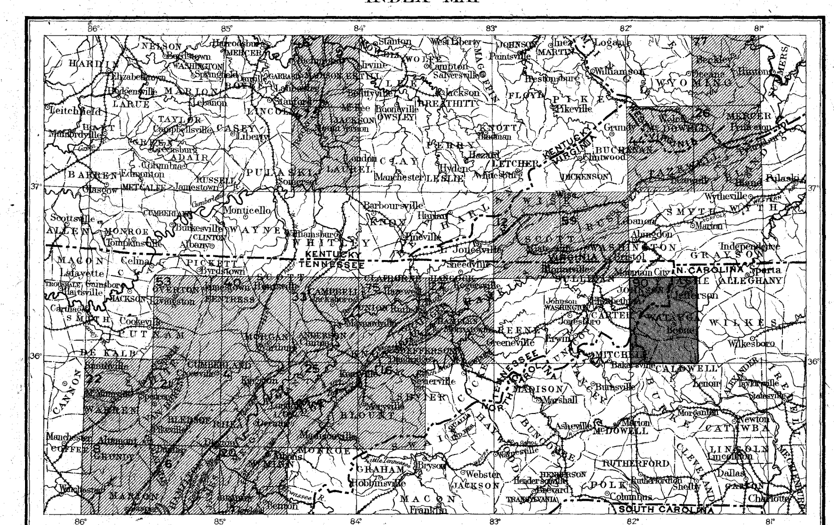
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS OF THE UNITED STATES

CRANBERRY FOLIO

NORTH CAROLINA - TENNESSEE

INDEX MAP



SCALE: 40 MILES-1 INCH

AREA OF THE CRANBERRY FOLIO

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LIBRARY EDITION

CRANBERRY FOLIO
NO. 90

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS S. J. KUBEL, CHIEF ENGRAVER
1903

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical 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:

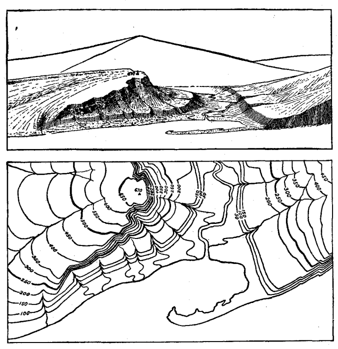


Fig. 1.—Ideal sketch and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the slope at 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 approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all 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 nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The 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 vertical 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 used 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.—Water courses are indicated by blue lines. If the streams flow the year round 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, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be 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 of "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

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 and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,000}$ to about 4 square miles; and on the scale $\frac{1}{250,000}$ to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory 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-quarter of a square degree; each sheet on a 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or 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 sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it may consolidate in cracks or fissures crossing the bedding planes, thus forming dikes, or spread out between the strata in large bodies, called sheets or laccoliths, or form large irregular cross-cutting masses, called stocks. Such rocks are called *intrusive*. Within their rock inclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock it is younger than that rock, and when a sedimentary rock is deposited over it the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive 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 over wide expanses, and as it rises or subsides the shore lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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 formations are remote one from the 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 rocks of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions and groups of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the one at the top of the column (Pleistocene) and the one at the bottom (Archean). The sedimentary formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint is printed evenly over the whole surface representing the period; a dark tint brings out the different patterns representing formations. Each formation is furthermore given

Period.		Symbol.	Color.
Cenozoic	Pleistocene	P	Any colors.
	Neocene { Pliocene, Miocene }	N	Buffs.
	Eocene, including Oligocene	E	Olive-browns.
Mesozoic	Cretaceous	K	Olive-greens.
	Juratrias { Jurassic, Triassic }	J	Blue-greens.
Paleozoic	Carboniferous, including Permian	C	Blues.
	Devonian	D	Blue-purples.
	Silurian, including Ordovician	S	Red-purples.
	Cambrian	Є	Pinks.
	Algonkian	A	Orange-browns.
	Archean	Æ	Any colors.

a letter-symbol composed of the period letter combined with small letters standing for the formation name. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations, chiefly Pleistocene, render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the metamorphic rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology sheet.—This sheet 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 particular colored pattern and its letter-symbol on the map 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet 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 symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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 name 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 the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting 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:

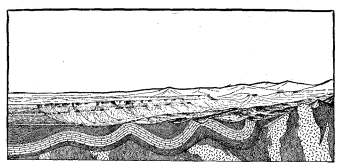


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane, so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

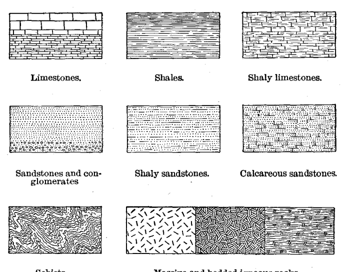


Fig. 3.—Symbols used to represent different kinds of rock.

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 beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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.*

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. 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 regarded as proof that forces exist which 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 slipped past one another. Such breaks are termed *faults.*

On the right of the sketch 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.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the 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 swelled upward 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 horizonal 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 strata thus rest upon an eroded surface of older strata 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 this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration 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, marking a time interval between two periods of rock formation, is another unconformity.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond 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 rock formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thicknesses of the formations, and the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given in figures which state the least and greatest measurements. The average thickness of each formation 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 is placed at the bottom of the column, the youngest at the top, and igneous rocks or surficial deposits, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

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

CHARLES D. WALCOTT,
Director.

Revised January, 1902.

DESCRIPTION OF THE CRANBERRY QUADRANGLE.

By Arthur Keith.

GEOGRAPHY.

General relations.—The Cranberry quadrangle lies chiefly in North Carolina, but includes also a portion of Tennessee. It is included between parallels 36° and 36.30′, and meridians 81° 30′ and 82° and it contains about 963 square miles, divided between Carter and Johnson counties in Tennessee, and Ashe, Watauga, Wilkes, Caldwell, and Mitchell counties in 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 covered by a single atlas sheet; hence it is necessary to consider the individual sheet 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 differs with the outcrop of different kinds of rock, so that sharp ridges and narrow valleys of great length follow the narrow belts of hard and soft rock. Owing to the large amount of calcareous rock brought up on the steep folds of this district its surface is more readily worn down by streams and is lower and less broken than the divisions on either side.

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

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

Altitude of the Appalachian province.—The Appalachian province as a whole is broadly dome shaped, its surface rising from an altitude of about 500 feet along the eastern margin to the crest of the Appalachian Mountains, and thence descending westward to about the same altitude on the 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 the New and Tennessee rivers. From this point northward it descends to 2200 feet in the valley of New River, 1500 to 1000 feet in the James River Basin, and 1000 to 500 feet in the Potomac River Basin, remaining about the same through Pennsylvania. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2000 feet.

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

Drainage of the Appalachian province.—The drainage of the province is in part eastward into the Atlantic, in part southward into the Gulf, and in part westward into the Mississippi. All of the western or Plateau division of the province, except a small portion in Pennsylvania and another in Alabama, is drained by streams flowing westward to the Ohio. The northern portion of the eastern or Appalachian Mountain division is drained eastward to the Atlantic, while south of the 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 the 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 the New (or Kanawha) River, which flows westward in a deep, narrow gorge through the Cumberland Plateau into the Ohio River. From New River southward to northern Georgia the Great Valley is drained by tributaries of the Tennessee River, which at Chattanooga leaves the broad valley and, entering a gorge through the Plateau, runs westward to the Ohio. South of Chattanooga the streams flow directly to the Gulf of Mexico.

Geographic divisions of the Cranberry quadrangle.—Within the limits of the Cranberry quadrangle three geographic divisions appear—one south of the Blue Ridge, one between the Blue Ridge and the State boundary, and one in Tennessee. The area in Tennessee consists of a series of sharp, straight mountains separated by deep valleys. South of the Blue Ridge extend the foothills, a great expanse of irregular ridges and mountains heading against the steep face of the Blue Ridge. Between the State boundary and the Blue Ridge lies the mountain district. Its surface is that of a high, irregular plateau much cut into by streams and containing many residuals, or areas standing above the plateau.

The region is drained in widely different directions. The Tennessee area and the southwestern half of the mountain district are drained through the Nolichucky and Watauga rivers into the Tennessee River; the northeastern half of the mountain district is drained into New River and thence into the Ohio; the foothill district is drained into the Yadkin, Johns, and Linville rivers and thence into the Atlantic. The main streams radiate from a small district around Grandfather Mountain, which thus forms one of the chief watersheds of the Appalachians. Streams of the foothill district have a heavy and continuous fall—from 3500 or 4000 feet near the Blue Ridge, down to 1300 feet where they pass out of the foothills. Northwest from the Blue Ridge the streams fall rapidly along the residual slopes, wind through bottoms and open valleys on the upper parts of the plateaus, and then descend in rapidly deepening canyons nearly to 2000 feet in Tennessee. The streams in Tennessee tumble down the sharp mountain slopes to the narrow valleys and then descend gradually, past terraces and bottoms, from 2500 to 1900 feet.

Valleys in the foothill district are wild, rocky, V-shaped ravines from their heads down to 1700 or 1800 feet. Below those elevations narrow bottoms appear, which broaden into terraces along the lower Yadkin and Johns rivers. Rounded, open basins between smooth hills form the valleys on the high plateaus. Upstream they pass into narrow ravines between the residual mountains, with slopes steadily increasing nearly to the divides; downstream they are cut away in deep, V-shaped canyons with close and rocky walls. The most notable feature of the entire region is the escarpment, or abrupt descent of 1500 feet in a mile, which bounds much of the Blue Ridge on the south, and which is produced by the backward wear of the streams flowing to the Atlantic.

The variations in the topography of this region depend very largely upon the influence of erosion on the different formations. Such rock-forming minerals as carbonates of lime and magnesia, and to a less extent feldspar, are removed by solution in water. Rocks containing these minerals in large proportions are therefore subject to decay by solution, which breaks up the rock and leaves the insoluble matter less firmly united. Frost, rain, and streams break up and carry off this 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, leaving the least residue, occupy the low ground. Such are the Shady limestone and many beds in the Watauga shale. These leave a fine clay after solution. The Shady limestone leaves also, besides the clay, a large quantity of silica in the form of chert, which strews the surface with lumps and retards its removal. 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. Apparently the hornblendic rocks of the Roan gneiss form an exception to this rule, for they contain much soluble matter in feldspar, and yet maintain great heights. For this result the immense mass of the formation and the insolubility of some of the hornblende are largely responsible.

Erosion of the sedimentary formations has produced a series of long ridges separated by narrow valleys, which closely follow the belts of rock. 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. Each turn in the course of a formation can be seen by the turn of the ridge or valley which it causes. Conspicuous examples of this are the various Cambrian quartzite mountains. Each rock produces a uniform type of surface so long as its composition remains the same; with each change in composition the surface changes form. The limestones have disappeared, through solution, over most of the valley floors, and the clays which they left have been swept over with waste from the adjacent sandstone mountains. This material forms the terraces and bottoms which follow the streams, even far up toward their heads. On the upper parts of Roane and Doe creeks these are conspicuous. Small plateaus also accompany these streams at altitudes of 2500 to 2600 feet.

The topography of the mountain district is as unlike that just described as are the rocks of the two districts. No regularity appears in either the height or the direction of the ridges. In some portions of the mountains the highest ground and hard rocks coincide, as in Rich Mountain, Beech Mountain, and the vicinity of Linville. No such correspondence appears near Blowing Rock, however, and the divide of the Blue Ridge bears no relation to the rock belts, being crossed repeatedly by nearly every formation. The only exception to this irregularity is the metadiabase, which forms depressions throughout; its bulk, however, is not sufficient to affect the larger lines of drainage. Each river wore its basin down to its particular local base-level, and the plateaus thus produced have different heights according to the difficulties in the way of each stream. In this district the rivers barely succeeded in reducing their immediate basins; consequently most of the region is drained by streams not yet adjusted to the rock belts, but forced by their high grades into the most direct channels. The plateaus of New River rise upstream from 3400 to 3700 feet; the plateau of the Watauga rises from 3400 to 3600 feet, while those of the Linville and North Toe include stages from 3500 to 4000 feet.

The topography in the foothills south of the Blue Ridge is entirely irregular and bears scarcely any relation to the belts of rock. The metadiabase, however, always makes small valleys, as elsewhere. The high ridge, also, which runs

ERRATUM IN CRANBERRY FOLIO, NO. 90.

The line at top of second column, page 2, reading "the metamorphism, at whatever time developed," belongs between the last two lines of the third column.

south from Green Park is formed by a heavy bed of Blowing Rock gneiss. Except in these cases the streams, hurried by heavy grades and loaded with sediment, have cut their way on the shortest lines, regardless of differences in the formation. The crests of the intervening ridges fall into a fairly uniform plane when viewed from their own altitude of 2500 to 2600 feet. They are the remnants of a deeply dissected plateau, which probably corresponds in age with the plateaus around Mountain City at similar altitudes.

GEOLOGY.

General geologic record.—The formations which appear at the surface of the Cranberry quadrangle and adjoining portions of the Appalachian province comprise igneous, ancient crystalline, and sedimentary bodies, all more or less altered since their materials were first brought together. Some of them are very ancient, going back to the earliest known period. They consist of three groups, of widely different age and character. These are: the igneous and crystalline rocks, including gneiss, schist, granite, diorite, and similar formations; the volcanic formations, embracing rhyolite, basalt, diabase, and their alteration products; and the sedimentary strata, of Cambrian age, including conglomerate, sandstone, shale, limestone, and their metamorphosed equivalents. The oldest of these groups occupies the greatest area, and the volcanic the least. The materials of which the sedimentary rocks are composed were originally gravel, sand, and mud, derived from the waste of the older rocks, and the remains of plants and animals living at that time. All have been greatly changed since their formation, 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 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 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 indicate the depth of water and distance from shore at which they were produced. Cross bedding and ripple marks in sandstones indicate strong and variable currents. Mud cracks in shales show that their areas were at times above and at times below water. Red sandstones and shales like those of the Watauga resulted 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. Conglomerates like those of Grandfather Mountain indicate strong currents and wave action during their formation.

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:

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 all original characters have been 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, the nature of the igneous rocks changed repeatedly, 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 the metamorphism, at whatever time developed, 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. Whether these ancient lavas represent a late portion of the Archean or are of Algonkian age is not certain. The latter, however, is more probable.

