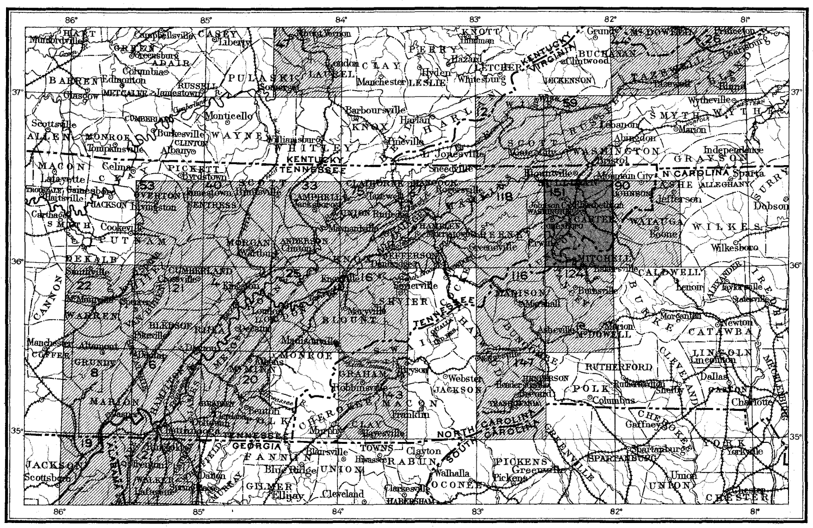
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

ROAN MOUNTAIN FOLIO

TENNESSEE-NORTH CAROLINA

INDEX MAP



SCALE: 40 MILES = 1 INCH

▆ ROAN MOUNTAIN FOLIO

▨ OTHER PUBLISHED FOLIOS

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GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

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

THE TOPOGRAPHIC MAP.

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

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

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

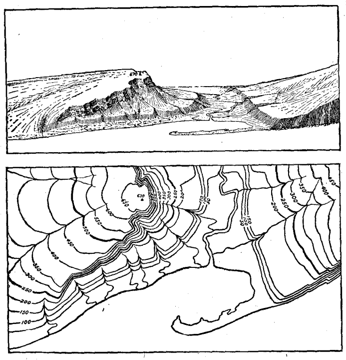


FIG. 1.—Ideal view and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

(Continued on third page of cover.)

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

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

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

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

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

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent Pleistocene	Q	Brownish-yellow.
	Tertiary	Pliocene Miocene Oligocene Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		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	Є	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:

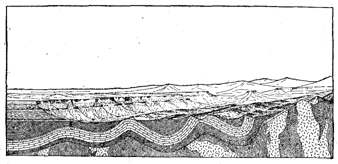
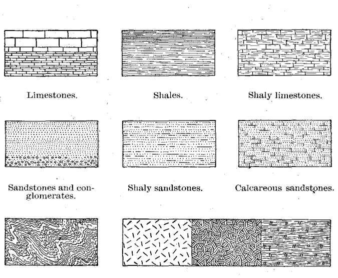


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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.

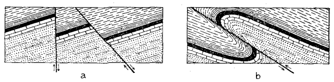


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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.

DESCRIPTION OF THE ROAN MOUNTAIN QUADRANGLE.

By Arthur Keith.

GEOGRAPHY.

GENERAL RELATIONS.

Location.—The Roan Mountain quadrangle lies mainly in Tennessee, but about one-fourth of its southern part is in North Carolina. It is included between parallels 36° and 36° 30′ and meridians 82° and 82° 30′, and contains about 963 square miles, divided between Washington, Sullivan, Carter, and Unicoi counties of Tennessee and Yancey and Mitchell 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, the Allegheny Mountains, and the lowlands of Tennessee, Kentucky, and Ohio. Its northwestern boundary is indefinite, but may be regarded as an arbitrary line coinciding with the eastern boundary of the Mississippi embayment as far up as Cairo, and then crossing the States of Illinois and Indiana. Its eastern boundary is sharply defined along the Appalachian Valley by the Allegheny Front and the Cumberland escarpment. The Cumberland Plateau, Allegheny Mountains, and associated plateaus are called the Appalachian Plateau. The rocks of this division are almost entirely of sedimentary origin and remain very nearly horizontal. The character of the surface, which is dependent on the character and attitude of the rocks, is that of a plateau more or less completely worn down. In the southern half of the province the plateau is in places extensive and perfectly flat, but it is more commonly 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, but south of New River all except the eastern slope is drained westward by tributaries of the Tennessee or southward by tributaries of the Coosa.

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

DETAILED GEOGRAPHY OF THE QUADRANGLE.

Geographic divisions.—Two of the major divisions of the Appalachian province are represented within the limits of the Roan Mountain quadrangle. The Appalachian Valley occupies about 350 square miles in the northwestern part of the quadrangle, the remainder being covered by the Appalachian Mountains. The Valley area lies on the southeastern border of the great Appalachian Valley, which stretches for hundreds of miles northeastward and southwestward. In this quadrangle the Valley is very irregular in outline and contains several ranges, such as Holston and Buffalo mountains, which project from the main mountain mass. The Mountain area consists of a group of ranges designated by the general term Unaka Mountains, which border the Valley with a general northeasterly course. These ranges are cut at many points by stream gaps and include Holston, Iron, Stone, Unaka, Buffalo, Cherokee, and Bald mountains. Southeastward from these ranges, trending toward the Blue Ridge, extend various cross ranges, such as Roan, Yellow, and White Rocks mountains. The Blue Ridge lies only 3 miles from the southeast corner of the quadrangle, so that the mountain mass is narrower here than at any other portion of North Carolina. From the Great Valley it is less than 40 miles across the Mountains to the Piedmont Plateau.

Drainage.—The entire region is drained by tributaries of Tennessee River—Watauga, Doe, Nolichucky, and South Fork of Holston rivers. The drainage basin of Doe River is almost entirely within this quadrangle, but the others have far distant sources and receive here a very small proportion of their water. The rivers flow, in general, northwestward through both Mountains and Valley. The courses of the creeks are generally northeast and southwest, being in the main adjusted to the beds of hard and soft rocks. This is notably the case where the Cambrian quartzites and limestones underlie the surface. Nolichucky River (called the Toe in North Carolina) and its tributary the North Toe fall in this quadrangle from 3000 down to a little less than 1500 feet above sea. Watauga River descends in this quadrangle from about 1800 feet to a little below 1300 feet. South Fork of Holston River falls from about 1500 feet nearly to 1200 feet. Doe River falls from 5500 feet to 1500 feet and its grade is characteristic of the large creeks in this section. The grades of the other rivers are those generally prevailing in the Mountains. All the rivers leave the border of the Mountains at 1500 to 1600 feet above sea. Their subsequent grades are exceptionally steep for rivers in the limestone districts, and not far below the Mountains they descend through narrow canyons where erosion is most active.

Topography.—There are many differences in the surface forms of this quadrangle. The variations in the topography result largely from the varying influence of erosion on the different formations. Such rock-forming minerals as carbonates of lime and magnesia, and, to a less extent, feldspar, are removed in solution by water. Rocks containing these minerals in large proportions are therefore subject to decay by solution, which disintegrates the rock and leaves the insoluble matter less firmly united. Frost, rain, and streams break up and carry off this insoluble remainder, and the surface is thus worn down. According to the nature and amount of the insoluble matter, the rocks form high or low ground. Calcareous rocks, of which the least residue remains, occupy the low ground. Such are the various limestones and many of the shale formations. Most of these rocks leave only a fine clay after solution. The Shady limestone and Knox dolomite leave also, besides the clay, a large quantity of silica in the form of chert, which strews the surface with lumps and retards the process of removal. The upper layers of the dolomite contain less chert, and the surface which they form is further reduced than the lower part of the dolomite. The least soluble rocks are the quartzites, sandstones, and conglomerates and since most of their mass is left untouched by solution, they are the last to be reduced in height. An apparent exception to this rule is formed by the Cranberry granite, for it contains much soluble matter in feldspar, and yet maintains great heights. For this result, the immense mass of the formation and the insolubility of its quartz are largely responsible.

Erosion of the sedimentary formations has produced a series of long ridges separated by narrow valleys that closely follow the belts of rock. This structure is conspicuously notable in the limestone valleys and quartzite mountains near Erwin and Hampton, and is shown in figs. 10 and 12 of the illustration sheets. Where the formations spread out with a low dip the valleys and ridges are broad, and where the strata dip steeply the valleys are narrower. The sharp crests formed by vertical quartzites are seen in Gap Creek and Little mountains. In Stony Creek valley the gently dipping quartzites have produced very irregular crests and spurs. Each turn in the course of the formation can be seen by the turn of the ridge or valley which it causes. This is well shown in Cherokee and Buffalo mountains and Limestone Cove. Each rock produces a uniform type of surface so long as its composition remains the same, but with each change in composition the surface changes form. The limestones have disappeared through solution over much of each valley floor. Near the sandstone and quartzite mountains the residual clays of limestone have been swept over with waste from the mountain-making rocks. This material forms the terraces and flood plains along the streams that enter Nolichucky and Watauga rivers from both sides. North Indian Creek and Stony Creek, in particular, have brought out from the quartzite mountains enormous gravel deposits which almost entirely cover up the limestone. These form the flat floors of the valleys seen in figs. 10 and 12. The smaller streams form similar but lesser deposits curving outward from the quartzite ridges. Deposits of the same nature are seen on all the creeks which flow away from the hornblende gneiss of Roan and Yellow mountains.

The quartzite mountains differ greatly in shape from the ranges formed by the granites and gneisses. Most of the crests formed by the quartzites are sharp and narrow (see fig. 12), but where the quartzite beds lie nearly flat the summits are broad and gently sloping. As a rule the summit of the mountain follows one hard bed for a considerable distance in a nearly straight line and then offsets to another. Rock ledges and cliffs are common throughout the extent of the quartzites, as is shown in figs. 4 and 14. The river courses through these rocks in particular are narrow gorges lined with cliffs hundreds of feet in height. The channels of the streams in the quartzite regions lie in wild, rocky, V-shaped gorges like those shown in figs. 4 and 11. The quartzite ridges are from 1000 to 3000 feet above the valleys and present steep, wall-like fronts, of which the north slope of Holston Mountain is a very striking example.

The mountain crests of the granites and the gneisses are much more irregular than those of the quartzites, since there are no specially hard beds to control their direction. The divide of White Rocks and Walnut mountains is a good example of this feature. In the Yellow Mountains, also, the independence of the crests and hard beds is apparent. The summits formed by the granites and gneisses do not differ greatly from each other. Most of them are smooth and rounded, but here and there ledges protrude and a few cliffs appear. The cliffs of Roan gneiss in Roan High Bluff and of Beech granite in Little Rock Knob and White Rocks Mountain are among the few conspicuous ones formed by granite or gneiss. Big Yellow Mountain and Roan High Knob (see fig. 5) are typical of the broad and rounded summits.

All the mountains of this quadrangle are of good height, and some are among the highest in the Appalachians. The quartzite mountains are from 2500 to 5200 feet above sea. The highest are Unaka Mountain, 5258 feet; Flattop, 4954; Holston Mountain, 4350; and Pond Mountain, 4300. The granite and gneiss mountains are from 2500 to 6300 feet above sea. The highest are Roan High Knob, 6313 feet; Roan High Bluff, 6287; Grassy Ridge Bald, 6200; Big Yellow Mountain, 5600: Little Yellow Mountain, 5400. Most of the area underlain by gneiss and granite lies above 3000 feet.

The topography of the Great Valley is of only one kind. Its surface consists of a series of long parallel ridges and lines of hills separated by narrow valleys. Its typical character is illustrated in fig. 16. The valley floors are in the main from 1500 to 1700 feet above sea, and the ridges rise from 100 to 300 feet higher. Into this general surface the rivers and larger creeks are lowering their courses in narrow canyons, which range in depth up to a maximum of 400 feet where Holston River leaves the quadrangle. Thus the Valley here consists of a plateau, whose surface is undulating and somewhat cut into by later stream canyons. The narrow valleys between the mountains, like those near Hampton and Erwin (figs. 10 and 12), correspond with the general plateau surface at a distance from the mountains. Thus North Indian Creek flows on this surface from Limestone Cove to its mouth near Erwin, and below that point Nolichucky River flows nearly on it for 6 miles. The plateau surface near the mountains has a very perceptible grade on account of the abundant waste from the quartzites. Farther downstream, in the Greeneville quadrangle, the Nolichucky Canyon steadily increases in depth. The same features appear along Watauga River below Hampton. These canyons have not greatly modified the general surface of the Valley. The minor valleys are shallow and open and the ridges more or less rounded, according as the underlying formation is limestone or shale.

GEOLOGY.

GENERAL GEOLOGIC RECORD.

Nature of the formations.—The formations which appear at the surface of the Roan Mountain 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 of Archean and Algonkian (?) age, including gneiss, schist, granite, diorite, and similar formations; and (2) sedimentary strata, of Cambrian and Ordovician age, including conglomerate, sandstone, shale, limestone, and their metamorphosed equivalents. The older of these groups occupies the greater area, and the younger the lesser. The materials of which the sedimentary rocks are composed were originally gravel, sand, and mud, derived from the waste of older rocks, and the remains of plants and animals. All have been greatly changed since their deposition, the alteration being so profound in some of the older gneisses and schists as to destroy their original nature.

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

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

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

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

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

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

These strata comprise conglomerate, sandstone, slate, shale, limestone, and allied rocks in great variety. They were far from being a continuous series, for the land was at times uplifted and areas of fresh deposits were exposed to erosion. The sea gradually advanced eastward, however, and land areas which furnished sediment during the early Cambrian were covered by later Paleozoic deposits. The sea occupied most of the Appalachian province and the Mississippi basin. The area of the Roan Mountain 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 farther 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, so far as determinable, the thickness of each formation exposed in the quadrangle.

DESCRIPTION OF THE FORMATIONS.

ROCKS OF THE QUADRANGLE.

The rocks exposed at the surface in the Roan Mountain quadrangle are of three great classes—metamorphic, igneous, and sedimentary. The sediments occupy the northwestern two-thirds of the quadrangle in a continuous area. The metamorphic rocks occur in the southeastern part of the quadrangle, occupying about 10 per cent of its area. Between the others lie the igneous rocks in a broad belt. The rocks range in age from the oldest in the Appalachians well into the Paleozoic, including Archean, Algonkian (?), Cambrian, Ordovician, and Triassic (?). The Archean is represented by a few of its principal formations and the Algonkian (?) appears in many small and discontinuous beds. The Cambrian is represented by many formations, with a full sequence from oldest to youngest. The Ordovician is seen in only a few of its lower formations. The sedimentary formations include the chief varieties of that class of rocks; the igneous and metamorphic rocks appear in only a few kinds.

These rocks are present in six general areas—two of sedimentary, three of igneous, and one of igneous and metamorphic origin. The Valley and its projections into the Mountain area are underlain by calcareous rocks of Ordovician and Cambrian age. These include the Shady limestone, Nolichucky shale, and subsequent formations. In the mountains which border the Valley is a belt of lower Cambrian quartzites about 10 miles wide, composed of many interrupted areas. Southeast of this belt lies the broad mass of Archean granites, which are bordered in the southeastern part of the quadrangle by the Archean gneisses. In the extreme southern part of the quadrangle are numerous small bodies of igneous rocks of probable Algonkian age. The older rocks in the southeastern part of the mountains are cut by many small dikes of gabbro and diabase, of probable Triassic age.

ARCHEAN ROCKS.

CAROLINA GNEISS

Distribution.—A number of narrow bands of the Carolina gneiss are present in the southeastern part of the quadrangle. Most of these are separate and parallel bands which come together in larger areas in the adjoining Mount Mitchell quadrangle. In reality, they form one large mass penetrated by many bodies of the different igneous rocks. The formation is named for its great extent in North and South Carolina, and is the oldest in this region, since it is cut by the igneous rocks, which in turn are overlain by the sediments. Inclosed within its areas are some igneous and metamorphic rocks. These are too small to be shown on the map, but 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 these are light or dark gray in color, weathering to a dull gray and greenish gray. By far 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 various minerals are segregated into layers, either singly or in combinations, thus producing a gneiss with a marked banded appearance. This rock generally has more feldspar than schist.

In the Mount Mitchell quadrangle, lying south of this, rocks of sedimentary origin, such as limestone, are interbedded with the Carolina gneiss. In that region also other sedimentary rocks appear to grade into the gneiss. It is thus probable that some of the Carolina gneiss is of a sedimentary nature, and the possible origin of the rock 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 hornblende gneiss, precisely like the Roan gneiss, and of the same origin, which constitute a transitional zone between the formations. For this reason, the boundary between these gneisses is indefinite at many places on the ground.

Garnet and cyanite gneiss.—Many beds of the Carolina gneiss are characterized by the presence of garnet crystals. These are in the main small and rounded, few of them exceeding one-fourth inch in diameter. They are more common near the bodies of Roan gneiss, but are not limited to that situation. For the most part the garnets follow roughly along some bands of the gneiss rather than others, but in the schists the garnets are evenly scattered through the rock. In the Cane Creek Mountains cyanite is associated with the garnet gneiss. This mineral occurs along bands in the gneiss and is mostly of a pale-gray color. Its crystals are about half an inch in length as a rule, and are of irregular form. In adjoining regions neither the garnet nor the cyanite shows the effects of the earliest metamorphism of the gneiss, and accordingly they are among the later or secondary minerals.

Granite-gneiss.—The granitoid layers of the gneiss contain quartz and feldspar, with a little muscovite and biotite. These micas are sparse in the light-colored layers. The granitoid layers and the schist alternate in beds of a few inches to a foot or two in thickness. Layers similar in arrangement and varying from 0.1 to 1 inch in thickness compose the banded gneiss. In the granitoid layers the minerals are much less distinctly parallel than in the schists and gneiss, depending largely on the amount of mica in the rock.

Pegmatite.—Included in the area of the gneiss are numerous veins or bodies of pegmatite. These occur in the shape of lenses, ranging in thickness from a few inches up to 20 feet. Some of the largest of the lenses can be followed for about a mile; smaller ones, however, can not be traced surely beyond the immediate outcrops. It is not practicable to represent them separately on the map, although they are of later date than the inclosing gneiss. For the most part, they lie parallel to the foliation of the gneiss, but in places they cut the gneiss abruptly. They appear to have been deposited from solutions, after the manner of veins. These pegmatites are most conspicuous near the contacts of the Roan and Carolina gneisses, but they occur also in other localities. They consist chiefly of very coarsely crystallized feldspar, quartz, biotite, and muscovite. Crystals of orthoclase feldspar and of mica have been found over 2 feet in dimensions. Many rare and valuable minerals occur in the pegmatite bodies of this quadrangle, including beryl, tourmaline, garnet, and cyanite. In the Mount Mitchell quadrangle, a few miles south of Bakersville, the pegmatite masses contain chromite, samarskite, and uraninite, which furnish ores of some of the rarer metals, including radium. Much merchantable mica has been procured from these pegmatites in the area between Bakersville and Plumtree. This is the northeastern part of the principal mica-producing district of North Carolina.

Metamorphism.—On account of the uniform aspect of this formation over large areas no true measure of its thickness can be obtained. Apparently the thickness is enormous, since it has been increased many times by the folding and great metamorphism to which the gneiss has been subjected. The original nature of this rock is uncertain; it is possible that much of the mass was once a granite. Some of the material has a granitic character now, and in many places similar schists are derived from granite. 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 adjoining gneisses near Toe River 2 miles south of this quadrangle—are doubtless of sedimentary origin. It is likely that still other sedimentary masses have not been recognized in the Carolina because of their total metamorphism and similarity to rocks of igneous origin.

Whatever may have been 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 later period the pegmatite bodies were formed. These were thoroughly mashed by the second deformation, and their original coarseness was greatly diminished. In the greater part of the formation excessive metamorphism has destroyed the original attitudes and most of the original appearance of the rock. The rocks of the formation are now composed entirely of the metamorphic minerals. These are usually arranged with their larger 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 shown more strongly by the micas than by other minerals the coarse and granitoid layers are less schistose and the mica schists most so. Fig. 7 shows the banding of the gneiss and the great folding to which it has been subjected.

Decomposition.—The planes of schistosity of the various layers afford easy passage for water, and the rocks are deeply decayed. After decomposition has destroyed the feldspar, the resultant clay is filled with bits and layers of schist, quartz, and mica. Solid ledges are uncommon far from the stream cuts and the steeper slopes. A few large ledges and cliffs appear along the higher mountain crests. 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 in general not heavy, even in the areas of gentle slope. 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 timber.

ROAN GNEISS.

Distribution.—Areas of the Roan gneiss are limited to the southeastern part of the quadrangle. They form one large general area into which many narrow tongues of the Carolina gneiss project from the southwest. This general area diminishes abruptly into narrow bands toward the southwest, in the Mount Mitchell quadrangle; and a short distance to the northeast, in the Cranberry quadrangle, the Roan is cut off by the Cranberry granite. The formation receives its name from Roan Mountain, which is situated in this quadrangle, on the State boundary.

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. However, the rocks included in the Roan are less altered as a whole than the Carolina gneiss, and so appear to be younger. Narrow dikelike bodies of the Roan in the Carolina support this view, some of the rock in these narrow bands being plainly of a dioritic and 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 were originally dikes cutting the Carolina gneiss.

Character.—The Roan gneiss consists of a great series of beds of hornblende gneiss, hornblende schist, and diorite, with some interbedded mica schist and mica gneiss. The hornblendic beds are dark greenish or black in color, and the micaceous beds are dark gray.

