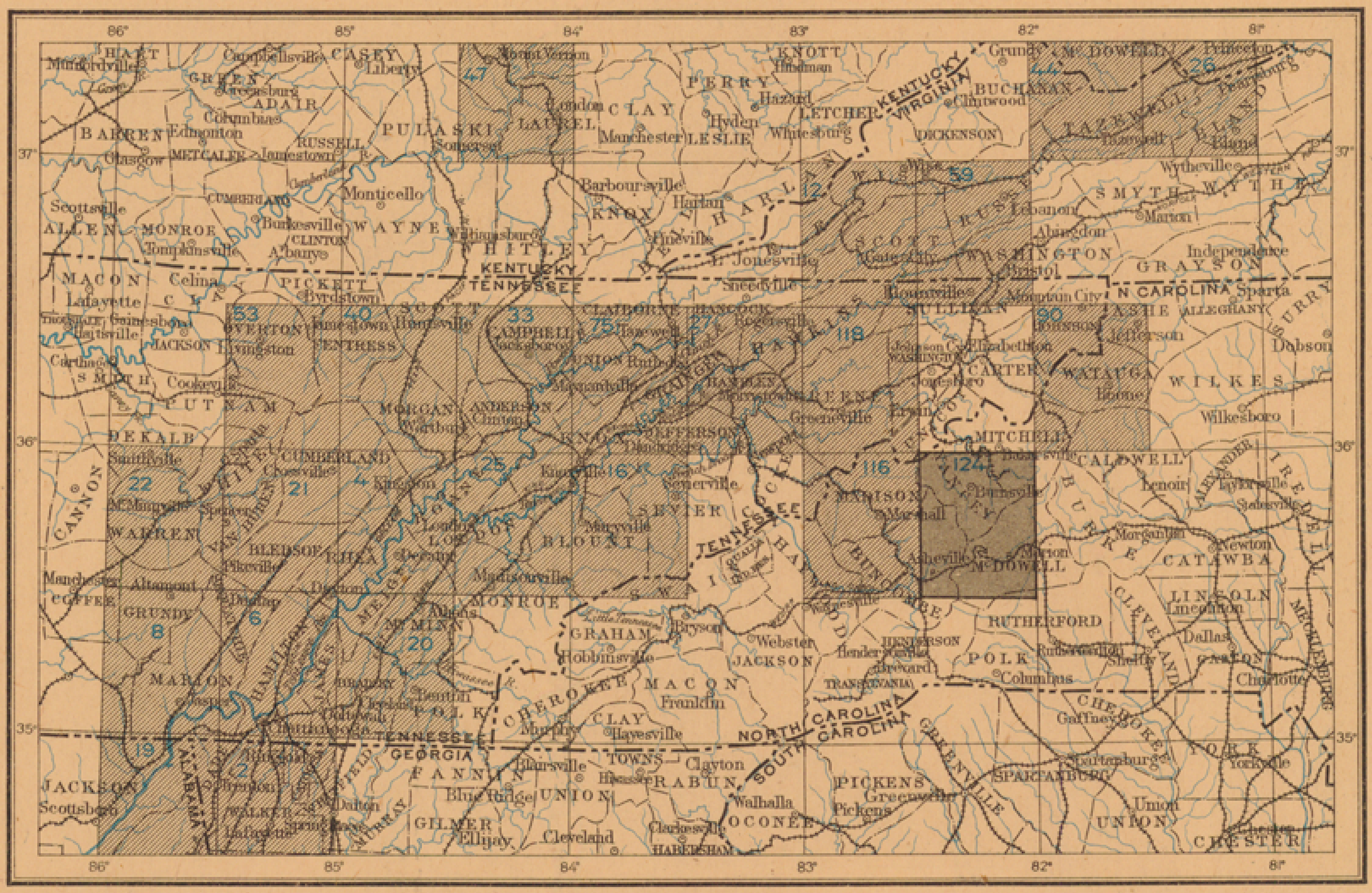
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

MOUNT MITCHELL FOLIO
NORTH CAROLINA-TENNESSEE

INDEX MAP



SCALE: 40 MILES - 1 INCH

▩ MOUNT MITCHELL FOLIO

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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
1905

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

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

THE TOPOGRAPHIC MAP.

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

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

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

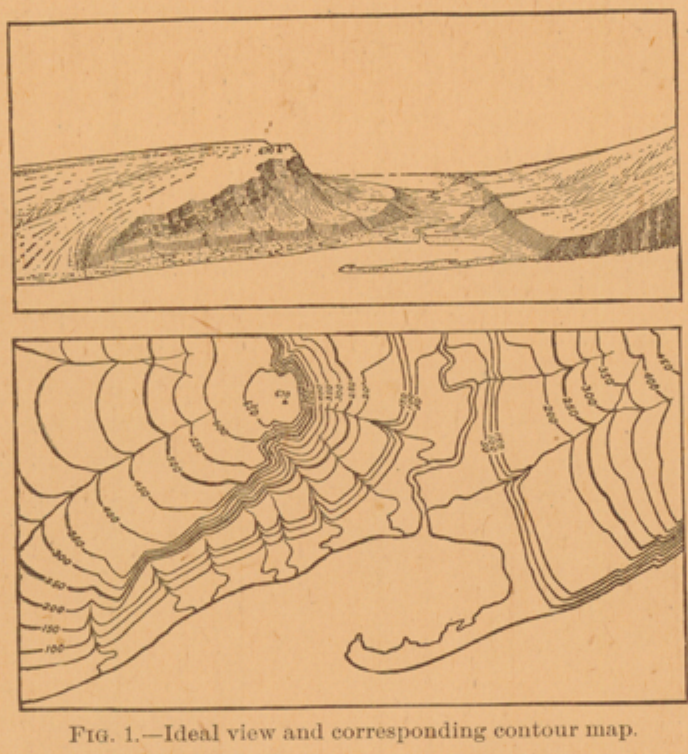

FIG. 1.—Ideal view and corresponding contour map.

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

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

(Continued on third page of cover.)

DESCRIPTION OF THE MOUNT MITCHELL QUADRANGLE.

By Arthur Keith.

GEOGRAPHY.

GENERAL RELATIONS.

Location.—The Mount Mitchell quadrangle lies almost entirely in North Carolina, but in its northwest corner includes about 2 square miles of Tennessee. It is included between parallels 35° 30′ and 36° and meridians 82° and 82° 30′, and contains 968 square miles, divided between Madison, Yancey, Mitchell, Buncombe, McDowell, and Rutherford counties of North Carolina.

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

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

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

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

The western division of the Appalachian province embraces the Cumberland Plateau 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 MOUNT MITCHELL QUADRANGLE.

Mountain ranges.—The Mount Mitchell quadrangle is included in the Mountain division of the Appalachian province. In the southeastern part of the quadrangle a few irregular tongues of the Piedmont Plateau separate the foothills of the mountain mass. The quadrangle is occupied by a large number of mountain ranges, separated here by rolling plateaus and there by deep, narrow valleys. The longest chain is the Blue Ridge, which runs diagonally through the quadrangle, winding back and forth between the different river basins and dividing the Atlantic from the Mississippi waters. Reaching north from this in the center of the quadrangle is the U-shaped crest of the Black Mountains, the most prominent range of the region. On this is situated Mount Mitchell, 6711 feet in altitude, the highest peak east of the Rocky Mountains. Other prominent ranges are the Great Craggy Mountains; the Bald Mountains, in the northwest corner of the quadrangle; and the Yellow Mountains, in the northeast corner. The Big Bald is 5530 feet above sea; Yellow Mountain is 5330 feet; Craggy Dome is 6105 feet; and the Black Mountains for more than half their length are above 6000 feet. The Great Craggy and Black mountains closely follow the trend of the rock formations. The same is true, though in less measure, of the Hickorynut Mountains. All of the other ranges in the quadrangle take their general directions regardless of the course of the formations.

The sides of the various mountains are steep and made up of smooth, flowing slopes. One of their striking features is the rarity of large cliffs. The large bodies of mica-gneiss which form the Black and Great Craggy mountains are among the hardest rocks in the quadrangle and cause long lines of cliffs and great ledges. Similarly, the granites which outcrop in Hickorynut and Stone mountains form a great series of cliffs. With these two exceptions, the even slopes of the weathered rocks are seldom broken, and the cover of heavy forest is continuous on the high and low ground alike.

Valleys and plateaus.—The valleys intervening between the mountain ranges are sharp, narrow, V-shaped at their heads, and descend rapidly to certain definite levels, at which they widen out into rounded and plateau-like valleys.

These plateaus are alike in origin and in form, but there is considerable variation in their altitudes. They rise gradually toward the heads of the rivers, each major stream having its own set of plateau altitudes. On the two forks of Toe River its plateau is well developed along the north edge of the quadrangle at an altitude of 2600 feet above sea. Cane River, emptying into Toe River just north of this quadrangle, has carved its plateau at substantially the same height. Ivy River, Swannanoa River, and Cane Creek, all emptying into French Broad River, have plateaus ranging from 2100 to 2300 feet. Catawba River, lying southeast of the Blue Ridge and draining into the Atlantic, has much the lowest plateau of all, its different portions ranging from 1200 to 1400 feet.

The different plateaus consist near the stream heads of a series of gently rolling and smoothly rounded summits only slightly varied by shallow valleys. The summits rise to heights which are remarkably uniform over large areas, and the plain which they once formed is readily to be seen from any of the summits. Nearly all of the plateaus of the streams lying northwest of the Blue Ridge belong to the same period of erosion. The streams have cut them at different altitudes, according to the amount of water and the differing hardness of the rocks over which they pass. The plateaus southeast of the Blue Ridge are parts of the great Piedmont Plateau and were formed at a later period of erosion, whose action did not produce similar features on the streams which drain into the Mississippi. The streams southeast of the Blue Ridge take shorter courses to the Atlantic and have been able to establish lower grades clear to their headwaters. Into all these plateaus the rivers have sunk their channels in canyons during the later periods of erosion. These have steep and rocky borders and are so narrow as to be easily overlooked except when close at hand.

Drainage.—The drainage of the quadrangle is nearly evenly divided between the streams flowing to the Atlantic and to the Gulf. The waters of Swannanoa, Ivy, and other branches of the French Broad join those of Cane, North Toe, and South Toe rivers in Tennessee River, and pass through the Ohio into the Mississippi. Catawba River flows direct to the Atlantic, as does also Broad River which has its headwaters in the southern part of the quadrangle. Thus the streams radiate in all directions from an area covering a few miles of the Blue Ridge south of the Black Mountains. From their heads high up on the mountains the streams fall with heavy grades down to the levels of the plateaus. For considerable distances near those levels the grades are light, until the heads of the secondary canyons are reached; thence downstream the currents descend swiftly, with many waterfalls and rapids. Thus South Toe River, heading in the Black Mountains above 6000 feet, descends with rapidly lessening grades to its plateau at 3000 feet. Along this it flows for 7 miles down to 2700 feet. Below that point the river descends more rapidly as the newly cut canyon is entered, and goes out of the quadrangle, 30 miles from its head, at an altitude of 2100 feet.

GEOLOGY.

GENERAL GEOLOGIC RECORD.

Nature of the formations.—The formations which appear at the surface of the Mount Mitchell quadrangle and adjoining portions of the Appalachian province comprise igneous, ancient metamorphic, and sedimentary bodies, all more or less altered since their materials were first brought together. Some of them are very ancient, going back to the earliest known period. They are found mainly in two groups, of widely different age and character. These are (1) igneous and metamorphic rocks, including gneiss, schist, granite, diorite, and similar formations; and (2) sedimentary strata, of lower Cambrian age, including conglomerate, sandstone, shale, limestone, and their metamorphosed equivalents. The older of these groups occupies the greater area, and the younger the less. 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 being 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 Mount Mitchell 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.

DESCRIPTION OF THE FORMATIONS.

ROCKS OF THE QUADRANGLE.

The rocks exposed at the surface in the Mount Mitchell quadrangle comprise three great classes—metamorphic, igneous, and sedimentary. The latter are found in several narrow bands crossing the Blue Ridge from Cane Creek and dying out on the headwaters of Catawba River. They cover barely 2 per cent of the quadrangle. Igneous rocks are very generally distributed throughout the quadrangle, the greatest areas being found in its southeastern and northwestern portions. The remaining area, about 80 per cent of the quadrangle, is underlain by the metamorphic rocks of the Carolina gneiss.

The sediments consist of one group of mica-schist, conglomerate, and graywacke, and another of black slates and schists. The slate group contains thin beds of limestone and marble in areas immediately southwest of this quadrangle. The age of the slates is not well determined, but they are probably Cambrian and are so considered in this discussion. The conglomerates are of unknown age.

Of the igneous rocks, granites are found in two large, irregular areas in the southeastern and northwestern parts of the quadrangle. Other igneous rocks are diorite, hornblende-gneiss, and dunite, which occur in a large number of narrow bands with no definite grouping. The width and frequency of the bands increase somewhat toward the north. The Carolina gneiss, which underlies most of the quadrangle, consists mainly of mica-schist and mica-gneiss throughout its entire extent. The masses which form the Great Craggy and Black mountains contain much cyanite, to whose greater resistance to weathering is due much of the height of those mountains. Garnetiferous bands are also frequent in the formation, especially near the borders of the Roan gneiss areas.

Practically all of the igneous and metamorphic rocks are of Archean age. There are, however, a few exceptions to this. The Brevard schist is regarded as Cambrian, and the neighboring conglomerates may possibly belong to the same system. In the northern part of the quadrangle, on the drainage of Cane River, are found many dikes of diabase. These are part of a series which outcrops extensively in the adjacent quadrangle toward the north and northeast. They cut through all the other rocks and do not show the slightest results of deformation. For this reason they are later than the Carboniferous and are probably of Triassic age. At many places in the Carolina and Roan gneisses dikes and small bodies of fine-grained granite are also found. These seldom exceed a few feet in thickness and are not of sufficient size be to represented on the map. That they are much younger than the other granites of the region is shown by the almost entire absence of the schistosity which appears in the other formations of the mountains. The latest time at which this schistosity was produced was post-Carboniferous. The granite dikes, therefore, are clearly later than Carboniferous, although they may have been produced during the later part of the deformation period.

There is probably a difference in age between the Cranberry granite on the north and the Henderson granite mass on the south. Whether the interval between them is great or not can only be surmised. Both of them cut the Carolina and Roan gneisses, but they do not come into contact with each other. There is no substantial difference in the degree of metamorphism of the two granite masses. The northern one contains more biotite as a rule and is seldom porphyritic; the southern shows very little biotite and is usually porphyritic. These differences prevail over immense areas in this and in other quadrangles, and distinguish the two formations, both in respect to their original composition and to the conditions under which they were formed. It is probable that the southern mass, the Henderson granite, is the later of the two.

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

ARCHEAN ROCKS.

CAROLINA GNEISS.