Next, after a period of erosion, the land was submerged, and sandstones, shales, and limestones were laid down upon the older rocks. Remnants of these strata are now infolded in the crystallines, 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 to the east, however, and land areas which furnished sediment during the early Cambrian were covered by later Paleozoic deposits. The sea covered most of the Appalachian province and the Mississippi Basin. The area of the Cranberry quadrangle was near the eastern margin of the sea, and the materials of which the rocks are composed were derived largely from the land to the southeast. The exact position of the eastern shore line of this ancient sea is not known, but it probably varied from time to time within rather wide limits. In the earliest Cambrian time it lay just east of the position of Grandfather Mountain.

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

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

Rocks of the Cranberry district.—The rocks of this district are sedimentary, igneous, and ancient crystalline, and comprise the chief varieties of those classes of rock. They range in age from the earliest known formation of the Appalachians well into the Paleozoic, including Archean, probably Algonkian, and Cambrian periods. Archean rocks are better represented than in any other part of the Appalachians, while the lower part of the Cambrian is better developed than in almost any other area.

The rocks lie in three distinct areas or groups of widely different age. The area included in Tennessee contains the formations of the lower Cambrian, with strata of sandstone, shale, and limestone. That portion of the mountain district which extends southwest from Boone, Valle Cruces, and Banners Elk also contains these formations, together with metadiabase and schists altered from volcanic formations which are probably of Algonkian age. The foothills and the remainder of the mountains are underlain by igneous and crystalline rocks, chiefly granites, gneisses, and schists. These three groups are sharply defined and in most places are separated from one another by faults. The formations into which the rocks are separated will be described in order of age, beginning with the oldest.

DESCRIPTION OF THE FORMATIONS.

ARCHEAN ROCKS.

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

The formation consists of an immense series of interbedded mica-schists, mica-gneiss, and fine granitoid layers. Most of them are light or dark gray in color, weathering to dull gray and greenish gray. Layers of white granitic material are not uncommon, and lenses and veins of pegmatite are frequent. Toward the southeast the strictly gneissic beds are more numerous and their banding becomes slightly coarser and better defined; otherwise the formation is unusually uniform in appearance throughout its area in this quadrangle. That part of the formation which is adjacent to the Roan gneiss contains some thin interbedded layers of hornblende-schist and -gneiss precisely like the Roan gneiss, constituting a transition between the formations, so that the boundary is somewhat indefinite. The mica-schists are rarely coarse grained and are composed of quartz, muscovite, a little biotite, and a very little feldspar. The granitoid layers contain quartz and feldspar, with muscovite and biotite in small amounts; in the light-colored layers the biotite and most of the muscovite are wanting. These granitoid layers and schists alternate in beds from a few inches to 50 feet thick. Layers similar in composition and from one-tenth to 1 inch in thickness compose the banded gneisses.

Included in the formation are many beds or veins of pegmatite. These occur in the shape of lenses from 1 to 10 feet in thickness and in places over a mile long. They lie for the most part parallel to the foliation of the gneiss, but sometimes cut the latter abruptly. Near the contacts of the Carolina and Roan gneisses these pegmatites are most conspicuous. They consist chiefly of very coarsely crystalline feldspar, quartz, biotite, and muscovite. Much merchantable mica is secured from the pegmatites, and many rare minerals are found in them, such as beryl, aquamarine, sapphire, ruby, and others less valuable.

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

The schistose planes of these layers afford easy passage for water, and they are deeply decayed. After decomposition has reduced the feldspar, the remaining clay is filled with bits and layers of schist, quartz, and mica, but solid ledges are seldom found far from the stream cuts and steeper slopes. The cover of clay on the decayed rocks is thin, and the soil is light and sterile on account of the large proportion of quartz and mica that it contains. Accordingly its natural growths are poorly sustained and the soils are of small agricultural value in this area. The greater amount of soluble matter and clay in the gneiss renders their areas slightly more productive than those of the schist.

Roan gneiss.—One area of this formation occurs south of Cranberry and a much larger one northeast of Boone. The formation receives its name from Roan Mountain, on the boundary of Tennessee and North Carolina. The Roan gneiss appears to cut the Carolina gneiss, but the contacts are so much metamorphosed that the fact can not be proved. The narrow dike-like beds of the former in the latter support this view, as well as the fact that the diorites are less altered than the Carolina gneiss and so appear to be younger. Moreover, narrow beds of diorite and hornblende-gneiss entirely similar to these cut the Carolina gneiss in adjoining areas toward the south.

The Roan gneiss consists of a great series of beds of hornblende-gneiss, hornblende-schist, and diorite, with some interbedded mica-schist and gneiss. The hornblendic beds are dark greenish or black in color and the micaceous beds are dark gray. The mica-schist and gneiss beds range in thickness from a few inches to 100 feet, and are frequent only near the Carolina gneiss, into which they form a transition. In composition the mica-schist and gneiss are exactly like the micaceous parts of the Carolina gneiss, and are composed of quartz, muscovite, a little biotite, and more or less feldspar. The hornblende-schists make up most of the formation and are interbedded with hornblende-gneisses throughout. The schist beds consist almost entirely of hornblende, in crystals from one-tenth to one-half inch long, with a very small amount of biotite, feldspar, and quartz; the gneisses contain layers or seams consisting of quartz and feldspar, interbedded with layers of hornblende-schist. In places these are regularly disposed and give a marked banding to the rock. Here and there the hornblende, feldspar, and quartz appear with the massive structure of diorite. Some of these beds are very coarse and massive and closely resemble the diorite beds which are found in the upper part of the Cranberry granite. The latter beds appear to be somewhat later in origin than the main mass of the formation, and to break through it irregularly. Many of the beds of this formation consist almost entirely of hornblende and are so basic that they appear to have been derived from gabbro. So thorough is the alteration, however, that such an origin is not certain. Southwest of Cranberry portions of the diorite have porphyritic orthoclase crystals an inch or more in length. In the same area the diorites contain many large crystals of garnet, due to alteration induced by intrusive granite and gabbro.

In the Roan gneiss area south of Cranberry, and to a limited extent north and east of Boone, veins and lenses of pegmatite of secondary growth are found, precisely similar to those described under "Carolina gneiss."

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

In reducing the surface of the formation the first steps of decay were taken by decomposition of the hornblende and feldspar, but the more siliceous layers and many of the harder hornblende-schists and mica-schists are extremely slow of solution. Their outcrops form cliffs and heavy ledges, and their fragments fill the streams and strew the surface and greatly retard its reduction. As a consequence the formation invariably occupies high ground and forms many of the highest mountains of this region. The bold line of summits beginning in Rich Mountain is characteristic of the formation, and the knife-edge cliffs in Three Top Mountain illustrate the hardness of many of the strata. The clays accumulating on this formation are always deep and have a strong, dark-red color; the soils are rich and fertile and well repay the labor of removing the loose stones. The hilly surfaces keep the soil well drained, and yet the clayey nature of the soil prevents serious wash; hence they are extensively cultivated, in situations however remote.

Soapstone.—Many small bodies of this formation are found within the areas of the Roan gneiss, few of them exceeding a quarter of a mile in width and 2 miles in length. Although these rocks break through and across the beds of Roan gneiss, and are thus seen to be distinct from and later than the gneiss, their association with the latter is close and marked and they are probably of about the same age. In this quadrangle the soapstone is not found in any other formation. In areas farther southwest it occurs sparingly in the Carolina gneiss as well as in the Roan gneiss. Rarely it is seen also in the shape of included masses in the eruptive Cranberry granite. It thus antedates the latter formation. Its alteration is as great as or greater than that of the Roan gneiss and exceeds that of the Cranberry granite, so that it appears to have shared in the earlier period of metamorphism which involved the Roan and Carolina gneisses. It thus is classed with the earliest part of the Archean.

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

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

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

Cranberry granite.—This is the most extensive formation in the quadrangle. It occupies a great belt, chiefly in the mountain district, and several small areas in the foothills. In its principal area is situated Cranberry, N. C., from which its name is derived. The formation consists of granite, of varying texture and color, and of schists and granitoid gneisses derived from the granite. Included in the formation are small or local beds of schistose basalt, diorite, hornblende-schist, and pegmatite, which are too small to be shown on the map. The prevalent metamorphism of the region and the heavy forest cover make it difficult to obtain precise evidence of eruptive contact with the adjoining formations. Such contacts can be found, however, and the granite clearly goes through and into the Roan gneiss and Carolina gneiss.

The granite is an igneous rock composed of quartz and orthoclase and plagioclase feldspar, with biotite, muscovite, and occasionally hornblende as additional minerals. Minor accessory minerals are magnetite, garnet, ilmenite, and epidote. The most noticeable variation of the rock is in the size of the feldspar crystals, which range from a fine, even-grained mass in places near Linville River and Boone to a coarse, rather porphyritic rock near Banners Elk and east of Rhea Forge. Especially 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. In a narrow belt near the northwestern border of the granite area the feldspars are filled with iron oxide, which gives a marked red appearance to the rock. This variety is often characterized by the presence of epidote in small veins and segregated masses. The changes in texture are most frequent in that part of the formation which is near the Roan gneiss.

The granite suffered great changes during the deformation of the rocks, both by folding and by metamorphism, the latter being much the more conspicuous, and each becoming greater toward the southeast. As the rock was folded, planes of fracture and motion were formed in the rock mass, along which metamorphism took place. As the process went on the quartz was broken and recemented, the feldspar developed into mica, quartz, and new feldspar, and chlorite replaced part of the biotite and hornblende. These minerals crystallized in general parallel to the planes of differential motion and produced schists and gneisses of a fairly uniform dip over large areas. The results varied in extent from rocks with no change or mere cleavage along the northwestern outcrops to those completely altered into siliceous schists and gneisses along the main faults and the southeastern areas. Thin, parallel layers and striations composed of different minerals are of frequent occurrence, and the most extreme schists bear no resemblance to the original rock.

Under the action of the weather the varieties of granite behave very differently. The coarse granites are very durable and stand out in ledges and bold cliffs; the finer grades, by reason of the decomposition of their feldspars, weaken to a crumbling mass which seldom outcrops except on steep slopes. The schistose portions of the formation break up most readily, the planes of schistosity seeming to afford a ready passage for dissolving waters. In spite of its decay the formation occupies high ground, on account of the great mass of its insoluble materials. Its heights are rendered less prominent, however, by the superior hardness and greater eminences of the neighboring Unicoi formation and Roan gneiss. It forms round knobs, ridges, and mountains without definite system, whose crests and slopes are usually smooth and rounded. A large part of its area is cultivated and the soils are light loams of fair depth and strength.

Blowing Rock gneiss.—This formation occupies a small belt near Creston and a much larger one crossing the Blue Ridge near Blowing Rock. In the latter belt the formation is finely exhibited near Blowing Rock, whence its name is derived. The narrow area of the formation near Creston indicates intrusion through the Cranberry granite, and the contacts, though ill defined, appear to corroborate this. South of the Blue Ridge, metamorphism has greatly obscured the original contacts of this with other formations. It plainly cuts through the Carolina gneiss, however, and appears to do the same in the Cranberry granite. Therefore it is considered later than the Cranberry granite.

The formation consists entirely of gneiss of two varieties, one with large, porphyritic feldspar crystals, the other of very fine, even grain. The former consists of large orthoclase crystals embedded in a groundmass of feldspar, quartz, biotite, and muscovite; the latter consists of the same minerals in crystals of uniform size and granitoid appearance. The porphyritic crystals are fresh and regular, frequently twinned, and range in length from 3 inches down to one-quarter of an inch. In the coarsely porphyritic rock are many layers of fine black and gray schist. Into these the coarse layers grade by a diminution of the crystals in the groundmass and disappearance of the porphyritic feldspar. Owing to the large amount of biotite in all varieties they have a dark-gray or blackish-gray color. The contrast between the large white feldspars and the dark body of the rock is very striking. In places the two varieties grade into each other; in other places they are repeatedly interbedded. A few contacts have been found where the finer was intrusive into the porphyritic rock, but they are so closely associated and alternate in such small layers that they can not be distinguished as separate formations.

The formation has been much altered by folding and metamorphism, whose effects are readily seen on account of the marked characters of the rock. During the squeezing and slipping under pressure, the large crystals were cracked and their fragments shoved and turned until they were nearly parallel with the planes of motion, the mica flakes were turned into similar planes, and the small grains of quartz and feldspar were broken and recomposed into quartz, feldspar, and mica. The result is a very gneissoid or schistose rock showing a great deal of biotite, feldspar, a little quartz, and many broken, porphyritic crystals. The latter are bent, cracked, or drawn out into separate eyes or strings, and the amount of the distortion can be plainly measured in the less extreme cases by the intervals between the fragments of one crystal. The large feldspars retained their shapes better than the finer groundmass, however, and the mica flakes in the latter are bent and wrapped around the large feldspars almost as if fluid. The entire mass shows the effect of pressure so extreme as to overcome practically all of the original strength of the rock.

Decay proceeds down the schistose planes of the formation, but the insoluble remainder, especially mica, is so abundant and so firm that its removal is slow. Consequently the rock constantly outcrops, except on the most deeply decayed surfaces, and forms great cliffs and precipices, as in the Blue Ridge near Blowing Rock. Its ability to form high ground is shown south of Boone in the line of buttes and ridges rising above the granite areas. Complete decay produces a reddish-yellow clay; soils are light, well drained, and fertile. Many ledges jut through the surface, however; rock fragments and large feldspar crystals strew the ground, and the soil is liable to wash away on account of the high ground that it occupies.

Beech granite.—This formation is confined to practically one area, and it is best developed in Beech Mountain, for which it is named. A second and smaller mass disconnected from this, though probably of the same age, is found near Blowing Rock.

The formation consists of a huge mass of coarse granite, frequently porphyritic and seldom fine grained. Porphyritic crystals of orthoclase feldspar as long as 2 inches are frequently to be seen. The minerals composing the rock are orthoclase and plagioclase feldspar, quartz, biotite, and a very little muscovite. In the porphyritic varieties constituting the bulk of the formation the feldspars make by far the greatest part of the rock, giving it a dull whitish or light-gray color. Biotite is more prominent in the massive portions, and causes a distinct spotted appearance on account of the large size of the crystals. A third variety, of considerable extent, is a coarse, red granite found near the border of the area. This differs from the massive variety only in having many red or pink feldspars, which give a decided red color to the whole rock. Medium- to fine-grained granites appear near the contact with the Cranberry granite.

The formation is intrusive in the Cranberry granite. The granite at Blowing Rock, since it has the same characteristics that distinguish the Beech granite from the Cranberry granite, is considered to be of the same age as the Beech. At Blowing Rock the granite cuts the Blowing Rock gneiss and is accordingly younger. The Beech granite is therefore considered to be the youngest of the massive plutonic rocks in this region.

