GEORGIA

STATE DIVISION OF CONSERVATION

DEPARTMENT OF MINES, MINING AND GEOLOGY

GARLAND PEYTON, Director

THE GEOLOGICAL SURVEY

Bulletin Number 58

GEOLOGY OF THE CRYSTALLINE ROCKS OF GEORGIA

By

Geoffrey W. Crickmay

ATLANTA

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Southern end of the Blue Ridge Mountains in Pickens County, Georgia

LETTER OF TRANSMITTAL

Department of Mines, Mining and Geology

Atlanta, December 19, 1951

To His Excellency, Herman E. Talmadge, Governor
Commissioner Ex-Officio of State Division of Conservation

Sir:

I have the honor to submit herewith Georgia Geological Survey Bulletin No. 58, "Geology of the Crystalline Rocks of Georgia," by Dr. Geoffrey W. Crickmay, a former Assistant State Geologist of Georgia. The report embodies the results of research extending, more or less on an intermittent basis, over a period of seven years.

The publication of this bulletin at this time fills a long-felt need for a descriptive treatise upon the crystalline rocks portrayed in color on the 1939 edition of the geologic map of Georgia.

The original plan to publish this manuscript in 1940 was abandoned due to lack of funds. The absence of the author on military or other assignment outside the United States during most of the intervening years has rendered impracticable the submission of the report in publishable form until just recently.

This report will be of most service where used in conjunction with the state geologic map of 1939. It contains much basic descriptive information of value to petrologists, structural geologists and mining geologists. It is our belief that the publication of this excellent report at this time will serve to stimulate further research upon the structure, stratigraphy, petrology and geologic age of our crystalline rocks.

Very respectfully yours,

Garland Peyton

GARLAND PEYTON
Director

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GEOLOGY
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CRYSTALLINE ROCKS OF GEORGIA

Geoffrey W. Crickmay

INTRODUCTION

GENERAL STATEMENT

The crystalline rocks of Georgia occupy the piedmont, upland, and highland provinces, and underlie about one third of the state. Their distribution is shown on the state geologic map, prepared by the Georgia Division of Mines, Mining, and Geology, with the cooperation of the U. S. Geological Survey. The character of some of these rocks has received description in special reports, particularly those by LaForge and Phalen (1913), Bayley (1928), Hopkins (1914), Shearer and Hull (1918), and Galpin (1915). This paper offers a general description, particularly of newly recognized units, but it is necessarily brief.

The writer has spent about twenty months in field work preparing the map of the crystalline rocks, thus covering about 250 square miles a week. The map therefore does not represent a finished product, but rather a summary and a synthesis of information previously published in the bulletins of the State Geological Survey. The writer extends thanks to Dr. G. W. Stose of the U. S. Geological Survey who has made pertinent suggestions as editor of the state geologic map, and has offered a stimulating discussion of the problems of the crystalline rocks as a visitor in the field. The late Dr. W. S. Bayley gave the writer a helpful introduction to the region during a month of field work in 1930.

Mineral Resources

The Crystalline area contains the greatest variety of minerals and offers the greatest opportunity for discovery of new minerals. In 1947, a production of $11,694,242, well divided between minerals of igneous and sedimentary origin, comprised 30 per cent of the total mineral production. "The igneous minerals and rocks including granite, sheet mica, ground mica, feldspar, serpentine, asbestos, and gold, are valued at a total production of $5,190,190, and sedimentary minerals and rocks (metasediments), including marble, talc, kyanite, ground mica, sand and gravel, and clay products, are valued at $6,505,052. Of this total production for crystalline rocks, marble and granite together are valued at $8,429,691. Increased need for crushed stone has greatly increased the value of the granite industry in recent years. The economic resources of this district are characterized by the almost unlimited supply of granite and marble, for which we may expect a steadily increasing demand in the future." (Furcron, 1950)

Granite is the leading mineral resource of the district, and production is rather evenly divided between dimension stone and crushed rock. The monumental industry is centered around Elberton, and there are four large quarries for crushed stone in the State located at Tyrone, Camak, Lithonia, and Stockbridge. Marble produced as dimension and monumental stone comprises the second greatest mineral industry in the district, coming from the vicinity of Tate and Marble Hill in Pickens County. Talc, ground for fillers and cut into pencils, is obtained from Fort and Cohutta mountains in Murray county. Sheet mica is produced from many districts in the crystalline area, and mica suitable for grinding is produced at Hartwell in Hart County. The kyanite-mica schists of Rabun and Habersham counties represent another source of ground mica, and large deposits of kyanite in that section have been worked commercially for many years. Chlorite and sericite mined in Pickens and Cherokee counties are ground and sold as fillers. Feldspar is ground at Monticello in Jasper County. White dolomite is quarried and crushed for agricultural uses and other purposes at Whitestone in Gilmer County. Flagstone is produced in a small way from numerous localities, but especially from the region around Jasper in Pickens County. A serpentine deposit in Columbia County has been used to a limited extent for the manufacture of magnesium sulphate. Numerous other minerals produced in small amounts are asbestos, gold, graphite, manganese, olivine, pyrite, vermiculite, etc.

Historical Summary

The first geologic map of Georgia, prepared by George White (1849), referred to the crystalline rocks as "Primary", a name previously applied to them by Cotting (1836). The "primary" region, according to White, consists of an eastern area made up of coarse-grained, massive rocks, and a western area, bordering the Appalachian Valley, underlain by fine-grained, well-laminated rocks. King (1894) followed this dual classification, calling the former "holocrystalline" and early pre-Cambrian, and the latter "semi-crystalline" and late pre-Cambrian. Following a correlation previously made by Smith (1878) in Alabama and Elliott (1883) in Georgia, King regarded the "semi-crystalline" rocks as equivalent to the Ocoee Group (Safford, 1856) of southeastern Tennessee. Keith (1904) later concluded the age of the Ocoee series to be early Cambrian, and thus the "semi-crystalline" rocks came to be classed as "metamorphosed Paleozoics". The "holocrystalline" group, regarded by Keith as pre-Cambrian, is made up mainly of two broad units, Carolina gneiss and Roan gneiss.

These general conclusions have been followed in Georgia by LaForge and Phalen (1913), Bayley (1928), and others, but they have frequently resulted in a classification that is artificial and arbitrary, as expressed in the following statement by O. B. Hopkins (1914, p. 9). "Some parts of the (holocrystalline) series resemble some of the metamorphosed Paleozoic rocks (semi-crystalline) to such an extent that they are practically indistinguishable in themselves but may be recognized by the presence of ancient intrusive rocks. This close resemblance, the fact that one type grades into the other, . . . demonstrate conclusively that a part of this (holocrystalline) series is sedimentary in origin and not far different in age from the metamorphosed Paleozoic rocks to the west."

The writer believes that all the sedimentary metamorphic rocks, including the inaptly named semi-crystalline types, are of the same general age and most probably are pre-Cambrian (Crickmay, 1936).

PURPOSE

The aim of a geological map is to give a clear and understandable picture of the geology and structure of the State. Its purpose is three-fold; economic, educational, and scientific. It outlines the location and extent of valuable rocks, such as marble, granite, and clays; it shows the distribution of formations known to contain mineral deposits, such as the ore-bearing belts; it indicates the relation of these deposits to topography, transportation facilities, and centers of population; in short, it offers a general view of the geological relations that should serve as an indispensable guide to the successful development of the State's mineral resources. To agriculture it offers a general map of the residual soils, as expressed by such terms as "limestone soil", "sand soil", and "granite soil". In other fields the map will also find application, its use depending largely on the interpretation of the data to special problems.

To the public schools, colleges, and universities of the State, this volume should serve as a companion to Bulletin 23, "Mineral Resources of Georgia", and Bulletin 42, "Physical Geography of Georgia". It embraces a field of which these earlier bulletins are special phases; it includes general information from many other bulletins of the Geological Survey; and it contains a foundation upon which to base future geological studies. The description of the geology is of necessity expressed in scientific language, which in part will be unfamiliar to the general reader, and no attempt has been made to popularize the subject. The volume represents a serious geological study, economic in its scope, and scientific in its treatment, thus any popular value it may possess is entirely incidental to its main purpose.

The scientific aspect of the geology of the State is an important but less practical consideration, and has consequently been subordinated in this report. A number of papers dealing with certain phases of the geology have been published in scientific journals and these are referred to by foot-note. In the course of the descriptions which follow it will be necessary to consider, however, the origin, age, structure, and interrelation of formations, particularly in such cases where ambiguity and misconceptions now exist. There are many problems to which it is not yet possible to give a complete or satisfactory answer for much is yet to be learned by future workers, particularly by those who study detailed or special problems. This report does not pretend to be a final dictum on the geology of this part of the State, but rather a general summary of existing knowledge which may serve as a basis for future advances.

STRATIGRAPHY

METAMORPHIC BELTS

Establishment of stratigraphic sequence among the crystalline rocks is beset with three main difficulties; the lack of distinctive horizons, extensive metamorphism, and very complex structures. Metamorphism may locally so dominate lithology that, without very detailed work, it is frequently impossible to decide whether or not a unit has any stratigraphic significance. The metamorphic rocks occupy northeast-trending belts, some of which are separated by strike faults of unknown displacement, and thus correlation between different belts can not be made with any assurance. For convenience of description, therefore, the crystalline rocks are here grouped into eleven belts, in part using names first proposed by Adams (1933). This scheme of classification has the practical advantage of bringing out the broader relations and subordinating the confusing complications of local detail. It is a method of generalization that obviates the necessity of introducing a multitude of new formation names. The recognized belts are shown in figure 1, and herewith briefly described.

Talladega belt: borders the area of Paleozoic rocks; is composed mainly of slate, mica schist, bedded biotite gneiss, quartzite, and marble of the Talladega series with intrusions of granite.

Amicalola belt: makes up the main mass of the Blue Ridge in Georgia; composed of the Carolina series with many intrusions of both basic and acid gneisses.

Wedowee-Ashland belt: is the Dahlonega gold belt; it consists mainly of fine-grained schists of the Wedowee, Ashland, and Canton formations.

Tallulah belt: like the Amicalola belt, is composed of the Carolina series but igneous gneisses are more abundant.

Brevard belt: lithologically similar to the Wedowee-Ashland belt; includes schists, fine-grained gneisses and marble.

Dadeville belt: essentially a repetition of the rocks of the Tallulah belt but dominated by very extensive intrusives of granite.

Wacoochee belt: very similar to the Brevard sequence; in western part of the State it includes the Hollis quartzite forming Pine Mountain.

Uchee belt: occupied by the Carolina series, with extensive intrusives. No detailed mapping of these rocks has been attempted.

Little River belt: occupied by slates, phyllites, schists, vol-

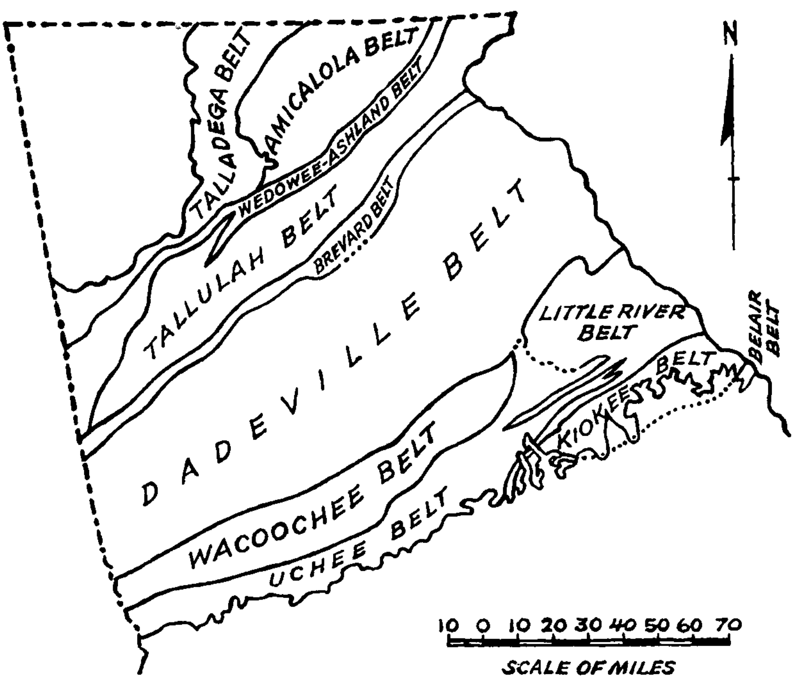

Fig. 1. Metamorphic Belts of Georgia

canics of the Little River series. This, with the Belair belt, is the southeastern termination of the Carolina slate belt.

Kiokee belt: is little known geologically but appears to be similar to the Uchee belt and possibly continuous with it, contains coarse-grained schists and gneisses of the Carolina series with many granite intrusives.

