asheville, and Roan Mountain. The evidence includes structural position, the details and sequence of the different formations, and the tracing of distinctive beds throughout the entire region from points where their age is known, as in the Roan Mountain quadrangle. The older, or Archean, group occupies the lesser area and the Cambrian rocks the greater.

The Archean and Cambrian rocks occupy two very distinct areas. South and east of Tusquitee Mountains and Tellico Bald lie the Archean rocks, while the remainder of the quadrangle is occupied by the Cambrian rocks. Along the line of Valley and Nantahala rivers are found the youngest strata in the region, while the basins of Cheoah and Little Tennessee rivers are mainly occupied by the Great Smoky conglomerate, the oldest sedimentary deposit. The two groups are sharply defined and only one area of the Archean rocks appears within the district occupied mainly by the sedimentary rocks. The formations into which the rocks are separated will be described in order of age, beginning with the oldest.

ARCHEAN ROCKS.

CAROLINA GNEISS.

Distribution.—A wide area in the southeastern part of this quadrangle is covered by this formation, which is so named because of its great extent in North Carolina and South Carolina. The formation is the oldest in this region, since it is cut by all igneous rocks and is overlain by the sediments. Inclosed within it are numerous representatives of the igneous formations, too small to be shown on the map.

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. Toward the southeast the strictly gneissic beds are more numerous and their banding becomes slightly coarser and better defined. In them the minerals are segregated into layers, either singly or in combinations, thus producing rocks with a marked banded appearance. These rocks have more feldspar than the schists. 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. 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 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 -gneiss precisely like the Roan gneiss. The areas of the formations thus merge somewhat, so that the boundary between them is seldom definite.

Garnet- and cyanite-gneiss.—Garnet-gneiss and -schist are common in the formation. They are not limited to any area or situation, but are generally found near the bodies of Roan gneiss. The garnets may be due in places to contact action near the eruptive Roan gneiss, but they also occupy situations too remote for such a cause. Most of the garnets are less than a quarter of an inch in diameter. In some places, however, as on Eagle Fork of Shooting Creek, they are from 1 to 2 inches in diameter. As a rule they lie in rather distinct bands in the gneiss, but are freely disseminated through the schist.

Cyanite is found in the gneiss of Nantahala Mountains east of Aquone. The mineral occurs in flat stubby crystals half an inch long accompanied by small garnets. They follow distinct layers in the rock and usually their crystals are parallel to the foliation. Their color is light gray or dark gray.

Pegmatite.—Included in the area of the formation are many sheets or veins of pegmatite. These occur in the shape of lenses from 1 to 10 feet in thickness and in places over a mile long. They lie for the most part parallel to the foliation of the gneiss, but sometimes cut the latter abruptly. Many of the smaller lenses can be seen to be surrounded on all sides by mica-gneiss, and apparently were deposited from aqueous solutions. Near the contacts of the Carolina and Roan gneisses these pegmatites are most conspicuous. They consist chiefly of very coarsely crystalline feldspar, quartz, biotite, and muscovite. Much merchantable mica is secured from the pegmatites, and many rare minerals are found in them, such as beryl, aquamarine, garnet, and others less valuable.

Metamorphism. — The Carolina gneiss covers a greater area 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 of no value. The thickness is apparently enormous, having been increased many times by the folding and the very great metamorphism to which the gneiss has been subjected. The original nature of this gneiss is uncertain. It is possible that the whole 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. In the Cowee quadrangle many parts of the formation—for instance, the marble beds and the adjoining gneisses—are doubtless of sedimentary origin. It is very likely that still other sedimentary masses have not been distinguished in the Carolina because of their total metamorphism and similarity to the igneous gneisses.

Whatever their original nature, one deformation produced a foliation of these rocks, and a subsequent deformation folded and crushed the earlier planes and structures. Before the latter period the 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 produced more strongly by the micas than by 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, mica, and granite. 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 of the Nantahala Mountains, especially, forms long cliffs and rocky slopes. 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 ordinary gneiss.

ROAN GNEISS.

Distribution.—Many areas of this formation occur in the southeastern part of the quadrangle. The formation receives its name from Roan Mountain, on the boundary of Tennessee and North Carolina. The Roan gneiss appears to cut the Carolina gneiss, but the contacts are so much metamorphosed that the fact can not be proved. The narrow dike-like bodies of the former in the latter support this view, as well as the fact that the diorites are less altered than the Carolina gneiss and so appear to be younger. Moreover, beds of garnet-gneiss follow the diorite and hornblende-gneiss and are apparently the results of metamorphism by the diorite.

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 the Roan gneiss there are found veins and lenses of pegmatite precisely similar to those described under "Carolina gneiss."

Alteration.—Deformation and recrystallization have extensively changed the original rocks of this formation into schists and gneisses. The exact measure of the alteration is unknown, because of the uncertainty as to the first nature of the rock. It is probable that most of the mass was originally a diorite and gabbro, of much the same composition as now. At present the minerals in most of the formation are secondary and are arranged for the most part in parallel layers, causing the schistosity. These minerals and schistose planes are bent and closely folded, to an extent equal in many places to all the folding of the later formations. Thus the Roan gneiss has passed through two deformations, one producing the foliation and a second folding the foliation planes. During or before the second deformation the bands of quartz and feldspar appear to have been formed. The total alteration is extreme.

In reducing the surface of the formation the first steps of decay were taken by decomposition of the hornblende and feldspar, but the more siliceous layers and many of the harder hornblende-schists and mica-schists are extremely slow of solution. Their outcrops form heavy ledges, and their fragments fill the streams and strew the surface and greatly retard its reduction. As a consequence the formation invariably occupies high ground and forms many of the high mountains of this region. It is less resistant than the Carolina gneiss, however, and often forms gaps and hollows between areas of the latter. 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 removing the loose stones. The hilly surfaces keep the soil well drained, and yet the clayey nature of the soil prevents serious wash; hence they are extensively cultivated, in situations however remote.

SOAPSTONE, DUNITE, AND SERPENTINE.

Distribution and relations.—Many small bodies of these rocks are found within the areas of the Roan gneiss, only that on Buck Creek exceeding a quarter of a mile in width and a mile in length. Although the rocks break through and across the beds of Roan gneiss, and are thus seen to be distinct from and later than the gneiss, their association with the latter is close and marked and they are probably of about the same age. In this quadrangle the soapstone is not found in any other formation except in one instance. In areas farther east it occurs sparingly in the Carolina gneiss as well as in the Roan gneiss. Its alteration is as great as or greater than that of the Roan gneiss and exceeds that of the later intrusive granites, so that it appears to have shared in the earlier period of metamorphism which involved the Roan and Carolina gneisses. It thus is classed with the earliest part of the Archean.

Character.—The group comprises many different rocks, such as soapstone, dunite, amphibolite, and serpentine, and many combinations of minerals derived by metamorphism from the original rocks. The most common varieties in this area are an impure soapstone containing many hornblendic minerals and dunite composed almost entirely of olivine. The soapstones are white and light gray. The other varieties of the formation have a greenish color, either bright or dull. In a few localities the soapstone contains little but talc and chlorite and is pure enough for industrial uses, but as a rule it contains many crystals of tremolite, actinolite, or other hornblendic minerals. All of the varieties of the formation may be present in a single ledge, or one variety may occupy the whole of an area. The dunite is most common toward the southwest and the soapstone toward the east, in this quadrangle.

Alteration.—The change from the original peridotite and pyroxenite, composed of olivine with more or less feldspar and pyroxene, to soapstone is enormous, far greater in appearance than that in any of the other formations. Around the borders of the dunite, where metamorphism was greatest, there is apt to be a narrower band of soapstone. The minerals which now appear, however, are very similar in chemical composition to those of the original rock. The intermediate stages are obscure or absent in this region, and even the dunite, which is close to the original rock, may itself have been wholly recrystallized. The metamorphism which caused these changes seems to have most easily affected rocks of this mineral composition. Unlike the other metamorphosed rocks, these show little schistosity, except the amphibolite, whose foliation is frequently well marked. Near its borders the soapstone may be schistose or fibrous, and the varieties with many hornblendic minerals are rendered somewhat schistose by the parallel arrangement of the latter. The pyroxenite near Tellico Creek is unusually massive and free from schistosity.

Few rocks are slower to decay than the soapstone, and its areas invariably show many ledges. In extreme cases the entire area is bare rock. Solution makes little progress on the rock material, which is, however, too soft to stand the direct action of frost and rain, so that it breaks down and occupies low ground. In places beds containing a large amount of tremolite or actinolite are hard enough to make small knolls and conspicuous ledges, and on the dunite ledges are very common. Final decay leaves a cover of stiff yellow clay of little depth and much interrupted with rock. Soils derived from this are of almost no value.

GRANITE.

There are five areas in the quadrangle where the rocks are mainly or entirely granite. Two of these are near Hayesville, in the southern part of the quadrangle, and three are near its eastern border, in the Nantahala Mountains. Only one of these masses lies entirely in this quadrangle, and the others passing northeastward or southwestward into the Cowee and Dahlonega quadrangles.

The formation consists almost entirely of biotite-granite of fine or medium grain. The rock is composed chiefly of orthoclase and plagioclase feldspars, quartz, biotite, and muscovite, named in the order of their abundance. Subordinate minerals are hornblende, pyrite, magnetite, and garnet. In the Nantahala Mountains the rock is coarsest, and has a somewhat spotted appearance, due to the larger biotite crystals. In that region also the biotite is more prominent than it is near Hayesville. The granite is found massive, gneissoid, and schistose, most of it being massive. The gneissoid or banded aspect was produced chiefly during the intrusion of the granite into the gneisses. The small amount of schistosity present is due to dynamic movements after the intrusion of the granite. These overcame the strength of the rock, fractured it, and developed new minerals out of the old. For the most part these secondary minerals consist of mica and quartz. In general they developed in nearly parallel flakes or crystals, and have produced a schistosity of the rock parallel to themselves.

The granite is intrusive in the Carolina and Roan gneisses. These relations are also seen in several other granites in the Appalachian Mountains. Since the granites here exposed are not connected directly with granites of known age, it is not possible to correlate these precisely with either the Cranberry or the Whiteside granites, which have similar relations in adjoining areas. In condition of metamorphism this granite is intermediate between these others. It is probably to be referred to the Cranberry granite.

Under the attack of weather the granite yields slowly and produces topographic forms much like those of the Carolina gneiss. It forms either low ground or mountains, according to its relation to the drainage lines. It finally breaks down into a light-yellow or red clay soil containing considerable fine mica and quartz.

CAMBRIAN ROCKS.

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

HIWASSEE SLATE.

Only about a square mile of this formation is found in the quadrangle, in the extreme northwest corner. It is the oldest sedimentary formation shown in this quadrangle and is of much importance farther north and west. It consists of blue and gray banded slate and sandy shale, which in other areas contain beds of limestone and limestone conglomerate. Only the slates are shown in this limited area, and they are of small importance here. Along the southeastern border of the sedimentary rocks this formation is absent, and the overlying Great Smoky conglomerate rests upon the Archean gneiss. It can not be said with certainty that the sequence shown is due to deposition and that it has not been caused by faulting. The prevalence of this relation both northeastward and southwestward, however, and the certainty that in the Mount Guyot quadrangle the sequence has not been caused by faulting, make it probable that here also it is due entirely to deposition. The formation usually occupies valleys or forms low hills. Owing to its limited extent these features are unimportant here.

GREAT SMOKY CONGLOMERATE.

Distribution.—Nearly half of the quadrangle is covered by this formation in one great irregular area. It is named for its extensive development in the Great Smoky Mountains north of Little Tennessee River. The formation corresponds in position and general character to the Cochran conglomerate in areas northwest of those mountains. Substantial differences appear, however, especially in bulk and in subsequent sediments, that make it advisable to distinguish the two. It is possible that in these regions the Great Smoky represents a greater lapse of time than the Cochran conglomerate.

Character.—The Great Smoky conglomerate contains a considerable variety of strata, comprising conglomerate, sandstone, quartzite, graywacke, mica-schist, garnet-schist, and slate. The original character of the beds is plainest in the conglomerates, whose layers are from 1 foot to 50 feet thick. All of these rocks, except the slate, have a decided gray color, becoming whitish on exposure and weathering of the feldspar which they contain. This is most noticeable in those conglomerates whose feldspars are the coarsest and least metamorphosed. The conglomerate pebbles are not often coarse and seldom exceed half an inch in length. From this they grade into coarse and fine sandstones, quartzites, and graywackes. Most of the pebbles are of white quartz; toward the north and northeast many blue-quartz pebbles are seen, derived from the blue quartz of the granites in that vicinity. Pebbles and flakes of black slate are often to be seen in the coarse beds, apparently derived from the slates interbedded with the formation. Feldspar pebbles everywhere characterize the conglomerates. As the formation is traced southward less and less conglomerate is found. There is always a heavy bed at the top of the formation, however, and usually several near the base.

Interbedded with these coarse rocks are numerous seams and beds of schist or slate. Southeast of Valley River the original shales have been metamorphosed to schists, while toward the northwest the alteration is less and seams of slate are most common. The schists are of light- and dark-gray color, while the slates are considerably darker, and all are indistinguishable from the strata of the Nantahala. Most of the beds of slate and schist are less than a foot in thickness. In some places, however, they reach 25 or 30 feet. The amount of these strata in proportion to the coarse beds is much greater near Nantahala River than elsewhere. The best measurements obtainable of the thickness of the formation place it at nearly 6000 feet. The deformation is such, however, that this figure is not very certain.

Alteration.—Some of the pebbles have their original rounded form, while many have been crushed and flattened. East of Tusquitee Mountain many pebbles are flattened to one-tenth of their original thickness. Much secondary mica was developed at the same time in coarse and fine flakes. The beds of graywacke are most altered from their original character and frequently can be distinguished from the gneisses of the Archean only with great difficulty. South and east of Valley River they are most metamorphosed; on the lower part of Nantahala River they are less so, and the change from coarse feldspathic sandstone to graywacke is readily followed. The feldspar grains during metamorphism have partly recrystallized into quartz and mica. Most of the schists are mica-schists, which strongly resemble those of the Carolina gneiss. Frequently they are filled with small crystals of garnet and ottrelite, and occasionally staurolite. In the schists the crystals are more numerous in bands following the original bedding, and are found in the coarser beds in the same way, but to a less extent.

The rocks of this formation are very resistant to erosion. The quartz and mica are relatively insoluble and the feldspathic material is not sufficient in the more altered varieties to cause ready disintegration. The immense mass of the formation and the hardness of the rocks unite in producing a vast expanse of mountainous ground. More high ground is caused by this formation than by any other in the mountain region. The summits are usually broad and rounded, the domes of the Great Smokies being characteristic. The slopes are steep. (See fig. 1 on columnar section sheet.) There are few cliffs, but ledges are found at frequent intervals. Decay enters through the joints and schistose planes and the rock breaks up, leaving many bowlders and fragments in the soils. Southeast of Valley River the soils are thin and sandy and in the most altered varieties are very micaceous. In the Cheoah and Little Tennessee basins, however, the formation is less altered and micaceous and the soils are much stronger. A heavy growth of timber is found clear to the summits, and especially in the coves and hollows.

NANTAHALA SLATE.

Distribution.—Many areas of this formation are found in the same region as the Great Smoky conglomerate. They are largest and most numerous along Valley and Nantahala rivers, the fine exposures along the latter giving the formation its name. There are 1400 to 1800 feet of these strata shown in the quadrangle, measurements of this, as of the other formations, varying widely.

