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DEPARTMENT OF MINES, MINING AND GEOLOGY
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THE GEOLOGY OF THE BREVARD LINEAMENT NEAR ATLANTA, GEORGIA

by
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LETTER OF TRANSMITTAL

Department of Mines, Mining and Geology

November 16, 1966

His Excellency, Carl E. Sanders
Governor of Georgia and
Commissioner Ex-Officio
State Division of Conservation
Atlanta, Georgia

Dear Governor Sanders:

I have the honor to submit herewith Bulletin 77 of the Department of Mines, Mining and Geology, entitled "The Geology of the Brevard Lineament near Atlanta, Georgia," by Michael W. Higgins.

The report is the expansion of work done for a Master's thesis at Emory University and partly sponsored at small expense by this department.

The Brevard rocks represent a belt of a low-grade metamorphic sedimentary series which is divided into formational units in this report.

In addition to the more academic uses, the mapping will assist in sampling the various rock units defined in the report so that their possible value to industries accessible to the Atlanta area may be determined. This study and future mapping of the Brevard rocks should guide the search for brick and tile clays, phyllites suitable for lightweight aggregate, and quite possibly other industrial minerals.

This bulletin will also be useful and important in the preparation of a new geologic map of Georgia.

Very respectfully yours,

A. S. Furcron
Director

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THE GEOLOGY OF THE BREVARD LINEAMENT NEAR ATLANTA, GEORGIA

ABSTRACT

The Brevard lineament is a conspicuous topographic feature extending from just northeast of Montgomery, Alabama, to the vicinity of Mount Airy, North Carolina. It is also a conspicuous magnetic lineament for a part of this course. In the Atlanta, Georgia area, it can be divided into two main belts of rocks: the Sandy Springs Sequence and the Brevard zone.

The Sandy Springs Sequence is a series of isoclinally folded, metamorphic rocks with a discernible stratigraphy. Evidence of sedimentary origin and top and bottom criteria were observed. The stratigraphic sequence can be determined from overall field relations and from two large folds. The lower unit in the sequence has probably been granitized. The rocks are in the staurolite-kyanite subfacies of the amphibolite facies. They show relic features and general lithologic characteristics indicating a warm, humid source area to the north-northeast. The sequence is believed to be correlative with the Tallulah Falls sequence about 80 miles northeast along strike.

The Brevard zone consists of retrograde rocks and cataclastic rocks believed to be the result of movement (right-lateral and reverse) on a major fault zone. These rocks can be divided into two main units or subzones characteristic of the top of the greenschist facies.

The Brevard zone and Sandy Springs Sequence contain major faults and en echelon-type faults, proved by a number of criteria. The major fault which separates the belts is named the Long Island Fault. Both belts contain blastomylonite dikes, and both are bounded for most of the area studied by distinctive natural units.

Latest movement on the Brevard zone probably took place before late Triassic, but later than about 280 million years ago. Mylonites along fault planes and a well-developed joint system cause apparent offset of modern streams.

The area has possible future economic value because of availability of good crushed-rock quarry sites, of dam sites for power and water supply and control, and of future park sites.

ACKNOWLEDGMENTS

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Professor R. J. Martin of Emory University suggested this project, helped with preparation of thin sections, gave advice, and served as an inspiration throughout the project.

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INTRODUCTION

The Brevard lineament is a conspicuous topographic feature extending from just northeast of Montgomery, Alabama to the vicinity of Mount Airy, North Carolina. It consists of narrow aligned valleys and linear ridges. (See U.S. Geological Survey 1:250,000-series quadrangles: Atlanta, Greenville, Knoxville, and Winston-Salem.) It was described in detail by Reed and Bryant (1964, p. 1177-1196). It is also a conspicuous magnetic lineament for at least part of this course (Philbin, Petrafeso, and Long, 1964).

The area studied covers approximately 225 square miles in Fulton, Cobb, Douglas, and Carroll Counties, Georgia and lies in the following U.S. Geological Survey 7½ minute-series quadrangles: Sandy Springs, Ga.; Bolton, Ga.; Mableton, Ga.; Ben Hill, Ga.; Austell, Ga.; Campbellton, Ga.; Palmetto, Ga. and Rico, Ga.; with a small part in the 15 minute Villa Rica, Ga., quadrangle. (See location map with geologic map—Plate I).

A generalized northwest-southeast topographic profile would show: a dissected plateau, a series of (2-5) narrow ridges and valleys, and a broader, deeper valley usually occupied by the Chattahoochee River. The average local relief is about 200 feet with a maximum of 430 feet. Maximum elevation is 1180 feet; minimum 700 feet.

The main drainage is the Chattahoochee River. Smaller streams and rivers drain from the northwest plateau and cross the ridges and valleys in a step-wise fashion to join the Chattahoochee. Streams joining the Chattahoochee from the southeast are not stepped (except in Sandy Springs Quadrangle where the river lies north of the ridges and valleys).

Much of the area is thickly wooded with a second growth of pines and deciduous trees. Cobb and Fulton Counties are densely populated but the rest of the area has sparse habitation.

GEOLOGIC INVESTIGATIONS

The rocks of the Atlanta area were described briefly by C. W. Purington (1894, p. 106-108). The geology was mapped by reconnaissance in 1939 by G. W. Crickmay (Georgia State Geologic Map) and described by him in 1952. A slightly more detailed study was made by Herrick and LeGrand in 1949, but they used Crickmay's map, and their chief interest was in ground water. Part of Douglas County was mapped by Eugene Schepis in 1952, but his work provides no structural data.

That part of Cobb County covered by this work was mapped in detail by James W. Smith in 1959 for the Georgia Department of Mines, Mining and Geology. His work, in closed file, was unavailable to the author.

Reed and Bryant have detailed the history of work on the Brevard zone as a whole (1964, p. 1179-1180).

SANDY SPRINGS SEQUENCE

The most conspicuous part of the Brevard lineament in the Atlanta vicinity lies not within Brevard rocks but in what is here named the Sandy Springs Sequence for exposures in Sandy Springs Quadrangle, Georgia. The Sandy Springs Sequence consists of structural and stratigraphic repetition of 4 rock units and has been mapped for 45 miles and followed in reconnaissance for another 40 miles.

ROCK UNITS

Gneiss-Schist-Amphibolite Unit—The basal unit in the Sandy Springs Sequence consists of gneiss, schist, and amphibolite intercalated in varying proportions. In most areas along strike gneiss predominates with schist and amphibolite occurring as pods and discontinuous layers, but locally schist and amphibolite predominate. The base of the unit is not found, so the thickness is unknown. Observed thickness is in excess of 1000 feet. The unit usually occupies the valleys.

The typical gneiss is a medium-grained, gray, biotite-quartz-microcline-oligoclase (An 12) rock with discontinuous striping (Barth and Reitan, 1963, p. 33) formed by extremely elongated minerals. In some outcrops, pink microcline augen showing well-developed cleavage are up to 7 x 4.5 cm. Locally, small red garnets are present. Other common accessories are muscovite, epidote, and opaque minerals. The content of biotite decreases toward the center of some outcrop belts and the rock resembles granite. The quartz content varies so greatly that the rock resembles a massive quartzite in places. Pegmatites cutting the gneiss are rare, concordant, and composed of pink microcline and quartz.

TABLE I

*Modal analyses of gneiss from the Gneiss-schist-amphibolite unit**

No.	1	2	3	4
Quartz	20.8	32.2	25.0	35.2
Microcline	35.2	21.6	10.6	8.4
Plagioclase	40.8	40.5	49.7	51.3
Biotite	2.7	4.3	9.3	1.5
Muscovite	0.6	1.6	5.4	3.6
Opaque minerals	Tr	Tr	Tr	Tr
Epidote	—	—	Tr	Tr
Garnet	—	—	—	Tr

The gneiss has a phacoidal texture (Heinrich, 1956, p. 185) in which thin trails of quartz-feldspar mortar anastomose between

*For all modal analyses 2000 or more points were counted except where otherwise noted. All analyses have been calculated to 100 percent.

feldspars. Quartz is strained and oligoclase shows bent twin lamellae and poikiloblasts which indicate rolling.

The typical amphibolite of this unit is medium- to coarse-grained, has a "salt and pepper" or stretched "salt and pepper" appearance, and is composed of hornblende, andesine (An 32-56), and quartz, with epidote and opaque minerals as common accessories and garnet and biotite as occasional accessories. Textures are granoblastic with well-developed foliation formed by nematoblastic hornblende. Veins of differentiated epidosites (Heinrich, 1956, p. 258-259) with pink feldspar are present in some outcrops.

TABLE II

Modal analyses of amphibolites (1, 2, and 3) and epidosite (4) from the Gneiss-schist-amphibolite unit

No.	1	2	3	4
Quartz	27.5	22.9	6.2	13.7
Plagioclase (An 32-56)	52.9	54.0	35.0	2.9*
Hornblende	14.4	18.0	50.4	—
Epidote	2.1	1.1	6.7	77.9
Garnet	0.5	0.8	Tr	—
Opaque minerals	2.6	3.1	1.0	4.9
Titanite	—	—	0.5	0.6
Zircon	—	—	0.2	—

The typical schist of the unit is a fine-grained biotite-muscovite-quartz schist with opaque minerals and garnet as accessories. Locally, large plates of muscovite are present.

The Gneiss-schist-amphibolite unit is believed to have originated by granitization and/or potassium metasomatism of an older sequence. The amphibolite and schist layers and pods represent the **paleosome** (Dietrich and Mehnert, 1961, p. 62; Hopson, 1964, p. 38); relics of a preexisting sequence. Barth and Reitan (1963, p. 32) described "vestiges" of older rocks in gneisses in Norway, and noted biotite enrichment of enclosed amphibolites with increasing granitization. Larson and Morris (1933, p. 92-93) described a simi-

*pink

lar situation in Massachusetts where hot ascending solutions had granitized a schist. They recognized a gradation whereby when the supply of solution was sufficient the schist was taken into solution leaving only relic pods of schist is what appeared to be granite. Gates and Sneider (1958, p. 1570) described a similar case in Connecticut.

Evidence for this origin is as follows:

1. The unit occurs in the centers of anticlines suggesting that it is the oldest unit and in a situation of relatively low pressure receptive to granitization.
2. The foliation, banding, and contact relations of the unit are concordant with the foliation of overlying units.
3. There is an increase in biotite content toward the edges of outcrop belts and locally amphibolite within the unit shows biotite enrichment.
4. The gneiss is usually coarser grained near the center of outcrop belts than near the edges.
5. Lineations and joint patterns in the unit conform to those of the other rocks of the area.
6. The gneiss is variable in composition within an outcrop belt.
7. Microcline occurs as augen elongated parallel to the foliation, indicating pre- or syntectonic origin.
8. Microcline sometimes shows evidence of having replaced plagioclase, indicating potassium metasomatism.
9. Microcline augen are not evenly distributed, indicating that the gneiss is not a metamorphosed porphyritic rock (Hopson, 1964, p. 44).
10. Myrmekite and perthite are present in the gneiss and are suggestive of the disequalibrium conditions of a metamorphic rock.

Lower Quartzite Unit—The Lower quartzite unit is present directly (and apparently conformably—p. 19) above the Gneiss-schist-amphibolite unit in most outcrops. Its absence in some cases (see geologic map—Plate I) could be due to tectonic thinning (p. 14), to non-deposition or facies change, or to erosion before deposition of the overlying unit. The fact that the absence occurs only on the overturned limbs of folds while normal thicknesses of quartzite outcrop are continuous on the normal limbs (only a relatively short distance away structurally and depositionally), and the fact that, when present, the rock exhibits striations, "pencil structures" and other evidence of stretching on these overturned limbs, suggests that its absence is due to tectonic thinning and elimination.

The unit consists of quartzite, micaceous quartzite, feldspathic quartzite, ocherous saprolite, and muscovite schists and varies in thickness from about 20 to about 140 feet. It is usually found on the flanks or tops of ridges.

The quartzite is typically massive, blocky, and varies in color from nearly pure white, through yellow, to blue. It is from 1 to about 40 feet thick. It contains small amounts of mica and usually smeared, elongated red garnets, and varies in appearance from saccharoidal to vitreous. The texture ranges from granoblastic to blastopsammitic. Quartz and muscovite are the major constituents with biotite, hornblende, epidote, opaque minerals, zircon, titanite, and garnet as sporadic accessories. The mineralogical composition of the quartzite fits what Pettijohn (1957, p. 296-297) called orthoquartzite.

TABLE III

Modal analyses of quartzite from the Lower quartzite unit

No.	1	2*	3
Quartz	94.1	84.2	96.9
Muscovite	3.4	0.3	2.9
Biotite	—	1.6	—
Hornblende	—	5.8	Tr
Opaque minerals	1.9	Tr	0.2
Epidote	0.3	7.5	Tr
Zircon	Tr	0.2	—
Titanite	0.3	0.4	—
Garnet	—	Tr	—

The quartzite changes along strike into micaceous quartzite, a less mature (Pettijohn, 1957) version of quartzite. Hopson (1964, p. 63) wrote of the micaceous quartzites in the Setters formation,

* only 1127 points

"The abundant muscovite in many of the quartzite beds shows that the original sand was mixed with argillaceous material, which suggests that the sediment was not well-sorted." The lateral gradation of quartzite into micaceous quartzite has been explained by Nasu (1954, p. 1290) as a normal sedimentary phenomenon.

Aluminous Schist Unit—The Aluminous schist unit consists of kyanite and/or staurolite schist with interbedded quartz-muscovite schist and thinly-bedded red micaceous quartzites. Quartzose amphibolites are a very minor inconsistent constituent.

Typical fresh kyanite schist is a lustrous, light gray schist (and/or gneiss) composed of quartz, biotite, muscovite, oligoclase (An 14-16), garnet, and kyanite, with very minor opaque mineral. Kyanite occurs as blue, bent, euhedral porphyroblasts, and staurolite is sometimes present. Purple-pink garnets are universally present, but their abundance varies greatly. Fresh rock is confined to deep cuts and the more typical rock is a reddish-mottled biotite-kyanite-garnet-muscovite-quartz schist. Biotite and plagioclase have been largely lost in solution during weathering and iron oxides produced.

TABLE IV

Modal analyses of kyanite schist from the Aluminous schist unit

No.	1	2	3	4	5	6	7
Quartz	41.6	33.2	46.2	38.5	61.7	39.7	46.1
Plagioclase	25.1	25.3	11.9	17.0	18.4	2.2	7.7
Biotite	12.1	18.1	15.6	20.3	5.5	17.1	9.7
Muscovite	16.2	19.0	23.0	20.2	11.9	34.9	29.7
Garnet	3.8	1.4	1.3	1.4	2.4	2.1	2.1
Kyanite	—	2.2	—	1.1	—	2.0	2.1
Opaque minerals	1.2	0.9	2.0	1.5	0.1	3.0	2.8
Epidote	—	—	—	—	—	Tr	—

Nos. 6 and 7 weathered.