The formation has suffered great changes by metamorphism. These are specially well shown by the porphyritic portions, where the change of form can often be measured. As in the preceding formations, the rock has been squeezed and mashed until 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. The latter have in places increased in length as much as three or four times the original, assuming pencil-like forms. Striated and striped surfaces, due to the linear growths of new minerals, are common in this formation, as in the Cranberry granite.

Under the attack of weathering agents the surface of the formation is but slowly reduced. Its siliceous composition and its great mass unite in maintaining the altitude of its areas, which culminate in Beech Mountain, one of the most conspicuous points of the region. Frequent cliffs mark the harder beds, and ledges protrude at short intervals. Upon complete decay the formation produces a brownish clay of no great depth, mixed with much sand. The soils thereon are strong and fertile, where they accumulate on the gentle slopes.

ALGONKIAN (?) ROCKS.

The four formations next described form a group distinct from all previous rocks, not only in distribution, in unconformable attitude against the preceding formations, and in close association with the sediments, but also by intrusion in the granitoid rocks, and by their origin as surface lavas. The Linville metadiabase, the metarhyolite, and the Flattop schist 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. When, therefore, as is frequently the case, 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 one 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 amygdaloidal basalt interstratified with the lower beds of the Cambrian indicates that the period of volcanic activity extended into Cambrian time.

Linville metadiabase.—This rock appears in many small areas near the line of the Blue Ridge, associated with the Montezuma schist, Flattop schist, and Cambrian quartzites, and in several narrow bands south of the Blue Ridge in the Cranberry granite. The areas of the formation grouped around Linville have a considerable mass and appear to be the underlying portions of a great surface flow. This was probably fed through narrow cracks in the underlying rocks, such as those now filled with metadiabase in the Cranberry granite.

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 chlorite, and the principal changes in its appearance are variations in the size of the epidote knots and of the crystals, which attain a greatest length of half an inch. Metamorphism of the diabase is extensive, but it is not so marked as in most of the adjacent rocks. Original minerals, such as olivine and augite, are now almost entirely replaced by hornblende, chlorite, and epidote. In the coarser varieties metamorphism is less obvious. The interlocking or ophitic arrangement of the feldspar crystals, a characteristic of diabase, is frequently to be seen unchanged. In addition to those alterations of the minerals which can be readily seen by the eye, with the microscope a few unaltered portions of the original minerals can be seen, particularly the augite, surrounded by rims of the secondary minerals, hornblende and chlorite. The secondary epidote occurs in grains and in knots as large as 6 inches. It is most conspicuous around Grandfather Mountain, but in many areas it is absent. As the chlorite and fibrous hornblende 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 into round masses is only partially overcome, and loose bowlders have a somewhat flattened, lenticular shape.

The outcrop of the schistose metadiabase is a sharp, high ledge; the less schistose portions have few and small outcrops. Weather quickly reduces the metadiabase 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 and epidote lumps. Consequently the formation always occupies depressions, usually stream valleys, if the areas are large. Its soils are deep, rich, and well drained; being sufficiently clayey, they retain their hold on any slope and are cultivated in the least accessible places.

Montezuma schist.—Areas of this formation occupy a series of narrow bands on the headwaters of Linville, Elk, and Watauga rivers. It consists of fine-grained epidotic and chloritic schists and amygdaloids, and is very uniform in appearance. In chemical composition it is very similar to the Linville metadiabase, and in many places appears to grade into the finer portions of that formation. In a general way its areas lie around those of the metadiabase, and it appears to form the upper portion of the great lava mass, from the lower part of which was formed the metadiabase. Originally it was probably a basalt, just as were precisely similar rocks of similar age in other parts of the Appalachians. In this region metamorphism is so extensive that the original characters of fine-grained rocks like this have practically all disappeared. No traces of the glassy base of basalt remain, and only a few indications of flow banding. The amygdaloid beds representing the vesicular portions of the lava are the commonest evidence of its original nature.

The color of the schist when fresh is bluish black, gray, or green, becoming more green and yellowish-green on weathering. The schists are composed of chlorite and feldspar in abundance and muscovite, epidote, and quartz in small quantities. The muscovite and chlorite crystals lie parallel to each other, causing planes of schistosity, and the other minerals fill the spaces between them. Less common in the formation are the beds of amygdaloid, which occur chiefly along the northwestern areas of the formation. These consist of a bluish-gray groundmass with amygdules or cavities filled with quartz, feldspar, and epidote; they rarely exceed the size of a pea and are thickly scattered through the rock. Very rarely the schists are found coarser and with a visible structure which approaches that of diabase. This original structure has in most cases been entirely lost in the schistosity.

Other additions to the ordinary schist are the lenses of epidote and quartz, which are more prominent in the northeastern outcrops. The lenses lie parallel to the planes of schistosity and attain a length of 8 feet and a diameter of 2 feet; ordinarily they are from 8 to 12 inches in thickness. Epidote is far more abundant than quartz in the composition of the lenses, although both minerals usually occur; only rarely is either of them coarsely crystalline. Judged by its extent and structure the series is at least 1000 feet thick.

Decay makes slow progress in this formation, since so much of its material is insoluble. The feldspar yields first and leaves the chlorite, muscovite, epidote, and quartz still closely fixed together. Beds containing epidote lenses, and the lenses themselves, are extremely durable and form high, sharp ledges and knife-edge cliffs, like the crest of Hanging Rock. All large areas of the schist cause high ridges and mountains; small areas often lie in valleys between sandstone mountains. Areas of amygdaloid offer somewhat less resistance to weather, and south of Linville occupy low ground. Yellow or red clays of good depth result from complete decay of the formation. Where the slopes are not too steep, rich soils are developed, interrupted by blocks of epidote and frequent ledges.

Flattop schist.—One large area of this formation appears south of Boone, extending in many narrow fingers to and across the Blue Ridge. The prominence of the schist in Flattop Mountain is the reason for its name. It consists of black, dark-blue, bluish-green, and greenish-gray schists, which weather to a yellowish- or greenish-gray color.

The schists are commonly marked by light-gray bands which are more feldspathic than the rest of the rock. The bands are seldom thicker than half an inch, and in places they are greater in bulk than the darker portions of the rock. Quartz and feldspar in grains of varying sizes make up these bands, and the rock strongly resembles a sandy slate of sedimentary origin. The gray bands of the schist are composed of quartz and feldspar grains with a little fine muscovite, and occasional fragments composed of the same minerals derived from some previous mass. These resemble thin sheets of volcanic ash.

Other portions of the schist contain porphyritic crystals of feldspar and amygdules, which show that its nature is volcanic. The amygdules are usually filled with quartz, feldspar, and epidote. In many places, also, there is a banding which exhibits the wavy flow structure of volcanic rock; this is especially true of the northeastern outcrops. In its western portions, near the Montezuma schist, this formation contains epidote grains and small lenses, quite the same in appearance as those of the Montezuma schist. In those areas the banding of the Flattop schist also becomes less conspicuous, and the two formations resemble each other closely. This apparent transition between the two schists is similar to that between the Montezuma schist and the Linville metadiabase. It is possible that the Flattop schist represents the topmost layers of a volcanic mass and was underlain successively by the Montezuma schist and the Linville metadiabase. In chemical composition the Flattop schist is slightly less basic than the others, and originally was perhaps of an andesitic nature. Most of the formation consists of very fine-grained schists, composed of quartz, feldspar, and mica of secondary origin. The micas are chiefly muscovite, which is replaced in part by chlorite in the greenish and weathered varieties. In the blue and black schists there is much magnetite in very fine grains. Pyrite and epidote also occur in grains in the greenish schists.

Metamorphism has affected this formation to a marked degree. Originally it was probably a flow of lava with a more or less glassy base. This was marked by bands of coarser minerals and perhaps fragments of lava, which now form the light-gray bands of the schist. No trace of a glassy base is now to be seen. This and most of the original minerals were replaced by the secondary quartz, feldspar, and mica that now make up most of the rock, perhaps by chemical action before the bulk of the metamorphism took place. Besides this form of alteration the banding of the rock has been disturbed or destroyed and the new minerals, especially the micas, have crystallized with their longer dimensions parallel. Thus is caused the schistose character which prevails. Near the Blue Ridge these results are most noticeable, and the resulting black schist gives no indication of its origin. In less extreme stages the porphyritic feldspars are seen more or less broken and drawn out, and the original flow banding is cut across by the schistose planes.

The formation resists decay and forms ridges and mountains of considerable height. Disintegration of the feldspars slowly breaks down the rock, leaving the more permanent quartz and mica skeleton. The more schistose portions contain less feldspar and are correspondingly slower to break up. Lumps of unweathered rock and flakes of schist strew the ground, and ledges are usually near the surface. Final decay produces a reddish and sandy clay. On this form soils of considerable depth and fertility.

Metarhyolite.—Areas of this formation appear in several north-south belts near the Blue Ridge and in several narrow belts near the State boundary. The formation consists mainly of fine metarhyolite, but comprises occasional layers which show porphyritic crystals of feldspar and quartz. The rock has an extremely fine groundmass of quartz and feldspar crystals, in which are set the few larger crystals of the same minerals. The colors of the fresh rock are dark blue, dark gray, and bluish black; but when the rock is badly weathered these change to dull yellow and yellowish gray.

The formation near the State boundary consists, not of a solid metarhyolite mass, but of thin sheets and dikes in the Cranberry granite, of immense number and greater amount than the granite. Near the Blue Ridge the formation appears in belts of considerable size, and apparently represents a thick surface flow. A few bodies of small size are plainly intrusive in the Blowing Rock gneiss and Carolina gneiss, and these may fill the openings through which flowed the molten material of the larger masses. Other small dikes appear to cut through the Flattop schists, but the original relations are much obscured by the metamorphism. In the vicinity of Blowing Rock the metarhyolite is less metamorphosed than usual and shows the fine wavy, banded structure characteristic of lava flows. In a few rare instances lithophysæ of small size are found in the metarhyolite. In still rarer cases small amygdules are visible. Taken as a whole, the volcanic nature of the formation is clear, from the presence of the flow banding, the lithophysæ, and the amygdules.

In its original condition the metarhyolite was a fine glassy rock of highly siliceous composition. This was marked by flow banding similar to that of the Flattop schist, but less pronounced and of a less feldspathic composition. In addition there were numerous small crystals of feldspar and quartz. On this rock deformation has produced widely different effects in different areas. The large body on the head of Yadkin River appears to the eye to be little altered; under the microscope, however, the groundmass is seen to be a collection of fine, secondary quartz and feldspar grains derived from the original glassy or cryptocrystalline base. In other areas, especially the thinner sheets near Blowing Rock, the rhyolite has been entirely transformed to a schist by the growth of new quartz and mica out of the feldspar. Some of these schists still show the original porphyritic feldspar crystals cracked and separated. Near Bull Ruffin Mountain both the little altered metarhyolite and the secondary schists occur in the same areas.

Decay proceeds slowly in this formation, since it contains only a small proportion of soluble material. After solution is far advanced, there remains a fine yellow and red clay, containing many flags and lumps of the less altered layers or slabs and flakes of the black schist. The latter is prone to form ledges and frequently outcrops. Soils are of small value over the schists; they are light and well drained but shallow, and the insoluble mica and quartz are so abundant that the soil is not readily built up when once worn out. The clays formed from the more massive portions are deeper and maintain a somewhat richer soil.

CAMBRIAN ROCKS.

With the deposition of the Cambrian rocks there came a great change in the physical aspect of this region. The sea encroached upon areas which were until then dry land. Eruptions of lava and erosion of the surface were replaced by deposition of sediments beneath a sea. Extensive beds of these were laid down in some areas before others were submerged. Here the sediments lapped over lavas and plutonic granites alike, and the waste from them all was combined in one sheet of gravel and coarse sand which now appears as sandstone, conglomerate, and quartzite. Some of this waste consists of epidote and jasper, the products of alteration in the Linville metadiabase. It is thus seen that the interval between the Algonkian and Cambrian was at least long enough to permit dynamic movements and chemical changes to effect considerable results, even before the period of erosion and reduction began.

Unicoi formation.—Many areas of this formation, the first sedimentary deposit in the quadrangle, appear in this region, chiefly in Iron Mountain, Forge Mountain, and Stone Mountain, and in the basin surrounding Linville. Its name is derived from Unicoi County, Tenn., where it is prominently displayed. The formation consists of a great series of sandstones and quartzites with small interbedded shales and slates and much conglomerate. The sandstones are light gray or white, and frequently feldspathic. Very near the base occur the conglomerate, arkose, and coarse sandstone beds, and in the center of the formation are layers of cross-bedded sandstone.

The most unusual feature of the formation is the thin bed of amygdaloid interstratified with the formation in Iron Mountain. This was a contemporaneous lava deposited as a sheet upon the conglomerates forming the lower part of the formation. Just above the amygdaloid are white quartzites and sandstones with a thin layer of reddish and purplish sandstone. Northeastward the red and purple beds become more prominent and persistent. The amygdaloid is in all respects like the amygdaloids of the Montezuma schist, and the lithologic description of the latter suffices entirely for this deposit. This amygdaloid has now a known length of over 100 miles and a width of 10 miles. Its northwestward extent is unknown because the inclosing formations are not exposed. On the southeast it disappears before the line of Stone and Forge mountains is reached. It diminishes southwestward and disappears about 40 miles west of this quadrangle. Its maximum thickness here is about 150 feet, and is fairly uniform in this quadrangle. The marked difference in the deposits above and below it, and its regular position with regard to these beds, as well as the lack of intrusive features, indicate its origin as a contemporaneous flow. In this region the rock has a fine and uniform grain and 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, where the rock is less metamorphosed and the grain is coarser, it has rarely the structure of diabase. As a rule, however, its chemical composition, its fine and uniform grain, and its amygdaloidal nature indicate that it was originally a basalt.

The sandstones and quartzites are generally massive and fine grained, in beds from 6 inches to 6 feet thick. In the upper third of the formation the interbedded shales are most frequent, but are always much less in amount than the sandstones. The shales are conspicuous in the southwest end of Stone Mountain, while some sections show very little trace of shale. The shale beds vary from 6 inches to 10 feet in thickness, and are of a bluish-gray color, becoming dull yellow when weathered. They are fine grained and argillaceous, and occasionally pass through sandy shales into feldspathic sandstone and arkose. The thickness of the formation is 2000 to 2200 feet in Tennessee, but ranges in North Carolina from 1500 to 2500 feet.