Character.—The formation is composed in the main of black and gray banded slates and of schists distinguished by mica, garnet, staurolite, or ottrelite. Most of the schists are near the base of the formation and strongly resemble the slate and schist beds in the Great Smoky conglomerate. The slates and ottrelite-schists are as a rule somewhat darker than the other beds, the color being due to very minute grains of iron oxide. The slates are banded light and dark gray and bluish gray, and these in particular can not be distinguished from the slates in other formations. In the northern half of the quadrangle slate makes up nearly all the formation, but only the upper beds at the south. Many sandstone and conglomerate beds are interstratified with the slate near its base and form a transition into the Great Smoky. These are most common in the Cheoah basin and farther north. Unimportant layers of graywacke or conglomerate are also found higher up in the slate.

Alteration.—Many of the slate layers are sprinkled with crystals of garnet and ottrelite, and with the increase of these and mica as a result of deformation the beds become almost entirely schists. The effects of this alteration are clearly shown along the lower part of Nantahala River, as is the case with other formations. The crystals of ottrelite are arranged with their cleavage at right angles to the schistosity produced by the other micas, a relation characteristic of this mineral throughout the region. The garnet crystals are usually grouped in bands following the stratification. This feature also characterizes the staurolite-garnet-schists which regularly form the base of the formation near Valley River. A band of the schist a few inches wide may be full of staurolite and the adjoining band contain none. The garnet and ottrelite crystals are seldom more than one-tenth of an inch in diameter, while the staurolite crystals are 3 or 4 inches in length. There appears to be no special arrangement of the axes of the staurolite crystals.

The decay of the formation is very slow because it has so few soluble constituents. The rocks gradually crumble, however, and the disintegrated portions are not hard enough to withstand great wear. Solid rock is seldom far from the surface, and many broad, rounded ledges characterize the formation. Its soils are thin and sandy and full of mica and slabs of schist or slate. It occupies lower ground than the Great Smoky conglomerate and forms spurs and depressions between the mountains of the latter. The upper part of the Nantahala slate in connection with the Tusquitee quartzite forms many high ridges, such as Tusquitee Mountains and Teyahali Bald. The steep slope of Cliff Ridge occupied by this formation is one of the most striking features of the region.

TUSQUITEE QUARTZITE.

Distribution.—Passing diagonally through the quadrangle are many narrow bands and outcrops of this formation. It is named for its excellent exposures in the Tusquitee Mountains. The synclinal folds in which the formation appears deepen toward the southwest, and around the ends of the two principal synclines the outcrops group themselves in a very much flattened S.

Character.—The formation consists almost entirely of white quartzite and is remarkably uniform in appearance throughout all its areas. The strata are composed of fine grains of rolled quartz sand. Here and there these are coarse and on weathered outcrops give the appearance of sandstone. North, west, and south of Marble there are a few seams of fine conglomerate in the quartzite. On the headwaters of Cheoah River some quartzites of medium grain contain slate pebbles of the same nature as the underlying Nantahala slate. As a rule, however, the grain of the rock is very fine. In many places there are fine feldspar grains intermingled with the quartz sand, but these do not change the general aspect of the rock. The individual beds of quartzite range from a few inches up to 2 or 3 feet in thickness. Interbedded with the quartzites are a few seams and layers of black slate and schist similar to those of the underlying Nantahala slate. These are seldom over a foot in thickness and are noticeable only in the stream sections where the strata are clear-cut. It is probable that the slate layers are generally distributed, although they are seldom seen in the weathered sections. Many stream sections, however, show only continuous beds of quartzite. The formation is strikingly distinct from the adjoining black Nantahala slate and the blue ottrelite-schist of the Brasstown formation. It is of the greatest assistance in working out the complicated folds of the region, and affords an excellent key rock.

Thickness.—The rocks of this formation vary much in thickness, ranging from 50 to about 200 feet. South of Valley River it is thinner, as a rule, than elsewhere, and ranges from 20 to 250 feet. On Peachtree Knob and Fires Creek it appears to expand locally to 500 feet, perhaps on account of the close folding in that region. Slightly greater thicknesses characterize the formation north of Valley River. In Teyahali Bald there is a local expansion of the formation, of probably the same nature as that on Peachtree Knob. On the Nantahala drainage the thicknesses vary from 50 to 400 feet, being generally greater than in other localities. When the extreme metamorphism of the rocks is seen, and the mashing and complex folding of the beds are considered, it is readily understood that measurements of the thickness of the formation are hard to obtain and of small value.

Alteration.—Since the deposit was indurated into a sandstone it has been still further changed by metamorphism. The most noticeable result of this is the silicification of the rock into quartzite. In many cases this is so complete that it has become a massive glassy rock with scarcely any indication of the original sand grains. Somewhat different results appear locally where metamorphism has been extreme. One or two miles southeast of Valleytown, in the vicinity of the fault plane, the quartzites have been intensely squeezed and the component minerals have been mashed and recrystallized. From the feldspar grains came new feldspar, quartz, and mica, the crystals being arranged in parallel flakes. Many of the mica flakes form sheets coating the more siliceous layers. Thus has been produced a quartz-schist. These phenomena can be traced for considerable distances northeast and southwest near the fault.

Somewhat similar phases are to be seen in the quartzites along Nantahala River in contact with the same fault. Here, however, there was compression, not only in a southeast-northwest direction, but to a less extent at right angles to that. This expressed itself in many minor folds and wrinkles of the quartzite and a tendency of the new minerals to crystallize in lines instead of planes, so that the quartzites are not schistose. They break up more readily into grains and are much broken and jointed. In the quartzites lying 2 to 4 miles west and southwest of Almond the new minerals and the schistose planes have an attitude quite different from their usual steep inclinations. At that place the quartzites dip at various angles, mostly steep, while the new minerals and schistose planes cut abruptly across them at dips of 20° or less. The semblance of bedding thus produced is very misleading. Results of the same kind are seen on Tusquitee, Weatherman, and Teyahali balds. In those localities the quartzites pass in a northwest-southeast direction straight across the general trend of the formations. Through them the schistose planes cut at high angles, entirely irrespective of the dip of the rocks. In Teyahali Bald the dips are nearly vertical, and in the other places they are in the vicinity of 30°, while the schistose planes dip from 70° to 75° SE. Unless considerable care is taken it is difficult to determine the actual dip.

The quartzites resist erosion to a marked degree. Only the feldspar grains are at all susceptible to solution, and they are generally of insufficient amount to affect the rock greatly. Decay works its way down through the schistose planes and the stratification and joint planes wherever they are common. Frost is the chief agent in breaking up the layers into small blocks. These slide down the steep slopes and are swept away by the streams to great distances.

BRASSTOWN SCHIST.

Distribution.—The strata of this formation are typically displayed on the waters of Brasstown Creek in this quadrangle. The greater part of the formation consists of banded ottrelite-schist, at the base of which is a variable thickness of banded slate with little or no ottrelite. This lower member of the formation is most developed south of Valley River, and the relations of the two members to each other are well seen between Brasstown and Hayesville. In the area of the formation which appears a few miles north of Brasstown the ottrelite-bearing rocks are much less conspicuous, and banded slates occupy a large area. The strata are less folded there, and the smaller amount of metamorphism is probably the reason of the relative absence of ottrelite. On the north side of Valley River basin practically all of the formation contains ottrelite. Eastward toward Nantahala River, however, the ottrelite diminishes, and disappears in the neighborhood of Nantahala.

Character.—All of the schists and slates of the formation are dark colored and vary from dark blue or bluish black to dark gray. They are nearly always marked by a fine banding of light-gray and dark colors. The light-gray layers are slightly siliceous and occasionally grade through sandy slate into seams of light-gray sandstone. This is frequently to be seen along the north side of Valley River. In the same region there is a small amount of interbedding of the sandy slates with the Tusquitee quartzites. The slates north of Brasstown and along Nantahala River have a decided bluish-gray color, while those east of Brasstown are much darker and frequently black in color.

Thickness.—It is practically impossible to obtain measurements of the thickness of the formation. Like all of the rocks in this region, the strata have been excessively folded. In places their thickness has been increased and in other places they have been thinned. The same layer is repeated again and again and only the top and bottom layers can be distinguished. As nearly as can be estimated from the areas, the dips, and the apparent folding, the formation is not less than 1000 feet thick, while it may be much more.

Alteration.—The slates are argillaceous and seem to be least altered in the belt north of Brasstown. On Nantahala River they are more micaceous and approach mica-schist in character. East of Brasstown the slates are more altered and are frequently phyllite or mica-schist of very fine grain. Scattered through the slates here and there are small crystals of ottrelite, which is very abundant in the upper part of the formation. It is distributed very generally throughout the rock, but usually is more common in the lighter gray bands. The ottrelite crystals are dull bluish or greenish gray, and are so set in the rock that their cleavage planes are at right angles to the schistosity and cleavage of the rock, thus being in striking contrast to the positions taken by the other metamorphic minerals. The crystals of ottrelite are of uniform size and rarely exceed one-tenth of an inch in diameter. Numerous crystals of garnet accompany the ottrelite, but are less conspicuous. These are usually a little smaller than the ottrelite crystals, and, like them, show a tendency to develop in bands. A third metamorphic mineral which is seen here and there is staurolite. This is found in crystals from one-half to 2 inches in length and frequently twinned. Its prisms are as a rule arranged at random in the schists, but they also show a tendency to grow in definite bands, like the other secondary minerals. Many of the ottrelite-schists, if the ottrelite and garnet were removed, would be practically the same as the altered slates that lie lower in the formation. Every step of the process is clearly visible in this region, and the ottrelite-schists are plainly derived from banded slates of the type seen north of Brasstown. The amount of change from one type to another is not great and is readily explained by slight differences in pressure and amount of metamorphism. Thus the variable amount of the lower slates and their absence in many places is readily understood.

Under the influence of weather the rocks of the formation vary considerably. The less altered slates are readily reduced and form low hilly ground. The rock breaks down into slabs and flakes. The cover of soil is thin and outcrops are frequent everywhere. The ottrelite-schists yield much more slowly. Decay is never deep, and the rock masses crumble and scale off. Fragments of the rock are less numerous in soils than in the case of the slates. Rock ledges are always near the surface and outcrops are plentiful everywhere. In places these form rounded cliffs of considerable size. Except near the largest streams the formation occupies high ground, as is seen in the ridges and mountains east of Peachtree. When the rock is half decayed the micaceous portions remain fairly firm. In these are set the crystals of ottrelite, weathered to a bright, brassy yellow. The soils are yellow and brown clays of no great depth or fertility. In the hollows more soil collects and there is a considerable growth of good timber.

VALLEYTOWN FORMATION.

Character.—In the vicinity of Valleytown the rocks of this formation are unusually well displayed. It consists in the main of mica-schist and fine-banded gneiss. In the basin of Valley River these rocks constitute practically all of the formation. As it is followed northeastward to Nantahala River the amount of metamorphism becomes less. Mica-schist gives way to mica-slate and argillaceous slate, and gneiss to graywacke and feldspathic sandstone. The mica-schist passes downward into the Brasstown schist, and individual layers of each formation can not be distinguished from those of the other. In the same region numerous beds of coarse quartzite and graywacke are to be seen. Near Hiwassee River the number and the thickness of the coarse beds are considerably less, and the boundary separating this formation from the Brasstown schist is very difficult to draw. At the great bend of Nantahala River the amount of coarse material in the formation is very small and slates predominate. In each direction from that point the slates become less and less prominent.

Thickness.—Measurements of the thickness of the formation are very conflicting. South of Valley River there is an apparent thickness of over 3000 feet, but in that region the amount of metamorphism makes these figures entirely without value. In the vicinity of Marble the formation appears to be less than 1000 feet thick, while a few miles to the northeast it seems to expand greatly, to more than twice that thickness. Along Nantahala River the measurements are most uniform and appear most trustworthy. In that locality the apparent thickness is 1000 to 1200 feet, and these figures are probably nearly correct for the formation in this area.

Alteration.—On the south side of Valley River, where metamorphism is greatest near a fault plane, the mica-schist is strongly developed and many of the gneissoid beds have received a secondary schistosity. Similar results are seen north and west of Andrews, along the border of the Murphy marble, where the folding has been excessive. The strata of the formation south of Valley River are filled with small crystals of garnet, which are much more prominent in the schists than in the coarser beds. Farther southwest the garnets are much less common. North of Valley River metamorphism is less at many points and the mica-schists reappear in the form of ottrelite- and garnet-schists. Along Nantahala River the progressive alteration of the feldspathic sandstones into graywacke and gneiss is admirably shown, most of the change taking place within 4 or 5 miles.

The metamorphism of these strata took place chiefly by the growth of new mica and quartz. The amount of this was greatest in the original slaty layers, whose fragments moved past one another the most in yielding to pressure. Along the planes of differential motion thus set up the new minerals were developed in parallel layers. Where the rocks were of uniform composition the schistosity bears no relation to the bedding planes. Where, however, the fine beds alternate rapidly with the coarse beds, the planes of motion were largely controlled by the thick layers and the resultant schistosity is nearly parallel to the bedding. In many places the bands of secondary minerals, as well as the sedimentary layers, are closely folded and even faulted. Thus it would appear that a certain amount of schistosity was produced first and the schistose planes were then folded by some later movement. These phenomena are readily to be seen in the many stream cuts along the north side of Valley River, where the strata are extremely folded and contorted. At many places what appears to be a light dip to the southeast is in reality made up of a series of closely squeezed horizontal folds. The schistose planes cut across these and parallel to their axes, simulating bedding in the most misleading fashion.

The rocks of this formation are very resistant to weathering action. They stand up in knobs and ridges somewhat above the adjoining Brasstown schist and rise abruptly from the areas of Murphy marble (see fig. 3). The difference between the latter and this formation is so striking that the limits of the marble can be readily seen from the topography. Along Nantahala River, where recent erosion is most rapid, the Valleytown strata stand up in rugged crags and almost precipitous slopes. On account of the siliceous nature of most of the formation decay is very slow. It works down the slaty layers and schistose partings and the coarse beds break off and crumble down. Soils are in all places thin and full of fragments of rock and crystals. In the area lying just south of Valley River the soils are also filled with garnet and staurolite crystals. The siliceous and micaceous nature of the soils renders them rather dry and sterile, and they are of very little value.

MURPHY MARBLE.

Distribution.—The localities in which this formation is developed fall into two belts, each consisting of two areas. One lies along Nantahala and Valley rivers, the other along Peachtree and Little Brasstown creeks. Chief of these is the area along Valley River. The town of Murphy is located partly on one of its areas.

Character.—The formation consists entirely of marble, rather fine grained and wholly recrystallized from its original condition (see fig. 2 on columnar section sheet). The predominant color is white. A large portion of the marble is of a dark-gray or blue color and many layers consist of banded or mottled blue and white. Some of the layers between Nantahala and Red Marble Gap have a beautiful rose-pink color. The amount of this is limited, however. Except these variations in color and small changes in the coarseness of the grain, the formation is very uniform in this region. The base of the marble is almost always covered in this region, and the precise character of its contact with the underlying rocks can be seen only near Nantahala River. There it passes downward into the Valleytown formation by interbedding with the slates of the latter. Upward it passes into the Andrews schist through several feet of interbedded marble and schist. This transition can best be seen at Marble Creek, at the western border of the quadrangle.

This formation is a decided exception in general character to the Cambrian formations of the Appalachian Mountains. In a general way it corresponds to the limestones and dolomites which overlie the Cambrian quartzites along the northwestern front of the mountains. The sequence of the formations underlying it is roughly the same, and the great change in the sediments deposited then is quite comparable to the change which began with the deposition of the Murphy marble. Like the other Cambrian formations, this can be traced southwestward well into Georgia. Its deposition thus covers a period of considerable extent and importance. Its purity and freedom from argillaceous and sandy materials, such as make up the entire bulk of all the preceding formations, shows that the geographic conditions changed abruptly and entirely at that time. In various analyses of the marble its composition varies from 58 to 93 per cent of carbonate of calcium and from 36 to 3 per cent of carbonate of magnesium. Accordingly the original strata included both limestone and dolomite.

