GEOLOGIC NOTES

Volume 13	October 1969	Number 4

Carolina Geological Society Guidebook

October 3-5, 1969

A GUIDE TO THE GEOLOGY OF NORTHWETERN SOUTH CAROLINA

INTRODUCTION

An attempt has been made to present here the current results of a detailed mapping program in northwestern South Carolina. The purpose of the two papers presented here is to air some of the conclusions arrived at independently by the two authors. A decision was made to do this in two separate papers where each would have the opportunity to air his own ideas and observations rather than present together in summary fashion facts and ideas which were still in an early stage of development. We believe that the large volume of data collected thus far permits conclusions of a major scope to be drawn regarding this data as it serves to aid the understanding of some of the fundamental geologic problems of this region.

Some of the concepts presented here were arrived at independently and simultaneously by the two authors from different approaches. This explains the concurrence of some of the ideas the reader may note while reading the papers.

P. J. Roper supplied Hatcher with detailed field data from the Tamassee, Satolah, and Cashiers quadrangles. In the low rank belt this information was treated as raw data and matched with interpretations on either side (to the northeast and southwest). Roper's contacts and structural interpretation of the basement rocks in this area appear on Plate 1 unchanged.

The northwest boundary joining the two separate areas of interest is of common interest to both authors. The following is a summary of criteria used by the authors in locating the position of this boundary:

1..The abrupt appearance in pegmatite as one enters the migmatite belt from the lower rank belt.

2..Change in grain size across the boundary in the amphibolites.

3..The boundary is close to the button schist and phyllite interlayered with amphibolites.

4..Presence of thin coarse amphibolite lenses in granite gneiss southeast of the boundary serves to delineate the granite gneiss from adjacent fine-grained Henderson gneiss.

5..Foremost is the abrupt change in macroscopic structural style.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1969 Annual Meeting
Pages 1-9

MIGMATITIC INNER PIEDMONT BELT OF NORTHWESTERN SOUTH CAROLINA

Villard S. Griffin, Jr.
Department of Geology, Clemson University

ABSTRACT

The migmatitic inner Piedmont belt is separated from the northernmost part of the Overstreet Bell (1965) Inner Piedmont by a major tectonic slide. This slide corresponds to the sole of the Walhalla nappe. The Walhalla nappe in the northwest is composed of rocks in the lower, almandine amphibolite facies. They are: amphibolite, feldspathic quartzite, biotite gneiss and granite gneiss. These lithologies grade laterally into one another and are believed to have formed originally from an unstable shelf assemblage during late Precambrian or early Cambrian time. Toward the southeast this assemblage was extensively migmatized and recrystallized. The fold system of the Walhalla nappe probably is conical. Axial surface traces vary widely. The nappe plunges gently but persistently northeastward.

The Six Mile nappe overlies the Walhalla nappe in the southeast and is separated from it below by another important tectonic slide. Rocks of high grade almandine amphibolite facies occur within this recumbent fold mass. The lithologies comprising this nappe are: muscovite biotite schist, biotite gneiss and biotite schist. Minor hornblende gneiss occurs also. This assemblage probably was formed in a late Precambrian or early Paleozoic eugeosyncline farther to the southeast. The Six Mile nappe is considered to have flowed westward over the lower Walhalla nappe during a middle to late Paleozoic orogenesis. The Walhalla nappe compressed and overrode in like manner the lower rank rocks lying immediately northwest of the northwestern slide boundary. These unmigmatized rocks were appressed against the Blue Ridge rocks as the Walhalla nappe flowed over them. Cataclastic deformation occurred in this lower rank belt in response to a gradual lowering of pressure and temperature.

The field relationships in northwestern South Carolina suggest a tectonic picture similar to those conceived from studies in the cores of other orogenic belts.

INTRODUCTION

This paper is a preliminary report on part of the results of a field and laboratory program initiated by the author at Clemson University in the fall of 1964. This purpose is to provide detailed information on the fundamental nature of the Inner Piedmont belt in northwestern South Carolina. This study extends the earlier work of C.Q. Brown and C. J. Cazeau (Cazeau, 1961; Cazeau and Brown, 1963; Brown and Cazeau, 1965; Cazeau, 1966 and 1967). Prior to their reconnaissance investigations, very little attention had been devoted to this terrane on South Carolina.

Acknowledgements

The writer acknowledges National Science Foundation grant GA-1409, which has provided full support for this program since February, 1968. The South Carolina Division of Geology underwrote the program prior to that time and has been a part-tie assistance since. H.S. Johnson, Jr., State Geologist has been of constant help. U.S. Water Resources Research Institute grant A-004-sc (364) provided financial aid to the author for detailed mapping in the southeastern portion of the Seneca Quadrangle in 1966 and 1967. The following students have assisted in the study: E.R. Clayton, 1965-1966; F.F. Bryant, 1968; L.L Acker, 1968-1969; T.M. Goforth, 1969. P.K. Birkhead and R.D. Hatcher, Jr. read the manuscript. The latter made available to the author field data from the Fairplay, Holly Springs and Tugaloo Lake quadrangles. T.M. Goforth conducted a point count analysis of some of the writer's petrographic thin sections. T.M. Goforth and M. Capps assisted in drafting the maps.

GEOLOGIC SETTING AND LITHOLOGY

The area concerned constitutes the northwestern portion of the Inner Piedmont belt of overstreet and Bell (1965, Plate I), but is separated from the northwesternmost part of the inner Piedmont by a significant structural discontinuity (Griffin, 1969; Hatcher, 1969). Northwest of this structural boundary the Inner Piedmont rocks are not migmatized, and pegmatites are rare. The rank of metamorphism is lower and the structural style significantly different. These northwesternmost rocks are stratigraphically and structurally related to the Brevard belt (Hatcher, 1969). The Brevard belt and westernmost rocks of the Inner Piedmont are the subjects of the companion paper.

The rocks of the migmatized Inner Piedmont, across the central part of the map area, lie well southeast of the Blue Ridge physiographic front (Plate 1). The underlying structure is often reflected subtly in the topography. Foliation and joint control stream directions. As the western boundary is approached in the Walhalla quadrangle and to the northeast, this southeastern assemblage shows diminishingly the effects of high grade regional metamorphism. The grain size decreases, pegmatites are fewer, granitization is weak and the rocks retain more of the characteristics of their apparent sedimentary origins.

The boundary is defined in the Walhalla, Old Pickens and southwestern Salem quadrangles by a thin zone of button schist. The author considers the button schist, similar to the button schist occurring between the boundary and the Blue Ridge belt, to occupy a position immediately northwest of this structural discontinuity. The button schist probably served as a zone of weakness along which extensive movement took place.

The rock types characteristic of the migmatitic inner Piedmont are: amphibolite and amphibole gneiss (Amgn), biotite gneiss (Bgn), biotite schist (Bs), granite gneiss (Ggn, BGgn and WGgn), muscovite biotite schist (MBs), and quartzite (Q). These lithologic types are widespread and often occur with one another in varying amounts.

Typically, the amphibole gneiss contains around 30 to 40 percent amphibole. The amphibole is usually hornblendic actinolite in the west and hornblende farther to the east. Plagioclase accounts for around 30 percent of the rock and generally is oligoclase-andesine, but labradorite sometimes occurs. Quartz rarely accounts for more than 20 percent of the rock; usually it occurs in amounts of around five percent. Occasionally epidote-clinozoisite, diopside, almandine and magnetite are present. There are rare occurrences of orthopyroxene south of Seneca in the southeastern part of the map area. The amphibolites contain amphibole in amounts of 70 percent or more.

The biotitic gneiss is commonly a dark, biotite-rich rock, schistose in places. Feldspar augen are not uncommon. A typical specimen contains 36 percent quartz, 9 percent microcline, 6 percent orthoclase, 31 percent biotite, 5 percent muscovite, with opaques, almandine and zircon accounting for the remainder of the rock. This rock type grades into the biotitic schist, which is compositionally similar, but has a higher biotite content. The biotite gneiss in the southeastern part of the map area also contains sillimanite as an accessory.

The biotite schist grades into muscovite biotite schist. The muscovite biotite has a very striking mesoscopic aspect due to the high muscovite content, which imparts a brilliant, sparkling aspect to the band specimens. Frequently both schists present also a reddish hue due to the weathering of garnets to hematite. In the southeast the biotite gneiss, biotite schist and muscovite biotite schist are characteristically coarse and their mineral constituents generally appear fresh. Characteristically the micas are unbent, the feldspars unfractured and quartz possesses no pronounced strain shadows. All grains are clearly interlocked with sutured contacts. These three lithologies underlie an extensive area in the southeastern portion of the map area (Plate 1).

Quartzite occurs in all lithologies. Its relationship to other lithologies is best seen toward the west near the structural boundary. Generally, the quartzite is feldspathic and often sericitic. Where relatively pure, this lithology may contain 80 percent or more quartz, with opaques, usually magnetic and garnet. Epidote-clinozoisite is also present in places. In the southeast several specimens were found with garnets accounting for half the mineral composition. Microcline occurs in lesser amounts. Where quartzite is associated with amphibolite and amphibole gneiss, plagioclase is the dominant feldspar, and hornblende or actinolite and epidote-clinozoisite are also present. Where micaceous, the quartzite often grades into sericite quartz schist in the northwest and muscovite quartz schist in the east. Where feldspathic, it often grades coarsening eastward, into biotite gneiss or granite gneiss.

The granite gneiss is generally a medium grained rock, rarely occurring with coarse or fine texture. Microcline is the characteristic feldspar, with only minor plagioclase. The microcline accounts for around 30 to 40 percent of the rock, with quartz present in amounts between 40 and 60 percent. Both biotite and muscovite usually are present; however, biotite commonly is the more abundant mica, accounting for less than 10 percent of the rock. Epidote-clinozoisite occurs only as an accessory, as do the opaques.

Coarser granitic rock composed almost entirely of quartz and microcline with little or no mica is also common, occurring as exposures of small areal extent through the area. Medium coarse grained examples of this type are alaskite. The very coarse phase constitutes simple pegmatites. Alaskite is also present as the neosome constituent in the migmatite. There appears to be a close genetic relationship between this felsic migmatitic component and pegmatite-alaskite pods and dikes (Griffin, 1967a, p. 45-48).

Small bodies of talc, cummingtonite-chlorite and anthophyllite occur throughout the northwestern migmatitic Inner Piedmont (Plate 1). The bodies may be classified into two categories: (1) altered dunite, and (2) magnesian schist. The altered dunite ranges from masses a foot or so in diameter up to several hundred feet. Anthophyllite is the common alteration product, but talc is also abundant. X-ray analysis of the unaltered dunite indicates that the olivine is fosterite. The largest body in the area lies just south of Newry (Plate 1).

The magnesian schist bodies are of larger areal extent and conform to the local foliation strike, though not always conforming with the dip. Cummingtonite and clinochlore are usually the two most abundant minerals. Talc schist and chlorite schist occur less frequently. Magnesite and epidote occur as accessories in most schists. The largest body of this type lies immediately southeast of Walhalla (Plate 1). This is a cummingtonite-chlorite schist with very steeply dipping foliation, contrasting with the attitude of surrounding granite gneiss and amphibole gneiss, which have low dips.

The origin of these bodies is enigmatic. Possibly they originated as ultramafic dikes and sills. The writer believes that they may have a common origin with other magnesian bodies in the crystalline Appalachians. A detailed study of these bodies is presently being made by the author.

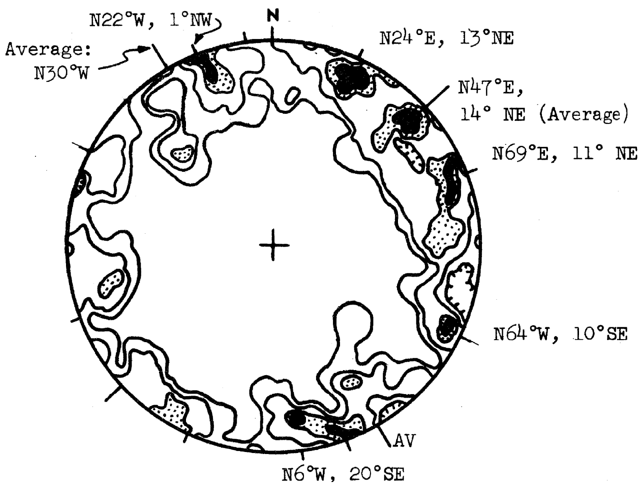

Figure 1. Fabric diagram of 117 mesoscopic recumbent folds from the migmatitic Inner Piedmont Belt. Contour intervals: 1%, 2%, 3%, 4-5% (black). Concentrations /1% area.

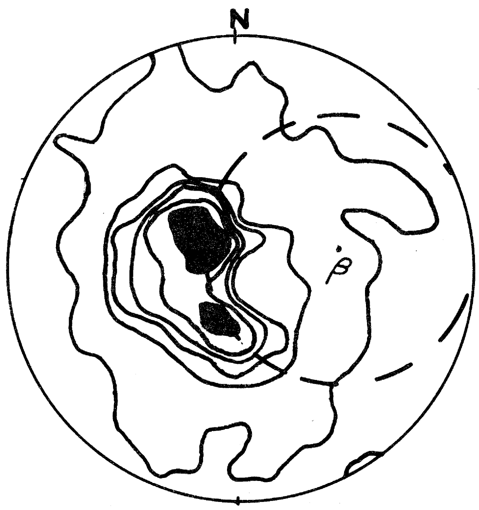

Figure 3. Pi-diagram of 726 foliations Poles from the migmatitic Inner Piedmont Belt. Contour intervals: 1%, 2%, 3%, 4%, 5%, 6-8% (black). Concentrations /1% area.

STRUCTURE

Description

Recumbent isoclinical folding is the basic structural style within this terrane. . This conclusion was reached by the writer early in the program from study of mesoscopic folds in the area (Griffin, 1967a; 1968). Recumbent isoclines appear to be the oldest folds. Upright synforms and antiforms of low amplitude are superimposed on the recumbent folds. Continuing work has brought to light small asymmetric folds, or mesoscopic crinkles, formed at a few localities by widely spaced shear surfaces intersecting the primary foliation. This is probably a slip cleavage.

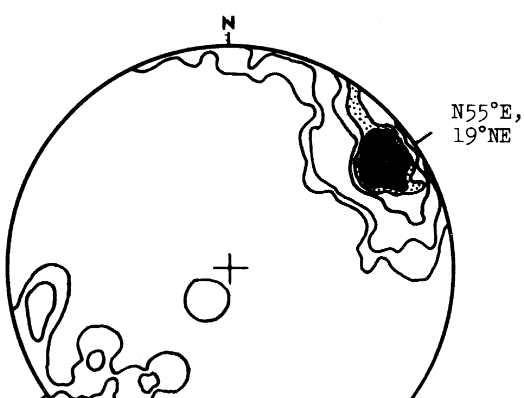

Figure 2. Fabric diagram of 90 mineral elongation lineations from the migmatitic Inner Piedmont Belt. Contour intervals: 1%, 2-5%, 6-8%, 9-10%, 11-10% (black). Concentrations /1% area.