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

General character.—The formation consists of an immense series of interbedded mica-schist, garnet-schist, mica-gneiss, garnet-gneiss, cyanite-gneiss, and fine granitoid layers. Most of them are light or dark gray in color, weathering to a dull gray and greenish-gray. Much the greater part of the formation consists of mica-gneiss and mica-schist. The schists are composed chiefly of quartz, muscovite, a little biotite, and very little feldspar. The schists have a fine grain and a marked schistosity, but their texture is even and the minerals are uniformly distributed. In most of the formation the component minerals are segregated into layers, either singly or in combinations, thus producing a gneiss with a marked banded appearance. This rock usually has more feldspar than the schist. A few thin layers in the mica-schist have a bluish-gray or black color, largely due to grains of iron oxides. These are most numerous in those portions of the formation near the Brevard schist. They strongly resemble the coarser portions of the Brevard schist; the component minerals are about the same, and the dark color given by the iron oxides is the most prominent characteristic of each. The similarity in appearance near the contacts suggests that part of the Carolina is of sedimentary origin. The possible origin of the Carolina is discussed under the heading "Metamorphism." That part of the formation which is adjacent to the Roan gneiss contains thin interbedded layers of hornblende-schist and -gneiss, precisely like the Roan gneiss and of the same origin, which constitute a transition between the formations. For this reason the boundary between the formations is often indefinite on the ground, notably so along the lower parts of North Toe, South Toe, and Cane rivers.

Cyanite-gneiss.—In a belt 6 or 8 miles wide, passing along the line of Black and Great Craggy mountains, the gneiss shows a marked increase in cyanite. This mineral is distributed along distinct layers of the gneiss and occurs in crystals an inch or less in length, giving the rock a decided porphyritic appearance. These are usually parallel with the foliation and the other minerals of the inclosing gneiss. Occasionally, however, as at the south end of the Black Mountains, while the layers in which they are contained are parallel to the other layers of the gneiss, the crystals of cyanite cross the layers at a considerable angle. The crystals correspond in position to a minor and secondary foliation which has been produced in the gneisses by later folding. It thus seems that the cyanite is of a later age than most of the other minerals composing the gneiss. The cyanite forms stubby, flat crystals or blades of a light-gray or dark-gray color. On weathered surfaces these stand out prominently from the rest of the rock. Associated with these cyanite layers in many places are prominent large patchy crystals of muscovite. These are distributed through the rocks just as the cyanite crystals are and, like them, probably have a secondary origin. Where they are frequent they give a noticeable silvery appearance to the schist or gneiss. Small garnets are often found in the same layers with cyanite and coarse muscovite.

Garnet-gneiss.—Garnet-schist and garnet-gneiss are a conspicuous part of the Carolina gneiss. These are more prominent in the southern and western portions of the quadrangle than elsewhere. They begin to be noticeable on the headwaters of Cane River and increase in a southerly direction. Thus, in this quadrangle they characterize bodies of gneiss 3 or 4 miles in width and 20 miles in length. They are also prominent along the Blue Ridge as far northeast as the head of Crabtree Creek. South of Catawba River they are also found in many narrower bands. The latter occurrences accompany the contacts of the Roan gneiss and the Henderson granite and are apparently due to them. In many parts of the main garnetiferous belt, northwest of the Blue Ridge, a similar relation holds. In most of the large areas, however, there is no apparent connection between eruptive rocks and the production of garnets, many of the garnets being miles from any outcrop of the Roan gneiss. If the igneous rocks caused the production of all the garnets, they must have accomplished this by inducing an extensive circulation of mineralizing waters. The garnets are small, seldom exceeding one-fourth of an inch in diameter. In those portions of the formation near the areas of Roan gneiss, and on the drainage of Ivy River, biotite is an abundant constituent. Its distribution in this way suggests that it is partly a contact feature of the Roan gneiss intrusion.

Granite-gneiss.—The granitoid layers of the gneiss contain quartz and feldspar, with small amounts of muscovite and biotite. In the light-colored layers the biotite and the muscovite are sparse. The granitoid layers and the schists alternate in beds ranging from a few inches to 1 foot or 2 feet thick. Layers similar in arrangement, varying from one-tenth of an inch to one inch in thickness, compose the banded gneiss. Toward the north and east in this quadrangle the granitoid layers increase in amount. In them the minerals are much less distinctly parallel than in the schists and gneisses. The parallel arrangement is usually seen more or less roughly, however, and its prominence depends largely on the amount of mica in the rock.

Marble.—About 8 miles northeast of Burnsville there is found with the Carolina gneiss a band of white marble, which extends from North Toe River about half a mile up Sinkhole Creek. It outcrops only near the streams and may extend considerably farther than can now be seen.

In the section along the river there are two bands of marble alternating with mica-gneiss, dipping southeastward at an angle of about 50°. The entire series is cut through by an irregular pegmatite vein, which passes in places across the beds, and in other places along them. The upper layer of the marble is about 70 feet thick and the lower about 8 feet; the intervening mica-gneiss is about 10 feet thick.

The marble is rather coarsely crystalline and has a white color in all cases observed. It is composed of 55 per cent of carbonate of calcium and 45 per cent of carbonate of magnesium, forming a dolomite. The ledges of marble have a dark-gray or black exterior. Near their surfaces there is some disintegration, and the carbonate crystals weather into coarse crumbling grains. There are a few impurities in the shape of thin sheets and lenses of fine silica. These are folded and appear to represent originally different layers in the rock, although the silica is secondary. The contacts of the marble and mica-gneiss are sharp, and there is no transition to be seen. Along one of them slickensides show that there has been recent motion. The contacts with the pegmatite are equally sharp, the latter being younger. For several feet at the bottom of the pegmatite there is a thin contact vein of actinolite which grades into the marble. Inclosed in the lower body of the marble there is also a small mass of serpentine and actinolite. The marble appears to be of practically the same age as the inclosing gneiss and to have suffered a similar amount of metamorphism. The intersecting pegmatite vein is also metamorphosed. The only reasonable explanation of so extensive a deposit of marble is that it formed an original sedimentary deposit. It is accordingly probable that the inclosing Carolina gneiss was in part of a sedimentary nature.

Pegmatite. — Included in the formation are numerous veins or beds of pegmatite. These occur in the shape of lenses ranging from 1 foot to 25 feet in thickness. Some of the largest of the lenses can be readily followed for 2 or 3 miles. The smaller ones, however, can not be traced surely beyond the immediate outcrops. They lie parallel to the foliation of the gneiss for the most part, but sometimes cut the latter abruptly. These pegmatites are most conspicuous near the contacts of the Carolina and Roan gneisses, but are not closely limited to those localities. They are also more prominent in the northern and eastern portions of the quadrangle. They consist chiefly of very coarsely crystalline feldspar, quartz, biotite, and muscovite. Crystals of orthoclase feldspar attain dimensions of 2 or 3 feet, oligoclase 1 foot, and mica 2½ feet. In them are also found many rare and valuable minerals, including beryl, emerald, tourmaline, garnet, cyanite, columbite, samarskite, autunite, and uraninite. The last four minerals are found in a few mica mines within a radius of 2 miles from Spruce Pine and furnish ores of some of the rarer metals, including radium. Much merchantable mica is procured from these pegmatites, and the area lying north and east of the Black Mountains is the principal mica-producing district of the State.

Many of the minerals of the pegmatite have been crushed and folded by the second deformation which folded the gneisses. The pegmatites, therefore, are older than this deformation. Their connection with the contacts of the Roan and Carolina gneisses is not sufficiently marked to prove that contact action caused the pegmatites. In areas farther southwest pegmatites have been extensively developed in connection with a granite which is eruptive in the gneiss, but no such association is visible in this region. The smaller lenses appear to have been formed by deposition from mineralized waters, after the manner of veins. Owing to the considerable alteration of the pegmatite contacts, however, it is difficult to determine this with precision.

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

Of similar nature, but of much greater age, are the beds of Cranberry granite included in the Carolina gneiss areas, near the granite. The Henderson granite also sends off many small sheets and dikes from its main bodies into the Carolina gneiss. Many areas of this granite which are too small to be mapped are represented with the Carolina gneiss. The contacts are seldom single lines, but are rather zones of transition, with many alternating bodies of granite and gneiss.

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. Many parts of the formation—for instance, the marble beds and the adjoining gneisses—are doubtless of sedimentary origin. Morever, the presence of sedimentary conglomerates makes it possible to distinguish the large area of sedimentary rocks in the Swannanoa Mountains. The apparent transition of the Carolina into the sedimentary Brevard schist indicates that other parts of the Carolina are sedimentary. It is very likely that still other sedimentary masses have not been distinguished from the Carolina because of their total metamorphism and similarity to the latter.

Whatever their original nature, one deformation produced a foliation of these rocks, 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 altitudes 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 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 Black Mountains, especially, forms long lines of 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 biotite-gneiss areas are rather more productive than those of ordinary gneiss, and the garnet- and cyanite-gneiss areas are somewhat less so.

ROAN GNEISS.

Distribution.—Areas of this formation are found generally throughout the quadrangle. As a rule, they form long, narrow bands. Southwest of the Black Mountains they diminish much in size and frequency, while northeast of that range they occupy many large areas. Along the northern border of the quadrangle a large number of these belts practically unite, so that as a whole they form one large and very irregular area. Only one of the bands which cross the southern border of the quadrangle is over one-eighth of a mile in width. The formation receives its name from Roan Mountain, on the boundary of Tennessee and North Carolina, north of this quadrangle.

Relation to Carolina gneiss.—The Roan gneiss appears to cut the Carolina gneiss, but the contacts are so much metamorphosed that the fact can not well be proved. Moreover, the rocks included in the Roan are less altered as a whole than the Carolina gneiss, and so appear to be younger. Narrow, dike-like beds of the former in the latter support this view, some of the Roan diorites in these narrow beds being plainly of an igneous nature. In fact, the shape and continuity of many of the narrow sheets of Roan gneiss can be explained only on the theory that they represent original dikes cutting the Carolina gneiss. The frequent development of garnets in the Carolina near the borders of the Roan gneiss is evidence of contact metamorphism by the intrusion of the latter.

Character.—The Roan gneiss consists of a great series of beds of hornblende-gneiss, hornblende-schist, and diorite, with some interbedded mica-schist and mica-gneiss. The hornblendic beds are dark greenish or black in color and the micaceous beds are dark gray. In thickness the hornblendic rocks vary from mere seams an inch or two thick up to great masses thousands of feet in thickness. The mica-schist and -gneiss beds range in thickness from a few inches to 50 or 60 feet, and are most frequent near the Carolina gneiss, into which they form a transition. This interbedding is undoubtedly due in part to the close folding which the formations have undergone, a relation which can be seen in the case of many of the smaller beds. It is also probable that much of it was due to the intrusion of many separate dikes of the Roan gneiss into the Carolina near the general line of contact. Later metamorphism of the rocks has so acted as to render the different beds more or less parallel to one another.

In composition the mica-schist and mica-gneiss beds are exactly like the micaceous parts of the Carolina gneiss and contain quartz, muscovite, biotite, and more or less feldspar. The hornblende-schists make up a large share of the formation and are interbedded with hornblende-gneiss throughout. The schists are most prominent north and west of Burnsville, near the Cranberry granite masses. The schist beds consist almost entirely of hornblende, in crystals from one-tenth to one-half an inch long, with a very small amount of biotite, feldspar, and quartz. The gneiss is composed of layers or sheets of quartz or feldspar interbedded with sheets of hornblende-schist. In places these are very regularly disposed and give a marked banding to the rock. An accessory mineral frequently seen is garnet. As already stated, this occurs in the Carolina gneiss near the contacts of the Roan gneiss, and it is common also in the Roan gneiss in similar positions. The garnets are seldom larger than a quarter of an inch in diameter and as a rule are much smaller.

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

Here and there the hornblende, feldspar, and quartz are found with the structure of diorite or gabbro. Some of these beds are very coarse and massive. Good instances of this are to be seen just north of Swannanoa and in the gap at the head of Ivy River. Many of the beds of the formation which consist almost entirely of hornblende are so basic that they appear to have been derived from gabbro. Of this kind are the hornblende-schist and many layers less strongly schistose. So thorough is the alteration, however, that such an origin is not certain. At many points in the Roan gneiss there are found veins and lenses of pegmatite of secondary growth, precisely similar to those described under "Carolina gneiss." They seldom, however, equal the latter in size and importance.

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

Weathering.—In reducing the surface of the formation, the first stage is the decomposition of the hornblende and feldspar. The more siliceous layers and many of the harder hornblende-schists and mica-schists disintegrate very slowly, however. Their outcrops form cliffs and heavy ledges near the streams and greatly retard the reduction of the surface. As a whole, the formation is somewhat less resistant than the Carolina gneiss and far weaker than the Cranberry or Henderson granites. Consequently its areas are reduced to plateaus in the large stream valleys and form gaps and depressions in the high ground away from the rivers. The rise of the mountains beyond its areas is quite noticeable in most cases. In this respect the formation differs much from its habit farther northeast in the Roan and Cranberry quadrangles. The clays accumulating on this formation are always deep and have a strong, dark-red color; the soils are rich and fertile and well repay the labor of clearing. The hilly surfaces keep the soil well drained, and yet the clayey nature of the latter prevents serious wash. Hence, the soils are extensively cultivated in situations remote from the principal settlements.

SOAPSTONE, DUNITE, AND SERPENTINE.

Distribution.—Many areas of these rocks are found within the quadrangle. While most of them are less than half a mile in length, a few exceed that considerably. The largest areas are on Swannanoa River a few miles below Swannanoa and on Ivy River just below Democrat. The Swannanoa area is one of the largest in the southern Appalachians, and has a length of 4 miles and a maximum width of nearly 1 mile. This mass contains nearly all of the different varieties of the formation and might well be considered the type. It is nearly all in contact with Carolina gneiss, but there are two narrow bands of Roan gneiss at its eastern end. In this respect this area differs considerably from most others of the formation, for its association with the Roan gneiss is close and marked. There are in this quadrangle only a few exceptions to this rule.

Relations.—The rocks of this group break through and across the beds of Roan gneiss and are thus seen to be distinct from and later than the gneiss. From the constant association of the two formations, however, and the rarity of the soapstone group in other situations, the difference in age can not be considered great. In the northwestern part of the quadrangle a number of outcrops of the soapstone are found in the Cranberry granite. In places they are accompanied by beds of Roan gneiss and in places they are actually inclosed in granite. Although it was not possible in any case to find the precise contact relations, the soapstones appear to be fragments caught up in granite at the time of its intrusion. Thus it appears that the soapstone is older than the Cranberry granite. Its alteration is as great as or greater than that of the Roan gneiss and exceeds that of the Cranberry granite, so that it appears to have shared in the earlier 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, and serpentine, and many other combinations of minerals derived from the original rocks by metamorphism. The variety most common in this quadrangle is an impure soapstone containing many hornblendic minerals. There are also many bodies of dunite composed almost entirely of olivine. These are most common near Swannanoa and Democrat and on the extension of the latter belt north of Burnsville. The soapstones are white and light gray, while the other varieties of the formation have a greenish color, either bright or dull. In some localities the soapstone contains little but talc and is fit for industrial uses, but, as a rule, it contains much chlorite and crystals of tremolite, actinolite, or other hornblendic minerals. The bodies of talc and pure soapstone are usually found around the borders of the dunite masses. All the varieties of the formation may be present in a single ledge, or one variety may occupy the whole of an area. The latter relation is most common where soapstone alone is seen. The dunite is usually more or less altered to serpentine. This change may appear in considerable masses of the rock, or in small patches or seams, and is very irregular in its distribution.