Thickness.—Such measurements of the formation as can be obtained place the thickness at nearly 500 feet. The best measurements are southwest of Tomotla, where the formation stands nearly on edge and so continues for a long distance toward the southwest. Between Marble and Valleytown the marble spreads out over large areas. This is caused in part by the flattening of the dips and in part by the extreme crumpling and repetition of the layers. Instances of both attitudes of the marble beds can be seen in various quarries and openings. Along Nantahala River the formation thins down to about 150 feet.

Alteration.—Originally the marble consisted mainly of massive layers of limestone and dolomite, with the latter more frequent in the lower portion of the formation. With its base were interbedded argillaceous shales and with its top calcareous shales. During the metamorphism of the formations the carbonates of lime and magnesia were recrystallized with no considerable change of form. The argillaceous materials were for the most part transformed into various micas and other silicates forming the schists. Still other silicates were developed through the mass of the rock, such as tremolite and garnet; their formation involved the addition of silica to the materials already in the rock. They are disseminated through the formation rather sparingly and also are concentrated into definite beds of the marble. The tremolite appears crystallized in radiating bunches, with no apparent relation to the schistosity of the adjoining rocks. It seems probable, therefore, that it was of later formation than the other minerals. Tremolite also appears crystallized in the same manner in the talc bodies which are found in the marble. Garnet is of much less frequent occurrence than the tremolite and is found in only a few places in the lower parts of the formation. The same layers which contain the garnet also carry pyrite in small grains. This mineral is found in disseminated grains in other layers as well.

In the upper layers of the formation, where the marble passes into the Andrews schist, many crystals of ottrelite are scattered through the beds of marble. This mineral is characteristic of the overlying schist. Besides the alternating beds of marble and schist near the contact, there is present nearly every gradation between the ottrelite-schist and the pure marble. The ottrelite crystals are arranged with their cleavage at right angles to the general schistosity of the rock wherever that is present.

Other deposits occurring in the marble are layers of talc, the hydrous silicate of magnesia, which are mined throughout their course in this State and in Georgia. These appear at frequent intervals near Nantahala and Valley rivers. In the southern areas of the formation, on Peachtree and Brasstown creeks, no talc deposits have thus far been discovered. The principal development is in the vicinity of Hewitts on Nantahala River. Near Marble they also become prominent and appear at frequent intervals toward the southwest. The talc occurs in the form of lenticular bodies embedded in the marble. They are from a few inches up to 6 or 8 feet in thickness and the largest are over 100 feet long. Few attain that size, however. They appear to be of a secondary nature and have been produced during the metamorphism of the formations. Small bits and flakes of talc are found at many places, but they too are lenticular in shape and distinct from the marble. The lenses of talc are not confined to any one situation in the marble, but appear at several distinct levels. In association with the talc deposits are often seen beds of calcareous sandstone. These have no definite relation to the talc, however, and are not always present.

Owing to the highly soluble nature of the Murphy marble its course is always marked by valleys. Where the formation spreads out along the upper part of Valley River it has caused the series of broad valley bottoms which have given the river its name (see fig. 3). Outcrops of the marble are scarce and are seldom found away from the sharp stream cuts or the steep slopes. In the bottom lands near Andrews and those along Peachtree Creek the marble may be found at almost any point by digging through the few feet of stream gravels which form the surface. As a consequence of this solubility it has no soils of its own, and those which overlie its areas consist almost entirely of materials washed in from other formations. The rock itself when found is not affected to any depth by the weather.

ANDREWS SCHIST.

Distribution.—This formation extends from the vicinity of Andrews practically to Georgia along its principal line of outcrop. A small area also appears near Peachtree Creek. The town of Andrews is situated upon it, and in the vicinity its exposures and topography are characteristically shown. It is absent along Nantahala River, where the Nottely quartzite directly overlies the Murphy marble.

Character.—The formation consists of a thin bed of calcareous schist. One of its most conspicuous features is the large number of crystals of ottrelite which spangle the rock. These are so situated that in nearly every case their flakes lie at right angles to the dip of the bedding. Muscovite and biotite also occur in frequent crystals, especially in the upper parts of the formation. The flakes of these minerals, however, lie parallel to the bedding and in large measure cause the schistose planes. These various micas are embedded in a fine matrix of carbonate of calcium, of about the same character as the underlying Murphy marble. The feature which makes this schist of particular importance is the development therein of deposits of brown hematite, which are described under "Iron ore." These occur in scores of places along the areas of the formation and are a characteristic part of it.

Thickness and relations.—Near Andrews the schist appears to be at its greatest thickness, about 350 feet. It thins toward the southwest to about 200 feet. At its base it grades into the Murphy marble by interbedding and by a diminution of the amount of ottrelite. Upward it passes into the Nottely quartzite, as the sandy material increases both in separate layers and as grains in the body of the schist.

Weathering.—This formation, like the Murphy marble, is very readily soluble and gives rise to similar topography. A small amount of micaceous material in the schist, however, prevents such entire solution as in the case of the marble, and its areas usually rise in small terraces from 10 to 30 feet in height above the marble areas (see fig. 3). No sharp lines exist between the fresh rock and the residual clay, but the rock is partly dissolved through a considerable thickness, leaving its micaceous skeleton behind. In this soft mass the ottrelite crystals, weathered to bright brassy yellow, are very conspicuous. The soils over this formation are fairly deep and consist of yellow and brown clays. In most areas, however, they are covered with materials washed from the neighboring harder formations.

NOTTELY QUARTZITE.

Distribution.—Two small areas of this formation appear along the lower part of Valley River, one of which is the end of a considerable area that passes southwestward into Georgia. Its excellent exposures along Nottely River give the formation its name. Three other small areas occur along Nantahala River, directly overlying the Murphy marble.

Character and thickness.—The formation consists entirely of white quartzite. As a rule the shapes of the original grains of sand forming the rock are not visible except under a microscope. By that means the original nature of the grains and their growth during metamorphism can be discerned. In some of the weathered outcrops and fragments the original form of the grains is again brought out, when the secondary quartz has been dissolved away. Besides the quartz a very small proportion of feldspathic material is usually present. Much of this was replaced by secondary quartz and muscovite during the alteration of the rock. These later minerals are now rudely parallel to the planes along which the motion in the rock took place. In this region these are coincident for the most part with the bedding planes. The schistose character thus introduced is strongest along the layers which were originally argillaceous or feldspathic. In some places the mica flakes become coarse and the rock approaches a quartz-schist in appearance. As a rule, however, the quartzite is very fine grained and glassy and is always white. Its thickness is not known because it lies in synclines and the upper part of the formation does not appear. Upward of 150 feet are found, however.

Weathering.—Weathering proceeds very slowly in the quartzite on account of the slight solubility of its minerals, and it forms a sharp ridge throughout its course. Outcrops are plentiful along the tops of the ridges and in all the many stream cuts through the course of the formation. On complete decay the rock breaks down into a loose, sandy soil containing many fragments of quartzite. Its soils are valueless for any purpose except for the small growth of timber which they contain.

POST-CAMBRIAN.

QUARTZ-DIORITE DIKES.

Distribution.—This rock is the latest of the formations which appear in this district. It occurs in the form of dikes of small dimensions and penetrates the youngest formations which appear here. On account of the small size of these dikes it is impossible to represent them on the map. They are developed in two belts about parallel to each other. The southeastern belt has a width of 5 miles southeast of Murphy. Along this belt the diorites appear at frequent intervals on both sides of the Valley River basin and pass down the valley of Nantahala River and across Little Tennessee and Tuckasegee rivers, being found for 60 miles northeast of the last-named stream. The northwestern belt of diorite dikes passes through Graham County in a northeasterly direction, but can not be traced northeastward beyond the Cheoah River basin. These diorite dikes are from a few inches up to 3 or 4 feet in thickness, and usually are parallel to the schistose partings. They are to be found in all of the Cambrian formations except the Murphy marble, and they are very conspicuous in the ottrelite-schist above and below the marble. The reason for this, as well as for the more general location of the dikes in the schistose formations, is probably that the schists and slates were more easily penetrated than the massive marbles and conglomerates.

Nature.—The nature of the rock itself, which is a holocrystalline aggregate of quartz, feldspar, and hornblende, proclaims its igneous origin. Various features of contact action between it and the surrounding beds are to be seen, although of limited extent on account of the small size of the intrusive beds. The influence of the contact is seen in the diorite in the marked diminution of the size of the crystals toward the contact. This is so pronounced in most cases that it is hard to tell where the fine diorite ends and the somewhat altered schists begin. In fact, the average contact is a transition zone, the change taking place within the limit of 1 or 2 inches. Outside of this intermediate zone the special characteristics of the schist and the diorite are distinct. In some places the beds of diorite cut across the lamination of the stratified rocks; in others they branch into layers or run out into thin edges and disappear. Garnets are frequently developed as contact minerals in the inclosing schists, which are also somewhat silicified. In no case as yet have inclosed fragments been discovered.

Composition.—The appearance of this diorite in the hand specimen is very striking. Quartz and feldspar predominate in its composition, so that the rock has a distinct white appearance, and in this groundmass appear sharp and separate crystals of hornblende. One usual feature in the disposition of this mineral is its location, for the most part in the central portions of the beds. The inch or two of diorite next to the contact is usually made up mainly of quartz and feldspar. The hornblende is an original mineral and is not the result of metamorphism in any degree. A relatively common addition to these main minerals of the diorite is garnet in clear, distinct crystals. These do not appear to have any particular association with the borders of the mass, and thus may be considered one of the original minerals of the diorite. The quartz and feldspar, while wholly crystalline, are seldom of sufficient size to be distinguished separately by the eye. The hornblende crystals range in length from one-eighth to three-fourths of an inch, and are usually well-formed prisms. Little is added to these most conspicuous facts by study of thin sections; the original nature of all the minerals is made clearer, and the holocrystalline nature of the rock can be traced further through the extremely fine varieties along the contact.

Amount.—Owing to the small bulk of the beds of the quartz-diorite, it exercises no influence upon the topography, and forms no distinctive soil. Its decay is extremely slow, because it is so siliceous, and its fragments can often be found where all traces of other rocks have been removed by weathering. The amount of diorite may for this reason be overestimated, especially upon the weathered sections. In the clear-cut section along Little Tennessee River above Bushnell the amount of the diorite is seen to be relatively small, even where it is most strongly developed. In this section the general aspect is that of a series of slates and schists, with a small number of siliceous beds which might be passed over as sandstone unless the outcrops were carefully examined.

General relations.—The intrusion of these quartz-diorites gives evidence of a period of igneous activity which has no representatives in other parts of the State, so far as known. These belts can be traced southwestward into Georgia for long distances, but northeastward they are limited, as has been described. A feature of considerable interest is the close association of these diorites with the Cambrian strata. In fact, they are scarcely found here outside of those strata. The precise meaning of this is not now understood. From the almost total absence of metamorphism in the diorite, it is probable that its layers were injected at or after the end of the metamorphic period. This absence of metamorphism may, however, be due to the hardness and siliceous nature of the rock. In any event, these rocks mark the activity of igneous forces in the southern Appalachians at a period when there was entire quiescence elsewhere, so far as has been observed. They thus occupy a unique position among the Appalachian rocks. How much younger they are than the sediments there is no means of telling. The latter were upheaved and metamorphosed, and the quartz-diorites were injected into them, but only in this portion of the Appalachians.

TERRACE DEPOSITS.

Along Hiwassee, Valley, Cheoah, and other rivers in the quadrangle gravel terraces and alluvial deposits occur at many points. In part, at least, these are auriferous, and they are therefore described in connection with the gold deposits.

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 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 structure and are usually much nearer together and smaller than the planes on which the deformation of the stratified rocks proceeded. In these more minute dislocations the individual particles of the rocks were bent, broken, and slipped past one another, or were recrystallized.

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

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 types prevail in different places. In southern New York folds and faults are rare and small. Through Pennsylvania toward Virginia folds become more numerous and steeper. In Virginia they are more and more closely compressed and often closed, while occasional faults appear. 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.

STRUCTURE OF NANTAHALA QUADRANGLE.

The rocks of this area have undergone many alterations in form and position since they were formed and they have been bent, broken, and metamorphosed to a high degree. The structures which resulted from these changes extend in a general northeast direction. The structures in the sedimentary rocks can be deciphered by the close tracing of the formations on the ground. In igneous and crystalline rocks, however, while it is easy to see that they 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 great size can not be detected.

Major features.—In a broad way the structure of the rocks of the Nantahala quadrangle is that of one general synclinal basin between two anticlinal uplifts. The great synclinal basin consists of lesser troughs, each of which is complicated by many small folds. These troughs pass in a northeasterly direction, one through Tusquitee Mountains and another along Nantahala and Valley rivers. In their southwestern portions these contain the youngest rocks of the region, but rise rapidly toward the northeast and almost disappear. The general anticlinal area comprising the Cheoah and Little Tennessee basins is composed of a great many minor anticlines and synclines, which, however, involve only the lower two Cambrian formations. The chief region of uplift lies in the southeastern part of the quadrangle and brings to the surface the different metamorphic and igneous rocks.

Synclinal basin.—The structures displayed in the sedimentary rocks of the great synclinal basin differ somewhat from those in the igneous and metamorphic rocks. In the sediments all the kinds of structure seen elsewhere in the Appalachians are to be observed, including folds, faults, and metamorphism. Faults are comparatively rare, the principal ones being situated on the southeastern sides of the great synclinal folds. In other situations compression was relieved by close folding and metamorphism. The pressure and the load to which the rocks were subjected were far too great for their strength and they were crumpled and bent in the most extreme fashion. So pronounced was this result that in most of the folds the strata on each side of the axis were bent until nearly closed and parallel. Thus for miles across the strike in the northern and northwestern part of the quadrangle only vertical dips are encountered. The same is true in many areas between Hayesville and Andrews, where for miles across the strike all of the rocks are nearly vertical, although there are many minor folds. This region may be fitly characterized as one of vertical dips. By no means all of the rocks are vertical, but a large portion of them are, and dips less than 45° are very rare. In a few situations the latter are found, usually on the different cross folds which traverse the regular system. Most of the dips are from 60° to 90° and are toward the southeast. Thus it is seen that the sedimentary rocks are practically on edge over the entire area. The amount of shortening of the earth's crust thus produced is enormous and probably greater than in any other equal area of the Appalachians.

Archean uplift.—Structures in the Archean uplift in the southeastern part of the quadrangle do not differ radically from those in the sediments. The predominant structures are folding and metamorphism, which are everywhere obvious. By far the greater part of the deformation has taken place through metamorphism. The smaller folds and the wrinkling of the beds are easily seen in all localities, but it is difficult to discover the larger folds. Both northeastward and southwestward from this quadrangle, however, the major synclines are defined by inclosed bodies of sedimentary rocks. It is possible also that faults occur, but for lack of distinctive or regular beds they can not be determined. In the gneisses of this quadrangle there are no particular folds which predominate over others.

Faults.—Like the folds from which they are developed, the faults have a northeast-southwest trend in this quadrangle. Two exceptions to this occur, one being the faulted anticline on Tusquitee Bald noted under "Cross folds" (p. 7), the other being immediately south of Andrews. The fault at the latter locality was apparently somewhat folded after its formation and now makes a Z-shaped outcrop. The close connection of this fault with the anticline lying to the southeast is clear at its termination west of Almond. In the Tusquitee anticline, also, the beginning of the fault in an unbroken anticline is clear on the north side of Valley River Mountains. In the same way the fault which outlines the sediments on the south begins in a steep anticlinal fold east of Nantahala River and grows progressively greater toward the southwest.