Belair belt: an exact replica of the Little River belt that can be traced only where rivers have stripped away the Coastal plain cover

CAROLINA SERIES

Definition.—The Carolina gneiss was defined by A. Keith (1901-1903) to include "an immense series of interbedded mica schists, mica gneiss, and fine-granitoid layers" exposed over a wide area in North and South Carolina. The gneiss has been identified in Georgia in the Dahlonega area (Jones, 1909), on the Ellijay (LaForge and Phalen, 1913), and Tate (Bayley, 1928) quadrangles, and in many other sections (Galpin, 1915) where detailed mapping has not been done. Because it contains rocks of diverse lithology, many of which cannot be termed gneiss, a series designation is here adopted

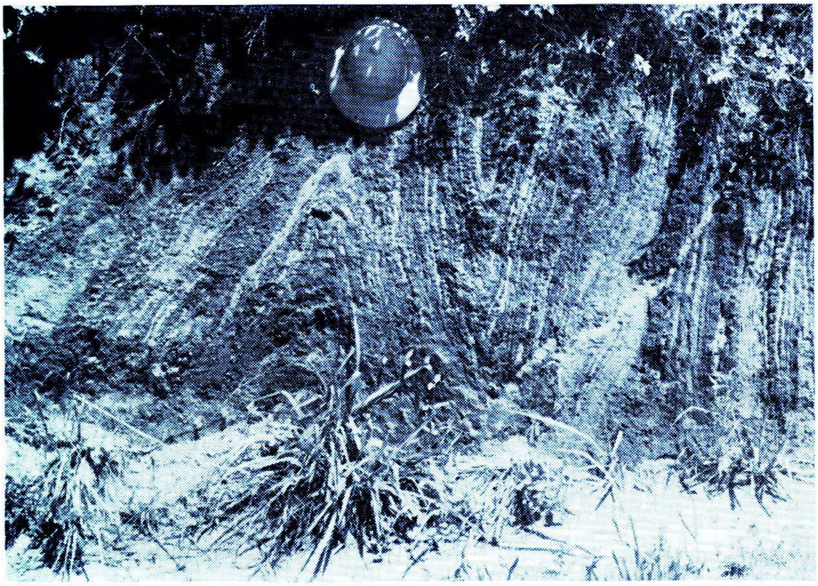

Fig. 2. Crumpled schist in the Carolina series with thin (light colored) injections of granite; exposure near Covington.

The Carolina series in Georgia includes rocks of three distinct facies, gneiss facies, schist facies, and cataclastic facies.

Gneiss Facies.—The most widespread expression of the series is fine- to coarse-grained biotite gneiss with layers of mica schist and massive quartzite. Fine-grained biotite gneiss, sometimes called greywacke, commonly occurs in flagstone beds eight inches or less in thickness, separated by thinner interbeds of mica schist. This interlayering is believed to indicate bedding, parallel to which a strong foliation has been developed. All variations can be found from such markedly layered rocks to massive granitoid gneiss in which all signs of bedding are obscured. The granitoid rocks are coarse-grained and give the superficial appearance of being older than the fine-grained rocks, but at some localities (Black Rock Mountain, Rabun County) the two types are interlayered. The coarser-grained gneisses lack the close parallel alignment of dark minerals, characteristic of the finer grained rocks, but generally show a strong banding of segregated minerals, emphasized in many places by innumerable thin injections of granite and pegmatite.

The mineralogy of the gneiss ranges from very quartzose varieties to highly micaceous types. Plagioclase (oligoclase to andesine) is generally present and commonly has a strong tendency to form porphyroblasts around which the other minerals are streaked in curving lines. Garnet is common but

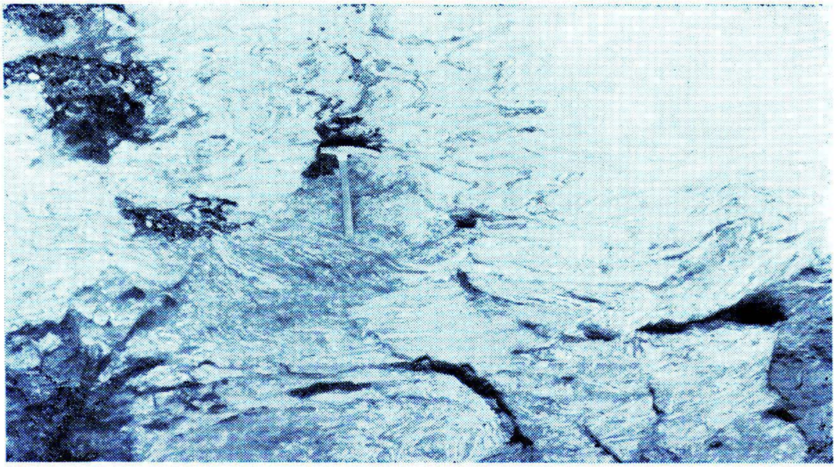

Fig. 3. Strongly foliated gneiss with injections of granite; exposure in Athens, Clarke County.

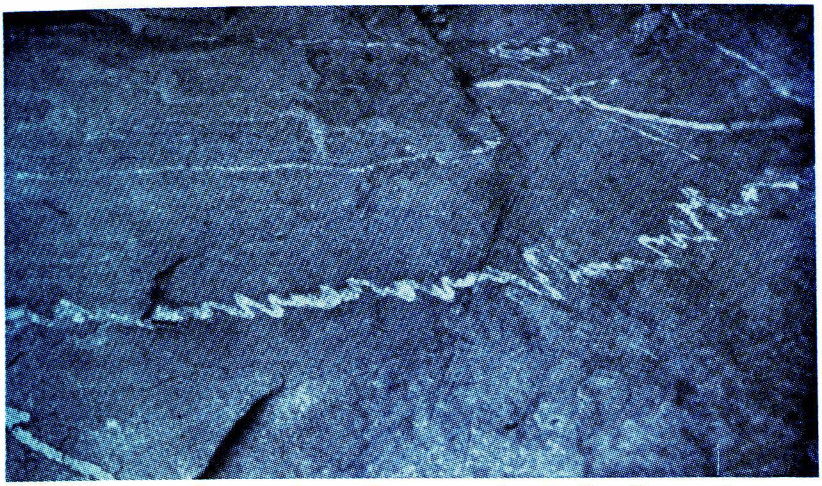

Fig. 4. Contorted pegmatite and quartz veins in Carolina gneiss, near Rudicil Mill, 4 miles south of Orange, Cherokee county.

only locally conspicuous (Woody Gap, Lumpkin County) An unusual gneiss in the Tate district is described by Bayley (1928) as a spangled gneiss because it contains unoriented biotite crystals a quarter of an inch in diameter A very similar gneiss occurs in the Ellijay district, east of Cherry Log (LaForge and Phalen, 1913)

Quartzite is abundant in the gneiss facies of the Tallulah belt, where it forms Sawnee Mountain, Forsyth County, Sweat and Black Jack mountains, Cobb County, and several ridges extending from northern Hall County, through Forsyth and Fulton Counties, into Douglas County A similar quartzite occupies the central part of a broad anticlinal area in Habersham and Rabun counties, named Tallulah Falls quartzite by Galpin (1915, p. 119) The upper part of the Tallulah Falls quartzite, exposed at Mathes Dam, is interlayered with garnet-biotite gneiss. The schistosity of the gneiss is essentially parallel to the bedding of the quartzite, this relation of metamorphic and sedimentary structure appears to be widespread.

No estimate can be made of the thickness of the gneiss facies, which probably makes up the lower part of the series. The gneiss facies occupies the Amicalola, Tallulah, Dadeville, Uchee, and Kiokee belts, but there is reason to believe that the series found in these belts are not exactly correlative.

Examined under the microscope, the biotite gneiss is found

Fig. 5. Tallulah Falls quartzite exposed in the gorge of Tallulah River, Rabun County.

to consist of quartz, plagioclase, (oligoclase to andesine), biotite, orthoclase, muscovite, and garnet, named in the order of their abundance. Accessory minerals observed include apatite, titanite, zircon, magnetite, zoisite, epidote, kyanite, sillimanite, hornblende, and tourmaline. The biotite is in most places a deep brown strongly-pleochroic variety, commonly spotted with pleochroic halos which surround inclusions of zircon. The plagioclase in many places has a strong tendency to form porphyroblasts around which the other minerals are streaked in curving lines. A myrmikitic inter-growth of feldspar and quartz is commonly present. Garnets are generally small and contain few inclusions. Considerable variation has been noted in the color of the garnets but accurate determinations of composition are lacking.

Mica schist differs from the gneiss mainly in containing a greater proportion of mica, which gives to the rock a strong fissility or schistosity The distinctive types of mica schist are named for their characteristic minerals such as kyanite, garnet, staurolite, graphite, and so on. The garnet in the schist is commonly in larger crystals than in the gneiss and on the cleavage surfaces forms knobs around which the mica flakes are wrapped. The schist of the gneiss facies differs from that of the schist facies in being generally coarser grained, in having less regular cleavage, and in the common preponderance of biotite over muscovite. In the Warm Springs district thin beds of schist in biotite gneiss are crowded with colorless sillimanite needles that lie in a felted aggregate parallel to the schistosity.

The alternation of schist and gneiss, with interbeds of quartzite, marks original differences in the deposition of sediments and points backwards in the history of these rocks to a time when they consisted of interstratified sands, grits, and muds. Metamorphism has brought complete reconstruction but has not entirely removed the evidence of origin. The schistosity is in most places nearly coincident with original bedding. This fact is particularly well shown where the Tallulah Falls quartzite is interbedded with biotite gneiss in Rabun County.

Distinctly conglomeratic rocks are very rare in the Carolina series. Bayley (1928) has described two localities in the Tate district where pebbles less than 4 inches in diameter occur in mica gneiss and schist. On Town Creek, Cherokee County, a conglomerate contains pebbles of granite, thus indicating the existence of granite intrusions older than the Carolina series. Unfortunately it has been impossible to trace these conglomerate beds and it is not known whether they mark a major break, or unconformity, within the series.

On Tiger Creek, at Lakemont, Rabun County, biotite gneiss contains spindle-shaped masses up to a foot and a half in length composed of quartz and garnet. The spindles are all oriented parallel to one another and oblique to the schistosity of the enclosing gneiss. It is possible that they represent pebbles that have been elongated and completely metamorphosed.

The gneiss of the Carolina series contains abundant evidence of contamination by granitic magma. The gneiss is streaked with granite layers and lenses of pegmatite. Large single feldspar crystals or several large crystals grouped in rows parallel to the schistosity with thin connecting films of granite are common in the gneiss. The injections at places are so numerous that they form more than half of the bulk of the gneiss, which thus forms a distinct lithologic type which is neither truly igneous nor truly sedimentary in origin. They are hybrid rocks known as injection gneisses that combine both sedimentary and igneous characteristics with others that are peculiar to themselves.

Injection gneisses are found in every belt where the gneiss facies of the Carolina series is present, but are most widespread in the Dadeville and Kiokee belts. They are particularly prominent near large granite intrusions. In fact, the boundaries of these intrusive masses are in most places not sharp lines but gradational zones, separating areas in which granite predominates from areas in which biotite gneiss predominates.

The following are analyses of rocks from the gneiss facies of the Carolina series:

Chemical Analyses of Quartzite and Gneiss from Carolina Series

	1	2	3	4	5
SiO_2	77.86	69.40	73.40	83.66	73.76
Al_2O_3	12.23	18.76	13.10	9.40	14.52
Fe_2O_3	.23	3.53	} 4.60	1.39	} 1.03
FeO	2.25	2.33		1.25	
MgO	tr.	.04	1.70	.22	.29
CaO	2.54	.00	3.50	.00	1.14
Na_2O	1.68	1.86	1.95	.67	4.16
K_2O	.70	1.68	1.15	2.33	4.63
MnO	.04	.17	.40	tr.	....
TiO_2	.80	.72	....	.54	....
S	....	....	....	....	....
SO_3	....	....	....	.00	....
P_2O_5	.27	.50	....	.05	....
H_2O+	.84	.78	....	.00	....
H_2O-	....	....	....	....	....
Total	99.44	99.77	99.80	99.84	99.53

1—Micaceous biotite gneiss, 3 miles northeast of Jasper, Pickens County. Edgar Everhart, Analyst. (Bayley, 1928, p. 22).

2—Biotite gneiss, 4 miles east of Jasper, Pickens County. Edgar Everhart, Analyst.

3—Garnet-biotite gneiss, 1½ miles north of Neel's Gap, Union County. J. S. Brogdon, Analyst (Crickmay, 1933, p. 169).

4—Quartzite, Tallulah Falls, Habersham County. Edgar Everhart, Analyst.

5—Granite gneiss, average of 12 analyses, inserted here for comparison. T. L. Watson, Analyst (Watson, 1902, p. 241).

The gneiss facies of the Carolina series is a host for many mineral deposits but the rocks themselves are of little commercial value. The mica of certain schistose layers has been altered to vermiculite (Prindle, L. M. 1935) in places, particularly near intrusions of peridotite, but no deposits of this mineral have yet been developed. Deposits of manganese (Watson, 1908) and iron oxides (Haseltine, 1924) have locally been formed by the residual decay of schists and gneisses but they are of low grade and of limited extent.

Some of the massive gneisses of the series are ideally suited for road construction and the State Highway Department has opened a few quarries to obtain rock for this purpose. Evenly layered gneiss, which occurs mainly in the Amicalola belt, has been quarried in small amounts for use as flagstone.

Schist Facies.—Mica schist with some layers of fine-grained biotite gneiss occurs in the Amicalola, Wedowee-Ashland, Tallulah, and Dadeville belts.

The Amicalola belt includes sinuous bands of muscovite-kyanite schist, commonly graphitic, in the area between Morganton, Fannin County, and Blairsville, Union County (LaForge and Phalen, 1913). There appear to be four or five distinct beds of schist distributed through a vertical range of several thousand feet. The dark-gray to steel-blue schist has silvery, crinkled cleavage surfaces with knobs of kyanite and more rarely garnet.

The Wedowee-Ashland belt is made up of the Ashland, Wedowee, and Canton schists.