Mesoscopic recumbent folds in the migmatitic Inner Piedmont trend in all directions, but there is a preferred orientation. Figure 1 shows preferred trends of the fold axes. From the concentration models in the diagram three northeast trends exist: N 24° E, 13° NE, N 47° E, 14° NE, and N 69° E, 11° NE. The average northeast trend is N 47° E. Three northwest-southeast trends exist also: N 6° W, 20° SE, N 22° W, 1° NW and N 64° W, 10° SE. The average of these trends is N 30° W. The northeast trending fold axes roughly parallel the macroscopic fold axial surface traces, but the southeast trending fold axes probably lie in *a* tectonic axis direction.

Lineations are sparse but occur widely throughout the terrane. They are best developed in schists. In general these lineations parallel the major fold axes. One type predominates and is characterized by elongated minerals, especially the micas. Amphibole alignment and feldspar elongations show this lineation to a lesser extent. Quartz elongations also have been observed in the Clemson and Fairplay quadrangles (Hatcher, personal communication). Figure 2 presents this lineation, which bears N 55° E and plunges 19° northeastward.

The attitude of the foliation within the migmatitic Inner Piedmont is illustrated by the Pi-diagram in Figure 3. The pole concentrations indicate low dipping foliations. One statistical foliation strikes northeast and dips approximately 20° southeastward. The second statistical foliation strikes northwest and dips around 20° to the northeast. The two maxima define a small circle girdle with center β. This pole bears N 75° E and plunges 59° SE.

A unique type of extreme recumbent fold development occurs in the biotite schist in the southeastern part of the area. Figure 4 is a typical example. These isolated pods of lenses of biotite schist and interlayered lithologies, usually

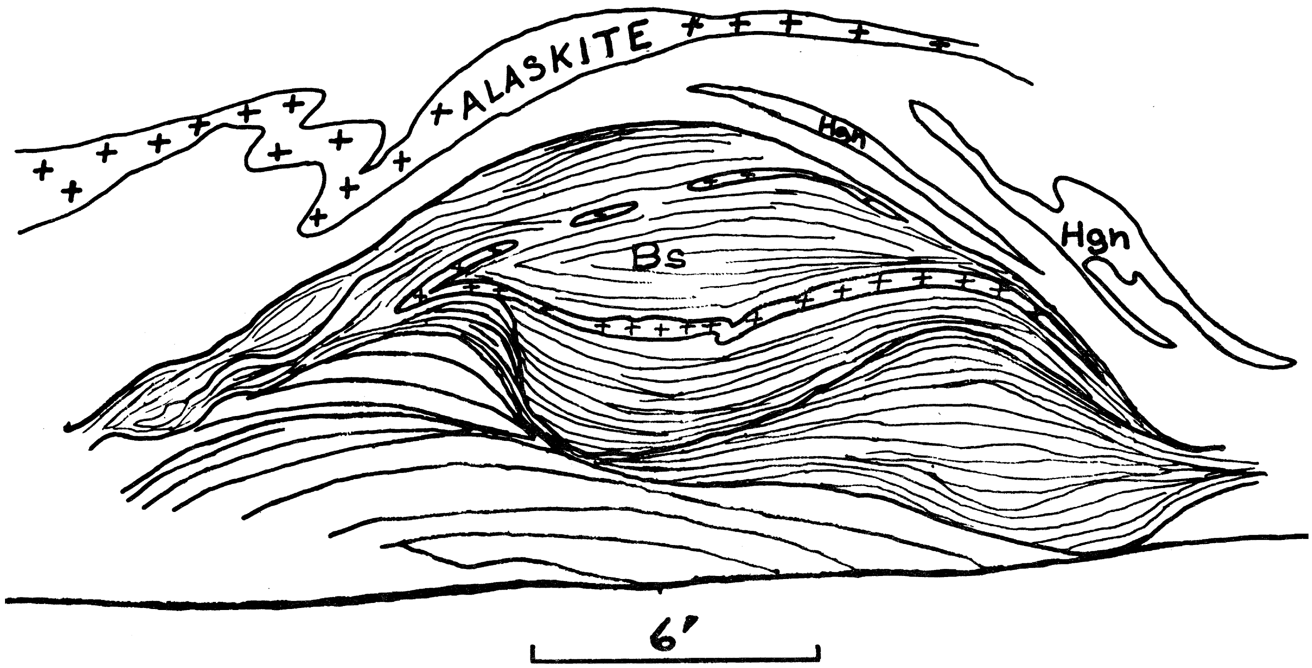

Figure 4. Road cut exposure of macrobutton developments in biotite schists.

alaskite of hornblende gneiss, form macroscopic and mesoscopic analogues of the microscopic buttons characteristic of the Brevard-type schists northwest of the migmatitic Inner Piedmont. The individual macrobuttons consist of isolated fold crests with pinched-off limbs.

Recent detailed field work has enabled the write to recognize macroscopic folds within the migmatized Inner Piedmont (Griffin, 1969; in press). Plate 1 shows the present understanding of this folding in plain view. The macroscopic folds adjacent to the northwestern boundary are presently the best understood and defined structures within the areas considered. Data are as abundant and reliable farther southeast. However, the structural patterns show there are somewhat conjectural in detail at this point in the investigation. This is due to these reasons: (1) the folding style is highly intricate and complex, (2) recrystallization is more pronounced to the southeast, (3) granitization effects progressively obliterate the original lithologic differences to the southeast, making it increasingly more difficult to follow marker units around fold structures and (4) relief is lower with correspondingly fewer and poorer outcrops.

The northwest boundary fold is a large recumbent anticline which over-rides the non-migmatitic, low rank rocks northwest of the boundary (Griffin, 1969, in press; Hatcher, 1969, in press). This major boundary fold, or complex of folds, plunges northeastward. This conclusion is supported by the predominant northeast plunging minor fold axes, lineations and β (Figures 1, 2 and 3). The northwest limb of the fold is highly attenuated. This is suggested by thinned lithologic units suddenly appearing immediately southeast of the boundary, and then progressively thickening northeastward around the fold nose and to the southeast, where the outcrop patterns are considerably widened in places (Plate 1).

In the southwest part of the map area (Plate 1), immediately southeast of the boundary slide, the boundary fold is cored by granite gneiss (WGgn) of the West minster Pluton of Cazeau (1967). Along the granite gneiss of Overstreet and Bell (1965, p. 64-65), previously termed Whiteside granite (Keith, 1907, map, p.405), but is now believed to be different from the typical Whiteside Granite gneiss of the Blue Ridge to the northwest. A sequence of intercalated thick amphibolites (Amgn), thin quartzites (Q) and biotite gneiss-quartzite (Bgn, Q) unites separate the two granite gneiss bodies along the axis of the boundary fold.

As these units are traced eastward a zig-zag outcrop pattern becomes apparent, establishing the existence of macroscopic recumbent isoclines (Plate 1). The fine-grained northwestern amphibolites zig-zag southeastward into the coarse-grained amphibolites and amphibole gneiss; the northwestern feldspathic quartzites and fine biotite gneisses, southeast of the boundary, in a like manner trace eastward into coarser-grained biotite gneiss, granite gneiss and migmatite. The complexity of structural map patterns and recrystallization effects is clarified to some degree in the southeast portion of the Salem quadrangle (Plate 1). Here the sharp contact between the biotite granite gneiss and amphibolite was traced by the author with relative certainty from the northwestern structural boundary into highly migmatized and recrystallized areas to the southeast.

Plate 2 presents the axial surface traces of these macro-

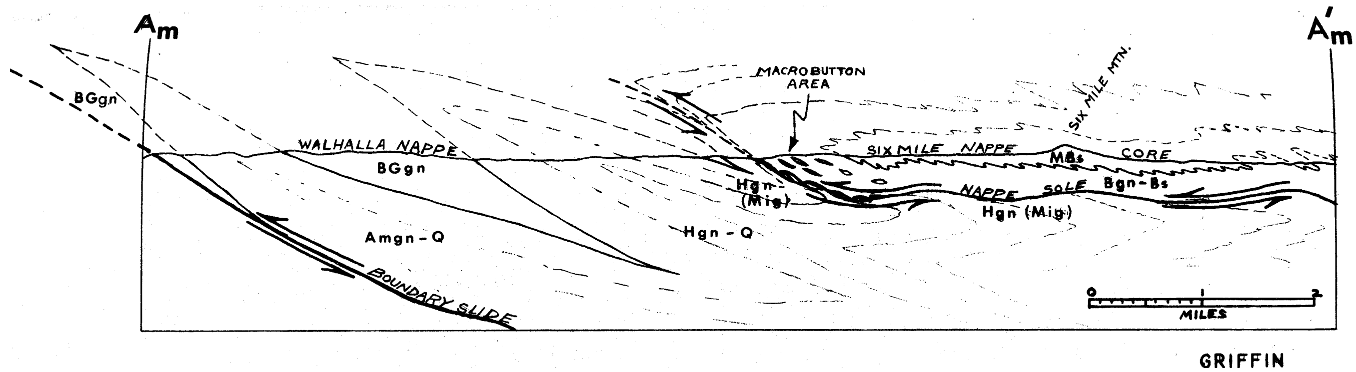

Figure 5. Cross section through the migmatitic Inner Piedmont Belt in northwestern South Carolina (Vertical scale equals horizontal scale).

scopic folds. Near the northwestern boundary, in the Salem area, the fold traces are nearly parallel suggesting that the folds may be cylindrical and coaxial. However, toward the southeast, especially between Walhalla and Seneca, some axial traces diverge widely from the general trend. This indicates that the entire system is non-cylindrical and only approaches cylindrically within certain local domains, e.g. near the northwestern boundary. This conclusion is supported further by the foliation –diagram of Figure 3. This diagram, base don foliations from the entire area, indicates that the total fold system is conical. Similar examples have been presented recently by Whitten (1966, p. 63-66).

A southeastern structural boundary, some five to ten miles southeast of the northwestern boundary, separates this migmatite complex from an extensive outcrop area of biotite gneiss- biotite (Bgn-Bs) schist. Muscovite biotite schist (MBs) also accounts for a substantial portion of outcrop area in the southeast, especially at higher elevations. The boundary is reflected in the topography by a low ridge or complex of ridges underlain by this assemblage and extending throughout the area mapped in the southeast (Plate 1). The attitude of the boundary is irregular, but subhorizontal in a broad sense, differing distinctively from the northwestern tectonic slide boundary which dips regularly southeastward between 15 and 40 degrees. Because of this subhorizontal attitude, many streams have dissected the biotite gneiss-schist assemblage, exposing in places rocks of this migmatite complex below.

The structural style of this eastern zone differs from that of the migmatite complex to the northwest in that no zig-zag pattern of northeast plunging macroscopic fold is evident. Recumbent isoclines exist on all scales, but the plunges vary widely. The author has recently mapped a recumbent fold within the boundary, southwest of Seneca, which plunges southwest.

Interpretation

The cross section in Figure 5 and the tectonogram in Figure 6 are based on the data presented above and Plates 1 and 2. They represent the author's present structural understanding of the migmatitic Inner Piedmont belt of northwest-

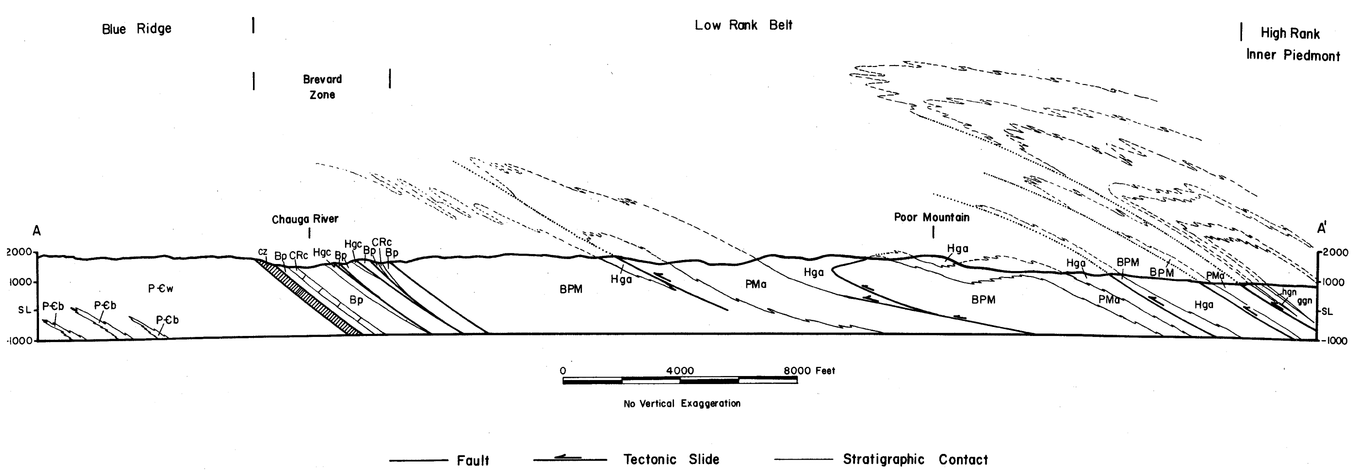

Figure 6. Tectonogram of a portion of the migmatitic Inner Piedmont Belt in northwestern, South Carolina (vertical scale equals horizontal scale in section T'_m - T''_m).