The mica-schist and mica-gneiss beds range in thickness from a few inches to 50 or 60 feet, and are most abundant near the Carolina gneiss, with which they are interbedded in a zone of transition. This interbedding is doubtless due in part to the close folding that the formations have undergone, a relation that can be seen in some of the smaller beds. It is also probable that much of it is due to the intrusion of many separate dikes 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.

The hornblendic rocks vary in thickness from mere seams measuring an inch or two up to great masses thousands of feet thick. The hornblende schist makes up a large share of the formation and is interbedded with hornblende gneiss throughout. The schist is most prominent west and northwest of Bakersville. It consists almost entirely of hornblende in crystals from one-tenth to one-half inch long, with a very small amount of biotite, feldspar, and quartz. The hornblende gneiss is composed of sheets of the hornblende schist interbedded with layers or sheets of quartz or feldspar. In places these layers are very regularly disposed and give a marked banding to the rock, as can be seen in fig. 8. A common accessory mineral is garnet, which occurs in both Roan and Carolina gneisses near their contacts. Few of the garnets are larger than a quarter of an inch in diameter and most of them are much smaller. The included beds of mica schist and mica gneiss are exactly like the micaceous parts of the Carolina gneiss, containing quartz, muscovite, biotite, and more or less feldspar.

Here and there the hornblende, feldspar, and quartz have the texture of diorite or gabbro. Some of these beds are very coarse and massive, as along the northern slopes of Big Yellow Mountain and Grassy Ridge Bald. Intermediate types of finer grain and more schistose character are to be found near North Toe River above Plumtree. Many parts of the gneiss, 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 that occur throughout the Roan gneiss areas. So thorough is their alteration, however, that such an origin is not certain. At many points in the Roan gneiss there are veins and lenses of pegmatite of later growth, precisely similar to those described under the Carolina gneiss. As a rule, however, they do not equal the Carolina pegmatites 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 in the main 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 planes of schistosity 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 foliation, and a second folding the foliation planes and minerals. During or before the second deformation many of the bands of quartz and feldspar in the gneiss appear to have been formed. The total alteration is extreme.

Still later alteration consists of the recrystallization of the gneiss minerals into epidote, hornblende, and quartz. These occur in small lenses and patches, replacing the earlier minerals more or less thoroughly. The lenses are associated with veins of epidote and the minerals of this class have not been metamorphosed.

Weathering.—Reduction of the surface of the formation is begun by 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 and greatly retard erosion. In this region the formation is about equally resistant with the Carolina gneiss and Cranberry granite. This change from its habit farther southwest is due to its greater masses here and its slightly more siliceous composition. Still farther northeast the Roan gneiss becomes the principal mountain-making formation. The clays accumulating on this formation are usually 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 land well drained and yet the clayey nature of the soil prevents serious wash. Cultivation is extensive, even in situations difficult of access.

SOAPSTONE, DUNITE, AND SERPENTINE.

Distribution.—Within this quadrangle there are six areas of soapstone, dunite, and serpentine—an unusually small number for so large an Archean district. None of these areas is over a quarter of a mile in length; and most of them are much less. All but two are surrounded by the Roan gneiss, and association with this gneiss is the rule in this region.

Relations.—The rocks of this class 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 rocks of the soapstone class in other situations the difference in age can not be considered great. The alteration of the soapstones is as great as that of the Roan gneiss and exceeds that of the Cranberry granite. Thus the soapstones appear to share in the earlier period of metamorphism which involved the Roan and Carolina gneisses, and are accordingly 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 the dunite. This rock is composed almost entirely of olivine in small, somewhat rounded grains of a yellowish-green color. Here and there it is altered to serpentine of a darker green color. This change may appear in considerable masses of the rock or in small patches or seams, and is very irregular in its distribution. Soapstone occurs south of Bakersville, where it is of a light-gray color and composed mainly of talc and chlorite. Small bodies of similar soapstone are found in places at the borders of the dunite masses.

Many minor deposits of minerals are contained in the formation. Nickel ores form thin seams and coatings between blocks of the dunite, and thin seams and veins of pure fibrous talc are present here and there. Asbestos also occurs in the shape of small veins and irregular rounded crusts between portions of the dunite. These are found a mile and a half east of Bakersville and at Frank, on North Toe River. Chromite is present in scattered grains and irregular beds and seams. The chromite appears to have been one of the original minerals of the rock, but the others are of later origin. Corundum is also found sparingly in association with the dunite at a few points. In this quadrangle neither of these associated minerals is of much economic importance.

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 soapstone 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. 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. The dunite appears to be one of the least metamorphosed rocks of the region. It is quite possible, however, that the olivine has been recrystallized. Serpentine, which is a common alteration product of the dunite, is not due to the same metamorphism as the schistosity 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 show many ledges. In some places almost the entire area of the formation is bare rock, as can be seen just south of Bakersville, in the Mount Mitchell quadrangle. Serpentine and dunite are not much affected by solution, but break down under the direct action of frost and in general occupy low ground. The soapstone outcrops much less and disintegrates more than the other varieties. Final decay leaves a cover of stiff yellow clay of little depth and much interrupted by rock.

CRANBERRY GRANITE.

Distribution.—The Cranberry granite lies in a broad belt from 5 to 15 miles wide between the Cambrian sedimentary rocks and the Roan gneiss. The southwestern portion of the granite fingers into the gneiss in several narrow bands, so that the width of the granite mass along Cane River is much less than is common in this region. The granite extends southwestward through the Asheville and Mount Guyot quadrangles and northeastward far into Virginia. It is typically developed in the vicinity of Cranberry, from which it receives its name.

Relations.—The Cranberry granite consists of massive granite of varying coarseness and color and of schist and granitoid gneiss derived from granite. Included within the areas mapped as Cranberry granite are small or local bodies of schistose basalt, metadiabase, metarhyolite, pegmatite, dikes of fine granite and of diabase, and small included masses of Roan and Carolina gneisses. The metadiabase and metarhyolite are eruptive in the granite and undoubtedly correspond in age to similar but larger masses in this and the Cranberry quadrangles. The metarhyolite occurs in the shape of sheets and dikes ranging from a few inches to a few feet in thickness. These are very numerous in Yancey County south of Flattop Mountain and in a belt passing thence northeastward nearly to Doe River. Few of these are of sufficient size to represent on the map and they can not be traced connectedly. In many places it is difficult to decide whether or not to represent the included bodies of Roan and Carolina gneisses. These are cut repeatedly by the Cranberry granite dikes, and the different rocks, which vary from a few inches up to many feet in thickness, alternate with great frequency. In only a few places do the boundaries shown on the map represent a single contact between two large masses, but rather they indicate a narrow zone beyond which the one rock or the other predominates. Some areas shown as gneiss may contain many small masses of granite, while others may be substantially all of 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 gneiss 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, quartz being next in importance. Minor accessory minerals are magnetite, pyrite, ilmenite, garnet, and epidote. In Yancey County, east of Little Bald, hornblende is common in the granite, but in other localities it 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 aspect is seen mainly in the southwest corner of the quadrangle and around Limestone Cove. 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 fine-grained, narrow dikes penetrating the gneisses. With an increase in the amount of biotite the color of the rock becomes dark gray. This is the case in the granites along Nolichucky River near the State boundary. Locally the feldspars of the granite are so filled with iron oxide that the rock has a marked red appearance. With this variety in many places epidote is associated in small veins and segregated masses. The red granite is very prominent along Doe River from Roan Mountain station to Fork Mountain, but little of it is seen elsewhere.

Metamorphism.—During the crustal movements that affected this region the granite suffered great changes, both by deformation and by metamorphism, the latter being much more conspicuous. When the rock was deformed planes of fracture and motion were produced in the rock mass and along these planes metamorphism took place. As the process went on the quartz was broken and recemented; 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 attitude over large areas. In but few places do the schists show secondary folding and nowhere any of the close wrinkling so common in the schists of the Carolina gneiss. The resulting forms vary from rocks with no change, or with mere cleavage, to those completely altered into siliceous schists and gneisses. The latter are more common near the borders of the formation than elsewhere. Thin parallel layers and striations composed of different minerals are abundant and the most schistose rocks bear little resemblance to the original granite. The thin sheets of metarhyolite which cut through the granite have been extremely metamorphosed. The original flow banding is now to be seen in few places. Here and there pink feldspar crystals occur, but most of the rock is a fine black schist, composed chiefly of quartz and muscovite with a sprinkling 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, such as are seen in Ripshin Ridge and Doe River gorge. The finer phases, 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 granite 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 granite occupies high ground on account of the great mass of its insoluble materials. Notable instances of this are Little Bald and Ripshin Ridge. In general, the granite forms knobs and mountains without definite system, whose crests and slopes are as a rule smooth and rounded. Many parts of its area are cultivated and the soils are light loams of moderate depth and strength.

BEECH GRANITE.

Distribution.—The Beech granite occurs in one large and two small areas in this quadrangle. The large area, in White Rocks Mountain, is the west end of the large area in the adjoining Cranberry quadrangle in which is situated Beech Mountain, from which the formation was named. The two small bodies are not connected with the main mass, but they exhibit the same rock types and the same relations to the Cranberry granite. They are accordingly considered to be the same formation.

Character.—The Beech consists mainly of coarse granite, commonly porphyritic and in few places fine grained. Porphyritic crystals of orthoclase feldspar an inch or more in length are abundant. The rock is composed mainly of orthoclase and plagioclase feldspar. With this are much quartz and biotite and a very little muscovite. In the porphyritic varieties, which constitute the bulk of the formation, the feldspars make by far the greatest part of the rock, giving it a dull whitish or gray color. Biotite is more prominent in the massive portions and causes a spotted appearance on account of the large size of the crystals. A modification of the massive variety is a coarse red granite which appears near the borders of the principal mass. This variety is well shown along Doe River and at many other points. It differs from the massive kind only in having many red or pink feldspars, which give a decided red color to the whole rock. Near the contact of this granite with the Cranberry there appear medium- to fine-grained granites. In the Cranberry granite also there are separated bodies of small size which appear to be disconnected dikes of the Beech granite. These can not be traced for any considerable distance and are too small and irregular to be mapped.

The Beech granite is intrusive in the Cranberry, and in this region only its main masses come into contact with that formation. The Beech is therefore considered to be the youngest of the massive plutonic rocks in the quadrangle. In the Asheville quadrangle, adjoining this on the southwest, a similar position is occupied by the Max Patch granite, which has the same varieties and may have been derived from the same igneous mass at great depths.

Metamorphism.—The granite has suffered great changes by metamorphism, especially in the porphyritic portions, where the change of form can sometimes be measured. Like the Cranberry granite, the rock has been squeezed and mashed, and a pronounced gneissoid structure has been developed. The change is most manifest in the growth of the new micas and in the elongation of the porphyritic feldspars. Some of the feldspars have increased to as much as three or four times their original length. In some places they have taken eye-shaped forms, and in others they are long, pencil-like structures. Striated and striped surfaces, due to the linear growths of new minerals, are common in this rock, as in the Cranberry granite.

Weathering.—The surface of the granite is but slowly reduced by weathering agents. Its siliceous composition and its great mass unite in maintaining the altitude of its areas, and it forms many of the conspicuous points of the region. Numerous cliffs follow the harder beds, and ledges protrude at short intervals. The names of the mountains which it causes in this region indicate the rocky character of its areas. On complete decay the granite produces a brownish clay of no great depth and mixed with much sand. The soils thereon are strong and fertile, where they accumulate in hollows and on gentle slopes.

ALGONKIAN (?) ROCKS.

The rocks included under the above heading form a group distinct from all those so far described, not only in distribution, in their unconformable attitude against the older formations, and in their close association with the sediments, but also in their intrusion in the granitic rocks and their origin as surface lavas. They are the Montezuma schist, Linville metadiabase, metarhyolite, and Flattop schist. In the Cranberry quadrangle the latter three cut through the Cranberry granite and the Blowing Rock gneiss, and thus are distinctly later. The metadiabase also cuts through the Beech granite, which is the latest of the Archean formations. The Beech granite and all older rocks are of plutonic origin and were formed at great depths below the surface of the earth. Three of the four Algonkian formations are plainly of a volcanic nature and were formed as flows of lava at the surface of the earth. Where, therefore, as is the case in many places, the surface lavas rest against the plutonic granites, it is obvious that a prolonged period of erosion followed the granite intrusions, bringing them slowly to the surface of the earth. The length of this break in the sequence of the formations is uncertain, but it must have been very great. It is not definitely determined, therefore, whether the surface lavas form a later part of the Archean or belong to a separate era. In this folio the break between the groups will be considered as great as the facts permit, and the later rocks will be treated as Algonkian. That they are separated from the Cambrian by a smaller interval than from the Archean is plain from the fact that the lavas, which were formed at the surface, were still at the surface when the Cambrian strata were laid down. Moreover, the sheet of basaltic amygdaloid interstratified with the lower beds of the Cambrian indicates that the period of volcanic activity extended a little into Cambrian time. These Algonkian (?) formations are well exhibited in the adjoining Cranberry quadrangle and extend northeastward from that region into Virginia. In this quadrangle only two of the Algonkian (?) formations are present—the metadiabase and the metarhyolite. These do not occur in typical development as surface flows, but they constitute a great series of small dikes and sheets that are too small to be separately shown on the map.

LINVILLE METADIABASE.

The metadiabase lies in a narrow zone running in a northeasterly course from the southern side of the Unaka Mountains to Doe River near Blevins. It is near the areas of Cambrian rocks, a position which is a striking characteristic of the formation in the Cranberry quadrangle. The metadiabase is eruptive in the Cranberry granite in the form of numerous small dikes. Few of these are as wide as 10 feet. Where good sections are found the metadiabase is seen to form but a small proportion of the rock. If judged by its loose bowlders, however, it seems to be the prevailing rock over considerable areas. In the Cranberry region the metadiabase spreads out over large areas and was formed near the surface of the earth. The portions seen in this region are probably of deeper origin and may represent the vents through which the flow reached the surface.

The metadiabase consists of plagioclase feldspar, with much alteration to chlorite, epidote, and quartz, and of hornblende in large part altered to chlorite and fibrous hornblende. The rock is of a dull yellowish-green color, due chiefly to the hornblende and the chlorite. In this quadrangle the rock is of medium grain and shows little variation. Metamorphism of the diabase is extensive. Original minerals, such as olivine and augite, are now almost entirely replaced by hornblende, chlorite, and epidote. As these formed in a more or less parallel growth considerable schistosity was produced. The larger minerals were, however, only partly rotated into the plane of schistosity as the rocks were mashed. Thus the natural tendency of the diabase to weather in round masses is only partially overcome and loose bowlders have a somewhat flattened lenticular shape.

In this region the metadiabase has few and small outcrops. It is reduced by disintegration of the feldspar and parts of the hornblende, leaving a deep red and brown clay strewn with a few of the harder fragments.

METARHYOLITE.

Rocks of the character of metarhyolite occur in this quadrangle mainly in a narrow belt from 1 to 2 miles wide. From the southern slopes of Little Bald this belt extends in an easterly direction, passing north of Huntdale, and thence northeastward up Pigeonroost Creek to the State boundary near Iron Mountain gap. In their course northeastward into Tennessee these rocks diminish in importance and scarcely show in the section of Doe River. Still farther east, in Walnut Mountain, they are represented by many schists cutting the granite. In the southwestern part of the quadrangle they are also present in a narrow belt along the foothills of Little Bald and on the border of the Cambrian sediments.

The metarhyolite occurs in thin sheets and dikes generally not more than 5 feet thick. These cut the mass of the Cranberry granite and in several places are so numerous as to compose a large part of the rock mass. Such is the case in this quadrangle only along the lower part of Pigeonroost Creek. In no place do these rocks form bodies large enough to be shown on the map. In this region, moreover, the heavy forest cover and the small size of the outcrops make it impossible to trace the metarhyolite far.

The metarhyolite, as seen in most places, consists of beds of black or dark schists composed mainly of very fine muscovite, quartz, and black iron oxides. Here and there it has been less metamorphosed and some of the original characteristics of the rock are preserved, as shown mainly by the porphyritic crystals of feldspar, more or less flattened. Associated with these feldspars in places are small porphyritic crystals of quartz. More rarely are to be seen the lines of wavy flow banding. This feature is plainest at the northern foot of Little Bald, near the southwest corner of the quadrangle. Within a few miles north and northeast of Huntdale the metarhyolite shows many porphyritic varieties. The color of these rocks varies through dark or light gray into nearly white. White schists of similar character are also present near Iron Mountain Gap. In places the porphyritic grades into a granular character and the rock is difficult to distinguish from the inclosing granite. As a rule, however, the metarhyolite is more schistose than the granite and contains more mica. This feature is very pronounced in many localities and gives the rock a glistening silvery appearance on the surfaces of schistosity. In the fine white varieties the amount of mica is less and quartz greatly predominates. Loose fragments of this rock are used for whetstones, which have great cutting power on account of the sharp edges of the quartz.

Except that the metarhyolite is later than the Cranberry granite and does not cut the Cambrian rocks, there is in this region no indication of its age. In the Cranberry quadrangle on the east rocks of the same character are probably of Algonkian age. Their similarity with these rocks in character and association makes it likely that the latter are of the same age.

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

CAMBRIAN ROCKS.

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

The region around Elizabethton and Johnson City in Tennessee is the only one in the Appalachians south of Virginia where there is an unbroken sequence of the formations from the base of the Cambrian into the Ordovician.

SNOWBIRD FORMATION.

The Snowbird formation is exposed with other Cambrian quartzites in the belt that runs diagonally through the quadrangle in a northeast-southwest direction. Many areas of the formation, more or less disconnected by faults, are included in this belt. In general the Archean granites lie southeast of the belt and the calcareous Cambrian and Ordovician rocks lie northwest of it. In a few places, notably along Nolichucky, Doe, and Watauga rivers, and north of Limestone Cove, the formation is seen in its normal position on the Archean granites. Its name is taken from Snowbird Mountain, in the Asheville quadrangle.

Character.—The materials derived from the waste of the granite are contained to a large extent in this formation. They consist of pebbles and grains of quartz and feldspar, mostly well rounded. In some places, however, these fragments are angular, showing that they have been transported only a short distance from the parent body of the granite. As displayed in this quadrangle, the formation is composed chiefly of coarse and fine quartzite. With this variety are interstratified beds of conglomerate and arkose and a few thin layers of gray slate. Here and there the rock is little silicified and is properly to be called a sandstone. Some of the quartzites contain a good deal of feldspar in small grains, but most of them are practically all composed of quartz grains. One of the slate beds in the upper part of the sections cut through Iron Mountain by Doe and Watauga rivers consists in part of slate conglomerate. The slate fragments are flattened and angular and have been carried but short distances. Similar fragments of slate are found at various positions in the formation inclosed in a quartzite matrix.

The arkose beds are best shown in the canyon of Nolichucky River near the base of the formation. Most of these beds are of a light color, white or gray, but there are considerable variations in this respect. Southwest of Erwin, for instance, many of the quartzites have a dark bluish-black color, due to the grains of iron oxide between the quartz grains. This feature shows, to a less extent, north of Erwin. Where these beds are considerably weathered, further oxidation of the iron gives the rock a rusty-brown or red color. Another variety seen at many points in the same areas is a fine greenish-gray sandstone or quartzite. In this rock there is considerable fine mica, in addition to the usual feldspar and quartz, and to this mica, in part chlorite, is due the greenish color. North of Erwin there are also numerous exposures of a dark-red slate that occurs in beds 10 to 30 feet thick and is the weathered representative of a fine dark-green slate. Most of the beds of the formation are massive and show little banding. The conglomerates, however, are banded more commonly than the quartzites. Numerous exposures of cross-bedded quartzite and sandstone are seen in all the clean-cut sections.

In the lower portion of the formation there is a rock which is very exceptional in Appalachian sediments—namely, amygdaloid. It occurs at many points in the Nolichucky canyon along the slopes of Buffalo Mountain, and near the foot of Iron Mountain northeast of Hampton. From the latter locality it is continuous for many miles into Virginia. In regions southwest of this quadrangle it does not appear. The rock consists of fine-grained schistose basalt and amygdaloid of a general green color. It is composed chiefly of plagioclase feldspar, chlorite, fibrous hornblende, and epidote. No traces of an original glassy base now remain. In areas northeast of this the grain is coarser and in places it has the structure of diabase. Its chemical composition, its fine and uniform grain, and its amygdaloidal nature indicate that it was originally a basalt. Most of the amygdules are filled with quartz and epidote. Small lumps of epidote and seams of asbestos also occur. Along Nolichucky River good sections show 25 to 30 feet of amygdaloid embedded in conglomerate and quartzite. In Iron Mountain the rock becomes much thicker toward the northeast, and in the adjoining Cranberry quadrangle it is about 150 feet thick. In the same direction the underlying quartzites contain many red beds. The amygdaloid was a contemporaneous lava deposited as a sheet upon the conglomerates that constitute the lower part of the formation.

The quartzites are generally massive and fine grained, in beds from 6 inches to 5 feet thick. The interbedded slates are most abundant north and west of Erwin, and vary from 6 inches to 30 feet in thickness. They are of a dark-gray color and are fine grained and argillaceous. Here and there they pass through sandy shales into feldspathic sandstone.

Thickness.—The Snowbird formation is about 2000 feet thick. It appears to be slightly thinner in Iron Mountain and thicker along Nolichucky River, but this is uncertain on account of faulting. In Iron Mountain, near the Cranberry quadrangle, the Hiwassee slate, which overlies the Snowbird formation, can no longer be recognized. It is not possible there to separate the Snowbird from the Cochran conglomerate, and the two are treated under one name, the Unicoi formation. The same is true farther south, in the Flattop and Unaka mountains.