TABLE V

Modal analyses of staurolite schist from the Aluminous schist unit

No.	1	2	3	4*
Quartz	47.4	56.7	46.9	60.8
Plagioclase	18.5	18.2	25.1	28.4
Biotite	12.5	8.0	16.5	9.6
Muscovite	20.8	11.8	9.8	0.5
Garnet	0.6	5.3	0.9	—
Opaque minerals	0.2	0.5	0.4	0.7
Epidote	—	0.3	0.3	Tr
Staurolite	Tr	0.2	0.1	—

The kyanite schist has a lepidoblastic texture with strained quartz, bent plagioclase twin lamellae, and bent kyanite indicative of cataclasis.

Interbedded with the Aluminous schist is an opaque mineral-biotite-muscovite-plagioclase-quartz schist (gneiss in many outcrops). It is quite thick in Mableton and Campbellton Quadrangles, Georgia and forms a broad high ridge.

Thickness of the Aluminous schist unit is uncertain due to probable structural repetitions within an outcrop belt, but a reasonable estimate would be about 1500 feet.

The mineral and chemical compositions suggest that the aluminous schists were originally aluminum-rich pelitic sediments (Clarke, 1924, p. 552, 554; Pettijohn, 1957, p. 106; Harker, 1939, p. 224-226; Shaw, 1956, p. 919-934).

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*quartz-rich phase.

TABLE VI

Chemical analyses of kyanite and staurolite schists, Aluminous schist unit

No.	1	2
SiO_2	70.94	77.11
TiO_2	0.80	0.60
Al_2O_3	12.90	10.59
Fe_2O_3	0.63	0.70
FeO	5.96	3.78
MnO	0.05	0.03
MgO	2.25	1.37
CaO	1.33	0.68
Na_2O	1.47	1.18
K_2O	2.25	1.98
Moisture @ 100 C	0.03	0.07
Loss on ignition	0.89	1.54
P_2O_5	0.14	0.00
SO_3	0.36	0.37
Total	100.00	100.20

Analyses by Dr. L. H. Turner, Chief Chemist, Georgia Geological Survey, 1964.

No. 1—staurolite schist on Riverside Dr. about ½ mile south of Johnson Ferry Rd., Sandy Springs Quadrangle.

No. 2—kyanite schist on the Perimeter highway just east of U.S. 41, Sandy Springs Quadrangle.

Upper Quartzite Unit—The Upper quartzite unit is usually a relatively pure quartzite with muscovite as the only major accessory. Locally plagioclase, epidote, and opaque minerals are present. The unit averages about 40 feet in thickness and generally occupies the crests of ridges. Outcrops are continuous for from 2 to 6 miles. This is the youngest unit in the sequence and is folded double with aluminous schist on either side.

Mineralogically it would correspond to Pettijohn's (1957, p. 296-297) orthoquartzite.

TABLE VII

Modal analysis of the Upper quartzite

Quartz	84.8	Opaque minerals	1.0
Muscovite	13.6	Epidote	0.4
Plagioclase	0.2	Titanite	Tr
Biotite	—	Zircon	—

SEDIMENTARY FEATURES IN THE SANDY SPRINGS SEQUENCE

Ball and Pillow Structures—Large (average 4 feet x 2½ feet) oblate inclusions of quartzite are found at some localities in the lower portion of the Aluminous schist unit. They are found in beds which show no evidence of boudinage. The inclusions bear a close resemblance to sedimentary ball and pillow structure (Pettijohn and Potter, 1964, Plates 100-104, p. 285). Besides adding to the evidence for sedimentary origin of the rocks, if the features are relic ball and pillow structures they suggest a somewhat unstable depositional environment.

Rhythmic Graded Bedding—The Lower quartzite unit contains micaceous quartzites and interbedded muscovite schist. The two lithologies alternate, and the bottoms of the quartzite beds have sharp contacts while the tops grade into quartz schist which grades into muscovite schist. This probably represents original grading of rhythmic bedding; sandstone-siltstone-shale (Pettijohn and Potter, 1964, Plates 5-9; Shrock, 1948, p. 80; Gorsline and Emery, 1959, p. 279; Cohen, *et al*, 1963, p. 1355). In many outcrops the tops of the schist beds contain large garnet porphyroblasts. This "reversal" in grain size due to growth of metamorphic minerals has been described by James in Michigan (1955, p. 1465), and by Hurst in Georgia (1955, p. 17-18, 69-70), and has been called "reversed" graded bedding by Shrock (1948, p. 423).

STRUCTURE

Sander's symbols as outlined by Cloos (1937, p. 62) are used in addition to the usual names applied to planar structures (bedding S_1, foliation S_2, cleavage S_3) and his coordinates as defined by Cloos (1946, p. 5) are also used.

Lineations—Lineations were separated into mica lineations, elongated minerals, small folds (less than 8 feet from limb to limb) and crenulations, and striations. Lineations taken as a whole show a wide spread of bearings and plunges indicative of non-uniform or multiple deformation (Cloos, 1946, p. 44-45). Most of the lineations in this area tend to trend parallel to the strike of the rocks (N 35-55 E), or approximately normal to this direction. As the Brevard zone is approached they tend to swing into line with its strike.

Boudinage—Boudinage is fairly common in the rocks of the Sandy Springs Sequence and has been shown on the map where well-developed. It appears to be what has been called the "far advanced stage from highly mobilized terrane" (Cloos, 1947, p. 630-631). It occurs in both the *a* and *b* directions. The indicated extension parallel to *b* possibly results from movements associated with the nearby Brevard zone (also parallel to *b*).

Third order folds and Crenulations—Small folds and crenulations in the Sandy Springs Sequence show the same general maxima as the lineations in the whole area. They fall into the two categories: isoclinal and overturned to the northwest, and open, gentle cross-folds.

Second order folds—These are folds which are from 8 to 100 feet from limb to limb. The majority are open cross-folds.

First order folds—The most persistent folds of the area are two parallel, isoclinal (overturned to the northwest) synclines and the intervening anticline. Their axes strike north 35-55 east and run almost the length of the map. They have been traced by reconnaissance for about 10 miles northeast beyond the area mapped. The northwestward-most syncline occupies the first ridge southeast of the "plateau" and has Aluminous schist (kyanite schist) in its center. Immediately southeast of this is a tight, valley--forming anticline with Gneiss-schist-amphibolite in its center, followed by a larger syncline occupying the next ridge with Upper quartzite in its center. In some cases the Lower quartzite of one limb of the anticlines is thinned or absent due to stretching

(Goguel, 1962, p. 133; De Sitter, 1964, p. 203) (see geologic map—Plate I; particularly the cross sections).

Plunges of *b* lineations near the centers of the folds indicate very low plunges of the axes (less than 10 degrees). Reconnaissance indicates that a large anticline (Gneiss-schist-amphibolite center) may occupy the area just northwest of the map (north of Sandy Springs, Bolton, and Mableton Quadrangles), so that the Lower quartzite unit may be correlative with some of the quartzites mapped by Hurst (1952) in the Kennesaw Mountain-Sweat Mountain Area.

Vinings Anticline—The only fold in the area with a mappable nose is here named the Vinings Anticline because of its proximity to the small community of Vinings, Georgia. It is a southwestward plunging anticline in which beds of Lower quartzite wrap around Gneiss-schist-amphibolite. Typical Aluminous schist (kyanite schist) outcrops on both limbs above the Lower quartzite and wraps around the nose outside the quartzite. Bedding (S_1) wraps around the nose of the fold, but foliation (S_2) is not parallel to the bedding and only turns slightly so that it crosses the nose of the fold. This suggests that the fold may be a pre-foliation feature. These relations are shown in Figure 1. (also see geologic map—Plate I).

Additional confirmation of the stratigraphic sequence observed in the Vinings Anticline is found in an S-shaped undulation of the three parallel folds (p. 14-15) in Chamblee Quadrangle, Georgia (U.S. Geological Survey 7½ minute-series, 1954). This fold is outside the area mapped, but was studied for stratigraphic purposes.

Faults—A transverse thrust fault is present on the northwest limb of the southeastern-most syncline (Geologic map—Plate I). It is marked by a thin zone of cataclastic rock and by development of a characteristic foliation and jointing in the rocks resembling "platy jointing" (Hills, 1963, p. 364). The fault crosses kyanite schist and micaceous quartzites of the Aluminous schist unit. Microscopically it causes slight crushing, extreme alignment, and buckling of micas.

The Long Island Fault—The fault separating the biotite-plagioclase gneiss (to be described later) of the Brevard zone from the Sandy Springs Sequence is here named the Long Island Fault because its trace occupies the valley of Long Island Creek for about 6 miles (Geologic map—Plate I). It has been mapped the entire

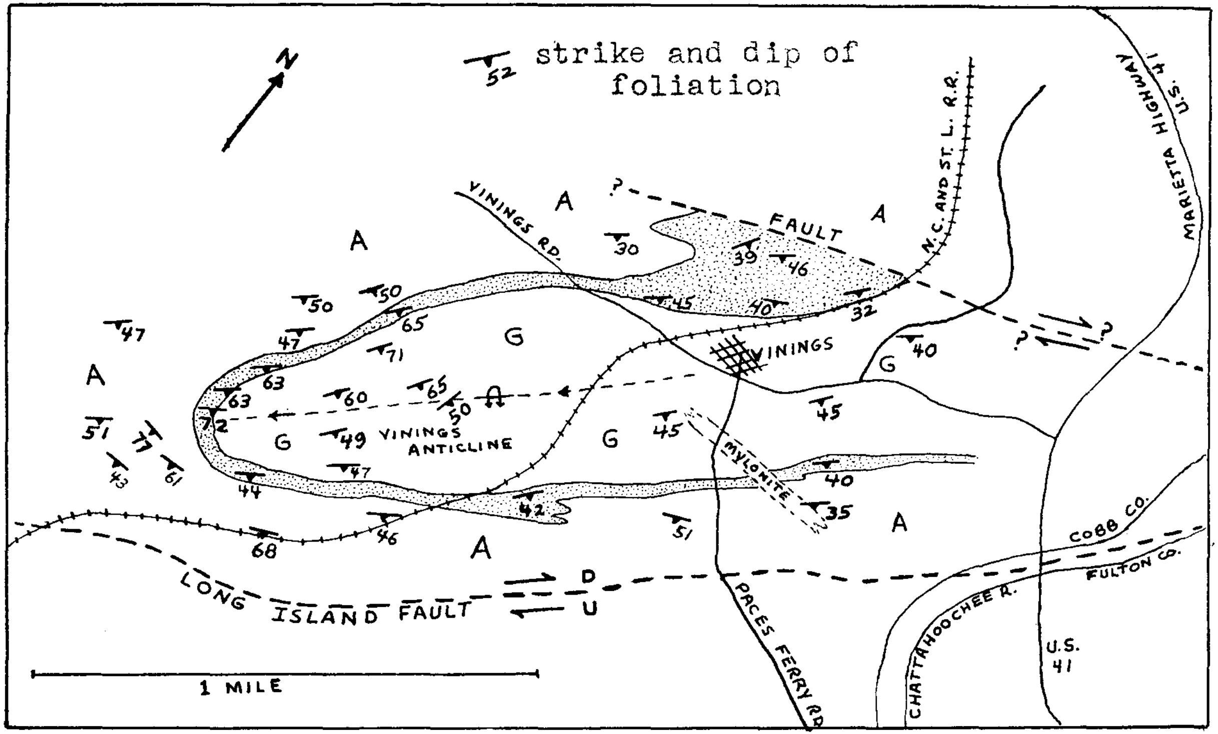


Fig. 1. Sketch map of the Vinings Anticline, with Gneiss-schist-amphibolite (G) in center of fold and Aluminous schist (A) on limbs. Lower quartzite is stippled.

length of the area, and southwest of the outcrop of the biotite-plagioclase gneiss it separates Brevard button schists from Sandy Springs Sequence rocks. The fault is marked by the following features:

1. Its trace is unusually straight and is usually marked by rectilinear valleys or by the Chattahoochee River valley.
2. The rocks on either side of the fault increase in deformational character as the trace is approached, and the trace is usually marked by cataclastic rocks (mylonite gneiss, breccia, flinty crushrock, and/or blastomylonite).
3. Intensity and amount of jointing increase as the fault is approached from either side, and locally (Higgins, 1965, p. 80, 83) joint poles rotate in sympathy with movement on the trace.
4. The number and distribution of blastomylonite dikes agree with a fault at this line.
5. The biotite-plagioclase gneiss is never found northwest of the trace.
6. As stated above, the trace separates two distinct series of rocks.

The character of the movement is not definitely known. The long straight trace suggests strike-slip (De Sitter, 1964, p. 159-160; Reed and Bryant, 1964, p. 1192-1194), and the swing of the lineations on the northwest side of the fault suggests right-lateral movement. Southeastward-plunging subhorizontal lineations and the attitude of the rocks on the southeast side of the fault suggest reverse movement with the southeast side moving up with relation to the northwest side. Probably, the fault had both components as is often the case (De Sitter, 1964, p. 160; Reed and Bryant, 1964, p. 1194; Moody and Hill, 1956, p. 1214-1216; Kennedy, 1946, p. 41-76), and a history of multiple movements.

Most of the narrow rectilinear valleys in the Sandy Springs Sequence are probably fault zones and many possess most of the features of the Long Island Fault.

Branches or "barbs" (De Sitter, 1964, p. 148) from the Long Island Fault are not uncommon and one such fault cuts off the Vinings Anticline (Fig. 1). Outcrop pattern and relation to the Long Island Fault suggest that this fault had right-lateral movement also.

Joints—The rocks of the Sandy Springs Sequence have a well-developed joint system (Higgins, 1965, p. 79-80). Apparent offset ("stepping") of streams and of the Chattahoochee River is usually due to their following joints or enlarged master joints (Noe-Nygaard, 1963, p. 17-19), and not to late faulting as has been proposed by some authors.

METAMORPHISM

The rocks of the Sandy Springs Sequence belong to the amphibolite facies, and have assemblages stable in the staurolite-kyanite subfacies (Turner and Verhoogen, 1960, p. 502-507, 531-560). Kinetic metamorphism is common. Evidence of movement includes: extremely strained quartz, two generations of garnets (one deformed) (Higgins, 1965, p. 17), granulation and cataclastic textures in some units, microfaulting, bending of grains, and bent twin lamellae in plagioclase. Kinetic metamorphism was probably later than regional metamorphism since recrystallization would have obliterated much deformation evidence.