The best defined member of the formation is the conglomerate, which is composed of pebbles and fragments frequently a foot in diameter. These fragments are in large part white quartz, but include also granite, slate, metarhyolite (schistose, massive, and porphyritic), black schist, epidote, feldspar, and jasper. In places the pebbles make up nearly all of the rock; in other areas they are surrounded by a matrix of white sandstone or siliceous arkose. Many of the pebbles are angular and sharp, showing no great amount of wear, but most of them have lost their original shapes during the deformation of the strata. The coarse conglomerate is at its maximum around Grandfather Mountain and extends in a narrow belt northeast through Shulls Mill and nearly to Boone; a small amount also appears at Banners Elk. Away from these places the amount of conglomerate and the size of the pebbles diminish rapidly. In Stone Mountain very little conglomerate is seen. In Iron Mountain the conglomerate is thin and variable and the pebbles are mainly of white quartz and are very well rounded.

The conglomerate bed varies from 20 to 500 feet in thickness. Around Grandfather Mountain and Shulls Mill it is repeated by folds and faults, giving the appearance of several distinct layers. At the time of its deposition, as shown by the sharpness and great size of the fragments, the conglomerate was very near its source and the shore line, and probably was a beach deposit.

Great changes have occurred in this formation through metamorphism since its deposition. Metamorphism is moderate north of Cranberry, but southward and eastward it increases very rapidly. The changes consist usually of the development of schistosity, recrystallization of quartz particles, and breaking up of feldspar into quartz, feldspar, and mica. The latter process is limited in extent, owing to the small amount of feldspar in the rock, but in some places, as from Blowing Rock to Grandfather, the mica (chlorite and muscovite) is sufficient in amount to cause a marked green banding. Alterations in the argillaceous beds consist chiefly of the growth of new mica, producing schistosity, and in the Linville basin are so extensive that schists are much more common than slates. The arkose beds are now in most places graywackes. Even the massive conglomerate has been extensively deformed. Its matrix has developed new chlorite and muscovite, in flakes wrapped around the pebbles, and the pebbles have been squeezed and flattened. The slate and schist pebbles have suffered most and appear to have received their schistosity since they were embedded in the matrix. Even the massive quartz, metarhyolite, and granite fragments have been flattened, dented, and elongated, with trails of quartz and mica, and the rock plainly shows the most intense compression.

Erosion of this formation proceeds with extreme slowness on account of the siliceous and insoluble nature of its materials. Decay finds its way down the bedding and schistose planes and through the few feldspar grains, and the rock gradually breaks down. The sandstone and quartzite ridges are high and rocky, but their crests are usually rounded on account of the great breadth of the areas. The shale and slate beds are relatively soft, and break up so much faster than the sandstones that they seldom outcrop but are covered with the harder fragments. Flakes of slate are numerous in the soil, however, and in this form are durable, being carried to great distances. The conglomerate is the hardest rock found in this region, as is shown by the massive cliffs and jagged crest of Grandfather Mountain. Its highly siliceous composition and massive beds give scarcely any opening for solution, and its course is everywhere marked by huge ledges and blocks. Perpendicular cliffs on Grandfather Mountain attain a height of 200 feet, and a single plate of the rock will project 50 feet above the surface.

Soils are shallow over the sandstones and quartzites, as would be expected, and the rock outcrops are frequent. The proportion of clay to sand is not sufficient to hold the soil together in exposed positions. Where the slaty beds are frequent the combined soil is light and rich. On favorable slopes and in hollows a deep accumulation of soil takes place and the forests are strong and heavy.

Hampton shale.—This shale occupies the same general localities as the preceding formation, and also two small areas in the Doe Mountain group. It is named for its occurrence near Hampton, Carter County, Tenn. In most places it consists of argillaceous and sandy shales, from 600 to 800 feet thick. Their color when fresh is bluish gray or gray, varying to yellow and buff on exposure. As a rule they are banded by thin, more or less siliceous layers. Near Linville the formation varies much in appearance. The metamorphism in that region has been sufficient to change the shale to slate and in places even to a schist. Seldom, however, is the banding entirely destroyed. The slates are gray or dark gray and the siliceous bands are light gray. The boundary between this formation and the Unicoi formation is not sharp, on account of the interbedding of the shales and sandstones.

The formation is of little account as a soil producer because its natural soils are much altered by wash from the adjacent sandstones. Occasionally upon divides it shows a thin yellow soil of small value. Decay is slow by solution, but the strata yield easily to the direct action of rain and frost. Steep slopes, narrow valleys, or depressions between sandstone crests mark the course of the shale. The more metamorphosed portions south of Linville give rise to hills of considerable size.

Erwin quartzite.—Many of the mountain crests of the Tennessee district are caused by this formation. It consists of white sandstone and quartzite, from 500 to 700 feet thick, and is very uniform in appearance. The strata are composed of grains of fine white sand, more or less cemented by secondary silica. Its layers are very massive and show scarcely any partings of shale. Between the quartzite and the overlying Shady limestone are a few feet of sandy shale and thin sandstone, in which are found a few lower Cambrian fossils of the Olenellus fauna. Scolithus borings are common in the quartzites. The quartzites of this and the Unicoi formation can only with difficulty be distinguished from one another.

Weather makes but little headway against the close texture and insoluble materials of these beds. The formation always causes high ground, and white cliffs mark its course. By direct action of frost its blocks are finally dislodged and strew the mountain sides. Its crests are sharp and rocky, and the cover of soil is thin and irregular. Hollows collect enough soil to support a fair vegetation, and where the summits are flat for considerable areas, as on Iron Mountain, a deep, rich soil accumulates.

Shady limestone.—This formation occupies two areas northwest of Iron Mountain and many others south and east of Doe Mountain. It derives its name from Shady, Johnson County, Tenn. The formation consists mainly of limestone and is 750 to 800 feet thick. The limestone is bluish or gray in color, and receives a dull gray or black color on the outside of the weathered outcrops. Some of the layers are mottled, gray, blue, and white, and often seamed with calcite, and a few beds of almost white limestone or marble are found. Its beds are very thick and massive and the stratification is hard to determine, unless large masses are seen. Thin seams of blue and gray shale occur in many parts of the formation. A few beds of red shale in the upper layers of this formation make a transition into the Watauga shale. Siliceous impurities in the form of sand, and more especially chert, are frequent. The chert usually forms small, rounded nodules with a gray surface and concentric gray and black bands inside. It also occurs in large, irregular masses with a rough white surface and a clear and translucent interior, and is a true chalcedony. Many masses are 3 or 4 feet in diameter.

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

Watauga shale.—Two principal belts of this formation appear, one on each side of Doe Mountain. The formation consists of a series of interbedded limestones, red, green, and variegated shales, and red sandstones. Large areas of it are drained by Watauga River; hence its name. The limestones are blue and blue-gray in color and show all grades in transition from pure limestone to the red shale. The thickness of the limestone beds seldom exceeds 10 feet, being usually from 1 to 2 feet. Much the greater part of the formation is made up of red, brown, purple, and yellow shale, in places calcareous, in places sandy, and usually argillaceous. When perfectly fresh much of the shale appears as a blue or drab limestone; slight exposure produces in this the reddish colors and the shaly partings. The beds of red sandstone are local and argillaceous, and differ from the sandy shale chiefly in being more massive. Rather unusual in appearance are a few layers of white sandstone near Stone Mountain. The sandstones range in thickness up to 6 feet and are closely interbedded with the shale. The thickness of the formation can not be determined here, on account of the extreme folding and crumpling, but in neighboring regions it is 1000 to 1100 feet.

A common feature of the calcareous strata is chert, which becomes more prominent in the lower beds of the formation. This occurs in nodules and masses up to 5 feet in diameter, of a very tough and durable nature. The iron oxide which colors the shales so strongly is frequently combined with the chert to such an extent that the mass becomes an ore. As a rule, however, the proportion of chert is far too great. Deposits of brown hematite free from siliceous impurity also occur in the shales. All these varieties of the formation may be present in one locality.

None of the beds of the formation withstand decay successfully. The calcareous beds are speedily dissolved, leaving the shales and sandstones to crumble and break down. The chert is extremely durable, but is not of sufficient amount to protect the other beds. The sandy material is able only to form low ridges and rounded knobs, which are brought into slight relief by the Shady limestone valleys. In the area north of Doe Mountain the ridges decend gradually to the southeast across the formation and have no regular system. Soils are deep only over the calcareous strata and are kept loose by the sand and bits of shale. While seldom very fertile, they are fairly productive and are all accessible and easily cultivated.

JURATRIAS (?) ROCKS.

Bakersville gabbro.—A single area of this formation appears in the quadrangle. In the Roan Mountain quadrangle, adjoining on the west, the formation is extensively developed in the shape of dikes cutting the older formations and in bodies resembling laccoliths. The occurrence in this quadrangle is more of the latter nature, the gabbro being rudely lenticular in shape, and lying along the foliation planes of the Roan gneiss. Farther west the gabbro is intrusive in the Roan gneiss, the Carolina gneiss, and the Cranberry granite, the only formations with which it comes in contact. Its most distinctive feature, however, is the entire absence of dynamic metamorphism, although the adjoining rocks are all metamorphosed, frequently to an extreme degree. Rocks of the character of gabbro are especially subject to metamorphism, so that its absence here indicates that the gabbro was formed after the period of metamorphic action. Inasmuch as rocks of precisely this character are of frequent occurrence among those of the Juratrias period and occur at intervals in the older rocks of other areas, and as there are no other formations of this character known in the Appalachians, this gabbro is considered to be of Juratrias age.

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

This rock withstands the action of weather most effectively. Decay works gradually in along the joints, and spheroidal masses and bowlders are formed. These are seldom far from the surface, and the cover of brown clay is usually thin. The round bowlders readily find their way downhill and block the stream channels, being almost as effective in that respect as massive ledges of other rocks. This superior hardness is also manifest in the line of buttes which the formation upholds on the slopes of Hump Mountain.

STRUCTURE.

Definition of terms.—Those rocks of the Cranberry quadrangle which were deposited upon the sea bottom must originally have extended in nearly horizontal layers. A similar position was taken by the volcanic formations, which solidified in nearly level beds. At present, however, the beds or strata are seldom horizontal, but are inclined at various angles, their edges appearing at the surface. In the description of their positions certain terms are used which may be defined as follows:

The *strike* of a bed is the course which its outcrop would take if it intersected a horizontal surface. The *dip* of strata is the angle at which they are inclined from the horizontal surface. A bed which dips beneath the surface may elsewhere be found rising; the fold or trough between two such outcrops is called a *syncline*. A stratum rising from one syncline may often be found to bend over and descend into another; the fold or arch between two such outcrops is called an *anticline*. A synclinal *axis* is that portion of a syncline along which any individual bed is lowest, and toward which the rocks dip from each side. An anticlinal *axis* is that portion of an anticline which throughout includes the highest portions of a stratum of the arch, and away from which the rocks dip on each side. The axis may be horizontal or inclined. Its departure from the horizontal is called the *pitch*, and is usually very much less than the dip.

In districts where strata are folded they are also frequently broken across and the parts are compressed until the arch is pushed up and thrust over upon the trough; such a break is called a *thrust fault*. If the arch is worn away by erosion and the trough is buried beneath the overthrust mass, the strata exposed at the surface may all dip in one direction. They then appear to have been deposited in a continuous series. About the same effect is produced by a series of close folds, all parts of which dip in the same direction. Such arrangements of the strata are termed *isoclinal*. In some faults the break was directly across the strata which appear at the surface, and the parts upon either side were moved past each other in a nearly vertical direction. These dislocations are called *normal* faults.

Folds and faults are often of great magnitude, 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 Cranberry region. In these folds the rocks change 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 rock. These are best developed in rocks of an originally massive structure and are usually much nearer together and smaller than the planes on which the deformation of the stratified rocks proceeded. In these more minute dislocations the individual particles of the rocks were bent, broken, and slipped past one another. Attending this was a greater or less growth of new minerals by recrystallization from the old, a process which is called *metamorphism*. Most of the new minerals crystallized with their longer dimensions about parallel to the planes on which the motion took place. The usual effect of this action upon the rocks is to cause an easy splitting, or *schistosity*, parallel to the longer dimensions of the new minerals.

GENERAL STRUCTURE OF THE APPALACHIAN PROVINCE.

Three distinct types of structure occur in the Appalachian province, each one prevailing in a separate area corresponding to one of the three geographic divisions. In the Plateau region and westward 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.

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

Faulting took place along the northwestern sides of anticlines, varying in extent and frequency with the changes in the strata. Almost every fault plane dips toward the southeast and is approximately parallel to the beds of the upthrust mass. The fractures extend across beds many thousand feet thick, and sometimes the upper strata are pushed over the lower as far as 6 or 8 miles. There is a progressive change in character of deformation from northeast to southwest, resulting in different types in different places. In southern New York folds and faults are rare and small. Through Pennsylvania toward Virginia folds become more numerous and steeper. In Virginia they are more and more closely compressed and often closed, while occasional faults appear. Through Virginia into Tennessee the folds are more and more broken by faults. In the central part of the valley of Tennessee folds are generally so obscured by faults that the strata form a series of narrow overlapping blocks of beds dipping southeastward. Thence the structure remains nearly the same southward into Alabama; the faults become fewer in number, however, and their horizontal displacement is much greater, while the remaining folds are somewhat more open.

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 metamorphosed by the growth of new minerals. The cleavage planes dip to the east at from 20° to 90°, usually about 60°. This form of alteration is somewhat developed in the valley as slaty cleavage, but in the mountains it becomes important and frequently destroys all other structures. All rocks were subjected to this process, and the final products of the metamorphism of very different rocks are often indistinguishable from one another. Throughout the southeastern part of the Appalachian province there is a great increase of metamorphism toward the southeast, until the resultant schistosity becomes the most prominent of the mountain structures. Formations there which retain their original condition unchanged are extremely rare, and frequently the alteration has obliterated all the original characters of the rock. Many beds quite unaltered at the border of the Valley can be traced through greater and greater changes until every original feature is lost.

In most of the sedimentary rocks the bedding planes have been destroyed by the metamorphic action, and even where they are distinct they are usually less prominent than the schistosity. In the igneous rocks planes of fracture and motion were developed, which, in a measure, made easier the deformation of the rocks. Along these planes of localized motion the original texture of the rock was largely destroyed by the fractures and by the growth of the new minerals, and in many cases this alteration extends through the entire mass of the rock. The extreme development of this process is seen in the mica-schists and mica-gneisses, the original textures of which have been entirely replaced by the schistose structure and parallel flakes of new minerals. The planes of fracture and motion 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°.