Metamorphism.—The chief change that has been produced in this rock since it was deposited has been the silicification of the sandstone into quartzite. In those portions which were feldspathic some of the smaller grains of feldspar have been recrystallized into quartz and mica, giving the rock a somewhat schistose structure. This was accomplished in the same manner as similar changes in the Cranberry granite, already described, but it is seldom conspicuous in this quadrangle. In the much faulted region near Devils Creek and Nolichucky River some of the quartzite and slate beds are metamorphosed to fine schists. The interstratified slate beds in general received some cleavage at the same time. The coarse sandstone and arkose conglomerate were less affected than the fine-grained beds.

Weathering.—The siliceous nature of the formation enables it to resist the attack of weather extremely well. The soils over its areas are thin and much interrupted by rock outcrops. The soil is sandy and poor in all places except in hollows and coves where considerable has accumulated. The formation causes high ridges and mountains like Iron Mountain, shown in fig. 12. The crests of the ridges are sharp where formed by quartzite, and somewhat rounded where underlain by the sandstones and conglomerates. Their slopes are invariably steep and in many places are formed almost entirely of large rock fragments. Ledges abound and the canyons cut by the larger streams are lined with cliffs from 100 to 1000 feet in height.

HIWASSEE SLATE.

Extent and character.—The rocks of the Hiwassee slate occupy many narrow bands in the Cambrian quartzite belt, being most prominent in Buffalo and Rich mountains north and west of Erwin. The name of the formation is derived from that of Hiwassee River, which cuts a fine section through these strata in Tennessee. As displayed in this region the formation consists mainly of slate of a bluish-gray or bluish-black color. When weathered, this color becomes greenish or yellowish gray and yellow. These slates are marked throughout by light-gray siliceous bands of sedimentary origin. Interbedded sandstones are numerous and there are a few layers of conglomerate. Those belts of the formation which pass near Hampton and Unaka Springs contain many more of the interbedded sandstones and quartzites. Southeastward from Unaka Springs the proportion of quartzite becomes greater until the slate is entirely replaced and can not be recognized. Most of the material of the slate layers is argillaceous. To this is added siliceous matter, making the gray bands and the sandstone-quartzite beds. In many of the layers mica in fine scales is a noticeable constituent. This was an original deposit in the strata, and it is seen in some of the least altered of the beds.

Thickness.—In some areas the formation is very much thinner than in others. From a thickness of about 800 feet west of Erwin it diminishes to 300 or 400 feet in Buffalo Mountain. Similar changes are seen southwest of Unaka Springs, where the formation thins from 400 to about 50 feet in a single area. Other areas southeast of Unaka Springs show from 100 to 300 feet of slate. In the areas between Erwin and Hampton the thicknesses vary from 200 to 500 feet. In the Watauga gorge the formation shows 100 feet thick, and not far to the northeast it thins and disappears.

Metamorphism.—The strata of the Hiwassee slate have not been greatly altered by deformation. The principal result has been the production of a slaty cleavage. This has not entirely obliterated the bedding in most places where that was originally well marked. In the fine portions the original grain was uniform throughout, and it is not very difficult to detect the bedding planes. Only in a few places has the deformation been sufficiently extreme to produce mica schist. These are in the upper part of the Nolichucky canyon, near some of the thrust faults, where the slates have been altered to dark-bluish or black schists. In many areas of the formation, notably north of Erwin, the rocks have scarcely been altered from their original shaly condition.

Weathering.—The rocks of this formation do not withstand the action of weather as well as the quartzites and form hollows between them (see fig. 12). Weathering makes its way down the partings of bedding and cleavage, and the rock is thereby broken up into small fragments and flakes. On the steep slopes, where the formation is upheld by the adjoining harder quartzites, there are many outcrops and the soil is thin and sandy. Where the formation is thin, its areas are largely covered by waste from the quartzites, and outcrops are limited to the divides and the stream courses.

COCHRAN CONGLOMERATE.

Extent and character.—Many areas of the Cochran conglomerate are included in the quartzite belt, having the same general range as the Cambrian formations already described. It is named for its occurrence in Chilhowee Mountain, on Cochran Creek, in the Knoxville quadrangle. The formation consists, for the most part, of quartzites and sandstones, which develop in many places into coarse and fine conglomerates. White or light-gray colors prevail throughout the formation. Its beds range from a few inches up to 3 or 4 feet in thickness. Most of them are massive and little banded; there are, however, many layers of cross-bedded quartzite.

The conglomerate beds are generally distributed throughout all the areas of the formation. They are most numerous in Buffalo and Rich mountains and in the Nolichucky canyon; northeast of Hampton they become less numerous. Much the greater part of the pebbles are of quartz and well rounded. Few of them exceed an inch in length. Pebbles and grains of feldspar are of general occurrence in the conglomerates throughout their areas. In many places the formation is characterized by pebbles of black slate. They appear to be derived from the underlying Hiwassee slate, as they resemble it in all particulars. Not uncommon in the Cochran are small pebbles of black metarhyolite derived from formations of probable Algonkian age.

A few unimportant beds of slate are interstratified with the quartzites. These slates are dark bluish and grayish in color and resemble the Hiwassee slate. At many points in Cherokee Mountain and around Embreeville beds of reddish and purplish sandstone are interstratified with the quartzite. These beds are from 10 to 20 feet thick and form the principal exception to the light colors of the formation. In the same localities small beds of dark-greenish sandstone and quartzite are found. Northeast of Hampton, where the Hiwassee slate disappears, the conglomerate can not be distinguished from the Snowbird formation, and the two are classed together as the Unicoi. The same is true in Holston, Unaka, and Flattop mountains. The formation varies in thickness. The minimum is seen near Hampton, where it is from 600 to 700 feet thick. Stone Mountain shows from 1100 to 1500 feet, Rich Mountain about 800 feet, and the remaining areas from 1200 to 1500 feet.

Metamorphism.—The principal alteration in the formation is the conversion of many of the sandstones and fine conglomerates into quartzites. This condition is very general throughout the quadrangle. In the coarse conglomerates the feldspathic matrix has been affected more than the coarse fragments. Alterations in this portion of the rock proceeded in the same manner as in the similar minerals of the granites. Secondary quartz, feldspar, and mica and a small amount of schistosity were produced. The schistosity is not striking at any locality in this area, except in the Nolichucky canyon; there the strata are rendered somewhat schistose in positions of extreme movement. The general bedded appearance of the rock, however, is as a rule not much altered. Some of the pebbles are cracked and dented by other pebbles; the fragments are somewhat dislocated and are mostly recemented by the secondary quartz.

Weathering.—The siliceous nature of the formation enables it to withstand erosion well. This characteristic is conspicuous throughout the region, especially where the quartzite stands up above the level of the limestone valleys. The soils are thin, sandy, and full of bowlders, and are of little value for agricultural or timber purposes. Many ledges or cliffs jut through the cover of the soil, and enormous cliffs are formed in the vicinity of the larger streams. The waste from this formation, like that from the adjoining quartzites, spreads far over the adjoining formations.

UNICOI FORMATION.

The rocks of the Unicoi formation occupy areas in Holston and Iron mountains east of Elizabethton and in Unaka and Flattop mountains. As already stated, this formation is the equivalent of the Snowbird formation, Hiwassee slate, and Cochran conglomerate. Where the Hiwassee slate thins out to the east and south the adjoining quartzitic formations are not separable from each other, and the entire mass is mapped as the Unicoi. The name of the formation is given on account of its strong development in Unicoi County, where there is a fine showing of its strata along Nolichucky River. Their general aspect is seen in fig. 4. Northeastward from this quadrangle the Unicoi passes far into Virginia.

The description of the Snowbird and Cochran formations can be applied to the Unicoi for the most part. The principal difference between the Unicoi and its divisions is in the arkosic character of its lower quartzites near Nolichucky River. These quartzites contain considerable feldspar in fine grains, and the rock shows much cross-bedding. Conglomerate pebbles also are less common than in the most of the Cochran. Near Beauty Spot, on Unaka Mountain, conglomerate is unusually prominent. The pebbles of quartz and feldspar are from 1 to 1½ inches in diameter. Similarly coarse conglomerate shows on the east end of Pond Mountain.

In Iron Mountain, east of Elizabethton, the conglomerate layers in the lower part of the Unicoi are the continuation of similar layers in the Cochran. In that locality also the bed of amygdaloid is continuous from one to the other. Although the lower part of the Unicoi and the Cochran are thus the same, it would be necessary, if the Cochran were extended farther northeast, to draw an entirely arbitrary line at the horizon where the Hiwassee slate is absent. This is also true of the section in Unaka and Flattop mountains.

Half a mile north of Poplar, on Nolichucky River, the quartzite is highly jointed, as shown in fig. 13. Along the joints there is incipient schistosity, all being about parallel to the great fault south of the river.

The topographic features of the Unicoi are the same as those of the other quartzitic formations. In Flattop and Unaka mountains, however, it appears to thicken considerably where the quartzites become arkosic. Consequently the mountains formed by these beds are higher and more rugged in this part of the quadrangle than elsewhere. The canyon of Nolichucky River is one of the wildest in the Appalachians for the few miles in which it passes through these mountains. Its ruggedness and depth are well shown in fig. 11. The soils of this formation are similar to those of the other quartzites.

NICHOLS SLATE.

Extent and character.—The area occupied by the Nichols slate is limited in this quadrangle to Cherokee Mountain and a small district near Embreeville. In the remaining quartzite areas about the same position is taken by the Hampton shale. The sequence of formations above the two differs somewhat, and it is not certain that they were deposited entirely at the same time. The Nichols slate consists of fine-grained rocks, either shale or slate, according to the amount of metamorphism. Most of the formation as shown here is made up of shale. The strata are dark gray and bluish gray, and in places are marked with light-gray bands like the layers of the Hiwassee slate. The shales are in the main micaceous, fine scales of mica having been deposited when the rock was formed. A very small amount of secondary mica was also developed as the strata were folded. Some of the layers of the formation are sandy, but the argillaceous character predominates. The formation also includes a few thin layers of quartzite and sandstone of the same character as the Nebo and Cochran above and below. It is named from the Nichols Branch of Walden Creek, in the Knoxville quadrangle.

Thickness.—There are considerable variations in the thickness of the formation. North of Bumpass Cove at the border of the Greeneville quadrangle it is nearly 700 feet thick, but diminishes to less than 100 feet at the northeast end of the same band, at a distance of about 3 miles. Various sections east of Embreeville show 400 or 500 feet.

In Cherokee Mountain the shale is generally less than 100 feet thick.

Weathering.—The action of the weather on the beds of this formation is similar to that on the Hiwassee slate. The rocks are not especially soluble, but they break down through their argillaceous components. The mass left by disintegration is comparatively soft and crumbling. The areas of the formation are in most places upheld by the quartzites adjoining them, but form depressions between the ridges and knobs of the quartzites. This relation is well seen near Embreeville. The soils of the shale are thin and dry and of small value.

HAMPTON SHALE.

The Hampton shale lies in numerous parallel belts southeast of Erwin and on both sides of Hampton. Other belts are present in Holston and Unaka mountains. The name of the formation is taken from the town of Hampton, near which are several fine sections of these strata.

The description given of the Nichols slate applies also to this formation so far as the character of the rocks is concerned. Very little slate is shown in this quadrangle, however, and the strata are in the main banded gray shales. There are considerable variations in the thickness of the formation, as in that of the Nichols. In most of its areas the thickness ranges between 100 and 300 feet. Here and there the formation is so thin that its presence can scarcely be detected. This is the case in many sections south and east of Erwin. Just northwest of Hampton it appears to expand to about 500 feet, diminishing both northeastward and southwestward. In Holston Mountain even greater thicknesses are shown, and in the adjoining Cranberry quadrangle the formation is from 700 to 800 feet thick. The surface formations and soils produced on the Hampton shale are the same as those of the Nichols slate.

NEBO QUARTZITE.

Extent and character.—The strata of the Nebo quartzite occur among the Cambrian quartzites north and west of Erwin, in the same general situation as the Nichols slate. Those which were deposited at the same time in regions farther east can not be separated from the overlying Hesse quartzite and both are classed as the Erwin quartzite.

Practically all of the formation is composed of quartzite and sandstone. Interbedded with these rocks are a few minor layers of shale and slate, which appear only near the streams. It is possible that the amount of slate is greater than it would seem, being covered by vegetation. The formation is named from Mount Nebo Springs, on Chilhowee Mountain in the Knoxville quadrangle. Nearly all the quartzite and sandstone is light colored, gray or white. Most of the beds are fine grained, although some, as those along Nolichucky River, 2 miles below Erwin, are coarse enough to be considered conglomerates. The quartzite beds are from a few inches up to 3 feet in thickness, and here and there show cross-bedding. The slates are gray, argillaceous, and sandy where fresh, but are in most places weathered to a yellow color. The siliceous beds are composed almost altogether of quartz. Originally this was all in the form of rounded grains of sand. Now, owing to the deposition of secondary silica during metamorphism, many of the original grains are closely cemented. When the rocks are broken, a clean conchoidal fracture passes through them, irrespective of bedding planes and the granular structure. This silicification is the principal change produced in the formation by metamorphism.

Thickness.—The thickness of the Nebo appears to vary considerably, although it is difficult to obtain good measurements. West of Embreeville between 400 and 500 feet appear. In Cherokee Mountain there are nearly 1000 feet.

Weathering.—The Nebo quartzite is very resistant to weathering, for its purely siliceous composition makes it nearly free from the effects of solution. It forms most of the summits of the mountains where it outcrops, as is well shown in Cherokee and Rich mountains. The siliceous beds gradually break up through the bedding and joint planes, chiefly by the action of frost. Slowly the fragments slide down the slopes and are carried far before disintegration is complete. The soils on the formation are very thin and sandy and support only the scantiest growth of timber.

MURRAY SLATE.

Only three areas of the Murray slate, which has the same distribution as the Nebo quartzite, are contained in the Roan Mountain quadrangle. Elsewhere this slate is absent from the quartzite series and the inclosing quartzites come together. The formation is named from Murray Branch of Walden Creek, in the Knoxville quadrangle. It consists of shales and slates, and is practically indistinguishable from the Nichols slate. The strata are argillaceous, micaceous, and in some places sandy. The micaceous character is most apparent in the least altered shales. Most of the layers are marked with gray bands, due to sedimentation. These characters have been little changed by metamorphism, which has produced only a small amount of cleavage. It is very difficult to obtain measurements of the thickness of the formation, since its areas are much covered with quartzite wash, and outcrops are scarce. It diminishes from 250 to 100 feet in a northeasterly direction and disappears altogether toward the southeast. This formation shows the same features under weathering as the Nichols slate.

HESSE QUARTZITE.

The Hesse quartzite is seen in two areas—one at Embreeville and the other in Cherokee Mountain. Elsewhere, as was stated of the Nebo quartzite, strata of this age are included in the Erwin quartzite, owing to the disappearance of the Murray slate. The formation consists mainly of white quartzite of the same character as the Nebo quartzite. Included in it are a few minor layers of argillaceous and sandy shale like those of the Murray. The quartzites are fine or medium grained and show practically no variation in appearance. The formation passes upward into the Shady limestone through about 30 feet of sandy shale and calcareous sandstone. These rocks have a decided reddish-brown color. At some localities a few scolithus borings are found in the quartzite layers, which are the same in appearance as those which characterize the top member of the quartzite series throughout the region. The formation is from 600 to 800 feet thick in this region, being heaviest in Cherokee Mountain. Its strata resist weathering in the same manner as those of the Nebo quartzite. Along Nolichucky River near Embreeville they are very conspicuous and form large ledges and cliffs. The soils are poor and sandy, and of little use for any purpose.

ERWIN QUARTZITE.

Distribution.—Areas of the Erwin quartzite are very common in this quadrangle. As already stated, it is represented in the Hesse and Nebo quartzites. It also occurs in many narrow belts around Erwin and most conspicuously farther northeast, in Iron and Holston mountains.

Character.—The formation is made up mainly of white quartzite and sandstone and is very uniform in appearance. The individual beds are as a rule from 6 inches to 3 feet thick. The topmost layer, however, consists of 25 to 30 feet of massive quartzite with almost no partings. This and the adjoining layers are illustrated in fig. 14. All these layers are composed of grains of fine white sand, in general well cemented by secondary silica. In many places the quartzites are highly vitreous in appearance; this is best seen in the region around Erwin. East and northeast of Elizabethton the upper layers of the quartzite are conglomeratic and contain many round pebbles of white quartz half an inch or more in diameter. Above this there are in most places a few feet of brownish sandy shale and thin sandstone forming a transition zone into the Shady limestone. Distributed through the formation are a few unimportant layers of shale and slate of the same character as the Hampton shale. A little slaty cleavage is seen in these layers. This cleavage and the silicification of the quartzite are the principal changes due to metamorphism. At the top of the quartzite in the Cranberry quadrangle a few lower Cambrian fossils of the *Olenellus* fauna have been found. Scolithus borings are common in this quartzite and are characteristic of the formation.

Thickness.—The thickness of the Erwin quartzite ranges from 800 to 1100 feet. It is apparently thinnest in the vicinity of Erwin, but the great deformation in that region makes the measurements uncertain.

Weathering.—The close texture and insoluble materials of these beds make the formation very resistant to weathering. It invariably forms high ground, in most places prominent ridges and mountains, even though its position next to the limestone valleys makes it more subject to erosion. Numerous ledges and cliffs mark its course, especially where it crosses the stream courses. It forms the summits and spurs of most of Holston Mountain. By direct action of the frost the quartzite blocks are finally dislodged and strew the mountain sides. Owing to the usual steep dip of the formation its ridges are sharp and rocky. The covering of soil is thin and irregular, but hollows collect enough to support a fair vegetation. Where the strata dip gently and the summits are flat considerable soil accumulates.

SHADY LIMESTONE.

Extent and source.—Two principal belts of the Shady limestone occur in this quadrangle—one passing through Hampton, the other in the valley between Iron and Holston mountains. On the line of the latter, in the adjoining Abingdon quadrangle, is situated Shady Valley, from which the formation is named. Several smaller areas are present—notably in Limestone Cove and Bumpass Cove. The formation consists almost entirely of limestone and dolomite of various kinds, and is more or less crystalline. With the advent of these strata there was a change in the distribution of land and sea that was one of the most marked in Appalachian history. Previous to this time the sediments had been coarse and siliceous and were plainly derived from the neighboring land mass, where erosion was active. In this formation the amount of shore material is very inconspicuous and by far the greater proportion of the rock is carbonate of calcium. The rock is fine grained and uniform in composition over very large areas. The amount of erosion and deposition was, therefore, abruptly reduced at this time, probably by submergence of the land and recession of the shore toward the south and east. The conditions which prevailed then continued, with some local modifications, far into Ordovician time.

Varieties.—Several kinds of limestone are represented in the formation. For the most part, they are of bluish-gray or gray color, and are apt to weather with a dull-gray or black surface. Some of the layers are mottled gray, blue, or white, and seamed with calcite. Beds of white limestone or marble are abundant near the base of the formation, but are covered in most places by wash from the adjoining quartzites. These limestone beds are best seen in various sections in Stony Creek valley. They show most noticeably a black surface on weathered outcrops. A considerable percentage of carbonate of magnesium is contained in some layers of this formation, an average analysis showing 57 per cent of carbonate of lime and 37 per cent of carbonate of magnesium. A few thin seams of gray shale occur here and there in the formation, and beds of red shale in its upper layers form a transition into the overlying Watauga shale.

Siliceous impurities in the form of sandy limestone are present in a few places in the formation, in addition to the sandy transitional beds at the base of the limestone. Silica is also very common in the form of chert. This forms as a rule small rounded nodules with gray surfaces and concentric gray and black bands inside. Another variety has the appearance of chalcedony and occurs in large lumps a foot or two in diameter. The small nodules can be seen occupying bands in the limestone; the large masses appear only in residual clays.

Thickness. — The thickness of the formation ranges from 750 to 1000 feet, being least along the eastern border of the quadrangle.

Weathering.—Weathering proceeds faster in this formation than in most others of the region. The rock dissolves, leaving a dark-red clay containing many lumps of chert. As these lumps are in few places abundant enough to protect the surface entirely from removal, the formation makes valleys and low hills. Its clays and soils are deep and strong and afford excellent farming land, wherever they are not too much encumbered with wash from the quartzite formations. Its natural soils are seen in Bumpass Cove and Stony Creek valley, and typical quartzite-covered areas are found near Erwin. As a rule the natural soils are much altered by this quartzite waste. In the red clays of this formation occur extensive deposits of brown hematite and manganese oxide. The iron ore has been mined in Bumpass Cove and Stony Creek valley for many years, and enormous quantities have been taken out. Where the clay has been removed in mining the ore (see fig. 6), the irregular and deeply pitted surface due to solution is easily seen.

WATAUGA SHALE.

Age and equivalents.—The Watauga shale has the same general distribution as the Shady limestone. It is absent, however, from Bumpass Cove. The strata were deposited at practically the same time as those of the Rome formation farther west and the Russell toward the north in the Great Valley. In the Knoxville quadrangle, below the Rome formation lie the Beaver limestone and the Apison shale. The latter resembles the Rome and Watauga very strongly. The Watauga occupies a position with reference to the Knox dolomite and the Nolichucky shale quite the same as that taken by the Rome and Russell formations. No fossils have been found in the Watauga. Its position in the sequence of Cambrian strata and its character indicate, however, that it is equivalent to the Russell and Rome formations, the Beaver limestone, and the Apison shale.