Many minor mineral deposits of later origin are found in the formation. Nickel ores form thin seams and coatings between portions of the dunite, and corundum occupies small veins and patches in dunite and soapstone. Near at hand in the Asheville quadrangle there are frequently to be seen veins of pure fibrous talc a few inches in thickness. A little of the talc of this kind is seen near Democrat, but it is comparatively unimportant in this quadrangle. Here and there small veins of asbestos are found in the dunite. They occur in the shape of both small veins and of irregular rounded crusts between portions of the dunite. These are prominent on the Paint Fork of Ivy River and also near Democrat, and the dunite itself is much altered to serpentine. On both forks of Ivy River and near Swannanoa this is commonly to be seen. The alteration proceeds along cracks into the mass of the rock, replacing the dunite more and more near the surface.

Metamorphism.—In their original form these rocks were peridotite and pyroxenite, composed of olivine, with more or less feldspar and pyroxene. The change from these to the soapstone group is enormous—far greater in appearance than that of any of the other formations. The minerals which now appear, however, are closely related in chemical composition to those of the original rock. The intermediate stages of alteration are obscure or absent in this region. These changes seem to have easily affected the peridotites and pyroxenites. Unlike the other metamorphosed rocks, these show only moderate schistosity. Near their borders the soapstones are in places schistose in consequence of the parallel arrangement of the talc and chlorite scales. In a few places in this quadrangle a schistose nature is given to the rock by parallel crystals of tremolite. This result, although common in adjoining regions, is rare in this quadrangle, for the usual alteration is to soapstone and serpentine. Entirely different is the arrangement of the actinolite crystals in many localities, for they form bunches and radiating clusters in the soapstone.

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

Weathering.—Few rocks are slower to disintegrate than those of this formation, and its areas invariably show many ledges. In extreme cases, such as are seen 2 miles northwest of Ledger and also the same distance south of Bakersville in the Roan Mountain quadrangle, almost the entire area of the formation is bare rock. In the great dunite mass near Swannanoa enormous ledges come to the surface and large bowlders are scattered everywhere. The rock is not much affected by solution, but breaks down under the direct action of frost and usually occupies low ground. The great mass near Swannanoa forms broad, rounded hills projecting slightly above the adjoining mica-gneiss. Final decay leaves a cover of stiff yellow clay of little depth and much interrupted by rock. Soils derived from this are of almost no value.

CRANBERRY GRANITE.

Distribution.—The Cranberry granite is limited to the northwest corner of the quadrangle, where there is an irregular area interrupted by several belts of Roan gneiss and Carolina gneiss. The granite forms part of a great mass which extends southwestward through the Asheville and Mount Guyot quadrangles and northeastward far into Virginia. It is typically developed in the vicinity of Cranberry, N. C., from which it receives its name.

Relations.—The formation consists of granite of varying texture and color and of schist and granitoid gneiss derived from granite. Included within the areas mapped as Cranberry granite are small or local beds of schistose basalt, metadiabase, metarhyolite, pegmatite, dikes of fine granite, and small included bodies of the Roan gneiss, Carolina gneiss, and soapstone, as already stated. The metadiabase and metarhyolite are eruptive in the granite and undoubtedly correspond in age to similar Algonkian rocks in the Roan Mountain and Cranberry quadrangles to the northeast. The metarhyolite occurs in the shape of sheets and dikes ranging from a few inches to a few feet in thickness. Outcrops are found on the southern slopes of the Big Bald, but they can not be traced connectedly and are not of sufficient size to be represented on the map. The same is true of the dikes of recent granite, such as were described in the Carolina gneiss. In many places it is difficult to decide whether or not to represent the included bodies of Roan and Carolina gneisses. The latter are cut repeatedly by the granite dikes, and the beds of each vary from a few inches up to many feet in thickness, alternating with great frequency. In only a few cases do the boundaries which are shown on the map represent a single contact between two large masses, but rather they indicate a narrow zone beyond which one rock or the other predominates. Some areas shown as gneiss may contain many small beds of granite, while others may be substantially all gneiss. On the other hand, many small bodies of gneiss are included in areas represented as granite. These may be continuous with one another or may be disconnected inclusions. Unless these bodies were found to prevail over considerable areas they were disregarded in the mapping.

Character.—The granite is an igneous rock composed of quartz and orthoclase and plagioclase feldspar, with biotite, muscovite, and hornblende as additional minerals. Most of the rock is made up of the feldspars, the quartz being next in importance. Minor accessory minerals are magnetite, pyrite, ilmenite, garnet, and epidote. In the vicinity of the Big Bald hornblende is common in the granite, but in other localities is comparatively rare. The most notable variation of the rock is in the size of the feldspar crystals. As these change the formation ranges from rocks with a fine, even grain to those with a decided porphyritic appearance. The latter is seen only in the vicinity of the Big Bald. In the coarse varieties the feldspar is by far the most prominent mineral and gives a prevailing light-gray or white color to the rock. The same is true of many of the narrow dikes penetrating the gneisses. In a few cases the feldspars of the granite are so filled with iron oxide that the rock has a marked red appearance. With this variety epidote is often associated in small veins and segregated masses.

Metamorphism.—The granite suffered great changes during the deformation of the rocks, both by folding and by metamorphism, the latter being much the more conspicuous. When the rock was folded, planes of fracture and motion were formed in the rock mass, along which metamorphism took place. As the process went on the quartz was broken and recemented, the feldspar developed into mica, quartz, and new feldspar, and chlorite replaced part of the biotite and hornblende. These minerals crystallized in general parallel to planes of motion in the rock; inasmuch as these were the result of broad general stresses, the planes of schistosity are fairly uniform in position over large areas. Very rarely do the schists show secondary folding, and never any of the close wrinkling so common in the schists of the Carolina. The results vary in extent from rocks with no change, or with mere cleavage, to those completely altered into siliceous schists and gneisses. The latter are commoner near the borders of the formation than elsewhere. Thin parallel layers and striations composed of different minerals are of frequent occurrence, and the most extreme schists bear no resemblance to the original rock. The thin sheets of metarhyolite which cut through the granite have been extremely metamorphosed. The original flow banding is now very seldom to be seen. Here and there porphyritic feldspar crystals occur, but most of the rock is a fine black schist composed chiefly of quartz and muscovite with a little of the black iron oxides.

Weathering.—Under the action of the weather the varieties of granite behave differently. The coarse granites are very durable and stand out in ledges and bold cliffs; the finer grades, by the decomposition of their feldspars, weaken to a crumbling mass which does not outcrop much except on steep slopes. The schistose portions of the formation break up most readily, and the planes of schistosity seem to afford a ready passage for the dissolving waters. In spite of its weathering the formation occupies high ground, on account of the great mass of its insoluble materials. A notable instance of this is the Big Bald. In general the granite forms knobs and mountains without definite system, whose crests and slopes are usually smooth and rounded. Many parts of its area are cultivated, and the soils are light loams of moderate depth and strength.

HENDERSON GRANITE.

Distribution.—The rocks of this formation lie in a large, irregular mass in the southeastern portion of the quadrangle. From this main body tongues project into the surrounding gneisses. In the vicinity of Montford, on Cove Creek, the area of the formation is nearly separated into two by the gneisses. The extensive areas and exposures of the granite in Henderson County, N. C., give the formation its name.

Relations.—This granite is intrusive in all of the Archean rocks with which it comes into contact. The ends of some of the granite bodies pass under the surrounding gneiss and are shaped like anticlines. The schistose planes of the gneiss arch over and dip away from the granite as if pushed up by the granite from below. This is plainest about 3 miles east of Old Fort. In most places, however, the granite appears to lie between the layers of gneiss, the whole mass having a moderate dip to the southeast. On the east the granite extends only a short distance beyond this quadrangle into the adjoining Morganton quadrangle, but toward the southwest it increases greatly in width and reaches far into South Carolina.

Character.—The granite is composed mainly of orthoclase and plagioclase feldspar, quartz, muscovite, and biotite, enumerated in order of their importance. The biotite varies a great deal in amount, but is usually subordinate. Porphyritic crystals of orthoclase feldspar are a prominent characteristic of the rock. The porphyritic varieties are not limited to any particular position in the granite mass, but are irregularly distributed over the entire area. They grade into granites of uniform grain, and the two varieties may be present in a single ledge. Along the southern border of this quadrangle around Stone Mountain, and in the extension of the granite northeast from Old Fort, considerable masses of it have a porphyritic appearance. In other portions of the formation the porphyritic feldspars are a decided characteristic of the rock. This is most strikingly the case along the south edge of the quadrangle, on the drainage of Broad River and Cove Creek. The rock has a general gneissoid aspect and many of the phenocrysts are drawn out into lenses (or augen) more than twice their original length. Where they retain their original shape they are an inch or less in length.

The massive granite which appears in the vicinity of Stone Mountain is usually of fine or medium grain and contains very little biotite. The feldspars make up a large portion of the rock and give it a decided white color. Southwest from Turkey Cove, and nearly to Old Fort, massive or slightly porphyritic granite composes the whole formation. The micas are plentiful in that part of the granite, also, and give it a gray color, darker than that usual in the massive varieties. The minerals are somewhat coarser toward the northeast, and north of Marion the biotite forms large patchy crystals.

At numerous localities, usually near its contacts with the Carolina gneiss, the granite shows a decided flow banding. This is due to the arrangement of the minerals in roughly parallel layers when the granite was forced in a molten condition into the other rocks. This can be well seen on Curtis Creek northeast of Old Fort. At that point the rock marked by wavy flow bands merges into the massive variety in the same ledge. Each variety is also marked by the secondary arrangement of the minerals during metamorphism on planes which bear little relation to the flow banding. At the same locality the intrusion of the beds of granite into the mica-gneiss is well shown.

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

Other results effected by deformation are the striated and striped surfaces which mark the granite in many places. These are due to the linear growths of new minerals with parallel arrangement. The dark stripes are composed in the main of fine biotite and fibrous hornblende, and the light stripes of quartz and feldspar, the new minerals having segregated in this unusual manner. This phenomenon is best shown northeast of Old Fort, where the rock contains the most biotite. The entire mass of the granite shows the effect of pressure so extreme as to overcome the original strength of the rock.

Weathering.—As the formation is attacked by weathering agencies its surface is slowly lowered. Its siliceous composition and its great mass unite in maintaining the relative altitude of its areas. The massive portions form high ground wherever found, such as Mackey Mountain and Stone Mountain. The porphyritic or gneissoid portions vary much in topographic form. Little Pisgah and Hickorynut mountains stand high above the valleys, while the same kind of rock is well reduced along Otter Creek, close at hand. Both varieties of the granite cause many ledges and cliffs, which are conspicuous features of the landscape along the southern border of the quadrangle and at points farther southwest. The bowlders and waste from the formation are carried for long distances over the adjoining formations. Upon complete decay the formation produces a yellowish or reddish clay, which is frequently leached out nearly white. This is mixed with sand and fragments of rock on the mountain sides and is of no great depth. In the valleys the rock is often decomposed and soft to depths as great as 30 feet, and the overlying clay is 6 or 8 feet in thickness. Except in coves and hollows the soil is infertile and is subject to drought.

ROCKS OF UNKNOWN AGE.

CONGLOMERATE AND GRAYWACKE.

Age and correlation.—A single large area of conglomerate, graywacke, and similar rocks runs from the Blue Ridge across Swannanoa River and the Swannanoa Mountains. These rocks are surrounded entirely by the Carolina gneiss and do not come in contact with any other sedimentary formations. In the Swannanoa Mountains, however, the conglomerate belt lies very near a parallel belt of the Brevard schist, which is also of sedimentary origin. The rocks of the conglomerate group bear a close resemblance in all respects to the metamorphosed portions of the Great Smoky conglomerate about 30 miles farther west, in the Asheville quadrangle. The rock types are the same and the degree of metamorphism is similar, so that they are possibly the same formation. Except for this lithologic identity and the restriction of conglomerates to the lower Cambrian, there is no evidence to define the age of these rocks. Between them and the adjoining Carolina gneiss there is apparent conformity, and it is extremely difficult to separate the two formations where the conglomerates are absent. The graywackes and schists of the conglomerate group can scarcely be distinguished from similar rocks in the Carolina. The suggestion is thus made that the Carolina and the conglomerate formation were of the same origin, the local presence of the conglomerate making the present distinction possible. Metamorphism of these rocks has been so great, however, as to destroy the original contact relations and any unconformity which may have existed. If the conglomerate group is of Cambrian age, there is a great difference between the basin containing the conglomerate and the basins adjoining on the southeast, which contain only black schist. Differences like these are seen in the similar rocks of the Asheville quadrangle, and are there due to the overlap of the younger sediments upon the older. A similar explanation would hold here, although the limits within which the overlap took place are narrow.

Character.—This formation contains a considerable variety of rocks, including conglomerates, graywacke, and mica-schist. The layers of conglomerate range in thickness from 1 inch to 2 feet and exhibit the original character of the rocks most plainly. The conglomerates form layers in the graywacke, in some places sharply separated from it, in other places grading into it. The conglomerate pebbles are composed mainly of quartz, with some of feldspar, and seldom exceed a half inch in length. On the south side of the Swannanoa Mountains they are an inch in length, and from this they grade into the coarse and fine graywackes. The matrix of the conglomerates is the same as the material of the graywacke and consists of fine-grained quartz, feldspar, muscovite, and a very little biotite. All of these rocks have a decided gray color, which becomes whitish by the weathering of the feldspar which they contain. Interbedded with these coarser rocks are many seams and beds of gray and bluish-gray mica-schist. These are from a few inches up to a foot or more in thickness and occur in rapid alternation with the graywackes. The schists are fine grained and are composed chiefly of quartz and muscovite. Some of the darker layers contain also a little biotite and minute grains of the iron oxides. The formation occupies a synclinal basin, so that its full extent is not exposed. The metamorphism and the uncertainty of the dips make the thickness of the formation very doubtful. About 1000 feet now remain after erosion.

Alteration.—The graywacke and schist are the most altered parts of the formation and usually can be distinguished from the Carolina gneiss only with great difficulty. The graywacke contains more feldspar and less quartz than the Carolina, as a rule, and is also slightly finer grained. In its present condition the graywacke is entirely metamorphosed, and its original nature can be inferred only by observations made in the Asheville quadrangle. Judged in this way, it was originally coarse, feldspathic sandstone. The flakes of mica are rudely parallel to one another, an arrangement which is carried out in less degree by the other minerals. The proportion of the mica is not sufficiently great to cause in this way a strong schistosity. The planes of these secondary minerals dip at high angles in most places, as do also the stratification planes, and the two sets usually coincide.

The layers of schist are also entirely metamorphosed. The fine grains of quartz and scales of mica of which they are composed lie closely parallel to one another and form a highly schistose rock. Usually they are finer grained than the schists of the Carolina, but the difference is not striking. Many of the layers also contain small secondary garnet crystals.

Some of the conglomerate pebbles retain their original rounded form. Most of them have been crushed and squeezed, however, and elongated to three or four times their original length, and correspondingly flattened. At the same time much secondary mica was developed in coarse and fine flakes. The feldspar grains recrystallized into quartz and mica during the metamorphism. The original character of the congolmerate is best preserved at the southern end of the conglomerate area.