The structures above described are chiefly the result of compression which acted most effectively in a northwest-southeast direction, at right angles to the general trend of the folds and of the schistose planes. 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 which appear here and there throughout the Appalachians. The earliest-known period of compression and deformation occurred during Archean time, and resulted in much of the metamorphism of the present Carolina gneiss. It is possible that later movements took place in Archean time, producing a portion of the metamorphism which appears in the other Archean rocks. In the course of time, compression became effective again, early in the Paleozoic era, and a series of movements took place culminating 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 was exerted at two distinct periods, the first producing great overthrust faults and some metamorphism, the second extending farther northwest and deforming previous structures as well as the unfolded rocks. The various deformations combined have greatly changed the aspects of the rocks—so much so, in fact, that the original nature of some of the oldest formations can be at present only surmised.

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

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

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

LOCAL STRUCTURES.

The rocks of this area have undergone many alterations in form and position since they were formed, and they have been bent, broken, and metamorphosed to a high degree. The structures which resulted from these changes extend in a general northeast direction, except in an east-west belt passing through Boone; in this belt the structures trend nearly west. Immediately south of this belt the structure lines for a considerable distance are nearly north and south, in extreme contrast.

Structures in the sedimentary rocks are readily deciphered. In the igneous and crystalline rocks, however, while it is easy to see that they have been greatly disturbed, and the details of the smaller structures are apparent, yet 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 not be detected.

In a broad way the structure of the rocks of the Cranberry quadrangle is that of two synclinal basins, where the sedimentary rocks appear, and a great, irregular area of uplift exposing the igneous and crystalline rocks. The basins are almost wholly cut off from the remainder by great faults.

In the synclinal basin which lies in Tennessee the rocks are folded and broken, about as are the adjoining parts of the Great Valley. In the southern part of the mountains, in the second basin, the strata are extremely folded, faulted, and metamorphosed, often in so exceptional a manner as to render the region unique. In the remainder of the mountain district such folds as can be traced are broad, metamorphism is great, and faults are few. The foothill district does not differ essentially in structure from the mountains.

The structures of the Tennessee area are of the usual Appalachian kinds, and the basin is composed of narrow anticlines and synclines, here and there broken by faults. The strata usually dip at angles greater than 30°. Along the junction of this basin with the mountain district the rocks all dip southeast with steep or vertical dips. One chief anticlinal area, made up of a number of lesser folds, appears in Doe Mountain and the neighboring ridges, with corresponding synclinal areas on each side. The axes of these folds pitch considerably at the ends, causing the formations to disappear in places. One of the chief syclinal axes of this region passes just north of Iron Mountain, marked here by a broad, open fold; the anticline corresponding is broken and thrust far into the air on the Iron Mountain fault, until the underlying granite appears. The Iron Mountain fault runs for many miles northeast and southwest from this area, and presents the unusual feature of a northwest dip. The great fault which passes southeast of Stone Mountain and bounds the synclinal basin is remarkable in many respects. It has a very irregular course and repeatedly cuts across the adjacent formations in a fashion quite unlike the typical Appalachian faults. The dip of its plane varies much, from horizontal up to 60°, and in some of its course is toward the northwest. Since it was produced the fault plane has been extensively folded, together with the adjoining formations; on this account its course as laid bare by erosion is extremely irregular. Its special features appear in Sections A—A, B—B, C—C, and E—E. Other faults have the usual dip to the southeast and begin or end in this area. Their origin in broken anticlines is plainly visible in the Doe Mountain area, shown in Sections B—B and C—C. A small exception to this is seen about 5 miles east of Butler, Section C—C. This is a normal fault, with a vertical break across the strata, and has no apparent connection with anticlinal structure. The throw of these latter faults varies from nothing to 1 mile, while the Iron Mountain fault has a throw of at least 2 miles. More extreme than these is the Stone Mountain fault, on which the rocks have slid for at least 8 miles, and probably more. In adjacent regions to the southwest the displacement on this fault is much greater still.

The strata of this basin were bent rather more than broken under compression, on account of their frequent bedding planes and changes of material. Beds like the Erwin quartzite, possessing few such planes and being very rigid, broke under the strain and caused faults to extend for some distance into other formations. Fragments of the quartzite form many breccias along the fault planes. Thinner beds, like those of the Watauga shale, bent and crumpled in an extreme degree without breaking, as appears in Sections B—B and C—C. As a whole, the amount of deformation is less than in other parts of the quadrangle.

While folds and faults are common in the second synclinal basin, in the southern part of the mountain, their importance is much less than that of metamorphism, the multitude of whose slips combined has equaled all larger structures. In the extreme western part of the basin metamorphism is not great, but it speedily increases toward the east until, near Banners Elk and Linville, the closest search is necessary to discover the true bedding of the rocks. East of those points the rocks are finer grained and it is almost impossible to find the stratification planes. Between Banners Elk and Shulls Mill the schistose planes cut directly across the layers and even the formation areas, and are exceedingly misleading. Less schistose portions of the rock stand up in ledges, like harder sedimentary layers, but run right across the formation. From the effects of compression upon the rocks, it seems as if they had been mashed and kneaded over and over. The alterations of the minerals were stated in describing the individual formations. The schistose planes dip nearly east at angles ranging from 10° to 80° or 90°, usually about 70°. The planes of the larger faults and of most of the axes of folds correspond in dip with the schistose planes. The area above noted, between Banners Elk and Shulls Mill, is, however, a striking exception to this relation.

The amount of throw on the fault planes can hardly be estimated. On the fault just north of Grandfather Mountain the displacement is about 2 miles; on the Boone or east-west fault it is at least a mile, and probably much more. The total dislocation due to the minor slips along the schistose planes is quite as great as that from any other cause, and it is hard to decide in many places whether or not it should be called a fault. A comparatively small thickness of strata is involved in these folds, and the same formations repeatedly appear at the surface. All the structural lines, folds, faults, and schistose planes trend nearly north and south, a direction differing by 30° or 40° from the usual trend in this region.

Along an east-west line passing through Banners Elk and near Boone the foregoing structures are cut off abruptly by a great cross fault, which places the Cranberry granite successively over all the more southern formations. The latter rocks appear to have been thrust in a northwest direction, past the granite, and their ends frequently show a slight curve, as if dragged against the overlying beds. The striation and elongation of the granite near the fault pass diagonally down the fault plane and show a northwest direction of the motion. Sections D—D, E—E, and F—F show the relation of the two groups of rocks. The sharp change from northerly to easterly dips and schistose planes on opposite sides of the fault forms one of the most remarkable structures in the Appalachians. At Bull Ruffin Mountain the east-west fault turns abruptly south. For 7 or 8 miles it can be traced fairly well, and it may extend much farther; the means of identifying it are wanting, however, in the Archean gneisses. This area and its southwestward extension are nearly surrounded by faults, forming a huge depressed block of the most unusual character.

In the great anticlinal mass forming the rest of the mountain area it is difficult to discover the larger structures. A few small synclines are defined by sediments folded in with the granite. It is possible also that faults occur, but for lack of distinctive or regular beds they can not be determined. By far the greater part of the deformation has taken place through metamorphism. The most striking structural features, the great faults which outline the synclinal basins, have been described.

Of importance equal to these are the great anticlinal mass of Beech Mountain, that of Rich, Elk, and Three Top mountains, and that of Roan Mountain, terminating just south of Cranberry. The anticlinal nature of these is not always clear, on account of the extreme nature of the deformation. The anticline of Beech granite can be seen to underlie the Cranberry granite north of Cranberry and west of Valle Cruces. At other points it has been mashed and thrust up so far that it overrides the Cranberry granite (Section E—E). The two other great anticlines, appearing in the Roan gneiss, have the form of overturned folds throughout this area, as shown in Sections A—A and B—B. It is very probable that the folds are complicated with faults along their borders; for instance, east of Boone and south of Cranberry. Just where the line should be drawn, however, between dislocation as shown in faults and in metamorphism it is difficult to decide.

The processes of metamorphism were in general along the following lines: The mineral particles were changed in position and broken during the folding of the rock. As the folding went on they were fractured more and more. New minerals, especially quartz and mica, grew out of the fragments of the old minerals. The new minerals were arranged at right angles to the greatest force of compression at any particular point. Inasmuch as the compression was about uniform in direction over large areas, there resulted a general parallelism of the longer dimensions of the minerals. To this is due the schistosity of the rocks. In folding, the differential motion in the sedimentary strata was to a large extent along bedding planes. As deformation became extreme, however, other planes of motion were formed through the separate layers, just as in the case of the massive igneous rocks. In rocks which were already gneissoid or schistose, as the result of previous metamorphism, the existent schistose planes served to facilitate flexure, as did the bedding planes of the sediments. In the massive igneous rocks there were no planes already formed, but they were developed by fracture and mashing, and the change of form expressed in folds was less than in the laminated rocks. The schistose partings are in a general way parallel to one another for long distances and over large areas. They sometimes diverge considerably for short distances around harder portions of the rock, which have yielded less under compression, but the influence of these portions is only local. Near the boundaries of formations, also, they are usually about parallel to the general contact of the formations, the yielding to pressure having been directed by the differences in strength between the formations. Thus, while the strike of the different formations may vary considerably in adjoining areas, yet the schistose planes swing gradually from one direction to another, and there is seldom an abrupt change.

There is great variety in the dips of structure planes in this portion of the mountains. A belt marked by east-west strikes passes through Boone and widens westward. Along the north edge of this the schistose planes swing quickly around into the northeast course usual in the Appalachians. A similar rapid change to a southerly course takes place just south and east of Cranberry. The dips of the foliation and schistose planes are as varied as the strikes. North and northeast of Elk Park and in the Beech granite area the dips are very slight, often being perfectly flat. Similar slight dips appear south and east of Elk Crossroads, mainly in the Carolina gneiss. Elsewhere the foliation planes of the gneisses and the schistose planes of the granites dip steeply. In the granites dips range from 40° to 80° and average about 50°; in the gneisses they range from 50° to 90°, averaging about 70°. Dips are toward the southeast except in the belt of east-west strikes, where they are for the most part toward the north.

Few structures can be traced in the foothill district. The formations are large, cover wide areas, and lack distinctive beds, so that it is difficult to determine any alterations but those of metamorphism. Folds undoubtedly exist, causing the changes of dip that appear here and there, and they can be detected when the formations differ materially. Many small wrinkles and puckers appear in the Carolina gneiss in the southeastern part of the district.

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

The latest form in which yielding to pressure is displayed in this region is vertical uplift or depression. Evidence of such movements can be found at various intervals during the deposition of the sediments, as at both the beginning and end of the periods of deposition of the Knox dolomite, the Athens shale, the Clinch sandstone, and the Newman limestone. While these formations are not displayed in this area, they appear in adjoining areas, and the movements recorded by them affected this region with the others. In post-Carboniferous time, after the great period of Appalachian folding just described, such uplifts took place again, and are recorded in surface forms. While the land stood at one altitude for a long time, most of the rocks were worn down to a nearly level surface. Over this whole region one such surface was extensively developed, and its more or less worn remnants are now seen in the plateaus of the mountain district, at altitudes of 3400 to 4000 feet. Actual profiles of parts of these plateaus are shown in Sections B—B, F—F, and G—G. This period is the oldest recorded in this form in the Appalachians. Remnants of another plain stand at elevations of 2400 to 2500 feet in the ridges south of the Blue Ridge. At similar elevations in the Tennessee district, and probably representing the same period, remnants of a plain appear in the plateaus and terraces along the north slope of Stone Mountain, between Doe and Iron mountains, and around Mountain City. This plain, though only scantily developed in this region, is much more prominent in regions farther away from the sources of the rivers. A third and still less conspicuous epoch is recorded in the terraces on Yadkin River and the terraces, probably of equivalent age, along Roan and Doe creeks and Watauga River. As the streams rise toward their heads, the terraces keep pace with them until they become indistinguishable from those of the preceding stage. These later terraces, like the remnants of the previous gradation period, represent a period of great length and of prominence in other regions. After the formation of each of these plains, uplifts of land gave the streams greater slope and greater power to wear; they have accordingly cut down into the old surfaces to varying depths and produced later plains or canyons, according to their power and the nature of the waste that they carried. The amounts of the uplifts can be estimated from the vertical intervals between the plateaus to be 1300 feet after the first period of reduction, 1200 feet after the second, and possibly 500 feet after the last period. Other uplifts and pauses undoubtedly occurred in this region, but their traces are obscure; and there probably occurred still others which were not of sufficient length to allow plains to form and record the movement.

MINERAL RESOURCES.

The rocks of this region are of use in the natural state, as soapstone, mica, building stone, ornamental stone, and road material, and in the materials developed from them, such as iron, copper, gold, lime, and clay. Through their soils they are of value for timber and crops, and in the grades which they occasion on the streams they cause abundant water power.

Soapstone.—In two places soapstone is found sufficiently pure for economic use. In most cases the hydrous silicate of magnesia forming the soapstone is too much mixed with other silicates, especially of the hornblende family, to be available. The special uses of soapstone demand a rock which is readily cut and sawed and which contains no mineral that is affected by fire. Some of the hornblendic minerals fuse readily, and others, which fuse less easily, are hard and injure the texture and working of the stone. In the metamorphism of the original rock, that which contained only olivine recrystallized as dunite, and that which contained feldspar and pyroxene, reappeared as soapstone with tremolite crystals, the changes being chiefly of form and not of chemical composition. Inasmuch as igneous rocks of this nature vary rapidly in composition, the beds of soapstone also vary much in quality, and a change from good to worthless or from poor to valuable rock may be found at any place. The quarries indicated near Baldwin, Ashe County, N. C., have been worked only to a limited extent, and the rock has found local use. The good quality of the material has long been known, but the difficulty of transportation has prevented development.