DEPOSITION

Gneiss-schist-amphibolite unit

Because the Gneiss-schist-amphibolite unit has probably undergone granitization with introduction of substantial amounts of K_2O, any discussion of its original character must be speculative. The schists are composed mostly of muscovite and quartz (biotite is usually less than 5 percent), but they are usually thoroughly weathered and easily weatherable constitutents may have been removed. The amphibolites vary in composition; again, granitization and/or weathering may have considerably altered their original characters. However, the association of amphibolites with muscovite-rich schists suggests: a) a sequence of graywackes, arkoses, or shales with interbedded calcareous shales, or b) a sequence of altered marine volcanic sandstones with thin interbeds of palagonite tuff or other mafic marine volcanic rock. According to Hopson (1964, p. 35) interbeds of mafic rock are atypical for graywacke sequences. Therefore it seems quite possible that the Gneiss-schist-amphibolite unit was originally a sequence of marine volcanic sediments similar to those described in Washington and Oregon by Wells and Waters (1935), in Washington by Fiske, Hopson, and Waters (1963), in Japan by Fiske and Matsuda (1964), and in New Zealand by Coombs (1954).

Contact, Gneiss-schist-amphibolite unit—Lower quartzite unit.

The thorough granitization and/or potassium metasomatism of the Gneiss-schist-amphibolite unit and the lack of features suggesting these processes in the overlying units indicates the possibility of an unconformity between this basal unit and the directly overlying Lower quartzite unit. At every observed contact the two units are apparently concordant, but this cannot discount the possibility that the contact might be an unconformity erased by later metamorphism (Hopson, 1964, p. 56-57).

Lower quartzite unit

The Lower quartzite unit consisted originally of an alternating sequence of orthoquartzite (Pettijohn, 1957, p. 296-297), siltstone, and shales (probably fairly rich in iron and alumina). According to Pettijohn (1957, p. 299), "The high quartz content and the excellent sorting and rounding exhibited by the orthoquartzitic sandstones is indicative of a high degree of textural and mineralogical maturity. These rocks are obviously the end product of protracted and profound weathering, sorting, and abrasion. In order for there to be sufficient time to achieve these results it is imperative either that the source area and site of deposition be tectonically very stable or that the sand go through several cycles of sedimentation." The interbedded shales might indicate a low, deeply weathered source area. The rhythmic alternation might result from cycles of climatic change or from slight tectonic disturbances of the source area periodically. The relative thinness of the unit would also seem to substantiate the above conditions.

Aluminous schist unit

The kyanite and staurolite schists of the Aluminous schist sequence were derived from aluminous shales as is shown by their high alumina/alkali and potassium to sodium ratios (Turner and Verhoogen, 1960, p. 545; Hopson, 1964, p. 83; Pettijohn, 1957, p. 106; Shaw, 1956, p. 919-934). They were probably deposited in a nearly-full basin, from a low, peneplaned, humid source-area, in which possible lateritic weathering was taking place (Pettijohn, 1957, p. 510-511, 358-360; Hopson, 1964, p. 123-124, 129; Rankama and Sahama, 1950, p. 209). According to Pettijohn (1957, p. 368), "Sedimentation following slight rejuvenation should be marked by the deposition of highly aluminous shales."

Upper quartzite unit

The Upper quartzite would represent a return to the conditions of deposition of the Lower quartzite.

BOUNDARIES

The boundary of the Sandy Springs Sequence on the southeast is the Long Island Fault. On the northwest the sequence is bounded for about half the length of the map by Austel Granite Gneiss (Hayes, 1901, p. 403-419). This rock has been described by Crickmay (1952, p. 41-42), and by Schepis (1952, p. 12, 18-26). Both considered it to be a metamorphosed rock and not one of the "later" granites (i.e., like Stone Mountain granite). I concur with their observations. It was not studied intensively for this project but was simply mapped as a natural boundary unit. Its contact with the Gneiss-schist-amphibolite unit is usually quite sharp.

INDEPENDENT LITHOLOGIES

Layered Amphibolite—Layered amphibolite crops out in continuous irregular belts up to 10½ miles long and ½ mile wide. It is finely layered and the layers are different in composition. In some outcrops the layers can be traced for hundreds of feet. The rock is composed of hornblende, plagioclase, quartz, and epidote, with garnet and titanite as accessories. It has a granoblastic texture. One outcrop belt contains intercalated specularite quartzite for about 4 miles of its length (Geologic map—Plate I).

TABLE VIII

Modal analyses of the Layered amphibolite

No.	1	2	3	4
Hornblende	58.3	59.9	57.1	62.0
Quartz	3.7	3.7	4.3	4.5
Plagioclase	29.2	28.2	33.8	28.4
Epidote	8.4	7.7	4.2	5.0
Titanite	0.3	Tr	0.4	Tr
Garnet	—	—	02	Tr

TABLE IX

Chemical analysis of the Layered amphibolite

SiO_2	56.39	K_2O	0.30	
TiO_2	0.60	Moisture @ 100 C	0.37	Analysis by Dr. L. H. Turner, Chief Chemist, Georgia Geological Survey, 1964.
Al_2O_3	15.67	Loss on ignition	0.35	
Fe_2O_3	3.26	P_2O_5	0.07	
FeO	8.11	SO_3	0.00	Sample from outcrop at Johnson Ferry Rd. and the Chattahoochee River, Sandy Springs Quadrangle.
MnO	0.18	Total	100.00	
MgO	4.01			
CaO	8.19			
Na_2O	1.60			

From its chemical composition the Layered amphibolite could be either a shale (dolomitic) or an igneous rock (Pettijohn, 1957, p. 106; Clarke, 1924, p. 552-560; Johannsen, 1932, p. 300-351, 142-158; Poldervaart, 1953, j. 259-270; Shaw, 1956, p. 919-934; Leake, 1963, p. 1193-1202). The regularity and continuity of the banding suggests a sedimentary or pyroclastic origin (Hopson, 1964, p. 31; Dietrich, 1959; Engel and Engel, 1963, p. 349-354). Although equally regular and continuous compositional banding has been observed in igneous rocks (Hess, 1960, p. 51, 133; Ruckmick and Noble, 1959, p. 983; Van Biljon, 1949, p. 193-194; Wager and Deer, 1939; Hopson, 1964, p. 135, 137), but all of these rocks are more mafic than the Layered amphibolite, and in some, opaque minerals (magnetite, ilmenite, chromite) are involved in the layering. From the modal and chemical compositions listed above, it is probable that the layered amphibolite was either a sedimentary rock or a volcaniclastic sediment. The unusual richness of some bands in quartz and the continuity of the unit along strike also suggest this origin.

Altered Ultramafic Rocks—Altered ultramafic rocks occur in the Sandy Springs Sequence. They are generally concordant and tend to occur at contacts, but one occurrence in Bolton Quadrangle, Georgia is a discordant dike. The ultramafic rocks vary greatly in mineral composition, but generally contain a center zone of chlorite and actinolite with surrounding amphibole bearing rocks. One layer in Mableton Quadrangle, Georgia is composed of talc and anthophyllite, and was mapped by Hopkins (1914, p. 47-48) as harzburgite.

TABLE X

Modal analysis, dike, altered ultramafic rock, Vinings, Georgia

Clinochlore	37.5	Magnetite	1.7
Actinolite	60.8	Analysis by W. H. Grant	

One fact should be noted about the ultramafic rocks: so far as I can determine they are far less numerous southeast of the Brevard zone, and they are never found in the Paleozoic rocks of the Valley and Ridge Province (Tectonic Map of the United States, 1962; Geologic Map of Georgia, 1939; Geologic Map of North Carolina, 1958; Geologic Map of Tennessee, 1966; Geologic Map of Alabama, 1926)*. The possible significance of this will be discussed later.

Graphite Schist—Extremely graphitic schist outcrops as thin (less than 10 feet thick) layers in the Aluminous schist unit, (kyanite schist). The layers are thought to be continuous but have not been shown on the map where unexposed (Geologic map —Plate I). The schist is muscovitic, quartzose and fine-grained. The graphite is possibly of organic origin (Rankama, 1948, p. 389; Bayley, 1928, p. 46; Harker, 1939, p. 49; Rankama and Sahama, 1950, p. 541; Eskola, 1963, p. 166).

*Some of the bodies mapped as ultramafic rocks in Georgia are probably altered gabbro, i.e., the Soapstone Ridge body south of Atlanta—in contrast to the small "alpine" ultramafic rocks in question here.

POSSIBLE CORRELATIONS

The Sandy Springs Sequence was traced northeast by reconnaissance through the Chamblee Quadrangle, Georgia (U.S. Geological Survey, 7½ minute-series, 1955). The writer has examined the rocks in Forsyth County (along strike, 40 miles northeast of the boundary of this study) and the unpublished map of Willis A. Holland, Jr. Although Holland did not produce a cross section or a stratigraphic sequence, the areal distribution pattern and the lithologies are believed to be correlative with the Sandy Springs Sequence.

In 1952, Crickmay (p. 9-10) wrote:

> "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 **(Lower quartzite of the Sandy Springs Sequence).** A similar quartzite occupies the central part of a broad anticlinal area in Habersham and Rabun Counties, named Tallulah Falls quartzite by Galpin (1915). The upper part of the Tallulah Falls quartzite, exposed at Mathes Dam, is interlayered with garnet-biotite gneiss." (**underlined,** in parenthesis is mine).

He goes on to describe the garnet-biotite gneiss:

> "Examined under the microscope, the biotite gneiss is found to consist of quartz, plagioclase (oligoclase to andesine), biotite, orthoclase, muscovite, and garnet, named in the order of their abundance. Accessory minerals include apatite, titanite, zircon, magnetite, zoisite, epidote, kyanite, sillimanite, hornblende, and tourmaline."

On Furcron and Teague's (1948) map of Rabun and Habersham Counties they show a broad anticlinal dome with "biotite and muscovite gneisses and schists (include some hornblende gneiss)" at the center, overlain by Tallulah Falls quartzite, with "kyanite-mica-garnetiferous schist with or without graphite" on the limbs. Part of their cross section is reproduced below.

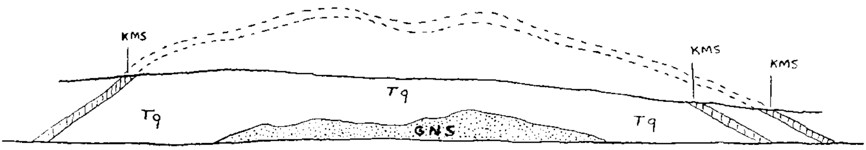


Fig. 2. Part of Furcron and Teague's (1948) cross section. GNS= gneiss, Tq = Tallulah Falls quartzite, KMS = kyanite schist.

Thus, by the work of several geologists we can extend the Sandy Springs Sequence from southern Douglas County to Habersham County (a total distance along strike of about 125 miles). I believe the Lower quartzite of the Sandy Springs Sequence is the same as Tallulah Falls quartzite, the Gneiss-schist-amphibolite unit is the same as the gneiss unit of Furcron and Teague (1948), and the Aluminous schist unit is the same as their kyanite-mica-garnetiferous schist. If this correlation is correct, it means that the quartzite was probably derived from the north-northeast and/or northwest because of differences in gross thicknesses.

THE BREVARD ZONE

The Brevard is a zone (½ to 2½ miles wide) of button schists, low-grade metamorphic rocks, cataclastic rocks, and blastomylonite, bounded on the northwest by a thin belt of mylonite gneiss and breccia and on the southeast by a sheared zone of Palmetto granite.

ROCKS OF THE BREVARD ZONE

Button schists—Button schists crop out in subzones within the Brevard zone. They are generally magnetite-(and/or graphite)-biotite-quartz-muscovite schists with a distinctive wavy secondary cleavage (S_3) causing buttons (Crickmay, 1952, p. 26) upon weathering. Locally, thin layers of fine-grained biotite gneiss are intercalated with the schists. This subzone may be comparable to the rocks described by Reed and Bryant (1964, p. 1187) adjacent to the main Brevard zone in North Carolina.

Phyllonites—Phyllonites (Knopf, 1931, p. 14-19; Reed and Bryant, 1964, p. 1181) occupy, with muscovite-eyed phyllonites, a subzone generally near the center of the Brevard zone. They are green or gray-green rocks with a dull waxy appearance. Occasional porphyroclasts of feldspar and quartz may be seen with a hand lens. In thin section the phyllonites are seen to be strongly foliated and composed of very fine quartz and mica with a fair amount of chlorite. In sections parallel to the foliation there is an orientation of elongated, nematoblastic micas, quartz and opaque mineral. Crossing this orientation at 33 degrees (average) are narrow zones of aligned mortar and opaque mineral. Intersecting the latter zones are wider veins of quartz. These veins have a center in which quartz is aligned parallel to the walls and outer zones where the quartz grows normal to the walls. The two orientations possibly represent shear planes and the quartz veins tension fractures (Fig. 3).

Muscovite-Eyed Phyllonites—These are rocks with a phyllitic groundmass with "fish-scale" muscovite aggregates on foliation planes. They vary in appearance with the percentage of these aggregates from a phyllonite with scattered "eyes" to a schist composed almost entirely of the aggregates. Well-formed, clear, dodecahedral garnets are present in some outcrops. In thin section the rocks consist of fine mica, chlorite and quartz (strongly foliated) with spindle-shaped muscovite aggregates which generally terminate in a sharp point on a gliding plane of fine mica (Fig. 4). Foliation within the muscovite aggregates is usually parallel to

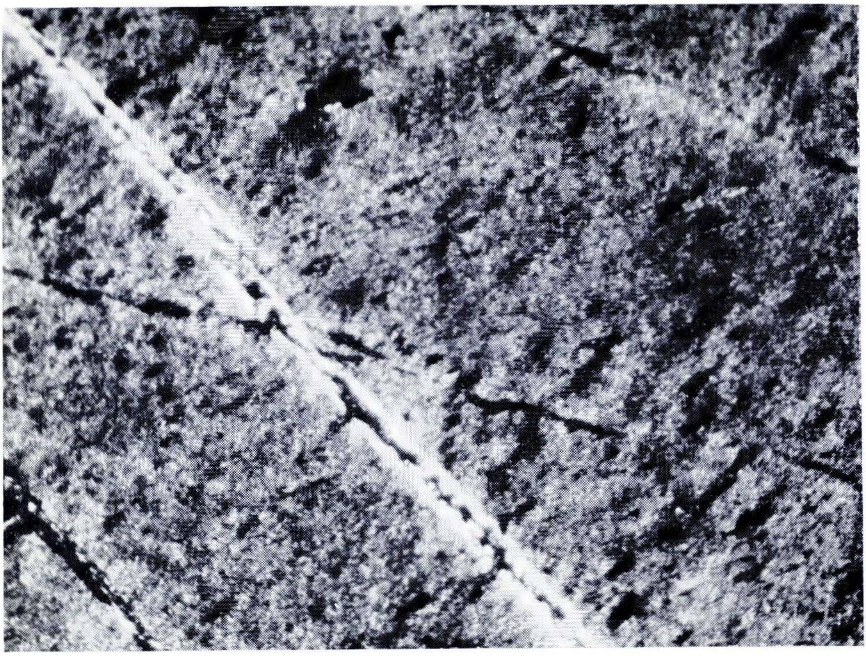


Fig. 3. Phyllonite showing shear orientations and tension fractures, nicols crossed, x 32. From an outcrop near the Cobb County sewage disposal plant on the Chattahoochee River (Mableton Quadrangle).

foliation in the rock, but the aggregates are sometimes folded almost double. Porphyroclasts of plagioclase are present but not common. These rocks differ from those described by Reed and Bryant (1964, p. 1181) and by Reed (1964, p. B24) in that the garnets are not altered to chlorite, and in having the foliation within the muscovite aggregates usually parallel the foliation instead of lying at angles to it. According to Knopf (1931, p. 19), "A completely phyllonitized rock does not show cleavage that cuts the old S-plane because its phyllitic texture is the result of a refolding and transposition of the old S-planes of the rock."