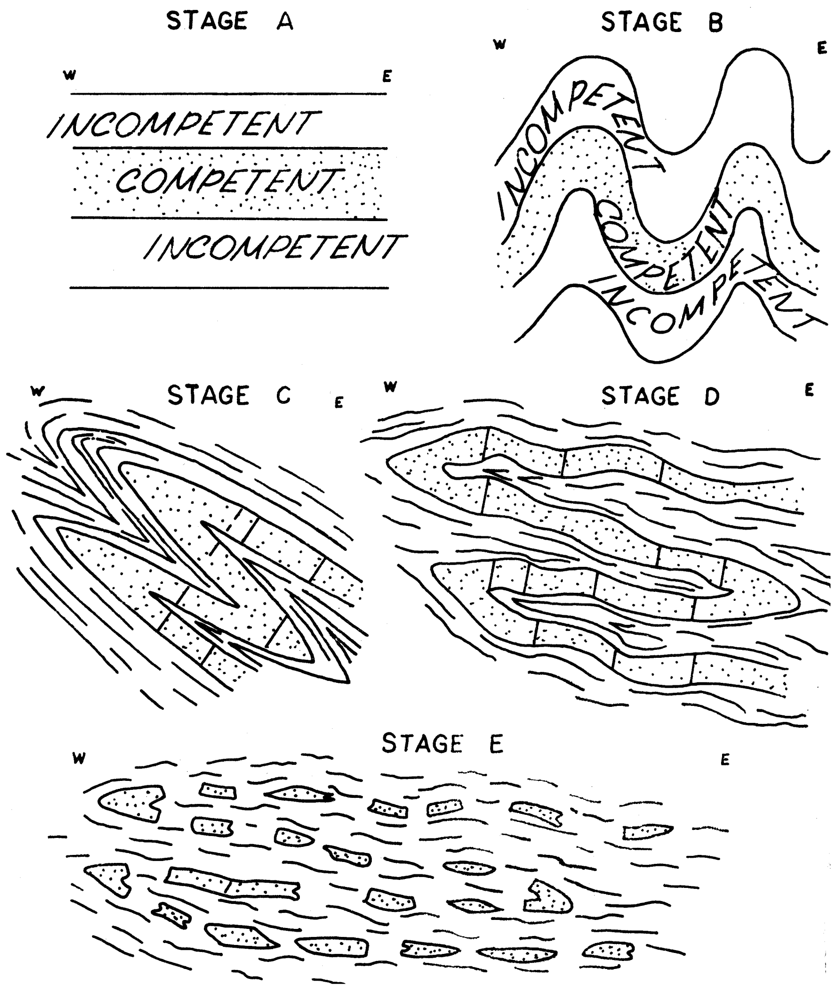

Figure 7. Sequence of fold development in northwestern South Carolina (after Griffin, 1967, Figure 7).

ern South Carolina (refer to Plate 1 for section and stereo gram locations). According to this interpretation, this high-rank terrane is separable into two major recumbent fold masses. They are isolated by tectonic slides and probably have been transported several miles from the southeast.

Bailey (1922, p. 87) defines a nappe as, "…a mass brought forward to a notable extent by recumbent anticlinal folding or thrusting." This definition essentially is in accord with others (Hills, 1953, p. 54-5, 1963a, p. 246; Billings, 1954, p. 189; Goguel, 1962, p. 141-142; Spencer, 1969, p. 215 and 218). According to Bailey's definition, these major recumbent anticlinal fold masses qualify as one type of nappe. For convenience, this author will refer to the western fold mass as the Walhalla nappe and to the eastern one as the Six Mile nappe.

A likely area for the Six Mile nappe to be rooted lies in the La France quadrangle and farther southeast. Cazeau (1967) maps extensive exposures of mica schist in this area. The Beverly granite gneiss also outcrops widely in this area (Cazeau and Brown, 1963, Plate 2) and may occupy th fold core, as the Westminister granite gneiss occupies the core of the Walhalla nappe. The Walhalla nappe, because it extends farther to the northwest, may be rooted beneath the Six Mile nappe at depth.

Figure 7 is a possible sequence of fold development earlier proposed for all scales within the region (Griffin, 1967a, Figure 7). According to this concept, primary stratification surfaces were gradually brought through each successive stage of folding by continuous deformation over a lon interval of time. Increasing temperature and confining pressure, as well as increased water pressure, with accompanying recrystallization, served to enhance the extreme elongation and attenuation of the primary fold limbs, resulting in tectonic slides and boudinage (Figure 7, Stage E). Resistance of the overlying rock masses served to redirect the stress field causing extension of the primary folds (F_1) into a subhorizontal position. Continuing flow against increasing resistance to this forward horizontal movement resulted in a superposition of secondary, low amplitude folds (F_2). As the plasticity of the fold masses decreased, probably in response to decreasing temperature, slip cleavage was superimposed on all pre-existing foliations, producing crenulation folds (F_3).

As the Walhalla nappe was appressed in the northwest against the tightly infolded non-migmatitic, low rank rocks (Griffin, 1969, in press; Hatcher, 1969, in press), the plastic recumbent folds there were aligned into a nearly cylindrical and coaxial attitude. Farther southeast, and correspondingly deeper within the nappe, migrating felsic neosome formed from mobilized quartzfeldspathic layers within amphibolites increased markedly the plasticity of the entire fold mass there.

Tischer (1963, p. 444) suggested that a rapid change in thickness of lithologic units in the Pegado anticline of the western Iberian chain may have been one cause fro the conical fold pattern he found. The author believes that a tectonic thickening resulting from a crowding in of the highly plastic upper folds of the Walhalla nappe (Figure 6), in the area between Walhalla and Seneca, as it was appressed against the western boundary is a possible explanation for conical folds here. By reference to Plates 1 and 2, the reader can see the eastern and western boundary slides are closer together to the northeast in the Salem quadrangle than in the area between SEnecas and Walhalla. Also the major recumbent folds in the Walhalla nappe are reduced in number to two. More material is crowded toward the southwest and hence a greater number of folds occur there to accommodate this lack of room. This apparent crowding of mobile material southwestward in the deeper portion of the northeast plunging Walhalla nappe has affected the northwestward advance of the Six Mile nappe. However, the reverse may be true. An irregular forward advance of the Six Mile nappe may have caused a crowding of material toward the Walhalla-Seneca portion of the lower nappe.

The northwest-trending mesoscopic recumbent folds common in the migmatitic Inner Piedmont belt probably resulted from stretching during forward flowage of the larger fold masses. Cloos (1952, p. 26-28) attributes most mesoscopic cross-folds to cylindrical flowage in the direction of tectonic transport (*a*-axis).

The author considers the lineation of elongate mineral grains common to this high rank terrane to result from a mimetic recrystallization parallel to pre-existent rock inhomogeneities produced by the major deformation. This conclusion is based on the fresh appearance of the elongate grains in hand specimen and thin section. The microscopic observations of the mica schist presented earlier especially support a post-deformational crystallization. The fold axes trending northeastward apparently served as the direction of easiest growth.

Macrobuttons (Figure 4) are common in the biotite schist of the Six Mile nappe near the slide boundary. Milici (personal communication) suggests that the mica buttons in Brevard-type schists resulted from extreme deformation of slip cleavage crinkles of other microscopic folds. Microscopic evidence for this usually is not clear, because the buttons are recrystallized and internal structure consequently has been destroyed. However, these macrobuttons give conclusive evidence in the validity of Milici's concept, at least in outcrop scale, here in the migmatitic Inner Piedmont.

This author believes that the macrobuttons were formed by extreme recumbent folding of the biotite schist above and probably within the sole of the Six Mile nappe. Intensive deformation continued after the recumbent folds had been formed, while the nappe advanced northwestward, caused extreme attenuation of fold limbs. The fold closures were finally isolated by transposition and the limb remnants, remaining with the closure, were compressed together. This situation corresponds to Stage E of the fold development sequence in Figure 7. Whitten (1966, p. 201) describes a similar "tectonic fish" in the Grampians of Scotland. The westward-plunging recumbent isocline in the sole of the Six Mile nappe southwest of Seneca may represent an exposure of an extremely large macrobutton or tectonic fish.

TENTATIVE STRATIGRAPHY

Because the western boundary fold is a recumbent northeast plunging anticline, a tentative stratigraphic sequence may be established in the rocks composing this fold. The granite gneiss of the Westminister pluton (WGgn) would be the oldest unit, because it occupies the fold core, if not due to plutonic injection as Cazeau (1967) proposes, but instead originating from deposition of quartzfeldspathic sediments, felsic pyroclastics or extrusion of granitic volcanics. The writer believes that this unit originally was sedimentary, or less likely volcanic, and was later subjected to anatectic remobilization. The main basis for this present belief is the gradual southeastward transition of layers of feldspathic quartzites, interbedded with amphibolite elsewhere in the sequence, into granite gneiss of similar composition (see Plate 1). By referring to the author's tectonogram for the area (Figure 6), an explanation is given for the proximity of high rank rocks, including the Westminister granite gneiss in the Walhalla nappe immediately adjacent to the northwestern boundary in the Holly Springs and Tugaloo Lake quadrangles. The deepest and highest rank portion of the Walhalla nappe, by virtue of its northeast plunge, has been exposed by erosion. Hence, the anatectic Westminister granite gneiss, and accompanying high rank migmatized amphibolites suddenly appear to the southeast as one crosses the boundary away from the low rank, non-migmatitic belt in the area.

Overlying the Westminister granite gneiss lie the intercalated amphibolite (Amgn) and thin micaceous or feldspathic quartzite units (Q). Some of these feldspathic quartzite-biotite gneiss-granite gneiss units are of major size and are shown on the map in Pate 1. The quartzite layers grade in places along strike into fine, dark augen biotite gneiss and schist (Bgn), probably resulting from sedimentary facies changes. Finally, the biotite granite gneiss (BGgn) overlies this unit in the Salem and Sunset quadrangles, and appears to be the youngest unit within the Walhalla nappe in this area. This granitic unit probably has a sedimentary or volcanic origin similar to that proposed for the Westminister granite gneiss. The sharp contact with the underlying amphibolite-quartzite (Amgn-Q) unit in the Salem quadrangle further supports this supposition of sedimentary gneiss.

Within the Six Mile nappe, to the southeast, the muscovite biotite schist (MBs) is considered older than the biotite gneiss-biotite schist (Bgn-Bs), providing that the author has correctly interpreted the nappe to the anticlinal (Figure 5 and 6). The stratigraphic relationship between the metamorphites in both the Six Mile and the Walhalla nappe is presently an unanswered question. Future studies in the root zones of both nappes, providing they can be recognized, may permit stratigraphic correlations between units in each nappe.

Because of the abundance of amphibolite repetitiously intercalated with and grading into quartzite, both feldspathic and micaceous, the writer presently speculates that unstable shelf conditions may have prevailed during the sedimentation of the units within the Walhalla nappe. The amphibolites are visualized as originally impure, iron-rich, sandy marls grading upward and laterally into argillaceous and/or feldspathic sand facies. Some of the amphibolites may also represent quartzose calcareous shales (D, Snipes, personal communication).

The two granite gneiss bodies originally may have represented thick arkosic and feldspathic sheets developed on this shelf during periods of uplift in the granitic provenance. Just as probable, these granitic units may represent periods of extensive argillaceous sand deposition, without accompanying carbonate formation. Two other possibilities exist also. Felsic pyroclastic deposition and/or felsic extrusion on the shelf could produce the same rock type through high grade metamorphism.

No significant equivalents of graywacke or of mafic extrusives, pointing to eugeosynclinal conditions, have been found in this assemblage. However, the biotite gneiss-biotite schist assemblage of the Six Mile nappe probably represents greywacke equivalents. Birkhead and Griffin (Overstreet and Bell, 1965, p. 59) as gabbro. The mineral composition suggests that many of these amphibolites and hornblende gneisses may represent original mafic extrusives and/or intrusives. The widespread presence of sillimanite, almandine and muscovite within this rock assemblage places it in the sillimanite-almandine-muscovite subfacies of the almandine amphibolite facies, which is higher in rank than most rocks of the Walhalla nape. This southeastern assemblage probably was formed in a eugeosynclinal environment some distance to the east and later tectonically transported westward to its present position while reaching an extreme grade of regional metamorphism.

SUMMARY AND CONCLUSIONS

The author concludes that the migmatitic Inner Piedmont belt is an extremely complex terrane characterized by recumbent folds, nappes, migmatites and widespread granitic bodies. This complex probably was derived from the deformation of a late Precambrian of early Paleozoic geosynclinal accumulation.

Unstable shelf conditions probably existed along the western border of the geosynclinal in which arkoses, feldspathic sandstones, quartzites, marls and calcareous shale were deposited. Farther eastward, this environment gave way to eugeosynclinal conditions, where greywacke arenites and lutites accumulated along with thin mafic volcanic flow and felsic pyroclastics.

Orogenesis began in the eastern eugeosyncline during early or middle Paleozoic. The Six Mile nappe moved westward from this active zone and overrode the more westerly Walhalla nappe. The Walhalla nappe, in like manner overrode the lithologically similar rocks to the west which overlay the Blue Ridge basement. These rocks of the lowgrade non-migmatitic belt were both passively pulled down into and overridden by the Walhalla nappe. During this process, the low rank belt was tightly compressed by both the Walhalla nappe and the Blue Ridge rocks to the northwest. A strong coaxial and almost cylindrical recumbent fold system developed in this narrow belt as a result of this deformation. Along the northwest boundary, where the temperature was somewhat less, mylonites developed against the Blue Ridge, perhaps at a later time (Hatcher, personal communication).

The author believes that the generally high-grade, migmatitic metamorphic assemblage in the northwestern South Carolina represents a structural picture not unlike that encountered within the cores of other orogenic belts. Wegmann (1935), Haller (1956), Krank (1957), Berthelsen (1957), and many other workers have described similar relationships within the core of a multitude of other orogenic belts.

The writer has stated previously (Griffin, 1967a; 1968; 1969, in press) that he believes stockwork folding, according to the concepts of Wegmann (1935) and Haller (1956), occurred within the Appalachian Piedmont during the early Paleozoic. Strong evidence for this view may be found in northwestern South Carolina in the fundamental recumbent folding style, the existence of granite gneiss bodies throughout the terrance, and the major infold of lower rank rocks within the migmatized complex, characterized by cataclastic deformation in places.