North of Swannanoa River metamorphism has been extreme, and at several localities small lenses and patches of pegmatite and granitoid material are developed in the beds of graywacke. At first sight these lenses appear to cut the sedimentary rocks. In reality, however, they grade more or less gradually into the graywacke, of which they appear to be merely the recomposed materials.

Weathering.—The rocks of this formation are very resistant to erosion. The quartz and mica are only slowly soluble and the feldspathic material is not sufficient to cause rapid disintegration. Decay works in along the planes of schistosity and the rock breaks up into slabs and small fragments. These are left in the soils, which are thin, sandy, and micaceous. High mountains are produced by the formation, and valleys also cross its course, as is true of the adjoining Carolina gneiss. Many ledges and small cliffs are found throughout its area and its wash is spread far and wide.

CAMBRIAN ROCKS.

BREVARD SCHIST.

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

Character.—As it is displayed in this quadrangle the formation consists only of schist and slate. Most of it is schist, of a dark bluish-black or black color. Between Swannanoa Gap and Old Fort the schistose character is less pronounced and the rock is a banded mica-slate. All of the strata are fine grained except a few siliceous layers, which represent original sandy strata. The rocks are composed mainly of very fine quartz and muscovite, through which are scattered countless minute grains of the iron oxides, producing the dark color. Another constituent commonly found is graphite. This is disseminated in minute grains through large masses of the rock and is only here and there concentrated into layers. Graphite is also found associated with quartz in small secondary lenses. About 4 miles northwest of Old Fort the graphite is so abundant as to have led to mining operations. Limestones are not found within this quadrangle. They begin a few miles southwest of Fairview, however, and appear at frequent intervals for upwards of 50 miles.

The principal variation in the appearance of the formation is in the presence or absence of garnets. These are very common in the vicinity of Fairview, and also on the head of Curtis Creek, north of Old Fort. They are disseminated through the schist in small crystals, seldom over one-eighth of an inch in diameter. Since the garnet is also abundant in the underlying Carolina gneiss in the same localities, it is sometimes very difficult to distinguish between the two formations. This is particularly true where they are much weathered. The mica-schist of the Carolina, however, is usually distinctly coarser and lighter colored. The garnets are of secondary origin and probably were developed by the same agencies in each of the formations during their metamorphism. Here and there in the formation crystals of dull-gray cyanite are found.

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

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

HAMPTON SHALE.

Distribution and relations.—One small area of this formation is found east of Turkey Cove, at the foot of Linville Mountain. It is here associated with the belt of Cambrian rocks which passes northeastward into the Morganton and Cranberry quadrangles. This belt of Cambrian rocks is now only 10 miles away from the Brevard schist. The strata which are now seen, however, were much farther apart when deposited and have been brought closer together by the extreme folding and faulting which have taken place. In the eastern Cambrian areas along Linville Mountain the strata which underlie the Hampton and rest upon the Archean granite correspond in age with the Cochran conglomerate. This conglomerate overlies the Hiwassee slate, which is probably the equivalent of the Brevard schist. Thus, an overlap can be inferred between Linville Mountain and the Blue Ridge, such as appears in many places among the earlier Cambrian sediments. From this it appears that the Brevard slate was deposited along a shore which ran north and south through the eastern part of the quadrangle.

Name and character.—The Hampton shale is named from Hampton, Carter County, Tenn., near which it occurs. The strata here shown consist of slates derived from argillaceous shales. They are gray or blackish-gray in color, and on exposure vary to yellow or yellowish-gray. They are somewhat banded by ribbons of a light and dark gray. Though metamorphism has been sufficient to change most of the shale to a slate, yet the banding is seldom entirely destroyed. The formation is of no importance in this region as a soil producer, on account of its small area; nor does it affect the topography.

ERWIN QUARTZITE.

Distribution and name.—A considerable body of this formation is found south and east of Turkey Cove. It passes northeastward through this and into the Morganton quadrangle, forming the crest and slopes of Linville Mountain. The formation is named from Erwin, in Unicoi County, Tenn., where it is conspicuously developed.

Character.—In this region it consists mainly of white quartzite with a little white sandstone, a few beds being feldspathic. More than 500 feet of these beds, of very uniform appearance, occur in Linville Mountain. They are composed of grains of white sand cemented by secondary silica. The sand grains are usually very fine, but in a few places some of the upper layers contain small pebbles of quartz. The layers are very massive and range from 6 inches to 3 feet in thickness. Between them, here and there, are small layers of slate or schist. These are more noticeable in the lower part of the formation. There are in this region no contacts visible between the quartzite and the overlying Shady marble. Toward the head of the North Fork of Catawba River the latter rests on the quartzite, with only a few inches of sandy shale between. South of Turkey Cove and near the great overthrust fault metamorphism of the quartzite was extreme. In that situation planes of motion were developed on and through the beds. The minerals of the sandstone were squeezed into thin sheets and a little muscovite was formed. Beds of schistose quartzite, quartz-schist, and itacolumite, or flexible sandstone, were produced.

Weathering.—The weather acts very slowly against the firm and insoluble beds of this formation. They always cause high ground, and their course is marked by many ledges and white cliffs. By the direct action of frost its blocks are finally dislodged and strew the mountain sides. Its crests are sharp and rocky, and the cover of soil is thin and irregular. On the flatter summits and in the hollows a fair amount of soil accumulates and supports considerable vegetation.

SHADY MARBLE.

Distribution and name.—This formation occupies three small areas adjoining those of the preceding quartzites. One of them underlies and causes Turkey Cove, and another extends up the North Fork of Catawba River for 10 miles or more. The formation derives its name from Shady Valley, Johnson County, Tenn.

Character.—The formation, as shown here, consists almost entirely of marble. This is of white or gray color, with many bands and beds of dark blue. Analyses of the marble give 33 to 41 per cent of carbonate of magnesium and 52 to 62 per cent of carbonate of calcium, so that much of the rock was originally a dolomite. The layers are very thick and massive and the stratification is hard to determine unless large ledges are seen. Outcrops are very scarce, except in the beds near the base of the formation, which contain considerable silica in the form of sand grains and chert. In the extension of this formation toward the northeast its layers are somewhat less metamorphosed and the darker blue and gray colors of the original limestone prevail. Many ledges of this kind have the black weathered surface which is characteristic of the formation. The top of the formation is not shown in this quadrangle. Owing to the scarcity of exposures its thickness is hard to determine, but probably there are over 500 feet in Turkey Cove.

Weathering.—Weathering proceeds faster in this formation than in any other rocks of this region. The rock dissolves, leaving behind a dark-red clay, and the formation makes valleys wherever it appears. In this region its course is followed by streams, the gravels of which are spread out widely over the areas of the formation. Its natural clays and soils are deep and strong and afford excellent farming land. As a rule, however, they are too much covered and impoverished by waste from the adjoining formations. In the red clays near the base of the formation are found small deposits of brown hematite.

TRIASSIC (?) ROCKS.

BAKERSVILLE GABBRO.

Distribution and relations.—Near the northern border of the quadrangle are found many dikes of this formation. They extend southwestward along the valley of Jack Creek from a large mass of the same rock in the Roan Mountain quadrangle. In the occurrences on Jack Creek the dikes are irregular in trend and in thickness, seldom being over 30 feet broad. Owing to their small size and irregularity, it is impracticable to represent them all on the map. Their general course coincides with that of the foliation of the inclosing gneisses, but here and there they cut across this at considerable angles. Their most distinctive feature is the absence of dynamic metamorphism, although the adjoining rocks are all metamorphosed, frequently to an extreme degree. Rocks of the character of gabbro are especially subject to metamorphism, so that its absence here indicates that the gabbro was formed after the general period of metamorphic action. Inasmuch as rocks of precisely this character are of frequent occurrence among those of the Triassic period and are found at intervals in the older rocks of other areas, and as there are no other formations of this character known in the Appalachians, this gabbro is considered to be of Triassic age.

Character.—The gabbro is a dense, hard rock of prevailing black or dark color, and on weathered surfaces has a reddish-brown or rusty appearance. It is composed chiefly of plagioclase feldspar, hornblende, and pyroxene, in crystals of medium size. The texture of the rock is usually massive and granular, but occasionally has the ophitic structure of diabase. Near the contacts with other formations the grain of the rock grows perceptibly finer, but it is seldom coarse at any place in this quadrangle. Plagioclase feldspar also occurs sparingly in porphyritic crystals one-half inch or less in length. Additional constituents are magnetite and garnet in small grains and crystals. The latter is usually developed near the contacts, both in the gabbro and in the older rocks, but frequently it seems to be a regular constituent.

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

STRUCTURE.

INTRODUCTION.

Those 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 on its opposite sides.

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

LOCAL STRUCTURES.

General features.—The rocks of this area have undergone many alterations in texture and position since they were formed, having been bent, broken, and metamorphosed in a high degree. The structures which resulted from these changes extend in a general northeast direction, except a narrow belt running southeastward between Burnsville and Turkey Cove. In this belt the structure planes swing into a northwest course, nearly at right angles to their prevailing direction. Many minor changes of this kind are to be found at various localities in the quadrangle.

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

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

In the structure sections it is not possible, on account of the small scale, to show the minor folds and wrinkles, so that the structure is generalized and represented as comparatively simple. It is not possible to represent the granite and gneiss occurring beneath the surface, since they have no known methods of disposition or occurrence, such as characterize the sediments. In many places the granite bodies can be seen protruding through the gneisses from below. In other places, the same relation can be deduced from a study of the topography. There are also instances in which the bodies of Roan and Carolina gneiss and soapstone rest at various discordant angles within and upon the bodies of the granite. As a general principle, moreover, it is evident that the granites were intruded into the gneisses from larger bodies of granite lying deeper in the earth. For these reasons the granite masses have been represented as growing larger downward. From a similar course of reasoning, the bodies of Roan gneiss, being probably eruptive in the Carolina gneiss, have been treated as enlarging beneath the surface.

Folds.—In a broad way, the structure of the rocks of the Mount Mitchell quadrangle is that of two synclinal basins, with three intervening areas of uplift. In the southeastern basin, which is composed of a considerable number of good-sized folds, are found the only sedimentary rocks of the quadrangle. In general, a group of these smaller folds can be traced along the Blue Ridge, through the contorted gneisses at the head of North Toe River, and into the southwest corner of the Cranberry quadrangle. The northwestern basin enters this quadrangle east of Asheville and passes across the head of Ivy River just west of Burnsville, where it becomes more obscure and disappears northeastward. It is defined in part by the dips of the foliation planes and in part by the disappearance, toward the southwest, of the Roan gneiss, which in general comes up into the Carolina gneiss from below.

Of the three areas of uplift, the northwestern and southeastern are marked both by the foliation planes and by the masses of granite which have forced the gneisses upward from below. The doming of the gneisses by the Henderson granite on the southeastern uplift is well shown east of Old Fort. The northwestern uplift is associated immediately north of this quadrangle with an enormous thrust fault, on which the granites have far overridden the sedimentary strata. The central anticlinal uplift passes through Mount Mitchell and the Black Mountains, across the head of Swannanoa River, and into the Saluda quadrangle. It diminishes both southwest and northeast of Mount Mitchell.

The folds, both anticlines and synclines, range in size from mere wrinkles up to arches and basins with breadths of miles. Folds of all intermediate dimensions are to be observed. Many of them are open, as in Section B–B, but the majority are nearly, or quite, closed. Thus, for long distances across the strike of the rocks, the dips of the rock masses and foliation planes are nearly parallel. The various schists, slates, and gneisses were bent more than broken under compression, on account of their frequent parting planes and changes of material. Beds like the Erwin quartzite, possessing few such planes and being very rigid, broke as well as bent under the strain and caused faults to extend out into other formations. Breccias are found at many points on the fault planes. Thinner beds, like those of the Brevard schist, bent and crumpled in an extreme degree without breaking, as appears in Sections D–D and E–E.

Faults.—The most exceptional structural feature of the region is in the area of Cambrian strata near Turkey Cove. Over these sediments the Archean granite and gneiss were thrust from all sides except northeast. In that direction, the sediments continue through the Morganton and into the Cranberry quadrangle, forming a group of remarkable structures, which are described in the Cranberry folio. The schistose planes of the granites in this quadrangle dip away from the Cambrian quartzites and marbles at angles varying from 20° to 50°. Since the principal overthrust took place secondary folds and faults have been developed in the same rock masses and have bent and broken the earlier fault plane and the inclosing rocks. These minor faults and folds are clear where the sediments are involved, but can not be traced far into the adjoining granites. It is probable, however, that they do so extend for considerable distances. The striation and elongation of the granites near the fault show no apparent relation to its present attitude, but have a general northwest-southeast direction. Section B–B shows the general relation of the rocks in this structure.

Metamorphism.—The third and most conspicuous result of deformation in this region is metamorphism. Its processes were in general along the following lines: The mineral particles were changed in position and broken during the folding of the rock; as the folding went on they were fractured more and more; new minerals, especially quartz and mica, grew out of the fragments of the old minerals and were arranged at right angles to the greatest force of compression at any particular point. Inasmuch as the compression was about uniform in direction over large areas, there resulted a general parallelism of the longer dimensions of the minerals. To this is due the schistosity of the rock. In folding, the differential motion in the sedimentary strata was to a large extent along bedding planes. As deformation became extreme, however, other planes of motion were formed through the individual layers, as in the case of the massive igneous rocks. In rocks which had already become gneissoid or schistose as the result of previous metamorphism the existent schistose planes served to facilitate flexure, as did the bedding planes of the sediments. In the massive igneous rocks there were no planes already formed, but these were developed by fracture and mashing, and the change of form expressed in folds was less than in the laminated rocks. 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 differences in strength between the formations. Thus, while the strike of the different formations may vary considerably in adjoining areas, the schistose planes swing gradually from one direction to another, and there is seldom an abrupt change.

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

In the granites, during the same period of folding, there were no existing foliation planes. Under the great stresses, however, planes and zones of shearing and mashing were produced and changes of form took place on them. These planes dip almost altogether toward the southeast and are nearly uniform over large areas. They vary in amount from 5° to 10° up to vertical, averaging about 50°. Along the contacts of the formations the planes of schistosity are roughly parallel to the contact in both dip and direction. Within the body of each formation, however, there are considerable divergences from the direction of the contact. Around more massive and resistant portions of the rocks, also, the schistose planes swing gradually. In places where the motion was especially localized, as in the vicinity of fault planes, the minerals of the granites were elongated into thin sheets and strings or striated forms. In many other places in the body of the granite, similar results are to be seen and may be considered due to the same conditions. In the porphyritic granites, like the Henderson, the large feldspar crystals were cracked, rotated, flattened, and elongated into eyes. Around these harder portions the secondary micas of the granite are closely bent.