The muscovite aggregates probably correspond to "allure lenticulaire" (Knopf, 1931, p. 18), and it is quite possible that the rocks were deeper when the movement occurred and hence the rank slightly higher and recrystallization of the muscovite aggregates was allowed to attain the attitude imposed by movement.

Sericite Quartzites—Laminated, blocky, sericite quartzites are present in all subzones of the Brevard zone. These rocks show stringers of quartz and segregation lenses of quartz and feldspar

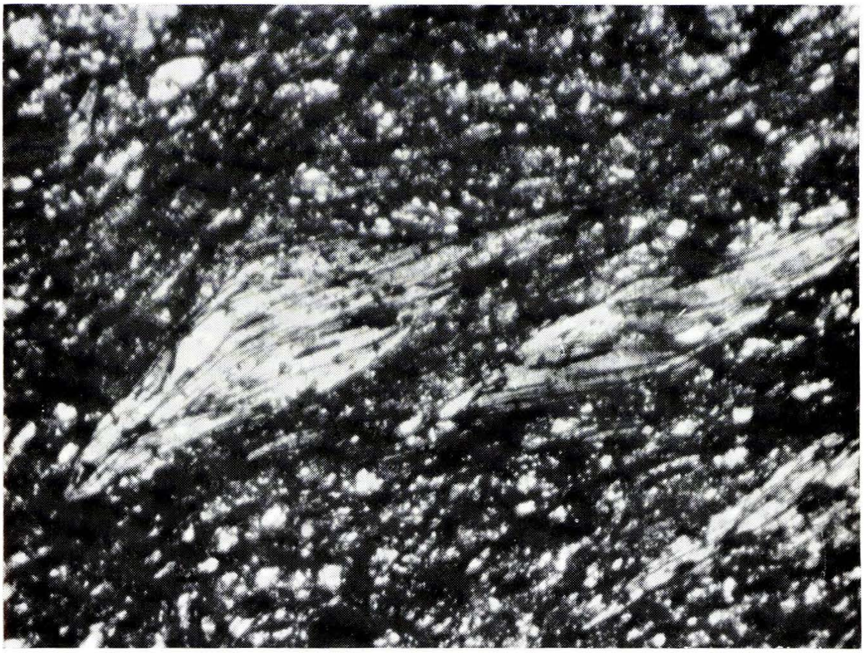


Fig. 4. "Fish-scale" muscovite aggregates in muscovite-eyed phyllonite, nicols crossed, x 64. From an outcrop about 3 miles south of the Fulton County Airport.

with a fine-grained granular texture suggestive of shearing and recrystallization. In the zone of button schists the micas and the quartz stringers are contorted and buckled. There is a striking resemblance microscopically between these rocks and the rocks which Holmquist (1910) called *hartschiefer* in the Torneträsk area of Lapland*.

Blastomylonite—Blastomylonite resembling sericite quartzite is present in the zone of phyllonites and muscovite-eyed phyllonites and to a much lesser extent in the button schist zone (see geologic map—Plate I). In thin section the rock is composed of broad bands of very fine micas with porphyroclasts of quartz. The bands anastomose around recrystallized quartz stringers. The fine micas appear to have grown from the finely comminuted rock powder between porphyroclasts. Some of the porphyroclasts have been recrystallized and one thin section shows an optically homogeneous grain enclosing clastic material. Figure 5 is a photomicrograph of blastomylonite.

*The rocks of Dr. A. C. Waters' collection from the Torneträsk area were studied for comparison.

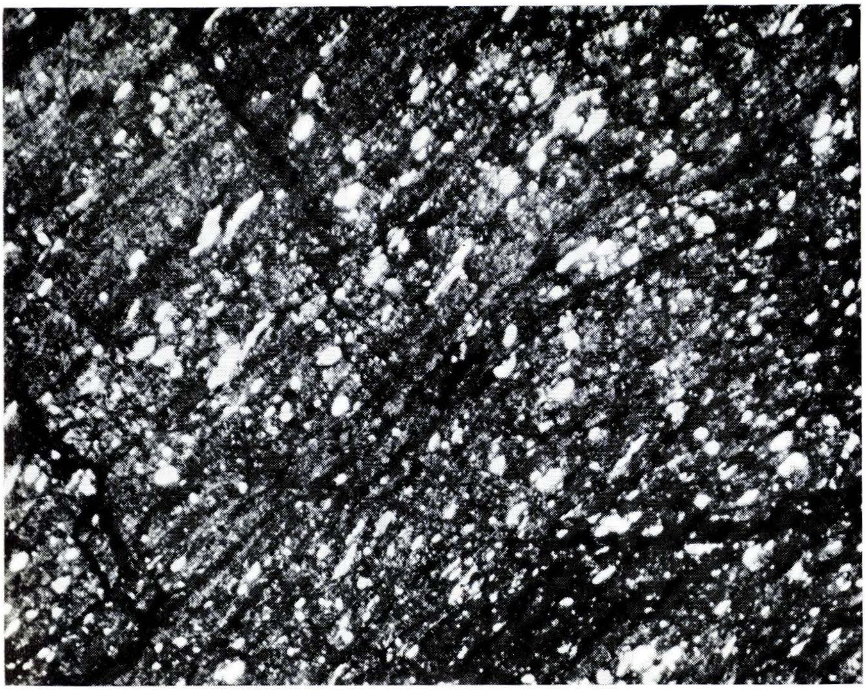


Fig. 5. Blastomylonite, fine micas have recrystallized from fine rock powder between porphyroclasts, nicols crossed, x 32. From an outcrop on U.S. 41 south of the Chattahoochee River, Bolton Quadrangle.

Amphibole schist—Well-foliated, fine-grained amphibole schists are a small part of the button schist zones. Some contain two amphiboles: one optically positive and one negative.

Carbonate quartzite—Locally, small lenses of dark gray carbonate quartzite are present in the Brevard zone. They contain 15-30 percent carbonate grains set in a matrix of finely granular quartz with minor muscovite and sericite.

Cataclastic rocks—Within the Brevard zone are discontinuous outcrops of cataclastic breccia which can be followed for as much as 3 miles. They usually occur at the contact between two of the subzones and probably represent late faulting under relatively low "confining pressure". Other cataclastic rocks in the area can be divided into several categories: flinty crushed rock (Clough, 1888, p. 22-24; Waters and Campbell, 1935, p. 477); mylonite gneiss (Quensel, 1916, p. 91-116; Waters and Campbell, 1935, p. 478) (Fig. 6); protomylonite (Backlund, 1918, p. 195-199; Waters and Campbell, 1935, p. 479) (Fig. 7); ultramylonite (Quensel, 1916,

Fig. 6. Mylonite gneiss, note "augen" (recrystallized porphyroclasts, and porphyroclasts), nicols crossed, x 32. From an outcrop on the Mableton highway (U.S. 278) just northwest of the Chattahoochee River, Mableton Quadrangle.

p. 91-116; Waters and Campbell, 1935, p. 481); Mylonite (Lapworth, 1885, p. 559; Waters and Campbell, 1935, p. 474-476, 478; Christie, 1960, p. 80-81) (Fig. 8 a, b, and c); and various breccias, many of which might be called brecciated mylonite (Conley and Drummond, 1965, p. 205) (Fig. 9). All of these rocks were separated in the field, but are shown together on the geologic map (Plate I).

Epidote-biotite-plagioclase-quartz gneiss—Within the Brevard zone, separated from Brevard rocks and from the Sandy Springs Sequence by faults, is an epidote-biotite-plagioclase-quartz gneiss which usually contains small euhedral titanite crystals and locally small red garnets. It is a well-jointed, coarse-grained, uniform, dark gray banded gneiss which sometimes has plagioclase augen and cataclastic zones of mylonite gneiss close to the faults. Upon weathering the rock turns a distinctive mauveyellow and a secondary cleavage (S_3) gives rise to a button effect. Locally, concordant lensoidal pegmatites of quartz and pink microline are present. Concordant quartz veins and layers are numerous.

The gneiss is found northeast of Atlanta, southeast of and within the Brevard zone, but is absent in this position southwest of

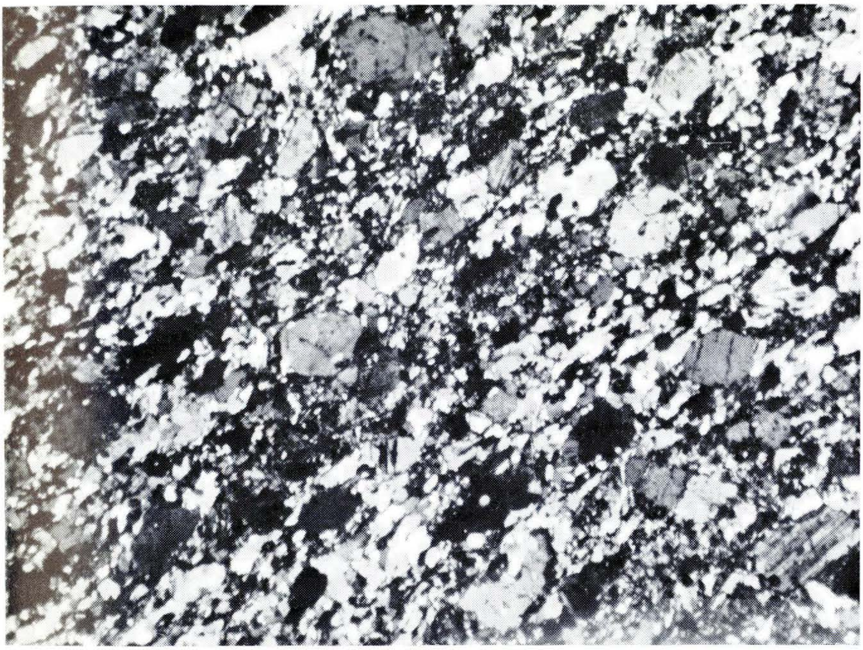


Fig. 7. Protomylonite, nicols crossed, x 32. From the Brevard zone in Palmetto Quadrangle.

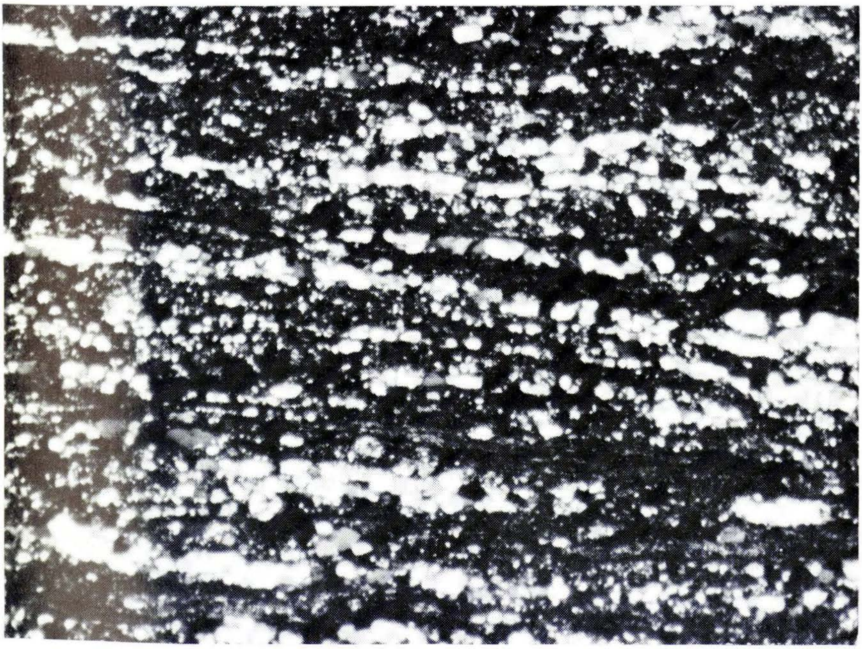


Fig. 8a. Mylonite, nicols crossed, x 32. Near Rico, Georgia, Rico Quadrangle.

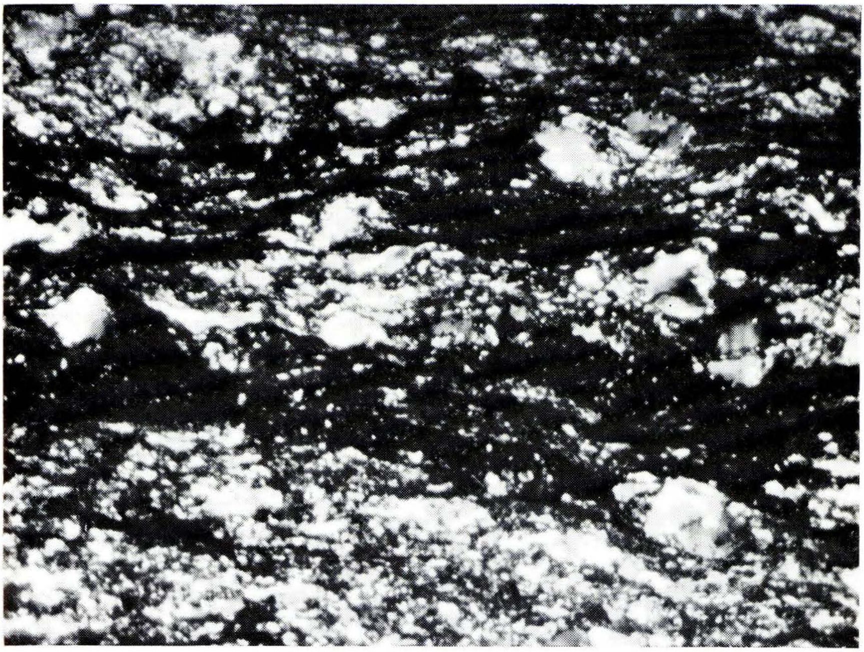


Fig. 8b. Mylonite, nicols crossed, x 32. Mableton Quadrangle.