Character and varieties.—The formation consists of a series of interbedded limestones, red, green, and variegated shales, and red sandstone. The limestones are blue and gray in color and show all grades in transition from pure limestone to the red shale. The thickness of the limestone beds in few places exceeds 10 feet, being as a rule from 1 to 2 feet. Much the greater part of this formation is made up of red, brown, purple, and yellow shale, in some places calcareous, in others sandy, and generally argillaceous. When perfectly fresh, much of the shale is a blue or drab limestone, but slight exposure produces in it the reddish colors and the shaly partings. The bright colors are due to considerable amounts of iron oxide disseminated through the layers. The beds of red sandstone are local and argillaceous and different from the sandy shale, chiefly in being more massive. The individual sandstone layers are from 1 to 3 feet in thickness and are closely interbedded with the shale.

Many of the layers are covered with ripple marks. From these, and from the frequent changes in sediment from sand to mud, it is plain that the formation was deposited in shallow water just as mud flats are now being formed. Trails left by crawling animals are numerous on many of the beds. In the equivalent Rome and Russell formations fossils of lower Cambrian age have been found, but none in the Watauga.

Chert is not uncommon in the lower beds of the formation, especially near the Cranberry quadrangle. It occurs in nodules and masses 2 feet or less in diameter, but of a very tough and durable nature. The iron oxide which colors the shale so strongly is in many places combined with the chert and forms a poor ore. As a rule, however, the amount of iron oxide in the chert is very small. In other respects these cherts resemble the chalcedonic cherts of the Shady limestone and are present only in the residual clays.

At Cardens Bluff, 4 miles northeast of Hampton, a few feet of conglomerate are interbedded with the red shale. The pebbles of the conglomerate consist of shale, limestone, and shaly sandstone, and indicate slight local erosion during the deposition of the shale.

Thickness.—The thickness of the formation is fairly constant, but is difficult to determine on account of the crumpled condition of the beds. It ranges between 1000 and 1100 feet in this quadrangle.

Weathering.—The beds of this formation do not withstand decay well, although they are more resistant than the Shady limestone. The calcareous beds are readily dissolved, leaving the shales and sandstones to crumble and break down. The sandy material is able only to form low ridges and rounded knobs, which are brought into slight relief by the

Shady limestone valleys. These relations are best shown south and east of Elizabethton. The soils of the formation are fairly deep and are kept loose by the sand and beds of shale. Though in few places very fertile, they are fairly productive and are all accessible and easily cultivated.

HONAKER LIMESTONE.

Distribution.—The rocks of Honaker age lie in a broad belt running southwestward from Elizabethton, and a number of narrow strips farther northwest in the Valley. In the narrow bands only the upper part of the formation appears in anticlinal or faulted masses. Around Elizabethton the full thickness of the formation is shown, as well as the normal position of the limestone in the Cambrian sequence. In the Bristol quadrangle, north of this, the limestone is split up by the Rogersville shale into two limestones—Maryville and Rutledge. These form the usual sequence toward the north and west. To the strata between the Watauga and Nolichucky the name Honaker is given on account of their development near Honaker, W. Va.

Character.—The formation is composed of limestones of a general dark-blue or gray color. These are massive and fine grained and contain almost no trace of shore sediment. Many of the beds are characterized by numerous earthy, siliceous bands of a brownish color. Just below the top of the formation are from 25 to 50 feet of a peculiar gray limestone that in many places is seamed with calcite and weathers into knots or balls which are noticeably round. These layers are also sandy in many places, a fact which appears plainly on the weathered surfaces. They weather with a very dark or black surface, like many layers in the Shady limestone. This blue-gray limestone at the very top of the formation is interbedded for a few feet with the overlying Nolichucky shale. An important exception to the usual blue or gray color of the limestone is seen in the white or dove-colored beds. These are found interbedded with the blue limestone at many points, but are best shown south and southwest of Elizabethton. The white layers are from 6 inches to 2 feet thick and are more numerous in the upper part of the formation.

Northwest of Johnson City cherts are scattered over the surface of the formation. It is difficult to determine whether they are derived from the limestone or from the Knox dolomite, not far away, but some of them appear to be part of the Honaker. Where the limestone is spread out with a light dip around Elizabethton, these cherts are plainly derived from the Honaker. They are of about the same character as those contained in the Knox dolomite, but are less numerous.

Thickness.—The limestone is from 1800 to 2000 feet thick, and is thinner toward the northeast.

Weathering.—The limestone decays readily by solution and forms a deep-red clay. From this protrude many ledges of limestone, especially among the upper beds. The blue limestone near the Nolichucky shale especially makes numerous outcrops. The upper part of the formation causes shallow valleys next to the ridges of Nolichucky shale—a relation well shown northwest of Johnson City. The middle and lower parts of the limestone form low, rounded hills like those of the Knox dolomite. Good examples of such hills can be seen around Elizabethton. The soils of the Honaker are clayey and deep and strong, forming excellent farming land.

NOLICHUCKY SHALE.

Distribution and character.—The Nolichucky shale occupies narrow bands having the same general range as the Honaker limestone. It is named from Nolichucky River, along whose course in the Greeneville quadrangle the shale is well exhibited. This is one of the most persistent of the Cambrian formations and furnishes the key rock for unraveling the structure. It is composed of calcareous shales and shaly limestones, with a few beds of massive limestone in its upper portion. The latter are best seen in the vicinity of Jonesboro. Most sections in this quadrangle show practically no limestone except in the uppermost part, where limestone and shale are interbedded for a few feet, forming a transition zone into the Knox dolomite. As already stated, the shale grades downward into the Honaker limestone. When fresh, the shales and shaly limestones are bluish gray and gray in color, but they weather readily to various shades of yellow, brown, and green. In most of the quadrangle yellow and greenish-yellow colors prevail. A few feet of peculiar limestone containing knots or eyes occurs at many places in the upper part of the formation next to the Knox dolomite. In the northwestern part of the quadrangle a few of the shale beds are somewhat siliceous or sandy. The formation is the most fossiliferous of the Cambrian rocks, containing abundant remains of animals, especially trilobites and lingulas.

Thickness. — The thickness of the formation varies much, decreasing toward the east and south. It reaches a maximum of about 500 feet just north of Johnson City. From that point the shale grows thinner northeastward into the Bristol quadrangle, and finally disappears. South of Johnson City it is about 250 feet thick. It is thinnest in the belt running between Elizabethton and Unicoi, where the maximum is 75 or 80 feet. In connection with this decrease in thickness the proportion of shale grows less, so that fresh sections show nearly as much limestone as shale.

Weathering.—Solution of the calcareous parts is so rapid that little of the rock is seen in a fresh condition. After removal of the soluble constituents decay is slow and proceeds by the direct action of frost and rain. Complete weathering produces a stiff yellow clay. Weathered rock is as a rule near the surface and the cover of soil is thin, but where the formation presents gentle slopes a deep clay results. Northwest of Johnson City the more siliceous shales rise in knobs above the adjoining formations. South and east of Johnson City the shale forms steep slopes along the Knox dolomite ridges. The soils are well drained by the abundant partings of the shale, but are poor and liable to wash.

ORDOVICIAN ROCKS.

KNOX DOLOMITE.

Age.—Although the Knox dolomite does not belong entirely in the Ordovician system, a large part of it is of that age, and as the formation can not be divided it is all described under the above heading. The lower portion contains a few middle Cambrian fossils and the upper portion Ordovician fossils, largely gasteropods; but it is impossible to draw any boundary line between these parts of the formation.

Extent and character.—The Knox dolomite is the most important and most widespread of all the Valley rocks. Its name is derived from Knoxville, Tenn., which is located on one of its areas. The formation consists of a great series of blue, gray, and whitish limestone and dolomite (magnesian limestone), most of which is very fine grained and massive. Many of the beds are banded with thin, brown siliceous streaks, and the average outcrop shows a dark-blue banded rock. The topmost beds are massive dark-blue limestone, weathering light blue. These beds are commonly marked by a growth of cedars and their usual bedding is seen in fig. 9. Blue limestone indistinguishable from these is found in numerous other parts of the formation. Below these uppermost limestones and above the middle of the dolomite the rocks are blue and blue banded and their areas are covered with numerous sinks, well exhibited west of Johnson City.

Interbedded with the dolomite and limestone are beds of white calcareous sandstone a few feet thick. Northwest of Johnson City these beds attain a thickness of 10 feet, and they can be traced for long distances. They are made up of fine, rounded sand grains embedded in a calcareous cement. These beds are most noticeable at two positions—one a little above the Nolichucky shale, the other in the middle of the dolomite. In the lower part of the formation there are also numerous white and sandy layers. Many of these layers are found over the dolomite areas near Holston River, where they are in places rather crystalline.

Four miles east of Bluff City the topmost layers of the dolomite are formed of a breccia or angular conglomerate of limestone. From this it is inferred that before the Athens shale was laid down the newly formed beds of dolomite were exposed to erosion and somewhat broken. Conglomerate is also found in many layers and beds at various horizons in the dolomite, composed of fine pebbles and grains of limestone cemented by similar limestone. Few of these layers are more than a foot or two in thickness; they are most common in the lower part of the formation, and also within a few hundred feet of the top.

The amount of earthy matter in the dolomite is very small (from 5 to 15 per cent), the remainder being mainly carbonates. The materials composing the dolomite were deposited very slowly, and deposition must have continued for a very long time to have accumulated so great a thickness of rock. The dolomite represents a longer epoch than any other Appalachian sedimentary formation.

Thickness.—The formation ranges between 3000 and 4000 feet in thickness, being thickest south of Johnson City.

Included chert masses.—Included in the beds of limestone and dolomite are nodules and masses of black chert, locally called "flint," and variations in the character and number of these cherts constitute the principal change in the formation. They are most conspicuous in the northern part of the quadrangle and are most abundant in the lower part of the formation. In places, by the addition of sand grains, they grade into thin sandstones.

Weathering.—The dolomite weathers rapidly on account of the solubility of its materials, and outcrops are rare at a distance from the stream cuts. The formation is covered to a great depth by red clay, through which are scattered the insoluble cherts. These are slowly concentrated by the solution of the overlying rock, and where they are most plentiful they constitute so large a part of the soil that cultivation is almost impossible. The cherts are white when weathered, and break into sharp, angular fragments. Very cherty areas invariably form high, broad, rounded ridges, protected by the cover of chert; good instances of this are the ridges north of Holston River. Near Holston River the dolomite forms shallow valleys, as well as ridges, because its chert is scanty and the Nolichucky shale is harder than elsewhere. The chert forms an impediment to cultivation, but when the amount of it is small the soil is very productive. Areas of cherty soil are subject to drought, on account of the easy drainage caused by the chert, and in such localities underground drainage and sinks prevail. Water is obtainable in such areas only from sinks stopped up with mud, from wells, or, rarely, from springs. The chert ridges are covered by chestnut, hickory, and oak to such an extent that many of them are named for those trees.

ATHENS SHALE.

Extent and character.—The Athens shale occupies wide belts near Johnson City and two small areas at the end of Cherokee Mountain. It is named from Athens, McMinn County, Tenn., where it is conspicuously exposed. Throughout this region it is composed of black and bluish-black shales which show little variation from one area to another. The shales are all calcareous and, especially at the bottom, are carbonaceous and full of remains of graptolites. With these exceptions the strata are very fine grained and thin bedded. Sedimentary banding is not visible as a rule, on account of the weathered condition of the rocks. In the stream cuts northeast of Johnson City, however, the banding is very plain and commonly seen. The contact of the Athens shale with the underlying Knox dolomite is sharp in all places and indicates a sudden change in the relations of land and sea at that time. This change is comparable in magnitude and extent with that which immediately preceded the deposition of the Shady limestone.

Thickness.—On account of the crumpling of the bedding planes in many places and the prominence of cleavage the thickness of the shale is difficult to measure, but it is probably not far from 1400 feet at the greatest. This diminishes to about 400 feet just north of Johnson City.

Weathering.—The rock weathers rapidly because of solution of the calcium carbonate it contains, so that ledges are found only near stream cuts. The lumps and flakes of argillaceous matter left behind decompose and crumble very slowly and turn yellow only after long exposure. Soils on this formation are thin on account of the insolubility of most of the rock and the steep slopes upon which it lies in places. The formation causes sharp, steep knobs of no great height. Where the areas widen the knobs are less conspicuous, but in the narrow belts of the formation on the Nolichucky plateau the knobs follow very distinct lines and rise above the Knox dolomite. The lower slopes of these knobs are occupied by the black and more carbonaceous shale. In areas where the Tellico sandstone appears it forms the tops of the knobs and the Athens shale lies upon the slopes.

TELLICO SANDSTONE.

Extent and character.—The Tellico sandstone is the latest formation shown in the quadrangle. Its outcrops are limited to two areas north and northeast of Johnson City, where it rests upon the Athens shale. It is named from Tellico River, in Monroe County, Tenn., where it is well exposed.

The formation consists mainly of calcareous sandstone, with interbedded calcareous sandy shale. When fresh these are bluish gray in color, but when weathered they become deep red or brown, the colors being due to the large amount of iron oxide in the rock.

Bedded in the sandstone are layers of calcareous conglomerate from 1 to 6 feet thick. These consist of pebbles of limestone like the Knox and of calcareous Tellico sandstone embedded in a matrix of calcareous sand. The pebbles are rather well rounded and range from half an inch to 4 inches in diameter.

Thickness.—The greatest thickness of the formation is 400 feet, and this amount includes only what is left by erosion in the synclinal folds. The Tellico and Athens are interbedded for a few feet.

Weathering.—By solution of the calcium carbonate which it contains the rock is readily reduced to a porous, sandy skeleton. This, however, is rather firm and causes elevations of 200 to 500 feet above the adjacent Athens shale. Its soils are moderately deep, but are too sandy and too rapidly drained to be of value. The large proportion of insoluble matter in the soils renders them sterile and they are little cultivated.

TRIASSIC (?) ROCKS.

BAKERSVILLE GABBRO.

Distribution.—In the southeastern part of the quadrangle are many rocks of the character of gabbro. These lie in a belt from 4 to 5 miles wide, passing just south of Huntdale, north of Bakersville, and through Roan, Big Yellow, and Hump mountains. A single sheet extends eastward into the Cranberry quadrangle and a number of dikes pass southwestward into the Mount Mitchell quadrangle. Gabbro is very prominent in Pumpkin Patch Mountain and along Little Rock Creek. Along the southeastern side of Stone and Fork mountains there are many dikes in a narrow belt.

In places a large part of the country rock is made up of gabbro, and it outcrops so much more strongly than other formations that it appears to form a continuous body. The gabbro consists of dikes, sheets, and small masses cutting the Roan gneiss and Cranberry granite. The dikes are most prominent in the southwestern part of the belt and there are more of the sheets in the northeastern part. The dikes cut the older rocks at a great variety of angles; the sheets lie rudely parallel to the foliation of the gneiss. There is, however, no difference between them except in form, and the same mass may be here a sheet and there a dike. These are not shown on the map because of their small size and extreme irregularity.

Age.—The most distinctive feature of the gabbro is the absence of dynamic metamorphism, although the adjoining rocks are all metamorphosed, in many places 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 common occurrence among those of the Triassic period and are present at intervals in 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. The texture of the rock is in the main massive and granular, but in places the gabbro has the ophitic structure of diabase. Near the contacts with other formations the grain of the rock grows perceptibly finer, but it is coarse at a few places in this quadrangle. It is composed chiefly of plagioclase feldspar, hornblende, and pyroxene in crystals of medium size. It contains also a small amount of plagioclase feldspar in porphyritic crystals. Rarely these are an inch or an inch and a half long, but as a rule are less than one-half inch. Such crystals are to be seen in the Stone Mountain belt. Additional constituents are magnetite and garnet in small grains and crystals. The latter is developed chiefly near the contacts, both in the gabbro and in the older rocks, but it seems in places 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 (see fig. 15), which are characteristic of the surface of the formation. Ledges are in general not far from the surface and the cover of brown clay is in most places thin. The rounded bowlders readily find their way downhill and block the stream channels for long distances. In this respect they are nearly as effective as ledges of other rocks.

STRUCTURE.

INTRODUCTION.

The rocks of this quadrangle that were deposited upon the sea bottom must originally have extended in nearly horizontal layers. At present, however, the beds or strata are in few places 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 planes are best developed in rocks of an originally massive texture and are usually much nearer together and smaller than the planes on which the deformation of the stratified rocks proceeded. In these more minute dislocations the individual particles of the rocks were bent, broken, and slipped past one another or were recrystallized.

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

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

GENERAL STRUCTURE OF THE APPALACHIAN PROVINCE.

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

Folds.—The folds and faults of the Valley region are about parallel to one another and to the northwestern shore of the ancient continent. They extend from northeast to southwest, and single structures may be very long. Faults 300 miles long are known, and folds of even greater length occur. The crests of most folds continue at the same height for great distances, so that they present the same formations. Many of the 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°; in many places 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 in some places the upper strata are pushed over the lower as far as 10 or 15 miles. There is a progressive change from northeast to southwest in the results of deformation, and different kinds prevail in different places. In southern New York folds and faults are rare and small. Through Pennsylvania toward Virginia folds become more numerous and steeper. In Virginia they are more and more closely compressed and many of them closed, while here and there faults appear. Through Virginia into Tennessee the folds are more broken by faults. In the central part of the Valley of East Tennessee folds are generally so obscured by faults that the strata form a series of narrow overlapping blocks of beds dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

Metamorphism.—In the Appalachian Mountains the southeastward dips, close folds, and faults that characterize the Great Valley are repeated. The strata are also traversed by the minute breaks of cleavage and are metamorphosed by the growth of new minerals. The cleavage planes dip eastward at angles of 20° to 90°, as a rule about 60°. This kind of alteration is somewhat developed in the Valley as slaty cleavage, but in the Mountain region it becomes important and locally obscures all other structures. All the rocks were subjected to this process, and the final products of the metamorphism of very different rocks are in many places 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. In that region formations whose original condition is unchanged are extremely rare, and in many places 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 in general 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 places 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 described in the foregoing paragraphs 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 at places 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. Most of the movements have resulted in a warping of the surface as well as in uplift. One result of this appears in overlaps and unconformities of the sedimentary formations.

As was stated under the heading "General geologic record" (p. 2), depressions of this kind took place at the beginning of Paleozoic time, with several repetitions later in the same era. These movements alternated with uplifts of varying importance, the last of which closed Paleozoic deposition. Since Paleozoic time there have been at least four, and probably more, periods of decided uplift. How many minor uplifts or depressions have taken place can not be ascertained from this region.

STRUCTURE OF THE ROAN MOUNTAIN QUADRANGLE.

Larger features.—The rocks of this quadrangle have undergone many alterations since they were formed, having been bent, broken, and metamorphosed to a high degree. The structures which resulted from these changes trend in general northeast and southwest, with the regularity usual in the Appalachians. This is conspicuously shown in the parallel folds and faults of Iron and Stone mountains.

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.

In a broad way the structure of the rocks of the Roan Mountain quadrangle exhibits one synclinal basin where sedimentary rocks occur, one area of uplift also bearing sedimentary rocks, and a second area of uplift exposing igneous rocks. The synclinal basin passes diagonally through the quadrangle and extends for many miles through Virginia and Tennessee. In this quadrangle it includes the syncline of Iron and Holston mountains and the syncline of Buffalo and Cherokee mountains; the latter passes into the Bald Mountain syncline of the Greeneville quadrangle. The anticlinal uplift lying northwest of this syncline occupies the plateau of Nolichucky and Watauga rivers, and southeast of the synclinal basin lies the principal uplift of granites and gneisses in the high Mountain area. Each of these anticlinal areas, as here shown, is but a part of great uplifts which extend far through North Carolina and Virginia. Minor folds in great numbers are contained in these main folds. In connection with the synclinal basin numerous faults have been developed, a relation which is exceptional in the Appalachians. In the uplifted area of the Watauga plateau many faults are seen in the usual association with anticlines.

Iron Mountain syncline.—Under this term are included several distinct axes. The principal one lies just northwest of Iron Mountain and passes down Stony Creek and through Buffalo Mountain and Bumpass Cove. It has a distinct pitch toward the southwest, so that the formations sweep across and around the axis in succession from the Cambrian quartzites of Stony Creek valley to the Ordovician shale on the west flank of Cherokee Mountain. In Buffalo and Cherokee mountains the pitch of the fold brings down an overthrust mass of the same Cambrian rocks that underlie Stony Creek valley. These are separated by a fault from the underlying Ordovician and Cambrian limestones, but all were folded as a whole, and the principal axis passes through all alike.

In the Iron Mountain basin the principal fold is broad and open. This is conspicuously the case from Buffalo Mountain northeastward and the rocks lie practically flat over considerable areas along Stony Creek and near Elizabethton. In Bumpass Cove the other end of the same axis shows similar light dips. Other dips nearly flat are to be seen in Rich Mountain, west of Erwin, and also near Hampton. Through other portions of the Iron Mountain basin the dips are comparatively steep and range from 45° to vertical and overturned. The change in the dips along Iron Mountain is shown in the various structure sections.