REFERENCES

Bailey, E. B., 1922, The structure of the south-west Highland of

Scotland; Quart. Jour. Geol. Soc. Of London, v. 78, p. 82-131.
Berthelsen, A., 1957, The structural evolution of an ultra- and poly-metamorphic gneiss-complex, west Greenland; Geologische Rundschau, v. 48, p. 173-185.
Billings, M. P., 1954, Structural geology (2nd edition); Prentice-Hall, Inc., Englewood Cliffs, 514 p.
Birkhead, P. K., and Griffin, V. S., Jr., 1968, Bedrock influence on sediment load of a Selected Hartwell reservoir tributary; Clemson University, Water Research Institute, Report No. b, 31 p.
Brown, C. Q., and Cazeau, C. J., 1965, Geology of the Clemson quadrangle, South Carolina; Div of Geology, S. C. State Devel. Board, MS-9.
Cazeau, C. J., 1961, Notes on the geology and structure of Oconee Country, South Carolina: Div. of Geology, S. C. State Devel. Board, Geologic Notes, v. 5, p. 89-91.
Cazeau, C. J., 1966, Geology of the LaFrance quadrangle, South Carolina: Div. of Geology, S. C. State Devel. Board, MS-10.
Cazeau, C. J., 1967, Geology and mineral resources of Oconee County, South Carolina: Div. of Geology, S. C., State Devel, Board, Bulletin #34.
Cazeau, C. J., and Brown, C. Q., 1963, Guide to the geology of Pickens and Oconee Counties, South Carolina: Div. of Geology, S.C. State Devel, Board, Geologic Notes, v. 7, no. 5.
Cloos, E., 1952, Lineation – a critical review and annotated bibliography: Geol. Soc. America, Mem, No. 18, 122p.
Goguel, J., 1962, Tectonics: W. H. Freeman and Company, San Fancisco, 384 p.
Griffin, V. S., Jr., 1967a, Folding styles and migmatization within the Inner Piedmont Belt in portions of Anderson, Oconee and Pickens Counties, South Carolina: Div. of Geology, S.C. State Devel. Board, Geologic Notes, v. 11, no. 3, p. 37-52.
Griffin, V. S., Jr., 1967b, Geology of the Six mile Quadrangle, South Carolina: Div. of Geology, S.C. State Devel, Board, MS-14.
Griffin, V. S., Jr., 1968, Structural styles within the Inner Piedmont Belt of northwestern South Carolina (abs.): Geol. Soc. Of America, Southeastern Section, Program, p. 41.
Griffin, V. S., Jr., 1969, Structure of the Inner Piedmont Belt along the Blue Ridge physiographic front north of Walhalla, South Carolina (abs.): Geol. Soc. America, Southeastern Section, Program, p. 29.
Griffin, V. S., Jr., In Press, Inner Piedmont tectonics in the vicinity of Walhalla, South Carolina: Div. of Geology, S. C. State Devel, Board, Geologic Notes.
Haller, J., 1956, Probleme der Tiefentektonik oestgroelandischen Kaledoniden: Geologische Rundschan, v. 45, p. 159-167.
Hatcher, R. D., Jr., 1969a, Structure of the Low Rank Belt of northwest South Carolina (abs.): Geol. Soc. America, Southeastern Section, Program, p. 32.
Hatcher, R. D., Jr., 1969b, Stratigraphy and petrology of the Brevard-Poor Mountain-Henderson belt of northwestern South Carolina (abs.): Geol. Soc. America, Southeastern Section, Program, p. 31.
Hatcher, R. D., Jr., In press, Stratigraphy of the Brevard zone and Poor Mountain belt in northwestern South Carolina: Geol. Soc. America, Bulletin (Short Notes).
Hills, E. S., 1953, Outlines of structural geology (3rd Ed.): John Wiley and Sons, Inc., New York, 182 p.
Hills, E. S., 1963, Elements of structural geology: John Wiley and Sons, Inc., New York, 483 p.
Krank, E. H., 1957, On folding movements in the zone of the basement Geologische Rundschau, v. 47, p. 261-282.
Overstreet, W. C., and Bell, Henry, III, 1965, The crystalline rocks of South Carolina: U. S. Geol. Survey Bull, 1183, 126 p.
Spencer, E. W., 1969, Introduction to the structure of the earth: McGraw-Hill, New York, 578 p.
Tischer, G., 1963, Ueber K-Achsen: Geologische Rundshau, v. 52, p. 426-447.
Wegmann, C. E., 1935, Zur Deutung der Migmatite: Geologische Rundschau, v. 26, p. 305-350.
Whitten, E. H. T., 1966, Sructural geology of folded rocks: Rand McNally and Company, Chicago, 623 p.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1969 Annual Meeting
Pages 11-32

STRATIGRAPHY, PETROLOGY, AND STRUCTURE OF THE LOW RANK BELT AND PART OF THE BLUE RIDGE OF NORTHWESTERNMOST SOUTH CAROLINA

Robert D. Hatcher
Department of Chemistry and Geology
Clemson University

ABSTRACT

The low rank belt of northwestern South Carolina is bordered on the northwest by the Blue Ridge belt and on the southwest by the high rank Inner Piedmont. Stratigraphic sequences have been recognized and mapped throughout the low rank belt and in part of the Blue Ridge belt.

The Chauga River Formation, recognized in the Brevard Zone, and the Poor Mountain Formation to the southeast are thought to be equivalent and comprise the Chauga River-Poor Mountain Group. The members, carbonate member, and basal graphitic phyllite member. This sequence traceable from Georgia to North Carolina. The Poor Mountain Formation consists of a marble-quartzite member, am amphibolite member and the Brevard-Poor Mountain transitional member. The Poor Mountain Formation is thought to be the southeastern facies equivalent of the Chauga River Formation and outcrops over a wide area in the low rank belt. It is traceable in to Georgia. The Chauga River-Poor Mountain Group underlies the Henderson Gneiss in this area.

The Henderson Gneiss is thought to be a thick feldspathic quartzite-arkose unit. Very coarse augen, coarse augen, and fine grained phases are mappable in the low rank belt.

The Whestone Group is an assemblage of metagraywacke, metasandstone, and schist occurring in part of the Blue Ridge belt immediately northwest of the Brevard Zone.

A Late Precambrian or Early Cambrian age is proposed for the Chauga River-Poor Mountain Group and Henderson Gneiss. The Whetstone Group i thought to be Late Precambrian.

Two deformational events have affected the rocks of the low rank belt and adjacent parts of the Blue Ridge and high rank Inner Piedmont belts. The earlier phase of deformation (Early to Mid-Paleozoic?) was a compressional event resulting in isoclinal recumbent folding and tectonic sliding as an extension of the isoclinal folding process. This earlier deformational event was associated with progressive regional metamorphism. The high rank-low rank boundary is a greatly extended tectonic slide which brought the migmatized rocks of the high rank Inner Piedmont up over the rocks of the low rank belt. Klippen of high rank rocks resting upon the rocks of the low rank belt occur as close as 3,000 feet to the Brevard Zone and up to 2 miles from the boundary.

The later deformation affecting this area is the faulting, shearing and cataclasis associated with movement on the Brevard cataclastic zone. This event is thought to have occurred in association with (slightly later than) movement on the Blue Ridge thrust. The major lineation of this area, a northeast-trending, subhorizontal crystallization lineation, is thought to have formed in association with the earlier isoclinal folding-regional metamorphic event and is a *b* lineation, not an *a* lineation formed in association with strike-slip faulting. This interpretation is thought to be valid for two reasons: (1) this lineation is regional in character, occurring in all rocks of this area (Blue Ridge, low rank belt, and high rank Inner Piedmont); and (2) parallelism and coaxiality with fold trends throughout the area. It is thought that the Brevard fault zone may be a zone of high angle reverse faulting associated with the Blue Ridge thrust.

INTRODUCTION

The geology of northwesternmost South Carolina may be divided into three distinct lithologic province: (1) the Blue Ridge belt of Precambrian basement rocks and metasediments; (2) the low rank belt consisting of the Brevard-Poor Mountain-Henderson assemblage of metasediments; and (3) the higher rank Inner piedmont characterized by extensive migmatization of the pre-existing metasediments (Figure 1). Close detailed mapping by the writer of a portion of the low rank belt and adjacent Blue Ridge has revealed a stratigraphic succession which has been traced throughout most of the low rank belt from Georgia into North Carolina (Hatcher, 1969a; Plate 1).

The study began in the summer of 1967 as an attempt by the writer to learn more about the nature of the Brevard zone and the rocks adjacent to it. Soon after initiation of detailed mapping in the Whetstone Quadrangle (Plate 1) it became apparent that compositional and sedimentary facies changes could be responsible for the diversity of rock types found in the low rank belt. Previously, it had been suggested that cataclasis was the principal determinant of this diversity of lithologies (Reed and Bryant, 1964). Cataclasis and retrogressive metamorphism are present in the low rank belt (as well as the other two belts), but it is now felt that the role of diaphthoresis has been overstressed by some writers (e.g., Reed and Bryant, 1964) with regard to the origin of the different types of rock present here. This writer believes that cataclasis has occurred here but it is superimposed upon rocks of the low rank belt that were raised by progressive

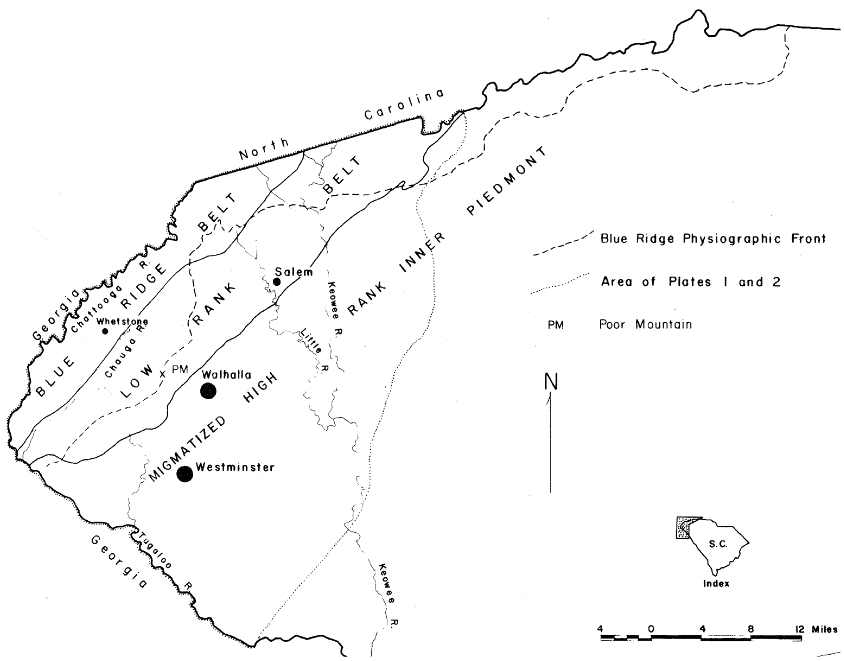

Figure 1. Location map.

regional metamorphism to a grade not very much higher than that superimposed by the cataclastic event. However, both regional and cataclastic metamorphic events are clearly discernable in this area.

Support for this study is being provided by the South Carolina State Development Board, Division of Geology and by the National Science Foundation, Grant Number GA-1409. The writer wishes to acknowledge L. L. Acker who has ably assisted him in the field from the summer of 1968 until the present. Also, W. R. Rivers assisted the writer during part of the summer of 9169. P. J. Roper has made available his field data from the Satolah, Tennessee, and Cashiers quadrangles. P. K. Birkhead and V. S. Griffin, Jr. read and criticized the manuscript. V. S. Griffin, Jr., also made available to the writer his field data from the Walhalla quadrangle. M. L. Capps assisted in the drafting of Plate 1.

STRATIGRAPHY

Introduction

A stratigraphic sequence has been recognized by the writer in the Blue Ridge and low rank belt of northwesternmost South Carolina. An attempt will be made here to present a workable stratographic succession for this assemblage of rock units (Table 1). The stratigraphy presented here is consistent with the structural interpretation of the writer. However, the writer had not discounted the possibility that some of the units may be overturned, and particularly that the Henderson gneiss may be older rather than younger than the Chauga River-Poor Mountain Group. But thus far all evidence leads to the conclusion that the sequence that will be presented here is not overturned except locally in the limbs of isoclinal folds.

Description of rock units will proceed from the oldest unit, the basement gneiss of the Blue Ridge, to the unit which is thought to be the youngest discernable unit in the

Table 1.

Keith (1907)	Sloan (1908)	Livingston (1966)	Cazeau (1967)	Present Work
Whiteside Granite (post-Cambrian)		Henderson Gneiss	Henderson Gneiss	Henderson Gneiss (Cambrian or Precambrian)
Brevard Schist (Cambrian?)	Chauga and Poor Mountain Zones (Cambrian?)	Brevard Rocks	Brevard Sequence	Chauga River-Poor Mountain Group (Cambrian or Precambrian)
			Whiteside Granite	Whetstone Group (Late Precambrian)
Archean: Henderson Granite, Roan Gneiss, Carolina Gneiss	Archean: Henderson Granite, Roan Gneiss, Carolina Gneiss	Precambrian: Cataclastic Rocks, Mica Schist, Amphibolite, Whiteside Granite	Mica Gneiss	Basement Rocks (Earlier Precambrian)

area, the Henderson gneiss. A comparison of the terminology used by previous workers for the rocks of this area with that of the present writer is presented in Table 1.

Basement Gneiss

The basement gneiss of this area, the Carolina and Roan gneiss of Keith (1907), is a complex assemblage of feldspathic gneiss and migmatite with some associated amphibolite. Livingston (1966) and McKniff (1967) have subdivided the basement gneiss in the Highlands-Cashiers area and Roper (see Plate 1) has brought their divisions into South Carolina. This writer thus far has not attempted to trace them into Georgia. Abundant pegmatites and at least one altered ultramafic body occur within this unit. This is thought to be the oldest unit in northwest South Carolina (probably of earlier Precambrian age) and is the unit upon which the Late Precambrian (?) metasediments were deposted.

Whetstone Group

The Whetstone Group consists of a sequence of metamorphosed pelitic and quartzofeldspathic sediments of unknown thickness. It is named for its widespread occurrence in the Whetstone Quadrangle near the crossroads of the same name (see Figure 1 and Plate 1). It is made up predominantly of an assemblage of quartz-oligoclase-biotite-muscovite metasandstone (and metagraywacke) and muscovite-biotite-quartz-oligoclase schist. Some clinozoisite-quartz-hornblende-actinolite-muscovite-almandine calc-silicate rock and quartz-oligoclase-muscovite-garnet-kyanite gneiss also occurs in this unit. Pegmatites are notably absent in these metasediments.

The Whetstone Group is thought to be of Late Precambrian age and equivalent, at least in part, to other Later Precambrian units of the Blue Ridge of the Southern Appalachians, such as, the Ocoee Supergroup, the Ashe Formation (Rankin, 1969), the Grandfather Mountain Formation, the Mount Rogers Volcanic Group, and the Davidson River Group, recently recognized by A. E. Nelson (written communication). This latter unit is closest geographically to the area of occurrence of the Whetstone Group. The composition, textures, and layering of the Davidson River rocks is similar to that of the Whetstone Group except that the Davidson River Group appears to be slightly more biotite-rich.

Chauga River-Poor Mountain Group

Introduction

The Chauga River-Poor Mountain Group is made up of the rocks of the Chauga River Formation. Poor Mountain Formation, and the perspective intermediate and gradational rock types (see Plate 1 and Table 1). Sloan (1908) named the Poor Mountain sequence from exposures on Poor Mountain, northwest of Walhalla, South Carolina (See Plate 1 and Table 1). Shufflebarger (1967), Livingston (1967), Livingston (1966), and Dunn et al. (1968) have suggested that a stratigraphic sequence may exist in the Brevard zone. Hurst and Crawford (1964) have traced a distinctive stratigraphic marker, the carbonate member of the Chauga River Formation, for some 20 miles across Habersham County, Georgia.