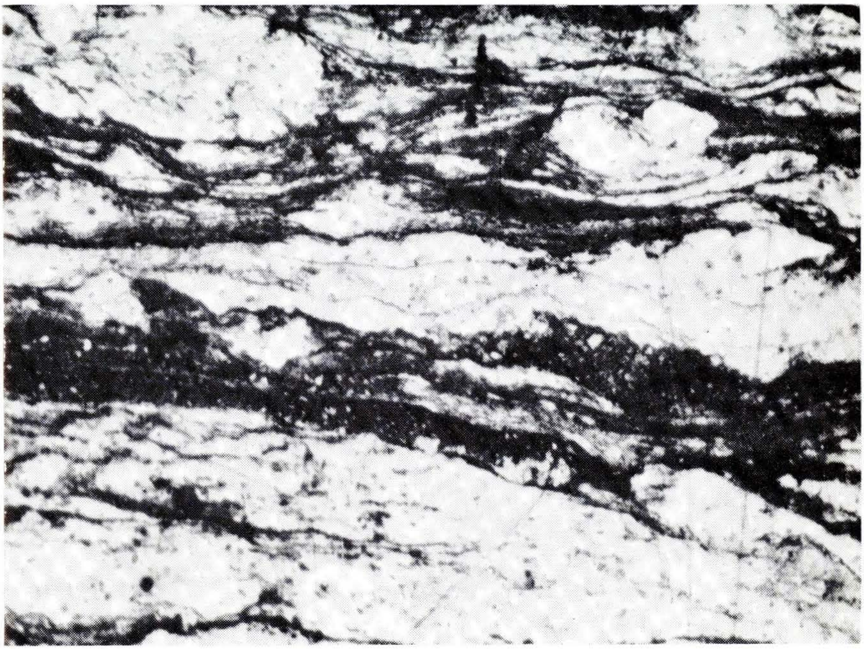


Fig. 8c. Mylonite, note strong fluxion texture, nicols not crossed, x 32. Same as Fig. 8b.

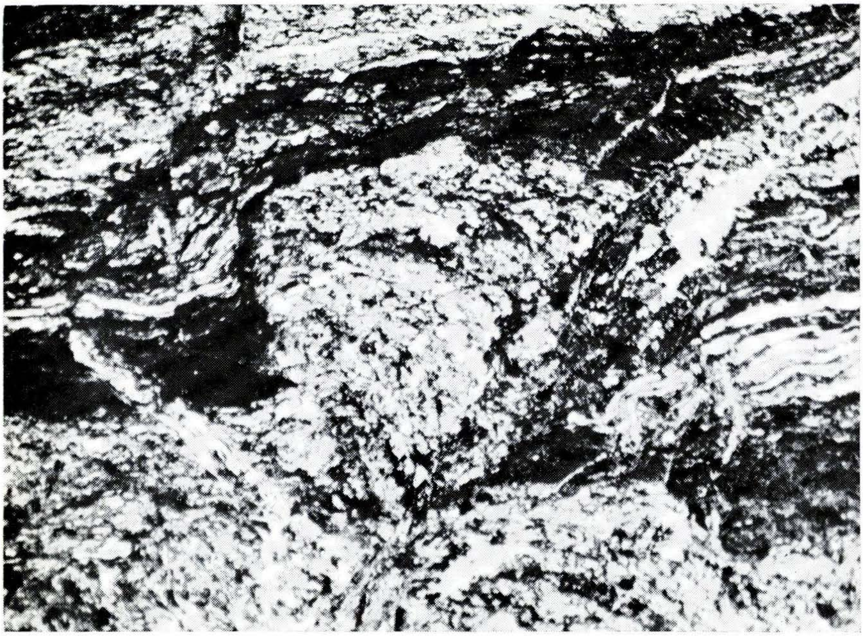


Fig. 9. Mylonite breccia, note "broken" fluxion texture, nicols not crossed, x 32. From the Long Island Fault, Rico Quadrangle.

Atlanta. It is never found northwest of the Brevard zone (Long Island Fault). The gneiss in the Brevard zone is thought to be a tectonic inclusion. The gneiss is a very distinctive unit and may provide a key for future workers for determining movement on the Brevard zone. Figure 10 shows a cataclastic zone in the gneiss.

Modal and chemical analyses of the epidote-biotite-plagioclase-quartz gneiss are given in Tables XI and XII.

TABLE XI

Modal analyses of the epidote-biotite-plagioclase-quartz gneiss

No.	1	2	3
Quartz	47.2	45.3	46.1
Plagioclase	35.3	38.6	36.2
Biotite	8.9	1.8	9.7
Muscovite	Tr	6.8	Tr
Titanite	1.2	0.9	1.1
Epidote	7.1	6.4	6.9
Garnet	0.3	0.2	Tr

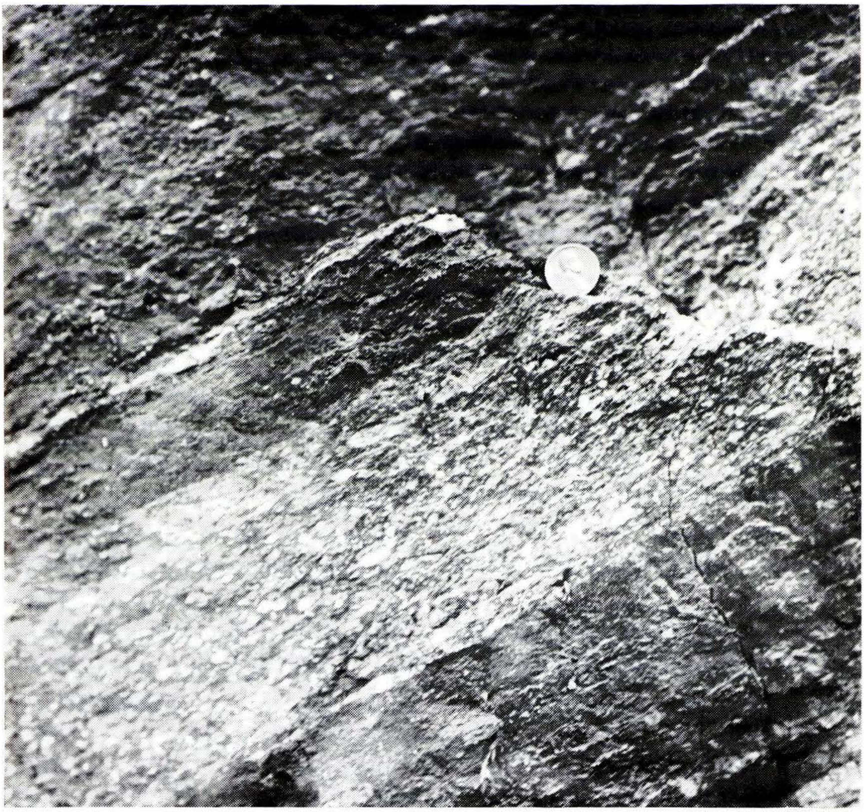


Fig. 10. Cataclastic zone in the epidote-biotite-plagioclase-quartz gneiss about 60 yards southeast of the trace of the Long Island Fault on Roswell Road (U.S. 19).

TABLE XII

Chemical analysis of the epidote-biotite-plagioclase-quartz gneiss

SiO_2	67.51	K_2O	1.98
TiO_2	0.80	Moisture	
Al_2O_3	15.42	@ 100 C	0.03
Fe_2O_3	1.03	Loss on	
FeO	2.32	ignition	0.41
MnO	0.05	P_2O_5	0.16
MgO	2.01	SO_3	0.07
CaO	4.34	Total	100.00
Na_2O	3.87		

Analysis by Dr. L. H. Turner, Chief Chemist, Georgia Geological Survey, 1964. From an outcrop at Lake Forrest Drive and Long Island Creek.

BOUNDARIES, STRUCTURE, AND METAMORPHISM

The northwest boundary of the Brevard zone is marked by a thin (40-100 yards) mylonite gneiss which blends locally into a breccia (Figs. 11a and b). It has fairly constant dip averaging

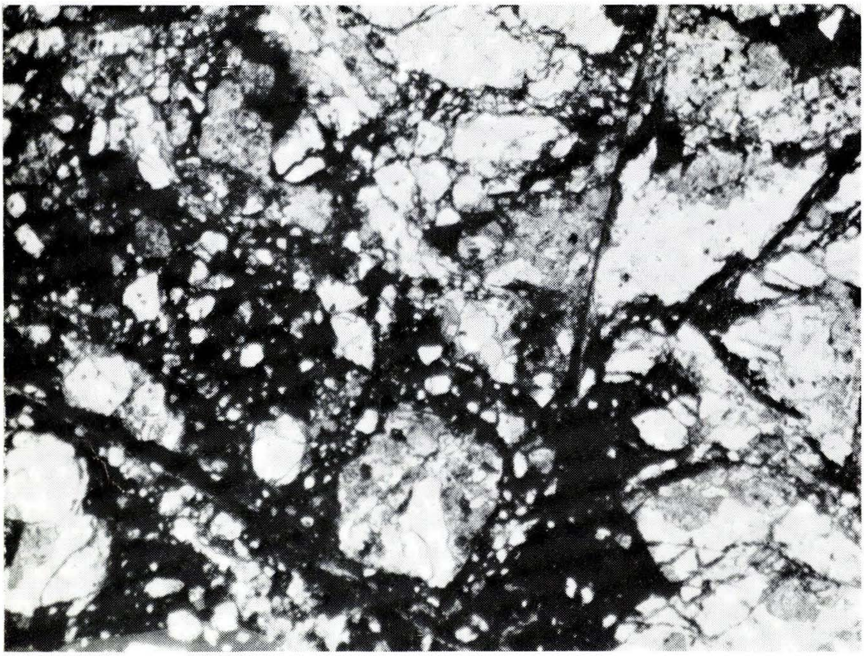


Fig. 11a. Boundary breccia from the northwest boundary of the Brevard zone (Long Island Fault), near the Chattahoochee River, Rico Quadrangle, nicols not crossed, x 32.

about 50 degrees to the southeast, and from all indications is a rock produced by faulting: late low-pressure where brecciated; early higher-pressure where it is a mylonite gneiss. Thus at least two phases of movement may have centered on this zone. It is part of the Long Island Fault.

The southeast boundary of the Brevard zone is marked by sheared Palmetto Granite (Watson, 1902, p. 104). About half a mile from the contact with the Brevard zone the granite is a coarse-grained, poorly-foliated rock with large (to 2 inch) feldspar phenocrysts*. As the contact is approached, the granite becomes pro-

*Watson, (1902) called these orthoclase because they have a habit similar to one commonly associated with orthoclase—forms represented are 001, 110, 010, and 201, with average beta angle of 64 degrees, and crystals elongated parallel to a—however, Grant and Lester have recently (1965) shown that they have an average composition of 74% microcline, 24% plagioclase (An 11), 1% biotite, ½% quartz and ½% sericite.

Fig. 11b. Boundary breccia showing large microfaulted microcline grain, nicols crossed, x 32. Specimen from the northwest boundary of the Brevard zone (Long Island Fault), Rico Quadrangle.

gressively better foliated with the dip of the foliation becoming steeper. For about 100 yards (average) next to the contact the rock is leucocratic and becomes progressively more sheared (Fig. 12). Micas have migrated to slip planes. The actual contact with the Brevard zone phyllonite is quite sharp (Fig. 13), and foliation steepens in dip from 45 degrees to vertical in about 15 feet.

In North Carolina, Reed and Bryant (1964, p. 1183, 1188) have found that the rocks of the Brevard zone are always steeply dipping. In the area of this report, foliation within the zone is generally low (20-50 degrees) and only increases at the edges.

Reed and Bryant (1964, p. 1188) also found that lineations swing into line with the Brevard strike as the zone is approached. In the area studied, the Brevard rocks themselves possess a second set of subhorizontal lineations nearly at right angles to the strike of the zone. This may be interpreted as indication of a thrust or reverse component. The idea of a vertical component is not out of line with the theory of a large strike-slip fault because such

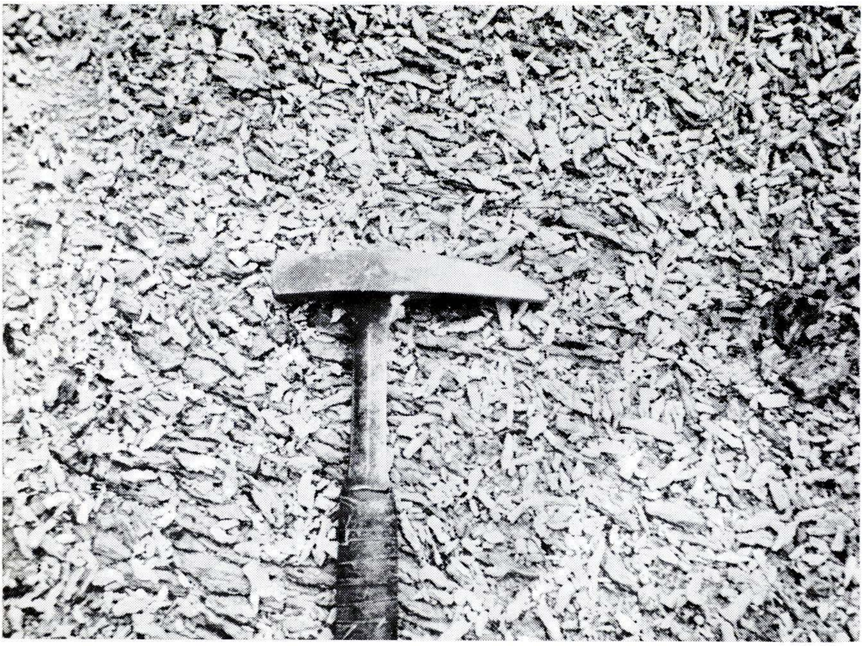


Fig. 12. Sheared Palmetto Granite, spindles released on weathering, about 2 miles south of the Fulton County Airport.

Fig. 13. Contact showing leucocratic, sheared Palmetto Granite on the left and Brevard phyllonite on the right; 2 miles south of the Fulton County Airport.

faults usually have vertical components for part of their course (De Sitter, 1964, p. 143-160).

Within the Brevard rocks at two locations there are small (unmappable at the scale of the map) inclusions which appear to be highly sheared Palmetto granite, and at another location (mapped) is a large body of granite completely surrounded by the phyllonite and believed to be a horse (Lahee, 1952, p. 213-214). Within the main belt of granite there are small inclusions of Brevard phyllonite. These relations indicate that the granite was intruded syntectonically with an early Brevard movement so that it invaded Brevard rocks, but was sheared by subsequent Brevard movements. This is evidence for a long history of more than one movement along the Brevard zone. The Palmetto granite has yielded a biotite age date of 282 (+ or − 14) million years (Pinson, *et al*, 1957, p. 1781).