The dip of these faults is toward the southeast in all cases except the fault along the Tusquitee anticline, the fault south of Andrews, a small one southeast of Teyahali Bald, and one just west of Almond. The first forms practically half a basin; the last two have a steep dip toward the northwest. The dip of the different fault planes varies from 20° to vertical. The average dip is from 45° to 60°. The throw of the faults varies from a few inches up to perhaps a mile. The fault passing south of Andrews may have a slightly greater throw than that. The one which passes just northwest of Hayesville displaces formations whose total thickness is about a mile, and it is probable that the throw of the fault is somewhat greater still. No estimate can be made of its maximum throw.

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 ottrelite during metamorphism. Similar metamorphic products are found in tracing these structures southwestward into Georgia. Northeastward the garnet-ottrelite phases extend for only 40 or 50 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 separate layers, just as in the case of the massive igneous rocks. In rocks which were already 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 they were developed by fracture and mashing, and the change of form expressed in folds was less than in the laminated rocks. The schistose partings are in a general way parallel to one another for long distances and over large areas. 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, they are usually about parallel to the general contact of the formations, the yielding to pressure having been directed by the differences in strength between the formations. Thus while the strike of the different formations may vary considerable in adjoining areas, yet the schistose planes swing gradually from one direction to another, and there is seldom an abrupt change.

The dips of the schistose planes are usually steep and, with the exception of the zone of fan structure, are inclined toward the southeast. Since a large portion of the strata are vertical the schistose planes as a rule dip at lower angles. There is less variation, however, in the amount of their dip than in that of the stratification. In a few exceptional cases—for instance, in the quartzites a few miles west and southwest of Almond—the schistose planes are nearly horizontal. This, however, was a local effect. Usually the dips are 50° or more. In describing the Tusquitee quartzite mention was made of the peculiar effects of the schistosity on that formation and its resemblance to the bedding. There is much less change in the direction of the schistosity than might be expected from the contortions of the strata. The strength of the latter was so far overcome by the force applied that the pressure was transmitted more or less independently of the separate layers. Where the differences in rigidity were greatest, as between the slate and the conglomerate layers of the Great Smoky conglomerate, local changes in direction of schistosity took place from layer to layer. The general attitude persists, however, throughout the region. The schistosity cuts squarely across the beds in Teyahali Bald and Tusquitee Bald, where the formations run at right angles to the usual trend.

Fan structure.—Two structural features of exceptional nature are seen in this region. Chief of these is the zone of fan structure which passes through this and adjoining quadrangles. Here it is well defined in a belt from 4 to 6 miles wide passing northeastward near Robbinsville, and its influence is manifested over twice as great a width. In this zone, while the axes of the fold have very steep dips and do not differ materially from the other axes of the region, both the axes and the schistose planes formed by the metamorphic minerals dip mostly toward the northwest. These northwestward dips, in contrast with the southeastward dips in the parallel structural belts, and with a somewhat radial or divergent arrangement, constitute the fan structure. Farther southwest, in the adjoining Murphy quadrangle, this structure has a greater width and is more pronounced.

Cross folds.—The second exceptional feature lies in a belt of abnormal structures which passes in a northwest direction through Standing Indian, Tusquitee Bald, and Teyahali Bald. Along this line almost all of the folds show a decided pitch toward the southwest, thus constituting a marked cross fold, complicating the usual system. The anticline with accompanying fault passing around Tusquitee Bald describes a complete U. Its sides are compressed and nearly vertical, while the top at Tusquitee Bald is overturned toward the northeast and faulted. Thus is shown most clearly a distinct shortening of the crust of the earth from southwest to northeast, as well as in the usual northwest-southeast direction. Other instances of this are to be seen in this region, as, for example, near Peachtree Knob and west of Almond.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The rocks and minerals of this region are of use in the natural state, as marble, talc, kaolin, soapstone, mica, corundum, building stone, ornamental stone, and road material, or in the materials developed from them, such as iron, gold, lime, and clay. The soils they form produce timber and crops, and the stream grades they cause furnish abundant water power.

MARBLE.

One of the most important rocks having commercial value in this district is marble. It covers many square miles, as represented on the geologic map, and it outcrops along two principal lines. The main one begins on Nantahala River below Hewitts and extends southwestward to and down Valley River a distance of over 25 miles. A shorter and parallel band extends from the head of Peachtree Creek nearly 10 miles southwestward and up little Brasstown Creek. The latter of these two belts terminates a few miles west of this quadrangle, but the principal belt extends through Cherokee County and many miles into Georgia, being nearly continuous with the marble belt of that State. Through most of its extent the marble is tilted up at a considerable angle and its outcrop forms only a narrow band. On Peachtree Creek, however, and on Valley River between Marble and Valleytown the dips are less and the marble spreads out over considerable areas.

Color and grain.—The marble has two principal colors—white and blue. Both of these are seen throughout the range of the formation, but the blue and bluish colors predominate toward the northeast. Very little of the blue stone has a uniform color; usually it is more or less banded or mottled with white. Where the marble beds are on edge or have a high dip the banding of color is more regular than in other places. There is, also, a banding due to lines of foreign minerals. This is best seen in the quarry a mile northeast of Andrews and is caused by lines of mica flakes. An exceptional color, and one of great beauty, is the rose pink which is seen just northeast of Red Marble Gap. This merges into white beds, and the amount of the pink stone is limited. The distribution of the colors of the marble can not be given in detail, on account of the few natural exposures and the few quarries which have been started. What is probably the largest body of white marble is in the bottom lands of Valley River below Andrews.

The grain of the marble is in all cases uniform and fine. It does not appear to be changed by the transition from one color band to another. Probably the grain of the rock is a little coarser toward the southwest, but the difference is very slight. Where the rock is composed of pure carbonates there is practically no tendency to part along the original sedimentary layers. Thin layers of micaceous minerals cause a slight schistosity where they are developed. This is not sufficient to affect the strength or the quarrying of the rock. Some of the upper layers next to the Andrews schist have more of the secondary minerals where the transition takes place between the two formations. This does not affect the marble as a whole. Northeast of Red Marble Gap similar transitions are seen at the base of the marble, and there is considerable development of micaceous minerals. This causes a decided schistosity, which, however, is limited to the few feet of interbedded marbles and slates. With these exceptions the marble is a uniform and massive rock, and blocks which have been sawed across the bedding planes show no indications of parting in those planes.

Composition.—The chief variations in the composition of the marble are in the proportions of the carbonates of lime and magnesia. These have no particular bearing upon the value of the rock, as they do not affect its strength, durability, or density. The lime varies from 53 to 32 per cent and the magnesia from 2 to 20 per cent. Other variations are due to the varying amount of the included minerals. These are talc, muscovite, biotite, tremolite, ottrelite, garnet, pyrite, and quartz. The amount of quartz varies. From 1 to 2 per cent is present in practically all the beds. The micas are practically confined to the uppermost and lowest layers of the formation. The tremolite and talc are concentrated into lenticular deposits and do not affect the working of the marble as a whole. Certain other layers contain tremolite crystals, as seen in the quarry on Marble Creek at the border of the quadrangle. The pyrite and garnet are found at a number of places in the lower layers of the formation, but are comparatively rare. In short, the minerals which would injure the working and appearance of the stone are very slight in amount and easily avoided.

During the metamorphism of the marble the carbonate crystals were formed interlocking with one another. This has produced a rock of great density and closeness of texture. Tests of marble from Hewitts, on Nantahala River, show that it is not liable to be acted upon by frost or solution. Four samples of rock from this locality gave an average crushing strength of about 11,000 pounds per square inch.

Thickness.—The total thickness of the marble beds is about 500 feet. The only obtainable measurements are in the southwestern end of the main marble belt. In the broader areas underlain by the formation the different layers have been repeated by folding. Since the beds do not part along the original sedimentary planes the effect of the thickening has been to increase the marble available for quarrying. Northeast of Valleytown the marble is bounded for the most part by fault planes; thus it varies much in thickness, and in places is entirely absent. Along Nantahala River the entire marble bed is present in many places, but appears to have been somewhat squeezed and thinned during the process of folding. Good measurements of its thickness in the vicinity of Hewitts give scarcely more than 150 feet. Below Hewitts the bed is soon cut off by a fault and does not appear toward the northeast. In the quarry on Marble Creek, where the marble passes into the Murphy quadrangle on the west, the following section is exposed: At the bottom are several feet of white marble with tremolite crystals; above this are 50 feet of pure white marble, 40 feet of blue marble, and 30 feet of white marble. After a small interval in which there are no exposures the ottrelite-bearing Andrews schist outcrops. Thus only a small part of the normal total thickness is exposed.

Joints.—The marble when pure is very resistant to weathering agencies. In course of time its upper parts have been dissolved away, but the remaining rock is perfectly fresh and hard. This general condition is affected somewhat by the lines of micaceous minerals near the top and bottom of the formation, down which weathering has penetrated to considerable depths. It is also seriously affected by joint planes and other planes along which slight movements have taken place. These are particularly conspicuous in some of the sections along Nantahala River, and the action of weather has broken up the marbles and adjoining quartzites into blocks of varying size. These were not caused during the formation of the fault, but seem to be due to later disturbances along the same lines of weakness. Somewhat similar phenomena are seen where the marble belt contracts again toward the southwest. In that situation too there is a fault plane within a short distance toward the southeast. The exposures of the marble are very poor in that area, but the quartzites are considerably jointed, and probably the marbles are affected in the same way. These joints do not appear when the fresh rock is taken out of the quarries, but are developed by exposure to weather. No noticeable amount of motion has taken place along these planes and they represent merely a tendency to separate. Of slightly different character are various seams along which motion has taken place. These are usually accompanied by a slight development of the silicates in thin films which are frequently striated in the direction of the motion. In places these seams disconnect the portions of the marble, even in the solid rock, and cause it to break up after short exposure. They are not present in all the marble, by any means, and the amount of good material seems to be very large. Where the rock has been extensively quarried in regions farther southwest the character of the stone is not greatly different and the geologic surroundings are substantially the same. It is therefore probable that good material will be abundant in this region.

Accessibility.—While the marble does not often outcrop in this region, there are numberless quarry sites available. The surface of the marble is covered by 6 or 8 feet of soil and gravel along the flood plains of the different streams (see fig. 1 on columnar section sheet), and in other positions by a slightly greater amount of wash from the various formations. This is true not only of the entire Valley River basin, but also of the Peachtree and Brasstown areas. In the latter situations, as well as in the bottom lands for large areas below Andrews, the presence of the marble has been proved in scores of places, although it scarcely outcrops at all. Northeast of Red Marble Gap even this thin covering is much lessened and natural outcrops of the marble are frequent. The Murphy branch of the Southern Railway follows closely along the principal marble belt. In fact, the low ground which the railroad follows is, with the exception of 4 or 5 miles, caused directly by the presence of the marble. Thus delivery of the quarried material to the transportation lines is exceptionally easy. Southwest of Marble the formation has an average dip of 50° to 60°, so that long-continued quarrying would entail deep cutting and hoisting. In the same degree the disposal of water would be a question to be considered. The surface of the marble in those localities is seldom more than 60 feet above Valley River, and much less above the minor creeks. Considerable pumping would therefore be necessary in quarries of any depth. Northeast of Marble the situation is much the same, except that the rock is seldom more than a few feet above drainage level. In all these areas, therefore, drainage and disposal of the waste material are of importance. Between Marble and Valleytown the dips vary much, but on the average are small. Consequently openings on the marble could readily be extended over the surface and the stone taken out more easily. Northeast of Red Marble Gap the topography is very rugged and presents great natural advantages so far as drainage and disposal of waste are concerned.

TALC.

One of the chief sources of talc in the United States is the series of deposits in the Murphy marble in this quadrangle. Talc is a hydrous silicate of magnesia, and is notable for its infusibility, its softness, and its smooth, greasy feel. On account of these characteristics its various uses have been developed. Its infusibility fits it for gas tips and vessels which have to stand extreme heat. When scratched or rubbed against any ordinary surface the talc gives a white streak. The massive varieties are manufactured into pencils and articles for marking. Little of the North Carolina talc is suitable for cutting into pencils, practically all of that character coming from the mine at Hewitts. It is easily cut or sawed, or ground into powder. On account of its unctuous nature the powder is used to diminish friction.

The talc occurs as a series of lenticular masses and sheets in the blue and white Cambrian marbles along Nantahala, Valley, and Nottely rivers. It is also found in the Great Smoky conglomerate, of Cambrian age, and in the Archean dunite and soapstone formation.

Talc in marble.—The Cambrian marbles as described above have a length of outcrop of about 40 miles in North Carolina, and are continued in Georgia for a much greater distance. Talc is known to occur in more than twenty-five places along the marble belt of North Carolina, but is less common in Georgia. It occurs in the shape of lenticular bodies inclosed in the marble and varying in size from mere scales up to masses 50 feet thick and 200 feet long. Owing to its soft nature the talc does not withstand weathering, but readily crumbles down. It does not outcrop, therefore, and its position is indicated merely by weathered fragments on the surface. Thus it is impossible to determine the full extent of the talc bodies except where they have been exposed by mining. For the same reason it is probable that many bodies of talc have thus far escaped observation. Some of the bodies are so extensive that they resemble sheets of sedimentary material. This is especially the case where the talc sheets grade into the adjoining sandstone beds. They are termed "veins" by the miners, but have none of the characteristics of true veins.

It is not probable that the talc was deposited as a sediment in its present form. The rocks of the entire region have been greatly folded and compressed, and most of the original sedimentary materials have been recrystallized. No sedimentary deposits of talc are known in the Appalachians; it is therefore probable that the constituents of the talc existed in the adjacent sedimentary rocks in some other form. Some of the beds of the marble formation now contain a considerable percentage of magnesia in the form of the carbonate. It is probable that the magnesium carbonates and the hydrous silicates have the same source, both being derived from the materials of an original sedimentary dolomite. The development of the talc in the scales which are disseminated through the mass of the marble is thus easily accounted for. The concentration of the talc into lenses and sheets is, however, difficult to understand. Some of the lenses are barely twice as long and broad as they are thick, while others are very much attenuated and form thin sheets, as already stated. The lenses appear to be somewhat drawn out, and pass into the marble with very thin edges.

The color of the talc varies considerably in the different lenses and sheets. By far the greater part of it is dull white. Of this color are all of the weathered or semiweathered portions which are near the surface. In the talc which is secured by mining from the solid rock light colors prevail, varying from bluish and greenish white to a dull blue and a pale green. The freshest mineral is translucent. This character has been lost by all of the weathered talc, which is perfectly opaque. Much of the weathered material is also stained with iron oxide from the ferruginous minerals in the schists which border the marble formation. This rust coats and stains the surface of the fragments and penetrates into their interior by cracks and seams. It is a serious detriment to the quality of the talc, since it is mixed throughout the latter when it is ground.

As can be readily understood from the dimensions of the talc lenses, the quantity of the talc varies greatly. It is only by actually working out each body or by thoroughly testing by diamond drill that any idea of the amount can be obtained. A lens whose edge only can be seen is as likely to be large as small. It is equally impossible to predict where a mass of talc will or will not be found. Many of the miners say that the talc is always overlain by a white sandstone called the "cap rock." This is often the case, but is not the rule, for the talc is frequently found where there is no associated sandstone. The talc lenses are not confined to one horizon in the marble, but may appear between several distinct layers. Variations in the quality of the talc are considerable, also, even in the same body of marble. For instance, at Hewitt's mine on Nantahala River both the massive and the fibrous varieties are found, as well as the blue, green, and white colors. One quality and one color usually predominate in a single lens or sheet.

The texture and grain of the talc are very variable, even in the same group of lenses, as was just stated in reference to the Hewitt mine. The talc scattered through the mass of the marble is usually in the shape of foliated scales. The same is true to a greater or less degree of the thin edges of the various lenses. Some of the thicker lenses are composed almost entirely of massive talc. This has no cleavage or tendency to part in one direction rather than another, and is sawed into pencils and sheets. Most of the talc has a tendency to break into long, thin fragments, flakes, and fibers.