This writer has recognized and mapped a definite stratigraphic sequence, herein termed the Chauga River Formation, lying within the Brevard zone in Oconee County, South Carolina. The appearance of some of the same, or different, lithologies of similar appearance farther to the southeast suggests that all the rocks underlying the Henderson gneiss in this areas are stratigraphic equivalents (here termed the Chauga River-Poor Mountain Group) and that they and the Henderson have a sedimentary origin. Cazeau (1967) came to similar conclusions regarding the Henderson and Chauga River (Brevard) assemblages in his reconnaissance study of Oconee County.

Chauga River Formation

The Chauga River Formation is a sequence of chlorite-muscovite button phyllite (Brevard schist of Keith [1907] or fish-scale schist of Reed and Brant [1964], graphitic phyllite, and impure carbonate named for extensive exposures occurring in the Brevard zone along and to the northwest of the Chauga River in Oconee County, South Carolina (see Figure 1). The base of the unit is obscured by the mylonites of the Brevard cataclastic zone. However, southeast of and within the principal mylonite zone is a distinctive fine-grained metallic gray graphitic (chlorite-muscovite) phyllite. This is the dominant lithology in the basal member of the Chauga River-Formation but it is interlayered with muscovite-chlorite button phyllite and some metagraywacke. Buttons, or augen, of micaceous minerals are not as well developed in the graphitic phyllite lithology as in the muscovite-chlorite phyllite. Overlying the graphitic phyllite member is the lower Brevard phyllite member which is predominantly a muscovite-chlorite phyllite with some interlayered metgraywacke. This lower member is no different from the upper Brevard phyllite member except that the upper unit contains a larger quantity of interlayered metagraywacke. These two lower members (graphitic phyllite and lower Brevard phyllite) are not separated on the geologic map (Plate 1).

Separating the upper from the lower Brevard phyllite members is the carbonate member (Plate 3 and 4). This unit is a distinctive stratigraphic marker, Hurst and Crawford (1964) traced it across Habersham County, Georgia on aerial photographs. It is also traceable across Oconee County, South Carolina where it is abundantly exposed in creeks that trend northwest-southeast across the Brevard zone. It always occupies the same position in the sequence and may be traced where exposures are poor or lacking by the subdued topography that accompanies this unit. Some 150 feet of similar carbonate has been cored by the Tennessee Valley

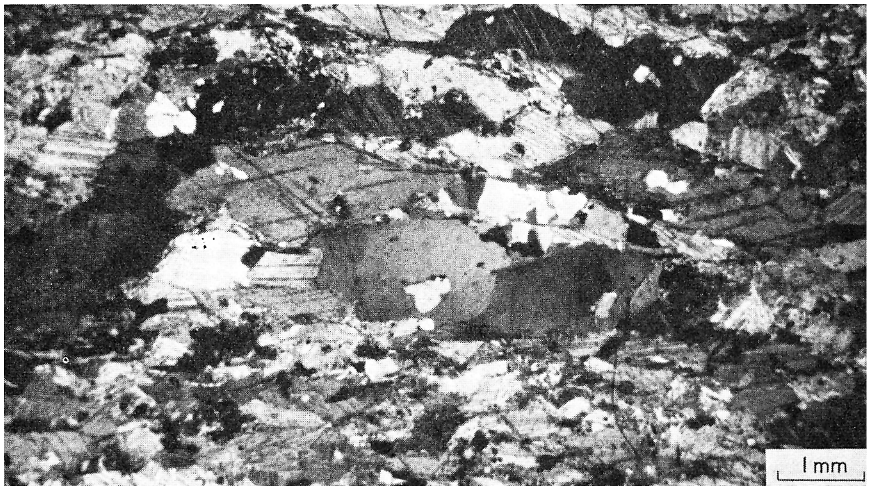

Plate 3. Thin section of Chauga River carbonate from the Tugaloo Lake Quadrangle (vicinity of Brasstown Creek falls). Abundant calcite is present, along with some muscovite, quartz, and opaque material. Section cut across the foliation. X-nicols.

Plate 4. Thin section of Chauga river carbonate from the Chauga River area of the Whetstone Quadrangle. This section is more impure than that in Plate 2 containing more muscovite and a composite quartz augen. Quartz augen of this type are very common in this lithology. Section is cut across the foliation. X-nicols.

Authority on Cane Creek near Fletcher, North Carolina. Moreover, the writer had observed lithologically similar carbonate beds in the Brevard zone near Black Mountain, North Carolina and in a graphitic schist unit in the Oconee series in the same area northwest of the Brevard zone. These latter occurrences near Black Mountain appear to be thinner carbonate-rich interlayers rather than a distinctive unit, but further work on the stratigraphy in this area might establish this for certain. J. R. Butler (personal communication) has mapped this area in detail and has been unable to trace these zones for any distance.

The Chauga River Formation is overlain by the Henderson gneiss. The relative uniformity of the sequence over a wide area allows the writer to estimate the thickness of the sequence to be 1,5000 to 2,000 feet. This may be greatly thinned or it could be closely approximate to the true thickness of the unit. In either case, the Chauga River Formation is a mappable unit consisting of several members that are recognizable over a narrow belt extending across Oconee County, South Carolina. It probably also extends across Habersham County, Georgia and into North Carolina.

Poor Mountain Formation

The type section of the Poor Mountain sequence as described by Sloan (1908) consists of two units: a fine-grained, laminated amphibolite overlain by a marble-calcareous quartzite unit (Plates 5 and 6). On the northwest slopes of Poor Mountain and in adjacent areas, however, the

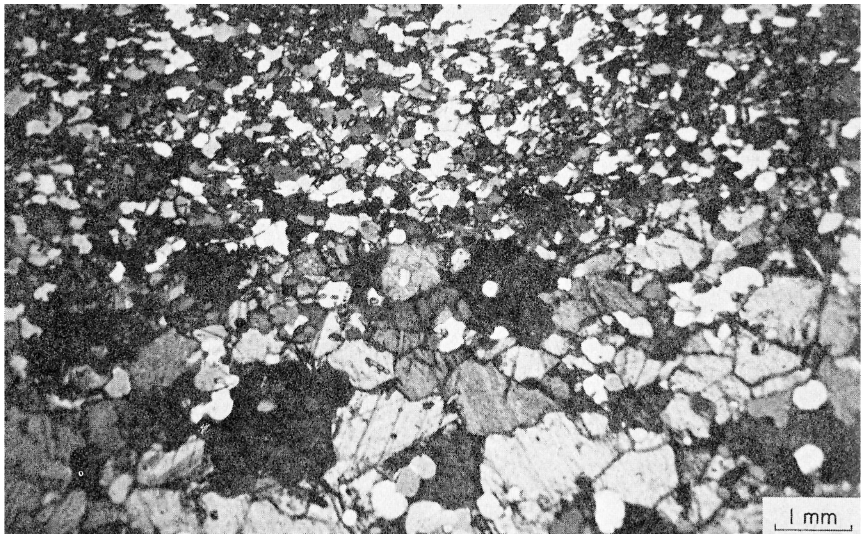

Plate 5. Thin section of the contact between Poor Mountain marble and quartzite from Cedar Creek Falls in the Whetstone Quadrangle. Relatively coarse marble containing a few rounded quartz grains may be seen near the bottom of the photograph. Sutured quartz grains at the top are in the fairly pure quartzite. Epidote is developed as a reaction product between the two rock types. X-nicols.

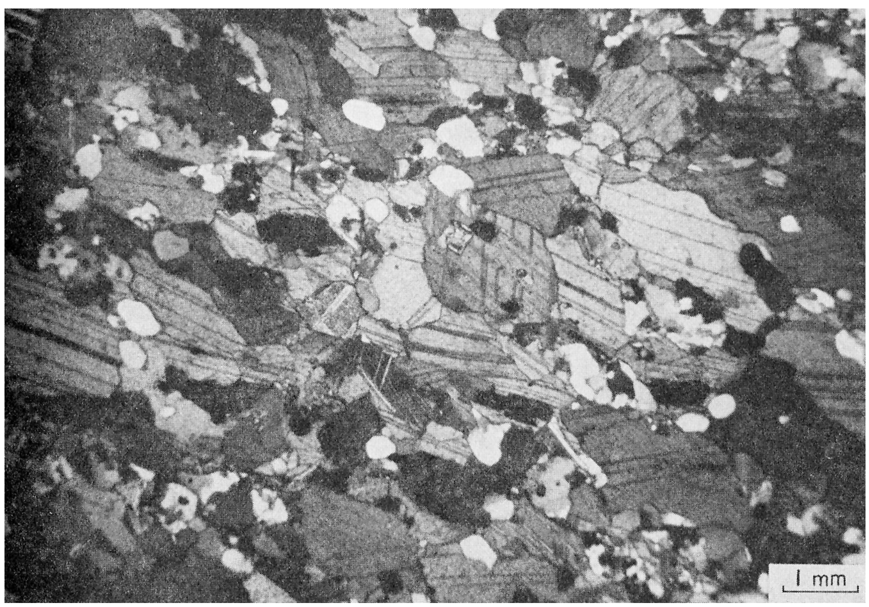

Plate 6. Poor Mountain marble from the Whetstone Quadrangle. It consists of an even-grained mixture of coarse calcite and rounded quartz grains. Section cut normal to the foliation. X-nicols.

amphibolite grades downward into a lithology that is almost identical to the Chauga River muscovite-chlorite phyllites (Brevard phyllite) except that it contains fewer muscovite augen. The writer has thus extended the Poor Mountain sequence to include this unit and it is termed the Brevard-Poor Mountain transitional member of the Poor Mountain Formation. It forms the lowest exposed portion or the formation. Muscovite augen in moderate concentration is a chlorite-quartz-feldspar groundmass characterize the unit. Augen-rich layers may alternate with augen-poor layers.

In the course of detailed mapping in the area between the Chauga River and Poor Mountain, the writer found that the amphibolite not only grades downward into the transitional unit it also grades laterally into it as well. An intermediate "transitional-amphibolite" lithology is actually recognizable over a fairly broad area and serves to delineate wherein this gradation occurs.

In places the amphibolite grades downward and laterally

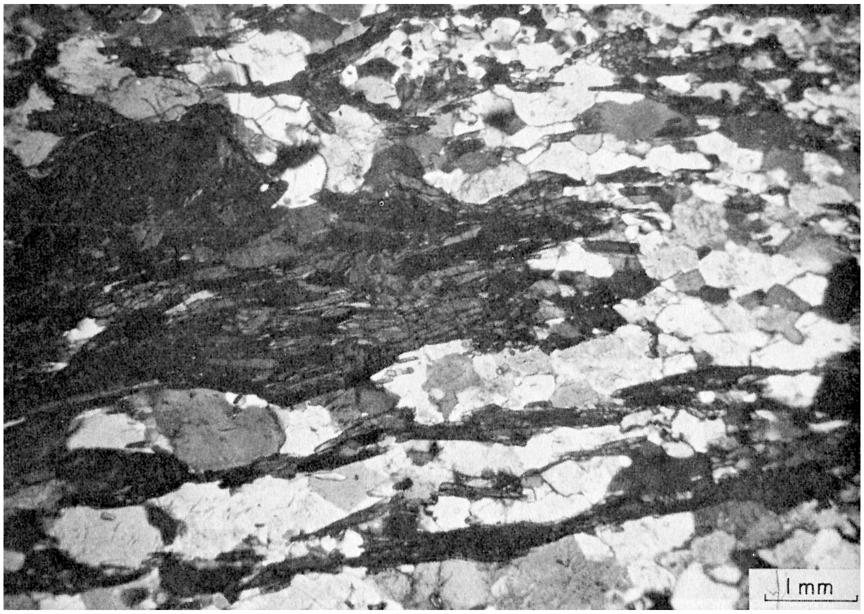

Plate 7. Poor Mountain amphibolite from the Rich Mountain area of the Whetstone Quadrangle. Thinly laminated amphibolite and feldspathic quartzite layers are folded with a thickened amphibolite zone preserved in the core of the fold. Section cut normal to the fold axis. X-nicols.

into a feldspathic metaquartzite. In the upper part of the amphibolite member the amphibolite and feldspathic metaquartzite are intimately associated in alternating layers a few millimeters or less in thickness (Plate 7). This interlayering is suggestive of a sedimentary origin as a calcareous shale or siltstone.

The Brevard-Poor Mountain transitional lithology also occurs as interlayers in the amphibolite several inches to several feet in thickness. Likewise, the amphibolite has been observed as interlayers in the transitional unit and as thin layers near the top of the Chauga River Formation in the Brasstown Creek and Jocassee area.

Another lithology, a feldspathic biotite metaquartzite (probably a metagraywacke), is interlayered with the amphibolite and transitional members and occasionally thickens to mappable proportions. It is thought that this rock type is an unsheared biotite-rich transitional lithology that therefore contains no muscovite augen. It is also very even-grained and does not possess a well-defined mesoscopic foliation. The feldspathic biotite metaquartzite may also contain feldspar porphyroblasts.

Southeast of the Poor mountain type locality and topographically within the Piedmont exist several subparallel belts of rocks that are bounded on the northwest and southeast by Henderson gneiss. Two units are commonly represented here: (1) an amphibolite at the Poor Mountain type locality; and (2) beneath the amphibolite, a button phyllite closely resembling the Chauga River Brevard phyllite or the Brevard-Poor Mountain transitional member.

The writer thinks the Poor Mountain formation is no thicker than the Chauga River Formation. However, anomalous thicknesses can arise due to thinning or thickening in the limbs or axial portions of the isoclinal folds in this area.

Henderson Gneiss

The Henderson Gneiss in northwesternmost South Carolina is a very complex unit. It consistently occurs above the Chauga River-Poor Mountain Group and thus is thought to be a younger unit. The augen gneiss lithology has been observed as interlayers a few feet thick within the Poor Mountain formation.

The Henderson gneiss consists of several lithologies, the most characteristic of which is very coarse quartz, microcline, oligoclase, biotite, muscovite augen gneiss (with microcline microperthite augen ½ inch in diameter larger). This lithology dominates from the North Carolina line to northeast of Salem, South Carolina, where a coarse augen gneiss (augen ¼ to ½ inch) become dominant (Plate 8) and the very coarse lithology disappears. In addition, a nonporphyroblastic medium-grained mica gneiss and feldspathic quartzite make up an appreciable portion of the basal part of this unit toward the southeast side of the low rank belt and also to the southwest.