Mica.—In the pegmatite veins of the plateau district mica occurs in crystals large enough to be of commercial value. Pegmatites are found in the Roan and Carolina gneisses and the Cranberry granite throughout a large portion of their areas, but are workable only in the district south of Cranberry. Elsewhere the crystals either were crushed and distorted by dynamic movements in the rock or were not originally of sufficient size. The mica is muscovite and is crystallized with quartz and feldspar, forming the pegmatite. From a texture similar to that of granite the pegmatite varies till the mica crystals attain a diameter of 12 to 15 inches; the average diameter is 3 to 5 inches. The distribution of the blocks of good mica in the vein 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 continue throughout the vein. Many of the crystals do not furnish sheets across their entire diameter, for seams and cuts divide the sheets into angular strips and pieces. These, however, are suitable for ground mica. Impurities in the form of dendrite figures, stains, and spots render much of the mica worthless for any purpose, and clay penetrates between the sheets where the rock is decayed. The latter impurities can be, for the most part, removed by careful washing, but the spots of dendrite can not be wholly removed, existing as they do between the thinnest sheets. Pits and shallow openings have been made in this region during many years, but were usually sunk in the decayed rock and soon exhausted. Mining in the solid rock is now carried on along Cane and Plumtree creeks, a few miles west of this area.

Building and ornamental stones.—Many formations appearing in this region contain strata suitable for building material, but few have been used. Some, such as the Roan gneiss, Erwin quartzite, and Cranberry granite, have been utilized for chimneys, foundations, and bridge piers, the loose rock being used nearly in the natural state. Stone for resisting heat is found in the soapstone, the Erwin and Unicoi quartzites, and the Carolina gneiss. Material for flagstones of the best quality is abundant in all parts of the Carolina gneiss, occurring in layers from 1 inch up to 1 foot thick, and the schistose portions of the metarhyolite furnish flags somewhat less durable. Suitable locations for quarrying flags from Carolina gneiss are numerous on Elk Creek and Yadkin River. Building stone of great durability and ease of working occurs in the harder layers of Roan gneiss, and access to good rock is very easy in the deep cuts made by Plumtree and Squirrel creeks and North Toe River, and by New River, Buffalo Creek, and Three Top Creek. Some of the more ferruginous hornblendes in these beds are liable to a coating of iron rust, but most of them retain their dark-green color and lustrous surface in spite of weather. The rock takes a handsome and durable polish and can be worked in beds of desirable thickness up to 3 feet.

The Erwin quartzite is well suited for building stone in many ways. It is free from stains and keeps its white color perfectly, and it occurs in even and readily separated layers from 3 inches to 2 feet thick. Dressing the rock beyond the natural surface of the bedding planes is difficult, owing to its extreme hardness. Fine quarry sites can be found at any of the stream gaps in the mountains between Butler and Mountain City.

Probably the most generally available and useful building stone of 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 the huge blocks of nearly fresh rock that fall down the steep slopes and withstand the wear of frost or streams, and by the massive ledges near the water courses. Colors grading from white to gray are usually shown, but in a narrow belt passing north of Osborn, Key Station, Hattie, and Norris, and near the belt of Unicoi strata, granite of a rich, red color appears. Beds of a similar red color and coarser grain are found near the border of the Beech granite. The beds of Cranberry granite are of even texture throughout large masses, and rock of any desirable or ordinary grain can be obtained. Along the northwest border of the granite area the rock has been less affected by metamorphism and dynamic action than elsewhere, and is consequently freer from joints and from the schistose planes which transform it into a schist in many areas. Countless quarry sites might be located in the canyons of Watauga and Doe rivers and North Fork of New River.

In the Carolina gneiss many of the massive beds can not be distinguished from granite. Their texture and color are very uniform and their grain is fine; their separation by schistose layers would make easy quarrying and little waste. For all purposes not requiring stone over 3 feet thick these beds are well suited, and the light- and dark-gray or white colors are very pleasing.

An ornamental building stone for special uses can be obtained in great abundance from the Blowing Rock gneiss, and the separation of the granitic and schistose from the porphyritic portions in distinct layers renders easy the work of taking out the porphyry in layers of any thickness required. The rock is very striking in appearance, the white feldspar crystals standing out from the black, glistening groundmass of mica, and its durability is manifest in the huge ledges that it forms in stream cuts and the high cliffs on the mountain sides. Excellent exposures for opening can be found at almost any point near water level.

Stone of beautiful color can be developed from the amygdaloids in the Montezuma schist, whose location has been described. These are best shown $1\frac{1}{2}$ miles northwest of Shulls Mill on Watauga River. The amygdules are usually white or bright green, occasionally pink and green in concentric rings, and are very conspicuous in their setting of dark-green and blue schist. The rock is hard and takes a high and durable polish, but it is very tough and difficult to dress. Its large exposures along the Watauga furnish abundant opportunity for quarrying, and blocks can be cut as large as 10 feet.

Material for the construction of roads can be obtained from many formations in this region.

The Shady limestone and the limestone beds of the Watauga shale contain rock which breaks easily into angular pieces that pack well and cement together into a solid bed. These beds are plentiful in the Tennessee district, but are not available in other areas. The Watauga shale is easily worked into a smooth roadbed, and outcrops are plentiful, but it is not durable under heavy wear. Material similar in ease of working and in wearing capacity can be obtained from the more schistose beds of the metarhyolite, the Blowing Rock gneiss, and the Carolina gneiss. The granite beds of the Carolina gneiss, the fine portions of the Cranberry granite, and the mica-gneisses and massive hornblende-gneisses of the Roan gneiss, all supply road material which breaks into angular pieces, packs well, and is durable. The coarse Cranberry granite as a rule pulverizes readily on account of the great size of the feldspars, but that of medium grain, especially the white, quartzose masses, furnishes very durable rock. Highly siliceous formations, like the Erwin and Unicoi quartzite and sandstone, form an exceedingly permanent roadway. The latter is more feldspathic and thus a little less durable than the others, but all of them break into angular bits, pack into a well-drained bed, and stand a great amount of wear.

Magnetite.—Magnetic iron oxide occurs along a line passing through Cranberry in a northwest direction. The ore has long been worked at Cranberry and produces iron well known for its purity. From a point near Old Fields on North Toe River the magnetite has been traced, with small intervals, south of Smoky Gap, through Cranberry, and on to Shell Creek, in Tennessee, just outside the quadrangle. This line of outcrop lies in the Cranberry granite, which is in places so mashed and metamorphosed as to resemble gneiss, and it is nearly parallel to the boundary of the granite aud Roan gneiss, a relation which is repeated in other districts toward the west.

A deposit of magnetite has been opened in Ashe County, in the northeast corner of the quadrangle, but the ore body is small. Just north of Richland, also, on Yadkin River, there is an undeveloped deposit of magnetite.

At the Cranberry mines open cuts have been made at intervals over an area 900 by 300 feet and through a vertical distance of 250 feet. From these, tunnels are run in for considerable distances. The ore occurs as a series of lenticular bodies of magnetite in a gangue of hornblende, pyroxene, and epidote, with a little feldspar and quartz and a few unimportant minerals. The ore and gangue occur as a series of great lenses dipping toward the southwest at angles of 45° to 50°, about parallel to the planes of motion and schistosity in the granite and Roan gneiss. The ore is found in the gangue in the shape of smaller lenses, dipping southwest from 40° to 60°. These vary from 50 feet down to a few inches in thickness and are from two to five times as long as they are thick. Sometimes the lenses have sharp limits, but usually 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. It yields an average of 42 to 46 per cent of iron with ordinary concentration. Considerable trouble is experienced in freeing the ore from the gangue before smelting, on account of the tough and refractory nature given to the mass by the epidote.

Because of the occurrence of the ore as a series of lenses the quantity is rendered more or less uncertain. Each lens will be worked out in time and its place be supplied by other lenses, and to what depth or distance the occurrences will extend it is quite impossible to state. The ore bodies may diminish, they may remain about the same, or they may increase. As judged by openings, tests by diamond drill, and surface outcrops, the deposit has a length of over half a mile, carrying bodies of ore throughout that distance. Large quantities of ore have been taken out, far greater quantities are in sight, and there is every reason to expect a large output in the future.

The minerals composing the ore and gangue were deposited at a time much later than the production of the inclosing rock. They are also younger than the period of deformation which produced the schistose arrangement in the granites. The minerals of the ore deposit are only slightly crushed or rearranged, although they are the same varieties which in adjacent formations show the greatest metamorphism. The ore deposit, therefore, was not due to original segregation from the igneous granite, but is entirely of a secondary nature. It may have replaced a preexisting mass of rock by solution and substitution of new minerals, or it may have been deposited from solution in open spaces in the inclosing formation. The latter result is very unlikely on account of the great dimensions of the opening required by the size of the ore deposit. If the deposit represents a substitution of new minerals for old, the latter were either portions of the inclosing granite or of a mass of a different original character. The shape of the ore deposits agrees with the general form taken by the smaller intrusive bodies in this region. The minerals composing the granite—quartz, mica, and feldspar—are among the least susceptible to chemical alteration. It is therefore probable that the rock replaced by the ore body was of a composition chemically less simple. If the present minerals represent a recrystallization of those pre-existing, the original rock might well have been a diabase similar to the Linville metadiabase. This rock contains almost exactly the same minerals as the ore deposit, but even the great alteration through which it has passed has not produced anything in the nature of an ore. Accordingly, some additional or separate cause must be sought besides dynamic alteration. An agency that fulfils the conditions, and that is everywhere at work, is water charged with mineralizing agents. This dissolved and perhaps added minerals to the rock and redeposited them in favorable places, either in the old or in new chemical combinations. In this case the deposits have not the size or shape of veins, but are discontinuous and lenticular in shape, as above stated. They are plainly controlled and directed by the schistosity of the granite in this and many other areas toward the west and southwest.

There is no indication whether the channels through which the solution entered correspond with the schistosity of the granite or not, although such an arrangement is probable. In the red feldspathic granites near Cranberry there are found at many places small veins and stringers of magnetite. These may represent deposition from the mineralizing solutions, where there was no body of readily altered rock which could have been changed into an ore deposit. Also, northwest of Cranberry the gangue minerals, and even magnetite, are developed in the mass of the red granite along more or less mashed zones. These perhaps represent the places where alteration was most active—that is to say, the actual channels through which the mineralizing solutions passed.

As to the cause that put into action the mineralizing solutions, some suggestions can be made. In many areas the heated solutions and vapors arising from bodies of intrusive rock have produced mineral alterations and deposits. As stated above, the magnetite deposits are later than the folding movements. That is also true of the Bakersville gabbro. These intrusive masses are frequent in the area of Roan gneiss west and southwest of Cranberry, and the magnetite bodies swing around their circumferences. It is thus suggested that the magnetites are due to alterations begun by the gabbro intrusions. Whether true or not in this locality, this explanation does not hold for the magnetite deposits in Ashe County, just northeast of this quadrangle, for there are no recent igneous rocks in that area.

Of the source of the iron there is as little evidence. The adjacent formations, the Cranberry granite and the Roan gneiss, both carry iron chemically combined in the biotite and hornblende. Solution of either might furnish the iron. There is, however, no apparent alteration or diminution of the ferruginous minerals in the adjacent granite. From the Roan gneiss iron might more readily have been obtained, on account of the extreme abundance of hornblende in that formation. That the mineralizing solutions passed through these formations and at more than one epoch is clear from the existence of a band of titaniferous magnetite deposits parallel to and southeast of this band. These are as regularly titaniferous as the ores of the Cranberry band are free from that mineral. Inasmuch as the two belts are in close proximity and each is extensive without overlapping the other, their depositing solutions were probably active at different times. Still another period of mineralization left its record in the pegmatite veins and lenses so common in this region. These, however, were crushed and distorted during the folding of the strata and thus are so much older than the magnetite deposits that they can have no origin in common.

Red hematite.—This ore is found in one locality in this area, on the east side of Bull Ruffin Mountain. It occurs in the schistose metarhyolite next to a fault plane, and it is rather an impregnation of the schist with hematite than a distinct and pure deposit of ore. Little work has been done in development of the ore, and its value and amount are questionable.

Specular hematite.—Iron ore of this nature is found at several points along the south slope of Beech Mountain. It is found in a small vein in black schist which occurs in a narrow band in the Cranberry granite about 2 miles long. The ore appears at several places along this line. It has not been developed beyond shallow prospecting, so that neither the depth nor the extent of the deposit is known. In association with similar black schist beds on Big Ridge, a northern spur of Beech Mountain, are a number of other veins of specular hematite. These have been examined only by test pits. In all of these localities the ores exposed are siliceous. The veins are of small or only moderate thickness and have a steep dip. The course of the veins is nearly east and west and is marked by scattered outcrops and fragments of ore. In the same black schist beds at various points northwest of Beech Mountain these ores are found, indicating a considerable range for the veins.

Brown hematite.—Ores of this nature are abundant in the Tennessee district and include limonite and various combinations of the oxide and hydrate of iron. They occur as lumps and masses in the residual clays of the Watauga shale and the Shady limestone, and are most plentiful in the vicinity of Mountain City. Ores of the Watauga shale are siliceous, and present all grades between pure limonite and pure chert. Masses in this formation attain a diameter of 6 feet. As a rule they are not available on account of the silica, and only within 2 or 3 miles of Shoun Crossroads have they been found sufficiently pure to be used. Ores of the Shady limestone are usually very pure and were worked in the old forges for many years. The deposits form two classes, masses scattered irregularly through the residual clay, and ores lying along fault planes. The latter usually contain considerable silica in the form of sand grains and fragments of Erwin quartzite, and they grade from good ore through ferruginous breccias into ordinary siliceous and calcareous fault breccias. The deposits in clay are very pure and have received the greatest development. Like all deposits of this nature, the amount of ore in the clay varies much; in this region, however, the ore lumps are distributed with unusual frequency and regularity. The lumps attain a size as great as 2 and 3 feet, and the deposits have been tested to a depth of 50 feet. The richest and most frequent deposits are found in the lower part of the limestone, near its junction with the Erwin quartzite. Considerable pyrite is found in the upper layers of the quartzite and may be the source of much of the iron. The deposits of ore occupy the synclinal basins, for the most part, and may be due to downward concentration toward the bottoms of the folds. This correspondence of structure and ore deposits is most striking in Shady Valley, just north of the Cranberry quadrangle.

Silver and lead.—At the north foot of Beech Mountain, on the waters of Buckeye Creek, galenite has been found in a few localities. It contains, besides the lead, a small percentage of silver and is associated with pyrite and quartz. These occupy small gash veins in a greenish schist which appears to be produced by the metamorphism of diabase, or similar rock. This occurs in the form of a dike cutting the granitic rocks and much metamorphosed. Only a small amount of the ore has been taken out, and the extent of the deposits is consequently unknown.

Copper.—Copper-bearing minerals are found at many localities in the Roan gneiss. The ore consists of pyrite and chalcopyrite, and occurs in grains disseminated through the body of the rock. At three places on the flanks of Elk Knob, Watauga County, considerable openings have been made and the copper sulphide has been found in sufficient amount to constitute an ore. The inaccessible location and medium grade of the ore have not encouraged development.