Garnet-biotite schist, quartz-muscovite schist, and graphite schist exposed near Ashland, Clay County, Alabama, have been named Ashland mica schist by Prouty (1923). The typical Ashland schist is cut off in southern Cleburne County and does not extend into Georgia.

Adams (1926) has mapped a belt of Ashland schist that lies to the southeast of Clay County and extends from Elmore County through Tallapoosa and Randolph Counties, to enter Georgia in Heard County. The schist in Georgia forms a belt with a maximum width of 10 miles extending across the State in a northeasterly direction. The belt passes through Allatoona, Bartow County, Canton, Cherokee County, Dahlonega, Lumpkin County, and Burton Lake, Rabun County. In Heard, Carroll, and Haralson Counties the Ashland schist is bordered on the northeast by the Wedowee formation but further northeast along the strike the Wedowee rocks are cut off by the

Whitestone fault and the Ashland schist is in contact with the Talladega series. From Dawson County northeastward to Rabun County, the Ashland schist is bordered on the northeast by the gneiss facies of the Carolina series into which it is gradational, and consequently the geologic boundaries are placed in a more or less arbitrary position. The recognition of the Ashland schist in this section emphasizes the structural continuity of the Dahlonega gold belt (Jones, 1909).

The Ashland mica schist in Georgia is predominately a fine-grained, scaly mica schist but it also includes beds of quartzite, garnet-biotite gneiss, graphite schist, and chlorite schist. The quartzite, generally feldspathic and micaceous, occurs only as thin inconspicuous layers in the schist. An unusual type of strongly-banded quartzite composed of quartz, magnetite (or jacobsite), and garnet occurs in a bed several hundred feet thick near the Bell-Star pyrite mine in Cherokee County (Shearer and Hull, 1918, pp. 146-153).

Biotite gneiss is more abundant than surface exposures indicate for weathering has reduced the feldspathic gneiss to residual clay that is masked by the more resistant mica schist. The gneiss is similar to part of the gneiss facies of the series but in most places contains many thin layers of mica schist. The schistosity is commonly crinkled into a series of minute folds which, where tightly compressed, yield a double cleavage by the parallelism of their axial planes. This double cleavage structure is characteristic of most of the Ashland schist. Fine conglomeratic layers occur in the gneiss in Paulding and Cherokee Counties. Garnet is abundant in some layers but absent from others. Biotite, which gives to the rocks their prevailing grey color, is generally more abundant than muscovite. Microscopic examination reveals a number of minor constituents not visible in the hand specimen. Chlorite is commonly present as an alteration of biotite and garnet, and in some places gives the rocks a green cast. Calcite is present in most of the chloritic rocks. Small crystals of apatite and opaque metallic oxides are present in most thin sections.

The mica schist which makes up the greatest part of the Ashland is a silvery-grey rock composed of muscovite, biotite, and quartz, and commonly also feldspar and garnet. The grain size ranges from medium-grained schist with feldspar "eyes" and large scales of mica to very fine-grained satin schist in which it is difficult to recognize the individual mineral grains without the aid of the microscope. Garnets where present form porphyroblasts with numerous inclusions of quartz and mica. At many localities the garnets have been crushed and drawn out into lenses of broken grains. Chlorite is commonly present in the schist. In Cherokee County, chlorite-sericite schist occurs interbedded with chloritic quartzite and crinkled garnet-mica schist. The rock is of such purity that it has been mined for much the same uses as scrap mica. In Carroll County, 4½ miles south southeast of Bowden, the Ashland contains silvery mica schist with sheaf-like bundles of actinolite and dodecahedrons of garnet. The garnet is partly altered to chlorite that retains the crystal form of the garnet.

Intrusive rocks in the Ashland schist include granite gneiss, granite augen gneiss, hornblende gneiss, ultramafic rocks, and dolerite, all of which are described in a later section. Hornblende gneiss, the commonest igneous rock in the schist, occurs in sill-like forms parallel to the schistosity.

The Ashland mica schist appears to overlie the gneiss facies of the Carolina series in the northeastern counties of the State. The schist, together with the Wedowee formation and the Canton schist, is here regarded as the upper part of the Carolina series. The Wedowee and Canton formations are conformable to the Ashland but their relative stratigraphic position is uncertain. Adams (1926) has expressed the opinion that the Ashland schist is older than the Wedowee and that the two are together equivalent to the Talladega series. The Talladega and Ashland series are brought together only by faulting so that their stratigraphic relations are unknown. However, it seems quite reasonable to suppose that the Ashland schist is represented in the Talladega series.

There is no positive evidence on the age of the Ashland schist. E. C. Eckel (1903) has suggested that the schists near Dahlonega may be of Cambrian or Lower Silurian age. Adams has also suggested that there may be Paleozoic rocks included in the Ashland schist which in the main he regards as late pre-Cambrian. Adam's conclusion was predicated on the assumption that the Talladega series is mainly Paleozoic. The Talladega series is more probably pre-Cambrian, and the Ashland mica schist is also here regarded as pre-Cambrian.

Adams (1926) has ventured the opinion that the Ashland schist is more than 10,000 feet thick in Alabama. The thickness of the formation in Georgia is probably as great but no satisfactory estimates can be made on account of repetitions by folding and faulting. Furthermore, it is difficult to recognize the base and the top of the formation with any certainty. Very coarse-grained gneisses occur in the center of an apparent anticlinal structure in western Carroll County. These possibly belong in the lower gneissic facies of the Carolina series and are followed in order by Ashland schist and Wedowee schist. If this is a normal sequence and no great number of unseen folds and faults intervene, the thickness of the Ashland schist is here at least 12,000 to 15,000 feet.

The areal extent of the Ashland schist corresponds closely to the Dahlonega gold belt, a belt characterized by deposits of gold, and pyrite, with locally a subordinate amount of copper and other sulphides. Although gold and the sulphides were introduced in one period of mineralization they are not equally distributed throughout the belt. Pyrite predominates in the southwestern part of the belt and gold is most abundant in the northeastern part. The deposits form veins, or groups of veins in lodes, or replacements of the country rock as leads, all of which roughly conform in direction to the foliation of the schist.

The main use of pyrite is in the manufacture of sulphuric acid and for this reason the mineral came to have a strategic importance during the war period of 1914-1918 which stimulated production throughout the country. At that time seven of the twelve active pyrite mines in the State were deposits in the Ashland schist closely associated with hornblende gneiss. In the post-war slump of war industries, all the pyrite mines in the State were abandoned.

In the early part of the 19th Century the southern Appalachian region was the most important gold producing area in the United States. The United States government established a branch mint at Dahlonega, Georgia, which during the 23 years of its operation (1838-1861), minted a total coinage of more than six million dollars. In the latter part of the century gold production declined and only since the United States currency was devalued in 1932 has there been a notable increase. The total production of gold in Georgia has been in the neighborhood of eighteen million dollars.

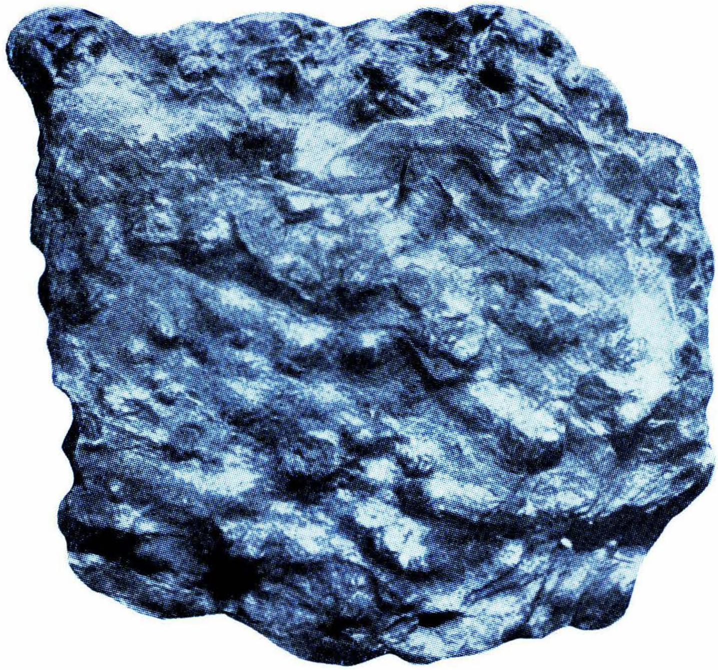

Fig. 6. Canton schist from Town Creek, Cherokee County, showing knobly cleavage surface.

The Canton schist was named by Bayley (1928) to include silvery graphite-mica schist typically exposed 1 mile southeast of Canton, Cherokee County, on the south fork of Town Creek. The schist closely resembles the Ashland but is distinguished by the presence of graphite (possibly volatile organic matter (Bayley, p. 46) in small specks freely sprinkled through the mica and quartz. Porphyroblasts of garnet, and less commonly staurolite, form pea-sized knobs on the wrinkled cleavage surfaces. Marble beds up to one and a half feet thick are reported in the formation at the abandoned Canton Copper mine, 1 mile south of Canton. (Shearer and Hull, 1918, pp. 154-160)

The Wedowee formation, typically exposed near Wedowee, Randolph County, Alabama (Adams, 1926, pp. 36-38), occupies an area extending from the Alabama state line, where it is twenty miles wide, to a point nine miles northeast of Buchanan, Haralson County, where it wedges out in the Ashland schist. It is possible that the Canton schist is equivalent but uncertainty of correlation recommends the retention of both

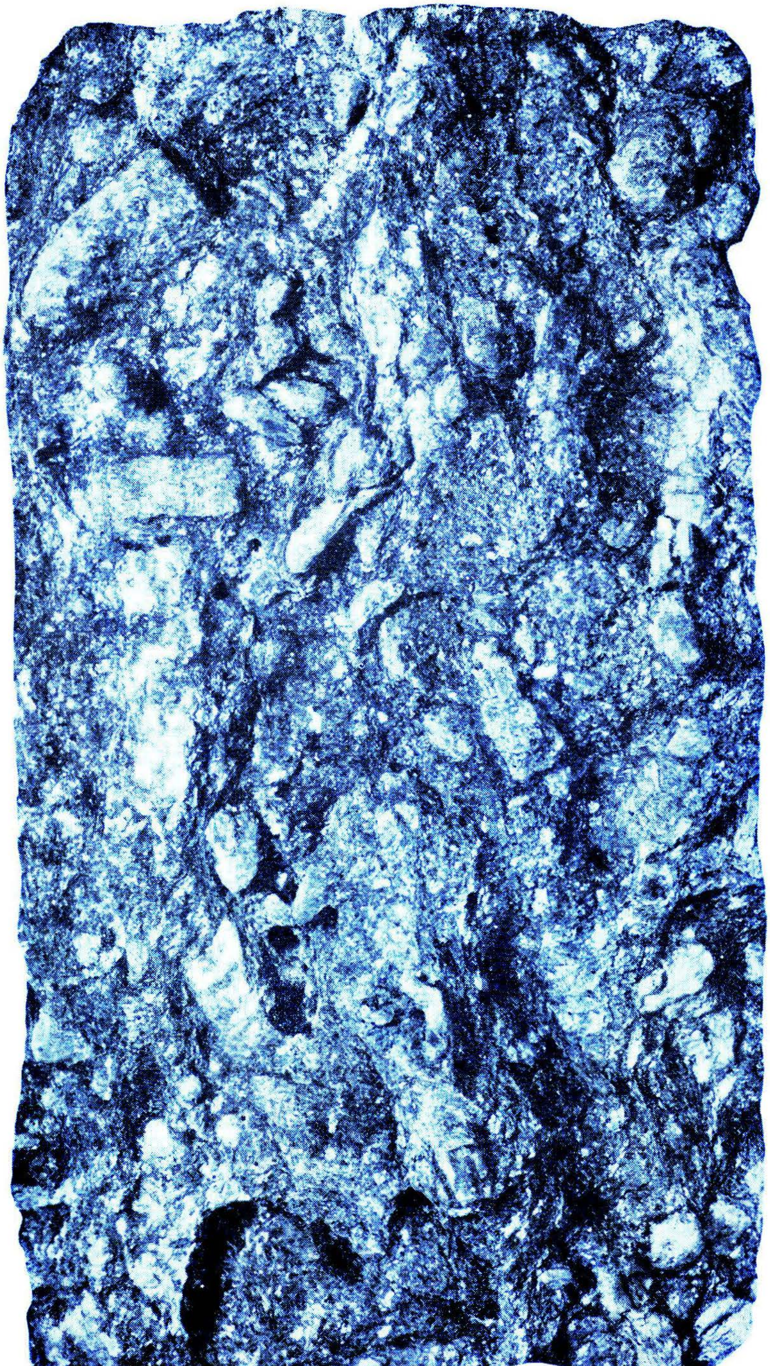

Fig. 7 Kyanite schist in the Carolina series of Rabun County.

names. Graphite schist in the Ashland of western Paulding County and in augen gneiss in Douglas County should probably be placed with the Wedowee formation.

The Wedowee formation in Georgia consists of dark, scaly mica schist, generally graphitic. The planes of schistosity, as in the Ashland schist, are commonly crenulated or wavy, with a strong tendency towards development of a double cleavage. Thin-sections show the schist to be similar in mineralogy to the Canton schist, but chlorite, in part replacing garnet and biotite, is more common. The Wedowee formation also closely resembles part of the Talladega series.

Estimates of thicknesses of metamorphic formations must be taken as approximate, and are included here only to give some measure of their order of magnitude. The Canton schist may have a thickness of about 2,000 feet, and the Wedowee formation as much as 10,000 feet (Adams, 1926). The Ashland schist is probably more than 10,000 feet thick.