Several minor synclines are associated with the principal one. These appear in the limestones and shales along the southeastern foot of Iron Mountain and in Limestone Cove. These folds expand in the adjoining Cranberry quadrangle toward the northeast, but disappear farther southwest in this quadrangle. It is possible that minor synclines are associated with the numerous shear faults seen south of Erwin in the Unaka Mountains. The relation is obscure, however, and the faults are more probably shears like those of Buffalo Mountain.

In the overthrust quartzite mass of Buffalo Mountain the synclinal fold is complicated by numerous shear faults along which the strata have been piled up like gigantic shingles (see fig 2). The planes of these shear faults pitch southwestward near the end of the overthrust mass, and northeastward just north of Erwin. These did not at their roots cause offsets in the main fault outlining the quartzites, although they probably did in their upper portions. Both the main fault and the shear faults are marked by strong curves and have plainly been deformed and folded since their production. Three miles northeast of Embreeville a subordinate uplift of the plane exposes the underlying Ordovician limestone. At the northeast end of the quartzites all the rocks dip from 15° to 20° W. The dips grow steeper as the beds are followed toward Erwin and within a short distance become vertical and overturned. Southwest of Erwin the overturn of the strata and fault plane gives place again to steep northwesterly dips.

As the fault plane which surrounds Buffalo Mountain is traced it exhibits the shape of a much flattened S (see fig. 1). It separates the quartzites of Cherokee and Buffalo mountains from the limestones of the Valley and swings in a semicircle around the western end of the Flattop Mountain group. Thence it passes northeastward, in the main outlining the Cambrian quartzites from the Archean granites. It passes successively downward through the underlying formations, from the Athens shale at the north into the Cranberry granite, in a southerly direction. A similar transgression is shown in the overthrust mass, but much less regularly and distinctly, and the fault lies in younger beds toward the north. At no point is there indication of association of the fault with an anticline, but its plane was due to a shear passing at a low angle through the formations in succession. Where the fault passes eastward into the Cranberry quadrangle it shears across the various formations more abruptly, and in that quadrangle it repeats the shearing at several places. Its present devious course is due in large measure to the subsequent folding and minor faulting to which it has been subjected. The only places at which the main fault appears to have been actually offset by the later faults are near Hampton. It is probable, however, that in the strata removed by erosion there was much offsetting of the upper layers. The magnitude of the pressures applied can be inferred from the squeezing and thinning of the underlying Knox dolomite beds, seen in fig. 9. Taken together, the minor faults, the later folding, and the overturns constitute an amount of folding comparable in extent with that seen in the ordinary Appalachian folds. It is thus probable that the great overthrust was practically completed before the period of folding began (see figs. 2 and 3), and that during the latter period were produced the shear faults of Buffalo, Unaka, and Stone mountains and those around Stony Creek basin.

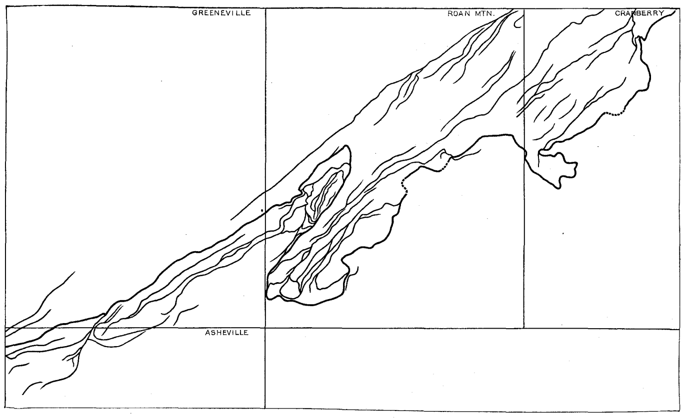


FIG. 1.—Map of the faults in the Roan Mountain and adjacent quadrangles, showing the relation of the minor faults (lighter lines) to the earlier major overthrust (heavy line).

Motion along the plane of the Buffalo Mountain fault was very great and is to be measured by many miles. Section F–F, through Flattop and Embreeville, cuts across the fault plane at three points, the extremes being 12 miles apart. With due allowance for the subsequent folding and faulting of the plane, it is probable that the original displacement on the shear plane along that line was at least 20 miles. A similar extent of the plane is shown in section E–E, which passes through Unaka and Buffalo mountains. When this amount of throw on the fault plane is compared with the usual throw of Appalachian faults, which is from 1 to 3 miles, the difference in importance is readily seen.

Nolichucky uplift.—The anticlinal area of the plateau drained by Nolichucky and Watauga rivers is notable for the closeness and regularity of its folds. This is especially clear in the Greeneville quadrangle on the west. A single formation, the Knox dolomite, rises and falls on the anticlines and synclines and occupies most of the area. In the synclines narrow belts of the overlying Athens shale are inclosed, and on the anticlines equally narrow strips of the underlying Nolichucky shale and Honaker limestone appear. Such is the regularity of the folds that no other formation than these appears on the plateau, except two small areas of the Tellico sandstone, left by erosion in the shallow synclines extending northeastward from Johnson City. Sections A–A and C–C represent this feature.

The force of compression seems to have been so controlled as to produce few structures except folds. There are many faults, but they are of no great length and are not of sufficient throw to involve any formations except those close to the Knox dolomite. They range in length from 2 or 3 to 15 miles. In many places the beginning of a fault in a sharp anticline can be seen. Two examples of this are shown in the northwest corner of the quadrangle (section C–C). The faults are situated on the northwestern sides of the anticlines and their planes are nearly parallel to the beds on the southeastern side of the fold. The fault planes dip to the southeast at angles ranging from 30° to 70°, the dip of most of them being about 50° or 60°.

Archean uplift.—The principal anticlinal area is occupied by the Archean granites and gneisses. It is marked by its position with reference to the syncline of sediments and to a much less extent by structures which can be deciphered in the granites themselves.

The granites and gneisses are the oldest rocks in the region and the sediments were deposited upon them; consequently, surfaces now occupied by the granites are areas of uplift in comparison with those occupied by the sediments. The granites are cut off from the sediments by faults, but for lack of distinctive or regular beds none can be determined in the main mass of the Archean rocks. The only anticlinal fold which can be definitely determined in the Archean rocks is seen in White Rocks Mountain. The Beech granite there passes under the Cranberry granite along most of its contacts and the foliation planes of both granites dip away from the mass of the Beech granite. Many of them have low or even flat dips, giving the Beech granite a general domed shape.

The area of Roan and Carolina gneisses in the southeast corner of the quadrangle has a general synclinal nature, and is the complement of the uplifted area of the granites. The Cranberry granite cuts the Roan gneiss and as a whole passes beneath it. Around Plumtree the Carolina gneiss rests upon the Roan gneiss in a rude syncline, but in other areas the two are interbedded rather intricately. The Carolina gneiss formed the covering mass in which the Roan gneiss was intruded, and the same position was filled by the Roan gneiss when the Cranberry granite was intruded. Likewise, the Cranberry granite overlay the intrusive body of Beech granite. Thus in a northerly direction successively deeper Archean formations appear at the surface. This relation is accompanied by the general dip of the foliation planes toward the south. The Cranberry granite and Roan gneiss swing in a semicircle around the Carolina gneiss bodies in this and the Cranberry quadrangles. These relations constitute a pitch of the formations into a synclinal basin near Toe River. A similar pitch in a northeasterly direction is to be seen in the Cranberry quadrangle. Toward the southwest, in the Mount Mitchell quadrangle, there is a steady diminution of the amount of Cranberry granite and Roan gneiss at the surface, which appears to indicate a continuation of the pitch of the fold in the same direction.

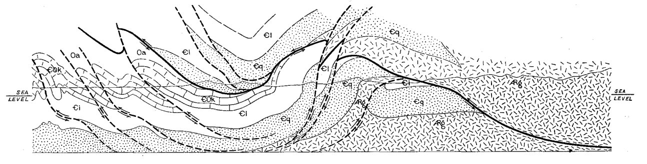


FIG. 2.—Theoretical section across Buffalo Mountain and Limestone Cove on line of section D—D.
Shows the character of the deformation and the relation of the younger faults to the older overthrust.
Major overthrust, heavy continuous line; minor faults, broken heavy line; Oa, Athens shale and overlying beds; ЄOk, Knox dolomite; Єl, Cambrian limestones and shales; Єq, Cambrian quartzites and slates; Æg, Archean granite and gneiss.

Metamorphism.—In the Archean rocks metamorphism is plainly the most conspicuous result of deformation, although folding and faulting are important. Faults can be discovered in the granites only near the sediments, but undoubtedly exist elsewhere. Folding is prominently shown by the Roan and Carolina gneisses (see fig. 7). Along the southern border of the quadrangle it is intense, and the layers are thickened, thinned, and crumpled to an extreme degree. In the Cambrian quartzites and slates of the Iron Mountain basin metamorphism was subordinate to folding and faulting. A few of the coarse conglomeratic beds near the base of the quartzite series were metamorphosed in the same manner, but not to the same degree, as the granites. The common result of the metamorphism was the production of slaty cleavage among the shales and shaly sandstones. Many of these rocks are now entirely transformed to slates. Another result of the metamorphism, equally prominent in the Cambrian rocks, is the transformation of fine sandstones into quartzites. That this is wholly the result of metamorphism through deformation can not be definitely stated, since a certain amount of it might be attributed to the passage of circulating waters through the rocks without any exceptional pressure. Many beds are now perfectly glassy and structureless, especially the top of the Erwin and many in the Snowbird. The sections of Nolichucky, Doe, and Watauga rivers give good illustrations of this feature.

By far the greatest discoverable effect of the deformation of the Archean rocks is metamorphism. Its processes were carried on 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. Simultaneously new minerals, especially quartz and mica, grew out of the fragments of the old minerals. The new minerals were arranged at right angles to the greatest force of compression at any particular point. As the compression was about uniform in direction over large areas, there resulted a general parallelism of the longer dimensions of the minerals, as shown in fig. 8. To this is due the schistosity of the rocks. In folding, the differential motion in the sedimentary strata took place to a large extent along bedding planes. As deformation became extreme, however, other planes of motion were formed through the separate layers, just as they were in the massive igneous rocks. In rocks which had already become gneissoid or schistose by previous metamorphism the existent schistose planes served to facilitate flexure, as did the bedding planes of the sediments. In the massive igneous rocks there were no planes already formed, but they were developed by fracture and mashing, and the change of form expressed in folds was less than that seen in the laminated rocks. The schistose partings are in a general way parallel to one another for long distances and over large areas. In places they 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 as a rule about parallel to the general contact of the formations, the yielding to pressure having been directed by the difference in strength between the formations. Thus, while the strike of the different formations may vary considerably in adjoining areas, yet the schistose planes swing gradually from one direction to another, and in few places is there an abrupt change. For the most part the planes of schistosity dip to the southeast in this quadrangle, and their dips are high—between 45° and 90°. Exceptional areas are those along the eastern border of the quadrangle and north of Hump Mountain, where the strikes are northwesterly and the dips are 5° to 30° SW. These areas are situated along a zone of cross folding.

Periods of deformation.—Just how much of the metamorphism proceeds from the period of deformation commonly termed the "Appalachian" is doubtful, for it is certain that some of the Archean rocks had attained considerable metamorphism during previous epochs. The amount of schistosity and folding received substantial additions in this period. Deformation was not, however, completed during one process. From the facts observed in this and 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. The great fault passing around Buffalo and Unaka mountains is of this class. In like manner vast masses of igneous rocks were folded, and the already existent schistose structures were deformed, as in the gneisses east of Bakersville.

Vertical movement.—The latest form in which yielding to pressure is displayed in this region is vertical uplift or depression. Evidence can be found that such movement occurred at various intervals during the deposition of the sediments, as at the beginning of the Snowbird deposition, and at both the beginning and end of the periods of deposition of the Shady limestone, Knox dolomite, and Athens shale. In post-Carboniferous time, after the great period of Appalachian folding just described, such uplifts took place again and are recorded in surface forms, such as peneplains and plateaus.

Various peneplains.—While the land stood at one altitude for a long time most of the rocks were worn down to a nearly level surface. Over most of this region one such surface was extensively developed. Its much-worn remnants are now to be seen as small plateaus in the Mountain district at altitudes of 3500 and 3600 feet. The best preserved of these plateaus lies north and east of Doe River and extends eastward for many miles. Evidences of another plain at an elevation of about 3000 feet are found in many of the Cambrian quartzite mountains along the border of the Great Valley. Still a third is shown in the basin of Toe and Cane rivers at 2600 feet above sea. (See fig. 17.) Many remnants of this plain are also present along the borders of the limestone valleys. Most prominent of all is the peneplain which occupies most of the Great Valley in the areas underlain by limestone and shale and which is illustrated in fig. 16. The greater part of this plain stands 1500 or 1600 feet above sea, but along its borders it curves upward toward the quartzite mountains to 1900 or 2000 feet. Greasy Cove, Hampton Valley, and Stony Creek valley are fine examples of the peneplain borders in their original form. Since its formation uplift of the land has given the streams greater fall and greater power to wear. They have accordingly cut down the old surface to varying depths, according to their size and power. Deep, narrow stream valleys have been produced along the lower courses of Watauga and Holston rivers, and the peneplain has been transformed into a plateau. As these streams are still wearing their channels downward and but little from side to side, they have not reached the grade to which the old plain was worn. The amount of uplift was, therefore, much more than the depth of the present stream cuts—probably as much as 500 or 600 feet. The amounts of uplift following each of the older peneplains were about the same as their present differences in altitude.

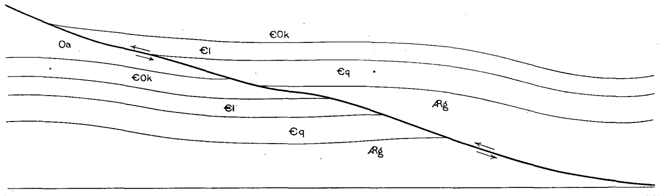


FIG. 3.—Theoretical section showing supposed relations of beds in fig. 2 after the major faulting but before the later folding and faulting.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

The rocks of this region yield various materials of value, such as iron ore, pyrite, mica, soapstone, talc, corundum, lime and flux, building stone, 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.

BROWN HEMATITE.

Hematite ores are abundant in the Tennessee portion of the quadrangle, and include limonite and various other hydrated oxides of iron. They occur principally as lumps and masses in residual clays of the Shady limestone, but minor deposits are found also in the underlying shales and quartzites.

The quartzite ores are present generally in the Cambrian quartzite areas, especially south of Erwin and Unicoi, and as a rule lie near fault planes. They grade into breccias of quartzite and iron ore, or into very siliceous limonite, and do not commonly occur in large quantities. Their concentration near the fault planes is probably due to the more ready passage of infiltrating waters in those situations. In a few places these lean ores appear to replace shaly beds between the quartzites. Ores of this class are of small value.

The ores in the Shady limestone clay are very pure and have received the principal development. As in all deposits of this nature, the amount of ore in the clay varies much. In Bumpass Cove and Stony Creek valley the ore lumps occur in the greatest abundance and regularity. The lumps attain a size as great as 2 or 3 feet, and the deposits have been worked to a depth of more than 50 feet. The richest and most numerous deposits are found in the lower part of the limestone near its junction with the Erwin and Hesse quartzites. Iron ore is almost everywhere found in the clays of the Shady limestone, but the considerable deposits lie in the synclinal basins, such as Bumpass Cove and Stony Creek valley. The greater richness in these situations is due to downward concentration and retention of the ore in basins by the underlying quartzite. The upper layers of the Erwin quartzite are very fine grained and dense and more impervious to the passage of water than any other formation in the region. The ore is formed by oxidation and hydration of pyrite in the quartzites. The pyrite is disseminated through the layers of quartzite and is most abundant in the upper beds, but it is found also in many other layers.

The ore banks of Bumpass Cove and Stony Creek have been worked for many years, Bumpass Cove in particular having furnished enormous quantities of ore. The ore is mined in open cuts, as shown in fig. 6, and is separated from the clay by washing. The cover of clay on the limestone ranges from 2 or 3 to more than 50 feet in thickness, and the entire mass is removed down to the rock surface. This surface is very irregular, being the product of solution. Ore is found throughout the clay and down to the bed rock. On Stony Creek the ore is now being worked at only one locality, 1 mile south of Carter. In Bumpass Cove many cuts are being worked and the product is smelted in the furnace at Embreeville, with a daily product of 100 tons. The ore is low in phosphorus, sulphur, and silica, and contains an average of 42 per cent of metallic iron.

MAGNETITE.

Magnetic iron ore is found at nineteen places in the quadrangle in quantities sufficient to have attracted mining. At many other points magnetite float is found and magnetite gangue minerals appear with little or no magnetite. These occurrences lie in a zone running northeastward from Huntdale and Red Hill and curving eastward around Roan Mountain. At the east end of the belt, just outside of this quadrangle, the Cranberry iron mine is located on the principal body of this ore.

Almost without exception the magnetite deposits occur in the Cranberry granite and schistose granite, and most of them are near the contact of the granite and Roan gneiss. The ore and gangue occur as a series of great lentils in the schistose granite about parallel to the planes of schistosity in the granite. Over most of the area these lentils dip to the southeast at angles ranging between 45° and 80°. Near Shell Creek, however, the dip is southwestward. The ore occurs as a series of lenticular bodies composed of magnetite with a gangue of hornblende, pyroxene, and epidote, a little feldspar, calcite, and quartz, and a few other unimportant minerals. The ore lies in the gangue in the shape of smaller lenses with the same general dip as the whole body. In none of the occurrences in this quadrangle is the deposit more than 60 feet thick or half a mile long, and as a rule it is much less. The lentils of ore run from a few inches up to 5 feet in thickness and most of them are from two to five times as long as they are thick. Some lentils have sharp limits, but as a rule the gangue and ore grade into each other at the contact. Considerable ore is sprinkled through the gangue and more or less gangue is scattered through the ore bodies. The ore is very free from the objectionable elements—phosphorus and sulphur—though it is not high in iron. The ore mined at Cranberry yields an average of 42 to 46 per cent of iron with ordinary concentration. Considerable trouble is experienced in freeing the ore from gangue on account of the tough nature given to the mass by the epidote. The minerals of the ore and gangue have not been crushed or metamorphosed, and in this respect differ from all the adjoining formations. It is thus probable that the ore was deposited after the Carboniferous period, since the metamorphism affected all the rocks of that age or older.

Because of the occurrence of the ore as a series of lentils its quantity is uncertain. As one lentil is worked out its place will be supplied by another. The ore bodies may be found to diminish, to remain about the same, or to increase in size. The openings in this quadrangle are not large and furnish little information as to the extent of the deposits. To judge from the exposures at Cranberry, it is probable that the individual lentils are about as deep as they are long. Accordingly, it would seem that the only deposits of importance are those near Shell Creek and about a mile south of Roan Mountain station, where the thickness and extent of the gangue minerals are greatest. At the latter place the amount of ore seems to be greater than near Shell Creek. Considerable prospecting has been done in this quadrangle, but no mining of consequence.

PYRITE.

Pyrite occurs in practically all of the Cambrian quartzites, but is most common in the upper layers of the Erwin. It is there found in the form of fine grains as a secondary replacement of the original siliceous material. Its amount is so considerable that mining operations were begun at Stony Creek for the purpose of utilizing the sulphur in the form of acid. This work was soon discontinued. The pyritous quartzites used for that purpose were at the very top of the formation; being but a few feet above drainage level, the sulphides were practically undecomposed. Over these beds are small bodies of gossan, and individual pieces can be selected grading from pyritous quartzite into gossan.

MICA.

Mica is of common occurrence in the pegmatite veins of the Roan and Carolina gneisses, already described, and to a small extent in the Cranberry granite. Nearly all the mica is mined from the bodies in the Carolina gneiss. Only in a belt about 4 miles wide running eastward from Bakersville is the mica sufficiently good to be worked. Elsewhere, the crystals were either crushed or distorted by movement in the rock, or were not originally of sufficient size. The mica is muscovite and is crystallized with quartz, feldspar, and biotite, forming pegmatite. Numerous other minerals are found in the pegmatite, notably beryl and garnet. Most of the mica in this district has a light-brown or "rum" color and is not much specked. In the pegmatites of the mica-bearing belt, southward from Bakersville, many rare and valuable minerals are found. Twelve mines in this quadrangle have furnished a great deal of mica and are among the oldest in the State. These are the Clarissa, 3 miles east, and the Hawk, $4\frac{1}{2}$ miles nearly east, of Bakersville; Henson, on the head of Henson Creek; Justice and Charlie Ridge, just west of Spear; Alfred, Doublehead, and Meadow, one-half to 2 miles north of Spear; Plumtree, just east of Plumtree; McConry, west of Frank; Lincoln and McKinney, at the head of Powdermill Creek.

From rock with a texture similar to that of granite the pegmatite ranges to one in which the mica crystals attain diameters of 12 inches or more. The average diameter is 3 to 5 inches. The pegmatites worked in this district range from $1\frac{1}{2}$ to 15 feet in thickness. They cut the gneisses or are about parallel to their foliation, the latter attitude being the more common. There is generally more or less concentration of the mica in a "vein." The position of this vein in the pegmatite is very irregular and can not be predicted. Consequently, the success of any mica mine is uncertain. Good mica may be found at once or barren rock may prevail throughout the vein. Mica has been proved to a depth of 65 feet in the Charlie Ridge mine, 300 feet in the McKinney, and over 300 feet in the Clarissa mine. Many of the crystals do not furnish sheets across their entire diameter, but are divided by seams and cuts, or "ruling," into strips and angular pieces. These, however, are suitable for ground mica. Imperfectly crystallized or "A" mica also diminishes the value of the mica "blocks," since only small-sized sheets can be cut from them. Much of the mica is rendered less valuable by impurities in the form of dendritic figures, stains, and specks, composed of fine magnetite. In the shallow openings, where the rock is decayed, clay works in between the sheets. The clay can be removed by picking and washing, but the figures of magnetite can not be taken out, since they exist between the thinnest sheets.