Gold.—This metal occurs in two forms of deposit in this region, in quartz ledges and in stream deposits. On the north side of Grandfather Mountain quartz veins containing pyrite with associated gold have been opened and considerable ore has been taken out. Analyses show a high percentage of gold, but it is not certain that sufficient material has been exposed to insure an average analysis. The quartz veins, which are situated in the black slate of the Hampton formation, strike nearly north and south, and dip nearly vertically. The principal vein is 8 feet thick, and several smaller ones with parallel strikes lie near at hand. At several other points in the vicinity along the strike gold-bearing quartz occurs, and the quantity of ore appears to be considerable. Southward and southeastward from this locality, on the opposite side of Grandfather Mountain, quartz veins with gold-bearing sulphides are found at many points. They have been opened up at two places, but the developments are small and the amount of ore is uncertain.

Along the southern slope of Grandfather Mountain gold is found in the stream gravels associated with one of the plateaus at 2650 to 2700 feet elevation. Gold is obtained in fair quantities by washing, and appears to have been concentrated from the waste of fissure veins corresponding to those on the north side of the mountain. During one period of surface reduction a series of open coves was formed above a barrier of hard granite, and the slacking of the grade deposited the gold and gravels. Although washing has been carried on recently only at Gragg, and there in an irregular fashion, dependent on the supply of water, gravels in similar situations for 2 miles eastward have produced gold. As the streams depositing the gravels and gold head more than 2 miles apart, the range of the gold-bearing veins is seen to be considerable. The thickness of the gravels is not well exposed, but it probably ranges from 3 to 15 feet. Gold-bearing gravels are found on Howard Creek, north of Boone, in a similar position with reference to a plateau, but about 900 feet higher. At many other localities, also, auriferous gravels are reported, and, indeed, might be expected from the wide range of sulphide-bearing rocks.

Lime.—Few formations in this area are suitable for burning into lime, and none occur in this portion of North Carolina. Some of the beds of the Shady limestone have been so used, but as a rule the formation is too siliceous and impure. Good lime has been burned on Doe Creek 3 miles west of Mountain City, and at Rhea Forge, the product finding local use. The rock of these beds was used as a flux in the old iron forges of this region. No lime is burned for agricultural use, and the industry is but a small one.

Brick clay.—Clay suitable for brick making is abundant in certain geographic situations. Such positions are the terraces on Doe and Roane creeks and Watauga River in Tennessee, where the clays underlie the gravelly top of the terrace in depths of 10 to 20 feet; the bottoms and meadows on the upper waters of Doe and North Toe rivers, as at Cranberry and Banners Elk; the meadows and open valleys high up on the South Fork of New River; the terraces on Yadkin River below Richland, similar to those of Watauga River; and countless small deposits in hollows and bottoms throughout the quadrangle which have no systematic geographic arrangement. Little use has been made of this material except for a few buildings at Elk Park, Mountain City, and Boone, so that the value of the clays has yet to be tested. So far as can be judged from this limited use, the clays are good, and the amount of material is very great. These clays are composed almost wholly of the wash from the crystalline and igneous rocks, with a small admixture of limestone clay in Tennessee, and the materials are usually carried far and sorted well by the streams.

Timber.—All of the formations of this region are timber covered in favorable localities, and many of them bear timber of great value. Siliceous formations like the Erwin quartzite and the Unicoi formation have few large trees except in the small hollows, where oaks, chestnuts, and pines flourish. Near the Blue Ridge and other places, where the Unicoi formation contains more feldspar, the timber is much heavier.

The Roan gneiss is well covered throughout and develops large oaks, chestnuts, and poplars in the deep hollows. The Carolina gneiss carries only a scrubby growth on the ridges and does not in this region maintain heavy timber. In ravines and bottoms the hemlock, spruce, chestnut, and poplar trees attain moderate size. This is especially the case on the broad bottoms and valleys at the head of New River. The Blowing Rock gneiss and Cranberry granite have by far the best cover of timber. Good trees are found up to the tops of the ridges, and in the valleys and hollows fine bodies of timber occur. Such trees as oak, chestnut, buckeye, linn, poplar, spruce, hemlock, pine, and walnut make up the bulk of the timber, the last occurring south of the Blue Ridge. The best timber lies on the headwaters of Linville, North Toe, Doe, and Watauga rivers and in the deep coves and ravines on the south side of the Blue Ridge. Only near the largest streams, around Cranberry and on the lower Watauga drainage, have logs been cut for export; elsewhere trees have been cut for local use and to clear the land. Walnut trees have been for the most part taken out, but, as a whole, clearing in the valuable forests has been little more than begun.

Water power.—Few regions possess more abundant water power than this. A glance at the topographic map shows that the streams, except those in the limestone valleys in Tennessee, have very rapid falls, and even the largest rivers can be profitably dammed at nearly any part of their courses. Falls of good height and very frequent occurrence are formed by the Roan gneiss on the drainage of North Toe River, and by the Cranberry granite on Doe and Watauga rivers and North Fork of New River. In the district south of the Blue Ridge good-sized falls are caused by all the Cranberry granite, Unicoi formation, and Carolina gneiss bodies, and at its head every stream has an enormous fall, regardless of the formation underlying. The streams of this region are fed by multitudes of springs, and the supply of water is great, because the height of the plateau district causes an unusually heavy rainfall. The virgin state of the forests also aids materially in maintaining and regulating the outflow.

January, 1903.

Names of sedimentary formations in the Cranberry quadrangle.

Arthur Keith: Knoxville Folio, U. S. Geological Survey, 1895.	Names and Symbols used in this Folio.		M. R. Campbell: Bristol Folio, U. S. Geological Survey, 1899.	Safford: Geology of Tennessee, 1869.
Rome formation.	Watauga shale.	€w	Russell formation.	Knox group.
Beaver limestone.				
Apison shale.				
	Shady limestone.	€sh		
Hesse sandstone.	Erwin quartzite.	€e		Chilhowee sandstone.
Murray shale.				
Nebo sandstone.				
Nichols shale.	Hampton shale.	€ht	Hampton shale.	
Cochran conglomerate.	Unicoi formation.	€u	Unicoi sandstone.	

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

TOPOGRAPHIC SHEET

NORTH CAROLINA - TENNESSEE
CRANBERRY QUADRANGLE

H.M. Wilson, Geographer in charge.
Triangulation by W.C. Kerr and S.S. Gannett.
Topography by Hersey Munroe, W.L. Miller and Albert Pike.
Surveyed in 1892 and 1897.

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 Aug 1902.

LEGEND

RELIEF *(printed in brown)*

5029 Figures *(showing heights above mean sea level instrumentally determined)*

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

DRAINAGE *(printed in blue)*

Streams

Intermittent streams

Lakes and ponds

Springs

CULTURE *(printed in black)*

Roads and buildings

Private and secondary roads

Trails

Railroads

State lines

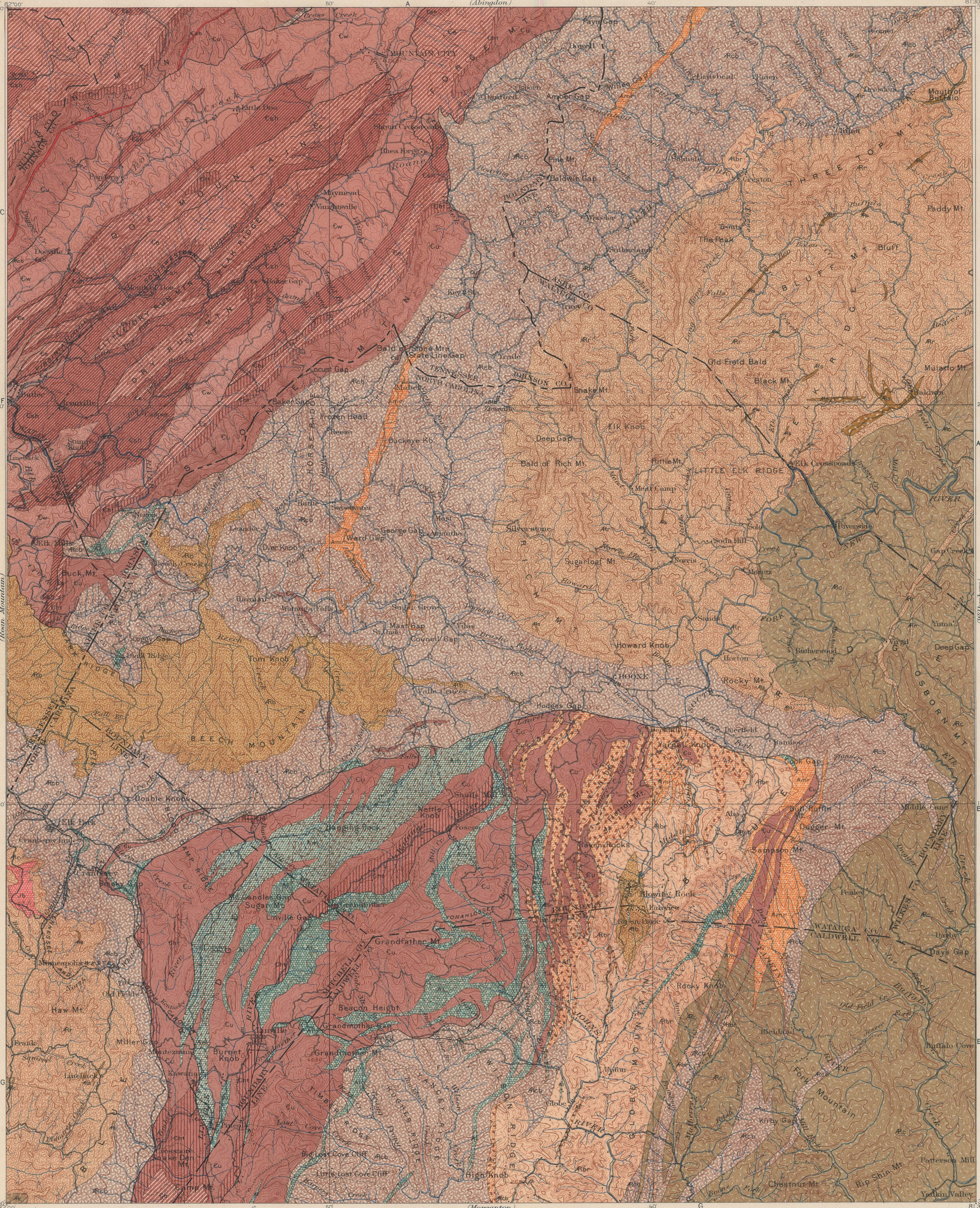
County lines

Triangulation stations

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

AREAL GEOLOGY SHEET

NORTH CAROLINA - TENNESSEE
CRANBERRY QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines)

CAMBRIAN

- Ꞓw — Watauga shale *(purple, reddish, and yellow shales with sandstone and limestone beds)*
- Ꞓsh — Shady limestone *(grayish limestone with chert)*
- Ꞓe — Erwin quartzite *(white quartzite and sandstone)*
- Ꞓht — Hampton shale *(bluish and gray shale with thin sandstones)*
- Ꞓu — Unicoi formation *(white sandstone and quartzite with shale and conglomerate, and a bed of amygdaloidal basalt)*

IGNEOUS ROCKS

(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Metamorphism is indicated by hachures.)

JURATRIAS

- Jb — Bakersville gabbro *(massive gabbro and diabase)*

CAMBRIAN

- Ꞓab — Amygdaloidal basalt *(lava bed interstratified in the Unicoi formation)*

ALGONKIAN?

- Amr — Metarhyolite *(grayish metarhyolite and rhyolite-porphyry)*
- Af — Flattop schist *(gray and black schist, probably altered andesitic rocks)*
- Am — Montezuma schist *(blue and green epidotic schist, probably altered basalt, and amygdaloidal basalt)*
- Al — Linville metadiabase *(altered greenish diabase and gabbro)*

ANCIENT CRYSTALLINE ROCKS

(Areas of Archean rocks are shown by patterns of short dashes.)

ARCHEAN

Igneous origin

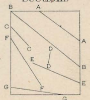
- Ꞓb — Beech granite *(coarse or porphyritic granite, light-reddish in color)*
- Ꞓbr — Blowing Rock gneiss *(chiefly dark, coarse, porphyritic gneiss)*
- Ꞓcb — Cranberry granite *(mainly granite and granite gneiss)*
- Ꞓs — Soapstone *(with peridotite and pyroxenite more or less altered)*
- Ꞓr — Roan gneiss *(chiefly hornblende-gneiss and diorite)*

Unknown origin

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

Faults

Sections



H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr and S. S. Gannett.
Topography by Hersey Munroe, W. L. Miller, and Albert Pike.
Surveyed in 1892 and 1897.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1902