The Ashland schist appears to overlie the gneiss facies of the Carolina series in the northeastern counties of the state. The Wedowee and Canton formations are conformable with the Ashland, but their relative stratigraphic positions are uncertain. According to Adams, the Ashland schist underlies the Wedowee formation, and the two are equivalent to parts of the Talladega series. This view is in complete conformity with the writer's observations in Georgia. Adams inclined to the belief that all these formations are Paleozoic in age, but because of their close relation to the gneiss facies of the Carolina series and lack of any tie to known Paleozoic rocks, the writer assigns them to the pre-Cambrian.

In addition to the Wedowee-Ashland belt, noteworthy masses of schist occur in the Amicalola, Tallulah, and Dadeville belts.

The Amicalola schists form sinuous bands in the Carolina series between Morganton, Fannin County and Blairsville, Union County. There appears to be four or five distinct beds distributed through a vertical range of several thousand feet (LaForge and Phalen, 1913). The schist is generally grey to steel-blue in color, with silvery cleavage surfaces, commonly crinkled. It is everywhere fine-grained with large crystals of kyanite which in many places are bent and broken.

Mica schist occurs on the flanks of a broad dome centering at Tallulah Falls in Habersham and Rabun Counties. The schist forms a discontinuous belt that has been traced from near Chattooga River, east of Tallulah Falls, northwestward to Tiger where it curves around to the southwest and extends southward to Alec Mountain, in Habersham county. South of Alec Mountain the belt swings to the east and finally to the northeast to taper out near Turnerville. In plan the belt has roughly the form of a horse shoe in the center of which lies the anticlinal core of Tallulah Falls quartzite. This schist generally contains abundant kyanite (Prindle, 1935).

In the Dadeville belt, between Vanna and Hartwell, Hart County, fine-grained muscovite schist outcrops for about 15 miles and with a maximum width of 1 mile. The schist can be traced from Hartwell to the northeast where it appears to wedge out in the surrounding coarser-grained biotite gneisses. The belt extends southward into Elbert County but in a short distance tapers out. East of Royston the strike of schistosity makes an abrupt turn from southwest to south. It seems possible that this deflection is conditioned by a small granite batholith in the area north and south of Vanna.

The schist of Hart County is interesting mainly because it contains a few gold deposits that were worked previous to 1860. Small placer deposits have been found on a few creeks that cut across the schist belt. Extensive sillimanite deposits, believed to be of commercial value, have been described recently from this district (Furcron and Teague, 1945).

The following are chemical analyses of typical rocks from the schist facies of the Carolina series.

Chemical Analyses of Schist from Carolina Series

	1	2	3	4	5	6	7
SiO_2	63.46	69.16	70.99	71.30	73.63	88.20	60.15
Al_2O_3	15.97	18.42	14.76	16.17	8.93	.96	16.46
Fe_2O_3	2.37	4.24	1.33	.68	1.02	2.69	4.04
FeO	4.59	1.55	3.08	.92	6.83	7.98	2.90
MgO	1.89	.71	1.75	.65	1.72	.12	2.32
CaO	2.76	.58	1.13	1.98	.96	.00	1.41
Na_2O	1.27	.07	1.87	4.48	1.02	.18	1.01
K_2O	3.01	2.16	2.69	1.23	2.07	.00	3.60
MnO	.31	....	.46	tr.	1.48	.15	tr.
TiO_2	1.66	.54	.60	.55	.55	.05	.76
S	....	.12	.04	.08	.03	tr.	....

SO_3	1.46	....	....	....	....	....	.58
CO_2	.00	....	.00	.00	.00	tr.	1.46
P_2O_5	.04	.01	.04	tr.	.00	tr.	.14
H_2O+	1.13	2.14	1.32	1.56	.92	.14	3.82
H_2O-	.00	.02	.09	.01	.10	.00	.89
Total	99.92	99.72	100.15	99.61	99.26	100.47	....

1—Gray feldspathic mica schist (Ashland mica schist) Creighton Mine, Cherokee County. Edgar Everhart, Analyst. (Jones, 1909, p. 66).

2—Silvery mica schist (Canton schist), on west branch of Town Creek, 1 mile south of Canton, Cherokee County. Edgar Everhart, Analyst. (Bayley, 1928, p. 46).

3—Biotite-muscovite schist (Ashland mica schist), Childs Mine, Nacoochee Valley, White County. Edgar Everhart, Analyst. (Jones, 1909, p. 69).

4—Mica schist (Ashland mica schist), Consolidated mine, near Dahlonega, Lumpkin County. Edgar Everhart, Analyst.

5—Garnet-biotite schist (Ashland mica schist), Findley mine, near Dahlonega, Lumpkin County. Edgar Everhart, Analyst. (Jones, 1909, p. 73).

6—Gray quartz schist (Ashland mica schist), Bast cut, near Dahlonega, Lumpkin County. Edgar Everhart, Analyst. (Jones, 1909, p. 70).

7—Composite analysis of fifty-one Paleozoic shales, by H. N. Stokes, inserted here for comparison (from Clarke, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, p. 552, 1924).

The mica schists include rocks of diverse character, and therefore the analyses here presented serve only to indicate the chemical make-up of a few rock types and are probably not representative of the formations as a whole. The mica schists are believed to be metamorphosed shales but comparison with a composite analysis of fifty-one Paleozoic shales shows that the schists are more siliceous, that they contain more ferrous than ferric iron, and that they have much less carbon dioxide and combined water than the shales. These differences are probably due to metamorphism and do not mean that the schists were originally far different from average shale in chemical composition. Like the shales, the schists are relatively high in potash as compared to either soda or lime.

Cataclastic Facies.—Parts of the Carolina series have been subjected to strong shearing stresses resulting in crenulation of schistosity and crushing of mineral grains. This is well shown through the Wedowee-Ashland belt. More intense differential movements have locally resulted in a microgranulation of mineral grains and the development of mylonite.

Mylonite occurs in the Amicalola belt (Crickmay, 1933), 1½ miles north of Neel's Gap, Union County, where it forms dike-like bodies in simple and branched forms penetrating granitized biotite gneiss in a zone 250 feet wide. Thin sections show porphyroclasts of feldspar and garnet embedded in a dark streaky ground-mass of comminuted biotite, quartz, and feldspar.

The Dadeville belt is separated from the Wacoochee belt in the western part of the state by the Towaliga fault, a steep, northward-dipping thrust fault. Biotite gneiss of the Carolina series lying within 500 feet of the fault has suffered extreme mechanical deformation and is in part reduced to mylonite (Hewett and Crickmay, 1937). The crushed gneiss is a fine-grained rock with feldspar eyes and with cleavage surfaces that lack the brilliant luster of the uncrushed gneiss. This lack of luster is due to a disruption of the parallel orientation of the mica plates on cleavage surfaces with consequent dispersion of reflected light. In a group of strongly metamorphic gneisses such as are included in the Carolina series, dull cleavage surfaces may be taken as a sure sign of mechanical deformation. Pegmatites in the gneiss are crushed and exhibit a dimensional parallelism of large broken feldspar and biotite crystals in a streaky lenticular mass of quartz, feldspar and biotite.

PINE MOUNTAIN SERIES

Definition.—The Pine Mountain series, named by Galpin (1915, p. 74), includes quartzites and schists of Pine and Oak mountains in the southwestern part of the Wacoochee belt. Four formations have been recognized, named in ascending order: Sparks schist, Hollis quartzite, Chewacla marble, and Manchester schist. The Chewacla marble is typically exposed in Lee County, Alabama (Prouty, 1916), where it appears to overlie the Hollis quartzite (Smith, 1875). The formation is not known in Georgia. The other formations are indicated on the map as schist and quartzite, for insufficient mapping has been done to extend the units recognized in the Warm Springs area (Hewett and Crickmay, 1937). Adams (1930) believes the series is Paleozoic, but Hewett and Crickmay have assigned it to the pre-Cambrian.

Sparks Schist.—Mica schist, biotite gneiss, and quartzite, apparently underlying the Hollis quartzite along Sparks Creek in the Warm Springs area have been named the Sparks schist

(Hewett and Crickmay, 1937). The formation is similar in lithology to the Manchester schist (described below), but generally contains many thin injections of granite uncommon in the higher formation.

Hollis Quartzite.—The Hollis quartzite is typically exposed near Hollis, Lee County, Alabama (Adams, 1926). The quartzite forms persistent ridges from the Alabama line to Barnesville, Georgia. It averages about 350 feet in thickness, including a lower and upper thinly-bedded part. The rock is highly siliceous but in most places contains some muscovite and albite. A characteristic feature of the thinly laminated upper beds is that on weathering they become flexible (itacolumite).

Manchester Schist.—The mica schist and biotite gneiss overlying the Hollis quartzite near Manchester, Georgia, have been named the Manchester schist (Hewett and Crickmay, 1937). The schist is generally a scaly muscovite-rich rock with variable amounts of quartz, biotite, oligoclase, and garnet. The gneiss is in flagstone layers with thin schist interbeds. Its mineralogy resembles the schist except that plagioclase, quartz and biotite are the most abundant minerals. About 850 feet above the base of the formation occurs a persistent bed of quartzite, 50 to 300 feet thick, which closely resembles the Hollis quartzite. The top of the Manchester schist is not known, but the formation appears to be at least 1,000 feet thick.

BREVARD SERIES

Definition.—The Brevard schist was named by Keith (1905) to include dark gray to black schists exposed near Brevard, North Carolina. The series occupies a belt averaging about two miles in width and extending from Habersham County southwestward across the state into Alabama. The series includes biotite gneiss, mica schist, quartzite, chlorite schist, and marble.

The Brevard schist was mapped as Cambrian by Keith (1907) but is similar lithologically to schists in the Carolina series. The Brevard schist can be traced southwestward into Alabama where it is included in the Ashland and Wedowee formations. Thus the Brevard is almost certainly correlative with the schist facies of the Carolina series. Although Keith

Analyses of Schist and Gneiss from Brevard Series

Edgar Everhart, Analyst

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
SiO_2	63.08	75.23	66.10	62.72	75.92	64.14	61.28	60.00	67.92	78.42	90.23
Al_2O_3	19.00	13.20	17.00	21.35	13.54	18.50	21.50	21.38	16.20	14.36	6.68
Fe_2O_3	7.48	.83	1.85	.70	.53	2.31	.71	1.80	3.36	2.26	.85
FeO	.75	3.24	5.50	6.24	4.52	4.99	5.61	4.62	1.37	....	....
MgO	.37	.82	.88	.59	.46	1.50	.81	1.29	Tr.	.15	.22
CaO	.00	1.32	1.80	Tr.	.48	2.16	1.80	.60	.00	.56	.34
Na_2O	.16	2.96	1.98	1.74	1.80	1.98	1.33	2.56	1.06	1.20	.44
K_2O	.60	.72	1.84	3.06	1.16	2.10	2.33	4.36	2.86	2.12	1.04
TiO_2	1.08	.36	.72	.72	.54	.90	.72	.99	.32	.18	.09
P_2O_5	.14	.09	.28	.18	.11	.33	.77	.20	.11	....	....
MnO	.00	....	.00	....	.00	.00	.00	Tr.	.12	Tr.	Tr.
SO_3	.00	....	....	....	....	....	....	Tr.	....	....	....
S	....	.03	.21	.15	.19	.03	.14	.23	.81	....	....
CO_2 (Graphite)	....	....	....	....	....	....	....	....	.86	....	....
Ignition	6.20	.90	1.42	2.50	.36	1.28	2.66	2.08	4.20	.92	.00
Moisture	.86	.30	.50	.00	.00	.00	.30	.00	.32	.04	.00
Total	99.72	100.00	100.08	100.15	99.71	100.22	99.98	100.11	99.91	100.21	99.89

1. Decomposed schist, Chattahoochee Station, Fulton County.
2. Mica schist, Chattahoochee Station, Fulton County.
3. Fine-grained biotite gneiss, county quarry near Moore's Bridge Fulton County.
4. Fine-grained biotite gneiss, county quarry near Moore's Bridge Fulton County.
5. Fine-grained biotite gneiss, county quarry near Moore's Bridge Fulton County.
6. Fine-grained biotite gneiss, county quarry near Moore's Bridge Fulton County.
7. Fine-grained biotite gneiss, county quarry near Moore's Bridge Fulton County.
8. Fine-grained biotite gneiss, county quarry near Moore's Bridge Fulton County.
9. Mica schist, near Pinkneyville, Gwinnett County.