There is a great variety in the direction of the structure planes in the mountains. Their average trend is between N. 20° to 45° E. Locally there are groups running north and south, and also northwest and southeast. These constitute a portion of an axis of cross folding and extreme compression which passes in a northwesterly direction through Turkey Cove and Burnsville. On this cross axis there is a general pitch of the structures toward the southwest. Another local pitch in the same direction, resulting in similar northwest strikes, is seen in the extreme northeast corner of the quadrangle. A group of structures which pitch in an opposite direction is seen in the granites and gneisses southeast of Old Fort. These have no connection with any general structural features and are probably caused by the superior rigidity of the masses of Henderson granite in that locality. Local twists and turns in the individual beds can be found in almost any large outcrop. These are accommodated to one another, however, so that the average course of the formations is very regular for long distances.

In the dips of the structure planes of this quadrangle there is very great variation. Throughout most of the area the dip of the schistose planes and sedimentary beds is toward the southeast at angles ranging from 10° to 90°. In certain belts there are usually distinct groups of dips. The exceptional feature in this respect is the series of northwestward-dipping beds and axial planes seen in the Black and Great Craggy mountains. This is best defined north and west of Mount Mitchell, in which locality the folds are overturned toward the east and most of the dips are toward the west at angles of 60° to 80°. These northwestward-dipping folds correspond in general with the zone between the Black Mountain uplift and the Asheville synclinal depression already alluded to. Southwest of Mount Mitchell the folds become more upright and nearly vertical. Northeast of that point they also become vertical and then overturned toward the northwest in the manner prevailing elsewhere in the quadrangle. Northwest of this exceptional belt the dips are steep toward the southeast, ranging from 50° to vertical. Southeast of the same belt the dips are almost entirely toward the southeast and at considerably lower angles. Many of the rocks are nearly flat and few have a dip greater than 60°. Along the southern edge of the quadrangle, in the Henderson granite, the foliation planes dip 5° or 10° southeastward for large areas. The average dip for the region southeast of the Blue Ridge is 40° or less.

Repeated deformation.—Metamorphism is plainly the most important result of deformation in this quadrangle. Just how much of it proceeds from the period of deformation commonly termed the "Appalachian" is doubtful, but it is certain that many schists and gneisses had attained great metamorphism during previous epochs. The Appalachian deformation was not, however, completed during one process. From the facts observed in this and in adjoining areas, it is clear that some of the great irregular faults were the first results of this deformation. At a somewhat later time these were themselves folded, as deformation took a different form of expression. In this area similar results are seen in the faults south of Turkey Cove (Section C–C). Schistosity was produced to some extent among the sedimentary formations during the first part of this epoch. In many places even the secondary minerals and schistose planes are folded, as well as the original layers of the rock. The metamorphic minerals were produced under certain conditions of pressure and load, and they could have been deformed only when these conditions were altered materially—that is to say, after a considerable lapse of time. The length of this interval is not known, but in comparison with the preceding epochs it was probably small. From present knowledge it seems clear that both these episodes and the interval are but parts of the Appalachian epoch of deformation.

Vertical movements.—The latest form in which yielding to pressure is displayed in this region is vertical uplift or depression. Evidence of such movements can be found at various intervals during the deposition of the sediments, as at the beginning of the deposition of the Brevard schist and the Shady marble. In post-Carboniferous time, after the great period of Appalachian folding just described, such uplifts took place again and are recorded in surface forms. While the land stood at one altitude for a long time, most of the rocks were worn down to a nearly level surface. Over a large part of this region one such surface was developed, but only a few of its worn remnants are now to be seen, at the heads of the main streams, where secondary cutting has not yet reached. On the upper part of Crabtree Creek is an excellent example of this plateau, at 3600 feet above sea, while many smaller remnants may be found here and there in the high mountains. Over much of this region another such surface was developed, which is still visible in the plateaus between and around the main mountain mass, at elevations of 2600 to 3000 feet. Actual profiles of small parts of these plateaus are shown in Sections D–D and E–E. East of the Blue Ridge another plain was extensively developed after further uplift and erosion had taken place. This now stands at heights of 1200 to 1400 feet above sea. The beginning of a third series of plains is recorded in the flood plains of Yadkin River, where it has cut down into the Piedmont Plateau.

After the formation of each of these plains, uplifts of the land give the streams greater slope and greater power to wear; they have accordingly cut down into the old surfaces to varying depths and produced canyons or later plains, according to their power and the nature of the waste they carry. The amounts of the uplift can be estimated, from the vertical intervals between the plateaus, at 1000 feet after the first period of reduction, nearly 1400 feet after the second, and perhaps 1000 feet after the last period. Other uplifts and pauses undoubtedly occurred in this region, but their traces are obscure; and there probably occurred still others which were not of sufficient length to allow plains to be formed and record the movement.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The rocks of this region are of use in the natural state, as soapstone, talc, mica, precious stones, corundum, marble, serpentine, and building stone, and in materials derived from them, such as graphite, magnetite, brown hematite, chromite, lime, and brick clay. Through their soils they are of value for timber and crops, and in the grades which they occasion on the streams they cause abundant water power.

SOAPSTONE.

Soapstone is found here and there through the Archean formations. It and allied rocks occur at frequent intervals throughout the entire length of the Appalachians. Although soapstone is thus very widespread, few areas of it are over a mile in length. Some of the bodies are to be measured by a few feet, and most of them cover only a few acres. Soapstone is derived from the metamorphism of very basic igneous rocks and is associated with dunite, serpentine, chlorite-schist, and other products of that metamorphism. It is customary to find several of the metamorphic varieties together in each area. In the district south of Marion three bodies of soapstone are known. North of the Blue Ridge there are many more, and at least 50 areas of the formation show a considerable amount of soapstone.

In places the soapstone is sufficiently pure for economic use. As a rule, however, the talc, the hydrous silicate of magnesia forming the soapstone, is too much mixed with other silicates, especially of the hornblende family, to be valuable. The special uses of soapstone demand a rock which is readily cut and sawed and which contains no material that is affected by fire. Some of the hornblendic minerals fuse readily, and others which fuse less easily are hard and injure the texture and the working of the stone. The igneous rocks from which the soapstones were formed vary much in composition, so that the beds of soapstone are equally variable in quality. Metamorphism of the original rock was not always complete and did not always produce a soapstone, even when complete. Accordingly, in this quadrangle large bodies of soapstone are rare, although several of the largest known bodies of the allied dunite and serpentine are found here. The soapstone usually occurs in seams or layers in serpentine and dunite, a few inches or a few feet thick, and in larger bodies at the ends and borders of their masses. On the economic geology map are indicated eleven areas of the formation where soapstone is found in sufficient purity and body to be valuable. The most promising localities are 1 to 2 miles northeast of Democrat, and on Toe River and Crabtree Creek 5 miles south of Boonford. Near Democrat the soapstone covers many acres, while at the latter localities its bands are from 100 to 1000 feet long. Thus far, however, only loose blocks and bowlders have been sawed and used for building fire places, and in no place has the rock been quarried to any extent.

TALC.

Deposits of pure talc are found in connection with the rocks of the dunite-soapstone group. The talc has the same origin as the soapstone bodies, both being derived from the metamorphism of peridotite, and is, in fact, only the purest form of those deposits. Talc is also found in veins a few inches thick intersecting the dunite. These veins are so small that they have no value.

On the economic geology map four localities for talc are shown. The principle bodies are 1 mile northeast of Democrat and 2 miles northeast of Burnsville. In all these localities the talc forms the entire outcrop of the formation. No tests have been made of the depth of the talc bodies. Since, however, they replace the dunite the depth of the talc is probably equal to that of the dunite. The shape of the dunite bodies is lenticular and their depth is doubtless as great as their length on the surface. Near Democrat the talc outcrops in an oval area about 500 feet long. Near Burnsville the talc forms 2 small lentils no more than 10 feet thick or 100 feet long.

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

MICA.

In the pegmatites of the Archean rocks, mica occurs in crystals large enough to be of commercial value. Pegmatites are found in the Roan and Carolina gneisses throughout a large portion of their areas, but they contain mica of workable size chiefly north and northeast of Mount Mitchell. The largest mica has been produced from a mine at the north end of the Black Mountains, from another 4½ miles northeast of Mount Mitchell, and from a third 2 miles northeast of Sprucepine. All of these mines are in the Carolina gneiss, as are most of the good mica mines of this region. The principal developments in mica mining have been in an area of 150 square miles northeast of the Black Mountains and north of the Blue Ridge; the mica industry centers chiefly in Sprucepine. The group of mica-bearing pegmatites passes northward into the Roan Mountain quadrangle. A few mines that produce good mica have been developed in other localities. In general, however, outside of the mica district above described the crystals of mica in the pegmatites either were not originally of workable size or they have been crushed or distorted during the deformation of the rock. In this quadrangle the pegmatites are of lenticular shape and lie in general parallel to the inclosing gneisses. Some can be traced for miles, while others extend only a few rods or a few feet.

The mica mined is the variety muscovite, and it is crystallized with quartz and feldspar, forming the pegmatite. In many localities biotite also occurs, and one of the notable constituents of the pegmatite in this region is beryl. Many other rare minerals, notably the compounds of uranium and columbium, are found in the pegmatites. From a texture like that of granite the coarseness of the pegmatite varies until the mica crystals attain a diameter as great as 30 inches. Crystals of this size are very rare, having been found only in the mine just northeast of Mount Mitchell and in that northeast of Sprucepine. The average crystals mined are from 3 to 8 inches in diameter.

In places the mica apparently follows rather irregular planes, which are termed the "vein." The distribution in the vein of the crystals or "blocks" of good mica is very irregular. They can not be predicted or traced far with a definite position in the pegmatite. Consequently, the success of any mica mine is uncertain at the start. Large mica may be found at once or barren rock may continue throughout. Coarse mica at one point may become smaller in a few feet, or the crystals may be deformed and crushed. Even when the mica is large, most of it may be "A" mica, with poor cleavage. Generally, however, one class of mica prevails for considerable distances. The deep incline of the Gibbs mine on South Toe River, 450 feet, shows an unusual persistence of the good mica in depth. A similar or greater extent of mica is seen in a horizontal direction in many lines of shallow pits and tunnels.

Many of the crystals do not furnish sheets across their entire diameter, for seams and cuts 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 latter impurities can be, for the most part, taken out by careful washing, but the spots of dendrite can not be wholly removed, existing as they do between the thinnest sheets. These spots are unimportant in mica used for electric insulation or where transparency is not required.

Pits and shallow openings have been made at scores of places in this region during many years, but they have usually been sunk in the decayed rock and soon exhausted. Later work in the solid rock is difficult, on account of the hardness of the quartz and feldspar. The most extensive of the old mines is the Ray mine, at the north end of the Black Mountains. At this point a shaft was sunk about 250 feet, and much mica and many rare minerals were taken out; the locality is one of the most noted in the State for unusual minerals. In the vicinity of Sprucepine several shafts have been sunk to considerable depths in recent years. In addition to mica, minerals were procured of considerable value for the radium, uranium, tantalum, columbium, and other rare elements which they contain. These minerals are present especially in a group of mines within 2 miles of Sprucepine—the Buchanan, Wiseman, Flat Rock, Dake, and Adams mines.

At present the only work carried on is at the Gibbs mine, on South Toe River, east of Celo Mountain. At that point an incline goes down for 450 feet at a dip of 45° to the west, following the dip of the pegmatite and the inclosing mica-gneiss. The mine lies just west of a sharp anticlinal fold in the mica-gneiss which pitches southwest. The pegmatite is composed of feldspar, quartz, muscovite, biotite, with a little garnet, apatite, and secondary epidote veins. The feldspar is mainly oligoclase, some of which is clear and glassy. Its crystals are large, occasionally exceeding 2 feet in length. The largest mica "block" found was nearly 2 feet across the sheets and 200 pounds in weight, but most of it is much less. The product is used chiefly for insulating work in electrical construction.

PRECIOUS STONES.

Mention has been made of various rare minerals occurring in the pegmatites of the Mountain region. Three places have been discovered within a few miles of Sprucepine in which these have commercial value. These minerals consist of the silicate of alumina and glucina, all being included under the general name of beryl. The transparent, bluish-green variety is called aquamarine and the clear emerald-green crystals are called emerald. The brilliant green color of the latter is due to the presence of small amounts of chromium.

The beryl occurs as hexagonal crystals in the quartz, mica, and feldspar of the pegmatites. It varies in size from minute prisms up to rudely crystalline masses, which sometimes exceed a foot in diameter. As a rule, the hexagonal and terminal planes are well developed. The prisms are usually two or three times as long as they are thick. They lie at all angles in the pegmatite, and they may occur singly or in groups of two or three. Most of the beryl is not transparent and thus is unfit for gems. The largest and most perfect beryls of the region came from the Ray mica mine, at the north end of the Black Mountains. The emerald crystals are usually small, slim prisms, less than one-eighth of an inch in diameter; the finest have diameters of half an inch. The beryls are intergrown with the other minerals of the pegmatite, so that it is clear that all were formed at the same time.

Two miles nearly south of Sprucepine active mining is carried on for aquamarine by the American Gem Company. At this point the pegmatite dips southeastward at an angle of 45° and many small tunnels and inclines have been opened upon it. The pegmatite is inclosed by mica-gneiss, but is very near the contact of the latter with a body of hornblende-gneiss. The beryl-bearing rocks have been traced by pits and small shafts for a distance of nearly a mile. The productive portions form a series of lenses somewhat overlapping one another and less than a foot in thickness. In these the beryls are most common. The minerals of the pegmatite are orthoclase feldspar, quartz, biotite, beyrl, garnet, and a little columbite and autunite. These are intergrown with one another, as well as in separate crystals, and are all apparently of the same age. The beryls are comparatively small, few exceeding 6 inches in diameter. Some of the crystals may be entirely clear and fit for gems, but usually only small parts are so available. The color of the beryls varies from colorless to light green, bluish green, and pink. The best stones have a deep bluish-green color.

Four miles southwest of Sprucepine emeralds are found in pegmatite. An incline has been sunk 135 feet by the American Gem Company, following the pegmatite and inclosing mica-gneiss, which dip nearly eastward at angles ranging from 45° to 50°. The emerald-bearing rock is reported to have been traced for about half a mile to the north. A few feet east of the mouth of the incline a small body of hornblende-gneiss is in contact with the mica-gneiss, but the extension of the vein toward the north does not follow this contact closely. The pegmatite consists mainly of feldspar, quartz, tourmaline, and beryl, with horses of biotite-tourmaline-schist. The beryls are found sparingly throughout the pegmatite, but are commonest along the upper contact of the pegmatite and mica-gneiss and in small bunches and horses of schist. The upper contact is followed for the "vein," which is seldom over 8 inches thick. As it increases in thickness the percentage of emerald grows less. Most of the beryls are opaque and valueless; many, however, are clear and of the brilliant green which marks the emerald. The latter vary in size from minute grains or slim prisms up to crystals with diameters of half an inch. Owing to flaws, cleavage cracks, and opaque spots, only small portions of some of the crystals are suited for gems. The slightly colored beryls have lengths as great as 6 inches. The tourmaline crystals are very perfectly formed and range from mere needles up to prisms 4 or 5 inches in length. They usually have no special positions in the pegmatite, but in places show a decided radiating arrangement.

CORUNDUM.