Inasmuch as the methods of manufacture of the talc depend upon its softness, any impurities which affect that quality are a detriment. Other impurities, such as stains by iron rust and soil, can be removed in part. The principal impediments to the working up of the talc are the associated minerals, mostly silicates. These are inclosed in the mass of talc in crystals arranged at a great variety of angles. The silicates consist chiefly of hornblende, tremolite, actinolite, and chlorite, all containing a large percentage of magnesia. There are also found occasional grains of pyrite and magnetite. In localities where the sandstone "cap rock" is found there is sometimes a mixture of the sand grains and the talc, as if the talc were a sedimentary deposit. The crystals of the silicates vary in size from mere needles up to prisms with diameters of half an inch and a length of 2 or 3 inches. These may be developed singly or arranged in radiating bunches and groups. The greatest development of these silicates is seen 5 miles northeast of Murphy, where the largest talc body of the region is rendered worthless by them for the present. They are intergrown with the talc in such numbers that it is not practicable to separate and work up the talc. The same minerals are to be seen crystallized in the marble in a number of localities where there is no talc.

The methods employed in extracting the talc lenses from the marble are very simple. For the most part the talc is obtained from pits and shallow shafts in the soil and decomposed rock. The pockets of talc thus encountered are usually very much weathered, and accordingly are of less value. In the large mass of talc exposed 5 miles northeast of Murphy an open cut 50 feet square has been made, and the amount of talc in sight is large. As above stated, however, the silicate impurities there render the talc less desirable and less easy to work. The chief developments in talc mining are confined to the extreme end of the Murphy marble belt, on Nantahala River. Tunnels and shafts have been sunk in several adjoining properties, extending about a quarter of a mile along the river, and a body of talc has been proved for a vertical extent of about 150 feet. The dip of the strata and the included talc sheets is about 45° SE., which carries them under the bed of the river. The talc has been found in a shaft sunk considerably below the level of the river and is now being mined. In the past most of the talc has been taken out from the smaller and more irregular lenses encountered here and there in the marble at points up to 100 feet above the river. From various tunnels of the Hewitt mine at this point a considerable amount of marble has been taken out in following up the talc. The slope of the hillside follows very nearly down the dip of the marble and has been stripped over a large area in the search for talc. All the talc deposits of the Murphy marble are readily accessible, for a branch of the Southern Railway runs within a few rods of the marble belt throughout its extent in North Carolina.

Talc in graywacke.—Talc is also found in a very unusual association $1\frac{1}{2}$ miles southwest of Wayside and near Little Tennessee River. The deposit at this point occurs in the graywacke and mica-schist that form part of the Great Smoky conglomerate. A shaft and tunnel have developed the talc for a depth of 100 feet. It lies in the form of a vertical vein which is parallel to the inclosing schists. At this point the width of the vein varies from 14 to 28 feet, being greatest in the tunnel at the lowest point seen. At the border of the vein the mica-schist is impregnated for a few inches with talc, forming a talcose schist. It is probable from this that the talc deposit is a replacement of the original mica-schist, but in the body of the vein none of the schist now remains.

The talc is thinly foliated and slightly schistose and has a dead-white color. The many partings in it render it unfit for cutting into pencils, but it works up into excellent powder. Associated with the talc in places are separate knots and groups of white tremolite crystals. These would cause a loss of some of the talc in the manufacture. At present the deposit is not being worked at this point, owing to its remote position. This vein has been traced by surface indications and test pits for considerably more than a mile with a northeasterly course. Since the talc itself does not outcrop it is likely that other beds now covered will be found, for the causes which produced it were probably of a general nature.

Talc in soapstone.—Another class of talc deposits is connected with the bodies of dunite and soapstone in the Archean rocks. Around these formations there is usually a border of talc or very pure soapstone. Besides these, seams of talc intersect the dunite masses in various directions. These seams are usually only a few inches thick and may be mere films, but the bordering beds vary from a foot or two up to 10 feet in thickness and contain large quantities of talc. Instances of this variety are seen a mile south of Shooting Creek post-office and at the extreme head of Shooting Creek. The quality of this material is rather uncertain, however, and the value of the talc is liable to be much lessened by the presence of the other silicates, such as tremolite, actinolite, hornblende, and chlorite. These are practically the same minerals which occur as impurities in the talc of the Murphy marble. It is impossible to say in advance of working where the quality is thus depreciated. The talc is almost entirely white, sometimes translucent, but usually opaque. It is probable that if work were pushed into the solid rock the translucent material would predominate. Thus far mining has been confined to pits in the clay and decomposed rock. Stains of earth and iron oxide are common in this material. This variety of talc varies from massive to fibrous and is fit only for grinding into powder. Although the amount of talc of this class is considerable, none has been mined in this region.

KAOLIN.

The same series of pegmatites from which the mica is derived also contains valuable deposits of kaolin. The pegmatites vary widely in the proportions of quartz, feldspar, and mica, and in places the feldspar forms much the largest part of the mass. In certain situations the feldspar is decomposed to kaolin and such deposits can be profitably mined. The kaolin is separated from the hard particles of quartz and undecomposed feldspar by washing and settling.

As has been stated in the discussion of the topography, large areas bordering the main streams were reduced to nearly level plains. These have been since cut into by the rivers and stand from 100 to 300 feet above the present streams and slightly over 2000 feet above the sea. On these old surfaces the rocks were deeply decayed, especially those which contained much feldspar. In this quadrangle only a small area of this deeply decayed surface is occupied by the rocks containing pegmatite. They are practically limited to a narrow belt 3 or 4 miles wide along Little Tennessee and Tuckasegee rivers above Bushnell, within which numerous small deposits of kaolin have been found. In the adjoining Cowee quadrangle there has been considerable development of these deposits, and some of the best kaolin of the State has been taken from them.

Within the Nantahala quadrangle kaolin is known to occur in quantity at seven localities, all within 4 miles southerly or easterly from Almond. At the Hewitt mine, $2\frac{1}{2}$ miles southeast of Almond and near Little Tennessee River, kaolin is now being mined. The pegmatite is found replacing the graywacke and schist of the Great Smoky conglomerate, which is an unusual situation. The pegmatite occurs as small round masses and nodules in the graywacke, and its minerals are not deformed like those of the inclosing rocks. Similar masses are to be seen in the conglomerates along Little Tennessee River toward the northeast.

The kaolin is mined near the top and on the southern slope of a small ridge. Test pits and a short tunnel have proved its extent for about 150 yards on the north slope of the same ridge. The deposit runs nearly north and south, as do also the adjoining schist and graywacke. The kaolinized pegmatite is removed from an open cut, the hard fragments are roughly picked out by hand, and the remainder is carried in a flume to Little Tennessee River. It is there washed, settled, and dried, and the product taken to the railroad by wagons. Some of the expense of this operation could be lessened by a tram or other railroad, and many other deposits in the vicinity might thus be profitably worked.

About a mile farther north and apparently on the same lead is another deposit of kaolin. About one-fourth mile westward kaolin is found in a different body. Judging from surface indications, there is in the vicinity a large amount of kaolin-bearing pegmatite which is undeveloped. Still other deposits have been opened up by test pits 2 miles southwest and $1\frac{3}{4}$ miles northeast of the Hewitt mine. These pits, however, demonstrate only the presence of the kaolin and not its amount. The locality northeast of the Hewitt mine is at the top of a ridge 200 feet above the river. At least two separate veins of the kaolin are exposed in the pits, and the kaolin extends vertically for at least 50 feet. On the lower slopes of the hill and near the river the pegmatite is not altered to kaolin, but outcrops as solid rock.

SOAPSTONE.

In three places on the headwaters of Shooting Creek soapstone is found in sufficient purity and body for commercial use. In most cases the hydrous silicates of magnesia forming the soapstone are too much mixed with other silicates, especially of the hornblende family, to be available. The special uses of soapstone demand a rock which is readily cut and sawed and which contains no mineral that is affected by fire. Some of the hornblendic minerals fuse readily, but others which fuse less easily are hard and injure the texture and working of the stone. In the metamorphism of the original rocks those composed of feldspar and pyroxene are altered to soapstone composed mainly of talc and chlorite with tremolite and enstatite crystals in variable amounts. The changes are chiefly of form and not of chemical composition of the rock as a whole. Inasmuch as igneous rocks of this nature vary greatly in composition, the beds of soapstone also vary much in quality, and a change from good to worthless or from poor to valuable rock may be found at any place. The localities indicated on the economic map would furnish material in large amounts and fairly free from the injurious minerals. Owing to the remoteness of the beds, however, there is no demand for the stone except locally for use in fire-places, and only surface bowlders have been used.

MICA.

In the pegmatites of the Archean rocks mica occurs in crystals large enough to be of commercial value. Pegmatites are found in the Roan and Carolina gneisses throughout a large portion of their areas of outcrop, but mica of workable size has been mined chiefly in a belt passing northeast and southwest near Wayah Bald. On the north end of Standing Indian, also, mica of good size is found. Elsewhere the crystals either were crushed and distorted during the deformation of the rock or were not originally of sufficient size.

The mica is muscovite and is crystallized with quartz and feldspar, forming the pegmatite. From a texture only a little coarser than granite the pegmatite varies until the mica crystals attain a diameter as great as 20 inches. Crystals of this size are very rare and the average diameter is from 3 to 6 inches. In this region the pegmatites are of lenticular shape and lie in general parallel to the inclosing gneisses. They may be traceable for long distances or may be quickly terminated.

The distribution of the crystals or "blocks" of good mica in the vein is very irregular and can not be predicted. In places the mica apparently follows rather irregular planes, which are termed the "vein." They can not be traced far with any definite position. Consequently the success of any mica mine is uncertain. Good mica may be found at once, or barren rock may continue throughout. Coarse mica at one point may become smaller in a few feet, or the crystals may be deformed and crushed. 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 or "rulings" divide them into strips and angular pieces. These, 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. The clay 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.

Pits and shallow openings have been made 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. The mine upon the eastern slope of Wayah Bald has furnished the largest mica known in this region, but it has been idle for a long time. In all the mica of this area the pegmatite cuts across the mica-gneiss at angles of 10° to 60°. Where the two have similar directions the contacts are irregular or step shaped.

The only mine worked in late years is on Burningtown Creek. Mining was carried on by the Flint Mica Company from 1903 to 1906, on the site of old workings. Electric power derived from the neighboring creek was used at first, but was later given up. The pegmatite, or "vein," was from 6 to 12 feet thick, striking about N. 10° E. and dipping 55° SE. Thus the vein cuts the mica-gneiss, which runs east-west with a high northerly dip. The mica is confined to the outer parts of the vein, its center being composed of quartz layers 3 or 4 feet in total thickness. A crosscut runs in southeast to the vein 40 feet below the outcrop where it crosses a small spur. Practically all of the vein was stoped out above the level of the tunnel, and the stope extended below it for 45 feet. No work is now being done there. Mining has been done at other points only in open cuts.

CORUNDUM.

Corundum is an oxide of aluminum and is found in association with the Archean rocks. Eight localities where it occurs are known within this area. There are two distinct kinds of occurrence. On Buck Creek, Little Buck Creek, Burningtown Creek, and at two localities on Shooting Creek the rocks accompanying the corundum are varieties of the dunite formation. At two other localities on Shooting Creek, and also near the head of Tallulah River, in the extreme southeastern part of the quadrangle, the corundum is found embedded in the Carolina gneiss.

Corundum in mica-gneiss.—Corundum differing entirely from the usual deposits of corundum in the region is found in crystals disseminated through the mica-gneiss beds of the Carolina gneiss. These beds are composed mainly of quartz, feldspar, muscovite, and a little biotite. Many of the layers are also garnetiferous. Differences in the proportion of the mica and feldspar in different layers give a bedded aspect to the gneiss in addition to the minor separation of the minerals into thin sheets. Along certain of these major layers corundum is found in association with garnet. It is not, strictly speaking, in a vein, nor is it a sedimentary deposit, though it resembles both.

The deposit at the head of Tallulah River has been traced southwestward through the adjoining Dahlonega quadrangle for a distance of 3 or 4 miles, and its extent may be much greater, for the accompanying conditions extend for many miles. Its dip varies with the gneiss and is 20° to 30° in this area. The thickness of the beds containing corundum varies from 6 to 14 feet in this region. The corundum forms hexagonal crystals, usually well shaped and tapering toward each end. They attain diameters as great as three-fourths of an inch and lengths of 3 inches. The corundum has a dull-gray color and is semitranslucent; in no case is it suitable for gems. The basal cleavage is fairly prominent and divides the crystals into a number of sections, which, however, are not separated from one another in position. The corundum itself is very dense and tough. The crystals are coated with a film or very thin layer of mica. The scales of this are extremely fine, but it appears to be of the muscovite variety.

The corundum on Eagle Fork of Shooting Creek has a similar general position in the mica-gneiss, and the layers inclosing it are full of garnets near the contact of the hornblende-gneiss. The corundum crystals themselves have a slightly different arrangement, however, from those on Tallulah River. Most of it is associated with biotite and muscovite in lenticular veins or segregations in the mica-gneiss. These are plainly secondary replacements of the gneiss and lack its foliation. Only small grains of corundum, of the size of wheat, are found in this relation. There are also a few corundum crystals of larger size distributed through the mica-gneiss. These have muscovite and a little biotite surrounding them. In places the corundum appears to have been replaced by the micas. Between these typical formations of the corundum there are numerous transition varieties. The two occurrences of this nature are in close proximity to the intrusive hornblende-gneisses and have the same general relations as the corundum of Tallulah River. Two miles northeast of these localities corundum, spinel, and cyanite are found in rudely spherical segregations in the Carolina gneiss. The gneiss at this point is garnetiferous near the contact of the hornblende-gneiss, and the general relations are the same as in the preceding localities.

The only workings in the Carolina gneiss corundum are on the east side of Tallulah River. At this point, high up on the east side of a peak called Scaly Mountain, several open cuts have been pushed into a precipitous slope along the dip of the vein, which varies from 20° to 30° W. Some rock has been crushed and the corundum cleaned, but not shipped. The difficulties of transportation are very great. The average proportion of corundum in the rock is estimated at about 5 per cent, and its total amount is very great, since the vein can be traced for several miles. The proportion of corundum to garnet appears to be greater near the surface. In crushing, the quartz, feldspar, and mica of the gneiss are pulverized much more easily than the corundum and thus are readily separated. More or less difficulty is encountered in cleaning the garnet from the corundum. Water is plentiful for all purposes.

On Shooting Creek only a few test pits have been sunk and the amount of corundum-bearing rock is uncertain. The separation of the corundum from the gneiss would be easily effected on account of the greater toughness of the corundum. The proportion of the garnet in the gneiss, however, is considerably greater than on Tallulah River and would cause trouble in the separation of high-grade corundum.

While the corundum crystals occupy a fairly definite position in the mica-gneiss as a whole, they are scattered apparently at random and at various angles through the individual layers of gneiss. They interrupt the parallel arrangement or foliation of the mica-gneiss abruptly, and plainly represent a replacement of small parts of the gneiss. It is thus seen to be a secondary mineral and much later than the bulk of the gneiss. The other minerals composing the gneiss, as has been stated, have a definite parallel arrangement, due to deformation of the rock. The entire absence of this in the corundum, although the length of its crystals and their prominent cleavage would facilitate it, is strong evidence that the corundum was formed later than the period of deformation.

There is little or no evidence as to the cause of its formation. The garnet with which it is associated is a secondary mineral and is due to and accompanies the contacts of Roan hornblende gneiss with the Carolina gneiss. On Shooting Creek the garnets are very coarse, being frequently 2 inches in diameter. However, although the garnets were secondary, they preceded the rock deformation, for they are in many cases crushed and distorted. Thus the corundum can not be attributed directly to the contact action of the hornblende-gneiss. From its prevalence in a few thin layers it would seem either that the original nature of the layers was conducive to the formation of the corundum or that they were the easiest channels for the passage of solutions forming the corundum. The deposition of corundum may have been in that respect controlled by differences in the rock caused by the original contact of the hornblende-gneiss.