Analyses of Marble from Bervard Series

Edgar Everhart, Analyst

	1.	2.	3.	4.	5.	6.	7.	8.	9.
SiO_2	11.97	18.35	65.52	16.33	17.38	5.74	14.20	6.83	26.87
Al_2O_3	1.82	5.65	8.16	.40	.75	.60	.80	.60	.35
Fe_2O_3	....	2.42		1.32	2.05	1.20	1.25	1.70	1.20
FeO	....	.62	....	....	....	....	....	....	....
MgO	15.14	9.70	1.81	16.16	15.22	18.88	16.06	17.98	8.48
CaO	30.18	27.04	11.64	27.10	27.04	28.88	28.00	30.02	29.72
Na_2O	....	....	.26	....	....	....	....	....	....
K_2O	....	....	.90	....	....	....	....	....	....
P_2O_5	....	Tr.	.32	02	.05	.04	.04	.06	.03
SO_3	....	.00	....	.02	.08	.02	Tr.	.02	.03
CO_2 & Organic Matter	40.69	36.60	11.39	38.65	37.43	44.64	39.65	42.79	33.32
Moisture	.05	.00	....	....	....	....	....	....	....
Total	99.85	100.38	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1. Marble, Gainesville, Hall County.
2. Marble, Panther Creek, Habersham County.
3. Marble, 1½ mi. SE of Hollywood, Habersham County.
4. Marble, Panther Creek, Stephens County (Maynard, 1912).
5. Marble, ½ mi. S. of mouth of Panther Creek, Habersham County (Maynard, 1912).
6. Marble, Billy Walker Quarry, Panther Creek, Habersham County, (Maynard, 1912).
7. Marble, quarry near Gainesville, Hall County (Maynard, 1912).
8. Marble, quarry near Gainesville, Hall County (Maynard, 1912).
9. Marble, Flowery Branch, Hall County (Maynard, 1912).

thought the Brevard schist rested unconformably on the Carolina gneiss and old granites, no evidence of this unconformity is to be found in Georgia. Both the Henderson granite gneiss in North Carolina and the Lithonia granite gneiss in Georgia are intrusive into the Brevard schist. The name is retained because the writer has not wished to diverge too far from the accepted nomenclature of the crystalline rocks, but he believes that the Brevard series is essentially part of the Carolina series and is pre-Cambrian.

Biotite gneiss.—The biotite gneiss is a fine-grained, dark gray, laminated rock, made up mainly of quartz, feldspar, biotite, and muscovite with rarely small clear garnets. The foliation surfaces of the gneiss are commonly flecked by blister-like lenses of fine mica scales. Quartzite beds occur in the series in Heard, Hall and Gwinnett counties. The rock is a vitreous quartzite containing golden-colored muscovite, and is gradational into quartz-mica schist. The quartzite members are generally less than 200 feet in thickness.

Mica Schist.—Fine-grained, gray to black mica schist predominates in the Brevard series. Its most characteristic feature is a scaly appearance caused by a lenticular structure of the schistosity closely comparable to the blisters found in the biotite gneiss. The lenses are button-shaped with average dimensions of one and a half inches in diameter and one-eighth to one-quarter of an inch in thickness. In areas where weathering is profound, the series can be readily identified by the presence of numerous buttons of schist in the residual soil. These "buttons" have originated by deformation of the original schistosity and the development of a secondary cleavage.

The mica schist contains muscovite, quartz, feldspar, biotite, and garnet. Green chlorite schists occur in association with marble in Habersham County, and graphite schist occurs in Gwinnett and Hall Counties.

Marble.—Discontinuous beds of bluish-gray magnesium marble, ranging up to 100 feet in thickness, occur between Flowery Branch, Hall County to Tugalo River, Stephens County. The marble everywhere lies within fine-grained mica schist, commonly chloritic and calcareous, but insofar as bedding is rarely seen, the structural relations are obscure. The largest mass of marble lies two miles south of Gainesville, Hall County (Maynard, 1912).

Analyses of rocks from the Brevard series are given, pages 24-25. They indicate a typical series of sedimentary types including original sands, shales, and limestone. Metamorphism has probably brought some change in chemical composition but the big change is in mineral constitution and texture.

TALLADEGA SERIES

Definition.—The Talladega series was named by E. A. Smith for exposure of slate, phyllite, quartzite, and marble in Talladega County, Alabama (Butts, 1926). The Talladega belt in Georgia is divided geographically into two parts; one extending west and southwest from Allatoona, Bartow County, the other north and northeast from that village. West of Allatoona the series closely resembles the typical expression in Alabama, with phyllites predominating. North of Allatoona the series comprises more highly metamorphic rocks, which have been grouped into ten formations named in ascending order (LaForge and Phalen, 1913; Bayley, 1928; Hull, LaForge, and Crane, 1919) :—Pinelog quartzite, Hiawassee slate, Great Smoky formation, Nantahala schist, Tusquitee quartzite, Brasstown schist, Valleytown schist, Murphy marble, Andrews schist, and Nottely quartzite. These units have not been used on the state geologic map because of lack of detailed work. The Talladega series has been estimated to be about 10,000 feet thick.

Smith (1896) regarded the Talladega series as the same as the Ocoee series (lower Cambrian), and Butts (1926) believed it included equivalents of many of the Paleozoic formations of the Appalachian Valley. The writer (1936) has presented evidence favoring a pre-Cambrian age for the series.

Quartzite:—The thickest quartzite in the series occurs on Pinelog Mountain, Bartow County, and has been named the Pinelog formation (Hull, LaForge, and Crane, 1919, pp. 40-41). It is dominantly a thick-bedded gray to pink quartzite containing layers of conglomerate and dark phyllite. The rock has in most places suffered severe mechanical deformation; quartz grains are crushed in lenticular streaks and pebbles of quartz are attenuated and possess irregular-sutured borders. The formation is similar to and may be equivalent to the Cheaha sandstone of Alabama (Butts, 1926).

The Nottely quartzite was named by Keith (1907) to include 200 feet or more of granular white quartzite occupying the highest position in his "metamorphic Cambrian" series. The formation is restricted to a small area in Georgia near Sweetgum, Fannin County (LaForge and Phalen, 1913).

The Tusquitee quartzite separates the Brasstown schist above from the Nantahala schist below on the Nantahala quadrangle (Keith, 1907). The formation reaches a thickness of 500 to 600 feet in Georgia (LaForge and Phalen, 1913) but is not known south of Gilmer County.

Biotite Gneiss.—The Great Smoky formation in Georgia is made up mainly of fine-grained biotite gneiss in flagstone beds with interbeds of mica schist (LaForge and Phalen, 1913; Bayley, 1928). Beds of conglomerate with blue quartz pebbles occur in Fannin and Gilmer counties, and further north, towards the type locality in North Carolina (Keith, 1903), conglomeratic rocks are abundant. The formation can not be identified west of Allatoona.

The biotite gneiss of the Great Smoky formation and similar gneisses in the Valleytown formation are composed mainly of quartz, feldspar, biotite, muscovite, and garnet. On the western side of the Talladega belt the gneisses contain very little biotite or garnet, and many of them may be appropriately called micaceous quartzite. These rocks are not as intensely metamorphosed as the garnet-biotite gneiss on the eastern side of the belt, which so closely resemble the Carolina series that separation is largely arbitrary. Where gneisses identified as Great Smoky are in contact with the Carolina series there is complete conformity.

Mica Schist.—The Brasstown, Valleytown, and Andrews formations, of which the Valleytown is by far the most extensive, are dominantly mica schists, but they include gneisses and phyllites. The rocks are commonly silvery-crenulated mica schists with porphyroblastic knobs of garnet, kyanite, or staurolite.

Calcareous chlorite-albite schist is common along the western margin of the Talladega belt, particularly on Raccoon, Hills, and Pinelog creeks. These green schists can be traced northeastward from Pinelog Creek, Bartow County, towards Sharp Mountain, where they grade into garnet-biotite schist in which both garnet and biotite are partly replaced by chlorite. The low-grade chlorite schists are believed to be retrogressive equivalents of higher grade rocks, a view conforming to the broad interpretations made by Miss Jonas (1932).

The Talladega series west of Allatoona consists of sericitic phyllites, in part graphitic, but its monotonous similarity is relieved in places by beds of chloritic quartzite and arkose, and at one locality by marble. The rocks contain no garnet, staurolite, or kyanite, and rarely any biotite. The lack of these higher grade minerals distinguishes the Talladega series of this western area from the Wedowee formation and Ashland schist to the south. Phyllites are also common north of Allatoona along the western border of the Talladega belt.

Graphite Schist.—Dark gray to black mica schist containing graphite (possibly volatile organic matter) occurs at many places in the Talladega series. The schists below and above the Great Smoky formation are persistently graphitic. The lower schist has been called (Bayley 1928, pp. 48-52) the Hiawassee slate, a name derived from the Ocoee sequence of Tennessee. It is entirely possible that the Ocoee series is a mildly altered equivalent of the Talladega series, as postulated by King (1949, 1951). The upper schist has been named Nantahala slate (Keith, 1907), but Bayley (1928) uses the more appropriate term Nantahala schist.

The graphite schists are made up mainly of biotite, muscovite, and quartz, with broken porphyroblasts of garnet and rarely staurolite. The schistosity is everywhere strongly crinkled to give a marked secondary cleavage. The schists are gradational into graphite phyllite in which the secondary cleavage masks the original schistosity.

Marble.—The Murphy marble (Keith, 1907) is the only highly calcareous formation included in the series. It consists of fine-grained dolomitic to coarse-grained calcareous marble of white, gray, to pink color. The formation forms discontinuous strips in a belt extending southwest from Murphy, N. C., through Blue Ridge and Tate, Georgia, to near Canton, Cherokee County. Isolated exposures occur two miles southwest of Waleska, Cherokee County, in hornblende gneiss, and three miles northeast of Buchanan, Haralson County, in phyllite.

The thickness of the marble may range from 150 to 500 feet, but in most places it has been so intricately folded that the width of outcrop has little relation to thickness. Close recumbent folding is indicated by contorted dark (graphitic) layers in the marble at Tate.

The following are analyses of rocks from the Talladega series:

Analyses of Schist and Gneiss from Talladega Series

Edgar Everhart, Analyst

	1	2	3	4	5	6	7
SiO_2	52.75	55.56	45.98	49.56	44.70	87.58	71.51
Al_2O_3	15.33	29.50	40.25	29.90	41.18	6.81	13.64
Fe_2O_3	5.00	.35	1.27	1.60	2.20	.14	.20
FeO	7.80	.63	.00	3.53	1.47	.88	2.51
MgO	4.08	.64	.10	.44	.43	.00	.87
CaO	7.23	.70	.00	.04	.04	1.00	2.29
Na_2O	1.47	.82	1.46	.36	.40	.60	3.25
K_2O	2.40	.68	1.72	3.90	3.90	1.36	2.23
TiO_2	2.02	.90	1.08	.54	.79	.36	.51
P_2O_5	.01	Tr.	Tr.	.15	.02	Tr.	.09
MnO	.26	....	.12	....	....	.00	.09
SO_3	....	.65	.00	.74	....	.17	....
S	.11	....	....	.78	.12	....	.01
CO_2	.00	....	....	....	....	.80	.28
Moisture	.01	1.48	2.68	.05	.04	.00	.04
Ignition	.67	8.02	5.44	8.22	4.53	.32*	1.90
Total	99.14	99.93	100.10	99.81	99.82	100.11	99.40

*Analysis #6 less Carbon Dioxide

1. Schist Hornblende, White Path Mine, Gilmer Co. Collected by S. P. Jones.
2. Pyritic schist C-27 (2) miles S. of Emerson, Bartow Co., Old Atlanta Vitr. Brick Co. Collected by R. W. Smith.
3. Sericite schist. Virgil Jones, Bartow Co.
4. Hiawassee schist. S. slope of ridge of Sharp Mt. Pickens Co.
5. Nantahala slate. ¾ mi. N. Hopewell Church, Cherokee Co. (Bayley, 1928).
6. Quartzite, Tate, Ga., 1 mi. W. of Jasper, Pickens Co.
7. Quartzite, Cohutta Gold Mine, Murray Co. (Jones, 1909).

LITTLE RIVER SERIES

Definition.—A series of intercalated volcanic and sedimentary rocks exposed along Little River in Wilkes, Lincoln, and McDuffie counties, are here named the Little River series. The series occupies three separate parallel belts, but to the northeast, in South Carolina, they unite to form the so-called Carolina "slate belt", well known for its included gold deposits (Nitze and Wilkins, 1897). The series has been regarded as younger than the bordering schists and gneisses of the Carolina series (Laney, 1910; Pogue, 1910), a conclusion to which the writer completely subscribes. Of all the metamorphic rocks in the state, this series alone may be Paleozoic, but its relationships to known Paleozoic slates further to the north (Quantico and Arvonia slates) are unknown.

Lithology.—Most of the sedimentary rocks in the series have been loosely referred to as "slate", but the series includes shales with only incipient slaty cleavage, phyllites which are commonly chloritic, and mica schist with strongly developed schistosity. In general, the most schistose beds occur along the northern and southern margin of the Little River belt. Massive quartzite containing abundant kyanite occurs in the series at Graves Mountain (Watson, 1912; Prindle, 1935).

The series includes many beds of tuff interbedded with shale and amygdaloidal volcanics in southeastern Wilkes and southern Lincoln counties. Light-colored phyllites and schists elsewhere in the series may represent metamorphosed tuffs.

Extrusive rocks, mainly andesitic, are common throughout the series. A common type is a dark-green phyllite made up of hornblende phenocrysts, in part altered to chlorite and epidote, in a fine-grained ground mass of hornblende, epidote, muscovite, chlorite, feldspar, and quartz. Original plagioclase (?) phenocrysts are represented by aggregates of epidote, muscovite, and quartz. Some of the phyllites are strongly amygdaloidal. The amygdules are filled with epidote, zoisite, feldspar, quartz, and mica, commonly with concentric arrangement. Siliceous volcanics of gray to purplish-gray color also occur in the series, but being more susceptible to weathering are not so well exposed as the more basic rocks. Biotite phyllite occurs in northern Wilkes County where the series is intruded by the Elberton granite.

The series is intruded by many dikes and sills, mainly basic in character, but no attempt has been made to map the intrusives (Jones, 1909).

The Little River series is a complex group of sedimentary, extrusive, and intrusive rocks of distinctly younger age than the surrounding more highly metamorphosed schists and gneisses of the Carolina series. Detailed mapping will be required before a sequence is established, and such mapping may show the unit to be far more extensive than shown on the State Geologic Map.