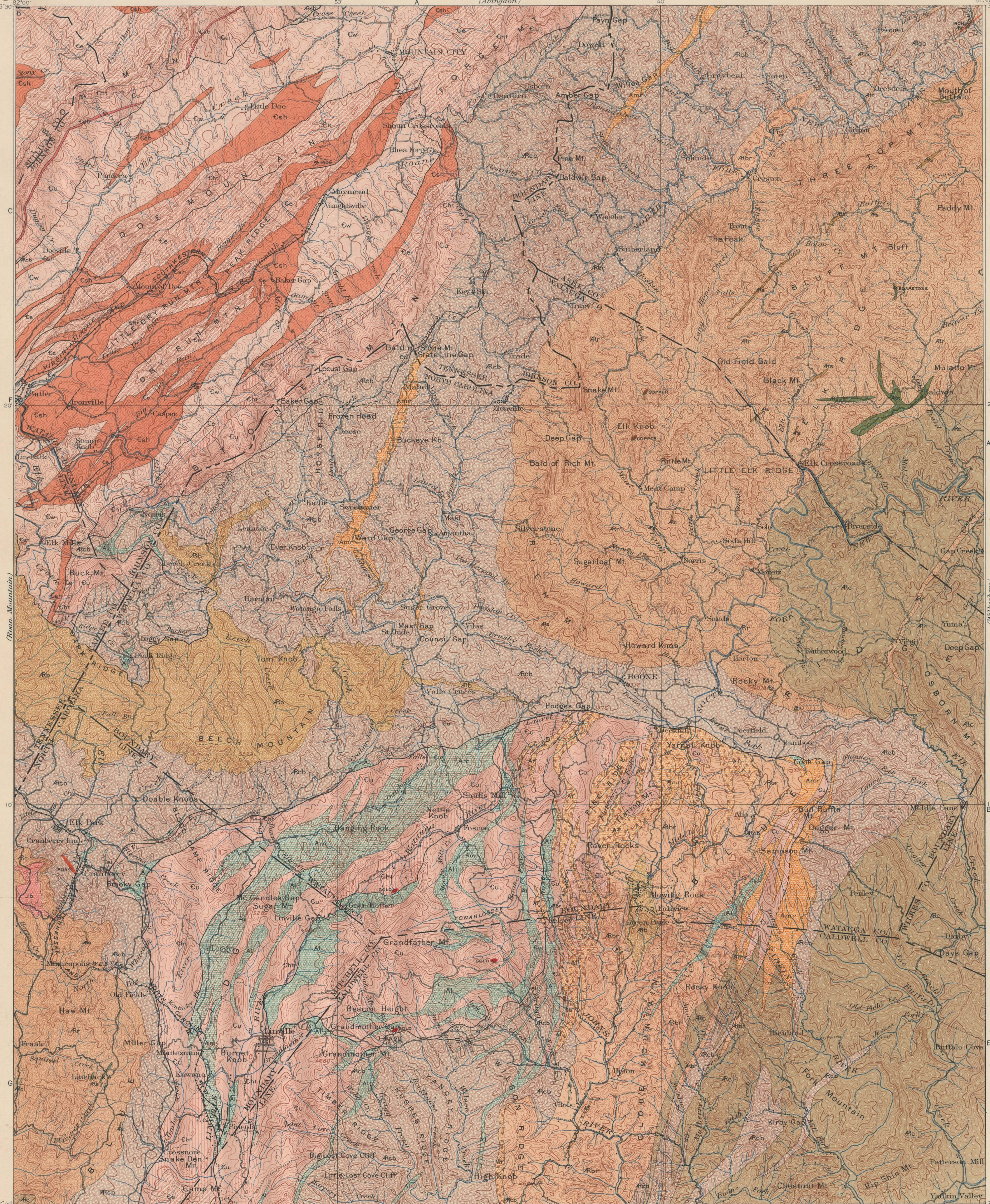
Scale $\frac{1}{125000}$
1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometers
Contour interval 100 feet.
Datum is mean sea level.
Edition of Oct. 1902.

Geology by Arthur Keith.
Assisted by H. B. Goodrich.
Surveyed in 1894, 96, 97, and 1900.

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

ECONOMIC GEOLOGY SHEET

NORTH CAROLINA - TENNESSEE
CRANBERRY QUADRANGLE



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TRUE NORTH
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Surveyed in 1894, 96, 97, and 1900.

LEGEND
(continued)

Known productive formations

Soapstone

Ꞓsh *Limonite* *(residual clay of Shady limestone contains irregular deposits of limonite or "brown hematite")*

Magnetite

Copper

Gold

LEGEND

SEDIMENTARY ROCKS
(Areas of Sedimentary rocks are shown by patterns of parallel lines)

CAMBRIAN

- Ꞓw — Watauga shale *(purple, reddish, and yellow shales with sandstone and limestone beds)*
- Ꞓsh — Shady limestone *(grayish limestone with chert)*
- Ꞓe — Erwin quartzite *(white quartzite and sandstone)*
- Ꞓht — Hampton shale *(bluish and gray shale with thin sandstones)*
- Ꞓu — Unicoi formation *(white sandstone and quartzite with shale and conglomerate, and a bed of amygdaloidal basalt)*

IGNEOUS ROCKS
(Areas of Igneous rocks are shown by patterns of triangles and rhombs. Metamorphism is indicated by hachures.)

JURATRIAS

- Jb — Bakersville gabbro *(massive gabbro and diabase)*

CAMBRIAN

- Ꞓab — Amygdaloidal basalt *(lava bed interstratified in the Unicoi formation)*

ALGONKIAN?

- Amr — Metarhyolite *(grayish metarhyolite and rhyolite-porphyry)*
- Af — Flattop schist *(gray and black schist, probably altered andesitic rocks)*
- Am — Montezuma schist *(blue and green epidotic schist, probably altered basalt, and amygdaloidal basalt)*
- Al — Linville metadiabase *(altered greenish diabase and gabbro)*

ANCIENT CRYSTALLINE ROCKS
(Areas of Archean rocks are shown by patterns of short dashes.)

ARCHEAN

Igneous origin

- ᴁb — Beech granite *(coarse or porphyritic granite, light-reddish in color)*
- ᴁbr — Blowing Rock gneiss *(chiefly dark, coarse, porphyritic gneiss)*
- ᴁcb — Cranberry granite *(mainly granite and granite gneiss)*
- ᴁs — Soapstone *(with peridotite and pyroxenite more or less altered)*
- ᴁr — Roan gneiss *(chiefly hornblende-gneiss and diorite)*

Unknown origin

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

Faults

⚒ Mines and quarries
X Prospects

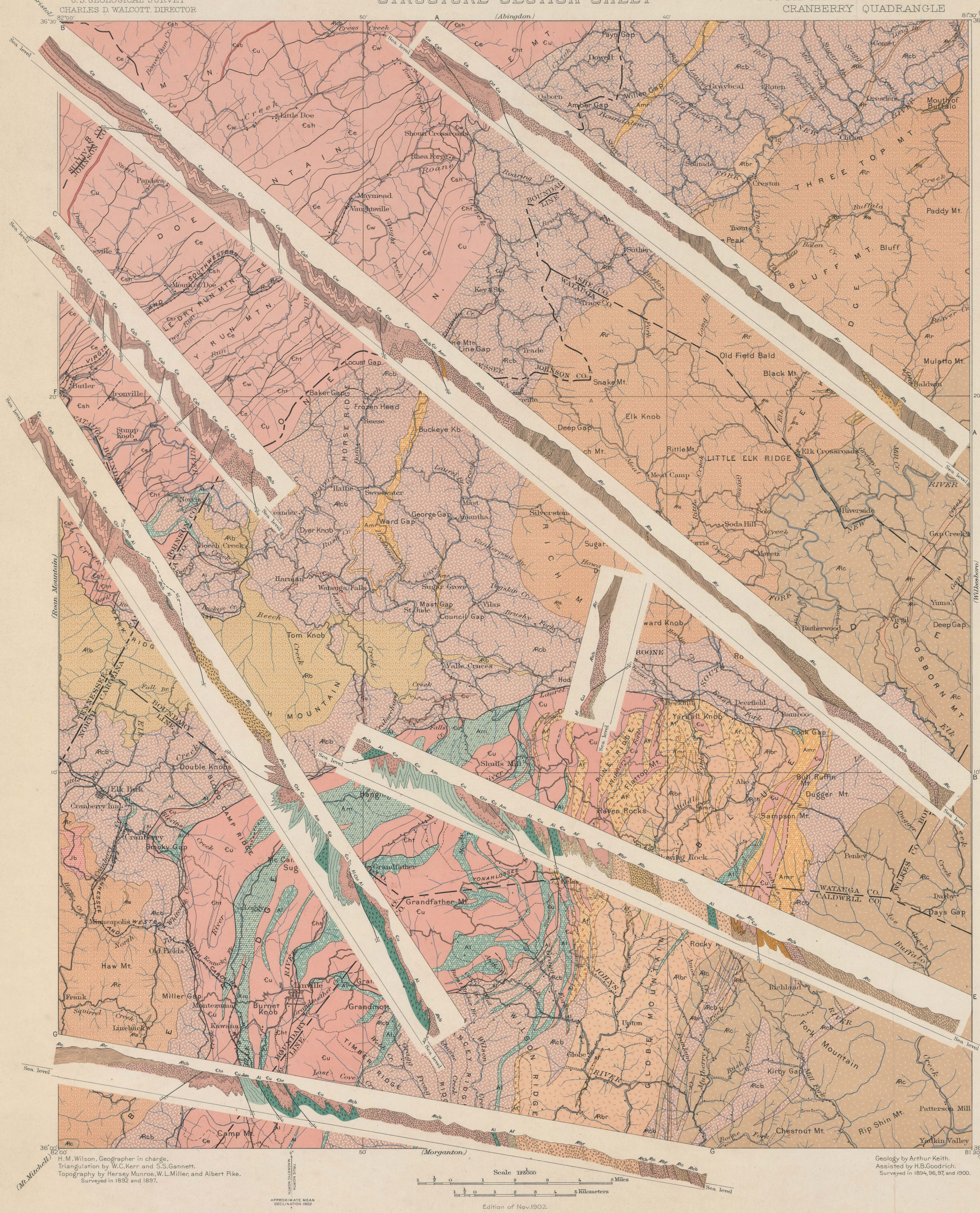
Sections

Legend is continued on the left margin.

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

STRUCTURE-SECTION SHEET

NORTH CAROLINA - TENNESSEE
CRANBERRY QUADRANGLE



H. M. Wilson, Geographer in charge.
Triangulation by W. C. Kerr and S. S. Gannett.
Topography by Hersey Munroe, W. L. Miller, and Albert Pike.
Surveyed in 1892 and 1897.

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

Edition of Nov. 1902.

Geology by Arthur Keith.
Assisted by H. B. Goodrich.
Surveyed in 1894, 96, 97, and 1900.

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL / SECTION SYMBOL

CAMBRIAN

- Єw — **Watauga shale** *(purple, reddish, and yellow shales with sandstone and limestone beds)*
- Єsh — **Shady limestone** *(grayish limestone with chert)*
- Єe — **Erwin quartzite** *(white quartzite and sandstone)*
- Єht — **Hampton shale** *(bluish and gray shale with thin sandstones)*
- Єu — **Unicoi formation** *(white sandstone and quartzite with shale and conglomerate, and a bed of amygdaloidal basalt)*

IGNEOUS ROCKS

SHEET SYMBOL / SECTION SYMBOL

JURATRIAS

- Jb — **Bakersville gabbro** *(massive gabbro and diabase)*

CAMBRIAN

- Єab — **Amygdaloidal basalt** *(lava bed interstratified in the Unicoi formation)*

ALGONKIAN ?

- Amr — **Metarhyolite** *(grayish metarhyolite and rhyolite-porphyry)*
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- Al — **Linville metadiabase** *(altered greenish diabase and gabbro)*

ANCIENT CRYSTALLINE ROCKS

SHEET SYMBOL / SECTION SYMBOL

ARCHEAN

Igneous origin

- ARb — **Beech granite** *(coarse or porphyritic granite, light-reddish in color)*
- ARbr — **Blowing Rock gneiss** *(chiefly dark, coarse, porphyritic gneiss)*
- ARcb — **Cranberry granite** *(mainly granite and granite gneiss)*
- ARs — **Soapstone** *(with peridotite and pyroxenite more or less altered)*
- ARr — **Roan gneiss** *(chiefly hornblende gneiss and diorite)*

Unknown origin

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

Faults

COLUMNAR SECTION SHEET

GENERALIZED SECTION OF THE SEDIMENTARY ROCKS OF THE CRANBERRY QUADRANGLE.

SCALE: 1 INCH = 1000 FEET.

Period.	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.	Mountains with sharp crests and steep, rocky slopes and cliffs. Thin, sandy soil.
	Hampton shale.	€ht		600–800	Bluish-gray and gray argillaceous and sandy shales, with thin sandstone layers.	Narrow depressions and valleys between quartzite mountains. Thin, sandy clay soil.
	Unicoi formation. Amygdaloidal basalt.	€n €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.
	UNCONFORMITY.					
PRE-CAMBRIAN	Gneisses, granites, and ancient volcanic rocks.				Descriptions given in table below.	Descriptions given in table below.

GENERALIZED TABLE OF THE IGNEOUS AND ANCIENT CRYSTALLINE ROCKS OF THE CRANBERRY QUADRANGLE, ARRANGED ACCORDING TO AGE.

SCALE: 1 INCH = 1000 FEET.

Period.	Formation Name.	Symbol.	Lithologic Symbol.	Character of Rocks.	Character of Topography and Soil.
JURA-TRIAS	Bakersville gabbro.	Jb		Massive black and brown gabbro and diabase dikes and sheets.	Smalls knobs and buttes, with many rock exposures. Yellow and brown clay soils.
ALGONKIAN	Metarhyolite.	Amr		Bluish- and blackish-gray rhyolite-porphyry and banded metarhyolite, schistose and massive.	Low ground and irregular knobs. Red and brown clay soils.
	Flattop schist.	Af		Bluish- and greenish-gray and black banded and porphyritic schists.	High, irregular ridges and rounded mountains. Deep, red and brown clay soils.
	Montezuma schist.	Am		Bluish-green and green epidotic and chloritic schists, with large masses of epidote and beds of amygdaloid.	High ridges and mountains with round tops and in places cliffs and sharp crests. Deep, red clay soil containing epidote bowlders.
	Linville metadiabase.	Al		Coarse, green metadiabase and metagabbro, schistose and massive.	Valleys and small depressions. Brown clay soil.
ARCHEAN	Beech granite.	Æb		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.
	Blowing Rock gneiss.	Æbr		Coarse, porphyritic biotite-gneiss and granite-gneiss, with interbedded, fine, schistose granite and mica-schist; color dark gray and black.	Mountains and high ground, with rounded summits and many large ledges and cliffs. Brown sandy and clayey soils.
	Cranberry granite.	Æcb		Biotite-granite and granite-gneiss, coarse and fine, with a little hornblende-granite; colors light gray, dark gray, or red. Includes many dikes of schistose and unaltered diabase and metarhyolite.	Mountains and high ground, with irregular divides and rounded, uneven surfaces. Red, yellow, and brown sandy and clayey soils.
	Soapstone.	Æs		Soapstone, often containing much hornblende and tremolite, and a little serpentine and dunite.	Small knolls covered with ledges and bowlders. Thin, yellow clay soil.
	Roan gneiss.	Ær		Hornblende-gneiss and -schist, with much massive and schistose diorite, in places porphyritic. Includes many beds of mica-gneiss and -schist, dikes of diabase, and a little gneissoid granite.	High mountains and ridges, with broad, round summits, steep slopes, and a few rocky crests. Deep, red and brown clay soils containing many rock fragments.
	Carolina gneiss.	Æc		Interbedded mica-gneiss and mica-schist, coarse and fine, bluish gray, gray, and white, containing many beds of fine granitoid gneiss, schistose granite, hornblende-granite, diorite, hornblende-gneiss, and garnet-schist.	Mountains and ridges, with steep slopes and rounded surfaces. Thin, sandy and micaceous soils.

ARTHUR KEITH,
Geologist.

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