Corundum is known to occur in two places within this quadrangle: one, 4 miles east of Big Bald, in the northwest corner of the quadrangle; the other, 3 miles east of Celo Mountain, near South Toe River. In each of these localities the corundum is found associated with the soapstone. In this respect it differs from the corundum localities farther southwest, which are almost altogether connected with the dunite variety of the same formation. In each case here the corundum is inclosed in scaly chlorite. In the Big Bald locality the corundum is found along the borders of the soapstone mass in knots, patches, and irregular veins. It is also reported to occur sparingly in the soapstone rock itself. The soapstone at this point contains much chlorite, actinolite, and other hornblendic minerals. At the locality east of the Black Mountains the chlorite and corundum form a vein dipping southward and crossing the trend of the soapstones. The corundum forms separate crystals or small groups of crystals in the chlorite, and the individual crystals vary from small grains up to half an inch in diameter. They are seldom well formed and are usually rather rounded and stubby. The corundum has been tested only by small open cuts and it is doubtful if the amount of it is great.

GRAPHITE.

Graphite is found here and there in many of the layers of the Brevard schist. It appears in two forms, being disseminated through the body of the schist in extremely fine particles, and also associated with quartz in small veinlets and stringers. While the deposits of this mineral have been mined only in the vicinity of Graphiteville, east of the Blue Ridge, the black schists are graphitic at many other places. In fact, graphite might be said to be a regular constituent of the schist in some areas. As to the cause of the presence of graphite in some places and its absence in others there is no sufficient evidence, nor is it known whether the graphitic material was introduced into the schists as an original or a secondary constituent. Its presence in veins, the quartz of which is secondary, indicates a secondary origin for the graphite. Other minerals frequently found in the graphitic schists are garnet and cyanite. The schist itself is composed of very fine quartz and muscovite scales with black iron oxides in extremely minute grains. These various minerals are distributed uniformly through the schist.

Several short tunnels and small open cuts have been made in the graphitic schists just north of Graphiteville. From this point northeastward the graphitic rocks have been traced for over 4 miles to and across the Blue Ridge. Within this area numerous test pits and outcrops show the presence of graphite, which, in fact, is present more or less through the entire mass of the schist. The amount of graphite is, therefore, very large, since the synclines containing the schists have great depth and thickness in this region. In Section D (see structure section) is shown the average bulk and position of these synclines of the schists. The schist is the only large and reliable source of the graphite. Although the small quartz stringers contain pure graphite, they are of small body and could not be mined economically.

A mill was erected at Graphiteville for crushing the schist and separating the graphite. Before the mill was completed operations were suspended and practically none of the ore was reduced. Tests of the graphitic schist on the extension of the same belt north of the Blue Ridge were made on a smaller scale. In this case the presence of large amounts of garnet caused suspension of the work. In the use of graphite for lubricating purposes and pencils it is important that the material be perfectly free from grit. The presence of a small amount of garnet in the finished product would be very injurious. If the schist should be ground in the usual manner, difficulty would be encountered in cheaply separating the garnet from the graphite, although there is considerable difference in specific gravity. The elimination of the quartz and muscovite by water would be even harder, since their weights are more nearly that of the graphite. Another difficulty in crushing the rock would be found in the action of the garnet and cyanite. These minerals are very hard and would form abrasives which would continually wear the machinery. In handling the deposit on a large scale these difficulties would have to be solved.

MAGNETITE.

Magnetic oxides of iron are known at seven places within this quadrangle. Most of the magnetite contains also a considerable percentage of titaniferous iron oxide, which renders the ore at present of little value. At two places, 2 miles northeast of Democrat and 2 miles southwest of Turkey Cove, the magnetite is relatively free from the titaniferous oxide. In neither place, however, is the body of ore great. Near Turkey Cove small pits and dip needle tests show that the magnetite extends for nearly a mile in a northeasterly direction. The magnetite forms thin seams and lenses in the Carolina gneiss. The deposit dips northwestward about 80° with the foliation of the inclosing gneiss. The downward extent of the ore deposit is unknown.

Deposits of titaniferous magnetite are found 3 miles north of Burnsville on Jack Creek, 5 miles northwest of Burnsville, one-half mile east of Moores Gap, and in two localities 3 and 5 miles northeast of Sprucepine. The deposit north of Burnsville is the only important one. The ore here is found in the Carolina gneiss, near the contact with the Roan gneiss, and dips southeast nearly 90°. The vein is from 6 to 10 feet wide and appears in two separate openings 75 feet apart. An analysis of this ore shows 9.25 per cent of silica, 39.42 per cent of metallic iron, 11.9 per cent of titanic acid. The depth of this deposit has not been tested.

BROWN HEMATITE.

Workable deposits of brown hematite are found at several points in the Cambrian strata south of Turkey Cove. The ore has been exposed by small open cuts and drifts at three points on Graveyard Mountain, as shown on the economic geology map. Numerous smaller deposits of hematite are found scattered over the surface of the quartzite in the same region. The ore is found associated with the Erwin quartzite in all cases and lies close to fault planes intersecting them. One of the deposits also borders the mass of Shady marble at the south side of Turkey Cove. The ore bodies dip to the southeast at angles ranging from 30° to 40°, corresponding to the dip of the strata. Most of the ore is inclosed in residual sandy clay near the surface. The beds of ore range from a few inches in thickness up to 4 feet or more. In one drift 2½ feet of ore was inclosed between quartzite walls. In one cut the brown hematite was found in close association with quartzite containing pyrite. Still another body of ore of good size at the surface was replaced downward by pyrite. At the North Fork of Catawba there were considerable bodies of ferruginous breccia along the same fault line which passes by the ore bodies. An analysis of ore from the principal bank on the south side of Graveyard Mountain gave 2 per cent of silica, 60 per cent of metallic iron, and .097 per cent of phosphorus. An assay of the titaniferous ore from the same locality showed values of $2 a ton in gold. These ore banks were worked over fifty years ago to supply local forges. Tests have been made of the ores at various times since then, but no considerable work has been done. The ores have the association and appearance of gossans, and their depth is problematical.

CHROMITE.

Chromite is a common constituent in the dunite bodies of this entire region. In five places it is found in quantities sufficient to constitute an ore. These localities are 4 miles north of Burnsville, 6 miles east of Burnsville, 6 miles southwest of Burnsville, and 1½ miles north of and half a mile west of Democrat. The deposits north of Burnsville and near Democrat have been considerably exploited.

The chromite occurs in grains scattered through the mass of the dunite, in which form it is seldom of value. It also forms balls and nodules of various sizes which constitute an ore. Most of these have diameters of only a few inches. One of these larger bodies north of Burnsville was 3 feet in its greatest length. At the locality southwest of Burnsville a large pocket was found containing several tons of ore. There is probably no difference in origin between these two forms of the chromite. North of Democrat a considerable amount of the dunite was explored and much chromite was found in grains and small bunches. Analyses of the chromite give 60 per cent of chromic oxide. A deposit giving promise of value is the one north of Burnsville. At this point various pits and open cuts have been put in, but no systematic attempts have been made to develop the ore. Owing to the usual irregular and pockety nature of the chromite, calculations as to its amount are far from certain.

West of Democrat several test pits and small shafts have been put in within a few months and have exposed considerable ore. The deposit consists of streaks and narrow bands of chromite crystals so grouped in the dunite as to form a kind of vein. This is from 4 to 8 feet wide in one shaft and shows a steep dip to the northwest. The "vein" runs through the open cut and, judged by the heavy wash of chromite sand, is more or less continuous for half a mile northeastward. It is there opened by an open cut showing a smaller "vein" or concentration of the chromite in a group of narrow bands. It is probable that further work would develop a considerable body of ore. The large amount of chromite in the soil would probably repay hydraulic work.

The dunite throughout the chromite areas contains nickel in small amounts, and the combination may be of value at some time in the manufacture of the harder kinds of steel.

BUILDING AND ORNAMENTAL STONE.

Most of the formations of this quadrangle yield stone suited for building. The best is found in the Henderson granite, Cranberry granite, and Erwin quartzite. The latter furnishes an extremely hard, white rock in beds ranging from a few inches up to 2, 3, and 4 feet in thickness. Along the North Fork of Catawba River its ledges descend to the water level, and stone can be readily obtained. In its areas west of the North Fork it is very schistose and much of the stone is unsuitable for building. In fact, the alteration is so considerable in places that the stone becomes a quartz-schist or itacolumite.

Granite.—The two granite formations contain by far the best and most abundant building material. The Cranberry granite is more variable in texture than the Henderson granite, but large quantities of massive, uniform stone can be procured. The rock is gray for the most part, but a few beds are nearly white. On Cane River and its tributaries extensive outcrops of the formation are everywhere found, and sites for quarrying are easily obtained. The Henderson granite yields the most uniform and the most desirable stone of this region. Two kinds of rock are found therein. The formation consists mainly of the porphyritic granite, which is usually schistose or gneissoid. In some localities, especially north and northwest of Marion, and also in Stone Mountain southwest of Old Fort, there are large masses of less schistose and less porphyritic rock. These bodies are usually nearly white and of much lighter color than most of the formation, which is light gray. The porphyritic feldspar crystals give a striking aspect to the rock and render it suitable for ornamental work. The stone can readily be opened along the schistose planes, and split into beds of any desired thickness. It dresses well, and is exceedingly hard and durable. The best localities for quarrying are in the Hickorynut Mountains, 5 or 6 miles south or southeast of Old Fort. In these situations many large outcrops and cliffs of granite reach the surface and the slopes are steep.

Serpentine.—Ornamental stone of great beauty is found in the dunite bodies, where considerable masses have been altered to serpentine. This alteration has taken place on a large scale west of Swannanoa, where the serpentine now constitutes most of the formation. Serpentine is also found in many other areas of the dunite, notably 1 mile north and 3 miles northeast of Democrat, on Ivy River. The color of the serpentine is green, of somewhat darker shade than the green of the dunite. The rock is itself exceedingly tough and strong, and resists weathering admirably. It takes a fine polish, but is difficult to dress. The serpentine mass west of Swannanoa causes low, rounded hills on which the rock outcrops extensively, so that the material is easily available. At that point the formation is cut through by the main line of the Southern Railway.

Marble.—Beds of workable marble are furnished by the Shady formation in the two larger of its areas. While the areas underlain by the marble are large in each of these cases, outcrops of the rock itself are very scarce. The marble is much more rapidly dissolved by circulating waters than the adjoining rocks, so that its surface is low and overspread with wash from the harder formations. The only considerable outcrops are next to the Erwin quartzite at the southerly side of Turkey Cove. In this quadrangle the strata of the formation consist mainly of marble. Most of it is white or light colored, but associated with this variety are beds of white marble with blue bands and numerous dark blue beds. Two analyses of the marble give 52 to 62 per cent of carbonate of calcium, 33 to 41 per cent of carbonate of magnesium, and 1 to 5 per cent of silica. The marble is finely crystalline, but is coarser grained than the limestone from which it is derived.

The lower beds of marble near the Erwin quartzits contain many sand grains and are not suitable for marble. Similar impurities are found in layers lying still higher. Silica is also present in the marble in the form of small grains and nodules of chert, which impair the quality of the stone. Considerable thicknesses of marble remain, however, which are suitable for ornamental stone. The total thickness of the formation shown in this region is over 500 feet. Probably the lower half of this is of little value as marble. The greatest thicknesses are shown at the south side of Turkey Cove. Higher up, on the North Fork of the Catawba, poor exposures render it impossible to tell the thickness of the marble.

No attempts have been made to quarry the marble. At the south side of Turkey Cove the diamond drill has been used, and a considerable thickness of marble has been proved thereby. That locality seems to afford the most available places for quarrying. The marble there rises considerably above the bottom lands of the cove, and both good drainage and hard rock would be afforded. The dip of the strata at that point is southeastward at angles ranging from 30° to 50°. At this angle the quarrying of definite beds of marble would involve handling a great deal of rock. Farther north in the cove it is probable that the dips are considerably less, but the quality of the marble under the bottom lands is unknown. Such outcrops as are found indicate that the marble resists weathering well. Its beds are usually massive and free from joints, so that large blocks could be quarried. Near the Erwin quartzite, where the marble is overturned, some layers have developed a small schistosity. Such beds, however, are comparatively scarce.

The beds of white marble in the Carolina gneiss on Toe River furnish excellent material. An analysis gave 55 per cent of carbonate of calcium and 45 per cent of carbonate of magnesium. Where the marble is exposed by the river and railroad cuts there is a workable bed 70 feet thick, practically all being of pure white color. A pegmatite vein cuts out part of the marble, but is not likely to extend far. The deposit probably extends for a mile northeast of the river and would furnish abundant material. Its dip is nearly south, at angles ranging from 50° to 60°, so that much waste material need not be handled. The rock appears to be free from joints, and its durability and hardness are shown by its massive outcrops.

LIME.

Lime for building and agricultural purposes can well be obtained in this quadrangle only from the beds of the Shady marble. Owing to the distance of these deposits from the railroads, their use for this purpose in the past has been merely local. Considerable quantities have been burned, and the quality of the product has been found excellent. With the advent of a proposed new railroad the lime from this source will become available. On the hillslopes at the south end of Turkey Cove, adjoining the Erwin quartzite areas, are beds from which the rock can be quarried. Here there are considerable outcrops of the marble, and the disposal of waste material and water would be easy. In that locality the waste from marble quarrying could well be utilized for lime. This deposit of marble is the only possible source of lime east of the Blue Ridge and north of Kings Mountain, at the southern border of the State, and lime burned from it should be valuable for agricultural purposes.

BRICK CLAYS.

All of the formations in this region form clays on decomposition. These are of various kinds—argillaceous, sandy, or micaceous—and they extend over most of the valleys and lower portions of the quadrangle. In the mountains the amount of clay on the slopes is very small. In the smaller valleys, throughout the area, however, more or less clay is always found. In the more level portions of the region east of the Blue Ridge the cover of clay and decomposed rock is very thick. The best clay is found in two situations—on the flood plains and terraces of the larger rivers and in the small valleys and hollows on the various plateaus. On most of the streams of this quadrangle, except those some distance southeast of the Blue Ridge, the grades are too heavy to permit the accumulation of clay. On the flood plains of the latter, however, there are extensive deposits. Into the small hollows of the old plateau surfaces, also, the finest portions of the decomposed rock were washed and excellent clay beds were formed. The total amount of this kind of material in the quadrangle is enormous. These clays are from 1 to 6 feet deep, being thickest in the bottoms of the hollows and thinner on the hillslopes. In many places, especially near Marion, these have been burned into bricks for local use.

WATER RESOURCES.

WATER POWER.

Within this quadrangle there are abundant resources in the form of water power. The streams, both great and small, fall rapidly in four-fifths of the area. Since they are fed from multitudes of springs, and drain well-forested areas, their flow is very steady from season to season. The stream grades are divided into three general groups, according to their relations to the large topographic features. These are above, below, or on the old plateau surfaces. As was explained under the heading "Geography," the latter were developed at various heights over about one-fourth of the quadrangle. Above them stood large mountain masses never reduced to the levels of the plateaus.