Corundum in dunite.—The corundum of the Buck Creek and some of the Shooting Creek areas is, as has been said, associated with the dunite formation. At the Cullakeenee mine on Buck Creek, the North Carolina Company's mine on Little Buck Creek, and the Isbel mine at the head of Shooting Creek the corundum is found with plagioclase feldspar and a little hornblende in veinlike or lenticular deposits in dunite. At the Behr mine, near Elk, on Shooting Creek, corundum occurs in tabular pink crystals and grains in the amphibolite, as well as in feldspathic veins. Most of the dunite corundum is light gray or whitish, but many pink crystals are found, and some are streaked with the clear blue of sapphire. They seldom form well-shaped crystals, but usually are in irregular lumps an inch or less in diameter. Larger bunches are frequently found, and at Little Buck Creek a mass was taken out 30 inches long and weighing 1800 pounds. The corundum is very dense and tough, but shows well developed cleavage. Numerous more or less rare accessory minerals are found.

The country rock inclosing the veins in nearly all these localities is amphibolite, chiefly composed of feldspar with chlorite and bright-green hornblende. The latter mineral has a distinct foliation and was produced from the original minerals of the rock during deformation. The veins are in most cases found close to the contacts of the amphibolite or dunite with the hornblende-gneiss, but in some instances they appear well within the dunite. Their dip and strike vary roughly with those of the inclosing rocks, and the dip is usually very steep. On Buck Creek the veins have been traced for considerable distances along the contacts and have been opened at eight or nine points. At the eastern one a shaft has been sunk on the vein, which is 3 feet or less in width.

Corundum is now being mined only at Corundum, on Little Buck Creek, and is cleaned and graded in a mill at that point. The corundum is mined from a group of veins which pass into the body of the dunite from the contact of the hornblende-gneiss. The veins vary greatly in direction and dip and range from a few inches up to 8 feet in thickness. Several veins have been developed in open cuts and tunnels more than 50 feet into the dunite. The corundum is white or grayish with many blue streaks, and forms rudely crystalline units and masses associated with albite, margarite, chlorite, diaspore, hypersthene, tourmaline, and actinolite. The corundum is tough and forms an excellent abrasive. The dunite is much altered to chlorite, asbestos, actinolite, and serpentine along cracks and veins. Corundum is found at several neighboring points, but has not been developed.

The origin of the corundum is a matter of considerable doubt. Its close connection with the borders of the dunite and the inclosing formations indicates that its deposition was determined by the contact. The associated chlorite and hornblendic minerals are all silicates of magnesia, much the same in composition as the minerals of the dunite and of allied masses where there is little or no corundum. Except the corundum there is little or no alumina in the dunite. In the adjoining formations, however, it is present in great quantities in the form of silicates, and chemical reactions between the two masses may have led to its deposition near the contacts. In the formation of the hornblendic minerals, which was the chief change from the original olivine of the dunite, there was a large addition of silica. This necessarily came from the adjoining more siliceous formations. It is possible, therefore, that the alumina was set free by the absorption of the silica into the dunite and crystallized as the oxide in the zone where the reactions took place. The veinlike form of the deposits is in favor of this view and strongly against an origin of the corundum earlier than the deformation of the rocks.

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

IRON ORE.

Iron ore is found in many situations in this quadrangle. The ore is in all cases brown hematite and for the most part occurs as deposits in the residual clays. Here and there iron ore outcrops in the areas of the Great Smoky conglomerate, forming gossans over the bodies of iron and copper pyrite. In only one place near this quadrangle do these bodies attain any size—on Hazel Creek, just across the northern border, where deposits of this character have been developed considerably.

The chief source of iron ore in this region is the Andrews schist. The ore is brown hematite, and it occurs both as layers interbedded in the partially weathered strata and as lumps and masses in the residual clays. The iron ores are encountered in practically all the areas of the schist. They can be traced connectedly for considerable distances and are best developed in the upper portion of the formation. They are found almost altogether above the stream levels, but in one case they have been followed to a depth of 80 feet below the surface. Many outcrops are 200 feet or more above the streams. Apparently they follow and replace definite beds, and are due to the concentration of the ore into certain beds by a replacement of the calcareous by ferruginous material. Thus, southwest from Tomotla, where the formations are tilted at high angles, the beds of hematite are similarly tilted. Between Andrews and Marble, at points where the schist has a slight dip, the iron-ore beds are also nearly flat and cover broad areas. In these latter situations they sometimes attain much greater thickness, as well as breadth.

The bodies of ore usually range from 1 to 6 feet in thickness; those that lie flat attain thicknesses as great as 50 feet. Just southeast of Marble is the largest body proved; this has a length of 175 feet, a depth of 40 feet or more, and a width of over 15 feet. Many shallow shafts have been sunk and pits or cuts made in the ore throughout its entire range. Many years ago this ore was reduced in the old forge north of Murphy, on Hanging Dog Creek, and furnished excellent iron. Since that time practically no use has been made of the deposits. Thirty samples of this ore averaged a little over 50 per cent of metallic iron, less than 9 per cent of silica, and just over 1 per cent of phosphorus. This brings it up to the standard of the first-class brown ores. Its position within a mile of the railroad is very advantageous.

A second group of brown hematites is developed in the vicinity of fault lines. These are best exhibited from 2 to 4 miles southwest of Valleytown. Along the same line near Peachtree Creek and Hiwassee River, and also northeastward from Valleytown, similar ores appear from place to place. The ores are found in the various slates and schists and near the fault plane, and consist of brown hematite rather irregularly distributed through clay and decomposed rock. In places the ore contains so much manganese oxide as to become an ore of that metal. The ore bodies follow the strike and dip of the rocks closely, and occasionally, as at Red Marble Gap, the ore can be seen to lie between the layers of the half-decayed slate. These ores are not present in as great degree and bulk as the ores of the Andrews schist. They do not exceed 5 feet in thickness and usually are about 1 foot thick. Beds of this ore can be traced for considerable distances, but are interrupted by sections showing no trace of the ore, so that the bodies must be intermittent or lenticular in shape. On that account the quantity of the ore is rendered more uncertain. The development of these ore bodies has been slight and they do not approach the importance of the ore in the Andrews schist. The quality is excellent, being low in sulphur, phosphorus, and silica. The iron-bearing minerals, staurolite, garnet, and pyrite, are greatly developed in the vicinity of the fault planes and seem to have a connection with these ores, and may possibly be their source.

A third group of brown hematites appears near the contact of the Murphy marble and the Valleytown formation. These ores occur here and there throughout the entire marble belt, being most prominent near the western border of the quadrangle. Like the preceding ores, these are situated in the red clays and overplaced soils. There is no visible association with the bedding of the marble, on account of the complete decay of the latter where the ores appear, nor do the ore bodies seem to have any definite dip, but they consist of irregular masses and lumps in the clay. None of these ores have been developed to any extent. The quality of the ore is good, but the quantity is uncertain on account of the nature of its occurrence and the small amount of present developments. It is possible that this hematite was derived from the decomposition of pyrite which occurs in the lower portions of the marble. To this would be added the hematite derived from the weathering of the adjoining schists, which carry large quantities of disseminated iron-bearing minerals. Concentration from this group of minerals at many points distant from the marble has resulted in unimportant deposits of hematite.

GOLD.

For many years this region has been the scene of mining for gold. Its chief forms of occurrence are the veins and stringers of gold-bearing quartz in the Cambrian slates and schists and the Archean gneisses, and the gravel deposits derived from the same veins and occupying the neighboring stream bottoms. Other occurrences of gold, of less importance and practically untested, are the deposits of gold-bearing galena which occur in the Murphy marble at various points, and the iron ores of the Andrews schist, which contain a small percentage of gold.

Quartz deposits.—Auriferous quartz is found in two forms—veins from a few inches to 8 or 10 feet in thickness and cutting the Cambrian and Archean rocks, and small lenses and stringers distributed through considerable masses of Cambrian schists and slates. The quartz veins occur in greatest size west and northwest of Peachtree Knob in a belt parallel to the course of Valley River. No development work has thus far been done upon these large veins. Similar deposits have been opened and tested on Partridge and Wesser creeks, which flow into Nantahala River. The ore consists of auriferous pyrite in quartz. The veins run in a general northeasterly direction through the country rock, which consists mainly of graywacke with beds of slate and schist. Assays show wide variations in the content of gold, and the work done in developing is not enough to determine the value of the deposits.

While these veins are most common in the sedimentary rocks, they are found also in the Archean gneisses. Six miles southwest of Hayesville and close to the Georgia–North Carolina boundary, at the Warren mine, a shaft was sunk and mining operations were carried on before 1895. The country rock is the Carolina gneiss. The vein dips steeply to the southeast and runs northeast with the inclosing mica-gneiss. The thickness of the vein could not be measured. In the vicinity are many quartz veins up to 3 or 4 feet in thickness and visible for hundreds of feet. The same rocks continue northeast into the Nantahala quadrangle and contain many quartz veins, which probably will be found to carry gold.

The small stringers and lenticular deposits of quartz a few inches thick, which carry a little pyrite and sometimes free gold, have not been tested at any point. Their average course is northeasterly, and they lie in general parallel to the schistose planes of the inclosing rocks. They are extensively distributed over the entire basin of Valley River and extend thence in a northeasterly direction. In the lower part of this basin the lenses and fragments of quartz derived from them are to be seen in greatest abundance.

The wide occurrence of the gold-bearing rocks is made clear not only by the outcrops and waste material, but also by auriferous gravels. The latter are derived by concentration from the veins and are to be found in the lower portions of practically every stream draining the area mentioned. From this it is necessary to infer a wide distribution for the veins themselves.

Gravel deposits.—The principal sources of gold in the quadrangle are the gravel deposits near the stream courses. These are a conspicuous feature of the surface of this region and closely follow the present streams. The deposits consist of gravel, loam, and clay, the coarser beds predominating at the base. The fragments consist mainly of quartz, quartzite, and conglomerate, with lesser amounts of the various slates and schist. Most of them are angular or partly rounded; only near the larger stream courses are they well worn and rounded. The deposits follow the grades of the streams very closely and have a perceptible slope, with the exception of those bordering the largest streams. The grade of those along Valley River can be determined only by instruments, while on some of the smaller creeks it is as great as 5°.

The deposits form two classes—those which occupy the bottom lands and flood plains of the streams, and older deposits of the same kind appearing in the shape of terraces (see fig. 2 on columnar section sheet). Both series are conspicuous in the basins of Hiwassee and Valley rivers and to a less extent near Cheoah River. Along Nantahala and Little Tennessee rivers deposits of this kind are uncommon. The gravels which occupy the terraces were at one time on the flood plains of the streams. By renewed elevation of the land the streams have been enabled to cut their courses lower, removing most of the earlier bottom lands and producing new and lower ones. The terraces descend with the fall of the streams and stand from 20 to 120 feet above the adjacent water level, with an average, however, of less than 30 feet.

The only deposits which have been worked for gold are those along Valley River below Andrews. The terrace gravels are nearly continuous from the vicinity of Valleytown for about 8 miles to and below the mouth of Vengeance Creek. On the north side of Valley River, between the same points, the gravel deposits at the mouths of the different tributary creeks have been washed for gold. These are but slightly above the flood plain of the river and grade into it. Below Marble the gravels are found chiefly on the north side of the river and only where they have been protected from removal by the ridges of Nottely quartzite. The great size of the gravel deposits in all these localities is due to the presence of the Murphy marble. The surface of this formation was easily reduced, and the streams attained grades so low that they were unable to transport the coarse waste from the surrounding mountains and were forced to deposit it. The gravels, therefore, form a curved surface between the steep slopes of the small streams and the lesser slopes of the larger ones. Thus the gravels as now seen in the terraces vary somewhat in height according to the part of the original surface which they formerly occupied. Around Valleytown there is a fine exhibition of these curving deposits in both the terraces and the flood plains.

Gold has been obtained from these gravels at many times and various places. Mining has been carried on at three localities on a considerable scale within the last five years. The gravels worked were the terrace deposits both below and above the mouth of Vengeance Creek, the flood-plain gravels on the opposite side of the river, and the terrace gravels on Marble Creek at the edge of this quadrangle. Water was brought by ditches to points near and above the gravel deposits and taken down in pipes to the workings. Hydraulic giants were used to excavate the gravel and considerable areas were stripped. The gold was for the most part coarse, the best paying gravels being near the bed rock. Fine gold was found in several layers at some distance from the bottom. The terrace gravels are all limited in amount and have been practically worked out. The profit was good for the amount of material handled. From the coarseness of the gold it is evident that its source is near. The tributary streams are from 2 to 4 miles long and the rocks which they drain are mainly schists and slates. The latest washings in the gravels a little over a mile northeast of Tomotla are now abandoned.

Gold-bearing gravels are probably not limited to Valley River. Erosion was at work in the other river basins at the same time and produced gravel deposits of corresponding extent. These are conspicuous along the tributaries of Hiwassee River, particularly Tusquitee, Peachtree, Brasstown, and Shooting creeks. The deposits, however, are far from being limited to the larger streams, but are found along every little branch where the recent stream cutting has not extended back from the river. These deposits have precisely the same relation to one another and to the draining streams as do those of Valley River. On the main creeks there is the same double system of flood plains and of terraces 10 to 30 feet higher, which curve upward into the hill slopes and toward the heads of the streams.

In the upper part of Cheoah River basin gravel deposits are found. Near Robbinsville they consist of a series of flood plains and terraces identical in appearance with those of the other rivers and about 400 feet higher above sea. Above Robbinsville the difference between the terraces and the flood plains is very slight. They rise in curves with the grade of the streams and are rather sharply marked from the hill slopes. Along Nantahala River deposits of gravel are much rarer than on the other streams. The channel of the river was not reduced to as low grades, and only locally were gravels deposited. Such are now to be seen on Jarrett and Choga creeks near Aquone, at Whiteoak Flats, and on the upper parts of Partridge and Briertown creeks. These deposits have a general altitude of 3000 to 3100 feet. In other portions of the river basin the deposits which may have existed have been swept away by the later stream action.

While none of these gravels have been tested for the presence of gold, so far as known, the probability is strong that they are gold bearing in most cases. The rocks which are known to contain gold in the basins of Valley and Hiwassee rivers pass into the Nantahala and Cheoah basins without change of character. They also contain veins of auriferous pyrite and quartz. The gravel deposits were formed with substantially the same grades, although at different altitudes, and under the same physical conditions. Since, therefore, they were produced in the same way and from the same series of rocks, it is highly probable that they will be found to contain gold.

In all of these areas hydraulic mining is easily carried on. The region is one of the best watered in the United States. The streams are fed from countless springs and the rainfall is considerable. Freshets are largely checked by heavy forest growth and periods of drought are extremely rare. The grades of the streams are considerable, especially in the smaller tributaries from which water would be secured. It is always possible, therefore, to get a good head of water and a plentiful supply without unreasonably long ditches. Those built to work the Valley River deposits run from 5 to 7 miles. The gravels of Peachtree, Tusquitee, and Shooting creeks could be reached by ditches of similar length, as could also those of Cheoah and Nantahala rivers.

LIME.

Material for the production of lime is common throughout the extent of the Murphy marble. As already stated, some of the layers contain as high as 93 per cent of carbonate of calcium, and layers of sufficient purity are plentiful. Except along the areas of that formation there are no calcareous strata. Within this quadrangle no use whatever has been made of the marble in this way. Although the marble does not outcrop over most of its area, it is seldom far below the surface and can usually be reached by clearing away a few feet of gravel or clay. Along Nantahala River there are abundant natural outcrops. In the latter locality the situation of the material and its composition are very well adapted for the burning of lime. In nearly all of the areas of the marble, however, it would be possible to establish kilns with the practical certainty of finding good materials for lime.