The metamorphic grade of the Brevard rocks is at the top of the greenschist facies. Assemblages are muscovite, quartz, biotite, epidote, chlorite, and garnet. The rocks immediately northwest in the Sandy Springs Sequence are in the staurolite-kyanite subfacies of the amphibolite facies. The transition is sharp. Southeast of the Brevard zone sillimanite is found in schists within the Palmetto granite.

AGE OF THE BREVARD ZONE

On the basis of structural evidence Reed and Bryant (1964, p. 1189) suggest that the latest movement along the Brevard zone was late Paleozoic to Triassic (1964, p. 1193). The age date of 282 (+ or − 14) million years was determined on biotite from the Palmetto granite about 15 miles southeast of the Brevard zone. Since biotite is one of the minerals most susceptible to "re-setting", the date probably represents a "thermal event", or the time when the biotite ceased to be an open system, and not the actual age of the granite. The microcline pseudomorphs after orthoclase (p. 36) are also evidence that the granite was metamorphosed after primary crystallization. The 282 million year date agrees with most other dates available and with field evidence as representing the last major metamorphism of the Georgia Piedmont as a whole (Pinson, *et al*, 1957, p. 1781; Grunenfelder and Silver, 1958, p. 1574; Tilton, 1965, p. 216-218). Since the Palmetto granite (in its present state—with microcline crystals) is affected by the Brevard zone movements (p. 36-38) it can be concluded that the latest movement occurred after 282 (+ or − 14) million years ago. Two diabase dikes of probable late Triassic age are known to cross the Brevard zone: one in North Carolina (Reed and Bryant, 1964, p. 1189, and map; Tectonic map of the U.S., 1962); and another in Georgia (Lester and Allen, 1950, map; Tectonic map of the U.S., 1962). Mainly on the basis of this evidence Reed and Bryant (1964, p. 1189, 1193) concluded that movement on the Brevard zone had ceased by late Triassic. I concur. The fact that the latest movement resulted in a retrogression of the rocks and produced mylonites (and/or brecciated mylonites) from pre-existing mylonitic rocks suggests that the Brevard existed as a movement zone even before the last Piedmont metamorphism. The striking difference in kind and abundance of certain rock types (alpine ultramafics) on either side of the zone suggests that the Brevard may separate major petrologic provinces, and the absence of ultramafics north of the Cartersville fault in the Paleozoic rocks indicates that it may possibly have been active before the Paleozoic.

It has been recently suggested (Dunn, *et al,* 1965) that "in some areas, large streams flowing across the Brevard zone show apparent left-lateral offset" indicating recent movement. In the area of this study is can be shown that the excellent *apparent* offset of streams is due to: (1) following a well-developed joint system, and/or (2) the effect of resistant mylonitic outcrops acting as barriers to drainage.

No evidence was observed for movement later than Triassic.

BLASTOMYLONITE DIKES—Associated with the Long Island Fault which marks the northwest boundary of the Brevard zone in Sandy Springs and Bolton Quadrangles, Georgia (1954, 1955; U.S. Geological Survey 7½ minute-series) are dikes ranging in width from ¼ inch to 20 feet (Fig. 14), and in length from 10 to several thousand yards.

The rock resembles chert, with numerous nearly equant porphyroclasts of feldspar. It occurs as discordant dikes having the foliation and joint system of the country rock. Very similar rock occurs in tabular sheets next to known faults in the Brevard zone. Movement on the plane of the dikes is disclosed by offset quartz veins and layers, and in one case by offset beds of schist and amphibolite. Most of the dikes show offset wall-rock features with displacement varying from a few to several hundred feet. Some dikes (particularly the larger ones) show what appears to be a gradation (over a narrow zone) into the country rock. Others show

Fig. 14. Large blastomylonite dike cutting schist of the Sandy Springs Sequence along U.S. 41 just north of the Chattahoochee River.

sharp contacts with the country rock even on a microscopic scale. The dikes are apparently not offset by the foliation.

In thin section, the rock shows relic cataclastic texture, with well-preserved porphyroclasts. In most slides the feldspar porphyroclasts and the feldspar component of the mortar have weathered to kaolinite leaving tiny fragments of quartz in a matrix of kaolinite. Even in these extremely weathered samples the cataclastic textures are apparent. Figure 15 shows a typical sample.

The average rock now consists of quartz, kaolin, and muscovite, but relic textures suggest that most of the kaolin was derived from feldspar. This would indicate that the dikes were quartzo-feldspathic rocks regardless of the type of host rock. From this it might be postulated that the dikes were originally igneous (pegmatites?) dikes along which shearing has taken place prior to the last major metamorphism.

Regardless of the origin of the rock, the dike-like bodies represent zones along which extensive movement took place. The gradational boundaries may represent the effect of different intensities or duration of movment.

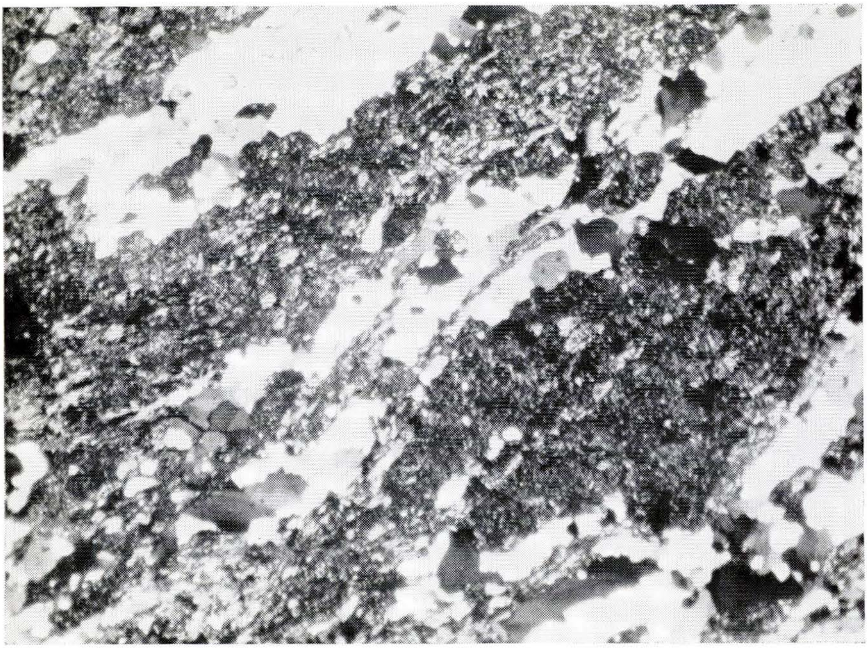


Fig. 15. Blastomylonite, from the large dike on U.S. 41 just north of the Chattahoochee River. Note recrystallized quartz trails. Fine "crush" has new-grown sericite, quartz, and feldspar, but much of the feldspar has altered to kaolinite, nicols crossed, x 32.

BREVARD ROCKS OUTSIDE THE BREVARD ZONE

In addition to the lenses of phyllonite in Palmetto granite there is an area in the Rico Quadrangle, Georgia (1954, U.S. Geological Survey 7½ minute-series) where rocks of the Sandy Springs Sequence blend gradually along strike into Brevard-type phyllonites, muscovite-eyed phyllonites, and blastomylonites. The low-grade area is completely isolated from the main Brevard zone by normal Sandy Springs units. Within a few miles the low-grade rocks grade back into what can be recognized as altered Sandy Springs units. This is believed to be evidence that the rocks of the Brevard zone formed by extreme shearing and retrogressive recrystallization of rocks similar to those now adjacent to that zone.

SUMMARY AND CONCLUSIONS

The Brevard lineament in the vicinity of Atlanta, Georgia can be divided into two main belts of rocks: the Sandy Springs Sequence and the Brevard zone.

The Sandy Springs Sequence consists of 4 units with a discernible stratigraphy. The seqeuence has been isoclinally folded and metamorphosed to the staurolite-kyanite subfacies of the amphibolite facies. Originally the sequence probably consisted of altered volcaniclastic sediments, pelitic sediments, and clean orthoquartzitic sandstones, indicating a low, sub-tropical to tropical source-area. The source area was probably affected by periodic tectonic disturbances as indicated by the nature of the sediments, and by their thinness and the rhythmic alternation of aluminous sediments with clean orthoquartzitic sandstones.

The Brevard zone consists of phyllonitized rocks belonging to the upper greenschist facies. It is believed to represent a major right-lateral fault, with some vertical displacement. It has had a long movement history, but the last major movement probably occurred between no later than about 280 million years ago and late Triassic. Apparent offset of streams in the Brevard lineament is due to a well-developed joint system and/or interference of mylonitic rocks on drainage.

The boundary between the Sandy Springs Sequence and the Brevard zone is marked by the Long Island Fault: a right-lateral fault with reverse (southeast side up) displacement. It has been traced the length of the map, and followed in reconnaissance north of the area.

Evidence indicates that the Brevard rocks were produced by retrogression of rocks similar to those adjacent to it now.

ECONOMIC GEOLOGY

Kyanite—Kyanite is abundant in the Aluminous schist unit of the Sandy Springs Sequence. The schists are usually deeply weathered so separation would offer no problems. The kyanite is probably not economic because of the high price of the land in the area, but recovery with subsequent resale of the land for residential purposes might prove worthwhile.

Crushed rock—The epidote-biotite-plagioclase-quartz gneiss has been used for crushed rock for road metal in the past. A small quarry was developed near the junction of Stewart Drive and Lake Forrest Drive. The gneiss has acceptable strengths and does not give rise to alkali aggregate reaction. Crushed epidote-biotite-plagioclase-quartz gneiss was also used recently for construction of part of Atlanta's freeway system in Chamblee Quadrangle, Georgia.

The gneiss of the Gneiss-schist-amphibolite unit (biotite-quartz-microcline-oligoclase gneiss) from a temporary quarry at Northside Drive and Powers Ferry Road has also been used in paving.

Atlanta is probably the fastest growing city in the southeast and much of the growth is toward the north. The epidote-biotite-plagioclase gneiss and to a lesser degree the biotite-quartz-microcline-oligoclase gneiss should prove valuable for highway materials necessary to this growth.

Quartzite—In the past, both quartzite units of the Sandy Springs Sequence have been used to a limited extent in residential construction. The desirability of limited use of natural materials from the immediate surroundings is one of the basic concepts of modern home design. The quartzites should find more and more use in this manner as the residential area grows.

Electric Power and Water Control—The Morgan Falls Dam on the Chattahoochee River in Sandy Springs Quadrangle, Georgia was finished in 1904 and began power transmission to the city of Atlanta the same year. A development program for the dam went into effect in 1959 as a joint project of the Georgia Power Company and the City of Atlanta.

> "The work was undertaken at the request of the City to permit regulation of the flow of the Chattahoochee River to supplement the City's water supply and to aid in the disposal of sewage. The $910,000 cost of the project was

> equally shared by the City and the power company."
>
> "The redevelopment project to enlarge the reservoir capacity of Morgan Falls became advisable following completion of the Buford Dam by the U.S. Army Corps of Engineers. Regulation of the river flow by Morgan Falls is necessary in order to provide adequate volumes of water at all times at the Clayton Sewage Treatment Plant in Atlanta." (Morgan Falls booklet, 1961).

In addition to water storage and water control for sewage disposal, the dam furnishes power for part of the city.

With rapid growth of the Atlanta area, need for more electricity, water storage, and river control for sewage treatment and for the proposed future channeling of the river for port facilities, may require more dams on the Chattahoochee River. Observation of the geologic and topographic maps of this study could save engineers time and money in evaluating dam sites.

Recreation—Although recreational facilities are not usually thought of as resources, their desirability is greatly dependent on the topography which depends in large part on the geology. The growing Atlanta area will have great need for parks and recreational areas.

The area in Sandy Springs Quadrangle below Morgan Falls Dam offers rugged mountainous scenery not found elsewhere for more than 50 miles from the city. It would make an excellent city, state, or national park.

REFERENCES CITED

Backlund, Helge, 1913, Algunas Observaciones sobre Rocas Notables provenientes de Olivarria (Buenos Aires): Direccion General de Minas, Serie B, v. 2.

Barth, T. F. W., and Reitan, P. H., 1963, The Precambrian of Norway: *in* The Precambrian, Rankama, Kalervo, ed., 1963: New York, John Wiley & Sons, Inc., p. 27-80.

Bayley, W. S., 1928, Geology of the Tate Quadrangle, Georgia: Georgia Geol. Survey Bull., no. 43, 167 p.

Christie, J. M., 1960, Mylonitic Rocks of the Moine Thrust-Zone in the Assynt Region, North-west Scotland: Trans. Edinburgh Geol. Soc., v. 18, Part I, p. 79-92.

Clarke, F. W., 1924, The Date of Geochemistry: U. S. Geol. Survey Bull. no. 770.

Cloos, Ernst, 1937, The Application of Recent Structural Methods in the Interpretation of the Crystalline Rocks of Maryland: Maryland Geol. Survey (Rept.), v. XIII, p. 27-105.

__________, 1946, Lineation: Geol. Soc. Amer. Mem. 18, 122 p.

__________, 1947, Boudinage: Amer. Geophy. Union Trans., v. 28, no. 4, p 626-632.

Clough, C. T., 1888, The Geology of the Cheviot Hills: Mem. Geol. Survey England and Wales, p. 1-60.

Cohen, L. H., Condie, K. C., Kuest, L. J., Jr., Mackenzie, G. S., Meister, F. H., Pushkar, Paul, Stueber, A. M., 1963, Geology of the San Benito Islands, Baja California, Mexico: Geol. Soc. Amer. Bull., v. 74, p. 1355-1370.

Conley, J. F., and Drummond, K. M., 1965, Ultramylonite Zones in the Western Carolinas: Southeastern Geology, v. 6, no. 4, p. 201-211.

Coombs, D. S., 1954, The Nature and Alteration of some Triassic Sediments from Southland, New Zealand: Roy. Soc. New Zealand Trans., v. 82, p. 65-109.

Crickmay, G. W., 1939, Geologic Map of Georgia: Georgia Geol. Survey, 1:500,000.

__________, 1952, Geology of the Crystalline Rocks of Georgia: Georgia Geol. Survey Bull. no. 58, 54 p.

De Sitter, L. U., 1964, Structural Geology: New York, McGraw-Hill Book Company, 551 p.

Dietrich, R. V., 1959, Geological Reconnaissance of the Area Between Kristiansand and Lillesand: Norges Geol. Underskelse, no. 205, p. 41-78.