Rocks of the High Rank Inner Piedmont

The rocks of the high rank Inner Piedmont near its northwest boundary consist of coarse amphibolite, feldspathic quartzite, granitic gneiss, and migmatite. These units are discussed in detail in the companion paper (Griffin, 1969). It is on the appearance of these coarse amphibolites

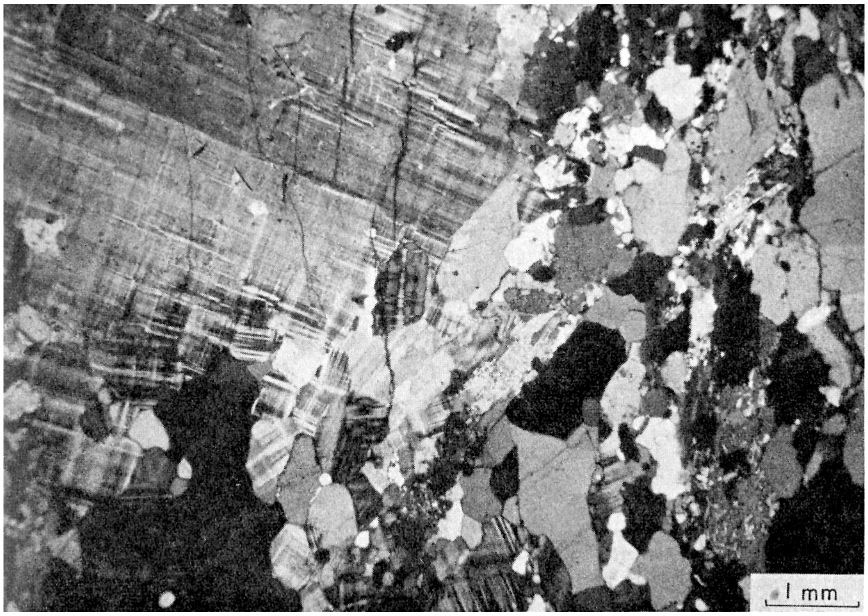

Plate 8. Henderson augen gneiss from the Cobb Bridge crossing of Chauga River on the Holly Springs Quadrangle. A portion of an augen of microcline bordered by microcline, quartz, biotite, and muscovite. Section cut normal to foliation. X-nicols.

and migmatites that the writer draws the boundary between the low rank belt and the high rank Inner Piedmont. These rocks appear to have been in a more plastic state at the time of folding.

Cataclastic Rocks

Cataclastic rocks have been observed by the writer across the low rank belt, in the Blue Ridge, and also in the high rank Inner Piedmont. The most extensively deformed part of this area is the northwest side of the Brevard zone. This narrow belt of cataclastic rocks separates the Blue Ridge from the low rank belt and appears to be a zone of extensive movement. Cataclastic effects within the Blue Ridge of northwest South Carolina and throughout the remainder of the low rank belt and possibly the northwest part of high rank Inner Piedmont are probably a direct result of movement on the Brevard zone.

Cataclastic Rocks of the Blue Ridge

Cataclastic effects observed in the Blue Ridge of South Carolina by this writer are confined to the area just northwest of the Brevard zone. There is a button or fish-scale character developed in the schists here and some noticeable mylonitization of some of the gneisses, pegmatite, metasediments, and other rock types found adjacent to the major Brevard cataclastic zone. No mortar gneisses or other uniquely cataclastic rocks have been found far into the Blue Ridge in this area. Coarse muscovite books occur in some of the basement rocks and metasediments in the Tamassee Quadrangle and also west of Rosman, North Carolina. These micas do not appear to have the bent character which Hamilton (1957) described in the cataclastic gneisses northwest of the Brevard zone near Old Fort, North Carolina.

Rocks of the Brevard Cataclastic Zone

Classic example of sheared and cataclastized rocks are contained within the narrow cataclastic zone separating the Blue Ridge from the Brevard zone. These include mylonites, cherty ultramylonites, ultramylonite breccia, sheared phyllites, and a carbonate slice mapped by the writer in the Whetstone Quadrangle.

The mylonites consist of very fine-grained poorly foliated quartzofeldspathic rocks. The ultramylonite consists of very fine-grained to cryptocrystalline quartz and feldspar (?), while the ultramylonite breccia consists of cryptocrystalline and feldspar (?) masses that have been broken and recemented by microcrystalline quartz (Plate 9).

The carbonate slice consists of banded white to gray very fine-grained to cryptocrystalline calcite and dolomite with sheared and granulated quartz lenses that display a "Manila rope" texture of overlapping fibrous lenticles (see Plate 10).

Other Cataclastic Rocks of the Low Rank Belt

Small mylonite zones are fairly common along the northwest side of the low rank belt but southeast of the Brevard zone. These are typical fine-grained quartzofeldspathic rocks and serve to delineate small fault zones.

The button, or fish-scale, structure in the phyllites of the Chauga River Formation and the Brevard-Poor Mountain Transitional member is probably of cataclastic origin. The buttons are composed of bundles of muscovite crystals which have a lenticular or augen configuration (Plate 11).

Plate 9. Ultramylonite breccia from the Boatwright Mountain area of the Tugaloo Lake Quadrangle. Several cycles of renewed movement affecting this lithology are exhibited here with the broken and remylonitized mylonite fragments that have been fractures and recemented by vein quartz, fractured again and recemented by limonite. Plane light.

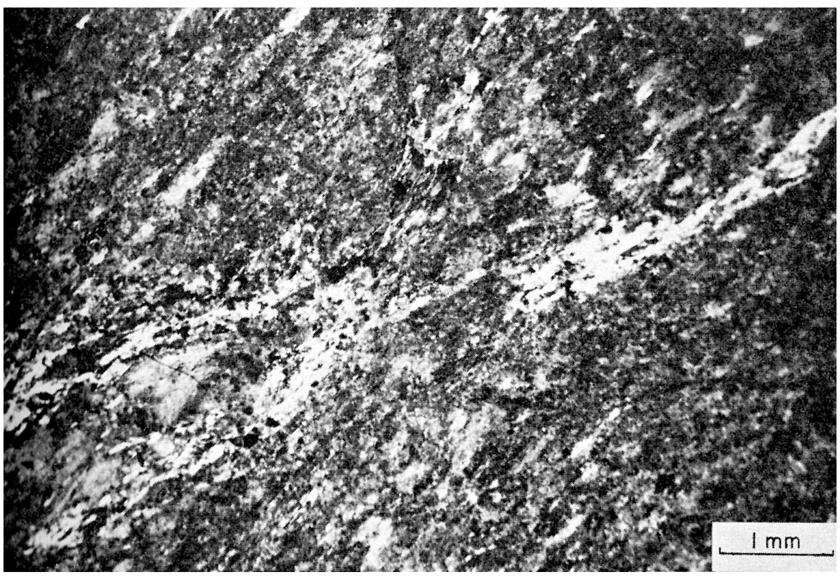

Plate 10. Carbonate slice from the Brevard cataclastic zone near the Blackwell Bridge crossing in Chauga River in the Whetstone Quadrangle. Sheared micro- and cryptocrystalline calcite is traversed by fibrous lenticular "Manilla Rope" textures sheared quartz. Section cut normal to foliation. X-nicols.

They are surrounded by a groundmass of fine-grained quartz, feldspar, chlorite, and muscovite. The groundmass generally does not appear to be greatly disturbed but the muscovite augen have replaced and pushed the groundmass aside. They also are oriented slightly obliquely to the original foliation.

A cataclastic mortar gneiss has been mapped just southeast of the Brevard zone in portions of the Whetstone, Walhalla; Tamassee quadrangles. This unit is very distinct and appears somewhat anomalous beneath rocks of the Chauga River-Poor Mountain Group. The unit consists of two lithologies, a light-colored mafic-poor gneiss and a dark green chlorite-rich lithology. The porphyroclasts in both rock types are composed of quartz, plagioclase, microcline, microperthite, (myrmekite), muscovite, and biotite. The groundmass, or mortar, in this gneiss consists of quartz, plagioclase, chlorite, muscovite, and biotite. The porphyroclasts do not resemble and of the material in the Chauga River-Poor Mountain Group and only bear a slight resemblance to the Henderson gneiss. Chlorite replacing garnet has been observed in several specimens (Plate 12).

Cataclastic Rocks of the High Rank Inner Piedmont

Development of incipient buttons as an extensin of

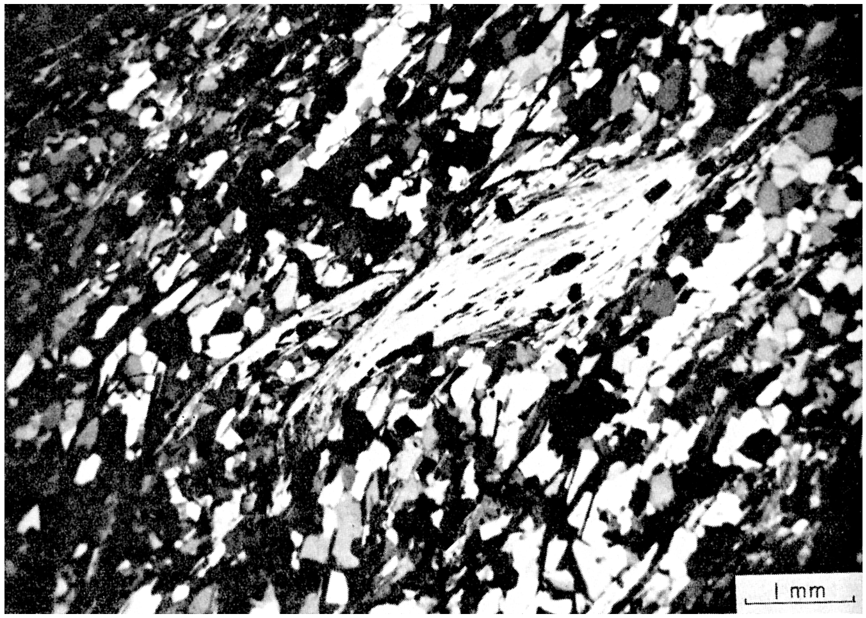

Plate 11. Brevard-Poor Mountain transitional lithology from the Whetstone Quadrangle. Lenticular-shaped augen of muscovite have grown in a matrix if quartz, muscovite, oligoclase, chlorite, and opaques. There appears to be a secondary foliation obliquely intersecting the primary foliation of the rock. Section cut normal to the foliation. X-nicols.

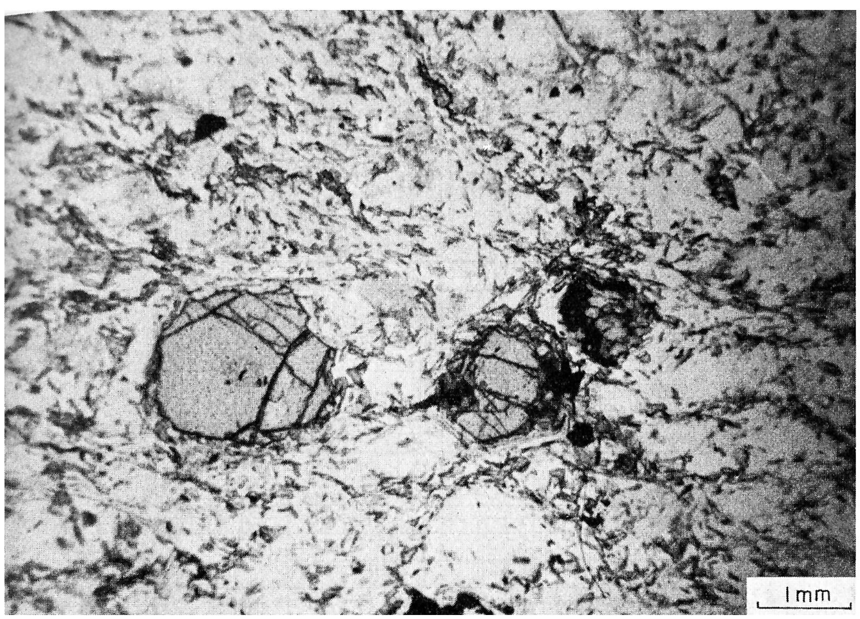

Plate 12. Cataclastic gneiss from the Whetstone Quadrangle. Fractured almandine is shown in three successive stages of chloritic replacement (Black). The garnets are surrounded by a matrix of chlorite, quartz, oligoclase, and opaques. Section cut normal to foliation. Plane light.

develpment of slip cleavage and shearing in some of the granitic gneiss and amphibolite has been observed by the writer in the Tugaloo Lake Quadrangle southeast of the low rank belt-high rank Inner Piedmont boundary. Chlorite and fine-grained muscovite appear on hand specimen examination to have developed on secondary S-surfaces at the expense of mafics, feldspars, and possibly muscovite. All gradations between slightly distorted and sheared gneiss, and well-developed layers of muscovite button schist occur here. Further study of this area is needed in order to establish the exact relationships.

Table 2. Mineral Composition of Major Lithologies.

		Quartz[ab]	Microcline[ab]	Microperthite[ab]	Oligoclase[ab]	Muscovite[abc]	Biotite[bc]	Chlorite[bc]	Hornblende-Actinolite[abc]	Carbonate[ac]	Epidote-Clinozoisite[abc]	Almandine[bc]	Allanite[c]	Apatite[c]	Tourmaline[bc]	Sphene[c]	Zircon[c]	Pyrite[c]	Other Opaques[c]
	Henderson Augen Gneiss	X	X	X	X	X	X	X					X			X			Y
Poor Mountain Formation	Calcareous Quartzite	X	Y		X	Y				X	X								X
	Marble	X	Y		X	X				X	Y								
	Amphibolite	X			X		X	X	X	Y	X	Y			X			X	Y
	Transitional	X			X	X	X	X			X	Y			Y			Y	X
	Feldspathic Biotite Quartzite	X			X	X	X	Y	Y		X						X		X
	Feldspathic Quartzite	X	X	X	X	X	X	X	Y		X	X			X				X
Chauga River Formation	Brevard Phyllite	X			X	X		X				Y							X
	Carbonate	X			X	X	Y	X		X	Y						Y		X
	Graphitic Phyllite	X			X	X		X											X[d]
Brevard Cataclastic Zone	Mylonite	X			X	X												X	X
	Carbonate Slice	X								X									X
	Cataclastic Gneiss (Dark)	X	X	X	X	X	X	X		X	X	Y					X	Y	X
	Cataclastic Gneiss (Light)	X	X	Y	X	X	X	X		Y									X
Whetstone Group	Metagraywacke	X	X		X	X	X	Y			X		X	X	Y	Y	Y		Y
	Schist	X	X		X	X	X	Y			Y								X
Basement Gneiss	Mica Gneiss	X			X[e]	Y	X				Y	Y				X			X

X- Present in all samples examined
Y- Present in some samples
[a] Major constituent
[b] Major accessory
[c] Minor accessory
[d] Graphite
[e] Oligoclase-andesine

PETROGRAPHY AND METAMORPHISM

In general, the mineral assemblage composing the rocks of the low rank belt and the southeast part of the Blue Ridge belong to the green-schist-amphibolite transition facies of progressive regional metamorphism (Turner, 1968). The mineral compositions of the respective rock units of the Blue Ridge and low rank belt are presented in Table 2. Fabric components are listed in Table 3.