BRICK CLAYS.

All of the formations in this region, with the exception of the white quartzites, form clays on decomposition. These are of various kinds—argillaceous, sandy, and micaceous. The residual clays left from the rock decomposed in place extend over nearly the whole quadrangle. On the slopes of the mountains and ridges and the steep borders of the stream canyons the amount of clay is very small. Over the plateau areas and the lower slopes of the ridges, where they grade into the plateaus and terraces, the cover of clay and decayed material is thick. In places on the plateaus it is as much as 30 feet in depth.

There are two types of occurrence of the best clays—in the flood plains and terraces of the larger rivers and creeks, and in the small valleys and hollows which have not been reached by the later cutting of the streams. The flood plains and terraces are small as compared with the area of the quadrangle, and their situation has already been described under "Gold." The clays deposited by Valley River are the finest and most extensive. On that stream the light grades—the lightest stream grades of the region—permit the fine material to be deposited. Somewhat similar conditions prevail on the Hiwassee, though to a less extent. On all of the other principal streams the grades are so high that most of the fine clayey material has been carried downstream. On the flood plains and terraces of Valley and Hiwassee rivers there is usually a cover of 2 to 4 feet of clay, underlain by sandy and gravelly beds. A small amount of this clay has been burned into bricks in the vicinity of Andrews, but no other use has been made of the material.

The chief deposits of clay are in the small hollows near the heads of the streams on the old plateau and terrace surfaces. Into these the finest portions of the decomposed rock washed and formed excellent clay deposits. There are a great many of these within the quadrangle and the total amount of material of that kind is very great. These clays are from 1 to 6 feet deep, being thickest in the bottoms of the hollows and thinner upon the hill slopes. Thus far no use whatever has been made of this class of clay deposits.

BUILDING STONE.

There is a great variety of building stone, although not at present developed, among the rocks of this quadrangle. The most productive formation in this respect is the Great Smoky conglomerate of the Cheoah and Little Tennessee river valleys. The same formation farther southeast is finer grained and more schistose and contains many slate and schist beds. Toward the northwestern part of the quadrangle, however, it becomes coarser, more massive, and uniform. The beds range from 1 to 8 feet in thickness. They have a very regular grain and can readily be worked into any shape. In general manner of working and also in its great hardness it resembles granite. The latter quality is well displayed in the numerous narrows and falls in the rivers. At any point along Little Tennessee, Tuckasegee, or lower Cheoah rivers may be found a great abundance of this material and excellent quarry sites. This is especially the case along the railroad above Bushnell. With the completion of the projected railroad down the Little Tennessee below Bushnell there will be even greater opportunities for quarrying and a readier outlet.

The Murphy marble is an excellent building stone, but has even more value for ornamental purposes. Another rock of value for these uses is amphibolite, which on the map is grouped with the soapstone and dunite. Six miles southeast of Hayesville, on Shooting Creek, this outcrops in considerable quantities. It has a bright grass-green color and a uniform texture. It is fine grained and the schistosity is not pronounced.

Nantahala.

The Cambrian quartzites furnish uniformly white material of great durability. Their layers are seldom over 2 feet thick, and they are considerably affected in places by joints and schistosity. The Tusquitee quartzite usually occupies high and inaccessible ground. In many places along Hiwassee River this is not the case and the rocks cross the streams with vertical dips. In the only places where the quartzites occur near the line of railroad and could be profitably quarried they are near fault planes and are considerably jointed.

The body of granite which occurs immediately southeast of Hayesville contains little useful building stone. It is schistose and varies considerably in grain and color. The Carolina gneiss contains many beds which will be useful for rough building stone, but none of great value. Few of its beds are as much as 2 feet in thickness, and in order to work those a considerable amount of the thin layers of schist must be handled. Some of the layers have the character of fine granite, but most of them are micaceous and schistose. It is well adapted for such purposes as retaining walls and foundations by its partings into moderate-sized blocks. Its strength is ample, especially at right angles to the planes of schistosity.

WATER POWER

The resources of this quadrangle in the form of water power are very great. The streams, both great and small, fall rapidly throughout the whole area. Their flow is very steady from season to season, since they are fed by multitudes of springs and drain heavily forested areas. Where the streams are of nearly the same altitude as the various plateaus their grades are considerably less than in other places. Part of the steeper grades are due to the later cutting of the streams into the plateau surfaces, and part of them were never reduced to low angles.

The only plateaus extensively developed in this region are connected with the drainage of Hiwassee River. On this and its tributary streams grades are less than in the rest of the region, especially in the case of Valley River. On the latter stream there is practically no opportunity to utilize the fall of the stream except above Valleytown. Near that point the stream is divided into several large creeks, each of which has a considerable fall but no great body of water. Along Hiwassee River the descent takes place over numerous rapids, at which points power could be readily developed. Little Tennessee and Tuckasegee rivers above their junction at Bushnell have about the same character as Hiwassee River. Below Bushnell to the narrows at the State boundary, a distance of about 25 miles, the river falls nearly 500 feet, an average of 20 feet per mile. The grade becomes progressively heavier downstream; this increase is due to the greater hardness and massive character of the Great Smoky conglomerate through which the river passes. Cheoah River, passing through the same rocks below Robbinsville, falls about 700 feet in the 10 miles before joining the Little Tennessee. Through that distance its principal tributaries have combined to make it a considerable stream, with about the same amount of water as Nantahala River.

By far the greatest amount of power can be developed along the Nantahala. From Jarrett down to its mouth its lowest grades are found, and even those are much steeper than the grades of Little Tennessee River in the same vicinity. In the 9 miles above the great bend of the river at Jarrett there is a descent of a little over 800 feet, the lower part being much the steepest. In the vicinity of Aquone the grade of the river lessens for a few miles, but above that point clear to its head it is a nearly continuous rapid. No other stream of its size in the mountain area has as great and continuous a fall as this. Although its basin is comparatively narrow, its upper half is above 3000 feet and the rainfall is very heavy; thus its flow is great in proportion to the size of its drainage basin, and it is less subject to drought than most other streams of the region. In this respect it is nearly equaled by Cheoah River, which also has a very high and heavily timbered basin.

April, 1904.

Table of formation names.

J. M. Safford: Geology of Tennessee, 1869.	Arthur Keith: Knoxville Folio, U. S. Geological Survey, 1895.	Names and Symbols used in this Folio.		Arthur Keith: Asheville Folio, U. S. Geological Survey, 1904.	W. C. Kerr: Geology of North Carolina, 1875.
		Nottely quartzite.	€ny		
		Andrews schist.	€ad		
		Murphy marble.	€mp	Shady limestone.	
Chilhowee sandstone.	Hesse sandstone.	Valleytown formation.	€vt	Hesse quartzite.	
	Murray shale.	Brasstown schist.	€bt	Murray slate.	
	Nebo sandstone.	Tusquitee quartzite.	€tq	Nebo quartzite.	
	Nichols shale.	Nantahala slate.	€nt	Nichols slate. Nantahala slate.	Siliceous, chloritic, clay and conglomerate slates.
	Cochran conglomerate.				
	Clingman conglomerate.				
	Hazel slate.	Great Smoky conglomerate.	€gs	Cochran conglomerate. Great Smoky conglomerate.	
Ocoee group.	Thunderhead conglomerate.				
	Cades conglomerate.				
	Pigeon slate.	Hiwassee slate.	€hi	Hiwassee slate.	
	Wilhite slate.				
		Granite.	Æg	Cranberry granite.	granite.
Altered rocks, gneiss, and mica slate.		Soapstone, dunite, and serpentine.	Æs	Soapstone, dunite, and serpentine.	Gneiss, hornblende slates, etc.
		Roan gneiss.	Ær	Roan gneiss.	
		Carolina gneiss.	Æc	Carolina gneiss.	

COLUMNAR SECTIONS

GENERALIZED SECTION OF THE SEDIMENTARY ROCKS OF THE NANTAHALA QUADRANGLE.

SCALE: 1 INCH = 1000 FEET.

System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CAMBRIAN	Nottely quartzite.	€ny		150+	Fine, white quartzite.	Sharp, narrow ridges. Rocky soil.
	Andrews schist.	€ad		200–350	Light-colored calcareous schist with ottrelite and iron ore.	Low terraces and slopes. Yellow clay soil.
	Murphy marble.	€mp		150–500	Thick-bedded, white, blue, and blue and white banded marble.	Valley floors washed over with gravel and clay.
	Valleytown formation.	€vt		900–1200	Graywacke and fine grained gneiss, interbedded with dark garnet- and ottrelite-schists.	Irregular ridges and high knobs. Thin sandy and micaceous soil.
	Brasstown schist.	€bt		1200–1500	Blue and black banded ottrelite-schist, garnet-schist, and slates, with a few layers of fine graywacke. Black slate usually at the base.	Irregular ridges and knobs. Thin sandy and clayey soil.
	Tusquitee quartzite.	€tq		20–500	Coarse and fine white quartzite with some quartz conglomerate.	High, sharp ridges and knobs. Sandy and rocky soil.
	Nantahala slate.	€nt		1400–1800	Black, bluish-black, and gray slate; in places altered to fine black schist with some fine ottrelite and garnet. Contains a few beds of gray sandstone and graywacke. Thick bed of staurolite-garnet-schist usually at the base.	Steep slopes, irregular knobs, and low hilly ground. Clay soils with slate and schist fragments.
	Great Smoky conglomerate.	€gs		5500–6000	Blue-quartz and feldspar conglomerate. Massive beds of quartz and feldspar conglomerate and coarse gray sandstone with beds and seams of black slate. Altered toward the southeast into coarse and fine graywacke and quartzite with beds of black schist, mica-schist, and ottrelite-schist.	High mountains and ridges with irregular trend. Deep clayey soils mixed with bits of rock and sand.
	Hiwassee slate.	€hi		500	Blue and gray banded slate.	Low country and slopes of ridges
	UNCONFORMITY					
ARCHEAN	Gneisses and granite.				Light-gray granite, fine granite, and gneissoid granite.	Mountainous country.

GENERALIZED TABLE OF IGNEOUS AND METAMORPHIC ROCKS OF THE NANTAHALA QUADRANGLE, ARRANGED ACCORDING TO AGE.

System.	Formation Name.	Symbol.	Lithologic Symbol.	Character of Rocks.	Character of Topography and Soil.
ARCHEAN	Granite.	ARg		Biotite-granite and granite-gneiss, coarse and fine; colors, light gray, dark gray, and white. Includes dikes of schistose and unaltered diabase and fragments of hornblende-gneiss and mica-gneiss.	Irregular hills and ridges. Yellow and brown clay soils.
	Soapstone, dunite, and serpentine.	ARs		Dunite in part serpentinized. Soapstone contains talc and tremolite.	Yellow clay soil with many ledges and fragments of rocks.
	Roan gneiss.	ARr		Hornblende-gneiss and -schist, with some massive and schistose diorite. Includes many beds of mica-gneiss, mica-schist, and hornblende-mica-gneiss, and dikes of altered and unaltered biotite- granite.	Mountainous country or depressions between Carolina gneiss areas. Dark-red and brown clay soils.
	Carolina gneiss.	ARc		Interbedded mica-gneiss and mica-schist, coarse and fine, bluish gray and gray. Contains many small beds of hornblende-gneiss, large bodies of garnet-schist and cyanite-schist, and dikes of biotite-granite, both altered and unaltered.	Ridges, peaks, spurs, and high mountains with irregular crests. Red and brown micaceous and clayey soils.

FIG. 1.—GORGE OF NANTAHALA RIVER AT CLIFF RIDGE; LOOKING NORTHEAST FROM 2 MILES SOUTHWEST OF NANTAHALA STATION.

The gorge is excavated along a narrow band of Murphy marble, and the rugged slopes on the left are upheld by Valleytown formation. Cliff Ridge, on the right, the edge of the plateau of Nantahala River, is formed by the hard topmost bed of Great Smoky conglomerate, Nantahala slate forming the steep slope.

FIG. 2.—SURFACE OF MURPHY MARBLE, STRIPPED FOR QUARRYING; 2 MILES SOUTHWEST OF TOMOTLA, LOOKING NORTHEAST ALONG THE STRIKE.

Beyond the quarry is seen a thin layer of auriferous gravel, which has elsewhere been successfully washed for gold. On the right is a ridge of Nottely quartzite; on the left a ridge of Valleytown formation.

FIG. 3.—VALLEY RIVER BOTTOM AND FLANKING RIDGES; LOOKING WEST FROM 2 MILES SOUTHWEST OF ANDREWS.

The floor of the valley is underlain by Murphy marble and the terrace hill on the left by Andrews schist, while the farther wall of the valley is formed by Valleytown schists and gneisses. Snowbird Mountains in the distance are composed chiefly of Great Smoky conglomerate.

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

TOPOGRAPHY

NORTH CAROLINA—TENNESSEE
NANTAHALA QUADRANGLE

LEGEND

RELIEF
(printed in brown)

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

DRAINAGE
(printed in blue)

Streams

CULTURE
(printed in black)

Roads and buildings

Trails

Railroads

Tunnels

Ferries

State lines

County lines

Triangulation stations

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by S.S. Gannett.
Topography by Chas. E. Cooke.
Surveyed in 1892.
Revised in 1904 by Arthur Keith.

APPROXIMATE MEAN DECLINATION 1902.

Scale 1/125000
Miles
Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of April 1906.

U.S. GEOLOGICAL SURVEY
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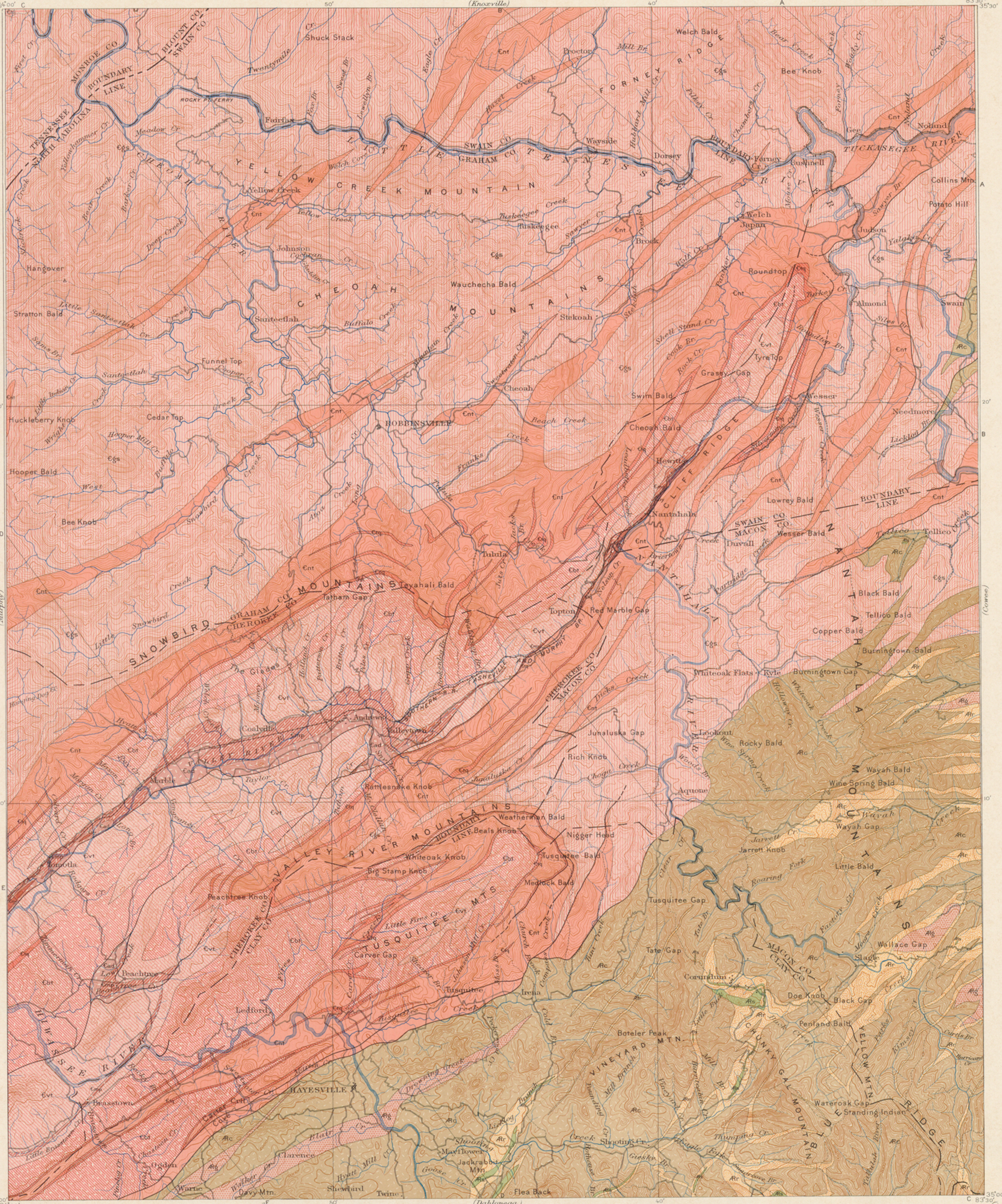
AREAL GEOLOGY

NORTH CAROLINA–TENNESSEE
NANTAHALA QUADRANGLE



35°00' 84°00'

Henry Gannett, Chief Topographer.
Gilbert Thompson, Chief Geographer.
Triangulation by S.S. Gannett.
Topography by Chas. E. Cooke.
Surveyed in 1892.
Revised in 1904 by Arthur Keith.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of Oct 1906.