Since the formation of the plateaus as plains the streams have acquired fresh power and recut their channels to greater depths. The new cuts are greatest in the lower portions of the main stream and are progressively shallower toward their heads. Down the slopes of the mountains the small streams descend with very heavy grades, usually from 100 to 300 feet to the mile. As they pass through the margins of the plateaus they descend more slowly, usually less than 30 feet a mile. When they reach the heads of the newer cut channels they descend more rapidly again, at grades of 20 to 50 feet to the mile. The heads of the newer cuts on all the rivers are found in this quadrangle. Thus, each stream passes through the three stages of development in regard to water power. In no case does the cutting extend back far from the main streams up the tributaries.

The total descent of South Toe River in this quadrangle is about 900 feet in 25 miles, beginning just east of Mount Mitchell. Cane River falls about 1000 feet in 20 miles. Catawba River, which has the lightest grades in the quadrangle, descends 250 feet in 14 miles below Old Fort, where the various branches unite to form a considerable river. The descent is accomplished on Catawba River by numerous small rapids, but flood plains and very low grades are its usual accompaniments. The same is true of Swannanoa and Ivy rivers. On Cane River and both North and South Toe rivers, flood plains are scarce and small, while rapids and little falls are numerous.

There are two areas in which extremely high grades are typical of all streams. The principal one is the southeastern slope of the Blue Ridge, from which the streams descend from altitudes usually over 3000 feet down to plateaus of 1300 or 1400 feet elevation. This drop takes place in a distance of 2 to 6 miles and the resultant grades are the heaviest of the region. The streams which make this descent, however, are only small creeks that head on the Blue Ridge. Of similar origin and character are the heavy falls on Crabtree Creek. This stream descends from the highest plateau, at an elevation of more than 3500 feet, down to North Toe River, at 2450 feet, about 800 feet of this being concentrated into 4 miles.

The water power developed in this region is thus obtained primarily by the elevation and cutting of the old plateau. Since the large streams are nearly all below the plateau levels, those water powers which are above the plateaus are in most cases on small streams and of no great amount. In this quadrangle the rocks are mainly granite and gneiss, which are not widely different in their influence upon the immediate stream grades. Thus there is less than usual of the concentration into falls and rapids due to hard beds of rock. The Henderson granite resists erosion sufficiently to have caused such effects, but its course is not crossed by any considerable stream in this quadrangle. The chief exception to the rule of the region is the Erwin quartzite, whose layers are among the most resistant rocks known. Where the formation is crossed by the North Fork of the Catawba a narrow gorge results, with steep grades and numerous little falls, in strong contrast to the country above and below along the stream.

The enormous water powers thus at hand in the quadrangle have received only the most limited development. Gristmills and a few sawmills have been turned by the small streams, but nothing more. With the advent of railroads and possibilities of electrical transmission the energy developed by the various streams should prove valuable in the future.

WATER SUPPLIES.

The various sources of water in the Mount Mitchell quadrangle furnish a very large supply. The region is almost altogether mountainous and is covered for the most part with a heavy growth of timber. The fall of rain and snow is heavy and the natural advantages for storage are very great. The rocks of the mountain district, particularly northwest of the Blue Ridge, have large numbers of schistose planes and thus are able to hold large quantities of water. The dip of these planes is usually steep and the rainfall is readily conducted into the interior of the rocks. Ample time is allowed for this transfer, for evaporation is checked by the forest growth and by the lower temperatures due to the height of the mountains. The streams rise and fall rapidly in times of flood, but the usual flow is full and steady. Countless springs maintain this flow in spite of occasional droughts. In the mountains, where rock comes close to the surface, most of the springs issue directly from the rock. In the valleys and lower areas the residual soils are from 6 to 50 feet thick. The flow of the springs is largely absorbed by this, and seeps out from the clay in the hollows. Actual springs are very much fewer on surfaces of this kind, which are practically limited to the remnants of the plateaus. As was stated under the heading "Geography," these plateaus are found chiefly along the upper waters of Swannanoa, Cane, Toe, and Yadkin rivers.

Until within a few years the only use made of the enormous outflow of water from this region was for domestic purposes. The houses were built within easy reach of springs, which was usually possible. Here and there shallow wells were sunk in the loose materials, chiefly on the uplands of the plateau surfaces and on the flood plains of streams. Up to this day no wells have been bored in solid rock. A few years ago the headwaters of Beetree Creek, a tributary of Swannanoa River, were dammed in the mountains and conveyed to the neighboring city of Asheville. This supply soon proved inadequate and a dam was constructed to utilize the waters of the North Fork of Swannanoa. From this point just east of Craggy Dome the water is piped to Asheville, a distance of nearly 18 miles. This supply is of the very best quality. The water is seldom turbid, even after the heaviest rain, and a good flow is maintained by the stream, however severe the drought. The situation of the catchment basin is most fortunate, since it drains a compact area of mountains, from 5000 to 6400 feet high, where the forest cover is very heavy and the precipitation unusually great. Except in this place no use has been made of the water supplies in a large way. Supplies similar to that of Swannanoa River are to be found on the heads of Ivy, Cane, and South Toe rivers, all rising on the Black Mountains, while the smaller creeks rising on the south side of the Blue Ridge and the various branches of Cane and Toe rivers furnish almost equally good supplies. The water of Curtis Creek, for instance, could be transported to the town of Old Fort in about 5 miles, or that of Buck Creek could be taken to Marion within 9 miles. Likewise, water from the head of Cane River could be transported to Burnsville in 9 miles or less.

May, 1905.

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

TOPOGRAPHY

NORTH CAROLINA-TENNESSEE
MOUNT MITCHELL QUADRANGLE

LEGEND

RELIEF
(printed in brown)

2676
Figures
(showing heights above mean sea level instrumentally determined)

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

DRAINAGE
(printed in blue)

Streams

CULTURE
(printed in black)

Roads and buildings

Churches and school houses

Private and secondary roads

Trails

Railroads

Tunnels

State lines

County lines

△
Triangulation stations

BM ×
Bench marks

H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr.
Topography by Glenn S. Smith and W. N. Brown.
Surveyed in 1899-1900.

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 Mar. 1902, reprinted Feb. 1905.

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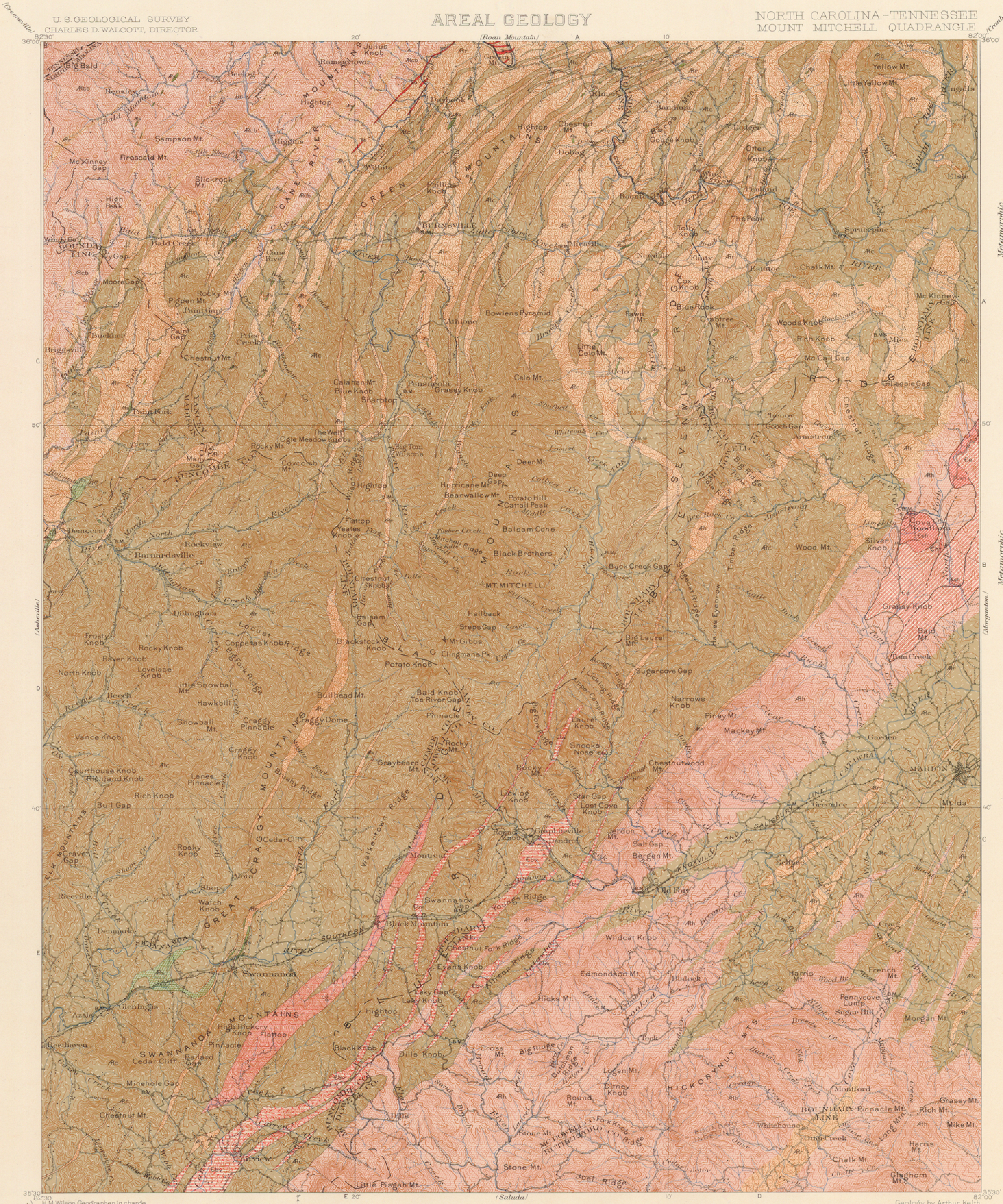
AREAL GEOLOGY

NORTH CAROLINA-TENNESSEE
MOUNT MITCHELL QUADRANGLE



H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr.
Topography by Glenn S. Smith and W. N. Brown.
Surveyed in 1899-1900.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1903.

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 Mar. 1905

Geology by Arthur Keith,
assisted by Hoyt S. Gale.
Surveyed in 1897-1901.

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

- ▨ Ꞓsh — **Shady marble** *(white and blue marble)*
- ▨ Ꞓe — **Erwin quartzite** *(white quartzite)*
- ▨ Ꞓht — **Hampton shale** *(bluish and gray shale)*
- ▨ Ꞓbv — **Brevard schist** *(fine-grained black schist and slate, in places graphitic)*

AGE UNKNOWN

- ▨ cg — **Conglomerate and graywacke** *(with beds of mica-schist)*

Metamorphic

IGNEOUS ROCKS

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

TRIASSIC ?

- ▨ Ŧb — **Bakersville gabbro** *(massive gabbro and diabase)*

ARCHEAN

- ▨ ᴁh — **Henderson granite** *(porphyritic granite and gneissoid granite)*
- ▨ ᴁcb — **Cranberry granite** *(mainly granite and granite-gneiss)*
- 🟩 ᴁs — **Soapstone, dunite, and serpentine** *(altered from peridotite and pyroxenite)*
- ▨ ᴁr — **Roan gneiss** *(chiefly hornblende-gneiss and diorite)*

Metamorphic

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

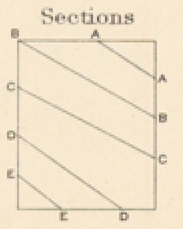
(Areas of metamorphic rocks of unknown origin are shown by hachures)

ARCHEAN

- ▨ ᴁc — **Carolina gneiss** *(chiefly mica-gneiss and mica-schist, includes other gneisses, schists, granite, diorite, and small lenses of marble)*

Faults
——— — —

Sections



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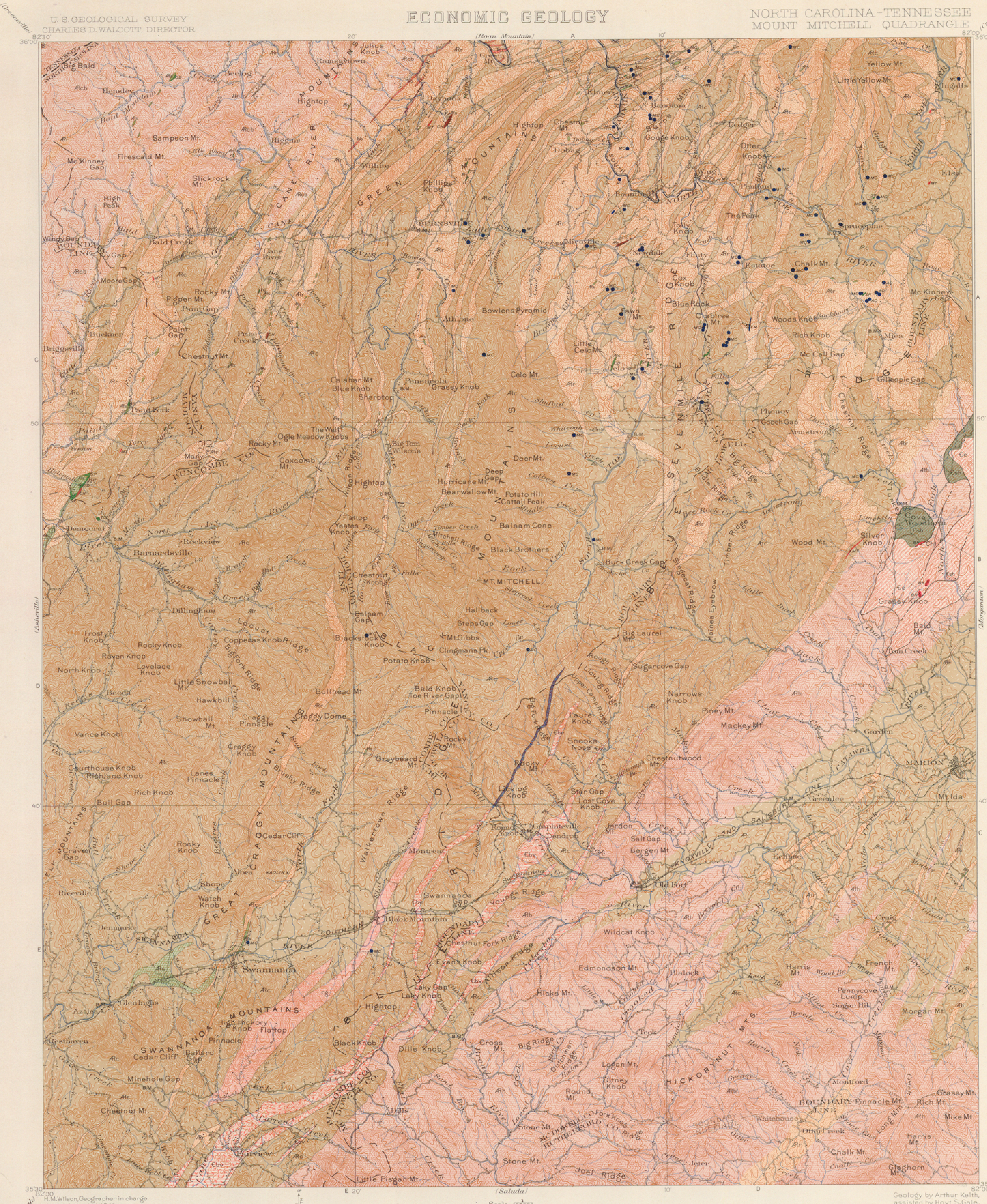
ECONOMIC GEOLOGY

NORTH CAROLINA-TENNESSEE
MOUNT MITCHELL QUADRANGLE



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Scale $\frac{1}{125000}$
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Contour interval 100 feet.
Datum is mean sea level.
Edition of Mar. 1905

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Surveyed in 1897-1901.