Hundreds of pits and shallow openings have been made in this region, but were usually limited to the decayed rock and soon exhausted. Mining in the solid rock was carried on at the points noted on the economic geology map. East of Bakersville, at the Hawk and Clarissa mines, shafts were sunk to considerable depths and much mica was taken out; but work there has long been stopped. Operations are now being carried on near Spear and Plumtree in most of the old mines and a few new ones, owing to the present high price of mica. The most extensive work is being done at the Justice and Charlie Ridge mines, where tunnels are being driven in for 250 feet or more to cut the pegmatite below the old open cuts.

TALC AND SOAPSTONE.

Talcose rocks are found at ten points near the southern border of the quadrangle. The rock is sufficiently pure to be useful at six points—two east of Bakersville and four near Little Bald, in the southwestern part of the quadrangle. Both the soapstone and talc are derived by metamorphism from rocks of the peridotite and pyroxenite group. Talc is a hydrous silicate of magnesia and is seen in nearly the pure form 1 mile east of Little Bald, where it has a white color and a schistose structure. It occupies the most of two small areas of the peridotite formation which is associated with hornblende gneiss. Two miles northwest of Little Bald two small bodies of soapstone are inclosed directly in the Cranberry granite. The soapstone at this point is a talc schist containing a great deal of chlorite and a little iron oxide in exceedingly fine grains. It is very schistose and intermediate in character between the talc schist and the ordinary form of soapstone. At the localities east of Bakersville the soapstone is of a light-gray color, is associated with dunite, and forms most of the outcrop of the formation. It is there surrounded by the Roan gneiss.

In connection with the other areas of the formation small quantities of talc and soapstone are also found. Most of the deposits are chloritic and contain more or less tremolite. All these bodies of soapstone and talc are of small size and in remote localities. The rocks have been used locally for fireplaces of dwelling houses, but are not likely to prove of value for other purposes.

LIMESTONE.

Limestone suitable for flux is widely distributed throughout this portion of the Great Valley. It is found principally in the upper layers of the Knox dolomite, in a similar position in the Honaker limestone, and in the Shady limestone. A large quarry was opened about 5 miles north of Elizabethton and the material was carried to a furnace in Virginia. The rock there used was taken from the topmost 50 feet of the Knox dolomite and consisted of dark-blue fine-grained nonmagnesian limestone. About $3\frac{1}{2}$ miles east of Johnson City limestone is quarried for use in the furnace at Carnegie in smelting the Cranberry magnetite. The layers that were used consisted of fine dark-blue limestone at the top of the Honaker. Equally suitable material is obtained from the gray and white beds of the Shady limestone, for use in the furnace at Embreeville.

Limestones suitable for lime burning are very abundant in the northern part of this quadrangle. Those beds which are used for flux are equally good for lime, and numerous other individual beds can be found in the Knox dolomite. So abundant is good limestone that small kilns are built and the rock is burned within a mile or two of the point where it is wanted. The beds most commonly used lie in the upper part of the Knox dolomite, in the Honaker limestone, and in the Shady limestone. The wide distribution of good lime rock has prevented the establishment of a considerable industry at any point.

CLAY.

Clay suitable for brickmaking is of wide occurrence in the quadrangle, especially in the Tennessee portion. Nearly all the formations are reduced to residual clay through much of their areas. In two situations, however, the clays are best developed. These are in the hollows and depressions of the plateau surfaces and in the bottom lands and terraces along the watercourses. On the plateaus long-continued decay thoroughly decomposed the formations and their finer particles were washed into the hollows. In those situations they still remain wherever recent cutting of the streams has not been active and removed them.

The clays occurring in the flood plains of streams are found practically everywhere outside of the granite and gneiss regions. They occur as a layer a few feet thick overlying sand and gravel. The best clays are found along streams which head in the limestone or shale areas and are not subject to wash from the harder formations. Along all the larger streams, at various small intervals above their flood plains, there are terraces upon which lie clays of the same character as those in the flood plains. These terraces are conspicuous near Nolichucky River and around Elizabethton, reaching 5 miles above and below the town. In Greasy Cove and Hampton Valley a combination of the flood plains and terraces forms the margin of one of the plateaus. The deposits of clay there rest upon limestone and are the most extensive of the region. The banks of Nolichucky River 2 miles southwest of Erwin show 20 feet of clay resting upon coarse gravel. At the base are a few feet of clay, a good deal of which is ocherous. Clay of the same character has been found in wells at various points around Erwin on the same terrace. The ocher is derived from the Watauga red ferruginous shales upon which the clays rest.

Quantities of bricks have been burned at Jonesboro, Johnson City, and Elizabethton. At Elizabethton flood-plain clays were used. At Johnson City and Jonesboro the clays were taken from hollows, and were formed by wash from limestone and calcareous shale. Small quantities of brick have been burned at scores of other places in the quadrangle for local use in chimneys, but no industry has been established at any point.

BUILDING STONE.

Good rock for building purposes is found in many formations of this region. It comprises granite, sandstone, limestone, marble, slate, and flagstone. Of these, limestone has been the most used. The Roan gneiss, the Cranberry granite, and the various quartzites and limestones have been utilized for chimneys, foundations, and bridge piers. Little quarrying has been done, but the loose rock has been used nearly in the natural state. Stone for resisting heat is found in the soapstone and the Cambrian quartzites and was employed in the old iron furnaces. Material for flagstones is abundant in the Carolina gneiss in layers from 1 inch to 1 foot thick. Ornamental stone can be obtained from the beds of white marble in the Shady limestone.

Probably the most generally valuable and most useful building stone found in the region is the Cranberry granite. This is widely distributed and is well exposed in countless stream cuts. Its strength and durability are shown by its massive ledges and its huge loose blocks. The usual colors grade from white to gray, but at many points the redness of the feldspar gives the rock a rich, handsome color. Such red granite is to be seen near the Cambrian quartzites south and southeast of Hampton. Rock of similar red color, but coarser grained, is found in the Beech granite near Craborchard, along its contact with the Cranberry granite. The beds of Cranberry granite are of even texture throughout large masses. Along the northwestern border of its area the rock has been less affected by metamorphism than elsewhere, and is, consequently, freer from joints and the schistose planes which characterize it in many localities.

The various limestones furnish abundant building material. Beds range from a few inches up to 2 feet in thickness, and the rock splits readily along the bedding planes and is easily dressed. Its durability is well shown in the natural ledges and in bridge piers and chimneys which have been standing for many years. The material is so abundant that it can be obtained within very short distances of the points where it is to be used. At one point or another practically all the limestone formations have been used for building purposes. The white marble in the Shady limestone is well adapted for ornamental work. Its color is white and uniform, and it is finely crystalline. Its beds vary from 1 to 3 feet in thickness, and it is comparatively free from seams and bedding planes. Many natural ledges attest the ability of the rock to withstand exposure. The best outcrops are found in the lower part of Stony Creek valley and half a mile northwest of Erwin.

Slates occur principally in the Hiwassee slate and the upper part of the Athens shale. Various areas of Hiwassee slate in Buffalo Mountain furnish the largest bodies, but considerable can also be had southwest of Chestoa. The rock is fine grained and argillaceous, and of a dark-bluish color. Most of it is ribboned with narrow bands of gray. The cleavage is generally strong and independent of the stratification. The rock is durable and forms considerable cliffs. The upper beds of the Athens shale would furnish a fair quality of slate. They are grayish in color and of fine grain. They are in most places banded with ribbons of lighter gray. In the various stream cuts through the formation north of Elizabethton these strata are well exposed. The cleavage is considerable, although not as strong as in the Hiwassee slate. No attempts have been made to quarry either of these slate formations.

WATER RESOURCES.

WATER POWER.

The resources of this quadrangle in the form of water power are abundant. The streams, both great and small, flow rapidly in four-fifths of the area. Since they drain well-forested regions and are fed from multitudes of springs 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 relations of position, either above, below, or on the old plateau surfaces. As is explained under the heading "Topography," the plateaus were developed at various heights over most of the quadrangle, except near the State boundary and along the main divides. A few of the large mountain masses have never been reduced to the levels of the plateaus.

Since the formation of the original peneplains, 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 streams and are progressively shallower toward their heads. Down the slopes of the mountains the small streams descend with very heavy grades—in general from 100 to 300 feet to the mile. As they pass through the margins of the plateaus they descend more slowly, the ordinary slope being less than 30 feet to the 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. Holston River has lowered its channel in a canyon throughout its course in this quadrangle. Watauga River here passes through three stages. Above Iron Mountain it is still cutting down into the 2600-foot plateau; below Iron Mountain it runs for a few miles nearly at the grade it established when the peneplain of the Valley was formed at 1600 feet; below Elizabethton it enters a canyon which steadily deepens to its junction with the Holston. Nolichucky River, called Toe River in North Carolina, flows in a sharp canyon 500 to 600 feet below the level of the 2600-foot plateau until it enters a gorge in the Cambrian quartzites, through which it falls rapidly to the limestone valley in Tennessee. It thence flows on a part of the 1600-foot plateau, cuts through Buffalo and Cherokee mountains, and emerges upon the plateau again in the Great Valley. The head of its canyon in this plateau is reached just west of this quadrangle. The smaller tributary creeks and rivers flow with similar courses from plateaus through canyons and thence to lower plateaus, the steep grades being in the stretches between the various plateaus. On these streams the backward cutting into each plateau is much less extensive than on the large rivers.

The total descent of Toe River and its extension, the Nolichucky, is from 2245 feet to 1495 feet. About 400 feet of this descent is between Poplar and Chestoa, a distance of 8½ miles, where the river cuts its gorge in the Cambrian quartzites. Its principal branch, Cane River, falls 175 feet in a little more than 7 miles. Holston River descends only from about 1490 feet to about 1215 feet in 28 miles. Watauga River enters the quadrangle from the east at an elevation of 1815 feet and joins the Holston at about 1280 feet. Its steepest descent is at its passage through Iron Mountain, where it falls nearly 100 feet in 2 miles. Doe River, a much smaller stream than the others, descends from 2565 feet at Roan Mountain to 1532 feet at Elizabethton, a distance of about 16 miles. The heaviest part of this fall is in the gorge above Hampton, where there is a drop of 400 feet in about 4 miles in passing through the Cambrian quartzites. There is a similar drop below Hampton, at the passage through Iron Mountain, of nearly 175 feet in 2 miles. The character of these gorges through the quartzites is shown in figs. 4 and 11.

Most of the other streams in the quadrangle are short and rise within its limits. In the mountains they have steep grades but no great volume for power purposes. North Indian Creek, for instance, between Limestone Cove and Unicoi falls at the rate of 80 feet a mile. Between Unicoi and its mouth its fall is about 50 feet a mile. Its grade, which is fairly uniform throughout its course, grows gradually steeper toward its head and there are almost no falls. Stony Creek has similar but lower grades and less water. Rock Creek, which is the principal minor tributary of Toe River on the north, unlike the creeks in Tennessee, has many small falls and some of its steepest grades are near its mouth. Laurel Fork of Doe River and Tiger Creek both rise on the high plateau at 3500 feet and fall about 1700 feet to their mouths near Hampton. Small falls are numerous on these creeks, and the amount of power which can be developed is great for the size of the streams. Laurel Fork, in particular, falls 500 feet in less than 2 miles, where it crosses the Cambrian quartzites.

There are thus two situations in which high grades are present in nearly all the streams. The grades are greatest where the Cambrian quartzites are crossed, and next in importance in the upper parts of the canyons in the several plateaus. Locally, hard portions in the granites and gneisses of the mountains cause small falls and rapids. These are manifest in the canyon of Doe River just below Blevins and to a less degree along Toe River at various points. Exceptions to the foregoing statements are found where the streams cross the hard beds at the plateau levels, typically shown by North Indian Creek just above Unicoi and by Nolichucky River below Erwin. These streams flow through the quartzites bordered by flood plains and with almost no rapids or falls.

The water power developed in this region is thus obtained primarily by the elevation and cutting of the plateaus. Since the larger streams have nearly all cut below the plateau levels, most of those water powers which are above the plateaus are on small streams and of no great amount. Rock Creek in North Carolina is typical of those above the 2600-foot plateau. Streams which are above the 3600-foot plateau are smaller and of no consequence for power. The major descents and water powers are between the 2600-foot and 1600-foot plateaus. The canyons below the 1600-foot plateau are cut mainly in limestone and the descent is nowhere concentrated into large falls. Where the steeper stretches between the plateaus coincide with the Cambrian quartzites the greatest falls occur. The quartzites are the hardest rocks of the region and concentrate the fall within narrow limits. The granites and the gneisses do not differ from each other greatly in their influence on the immediate stream grades, and in them there is thus less of the concentration into falls and rapids due to hard beds of rock. The Beech granite is hard enough to produce heavy stream grades, but it is not crossed by any considerable stream in this quadrangle.

The foregoing statements show that this quadrangle contains an enormous amount of water power. It is still practically undeveloped, however. Temporary wooden dams have been put in at a few points on the rivers, such as Chestoa on Nolichucky River and White Rock on Doe River; but these utilized less than 10 feet out of the hundreds of feet of head. These dams furnished power for sawmills. Small creeks throughout the quadrangle are dammed at many points and their power used for gristmills, but the power thus developed is trivial and not even 1 per cent of the total has been used. Inasmuch as the main streams of the quadrangle are followed by railroads the facilities for transportation will be excellent whenever the power is put to use. With the present possibilities in the way of electrical transmission of power, the energy of the mountain streams is of great value and should soon be transmitted to the towns along the borders of the valley and used in manufacturing.

WATER SUPPLIES.

The various sources of water in the Roan Mountain quadrangle furnish an abundant supply. About three-fourths of the region is mountainous and the remainder is gently rolling and hilly. The mountainous portion is, for the most part, covered with a heavy growth of timber, although near the course of Toe River the dissected plateau and uplands are extensively cleared. A large amount of land in the valley also is cleared. The fall of rain and snow is heavy in the mountains and the natural advantages for water storage are very great. The rocks have numerous joints and planes of schistosity, and these are able to hold large quantities of water. The dip of these planes is in general steep, and the rainfall is readily conducted into the interior of the rocks. Evaporation is checked by the forest cover and by the low temperatures due to the height of the country, so that ample time is allowed for the transfer of the water into the earth. The streams rise and fall rapidly in times of flood and the usual flow is full and steady. Countless springs maintain this flow in spite of occasional droughts. In the mountains, where solid rock comes close to the surface, many of the springs issue directly from it. In the valleys and plateau areas the residual soils are from 6 to 50 feet thick, and the flow of the springs is largely absorbed by these soils and seeps out from the clay in the hills. On surfaces of this kind actual springs are much fewer than on the steeper mountain slopes. The plateaus are most prominent along Toe and Cane rivers and around the headwaters of Doe River. The Valley portion of the quadrangle is underlain by limestones and shales. Many waters coming from the shales have a considerable mineral content, owing to the presence of pyrite in the shale. The shale regions are also the most poorly supplied with water. In the limestone areas the water is less abundant than in the mountains. Much of the drainage is underground and over large areas the rainfall disappears in sinks. Elsewhere the water comes to the surface and springs are numerous. Some of these have a bold flow, being sufficient to run small gristmills. The water of the Valley is almost altogether calcareous, except in the shale areas, as above stated.

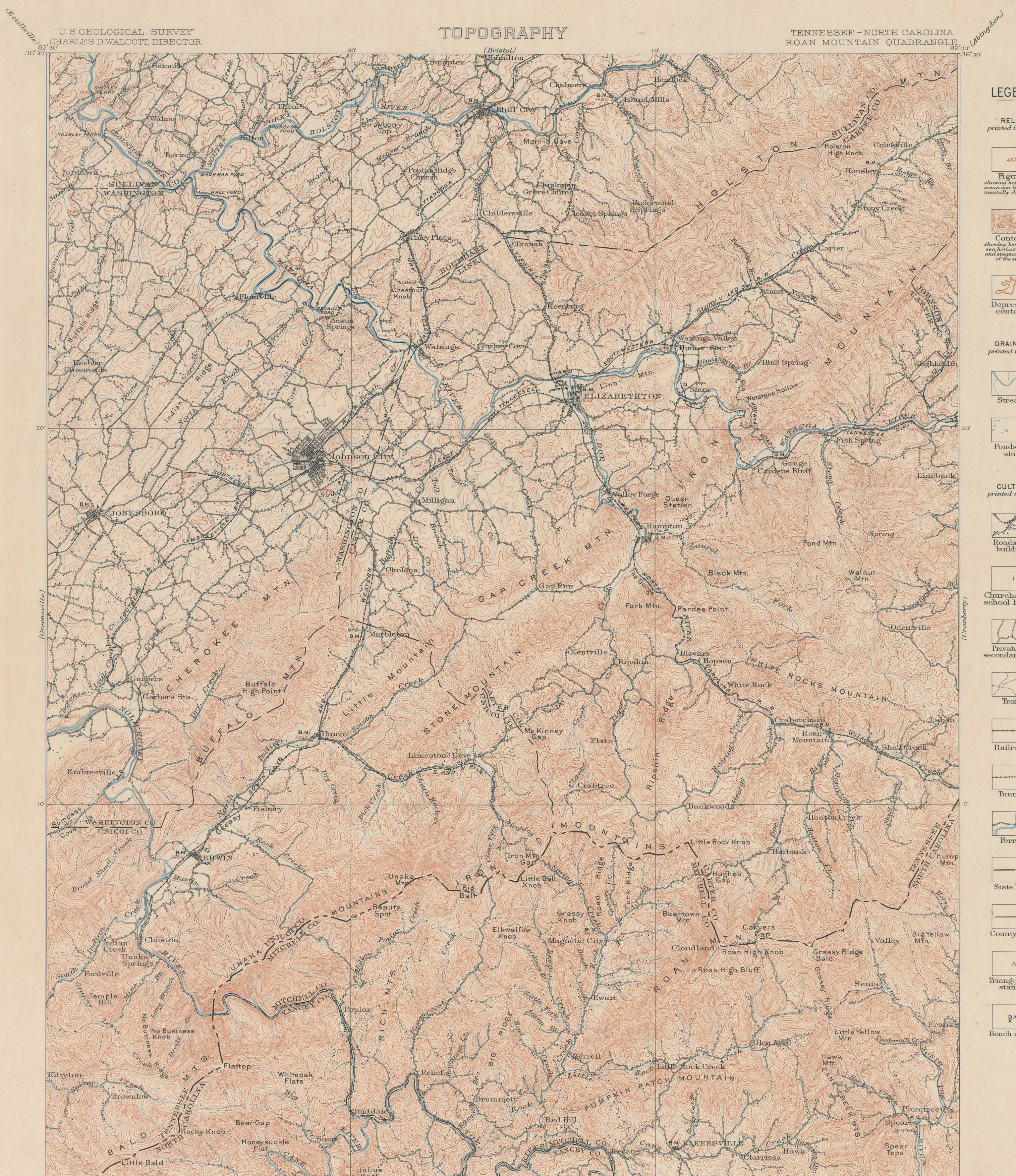
The only use made of the enormous outflow of water from this region is for domestic purposes. The houses are built within easy reach of springs, which is possible in most places. In the areas of sinks and underground drainage shallow wells are sunk in clay and in some localities water is stored by stopping up the sink holes. A large part of the water supply of the town of Hampton is procured from a single spring which flows out of the limestone. This is probably the outflow from a large area of gravel-covered limestone in which there is no surface water. Water is also obtained from shallow wells in the limestone valleys, where the cover of gravel is heavy. Such is the case in the valleys of Indian and Stony creeks. Up to this date no wells have been bored in the solid rock. The water supply of Johnson City is obtained by damming the head of Sinking Creek, about 5 miles distant, just below the point where it emerges from Cherokee Mountain. This water is noncalcareous, since it drains quartzite and slate areas, and is of excellent quality. Abundant water supplies for any of the small towns could be had from adjacent creeks, but no concerted action of that kind has been taken. Bakersville, for instance, could get an abundant and excellent supply from the head of Cane Creek, 5 or 6 miles distant. This water collects from the forest-covered slopes of Cane Creek and Yellow mountains, all above 3000 feet in height. The water supply of Elizabethton is derived almost entirely from shallow wells in the gravels and clays of the flood plains along Doe and Watauga rivers. It is certain that in time this supply will prove insufficient. A further supply, could readily be obtained from Doe River, but would require an extensive system of filters in order to purify it. A better supply, though harder to procure, could be had from Little Stony Creek by damming its lower portion a little over 3 miles from Elizabethton. This water is drained from the quartzites and shales and is very pure. The catchment basin lies at elevations of 1700 to 4000 feet and is almost entirely forest covered. Jonesboro gets its water from springs and shallow wells in limestone clay. The town is situated nearly at the divide between a number of small creeks and a large water supply is difficult to obtain. To utilize the best source—Dry Creek—would involve considerable expense and an aqueduct 7 or 8 miles in length. The water of Dry Creek is derived from the Cambrian quartzites and slates, like the Johnson City supply, and is of excellent quality. The drainage basin is forest covered, except for small areas in its lower part, and there would be no difficulty in procuring and storing a plentiful supply. The level of the cove in the lower part of Dry Creek is practically that of the main streets in Jonesboro. A small amount of pumping would, therefore, be necessary to maintain the flow and give a working head. It would seem to be only a question of time when it would be necessary to obtain water for Jonesboro from this source. The other creeks in the vicinity rise in and drain limestone countries and are of variable flow and quality. The water from the Nolichucky is as far away as that of Dry Creek and would require in addition a system of filtration.