Dietrich, R. V., and Mehnert, K. R., 1961, Proposal for the Nomenclature of Migmatites and Associated Rocks: *in* Symposium on Migmatite Nomenclature, Sorensen, H., ed.: Intern. Geol. Congress, XXI Session, Norway, 1960, Pt. XXVI, Suppl. vol. sect. 14, p. 54-78.

Dunn, D. E., Butler, J. R., and Centini, B.A., 1965, Brevard Fault Zone, North Carolina: New Interpretation: Paper given at Geol. Soc. Amer. S.E. Sect., Nashville Meeting, 1965.

Engel, A. E. J., and Engel, C. G., 1963, Metasomatic Origin of Large Parts of the Adirondack Phacoliths: Geol. Soc. Amer. Bull., v. 74, p. 349-353.

Fiske, R. S., Hopson, C. A., and Waters, A. C., 1963, Geology of Mount Rainier National Park, Washington: U.S. Geol. Survey Prof. Paper 444, 93 p.

Fiske, R. S., and Matsuda, Tokihiko, 1964, Submarine Equivalents of Ash Flows in the Tokiwa Formation, Japan: Amer. Jour. Sci., v. 262, p. 76-106.

Galpin, S. L., 1915, The Feldspar and Mica Deposits of Georgia: Georgia Geol. Survey Bull. 53.

Gates, R. M., and Sneider, R. M., 1958, Syntectonic Amphibolites (abst.): Geol. Soc. Amer. Bull., v. 69, p. 1570.

Georgia Power Company, 1961, Morgan Falls Booklet.

Goguel, Jean, 1962, Tectonics: San Francisco, W. H. Freeman and Company, 384 p.

Gorsline, D. S., and Emery, K. O., 1959, Turbidity Current Deposits: Geol. Soc. Amer. Bull., v. 70, p. 279-290.

Grant, W. H., 1958, The Geology of Hart County, Georgia: Georgia Geol. Survey Bull. no. 67, 75 p.

Grant, W. H., and Lester, J. G., 1965, Feldspar Phenocrysts from Ben Hill, Georgia: abstract, Bull. Ga. Acad. Sci. Spring, 1965.

Grunenfelder, M., and Silver, L. T., 1958, Radioactive Dating in Georgia (abst.): Geol. Soc. Amer. Bull., v. 69, p. 1574.

Harker, Alfred, 1939, Metamorphism: New York, E. P. Dutton & Company, Inc., 362 p.

Hayes, C. W., 1901, Geological Relations of the Iron Ores in the Cartersville District, Georgia: Am. Inst. Min. Eng., Trans. 30, p. 403-419.

Heinrich, E. W., 1956, Microscopic Petrography: New York, McGraw-Hill Book Company, Inc., 296 p.

Herrick, S. M., and LeGrand, H. E., 1949, Geology and Ground Water Resources of the Atlanta Area, Georgia: Georgia Geol. Survey Bull. no. 55.

Hess, H. H., 1960, Stillwater Igneous Complex, Montana: Geol. Soc. Amer. Mem. 80, 230 p.

Higgins, M. W., 1965, The Geology of Part of Sandy Springs Quadrangle, Georgia: Unpublished Master's thesis, Emory University, 141 p.

Hills, E. S., 1963, Elements of Structural Geology: New York, John Wiley & Sons, Inc., 483 p.

Holland, Willis A., Jr., unpublished map of Forsyth County, Georgia, in files Georgia Department of Mines, Mining and Geology.

Holmquist, P. J., 1910, Die Hochgebirgsbildungen am Tornetrask in Lappland: Geol. Foren. Forhandl., Bd. 32, H. 4, p. 913-983.

Hopkins, O. B., 1914, Asbestos, Talc, and Soapstone Deposits of Georgia: Georgia Geol. Survey Bull. no. 29, 319 p.

Hopson, C. A., 1964, The Crystalline Rocks of Howard and Montgomery Counties: *in* The Geology of Howard and Montgomery Counties; Maryland Geol. Survey, p. 27-337.

Hurst, V. J., 1952, Geology of the Kennesaw Mtn.-Sweat Mtn. Area, Cobb County, Georgia: Unpublished Master's thesis, Emory University, 165 p.
————, 1955, Stratigraphy, Structure, and Mineral Resources of the Mineral Bluff Quadrangle, Georgia: Georgia Geol. Survey Bull. no. 63, 137 p.

James, H. L., 1955, Zones of Regional Metamorphism in the Precambrian of Northern Michigan: Geol. Soc. Amer. Bull., v. 66, p. 1455-1488.

Johannsen, A., 1932, A Descriptive Petrography of the Igneous Rocks, v. I: Chicago, Univ. of Chicago Press, 267 p.

Kennedy, W. Q., 1946, The Great Glen Fault: Geol. Soc. London Quart. Jour., v. 102, p. 41-72.

Knopf, E. B., 1931, Retrogressive Metamorphism and Phyllonitization: Am. Jour. Sci., Fifth series, v. XXI, no. 121, p. 1-27.

Lahee, F. H., 1952, Field Geology: New York, McGraw-Hill Book Company, Inc., 883 p.

Lapworth, Chas., 1885, The Highland Controversy in British Geology: its Causes, Course, and Consequences: Nature, v. 32, p. 558-559.

Larson, E. S., and Morris, F. K., 1933, Origin of the Schists and Granite of of the Wachusett-Coldbrook Tunnel, Mass. (abst.): Geol. Soc. Amer. Bull., v. 44, p. 92-93.

Leake, B. E., 1963, Origin of Amphibolites, Northwest Adirondacks, New York: Geol. Soc. Amer. Bull., v. 74, p. 1193-1202.

Lester, J. G., and Allen, A. T., Jr., 1950, Diabase of the Georgia Piedmont: Geol. Soc. Amer. Bull., v. 61, p. 1217-1224.

Moody, J. D., and Hill, M. J., 1956, Wrench-Fault Tectonics: Geol. Soc. Amer. Bull., v. 67, p. 1207-1246.

Nasu, Noriyuki, 1954, Origin of Sand and Silt Alternations (abst.): Geol. Soc. Amer. Bull., v. 65, p. 1290.

Noe-Nygaard, Arne, 1963, The Precambrian of Denmark: *in* The Precambrian, Rankama, Kalervo, ed., 1963: New York, John Wiley & Sons, Inc., p. 1-25.

Pettijohn, F. J., 1957, Sedimentary Rocks: New York, Harper & Brothers, 718 p.

Pettijohn, F. J., and Potter, P. E., 1964, Atlas and Glossary of Primary Sedimentary Structures: New York, Springer-Verlag New York, Inc., 370 p., 117 plates.

Philbin, P. W., Petrafeso, F. A., and Long, C. L., 1964, Aeromagnetic Map of the Georgia Nuclear Laboratory Area, Georgia: U. S. Geological Survey, Geophysical Investigations, Map GP-488.

Pinson, W. H., Jr., Fairbairn, H. W., Hurley, P.M., Herzog, L. F., and Cormier, R. F., 1957, Age Study of Some Crystalline Rocks of the Georgia Piedmont (abst.): Geol. Soc. Amer. Bull., v. 68, p. 1781.

Poldervaart, A., 1953, Metamorphism of Basaltic Rocks: Geol. Soc. Amer. Bull., v. 64, p. 259-270.

Purington, C. W., 1894, Geolgical and Topographical Features of the Region about Atlanta, Georgia: Am. Geologist, v. 14, p. 105-108.

Quensel, Percy, 1916, Zur Kenntnis der Mylonitbildung, erlautert an material aus dem Kebnekaisegebiet: Bull. Geol. Inst. Upsala, v. 15, p. 91-116.

Rankama, Kalervo, 1948, New evidence of the Origin of Pre-Cambrian Carbon: Geol. Soc. Amer. Bull., v. 59, p. 389-416.

Rankama, Kalervo, and Sahama, Th. G., 1950, Geochemistry: Chicago, Univ. of Chicago Press, 911 p.

Reed, J. C., Jr., 1964, Geology of the Linville Falls Quadrangle, North Carolina: U.S. Geological Survey Bull. 1161-B, 53 p.

Reed, J. C., Jr., and Bryant, Bruce, 1964, Evidence for Strike-slip Faulting along the Brevard Zone in North Carolina: Geol. Soc. Amer. Bull., v. 75, p. 1177-1195.

Ruckmick, J. C., and Noble, J. A., 1959, Origin of the Ultramafic Complex at Union Bay, Southeastern Alaksa: Geol. Soc. Amer. Bull., v. 70, p. 981-1018.

Schepis, E. L., 1952, Geology of Eastern Douglas County, Georgia: Unpublished Master's thesis, Emory University, 56 p.

Shaw, D. M., 1956, Geochemistry of Pelitic Rocks: Geol. Soc. Amer. Bull., v. 67, p. 919-934.

Shrock, R. R., 1948, Sequence in Layered Rocks: New York, McGraw-Hill Book Company, Inc., 507 p.

Teague, K. H., and Furcron, A. S., 1948, Geology and Mineral Resources of Rabun and Habersham Counties, Georgia, scale 1:12,500: Ga. Dept. of Mines, Mining, and Geology.

Tilton, G. R., 1965, Compilation of Phanerozoic Geochronological Data for Eastern North America: Geochronology of North America, Nat. Acad. Sci.-Nat. Research Council, Pub. 1276, p. 181-220.

Turner, F. J., and Verhoogen, John, 1960, Igneous and Metamorphic Petrology: New York, McGraw-Hill Book Company, Inc., 694 p.

Van Biljon, S., 1949: *in* Dutoit, A. L., 1953, The Geology of South Africa: New York, Hafner Publishing Company, 611 p.

Wager, L. R., and Deer, W. A., 1939, Geological Investigations in East Greenland. Part III., The Petrology of the Skaergaard Intrusion, Kangerdlugssuak: Medd. Grcnland, v. 105, no. 4, p. 1-352.

Waters, A. C., and Campbell, C. D., 1935, Mylonites from the San Andreas Fault Zone: Amer. Jour. Sci., Fifth Series, v. XXIX, no. 174, p. 473-503.

Watson, T. L., 1902, The Granites and Gneisses of Georgia: Georgia Geol. Survey Bull. no. 9, 367 p.

Wells, F. G., and Waters, A. C., 1935, Basaltic Rocks in the Umpqua Formation: Geol. Soc. Amer. Bull., v. 46, p. 961-972.

Maps Cited

Geologic map of Alabama, 1926, scale 8 miles to the inch: Geol. Survey of Alabama.

Geologic map of Georgia, 1939, scale 1:500,000: Ga. Dept. of Mines, Mining, and Geology.

Geologic map of North Carolina, 1958, scale 1:500,000: North Carolina Dept. of Conservation and Development.

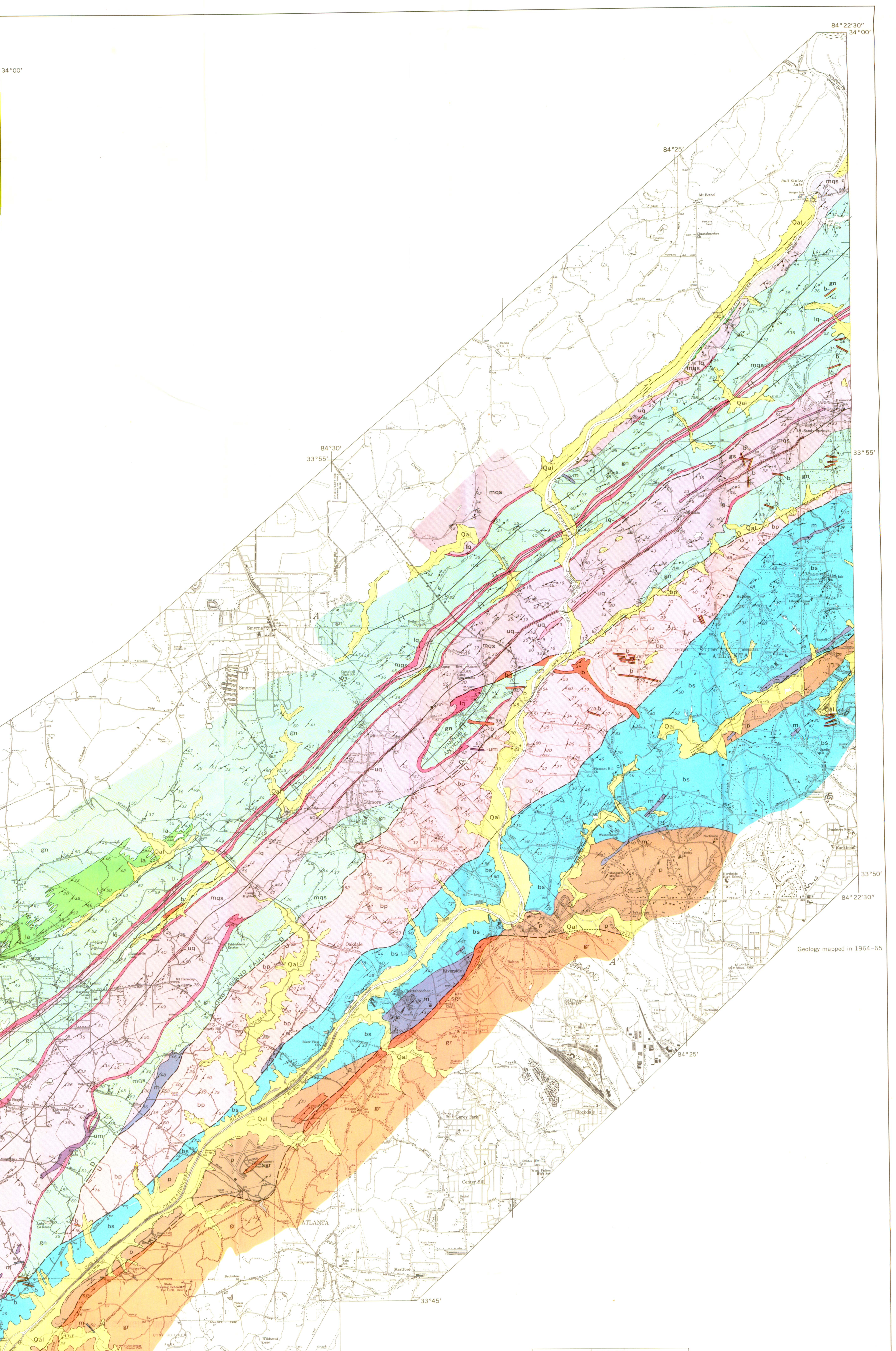
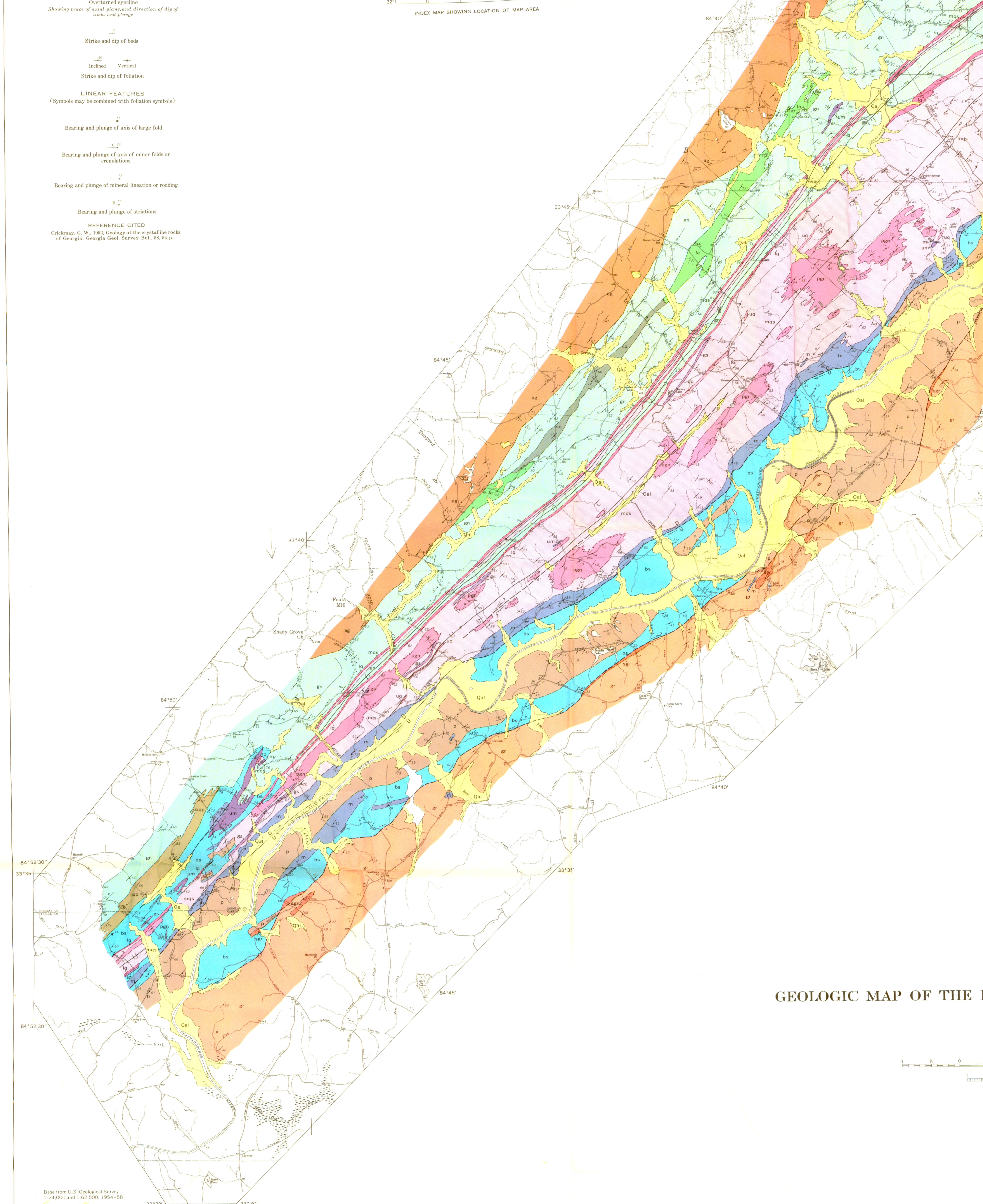
Geologic map of South Carolina (Crystalline Rocks), 1965, scale 1:250,000: U. S. Geol. Survey, Map I-413.