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

Ꞓsh — **Shady marble** *(white and blue marble)*

Ꞓe — **Erwin quartzite** *(white quartzite)*

Ꞓht — **Hampton shale** *(bluish and gray shale)*

Metamorphic

Ꞓbv — **Brevard schist** *(fine-grained black schist and slate, in places graphitic)*

AGE UNKNOWN

cg — **Conglomerate and graywacke** *(with beds of mica-schist)*

IGNEOUS ROCKS

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

TRIASSIC ?

Ꞔb — **Bakersville gabbro** *(massive gabbro and diabase)*

ARCHEAN

Ꞓh — **Henderson granite** *(porphyritic granite and gneissoid granite)*

Ꞓcb — **Cranberry granite** *(mainly granite and granite-gneiss)*

Metamorphic

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

Ꞓr — **Roan gneiss** *(chiefly hornblende-gneiss and diorite)*

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

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

ARCHEAN

Ꞓc — **Carolina gneiss** *(chiefly mica-gneiss and mica-schist, includes other gneisses, schists, granite, diorite, and small lenses of marble)*

Faults
——— — —

Sections
B A
C A
D B
E C
E D

⚒ *Mines and quarries*
x *Prospects*

Known productive areas

Graphite *(black schist containing graphite)*

MB — *Marble*

SP — *Soapstone*

EM AQ — *Emerald and aquamarine*

MC — *Mica* *(in pegmatite veins)*

CD — *Corundum-bearing veins*

TC — *Talc*

MT — *Magnetite* *(including titaniferous iron oxide)*

CR — *Chromite* *(deposits in dunite)*

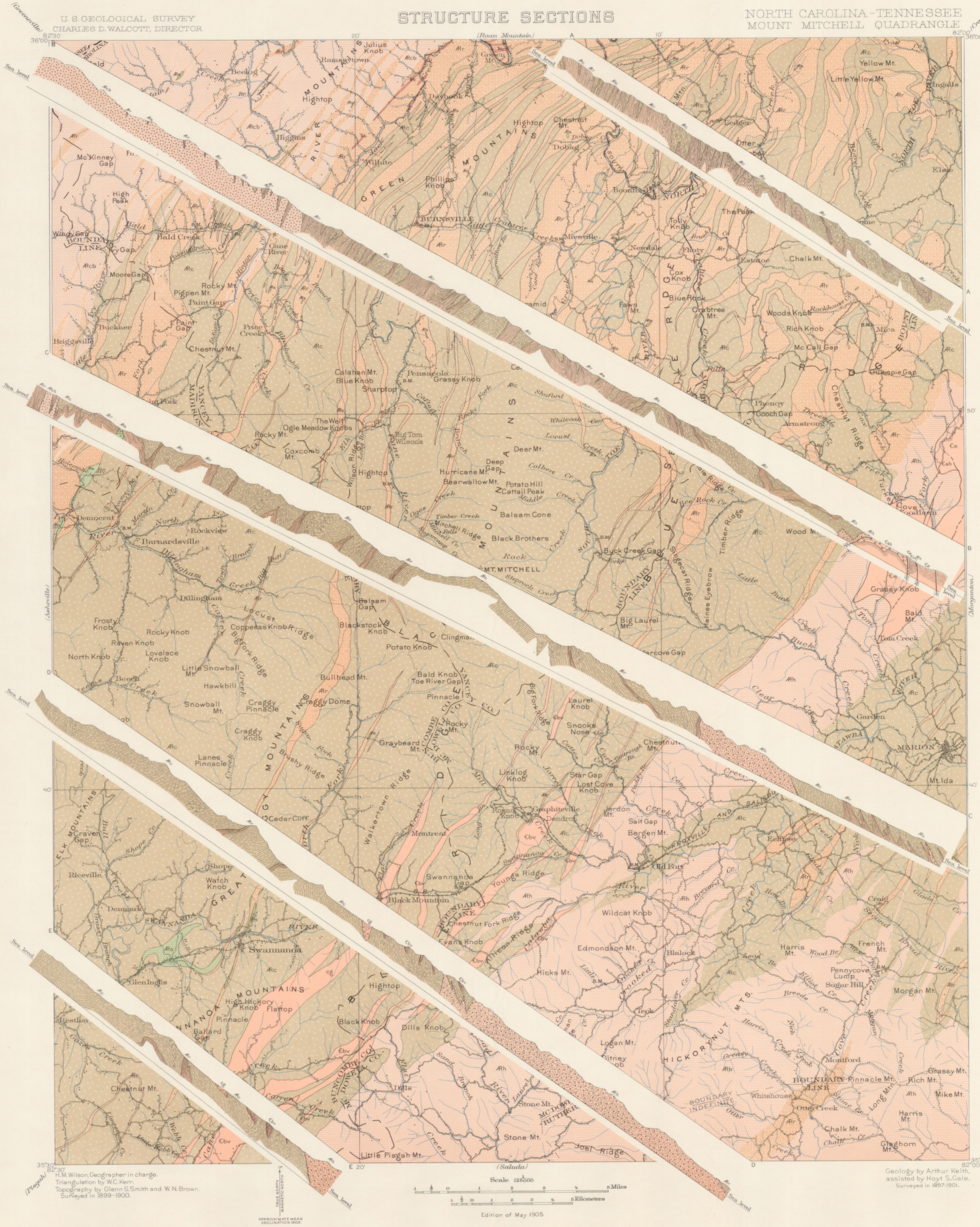
BH — *Brown hematite or limonite*

AS — *Asbestos*

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

STRUCTURE SECTIONS

NORTH CAROLINA-TENNESSEE
MOUNT MITCHELL QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL	SECTION SYMBOL		
Єsh	Єsh	Shady marble *(white and blue marble)*	CAMBRIAN
Єe	Єe	Erwin quartzite *(white quartzite)*	
Єht	Єht	Hampton shale *(bluish and gray shale)*	
Єbv	Єbv	Brevard schist *(fine-grained black schist and slate, in places graphitic)*	Metamorphic
cg	cg	Conglomerate and graywacke *(with beds of mica-schist)*	AGE UNKNOWN

IGNEOUS ROCKS

SHEET SYMBOL	SECTION SYMBOL		
Ѣb		Bakersville gabbro *(massive gabbro and diabase)*	TRIASSIC ?
Ꞓh	Ꞓh	Henderson granite *(porphyritic granite and gneissoid granite)*	ARCHEAN
Ꞓcb	Ꞓcb	Cranberry granite *(mainly granite and granite-gneiss)*	
Ꞓs	Ꞓs	Soapstone, dunite, and serpentine *(altered from peridotite and pyroxenite)*	Metamorphic
Ꞓr	Ꞓr	Roan gneiss *(chiefly hornblende-gneiss and diorite)*	

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

SHEET SYMBOL	SECTION SYMBOL		
Ꞓc	Ꞓc	Carolina gneiss *(chiefly mica-gneiss and mica-schist, includes other gneisses, schists, granite, diorite, and small lenses of marble)*	ARCHEAN

Faults — — —

H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr.
Topography by Glenn S. Smith and W. N. Brown.
Surveyed in 1899-1900.

Scale $\frac{1}{125000}$
1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometers

Edition of May 1905

Geology by Arthur Keith,
assisted by Hoyt S. Gale.
Surveyed in 1897-1901.

COLUMNAR SECTIONS

GENERALIZED SECTION OF THE SEDIMENTARY ROCKS OF THE MOUNT MITCHELL QUADRANGLE.

SCALE: 1 INCH=1000 FEET.

System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Soils and Surface.
	Shady marble.	Ꞓsh	▨	600+	White and blue massive banded marble.	Open, flat valleys. Deep, dark-red, clay soils.
CAMBRIAN	Erwin quartzite.	Ꞓe	▨	600+	Massive white quartzite.	High, rocky mountains. Thin, sandy, and rocky soils.
	Hampton shale.	Ꞓht	▨ SEQUENCE BROKEN		Blue and gray shale and slate.	Valleys and slopes. Light, sandy soils.
	Brevard schist. UNCONFORMITY	Ꞓbv	▨	1000+	Fine-grained black schist and slate, in places graphitic.	Valleys with low knobs and ridges. Thin, micaceous, and sandy soils.
ARCHEAN	Gneisses and granites.		▨		Description given in table below.	Description given in table below.

SECTION IN THE SWANNANOA MOUNTAINS, MOUNT MITCHELL QUADRANGLE.

SCALE: 1 INCH=1000 FEET.

System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Soils and Surface.
AGE UNKNOWN	Conglomerate and graywacke. UNCONFORMITY	cg	▨	750±	Gray feldspathic quartzite, graywacke, and some conglomerate, with beds of gray mica-schist and slate.	High mountains and peaks with cliffs. Thin, rocky, micaceous, and sandy soils.
ARCHEAN	Carolina gneiss.	ARc	▨		Description given in table below.	Description given in table below.

TABLE OF IGNEOUS ROCKS OF THE MOUNT MITCHELL QUADRANGLE, ARRANGED IN ORDER OF AGE.

System.	Formation Name.	Symbol.	Lithologic Symbol.	Character of Rocks.	Character of Soils and Surface.
TRIASSIC ?	Bakersville gabbro.	TRb	▨	Massive black and brown gabbro and diabase dikes and sheets.	Small knobs and butts, with many rock exposures. Yellow and brown clay soils.
ARCHEAN	Henderson granite.	ARh	▨	Porphyritic granite, normal granite, gneissoid granite, and augen-gneiss, usually light colored.	Irregular mountains and plateaus with smooth, rolling surfaces. Thin, light-colored, sandy and clayey soils.
	Cranberry granite.	ARcb	▨	Biotite-granite and granite-gneiss, coarse and fine; colors, light gray, dark gray, and white. Includes dikes of schistose and unaltered diabase, fragments of hornblende-gneiss, and dikes of unaltered, fine biotite-granite.	High, irregular mountains, peaks, and spurs, with round summits. Red and brown clayey soils with many ledges.
	Soapstone, dunite, and serpentine.	ARs	▨	Dunite in part serpentinized. Soapstone contains talc and tremolite.	Yellow clay soils, with many ledges and fragments of rocks.
	Roan gneiss.	ARr	▨	Hornblende-gneiss and hornblende-schist, with some massive and schistose diorite. Includes many beds of mica-gneiss, mica-schist, and hornblende-mica-gneiss, and dikes of altered and unaltered biotite-granite.	Broad plateau surfaces or depressions in Carolina gneiss ridges. Dark-red and brown clay soils.
	Carolina gneiss.	ARc	▨	Interbedded mica-gneiss and mica-schist, coarse and fine, bluish gray and gray. Contains many small beds of hornblende-gneiss, large bodies of garnet-schist and kyanite-schist, and dikes of biotite-granite, both altered and unaltered.	Ridges, peaks, spurs, and high mountains with irregular crests. Red and brown micaceous and clayey soils.

NAMES OF FORMATIONS.

System.	Arthur Keith: Cranberry Folio, U. S. Geological Survey, 1903.	Names and Symbols used in This Folio.		Arthur Keith, Asheville Folio, U. S. Geological Survey, 1905.
Triassic ?	Bakersville gabbro.	Bakersville gabbro.	TRb	
CAMBRIAN	Shady limestone.	Shady marble.	Ꞓsh	Shady limestone.
	Erwin quartzite.	Erwin quartzite.	Ꞓe	Hesse quartzite.
	Hampton shale.	Hampton shale.	Ꞓht	Murray slate.
		SEQUENCE BROKEN		SEQUENCE BROKEN
		Brevard schist.	Ꞓbv	? Hiwassee slate.
?		Conglomerate and graywacke.	cg	
ARCHEAN	Blowing Rock gneiss. ?	Henderson granite.	ARh	
	Cranberry granite.	Cranberry granite.	ARcb	Cranberry granite.
	Soapstone.	Soapstone, dunite, and serpentine.	ARs	Soapstone, dunite, and serpentine.
	Roan gneiss.	Roan gneiss.	ARr	Roan gneiss.
	Carolina gneiss.	Carolina gneiss.	ARc	Carolina gneiss.

ARTHUR KEITH,
Geologist.

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		TR	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	€	Brick-red.
	Algonkian		A	Brownish-red.
	Archean		AR	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:

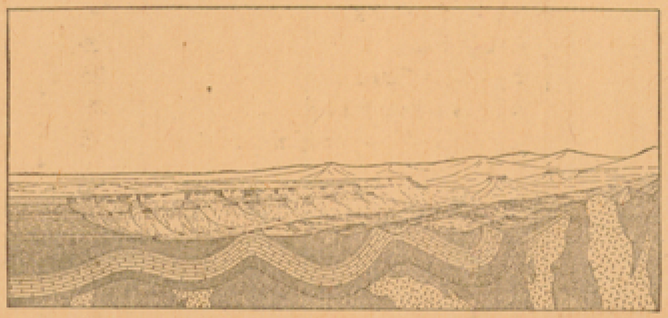
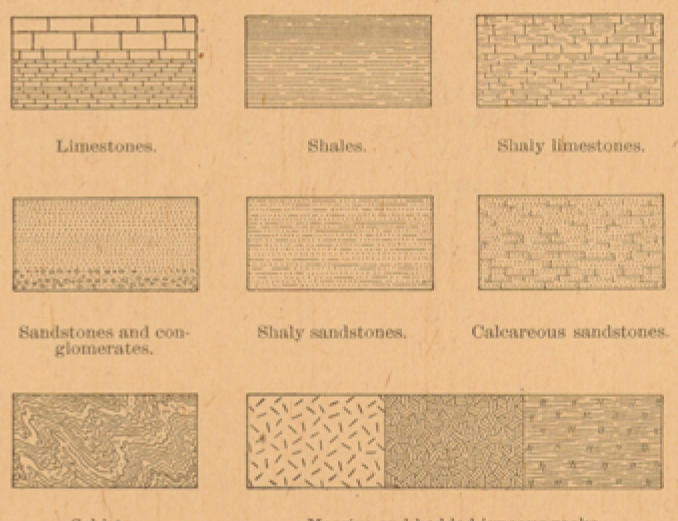


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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:



Limestones.

Shales.

Shaly limestones.

Sandstones and conglomerates.

Shaly sandstones.

Calcareous sandstones.

Schists.

Massive and bedded igneous rocks.

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

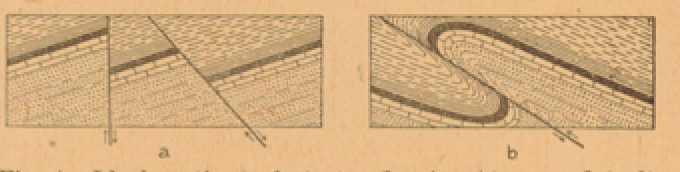


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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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111	Globe	Arizona	25
112	Bisbee	Arizona	25
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118	Greeneville	Tennessee-North Carolina	25
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