Geology by Arthur Keith,
assisted by H.B. Goodrich and H.S. Gale.
Surveyed in 1892, 1893, 1899, 1903, and 1904.

LEGEND

SEDIMENTARY ROCKS

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

CAMBRIAN:

- €ny — **Nottely quartzite** *(white quartzite)*
- €ad — **Andrews schist** *(calcareous ottrelite-schist, with iron-ore beds)*
- €mp — **Murphy marble** *(white and blue marble)*
- €vt — **Valleytown formation** *(graywacke, garnet-and ottrelite-schist, and slate)*
- €bt — **Brasstown schist** *(blue and black banded ottrelite-schist and slate)*
- €tq — **Tusquitee quartzite** *(white quartzite)*
- €nt — **Nantahala slate** *(black slate, with garnet-staurolite-schist at base)*
- €gs — **Great Smoky conglomerate** *(conglomerate, coarse gray sandstone, and graywacke, with many beds of black slate and schist)*
- €hi — **Hiwassee slate** *(bluish-gray and banded argillaceous slate)*

IGNEOUS ROCKS

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

ARCHEAN:

- Ag — **Granite** *(granite and gneissoid granite)*
- As — **Soapstone, dunite, and serpentine**
- Ar — **Roan gneiss** *(hornblende-gneiss, hornblende-schist, and diorite)*

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

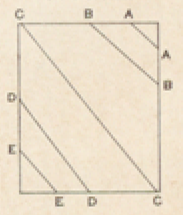
(Areas of metamorphic rocks of unknown origin are shown by patterns of short dashes)

ARCHEAN:

- Ac — **Carolina gneiss** *(mica-gneiss and mica-schist)*

Faults

Sections



ECONOMIC GEOLOGY

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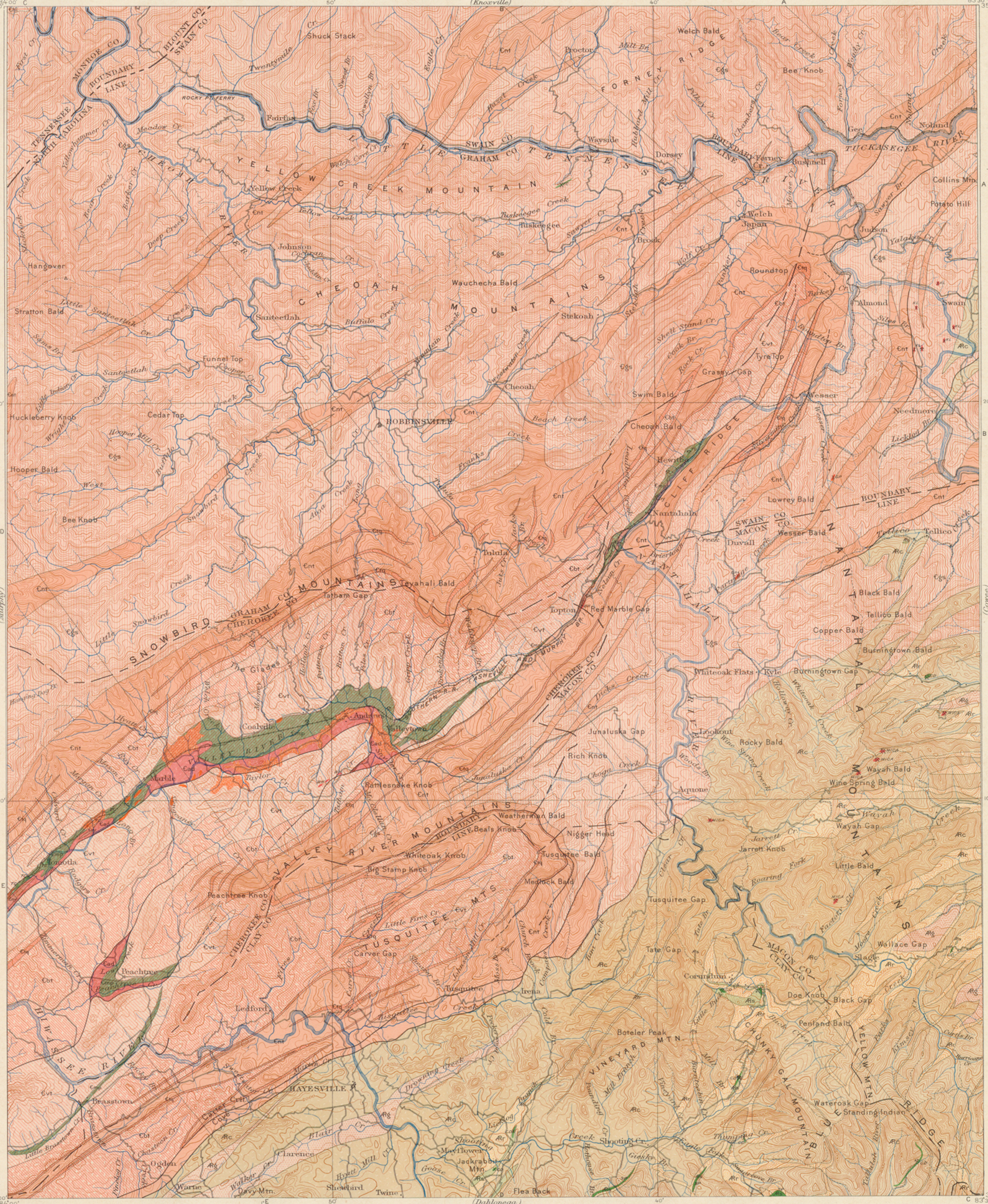
NORTH CAROLINA–TENNESSEE
NANTAHALA QUADRANGLE



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MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

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LEGEND

SEDIMENTARY ROCKS

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

CAMBRIAN:

- €ny — Nottely quartzite *(white quartzite)*
- €ad — Andrews schist *(calcareous ottrelite-schist, with iron-ore beds)*
- €mp — Murphy marble *(white and blue marble)*
- €vt — Valleytown formation *(graywacke, garnet-and ottrelite-schist, and slate)*
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- €tq — Tusquitee quartzite *(white quartzite)*
- €nt — Nantahala slate *(black slate, with garnet-staurolite-schist at base)*
- €gs — Great Smoky conglomerate *(conglomerate, coarse gray sandstone, and graywacke, with many beds of black slate and schist)*
- €hi — Hiwassee slate *(bluish-gray and banded argillaceous slate)*

IGNEOUS ROCKS

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

ARCHEAN:

- Ꜳg — Granite *(granite and gneissoid granite)*
- Ꜳs — Soapstone, dunite, and serpentine
- Ꜳr — Roan gneiss *(hornblende-gneiss, hornblende-schist, and diorite)*

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

(Areas of metamorphic rocks of unknown origin are shown by patterns of short dashes)

ARCHEAN:

- Ꜳc — Carolina gneiss *mica-gneiss and mica-schist*

Faults

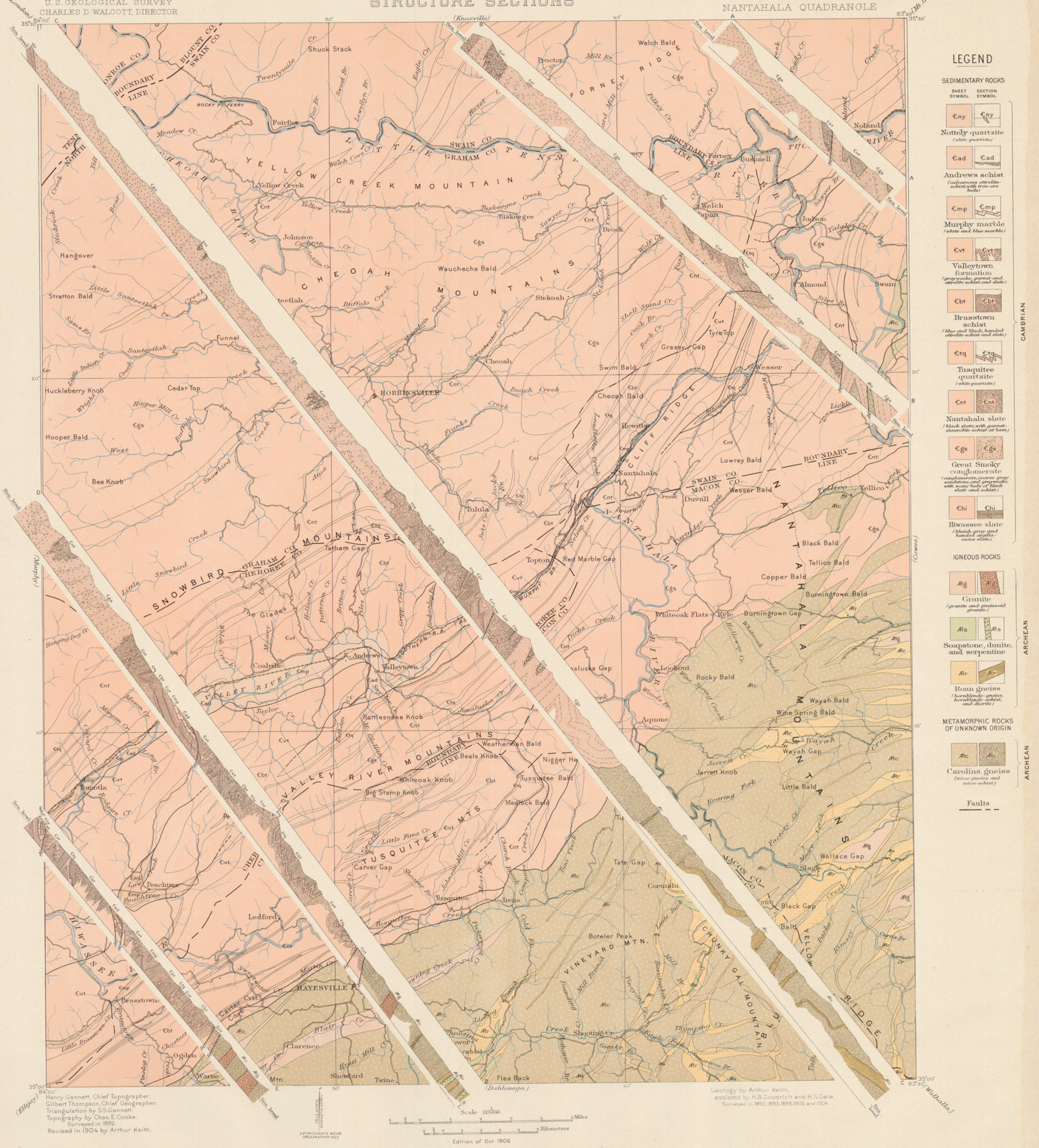
Sections

Mines and quarries
Prospects

Known productive areas

- *Gold-bearing gravels (on terraces and in bottom lands)*
- *Probably gold-bearing gravels (extension of gold-bearing terrace deposits)*
- GP — *Gold-bearing pyrite deposits*
- €ad, BH — *Brown hematite (Andrews schist contains beds and scattered deposits of iron ore; lenses also in Valleytown schist)*
- TC — *Talc (lenses in Murphy marble)*
- €mp — *Marble (Murphy marble, white or blue banded)*
- CD — *Corundum-bearing rocks (veins in dunite and mica-gneiss)*
- SP — *Soapstone*
- KL — *Kaolin (decomposed pegmatite lenses)*

STRUCTURE SECTIONS



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Edition of Oct. 1906

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.......	....	Ꞧ	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......	Ꞓ	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:

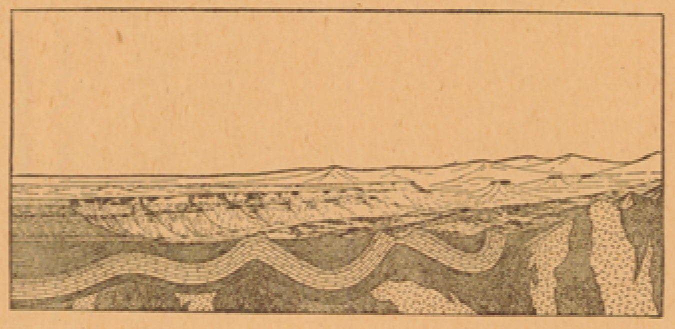

Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:

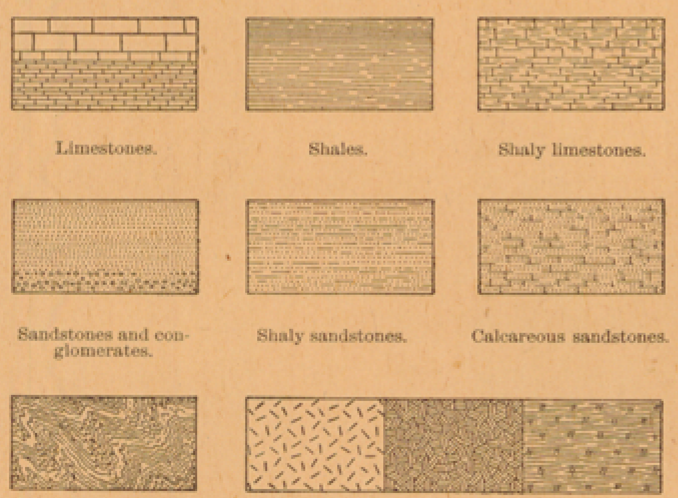

Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

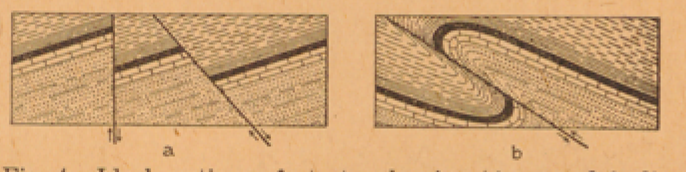

Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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.

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