April, 1907.

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

TOPOGRAPHY

TENNESSEE - NORTH CAROLINA
ROAN MOUNTAIN QUADRANGLE



LEGEND

RELIEF
printed in brown

- Figures *showing heights above mean sea level instrumentally determined*
- Contours *showing height above sea, horizontal form, and steepness of slope of the surface*
- Depression contours

DRAINAGE
printed in blue

- Streams
- Ponds and sinks

CULTURE
printed in black

- Roads and buildings
- Churches and school houses
- Private and secondary roads
- Trails
- Railroads
- Tunnels
- Ferries
- State lines
- County lines
- Triangulation stations
- Bench marks

H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr and S. S. Gannett.
Topography by Hersey Munroe, W. L. Miller, W. N. Brown,
Geo. H. Guerdrum, and E. G. Hamilton.
Surveyed in 1901-1902.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.
Datum is mean sea level.

Edition of June 1904, reprinted May 1907.

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

AREAL GEOLOGY

TENNESSEE - NORTH CAROLINA
ROAN MOUNTAIN QUADRANGLE

H.M. Wilson, Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by Hersey Munroe, W.L. Miller, W.N. Brown,
Geo. H. Guerdrum, and E.G. Hamilton.
Surveyed in 1901-1902.

TRUE NORTH
MAGNETIC NORTH
2½°
APPROXIMATE MEAN
DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.

Datum is mean sea level.

Edition of April 1907

Geology by Arthur Keith,
assisted by H.B. Goodrich and H.S. Gale.
Surveyed in 1893, 1900, 1904, and 1906.

LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines

ORDOVICIAN

Ot
Tellico sandstone
(red and gray calcareous sandstone)

Oa
Athens shale
(blue and black calcareous shale)

UNCONFORMITY

€Ok
Knox dolomite
(light and dark magnesian limestones with chert nodules)

CAMBRIAN

€n
Nolichucky shale
(variegated calcareous shales and thin limestones)

€hk
Honaker limestone
(massive blue and gray limestone with chert)

€w
Watauga shale
(purple, reddish, and yellow shale and sandy shale, with thin limestones)

€sh
Shady limestone
(grayish limestone with chert)

€h
Hesse quartzite
(massive white quartzite)

€e
Erwin quartzite
(massive white quartzite)

€mr
Murray slate
(gray slates and shales)

€nb
Nebo quartzite
(chiefly white quartzite)

€nc
Nichols slate
(grayish slate and shale, with sandy layers)

€ht
Hampton shale
(banded gray shale with thin sandstone layers)

€ch
Cochran conglomerate
(white sandstone, quartzite, and conglomerate)

€hi
Hiwassee slate
(chiefly dark, banded slate with layers of sandstone and conglomerate)

€u €a
Unicoi formation
(white sandstone and quartzite, with shale, arkose, conglomerate, and a bed of amygdaloid, €a)

€sb €a
Snowbird formation
(chiefly light-colored quartzite and sandstone; includes beds of slate, conglomerate, arkose, and amygdaloid, €a)

IGNEOUS ROCKS

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

ARCHEAN

ARb
Beech granite
(coarse or porphyritic granite, light or reddish in color)

ARcb
Cranberry granite
(mainly granite and granite-gneiss)

ARs
Soapstone, dunite, and serpentine

ARr
Roan gneiss
(chiefly hornblende gneiss and schist, with some diorite)

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

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

ARCHEAN

ARc
Carolina gneiss
(chiefly mica-gneiss and mica-schist; includes other gneisses, granite, and diorite)

Faults ━━ ‒ ‒

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

ECONOMIC GEOLOGY

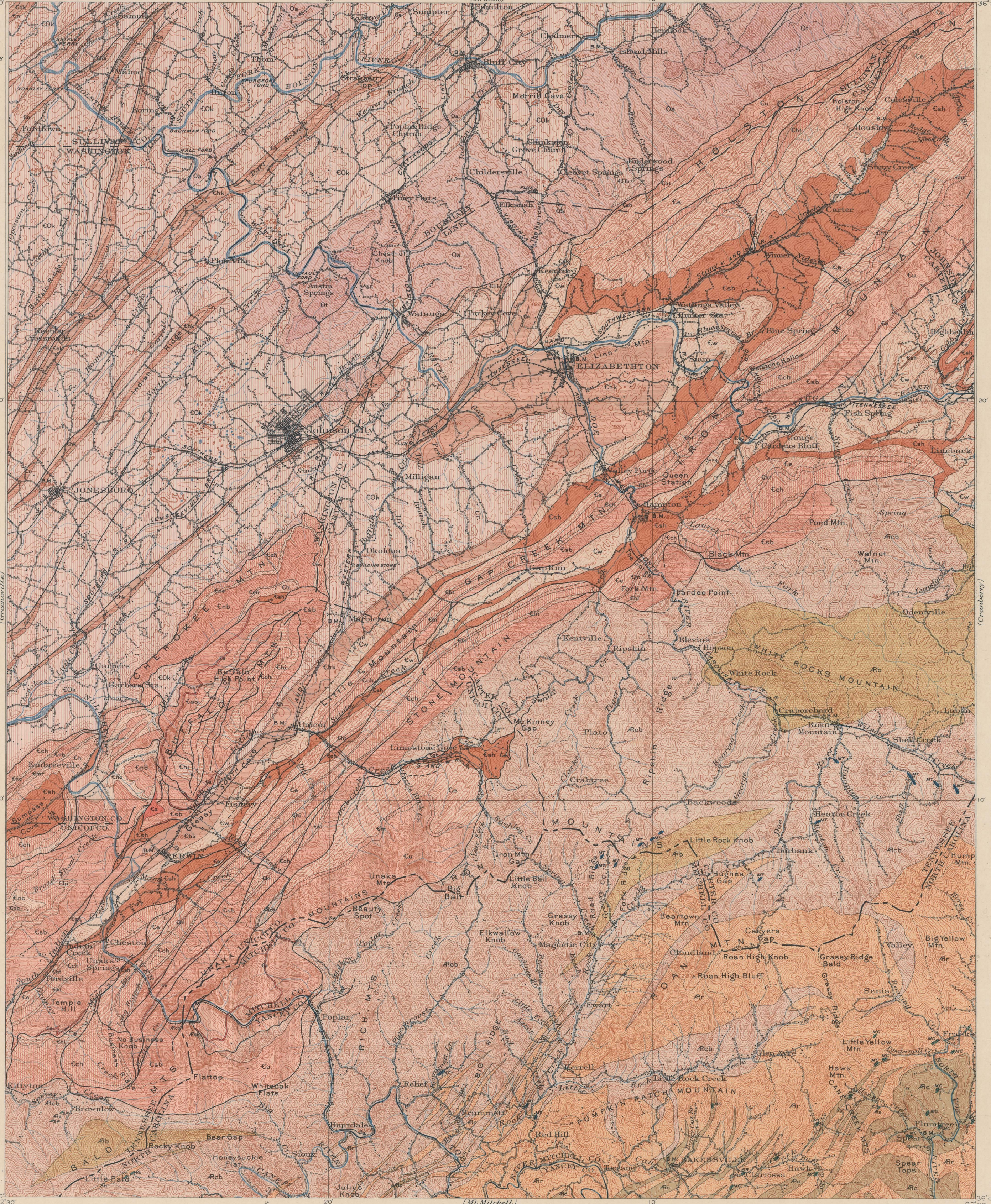
TENNESSEE - NORTH CAROLINA
ROAN MOUNTAIN QUADRANGLE

LEGEND
(continued)

⚒ *Mines and quarries*
x *Prospects*

Known mineral deposits

€sh	*Brown hematite* *(deposits in residual clays of the Shady limestone)*
MT	*Magnetite* *(lentils near contact of Cranberry granite and Roan gneiss)*
TC SP	*Talc and soapstone* *(bodies in Roan gneiss)*
MC	*Mica* *(in pegmatite lenses)*



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Surveyed in 1901-1902.

TRUE NORTH
MAGNETIC NORTH
½°
APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

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LEGEND

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

ORDOVICIAN

Ot	Tellico sandstone *(red and gray calcareous sandstone)*
Oa	Athens shale *(blue and black calcareous shale)*

UNCONFORMITY

CAMBRIAN

€Ok	Knox dolomite *(light and dark magnesian limestones with chert nodules)*
€n	Nolichucky shale *(variegated calcareous shales and thin limestones)*
€hk	Honaker limestone *(massive blue and gray limestone with chert)*
€w	Watauga shale *(purple, reddish, and yellow shale and sandy shale, with thin limestones)*
€sh	Shady limestone *(grayish limestone with chert)*
€h	Hesse quartzite *(massive white quartzite)*
€e	Erwin quartzite *(massive white quartzite)*
€mr	Murray slate *(gray slates and shales)*
€nb	Nebo quartzite *(chiefly white quartzite)*
€nc	Nichols slate *(grayish slate and shale, with sandy layers)*
€ht	Hampton shale *(banded gray shale with thin sandstone layers)*
€ch	Cochran conglomerate *(white sandstone, quartzite, and conglomerate)*
€hi	Hiwassee slate *(chiefly dark, banded slate with layers of sandstone and conglomerate)*
€sb €a	Snowbird formation *(chiefly light-colored quartzite and sandstone; includes beds of slate, conglomerate, arkose, and amygdaloid, €a)*
€u €a	Unicoi formation *(white sandstone and quartzite, with shale, arkose, conglomerate, and a bed of amygdaloid, €a)*

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

ARCHEAN

ARb	Beech granite *(coarse or porphyritic granite, light or reddish in color)*
ARcb	Cranberry granite *(mainly granite and granite-gneiss)*
ARs	Soapstone, dunite, and serpentine
ARr	Roan gneiss *(chiefly hornblende gneiss and schist, with some diorite)*

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

ARCHEAN

ARc	Carolina gneiss *(chiefly mica-gneiss and mica-schist; includes other gneisses, granite, and diorite)*

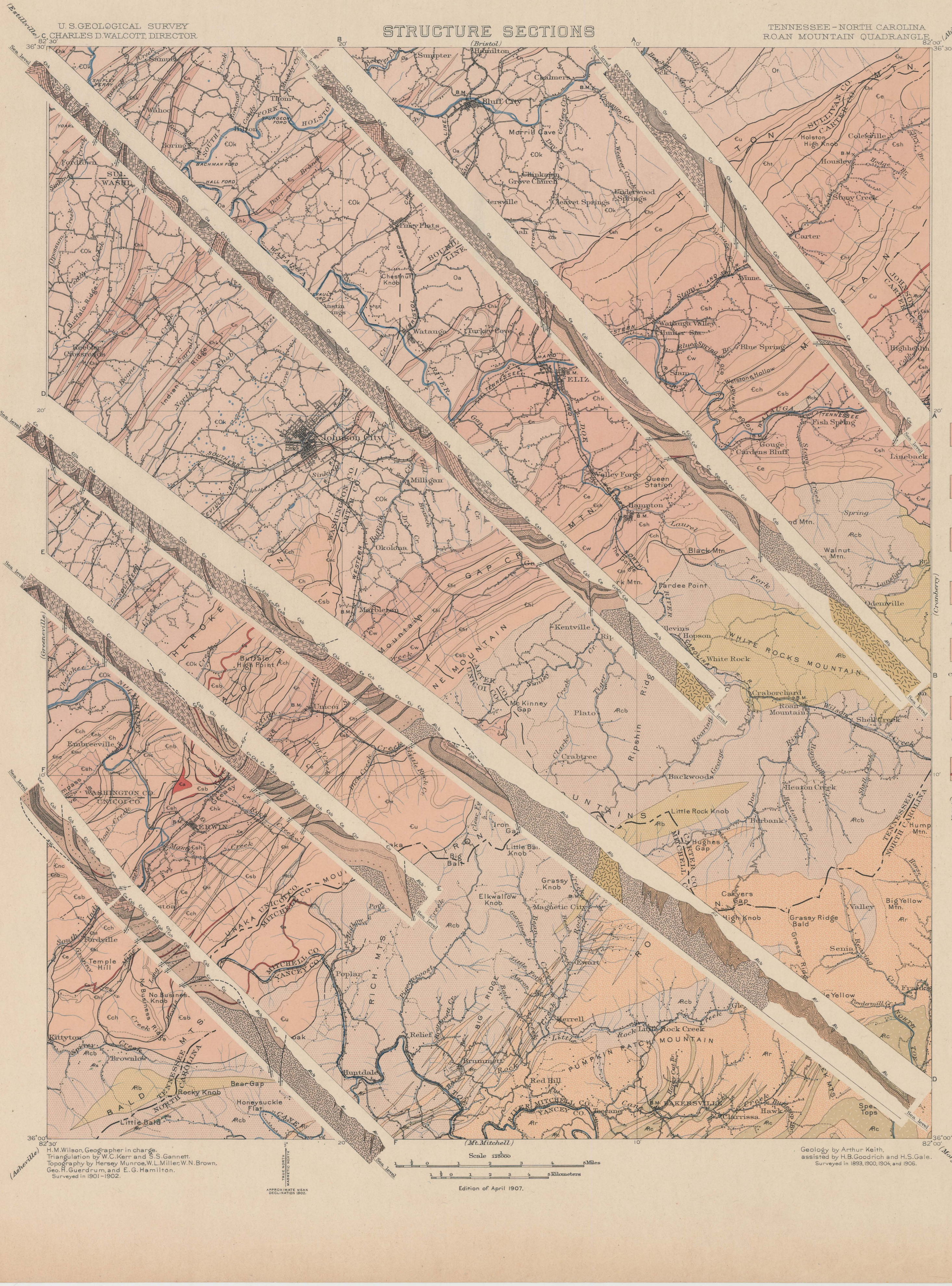
Faults ——— — —

Legend is continued on the left margin.

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

STRUCTURE SECTIONS

TENNESSEE–NORTH CAROLINA
ROAN MOUNTAIN QUADRANGLE



H. M. Wilson, Geographer in charge.
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Surveyed in 1901–1902.

Edition of April 1907.

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Surveyed in 1893, 1900, 1904, and 1906.

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL | SECTION SYMBOL

ORDOVICIAN

- Ot — **Tellico sandstone** *(red and gray calcareous sandstone)*
- Oa — **Athens shale** *(blue and black calcareous shale)*

UNCONFORMITY

CAMBRIAN

- €Ok — **Knox dolomite** *(light and dark magnesian limestones with chert nodules)*
- €n — **Nolichucky shale** *(variegated calcareous shales and thin limestones)*
- €hk — **Honaker limestone** *(massive blue and gray limestone with chert)*
- €w — **Watauga shale** *(purple, reddish, and yellow shale and sandy shale, with thin limestones)*
- €sh — **Shady limestone** *(grayish limestone with chert)*
- €h — **Hesse quartzite** *(massive white quartzite)*
- €e — **Erwin quartzite** *(massive white quartzite)*
- €mr — **Murray slate** *(gray slates and shales)*
- €nb — **Nebo quartzite** *(chiefly white quartzite)*
- €nc — **Nichols slate** *(grayish slate and shale, with sandy layers)*
- €ht — **Hampton shale** *(banded gray shale with thin sandstone layers)*
- €ch — **Cochran conglomerate** *(white sandstone, quartzite, and conglomerate)*
- €hi — **Hiwassee slate** *(chiefly dark, banded slate with layers of sandstone and conglomerate)*
- €sb — **Snowbird formation** *(chiefly light-colored quartzite and sandstone; includes beds of slate, conglomerate, arkose, and amygdaloid, €a)*
- €u — **Unicoi formation** *(white sandstone and quartzite, with shale, arkose, conglomerate, and a bed of amygdaloid, €a)*

IGNEOUS ROCKS

ARCHEAN

- Ꞩb — **Beech granite** *(coarse or porphyritic granite, light or reddish in color)*
- Ꞩcb — **Cranberry granite** *(mainly granite and granite-gneiss)*
- Ꞩs — **Soapstone dunite, and serpentine**
- Ꞩr — **Roan gneiss** *(chiefly hornblende gneiss and schist, with some diorite)*

METAMORPHIC ROCKS OF UNKNOWN ORIGIN

ARCHEAN

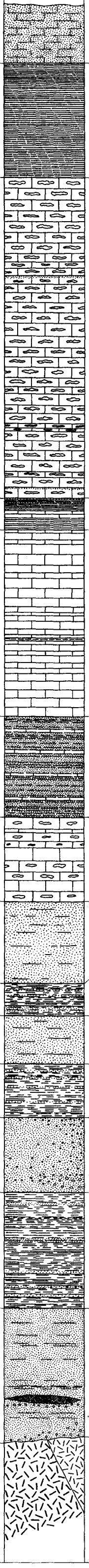
- Ꞩc — **Carolina gneiss** *(chiefly mica-gneiss and mica-schist; includes other gneisses, granite, and diorite)*

Faults — — —

COLUMNAR SECTIONS

GENERALIZED SECTION OF THE SEDIMENTARY ROCKS OF THE ROAN MOUNTAIN QUADRANGLE IN VICINITY OF ERWIN.

SCALE: 1 INCH = 1000 FEET.

System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
ORDOVICIAN	Tellico sandstone.	Ot		600+	Red and gray calcareous sandstone with seams of limestone conglomerate.	Round knobs. Light sandy soil.
	Athens shale.	Oa		800–1600	Black and bluish-black calcareous shale below, blue-gray banded slaty shale above.	Low, narrow valleys and sharp, steep knobs. Thin, yellow clay soil.
—?—	Knox dolomite.	€Ok		3000–3700	Magnesian limestone; light and dark blue, white, and gray, with nodules and layers of chert and a few beds of calcareous sandstone.	Broad ridges and irregular rounded hills. Deep, red clay soil mingled with chert.
CAMBRIAN	Nolichucky shale.	€n		50–600	Yellow, green, and brown calcareous shale with limestone beds.	Steep slopes or narrow, sharp ridges. Thin, yellow clay soil.
	Honaker limestone.	€hk		1800–2200	Massive dark-blue and dark-gray limestone. White and blue limestones.	Open valleys and slopes of knobs. Deep, red clay soil.
	Watauga shale.	€w		1000–1100	Purplish, red, green, and variegated shales, sandy shales, and thin sandstones, with calcareous shales and thin blue limestones interbedded.	Valleys with irregular rounded knobs. Purplish and brown clay soil.
	Shady limestone.	€sh		750–1000	Gray, bluish-gray, mottled-gray, and white limestone, with nodules and masses of chert.	Valleys and low hills. Deep clay soil, dark red and cherty.
	Hesse quartzite	€h		700–1000	Massive white quartzite and sandstone.	High, sharp mountains and ridges. Thin, sandy and rocky soil.
	Murray slate.	€mr		300–400	Bluish-gray to gray argillaceous and sandy shale and slate, with thin sandstone seams.	Depressions and slopes of mountains. Light sandy soil.
	Nebo quartzite.	€nb		200-900	Massive white quartzite and sandstone, coarse and fine, with layers of sandy shale, slate, and reddish sandstone.	High, sharp mountains, with cliffs. Thin, sandy and rocky soil.
	Nichols slate.	€nc		400–700	Bluish-gray to gray argillaceous and sandy shale and slate with thin sandstone layers.	Depressions between mountain crests. Light, sandy soil.
	Cochran conglomerate.	€ch		200–1600	Massive quartzite, sandstone, and conglomerate, white or gray, with seams of dark slate.	High buttes and mountains. Thin, rocky and sandy soils.
	Hiwassee slate.	€hi		300–1500	Bluish-gray to black and banded slates with a little fine mica schist. Includes layers of sandstone and conglomerate.	Slopes of mountains, or low hilly ground. Thin, clayey or sandy soil.
	Snowbird formation. (Amygdaloid.)	€sb (€a)		700–2000	Gray and white feldspathic quartzite and sandstone, with dark slate beds and lentil of amygdaloid. Locally becomes conglomerate and dark-purplish sandstone. Fine quartz conglomerate and arkose at base.	High, irregular mountains and buttes, with round summits. Thin, sandy soil.
ARCHEAN	Granites.				Descriptions given in accompanying table.	Descriptions given in accompanying table.

GENERALIZED SECTION OF THE SEDIMENTARY ROCKS OF THE ROAN MOUNTAIN QUADRANGLE NORTHEAST OF ELIZABETHTON.

SCALE: 1 INCH = 1000 FEET.

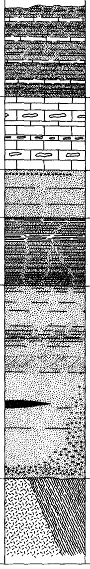
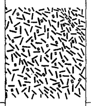
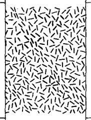
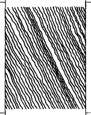
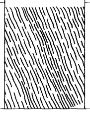
System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CAMBRIAN	Watauga shale.	€w		1000–1100	Purplish, reddish-brown, and yellow shales, sandy shales, and thin sandstones, with calcareous shales and thin blue limestones interbedded.	Valleys with irregular rounded knobs. Purplish and brown clay soils.
	Shady limestone	€sh		750–800	Gray, bluish-gray, and mottled-gray limestone, with nodules and masses of black chert.	Smooth, rounded hills and smooth, open valleys. Deep, red clay soil containing chert masses.
	Erwin quartzite.	€e		500–700	Massive white quartzite and sandstone, with thin conglomerate layer near the top.	Mountains with sharp crests, cliffs, and steep, rocky slopes. Thin, sandy soil.
	Hampton shale.	€ht		600–800	Bluish-gray and gray argillaceous and sandy shales with thin sandstone layers.	Narrow depressions and valleys. Thin, sandy clay soil.
	Unicoi formation. (Amygdaloid.)	€u (€a)		1500–2500	Massive white sandstone, feldspathic sandstone, and quartzite, with interbedded shales and sandy shales in the upper part, a thin bed of amygdaloid near the middle, and conglomerate, arkose, and graywacke in the lower part.	High mountains with steep, rocky slopes and lines of cliffs. Light, sandy soil of considerable depth along summits.
ARCHEAN	Gneisses and granites.				Description given in table below.	Description given in table below.