The principal plagioclase present in the rocks across this belt is oligoclase whose average composition An_{15-20}. Slightly more calcic plagioclase becomes dominant in the northwest part portions of the Blue Ridge in South Carolina. Paul Ropper (personal communication) reports plagioclase compositions in the andesine range in the Blue Ridge of the Tamassee Quadrangle.

Coexistent biotite and chlorite are observable in many rocks either as distinct separate entities or as replacements on the same crystal. At least two (possibly three) varieties of chlorite are present in many of the chlorite-bearing rocks. Some chlorite is clearly a later mineral.

The amphibole present in he rocks of the Whetstone Group and Chauga River-Poor Mountain Group is a low hornblende or hornblendic-actinolite. Epidote-clinozoisite is very common here and almandine occurs in many of the rocks of all three belts. Tourmaline, zircon, allanite, apatite, and sphene are common accessories in the rocks of this area.

As discussed above, the effects of cataclastic metamorphism are widespread throughout this area. The mineral paragenesis in rocks such as the Brevard phyllite and Brevard-Poor Mountain transitional can certainly be partly attributable to cataclasis. The button or fishscale structure of muscovite augen in these unit has been entirely attributed to cataclastic metamorphism by Reed and Bryant (1964). However, this structure is present, but perhaps less prominently, in schistose rocks over a large area of the Blue Ridge, low rank belt, and high rank Inner Piedmont of North and South Carolina. This writer believes that the structure is due to shearing and perhaps the extension of a secondary foliation that was superimposed onto the original foliation. R. C. Milici (personal communication) thinks they result from extension of a slip cleavage. The Brevard phyllite could represent a more sheared and the Brevard-Poor Mountain transitional a less sheared equivalent of the same micaceous quartzofeldspathic parent. The feldspathic biotite quartzite could be this unsheared parent.

Cataclastic effects (other than mylonitization) are best exhibited by the Brevard phyllite and Brevard-Poor Mountain transitional members. Why do the adjacent carbonates and amphibolite units lack obvious cataclastic features' One possibility is that the P-T conditions were still sufficiently high when the cataclastic event occurred that these lithologies were recrystallized continuously during the deformation and were not subjected to crushing.

Strained and sutures quartz is no indication of cataclasis.

Table 3. Fabric Constituents of the Major Lithologies.

		Grain Size	Myrmekite	Microperthite	Feldspar Porphyroblasts	Poikiloblastic Plagioclase	Sericitized Feldspars	Fractured Grains	Muscovite Augen	Quartz Augen	Euhedral Almandine	Poikiloblastic Almandine	Epidote with Cores[a]	Mortar Texture	Chlorite-Biotite Replacement	Well-Developed Foliation	Sutured Quartz	Strained Quartz	Microfolds	Microbedding	Helicitic Structure
	Henderson Augen Gneiss	4-5	Y	X	X	X		Y					X			X		X			
Poor Mountain Formation	Calcareous Quartzite	2-3											Y			X				X	
	Marble	3-4			Y	Y										X	X	X		Y	
	Amphibolite	2-3			Y		Y					Y[b]				X		X	X	X	Y
	Transitional	2-3	Y	Y	X				X	Y					Y	X	Y	Y	Y	Y	X
	Feldspathic Biotite Quartzite	2-3	Y	Y	Y[d]	Y	Y		Y	Y	Y		Y								
	Feldspathic Quartzite	2-3			X	X					Y				X	X	X	X			
Chauga River Formation	Brevard Phyllite	2-3						Y	X	Y					Y	X		Y	Y	Y	
	Carbonate	2-3			Y	Y			X	X								X	Y	X	
	Graphitic Phyllite	1-2							X							X		X			
Brevard Cataclastic Zone	Mylonite	1-2			Y	Y	Y	Y									X	X			
	Carbonate Slice	1														X		X[c]	Y		
	Cataclastic Gneiss (Dark)	1-4	X	Y	X[d]		X	X						X	X	X		X			
	Cataclastic Gneiss (Light)	2-4	X		X[d]		Y	X						X	X	X		X			
Whetstone Group	Metagraywacke	2-3					X	Y		Y			Y		X	X		X	Y	Y	
	Schist	3-4							X							X		X			
Basement Gneiss	Mica Gneiss	4-5			Y	Y	Y				X		X			X	X	X			

1- Very fine grained
2- Fine grained
3- Medium grained
4- Coarse grained
5- Very coarse grained

X- Present in most samples examined
Y- Present in some samples
[a] Cores are allanite in most samples
[b] Amphibole in this lithology
[c] Granulated
[d] Composites

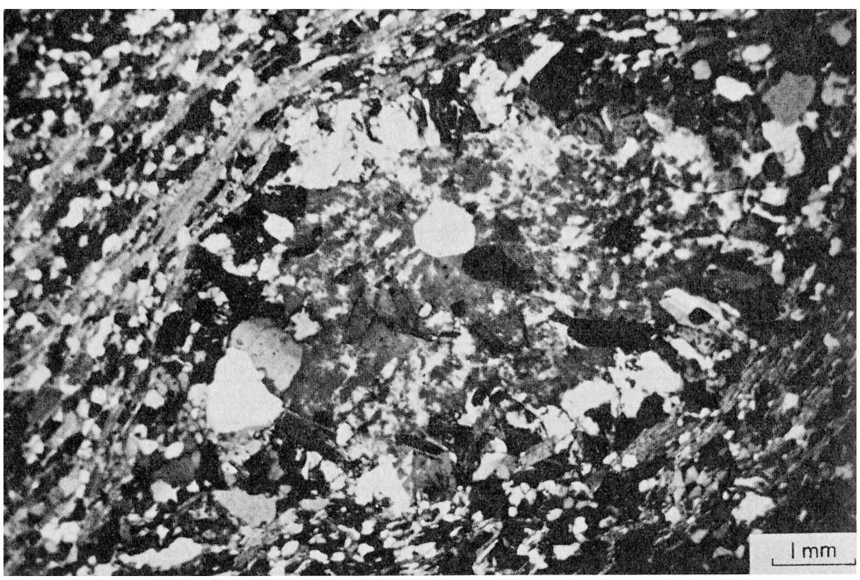

Plate 13. Feldspathic biotite quartzite from U. S. 76 near Holly Springs community (Holly Springs Quadrangle). Coarse composite porphyroblast of microperthite, biotite and quartz is surrounded by a reaction rim of myrmekite, quartz and muscovite. It is thought that this porphyroblast is a clast that was partially replaced during the regional metamorphic event. Section cut normal to foliation. X-nicols.

It is common in the Blue Ridge, across the low rank belt, and throughout the high rank Inner Piedmont (V. S. Griffin, Jr., personal communication). Strain patterns in quartz and other minerals examined by the writer are no more prominent in mylonites than in other rocks in the area either inside or outside the cataclastic zones. This indicated that recrystallization accompanied strain and that shearing movement probably occurred as one of the last events during the major thermal event affecting the region.

Composite porphyroblasts have been observed in the feldspathic biotite quartzite and Brevard-Poor Mountain transitional lithologies. Many of these composite porphyroblasts are composed of a core of microperthite, quartz, muscovite, and biotite with a distinct reaction rim of myrmekite, quartz, and micas (Plates 13 and 14).

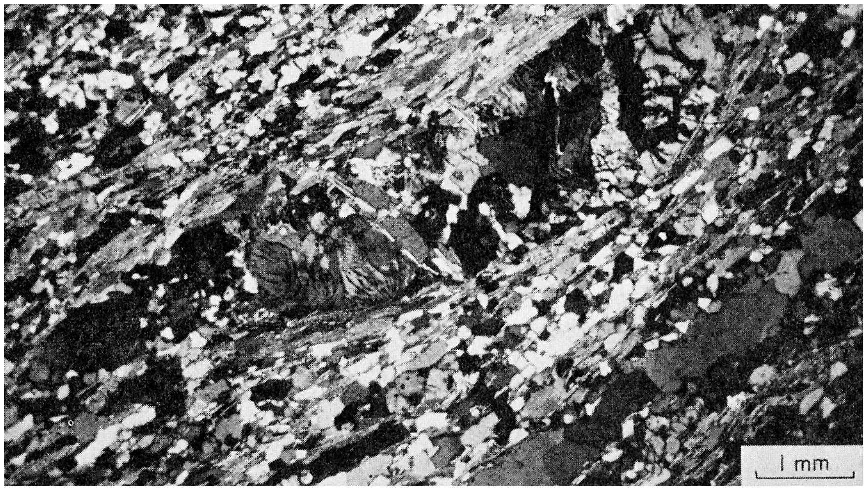

Plate 14. Feldspathic biotite quartzite from U.S. 76 near Holly Springs community (Holly Springs Quadrangle). Composite porphyroblasts that is almost totally replaced by myrmekite. Section cut normal to foliation. X-nicols.

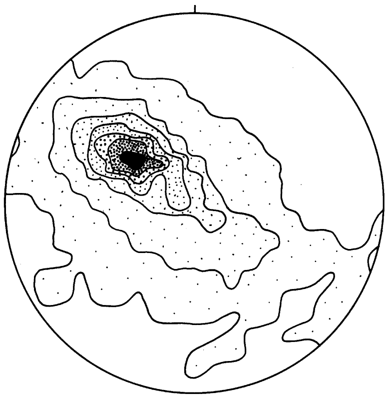

Figure 2. 1487 poles to foliation and compositional layerin from the low rank belt of northwestern S. C. Contours 16% 13%, 10%, 7%, 4%, 1%, 0.1%, per 1% area.

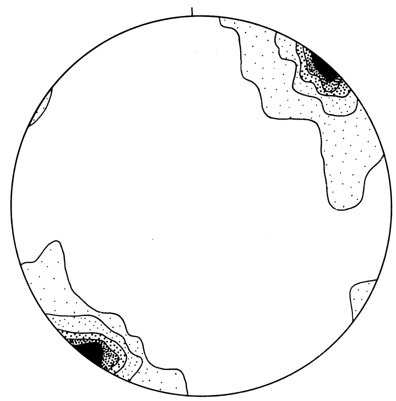

Figure 3. 158 lineation from the low rank belt. Contours 20%, 15%, 10%, 5%, 0.6%, per 1% area.

DESCRIPTIVE STRUCTURE

In general, the rocks of this area dip gently to moderately to the southeast (Figure 2). Some steep dips to the northwest were measured on the northwest side of the low rank belt. Gentle northwest dips are common in some areas of the low rank belt and high rank Inner Piedmont. The average strike of foliation and compositional layering is N40^{o}E. Throughout most of the belt foliation parallels compositional layering and, where recognizable, also parallels bedding.

The major lineation (L_1) in this belt strikes N45^{o}E and is subhorizontal (Figure 3). This lineation results from synkinematic crystallization of quartz, muscovite and feldspar (the writer prefers not to use the term mimetic crystallization because the writer thinks the term "mimetic crystallization" is ambiguous and somewhat confused as applied here). Streaking (L_3) and crinkle lineations (L_2) are present but are less common than the crystallization lineation. Streaking has a more southeast trend and a moderate to steep downdip plunge. Boudinage has been observed in so few localities that no conclusions should be attempted using this type of structure.

Joints are abundantly present in the rocks in this region. They probably record the most recent movements affecting these rocks. In general, the joints fall in to two basic groups: (1) a longitudinal set having a N45^{o}E strike; and (2) a N45^{o}W transverse set (Figure 4). Many lesser sets also exist in this area but the two major sets may reflect stresses set up during isostatic uplift of this region during the Mesozoic and Cenozoic. Moreover, the other sets could represent local variations in the stress field due to influence of lithologies and earlier structures. Considerable control of drainage is exerted by jointing in this area (Acker and Hatcher, in press).

Isoclinal and isoclinal recumbent folds are the predomi-

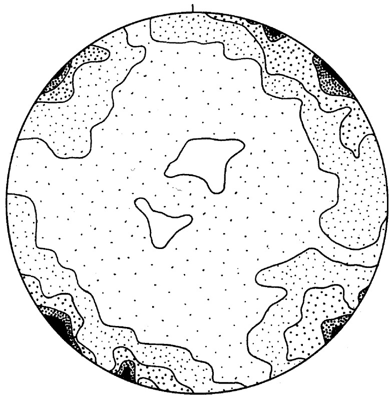

Figure 4. 1294 poles to joints from the low rank belt. Contours 4%, 3%, 2%, 1%, 0.1% per 1% area.

nant mesoscopic folds in the low rank belt (Hatcher, 1969b). Open folds superimposed onto the isoclinal folds are also very common on the mesoscopic scale. Axes of both isoclinal and open folds trend the same. Predominant trend of both isoclinal and open folds is N50 °E (Figure 5). An important crossfold trend (F_3) is N20 °W. This is predominantly an open fold trend by a 3:1 ratio of fold axes measured (Figure 5A). A lesser trend of N10 °E is also notable. Few steeply plunging folds have been observed. The plunge of most fold axes id less than 20 degrees. Moreover, the majority of axial planes of folds dip southeastward. On the macroscopic scale (see Plates 1 and 2) isoclinal and isoclinal recumbent folding (F_1) are the predominant early deformational styles of the Blue Ridge, low rank belt, and high rank Inner Piedmont (Griffin, 1967a; 1968) of northwestern South Carolina. Open folds (F_2) with near vertical axial planes are also present on the macroscopic scale.

A considerable amount of faulting has been mapped toward the northwest side of the low rank belt culminating in the Brevard cataclastic zone. The major shear zone has a dip of some 40 to 50 degrees and may be up to 1,000 feet in thickness. To the southeast the Chauga River Formation and Henderson Gneiss are repeated several times by faulting. Most of these faults are recognizable by the presence of mylonite zones and by repetition or omission of stratigraphic units. Some faulting has been mapped solely upon the latter criterion, along with the outcrop patterns of the units involved.

No direct indicators of movement, such as drag folds, have been observed in the rocks of this area. In some sections of Brevard phyllite cut normal to the foliation, drag or turning of mica foliatons at the boundaries of garnet prophyroblasts yields a sense of shear which is across the foliation. However, this is a two dimensional view and movement could very well be oblique-slip with strike-slip and dip-slip components. Systematic repetition of stratigraphic units along the Brevard zone is suggestive of thrust faulting, provided the stratigraphy is correct.

Pure faulting diminishes southeastward. However, from a study of many sawed hand specimens of folds (Plates 15, 16, and 17) and the geometry of mesoscopic folds in outcrop there appears to be an earlier thrusting of isoclinal folds. This thrusting is due to an overextension and attenuation of the common limb between isoclinal synclines and anticlines, and has recently been called tectonic sliding (Fleuty, 1964)[1]. Since tectonic sliding of isoclinal folds is associated with

1.Fleuty (1964, p. 454) defined a tectonic slice as “a fault formed in close connection with folding, which is broadly conformable with a major geometric feature (either fold limb or axial surface) of the structure, and which is accompanied by thinning and/or excision of members of the rock succession affected by folding.” Fleuty appealed for the use of the term tectonic slide as opposed to the older term slide because of ambiguities that may arise.