The following are analyses of rocks from the Little River Series. These analyses show that the phyllite and schist of

Chemical Analyses of Phyllite and Schist from Little River Series

Edgar Everhart, Analyst

	1	2	3	4	5	6	7
SiO_2	71.30	61.28	67.02	59.50	65.09	62.45	61.25
Al_2O_3	15.06	24.10	18.17	20.79	21.69	15.91	17.18
Fe_2O_3	4.45	8.96	3.95	7.89	2.33	2.07	4.49
Fe O	4.45	8.96	3.95	7.89	2.33	3.80	2.54
MgO	.70	.51	.55	1.51	Tr.	1.76	2.21
CaO	1.10	.00	.00	.18	.00	3.70	3.78
Na_2O	.52	.18	.23	.09	.36	2.33	2.50
K_2O	1.57	.14	.09	1.22	.20	.40	1.60
TrO_2	.36	.54	.73	.91	1.08	.82	.92
P_2O_5	Tr.	.05	.10	.16	.42	.13	.02
SO_3	.26	.00	.34	.00	.34	....	....
H_2O+	4.66	4.16	8.76	7.41	8.73	5.41	3.03
H_2O-	....	....	....	....	....	.03	.01
CO_2	....	....	....	....	....	.50	.00
S	....	....	....	....	....	.22	.24
MnO	....	....	....	....	....	.37	.27
Total	99.98	99.92	99.94	100.06	100.24	99.90	100.04

1. Soft weathered, vari-colored phyllite, west of Ogeechee River on the Sandersville-Mitchell road, Washington County (Smith, 1931).
2. Hard, gray phyllite, Hamburg, Washington County (Smith, 1931).
3. Light-gray phyllite, 2 miles of Martinez, Richmond County (Smith, 1931).
4. Gray phyllite, Belair, Richmond County (Smith, 1931).
5. White phyllite, Belair, Richmond County (Smith, 1931).
6. Chlorite-mica schist, Columbia mine, McDuffie County (Jones, 1909).
7. Epidote-chlorite schist, Parks mine, McDuffie County (Jones, 1909).

Chemical Analyses of Igneous Rocks in the Little River Series

Edgar Everhart, Analyst

	1	2	3	4	5
SiO_2	68.07	68.13	77.12	69.30	58.71
Al_2O_3	15.07	17.49	12.65	15.91	14.96
Fe_2O_3	1.13	1.19	2.60	3.20	1.70
FeO	3.42	1.38	.73	.18	4.59
MgO	2.27	1.00	1.08	.21	3.19
CaO	.73	.75	tr.	5.92	4.90
Na_2O	6.06	3.50	2.07	3.35	3.24
K_2O	.29	3.00	.21	.14	.94
TrO_2	.37	.75	.28	.48	.83
P_2O_5	Tr.	Tr.	.00	.00	.04
S	1.14	.22	.08	.03	.08
CO_2	.00	.00	.00	.00	2.20
MnO	.31	.30	.31	.11	.28
H_2O+	1.25	2.06	2.64	1.80	3.89
H_2O-	.01	.03	.10	.52	.05
Total	100.12	99.79	99.87	101.15	99.60

1. Quartz-albite porphyry, near Seminole mine, Lincoln County (Jones, 1909).
2. Schistose quartz-albite porphyry, Seminole mine, Lincoln County (Jones, 1909).
3. Quartz sericite schist, Seminole mine, Lincoln County (Jones, 1909).
4. Granite porphyry, Seminole mine, Lincoln County (Jones, 1909).
5. Chlorite schist, probably an altered andesite, Morgan mine, Oglethorpe County (Jones, 1909).

the Little River series are siliceous rocks with an unusually high percentage of alumina with respect to the alkaline earths. In some analyses lime exceeds soda and potash together, and in many the soda exceeds potash. These characteristics suggest an igneous origin for part of the phyllite which, as previously noted, may be tuffaceous in origin.

IGNEOUS ROCKS

GENERAL STATEMENT

It will be possible to present only the briefest outline of the igneous rocks. They have evidently been intruded at several distinct periods, and although their geologic age is uncertain, the general field relations appear to justify the following tabular summary of intrusive sequence from oldest to youngest.

1. Intrusion of basic sills, dikes, and stocks into sedimentary gneisses and schists. These intrusions were later altered to hornblende gneiss and diorite gneiss.

2. Intrusion of granite, in places porphyritic, later changed to biotite augen gneiss (Corbin-type). The relative position of group 2 and 3 is uncertain.

3. Intrusion of granite (Lithonia type) in immense masses. These rocks have a strong gneissic banding probably induced by crustal stresses prevailing at the time of intrusion.

4. Intrusion of small masses of pyroxene granite (Cunningham type). These rocks are closely related in mineralogy to group 2.

5. Intrusion of gabbro and ultra-mafic rocks in small bodies, some of which were later profoundly altered.

6. Extrusion of lavas and pyroclastics, and intrusion of dikes and sills in the Little River series.

7. Intrusion of granite (Stone Mountain type) and porphyritic granite (Palmetto type) in batholiths, stocks, and dikes. The rocks of this group are frequently called the "younger granites" as opposed to the "older granites" of groups 2, 3, and 4.

8. Intrusion of dolerite dikes along nearly vertical joints striking north and northwest across the older structural trend.

Hornblende Gneiss and Diorite Gneiss

Hornblende gneiss occupies lenticular and sheet-like masses ranging from a few feet to several thousand feet in thickness, generally conformable to the surrounding schists and mica gneiss, more rarely cutting obliquely across them. The hornblende gneiss bodies in the Ashland belt are as much as twenty miles in length and a mile or two wide, closely conforming to the structural trend. The bodies in the Opelika belt have a confused structure and sporadic occurrence, thus are not separately mapped. The gneiss weathers to a deep-red clay soil (Davidson soil series), sufficiently distinctive to be used for mapping in deeply weathered areas.

Hornblende gneiss is widely distributed over the entire area of crystalline rocks, and attains greatest development in the Carolina series, particularly in the Tallulah belt of Paulding County, and in the Wacoochee belt of Jasper and Putnam counties. Hornblende gneiss is unknown in the Little River series and rare in the Talladega, Brevard, and Pine Mountain series.

The hornblende rocks present considerable diversity in appearance. Detail mapping may show that two types can be recognized; fine-grained gneiss with close parallelism of hornblende crystals found mainly in the Ashland and Wacoochee belts, and coarse-grained gneiss gradational into diorite gneiss, found only in the gneiss facies of the Carolina series. Coarse-grained diorite is mapped separately in Cobb and Cherokee counties. The rocks of both types are generally similar in mineralogy. They contain green amphibole (mainly hornblende), quartz, plagioclase, and epidote. Garnet, biotite, apatite, clinozoisite, titanite, chlorite, calcite, and metallic sulphides are commonly present. The finer grained rocks contain more epidote and chlorite than the coarser varieties.

Hornblende gneiss in the Ashland belt occurring near the Whitestone fault has been reduced to fine-grained schist and phyllite, but recrystallization has effectively masked cataclasis. These very fine-grained rocks have needle-like crystals of hornblende as opposed to the relatively stout crystals in coarse-grained gneiss. The index of elongation of hornblende crystals (length divided by width) has a close correlation with the average diameter of interstitial minerals (mainly feldspar and quartz) as shown in figure 6. This figure does not include sections of gneiss obtained from gold or pyrite deposits for there, hydrothermal alteration has locally resulted in a coarsening of interstitial minerals and recrystallization of hornblende.

The hornblende gneisses are thought to have originated by intense metamorphism of igneous rocks of andesitic composition intruded as sills (rarely as dikes) parallel to the bedding

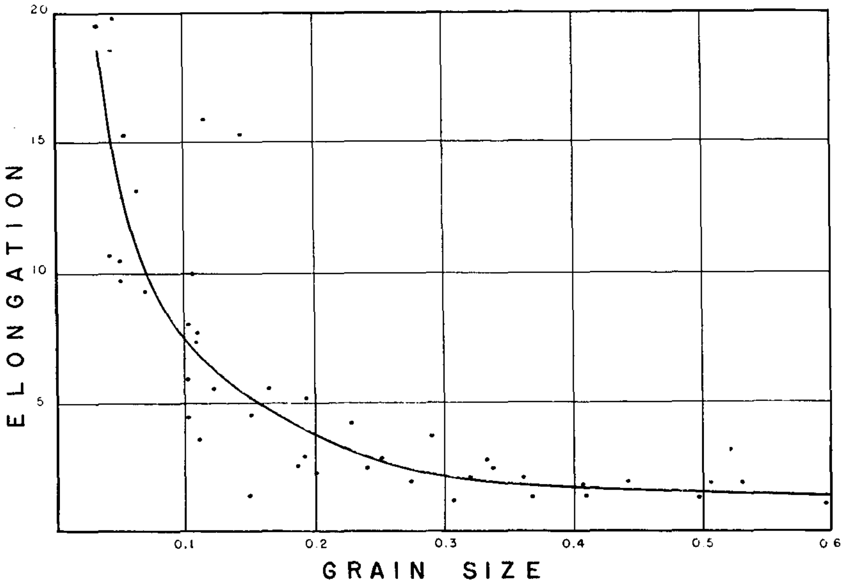

Fig. 8. Index of elongation of hornblende crystals compared to diameter of interstitial minerals in hornblende gneiss.

of the Carolina series. Hornblende gneiss within the Murphy marble at Tate, Cherokee County, may have originated by intense metamorphism of impure marble (Shearer and Hull, 1918, pp. 10-11), but more probably by contamination of the marble by basic magma (Bayley, 1928). Hornblende gneiss in western Cherokee County entirely surrounds marble and may be derived from impure calcareous beds.

Examination of the fine-grained hornblende gneiss in thin section shows it to be composed entirely of newly crystallized minerals with crystaloblastic texture. Amphibole, mainly pleochroic green hornblende, occurs in slender prisms whose index of elongation, that is the length divided by the width, ranges from 4 to 30. The prisms lie in nearly parallel orientation, marking the direction of schistosity. Some specimens, it is estimated, contain as much as 85% hornblende. Anhedral grains of quartz, epidote and plagioclase lie between and within the hornblende prisms. Minor constituents include biotite, orthoclase, apatite, clinozoisite, titanite, chlorite, calcite, magnetite, ilmenite, and metallic sulphides.

The coarse-grained gneisses are similar in mineralogy to the fine-grained varieties except that epidote is far less abundant. The gneissic structure is commonly dependent more on the interlayering of bands of slightly different composition than on the parallel orientation of minerals. In many places the hornblende, which is in stout prisms, has a haphazard orientation. Some of the rocks belonging in this group contain about equal proportions of feldspar and hornblende and have a gray "pepper and salt" appearance.

The coarse-grained hornblende gneiss shows in thin section persistent differences to the finer grained rocks. The hornblende is in stout prisms, with sieve texture. Plagioclase, andesine or labradorite, is abundant, commonly making up 15% to 35% of the rock. Epidote occurs mainly along the margin of the hornblende prisms suggesting reaction rims and is not as abundant as in the finer grained rocks. Quartz is also far less abundant being minor to plagioclase in all sections studied. The association of leucoxene with ilmenite, chlorite with biotite and hornblende, sericite with feldspar, and calcite with all minerals indicate the main alterations that have taken place. In some of the rocks the spongy porphyroblasts of hornblende are almost entirely replaced by later minerals.

The age of the hornblende gneiss is unknown. It appears to be correlative with the Roan gneiss of North Carolina (Keith, 1903; 1907), and this term has been applied in the Ellijay (LaForge and Phalen, 1913) and Tate (Bayley, 1928) quadrangles, and elsewhere in the state (Jones, 1909; Shearer and Hull, 1918). The gneiss is certainly older than the slightly metamorphosed, extrusive rocks of the Little River series. The fine grained hornblende schists have been traced into Alabama where they correspond to the Hillabee schist (chlorite schist) and to hornblende gneiss in the Ashland schist.

The following are analyses of the hornblende-rich rocks mapped as hornblende gneiss, schist, diorite, and gabbro.

Chemical Analyses of Hornblende Gneiss and Schist

	1	2	3	4	5	6	7	8
SiO_2	49.28	46.77	38.45	41.40	48.67	47.06	51.91	46.00
Al_2O_3	19.89	17.31	25.00	16.38	16.18	20.14	18.02	15.65
Fe_2O_3	1.60	2.24	9.08	7.16	10.18	8.24	2.38	.03
FeO	4.39	6.48	1.73	4.90	.78	4.02	6.42	10.53
MgO	7.40	10.44	7.48	1.13	7.82	3.95	5.69	6.31
CaO	13.22	12.24	15.00	25.62	10.68	10.12	11.00	12.35
Na_2O	2.05	2.40	.60	.40	2.71	4.34	.43	2.35

K_2O	.24	.21	.85	1.20	.03	.20	2.62	.03
H_2O—	.11	.01	.02	.05	.10	.10	.00	.09
H_2O+	.58	.69	.08	.30	.66	.38	.83	1.40
TiO_2	.30	.81	.50	.60	1.42	1.08	.71	1.38
P_2O_5	Tr.	Tr.	.50	.54	.03	....	.02	.00
S	.12	Tr.	.08	.04	.02	....	Tr.	.27
Cr_2O_3	.04	Tr.	....	....	....	....	....	....
NiO	.00	.00	....	....	....	....	....	....
CoO	.00	.00	....	....	....	....	....	....
MnO	.22	Tr.	.08	Tr.	.04	Tr.	.27	.73
Total	99.44	99.60	99.45	99.72	99.32	99.63	100.30	
							CO_2	3.66
					Total			100.78

1. Hornblende Gneiss (Hessose) Meckline Prop. 1½ mi. N. of Toccoa (Hopkins, 1914).
2. Hornblende Gneiss (Auvergnose) near Burton, Rabun Co. (Hopkins, 1914).
3. Epidote Gneiss, 5 miles East of Phinizy, Columbia Co. (Hopkins, 1914).
4. Hornblende Gneiss, 5 miles East of Phinizy, Columbia Co. (Hopkins, 1914).
5. Hornblende Gneiss, Burnt Hickory Ridge, Paulding Co. Collected by S. P. Jones.
6. Hornblende Schist, 3½ miles South of Dennis, Putnam County, Collected by S. L. Galpin.
7. Hornblende Schist, Creighton Mine, Cherokee County, Collected by S. P. Jones.
8. Hornblende Schist (Auvergnose) Base of Findley Ridge near Dahlonega (Hopkins, 1914).