TABLE OF IGNEOUS ROCKS OF THE ROAN MOUNTAIN QUADRANGLE, ARRANGED IN ORDER OF AGE.

System.	Formation Name.	Symbol.	Lithologic Symbol.	Character of Rocks.	Character of Topography and Soil.
ARCHEAN	Beech granite.	ARb		Very coarse biotite granite, massive and schistose, in places coarsely porphyritic; color usually light, but frequently red near the border.	High mountains with broad crests and many ledges and cliffs. Brown, sandy and clayey soils.
	Cranberry granite.	ARcb		Biotite granite and granite-gneiss, coarse and fine; color, 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, massive mountains. Dark-red and brown clay soils.
	Carolina gneiss.	ARc		Interbedded mica gneiss and mica schist, coarse and fine, dark and light gray. Contains many small beds of hornblende gneiss, large bodies of garnet schist and cyanite schist, and dikes of biotite granite, both altered and unaltered.	Ridges, peaks, spurs, and high mountains with irregular crests. Red and brown micaceous and clayey soils.

NAMES OF FORMATIONS.

System.	M. R. Campbell: Estillville Folio, U. S. Geological Survey, 1894.	Arthur Keith: Greeneville Folio, U. S. Geological Survey, 1905.		Names and Symbols used in this Folio.				Arthur Keith: Cranberry Folio, U. S. Geological Survey, 1903.
ORDOVICIAN	Sevier shale.	Tellico sandstone.		Tellico sandstone.			Ot	
		Athens shale.		Athens shale.			Oa	
	Moccasin limestone.	Moccasin limestone.						
	Chickamauga limestone.	Chickamauga limestone.						
	Knox dolomite.	Knox dolomite.		Knox dolomite.			€Ok	
CAMBRIAN	Nolichucky shale.	Nolichucky shale.		Nolickucky shale.			€n	
	Maryville limestone.	Maryville limestone.	Honaker limestone.	Honaker limestone.			€hk	
	Rogersville shale.	Rogersville shale.						
	Rutledge limestone.	Rutledge limestone.						
	Russell formation.	Rome formation. (SEQUENCE BROKEN).		Watauga shale.			€w	Watauga shale.
		Shady limestone.		Shady limestone.			€sh	Shady limestone.
		Hesse quartzite.		Hesse quartzite.		Erwin quartzite.	€h €e	Erwin quartzite.
		Murray slate.		Murray slate.	€mr	Hampton shale.	€ht	Hampton shale.
		Nebo quartzite.		Nebo quartzite.	€nb			
		Nichols slate.		Nichols slate.	€nc			
		Cochran conglomerate.		Cochran conglomerate.	€ch	Unicoi formation.	€u	Unicoi formation
		Hiwassee slate.		Hiwassee slate.	€hi			
		Snowbird formation.		Snowbird formation.	€sb			
ARCHEAN		Max Patch granite.		Beech granite.			ARb	Beech granite.
		Cranberry granite.		Cranberry granite.			ARcb	Cranberry granite.
				Soapstone, dunite, and serpentine.			ARs	Soapstone.
				Roan gneiss.			ARr	Roan gneiss.
				Carolina gneiss.			ARc	Carolina gneiss.

ILLUSTRATIONS I

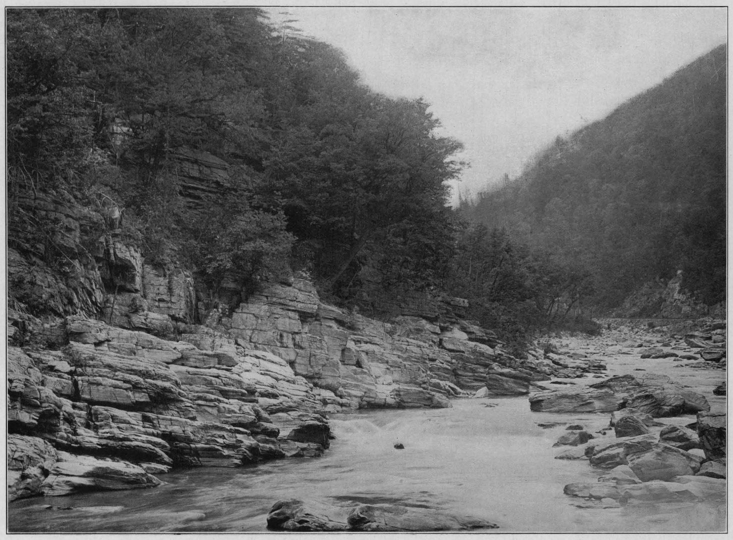


FIG. 4.—GORGE OF NOLICHUCKY RIVER, 1 MILE WEST OF POPLAR, N. C. LOOKING N. 80° E.

The ruggedness of the channel is caused by hard ledges of Unicoi quartzite. The narrow channel shown in the lower left corner is in strong contrast with the broader stretch shown in fig. 11.

FIG. 5.—ROAN MOUNTAIN, FROM POINT ONE-FOURTH MILE EAST OF ROAN MOUNTAIN STATION, TENN. LOOKING S. 30° W.

The hills in the foreground and the distant spurs of Roan Mountain are composed of Cranberry granite. The broad, rounded summits of the mountains are characteristic of the Roan gneiss. The highest summit is 4,000 feet above Doe River, in the foreground.

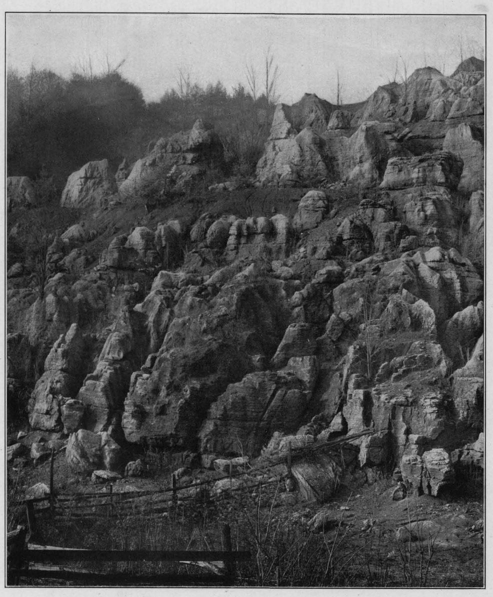


FIG. 6.—LEDGES OF FLAT-LYING SHADY LIMESTONE AT EAST END OF BUMPASS COVE, TENN. LOOKING S. 60° W.

The rock surface has been stripped of its residual clay in mining iron ore. The irregular and deeply channeled surface, due to solution of the rock, is characteristic of the decay of limestone formations.

FIG. 7.—GRANITOID GNEISS WITH FOLDED QUARTZOSE LAYERS, 5 MILES EAST OF BIG YELLOW MOUNTAIN.

The quartz layers were added to the granitoid rock before its metamorphism, and show the great crumpling to which the gneisses have been subjected in places. They present marked contrast with the veins in Roan gneiss shown in fig. 8.

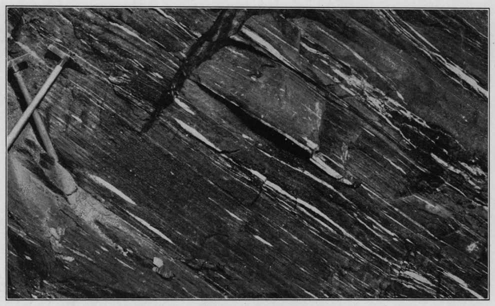


FIG. 8.—ROAN GNEISS WITH SECONDARY LENSES OF QUARTZ ALONG THE PLANES OF SCHISTOSITY, 2¼ MILES SOUTH OF TOECANE, ON TOE RIVER.

The gneiss is highly metamorphosed and schistose, while the quartz lenses, which are later, are unmetamorphosed. This parallel foliation is characteristic of the Roan gneiss.

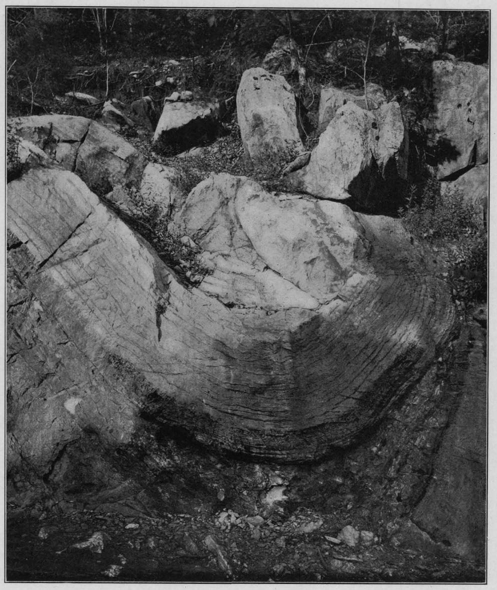


FIG. 9.—CLOSE FOLDING IN MASSIVE BLUE KNOX DOLOMITE ALONG NOLICHUCKY RIVER NORTHEAST OF EMBREEVILLE, TENN.

The great compression during folding is shown by the thinning of the darker lower layers on the steeply upturned side of the fold. Incipient flat shear faults, similar to larger faults in this vicinity, are seen near the base of the fold.

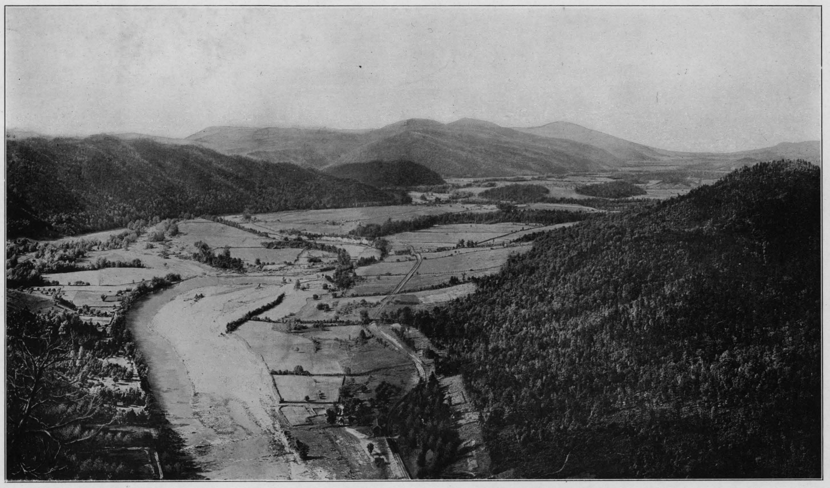


FIG. 10.—EASTERN BORDER OF EAST TENNESSEE VALLEY, ONE-HALF MILE WEST OF UNAKA SPRINGS, TENN. LOOKING N. 30° E.

The flat valley is underlain by the Shady limestone, Watauga shale, and Honaker limestone. The foothills of the Unaka Mountains, on the right, are composed of the uppermost Cambrian quartzites. In the distance, Rich Mountain, on the left, and Buffalo and Cherokee mountains, on the right, are composed of lower Cambrian quartzites, which were thrust forward from their original location, far to the right. They now rest upon younger Cambrian strata, with which they have since been folded and faulted in a general syncline.

FIG. 11.—CANYON OF NOLICHUCKY RIVER, 2 MILES SOUTHEAST OF UNAKA SPRINGS, TENN. LOOKING S. 30° E.

Flattop Mountain and its spurs form the background, and Devils Creek enters from the right in a sharp V-shaped canyon. The cliffs and ledges of Snowbird quartzite are characteristic of this part of the river.

ILLUSTRATIONS II

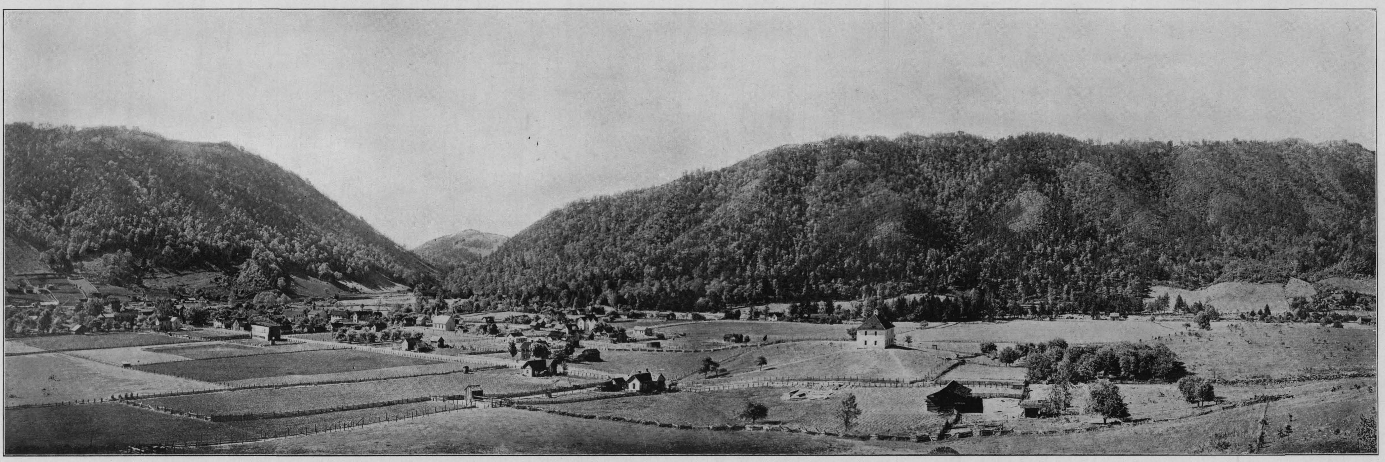


FIG. 12.—DOE RIVER GAP, IN IRON MOUNTAIN, HAMPTON, TENN. LOOKING N. 10° W.

The floor of the valley is covered by gravel and clay overlying Shady limestone. Iron Mountain is formed by the entire Cambrian quartzite series faulted up on top of the Shady limestone. The portion on the left of the gap shows a double crest formed by the Snowbird formation and the Cochran conglomerate, a depression of the Hiwassee slate lying between. The knob seen through the gap is formed by Erwin quartzite.

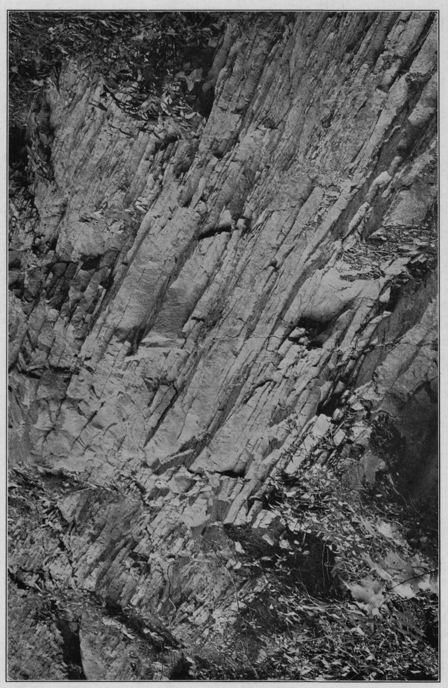


FIG. 13.—HORIZONTAL BEDS OF UNICOI QUARTZITE, STRONGLY JOINTED, ABOUT 1 MILE WEST OF POPLAR, N. C. LOOKING S. 63° W.

This quartzite is feldspathic, strongly jointed, and shows incipient schistosity along the joint planes. The joints are nearly parallel to the great overthrust fault plane farther south and show how the quartzite beds are sheared across by the faults.

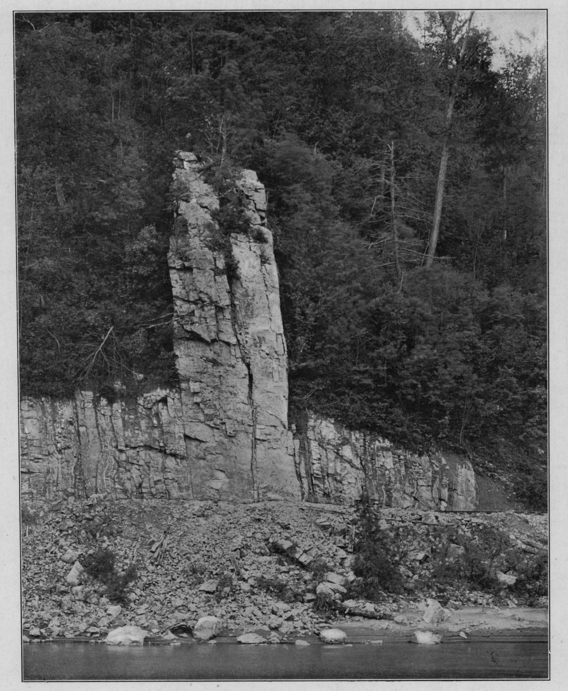


FIG. 14.—UPPER PART OF ERWIN QUARTZITE, THREE-FOURTHS OF A MILE EAST OF UNAKA SPRINGS, TENN. LOOKING SOUTHWEST.

The quartzite layers are interbedded with thin layers of slate. The prominent bed is composed of about 20 feet of extremely hard, vitreous, white quartzite, which forms the crests of most of the ridges and covers their slopes with talus. On the extreme right is seen the dark residual clay of the overlying Shady limestone.

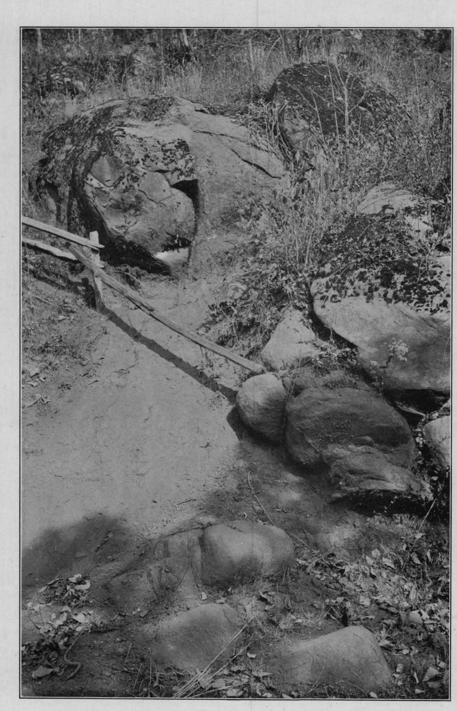


FIG. 15.—CHARACTERISTIC OUTCROP OF GABBRO, ONE-HALF MILE NORTH OF TOECANE, N. C. LOOKING NORTHEAST.

Spheroidal weathering is characteristic of the gabbro in this region, and round bowlders strew its surface. The rock is not metamorphosed and presents a strong contrast to the Roan gneiss, which is of similar composition.

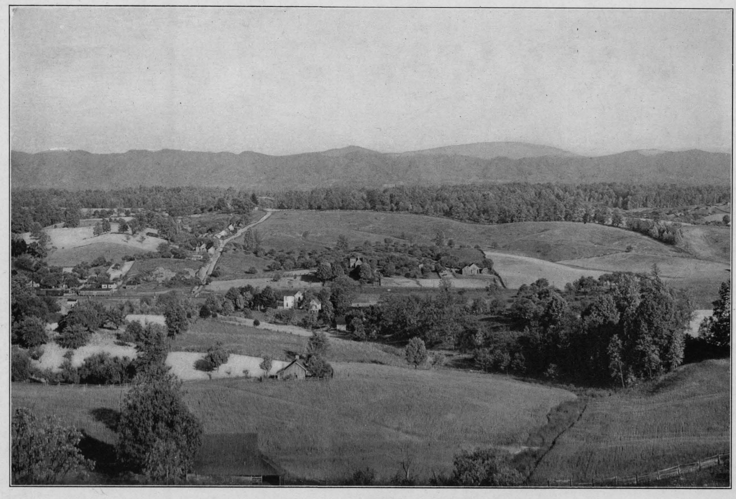


FIG. 16.—VALLEY OF EAST TENNESSEE NEAR JONESBORO. LOOKING SOUTHEAST.

The valley is composed of many rounded hills, characteristic of Knox dolomite, with red clay soil and some chert. The summits rise in general to elevations of 1,700 or 1,800 feet, and are remnants of an ancient plain that extends to the foot of Cherokee Mountain, in the background. This mountain rises abruptly about 1,000 feet above the limestone hills. Beyond, a peak of Buffalo Mountain and the high dome of Unaka Mountain are visible.

FIG. 17.—TOE RIVER AND ITS DISSECTED PLATEAU, 1 MILE NORTHWEST OF TOECANE, N. C. LOOKING S. 70° W.

The point of view is nearly 1,000 feet above the plateau summits, which lie in a plain about 2,600 feet above sea level. The large streams have cut canyons into the plateau 400 to 600 feet deep. Both the plateau and the bordering mountains were worn from a complex mass of granites and gneisses irrespective of their composition and structure.

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