Geologic map of Tennessee, 1966, Scale 1:250,000: Tennessee Division of Geology.

Tectonic Map of the United States, 1962, scale 1:2,500,000: U. S. Geological Survey and Amer. Assoc. Petroleum Geologists.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-511

EXPLANATION

QUATERNARY

Qal

Alluvium
Sand, silt, clay, and gravel on floodplains and low terraces along modern streams

ROCKS NORTHWEST OF THE BREVARD FAULT ZONE

PRECAMBRIAN TO LOWER PALEOZOIC

um

Ultramafic rocks
Altered ultramafic rocks composed principally of chlorite and amphibole. Contacts generally concordant with foliation in enclosing rocks

METASEDIMENTARY ROCKS
(Arranged in stratigraphic order)

uq

Upper quartzite unit
Muscovite-bearing quartzite containing small amounts of plagioclase, epidote, and opaque minerals

mqs, pgn, gs

Aluminous schist and associated rocks
mqs, *light-gray lustrous garnet-biotite-oligoclase-muscovite-quartz schist locally containing kyanite or staurolite. Contains layers of quartz-muscovite schist and thinly bedded red micaceous-quartzite*
pgn, *muscovite-biotite-plagioclase gneiss*
gs, *graphitic-muscovite-quartz schist*

lq

Lower quartzite unit
Massive white, yellow, or blue sugary to vitreous quartzite containing accessory mica and elongated garnet. Locally displays graded bedding. Forms beds 1 to 4 feet thick interlayered with feldspathic quartzite and muscovite schist

gn, bqp, sq, la

Gneiss, schist, amphibolite, and associated rocks
gn, *muscovite-biotite-microcline-quartz-plagioclase gneiss. Medium-grained gray discontinuously striped gneiss locally displaying pink microcline augen as much as 7cm long. Contains small amounts of epidote, opaque minerals, and locally of garnet. Locally contains concordant quartz-microcline pegmatites. Pods and discontinuous layers of muscovite-biotite-quartz schist, amphibolite, and hornblende schist are common and locally comprise the bulk of the unit. Some parts of the gneiss resemble massive quartzite. Plagioclase is typically oligoclase (An_{12})*
bqp, *biotite-quartz-plagioclase gneiss*
sq, *specularite quartzite*
la, *layered amphibolite*

METAIGNEOUS(?) ROCKS
(Stratigraphic position uncertain)

ag

Augen gneiss
Granite gneiss containing conspicuous augens of microcline microperthite rimmed by albite and quartz. Austell Granite of Crickmay (1952)

ROCKS IN THE BREVARD FAULT ZONE
(No stratigraphic order implied)

UPPER PALEOZOIC TO LOWER MESOZOIC

b

Blastomylonite
Light-colored aphanitic rock resembling chert and containing porphyroclasts of feldspar. Cataclastic texture obvious in thin section. Occurs in dikes 0.5 inch to 20 feet thick and in lenticular sheets along faults

m

Mylonite gneiss, breccia, and flinty crush rock

p

Phyllonite
Lustrous green or gray green waxy-appearing rock containing scattered porphyroclasts of quartz and feldspar in a matrix of fine-grained quartz, mica, and chlorite

PRECAMBRIAN TO LOWER PALEOZOIC

bs

Button schist
Biotite-quartz-muscovite schist displaying distinctive wavy secondary cleavage that causes the rock to weather into fragments resembling buttons. Interleaved with blastomylonite, sericite schist, amphibole schist, biotite gneiss, and quartzite

bp

Epidote-biotite-plagioclase gneiss
Dark-gray coarse-grained uniform gneiss containing small euhedral crystals of sphene and a few small grains of garnet. Weathers massive, yellow. Rock is well jointed and locally displays secondary cleavage. Contains a few concordant lenses of quartz-microcline pegmatite and numerous veins and layers of quartz

ROCKS SOUTHEAST OF THE BREVARD FAULT ZONE

PALEOZOIC

gr, sgr

Granitic rocks
gr, *medium- to coarse-grained poorly foliated granite containing orthoclase phenocrysts as much as 5 cm long and inclusions of sillimanite schists. Palmetto type granite of Crickmay (1952)*
sgr, *intensely sheared and strongly foliated granite adjacent to the Brevard fault zone. Also occurs as tectonic lenses within the fault zone*

Contact
Dashed where approximately located

U
D

Fault, approximately located
Dotted where concealed. Arrows indicate inferred relative horizontal movement. U, *upthrown side;* D, *downthrown side. In section* T, *toward observer;* A, *away from observer*

Overturned anticline
Showing trace of axial plane, and direction of dip of limbs and plunge

Overturned syncline
Showing trace of axial plane, and direction of dip of limbs and plunge

2

Strike and dip of beds

50

Inclined Vertical

Strike and dip of foliation

LINEAR FEATURES
(Symbols may be combined with foliation symbols)

11

Bearing and plunge of axis of large fold

c 22

Bearing and plunge of axis of minor folds or crenulations

12

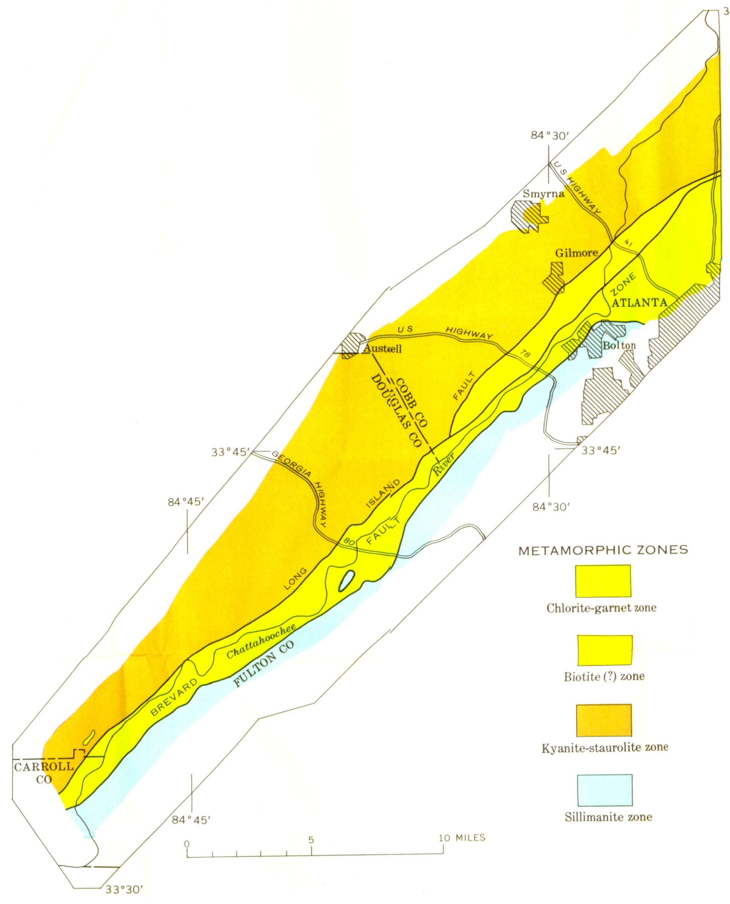
Bearing and plunge of mineral lineation or rodding

s 15

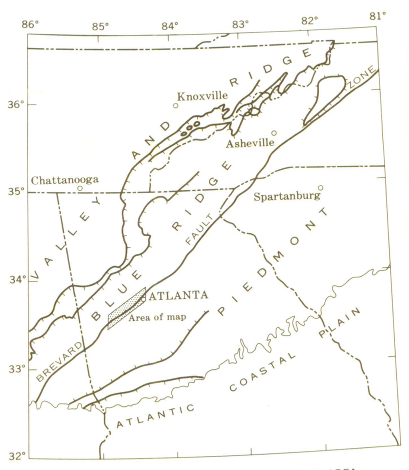
Bearing and plunge of striations

REFERENCE CITED

Crickmay, G. W., 1952, Geology of the crystalline rocks of Georgia: Georgia Geol. Survey Bull. 58, 54 p.

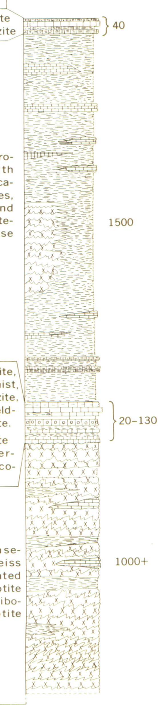


MAP SHOWING METAMORPHIC ZONES WITHIN THE BREVARD FAULT ZONE

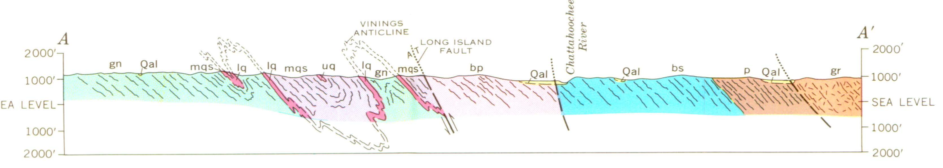


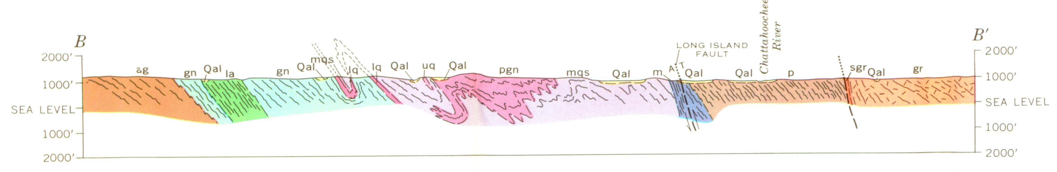
INDEX MAP SHOWING LOCATION OF MAP AREA

MAP UNIT	THICKNESS (feet)	DESCRIPTION
Upper quartzite	0 to 40	Micaceous quartzite and massive quartzite
Aluminous schist and associated rocks	About 1500	Kyanite and staurolite schist with interbedded micaceous quartzites, amphibolites, and quartz-muscovite-biotite-plagioclase gneiss.
Lower quartzite	20 to 130	Micaceous quartzite, muscovite schist, massive quartzite, Ocherous layer, feldspathic quartzite. Micaceous quartzite with garnets alternating with muscovite schist.
Gneiss, schist, amphibolite, and associated rocks	More than 1000	Biotite-oligoclase-microcline gneiss with intercalated muscovite biotite schists, amphibolites, and biotite amphibolites.



DIAGRAMMATIC STRATIGRAPHIC COLUMN OF METASEDIMENTARY ROCKS NORTHWEST OF THE BREVARD FAULT ZONE (SANDY SPRINGS SEQUENCE)





GEOLOGIC MAP OF THE BREVARD FAULT ZONE NEAR ATLANTA, GEORGIA

By
Michael W. Higgins

SCALE 1:48 000
1 ½ 0 1 2 3 4 5 MILES
1 .5 0 1 2 3 4 5 KILOMETERS

1968

Base from U.S. Geological Survey
1:24,000 and 1:62,500, 1954–58

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1968—G67157

For sale by U.S. Geological Survey, price $1.00