Chemical Analyses of Quartz Diorite, Diorite and Gabbro

	1	2	3	4	5	6
SiO_2	48.42	41.65	46.87	46.00	73.56	63.87
Al_2O_3	19.46	26.54	14.36	15.65	17.27	19.75
Fe_2O_3	1.44	1.60	1.68	.03	.50	2.00
FeO	4.22	5.76	6.05	10.53	.14	.24
MgO	8.69	7.20	11.10	6.31	.10	1.12
CaO	11.66	13.48	15.50	12.35	1.87	5.20
Na_2O	3.29	.20	1.20	2.35	6.40	6.92
K_2O	.18	1.02	1.80	.03	.15	.53
H_2O—	.08	.10	.10	.09	.04	.02
H_2O+	1.06	2.00	.60	1.40	.05	.04
TiO_2	.60	Tr.	.30	1.38	.30	.63
P_2O_5	.15	.56	.19	.00	....	....
S	.10	tr.	tr.	....	....	....
SO_3	....	....	....	.27	....	....
Cr_2O_3	.08	....	....	....	....	....
NiO	tr.	....	....	....	.00	.00

CoO	tr.	....	....	....	.00	.00
MnO	.10	.00	.10	.73	.12	.25
CO_2	....	....	....	3.66	....	....
Total	99.53	100.11	99.85	100.78	100.50	100.57

1. Gabbro (Hessose) Ogeechee Brick Plant, Union Point (Hopkins, 1914).
2. Gabbro (Corsase) 8 mi. SE of Elberton (Hopkins, 1914).
3. Hornblende Gabbro, Bethlehem Church, 13 mi. E. of Elberton (Hopkins, 1914).
4. Sheared Diorite, Gainesville Road, Dahlonega, Lumpkin Co. Collected by S. P. Jones.
5. Quartz Diorite, 3 mi. NW of Jefferson, Jackson Co. Collected by S. L. Galpin.
6. Diorite, 3 mi. NW of Jefferson, Jackson Co. Collected by S. L. Galpin.

GABBRO

Gabbro occurs in dikes and small intrusive bodies cutting the Carolina series in the Amicalola, Tallulah, Dadeville, and Wacoochee belts. Gabbro dikes cut the Talladega series in Fannin County. Gabbro is most abundant (but not separately mapped) in the Wacoochee belt in Greene and Elbert counties. The gabbro is generally a medium to coarse-grained rock of greenish gray to black color, made up of calcic plagioclase and pyroxene (diallage). The great variety of secondary minerals include hornblende, anthophyllite, epidote, zoisite, chlorite, and talc. The primary pyroxene is in places entirely altered to hornblende.

LaForge and Phalen (1913) were of the opinion that the gabbro in Fannin County is Paleozoic in age, but this view is determined by their belief in the Paleozoic age of the Great Smoky formation which the dikes cut. The writer regards the Great Smoky formation as more probably pre-Cambrian, thus the age of the gabbros is unknown. According to Hopkins (1914), the occurrence of olivine gabbro and troctolite in Towns County points to a close relation to the ultramafic rocks next described. Both are clearly intrusive into the hornblende gneisses.

ULTRAMAFIC ROCKS

The ultramafic rocks of Georgia occur as small, more or less lenticular bodies, generally less than 200 feet across and 3,000 feet in length, with longer dimension parallel to the foliation of the intruded rocks. In mineralogy, they range from a rock composed entirely of olivine to one made up mainly of pyroxene, both monoclinic and orthorhombic varieties. According to Hopkins (1914), peridotites (harzburgite and lherzolite) are more common than the pyroxenites (enstatitite and websterite).

Ultramafic rocks occupy a very small part of the total area of crystalline rocks. They are most abundant north of the Brevard belt but a few bodies occur in the Dadeville and Kiokee belts. The reader is referred to the excellent report by Hopkins (1914) for location of bodies too small to indicate on the state map. Economic interest in the ultra-mafic rocks centers on associated deposits of chromite, anthophyllite, talc, and vermiculite.

GRANITIC ROCKS

Classification.—Watson (1902) divided the granitic rocks into an older group of gneissic rocks and a younger group of non-gneissic rocks. The older group is here further divided into augen gneiss (Corbin type), a granite gneiss (Lithonia type) in part porphyritic, garnet-pyroxene granite (Cunningham type); and the younger group further divided into the non-porphyritic (Stone Mountain type), and porphyritic (Palmetto type) granite.

Chemical Composition.—The chemical composition of the various granitic rocks in the state was found by Watson to be remarkably similar. He notes the distinctively high-soda content; twenty analyses of normal granite average 4.73 per cent soda and 4.71 per cent potash; twelve analyses of granite gneiss average 4.33 per cent soda, and 4.63 per cent potash. The granite gneisses are distinguished mainly by having much less lime than normal granite, 1.14 per cent to 2.16 per cent.

Age.—Although lacking direct evidence, Watson regarded the older granites as pre-Cambrian and the younger granites as epi-Paleozoic. Some of the older granites intrude formations (Talladega, Brevard, Pine Mountain series) thought by some to be Paleozoic, but here interpreted as pre-Cambrian. Thus the general relationships conform to, but by no means prove, Watson's interpretation.

More significance is attached to the time of intrusion in relation to the two periods of metamorphism to which the sedimentary rocks have been subjected. The older granites are associated with the first period of metamorphism; the younger granites followed the second period. Of the older granites, the evidence indicates that the Corbin type granite was intruded before or at the beginning of metamorphism; the Lithonia type during the waning of metamorphism; the Cunningham type near the end of metamorphism. This evidence involves consideration of structural and textural detail which is not within the scope of this general account.

Form of Intrusions.—The older granites of the Corbin and Lithonia types are largely concordant, whereas the younger granites are in general discordant. The bodies of older granite are commonly phacolithic, occupying both anticlinal and synclinal areas. The Snelson granite has the form of a series of coalesced lenses occupying the trough and flanks of a broad syncline in Meriwether County. A small mass of Lithonia granite forms a sill-like body in DeKalb County.

GRANITE AUGEN GNEISS (Corbin Type)

Corbin Granite.—Typical of granite augen gneisses in the state is the Corbin granite (Hayes, 1901) exposed in eastern Bartow and western Cherokee counties. The rock is generally a strongly gneissic aggregate of feldspar, smoky-blue quartz, biotite, augite, and garnet. Unoriented phenocrysts of microcline are abundant but are everywhere more or less modified. Some exhibit only a slight rounding of the corners and a tapering parallel to the orientation of dark minerals; others consist of "eyes" with fragmental trains; still others have been smeared out into thin layers as much as fourteen inches in length. In places a marked segregation of minerals into parallel bands and lenses, generally less than a quarter of an inch in width emphasizes the foliation. The Corbin augen gneiss is clearly intrusive into the surrounding Talladega series.

Augen gneiss similar to the Corbin granite occurs in Paulding County, west of Dallas, intrusive into Ashland schist.

Austell Granite.—Hayes' manuscript name of Austell granite is here applied to an augen gneiss exposed in an elongate area extending from Austell, Cobb County, southwestward across Douglas County, into eastern Carroll County. A small body of the same gneiss is exposed between Carrollton and Clem in southern Carroll County. The rock closely resembles the Corbin granite but generally lacks pyroxene. The "phenocrysts" or "eyes" are aggregates of microcline, micro-perthite, albite, and quartz, and have resulted largely from replacement. The "eyes" are abundant, ranging from 30 to 240 to the square foot of exposure.

Woodland Gneiss.—A coarse-grained biotite augen gneiss intrusive into the Pine Mountain series in the Warm Springs area has been called the Woodland gneiss (Hewett and Crickmay, 1937). This gneiss covers a large area in Upson and Monroe counties where it is intruded by the Cunningham granite.

BIOTITE GRANITE GNEISS (Lithonia Type)

Lithonia Granite.—A medium-grained, biotite-granite gneiss with strongly marked foliation exposed near Lithonia, DeKalb County, is here called the Lithonia granite. The foliation is due mainly to a segregation of minerals into thin dark bands made up mainly of biotite and rarely garnet, alternating with broader light bands containing abundant quartz and feldspar. The foliation is nearly everywhere contorted in the form of a series of parallel folds, commonly attenuate and recumbent, and broken by closely-spaced faults. Many of the faults are filled with granitic material, pegmatite or aplite, but this filling is gradational into the quartz-feldspar bands of the gneiss itself.

All the strongly gneissic granites have been mapped as of the Lithonia type, but considerable variations in mineralogy and texture suggest that several very distinct intrusions are included. In places the gneiss has modified phenocrysts of microcline similar to, but generally smaller than the eyes in the Corbin type. A distinctly porphyritic phase is mapped in Heard County where phenocrysts are in parallel alignment, in Gwinnett County where the rock approaches an augen gneiss (and may actually be a phase of the Greene County granite.) The "Toccoa Falls quartzite" (Galpin, 1915) is a fine-grained phase of the Lithonia granite.

Snelson Granite.—The Snelson granite is typically exposed in the Warm Springs area (Hewett and Crickmay, 1937). The rock closely resembles the Lithonia granite but oligoclase is generally more abundant than orthoclase. It is intrusive into the Carolina gneiss.

Salem Church Granite.—A light gray granite gneiss intrusive into the Talladega series in Pickens County has been named the Salem Church granite by Bayley (1928, pp. 103-108).

Hightower Granite.—The granite gneiss of the northeastern part of the Tallulah belt is a light gray to white gneissic granite, differing from place to place in coarseness of grain and in proportion of biotite present. The name Hightower was applied by Bayley (1928) for the granite in northwestern Forsyth County, but may be appropriately used for the granite gneiss on the southwestern side of the Ashland belt in Dawson, Lumpkin, and White counties. The granite is intrusive into the Carolina series and the contact is generally a broad zone of injection gneiss.

In the southwestern part of the Tallulah belt the granites generally contain more muscovite than biotite as exemplified by fine exposures near Villa Rica. This granite forms a complex injection gneiss over most of Paulding County.

GARNET-PYROXENE GRANITE (Cunningham Type)

Cunningham Granite.—The Cunningham granite, typically exposed in Talbot County (Hewett and Crickmay, 1937), is a dark-colored, porphyritic rock containing orthoclase, andesine, quartz, biotite, garnet, and pyroxene. The feldspar phenocrysts contain ground-mass minerals which appear to have grown amoeba-like by replacement. The unoriented phenocrysts are in places slightly modified by gneissic foliation, apparent only on the margin of the intrusions. This granite is known to occur only in Talbot and Upson counties, but it is similar to massive phases of the Corbin granite.

The Cunningham granite may be the same as the Corbin-type granite, and represent non-gneissic residuals, for the Cunningham intrusives are found only in augen gneiss, and their borders are in places gneissic. However, Hewett and Crickmay (1937) interpret the typical exposures as intrusive into and later than the surrounding Woodland augen gneiss.

GRANITE (Stone Mountain Type)

Nearly every belt of metamorphic rocks includes intrusions of equi-granular, non-gneissic granite, the largest of which are indicated on the geologic map. The prevailing rock is a gray, biotite-muscovite granite, but at some places, notably at Stone Mountain, muscovite predominates over biotite. The form of the intrusions in plan is roughly oval, but the longest dimension does not closely conform to the structural trend. In many places the granite can be seen to cut directly across the schistosity of surrounding rocks, particularly the Carolina gneiss and granite gneiss of the Lithonia type. A very large mass of granite in Elbert and Oglethorpe counties is in part bordered by an intrusive breccia.

PORPHYRITIC BIOTITE GRANITE (Palmetto Type)

The Palmetto type granite closely resembles the Stone Mountain type except that it includes many phenocrysts of feldspar, generally microcline. Good exposures occur south of Palmetto, Fulton County. In Greene and Elbert counties the Palmetto type is gradational into the Stone Mountain type and one appears to be but a phase of the other. In Greene County the porphyritic type predominates, whereas in Elbert county the equi-granular type is most common. In both areas the rock is extensively quarried.

The phenocrysts average one and a half inches in length and half an inch in width. In places they make up most of the bulk of the rock but Watson (1902, pp. 183-187) has estimated that the average proportion of phenocrysts to ground mass is in the ratio of 1:1.

DOLERITE

Dolerite and basalt occupy dikes striking north and northeast across the structural trend. The dikes range in width from a few inches to 300 feet, but average about 20 feet. Their length ranges from a few hundred feet to 34 miles, the length of a dike crossing Coweta, Meriwether, and Talbot counties. Most of the dikes are nearly vertical.

The dolerite is of the common variety found throughout the Appalachian piedmont. It ranges from aphanitic to medium-grained, and from dark gray to black. The dikes have generally been regarded as of Triassic age (McCallie, 1901).

MIXED ROCKS

GENERAL FEATURES

Nearly all the granite-gneiss bodies in the state have gradational contacts into surrounding schist and gneiss. Contacts shown on the map commonly approximate the position where dominantly intrusive rocks grade into injection gneiss. Two types of injection gneiss are common: granite and biotite gneiss, and granite and hornblende gneiss.

BIOTITE INJECTION GNEISS

The gneiss facies of the Carolina series nearly everywhere includes injection gneiss. The rock generally has a strong banding of dark, biotite-rich layers and light, quartz-feldspar layers, and this banding has a confused and disordered structure. Granite layers intruded parallel to the foliation range from tens of feet thick to thin stringers a quarter inch thick, commonly tapering off into a series of disconnected lenses. Where the contorted foliation is faulted, granite also is found along the fault but has indefinite borders.

Galpin (1915) has argued that the Lithonia type granite originated by granitization of the Carolina series. The granite gneiss, he claimed, differs from the Stone Mountain type granite only in that the former contains an inherited relict structure, in places represented by phantom streaks and recognizable inclusions of the intruded series. This view fails to account for the homogeneous character of the granite gneiss compared to the diverse assemblage of hornblende-rich and biotite-rich rocks in the intruded series. The chemical composition of the normal and gneissic granites do not conform to the idea that the gneissic varieties originated by partial assimilation of biotite and hornblende gneiss by the same magma giving rise to the normal granite.

HORNBLENDE INJECTION GNEISS

Two areas of hornblende injection gneiss are indicated on the state map: one in the extreme western part of the Uchee belt, the other in the northeastern part of the Dadeville belt. In both areas the rock consists of a coarse-grained diorite with innumerable injections of granite so that in some places the diorite is dominant, in other places granite is most abundant. Similar mixed rocks occur at Kennesaw Mountain, Cobb County, and extend northeastward into Cherokee County.

In some places hornblende gneiss is included in granite gneiss in angular blocks. Although the blocks locally have a dimensional parallelism, the well-developed foliation of hornblende gneiss in different inclusions is by no means parallel.

A very remarkable injection gneiss occurs in Paulding and Cobb counties, where hornblende gneiss is intruded by sheetlike masses of granite gneiss. The two rocks have been separated arbitrarily on the state map; actually all gradations may be found from dark-green hornblende gneiss with narrow, white feldspathic streaks, through a series in which the hornblende is embayed by a sugary quartz-feldspar aggregate, to biotite granite gneiss containing patches and nests of hornblende and epidote. In the passive insinuation of the granite magma upon the hornblende gneiss, the schistosity of the latter was not disrupted although it is commonly, sharply folded, and contorted. Aside from the addition of granitic materials, the main effect on the gneiss has been a marked coarsening of grain size.

STRUCTURAL GEOLOGY

METAMORPHIC STRUCTURES

Schistosity and gneissic foliation of sedimentary rocks have a prevailing northeast trend, but a marked deflection to the northwest occurs in Pickens and Dawson counties where the Whitestone fault bends to the northwest around the Corbin-Salem Church intrusive axis. Near overthrust faults, and in shear zones, there is a close adherence to the trend, particularly to the strike of the fault zone. But elsewhere marked deviations occur. Thus in the gneiss facies of the Carolina series, in the Amicalola, Tallulah, Dadeville, Uchee, and Kiokee belts, measured strikes can be found in almost all directions, and any individual measurement is almost meaningless. The dip of schistosity is generally to the southeast, but northwest dips are found in some belts, particularly near the Towaliga fault and in the Belair belt.

The schistosity of the sedimentary rocks is generally parallel to bedding, as indicated where contrasted rock types are interlayered.

Near faults and shear zones the schistosity is commonly strongly deformed into minute plications broken along one limb, giving a secondary cleavage across the schistosity. This secondary cleavage is in places so strongly developed that original schistosity is not evident. The scaly character of many of the schists (Brevard, Manchester, Ashland) has resulted from such secondary deformation of earlier formed structures. Shear zones commonly include schists with a strong linear element or fluting the direction of which is more constant than the strike of schistosity.

FAULTS

General Features.—The crystalline rocks are cut by a number of thrust faults which strike nearly parallel to the schistosity. Some of these faults (Cartersville, Whitestone, Towaliga) are marked by truncation of formations, but others are indicated only by microgranulation of rocks, and the development of mylonite (Dahlonega and Brevard shear zones, Goat Rock fault). The thrust faults all appear to dip to the south and southeast with dips ranging from nearly horizontal to 60 degrees, except the Towaliga fault which dips north about 50 degrees. Along the Towaliga fault, the banding of mylonite at the base of the overthrust block and secondary cleavage in schists which have been overriden are both parallel to the fault plane, but whether this relationship prevails with all other faults is questionable.

Cartersville Fault.—The Talladega series is thrust over the Paleozoic rocks of the Appalachian Valley along the Cartersville fault. At places where the Talladega phyllites are thrust onto fossiliferous shales (Connasauga) or limestone (Connasauga and Newala), the fault contact is generally clear cut. But where the lithology of rocks on both sides of the fault is similar, as near Cartersville, Bartow County, and near Chatsworth, Murray County, the fault is obscure. The position of the fault in Murray County is shown on the map in arbitrary position, for detailed work will be required to determine boundaries in this complex area. (Furcron, Teague, Calver, 1947).

The dip of the fault in most places is low to the southeast, but in the Cartersville district it probably averages 40 degrees. Generally low-grade metamorphic rocks make up the Talladega series next to the fault.

Whitestone Fault.—LaForge and Phalen (1913) have shown that the marble belt from Murphy, N. C., to Whitestone, Georgia, is cut by two strike faults, the most persistent of which they named the Whitestone fault. Bayley (1928) traced this fault southward to southern Cherokee County. Apparently the same fault continues to the southwest into Alabama, separating the Ashland-Wedowee series from the Talladega series. The continuity of this fault is not assured for only where formations in the Wedowee-Ashland belt are truncated is there positive evidence for its position. According to Adams, the fault in Alabama is marked by the outcrop of the Hillabee schist.

Dahlonega Shear-Zone.—The Wedowee-Ashland belt borders the Talladega belt southwest of Ball Ground, Cherokee County, but northeast of this town the two belts are separated by the southern end of the Blue Ridge (Amicalola belt). The Wedowee-Ashland belt everywhere bears the mark of intense differential movements, similar to that found along known major faults, but no distinct fault is known. The movement appears to have been distributed through the schists with the result that schistosity is deformed and earlier metamorphic minerals are in places cracked and granulated. A secondary (cataclastic) cleavage is common throughout the shear zone and locally is more prominent than schistosity. Thus, although the Ashland-Wedowee, and Canton formations are to be thought of as stratigraphic units, their lithology is partly the result of structural position. The Dahlonega shear zone has long been recognized as one of the most persistent gold belts of the state (Jones, 1909).

Brevard Shear-Zone.—A thrust fault is indicated on the geologic map approximating the southeastern border of the Brevard belt. This fault probably comprises several faults in a zone of distributed movement, indicated by strong development of secondary cleavage in schists and by mylonite gneiss originating from Lithonia type granite intrusive into the Brevard schist. The mylonite gneiss is well exposed in Fulton County, at Bolton, and in Hall County, between Gainesville and Lula. It is also well exposed near Rossman, North Carolina, near the typical exposures of the Brevard schist.

Towaliga Fault.—In contrast to the Dahlonega and Brevard shear zones, the northwest border of the Wacoochee belt is a sharply defined fault dipping steeply to the northwest. The fault has been traced from the Alabama state line northeastward into Jasper County. The fault is indicated by a narrow, but nearly continuous belt of mylonite whose banding dips to the northwest. A strong fluting both in the mylonite and in adjoining schists (Manchester) is directed at right angles to the fault.

Goat Rock Fault.—A well-marked zone of mylonite extends across Harris and Talbot counties marking the Goat Rock fault. The mylonite commonly has a strong cleavage due to orientation of comminuted biotite and muscovite flakes. The cleavage is parallel to banding, and both dip steeply to the southeast. The mylonite in places looks like a black slate but can be recognized megascopically by the abundance of plagioclase porphyroclasts. The Wacoochee belt of west-central Georgia includes many exposures of mylonite whose structural meaning is not known; much detail work must be done in this area, particularly in Harris County between the Goat Rock and Towaliga faults, to decipher the complexities of structure.

Normal Faults.—There are probably very few normal faults in the area of crystalline rocks. Distinctive beds, particularly quartzite formations, can be traced for tens of miles without displacements, and northwest-trending dikes are rarely offset.

FOLDS

One of the most striking contrasts within the crystalline rocks is the association of small, tightly compressed structures with broad, open structures. Thus, a broad anticlinal structure is found in the Talladega belt, extending from Bartow to Pickens county. Its axis is occupied by the Corbin and Salem Church granites. On the flanks of the uplift, particularly to the northwest, sharply recumbent, small folds prevail.

A broad anticline crosses Carroll and southwestern Haralson counties, and its axis is occupied by granitized Carolina gneiss, whereas the flanks are made up of crenulated schists of the Ashland and Wedowee formations. The northeastern part of the Tallulah belt is anticlinal (Prindle, 1935), and the southwestern part of the Wacoochee belt is anticlinal (Hewett and Crickmay, 1937).

CONCLUSIONS

The following conclusions are made:

1. The Ashland and Wedowee formations are a schist facies of the Carolina series. The lower part of the Talladega series (Great Smoky formation) is probably equivalent to the gneiss facies of the Carolina series. The Brevard, Pine Mountain, and upper part of the Talladega series are probably roughly equivalent to the upper schistose part of the Carolina series (Ashland and Wedowee formations).

2. The age of the metamorphosed sedimentary rocks is probably pre-Cambrian, except the Little River series which may be either late pre-Cambrian or lower Paleozoic. A review of the evidence has led the writer to favor a pre-Cambrian age for the Talladega series. If, as some authors have assumed, the Talladega series can be shown to be Paleozoic, then the writer would regard all the crystalline rocks as Paleozoic. No unconformity is found at the base of the Talladega, Brevard, or Pine Mountain series, all of which have by some authors been assigned to the Paleozoic.

3. Close correlation of metamorphic formations in Georgia can not yet be made with those in Virginia and Maryland. The Baltimore gneiss is seemingly not represented in Georgia, but the overlying Glenarm series is probably correlative with the Carolina gneiss of the Tallulah belt, and probably also with that of the Dadeville, Uchee, and Kiokee belts. The Lynchburg gneiss appears to extend southward and correspond to the Carolina series of the Amicalola belt. Recent evidence suggests that the Lynchburg gneiss is younger than the Wissahickon gneiss (Glenarm series), but no evidence has yet been found for an unconformity within the Carolina series.

The Little River series is equivalent to the Carolina "slate belt", which in turn may be equivalent to the Paleozoic Arvonia and Quantico slates of Virginia. The Quantico slate and volcanic series, exposed on Quantico Creek, west of Dumfries, Virginia, is closely comparable to the typical Little River series in southern Lincoln County, Georgia. No fossils have yet been found in the Little River series or in the "slate belt".

4. Most of the crystalline rocks have been subjected to two periods of metamorphism. The first, possibly in late pre-Cam-

brian time, was generally of high intensity, but there is a noticeable decrease in intensity toward the northwest border of the crystalline belt. The second period of metamorphism, possibly in late Paleozoic time, was of low intensity and resulted in degradation of earlier minerals and structures, particularly along major thrust faults. The most noticeable feature induced by the second metamorphism is a strong double cleavage in schistose rocks and micro-granulation of gneissic rocks.

5. The commonest igneous rocks of the state are hornblende gneiss and granite. The former has resulted from intense metamorphism of basic sills and dikes. The granites are of two general types; the gneissic varieties, which are probably old and intruded near the time of the first period of metamorphism; and non-gneissic granites, which are probably epi-Paleozoic. It is not always easy to distinguish between the older and younger granites where they are deeply weathered. The granite of Taliaferro County, intrusive into the Little River series, has been mapped as older granite, but it may quite well belong with the younger group. Many of the granites are porphyritic, but the phenocrysts (mainly microcline) are generally secondary and have grown by amoeboid replacement.

Many of the older granites have been greatly deformed and locally reduced to mylonite. The younger granites have nowhere been microgranulated, and thus are thought to have been intruded after the major thrust faults were developed.

5. Finally, it is concluded that there are many problems for which a full solution has not yet been reached, and thus the crystalline rocks are a promising field for further research. A definite contribution can be made by the detailed mapping of certain key areas, particularly the Fort Mountain area in Murray County, the Dahlonega area in Lumpkin County, and the Cartersville area in Bartow County. As much time as the writer has spent on the entire crystalline belt could be profitably used in any of these small areas.

Structural features can be profitably studied in the Wacoochee belt, particularly in Harris County, where the distinctive Hollis quartzite is a recognizable key bed. It would be very advantageous to know what relation exists between linear elements, minor folds, secondary cleavage and major structures. Injection gneiss merits more detail work, particularly in Paulding County, where a very broad belt of injection gneiss is well exposed. The granite intrusions, particularly Stone Mountain, are worthy of detailed work for as yet little is known of the structural features of the intrusives. The Little River series is as yet very incompletely known, and could be studied to advantage in McDuffie and Lincoln counties.

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