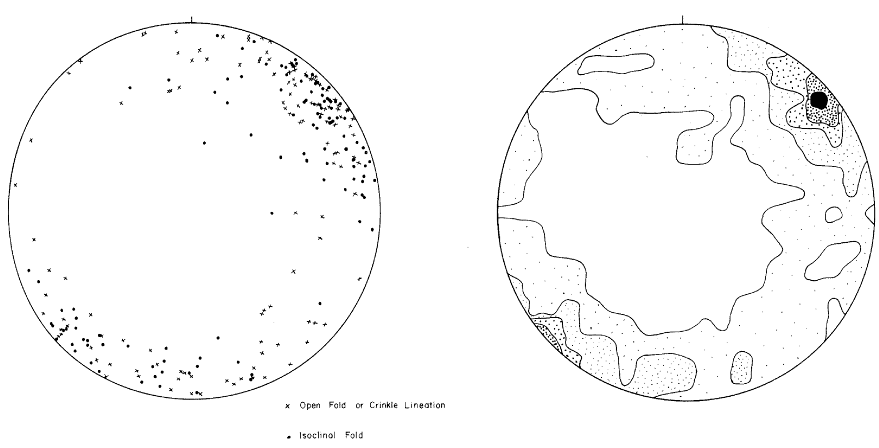

Figure 5. 233 fold axes from the low rank belt including 122 open folds and crinkles and 111 isoclinal folds. 5A presents the uncontoured data to show the dominant open cross-fold trend, 5B. Contours, 11%, 8%, 5%, 2%, 0.4% per 1% area.

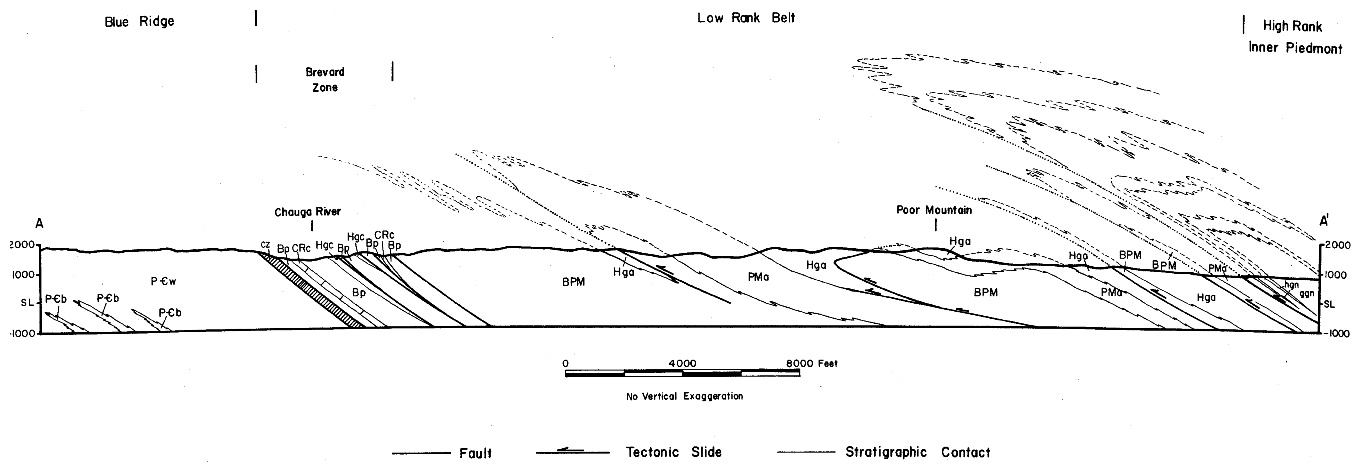

Figure 6. Structure section across the low rank belt (see Plate 1 for location). PCb-Precambrian basement rocks. PCw- Whetstone Group. CZ- Brevard cataclastic zone. Bp- Brevard phyllite. CRc- carbonate member of the Chauga River Formation. BPM- Brevard-Poor Mountain transitional. PMa- Poor Mountain amphibolite. Hgc- cataclastic Henderson Gneiss. Hga- Henderson augen gneiss. ggn- granitic gneiss. hgn- hornblende gneiss.

most of the isoclinal folds on the mesoscopic scale it is thought to be present on the macroscopic scale as a major style of deformation. The outcrop patterns of many units within the low rank belt and the high rank-low rank boundary zone are best interpreted as tectonic slides (see Plate 1 and Figure 6).

SYNTHESIS

Metamorphism

This portion of the Southern Appalachians has undergone at least two Paleozoic metamorphic events, one progressive and the other retrogressive. Moreover, the earlier precambrian basement rocks of this area were regionally metamorphosed prior to Late Precambrain deposition. The earlier Paleozoic regional metamorphism was probably initiated during the late geosynclinal phase of the Appalachian trough. The Late Precambrian sediments, along with the rocks of the Chauga River-Poor Mountain Group and Henderson Gneiss, were metamorphosed to the lower to middle part of the amphibolite facies. The rocks of the high Inner Piedmont were raised to the middle and upper portions of the amphibolite facies (Overstreet and Bell, 1965) and were partially melted (probably under the influence of a high P_{H20}). Isoclinal folding and tectonic of sliding these rocks then served to bring the higher and lower rank rocks into contact with one another whereupon there was probably some further pressure-temperature preadjustment (and hence recrystallization) along the boundary. These events are thought to have taken place during the early to middle Paleozoic (Late Ordovician to Devonian).

Pegmatites were intruded into the high rank Inner Piedmont rocks during and after folding (Griffin, 1967a). Pegmatites are notably absent in the rocks of the low rank belt in the southwest part of the outcrop belt and in the rocks of the Whetstone Group. To the northeast pegmatites are present in the Henderson Gneiss as irregular pods and a few distinct bodies.

Cataclasis and retrogression of the rocks of this area occurred as later events associated with movement on the Blue Ridge thrust and the Brevard zone. Superposition of this event onto the progressively metamorphosed rocks of this area caused the metamorphic rank of part of the Blue Ridge to drop significantly while that of the low rank belt dropped slightly from the lower amphibolite facies to the greenschist-amphibolite transition facies. If the low rank belt had been at a much higher grade of metamorphism and then lowered significantly by cataclasis, the writer thinks the stratigraphic sequences would have been obliterated, particularly that in the Brevard zone.

Stratigraphic Synthesis

The gradational and similar character of the Chauga River-Poor mountain and Henderson rocks with their diverse compositional variations have led the writer to conclude that: (1) these units are part of two large sedimentary units of marine origin (the Chauga River-Poor Mountain Group overlain by the Henderson Gneiss); (2) sedimentary facies changes are responsible for the observed compositional variations. Tectonic pinches and swells occur in this area and are responsible for variations in thickness and distribution of units but not for variations in their overall composition. Cataclastic effects would probably not modify the bulk composition of the units but could change the megascopic and microscopic appearances of a rock.

The facies changes that are thought to be present here occur across strike and parallel to the regional strike as well

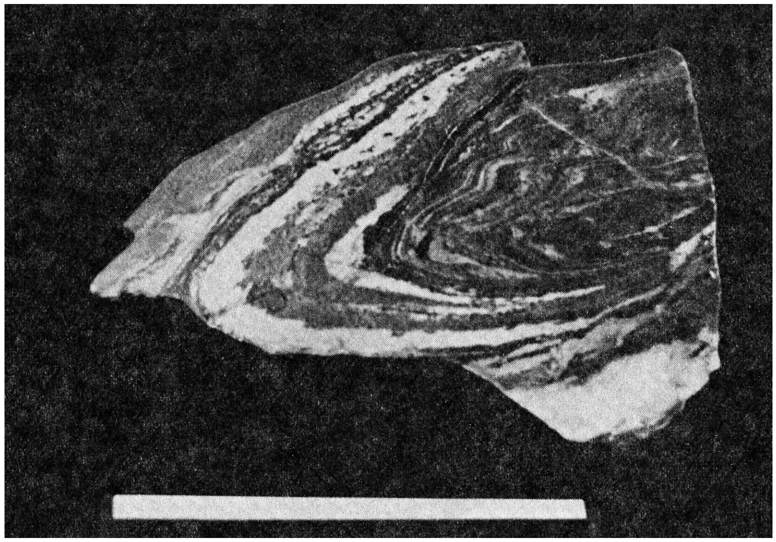

Plate 15. Poor Mountain amphibolite from Poor Mountain in the Whetstone Quadrangle. Hand specimen of a fold exhibits considerable attenuation of one limb and thickening in the crest. Sawed normal to the fold axis. Bar beneath the specimen is 6 inches long.

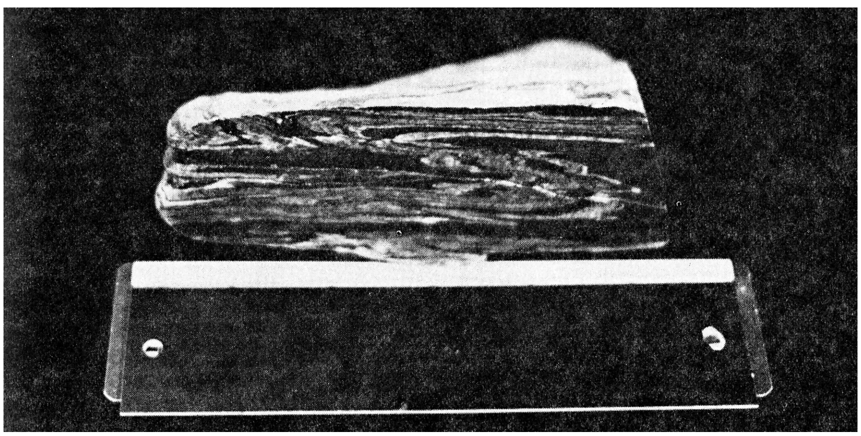

Plate 16. Poor Mountain amphibolite from the Lake Jemike area of the Whetstone Quadrangle. Hand specimen of an isoclinal fold exhibits attenuation and some thrusting of the common limb between the "anticline" and "syncline." Sawed normal to the fold axis. Scale is 6 inches long.

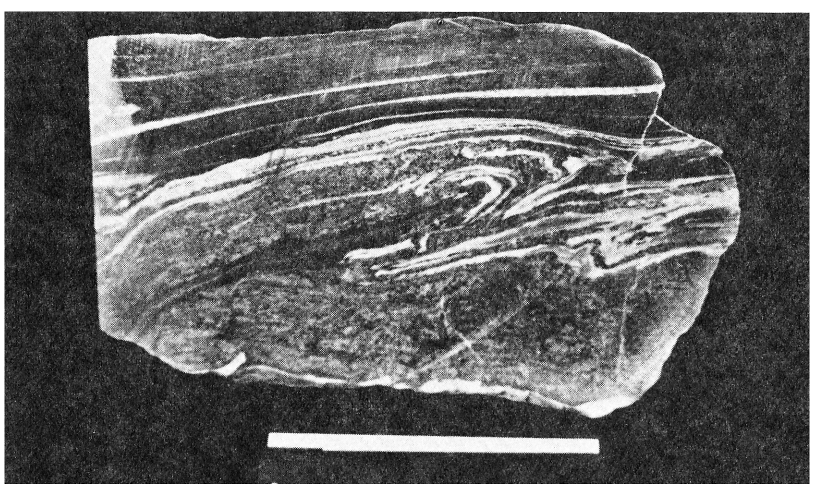

Plate 17. Epidote-rich Poor Mountain amphibolite from the new cut on State Highway 11 near Lake Keowee, Salem Quad. Isoclinal recumbent fold in which the folding process has been carried to an extreme producing a tectonic slide. Sawed normal to the fold axis. Scale is 6 inches long.

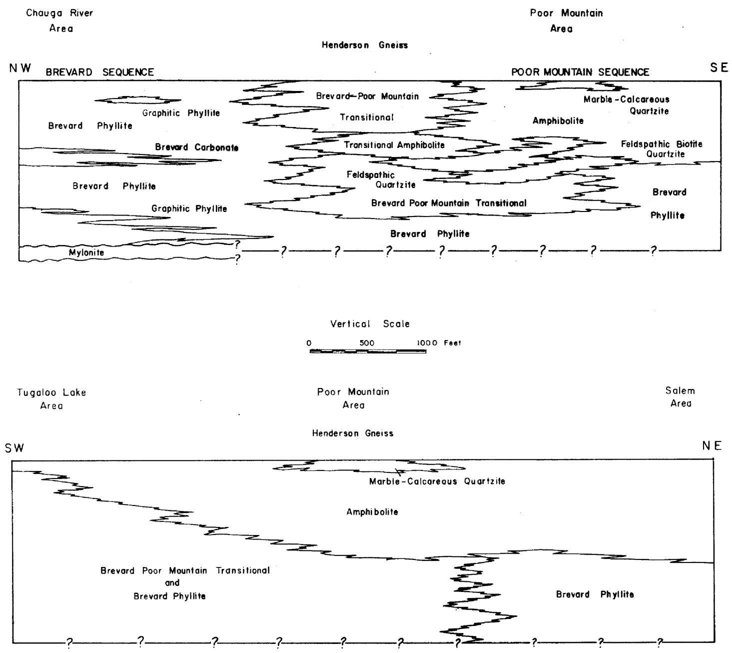

Figure 7. Facies relationships in the Chauga River-Poor Mountain Group. The uper diagram shows the facies relationships along section A-A' (Plate 1).

(Figure 7). Within this framework, the Chauga river and Poor Mountain formations are stratigraphic equivalents constituting the Chauga River-Poor Mountain Group discussed earlier. The Henderson Gneiss, which in places is interlayers with the rocks of the Poor mountain Formation and in others grades into it, is thought to comfortably succeed the Chauga River-Poor Mountain Group.

The Chauga River-Poor Mountain Group and Henderson Gneiss were composed as an assemblage of geosynclinal and shelf sediments prior to metamorphism. The sediments of the Chauga River-Poor Mountain Group included impure siltstones, black shale, impure limestone, calcareous siltstone, graywacke, feldspathic to calcareous sandstone and sandy limestone. The Henderson Gneiss was originally a feldspathic sandstone-arkose unit.

There is a considerable body of evidence against a purely cataclastic origin for these rocks. This evidence include: (1) the presence of the graphitic phyllite member near the base of the Chauga River Formation; (2) the mappable stratigraphic sequences; (3) presence and persistence of a uniformly southeast-dipping carbonate unit in the same position in the Chauga River Formation for many miles across Georgia, South Carolina, and possibly North Carolina; (4) the diversity of compositional variations occurring over a small interval; and (5) interlayering of all lithologies of the Poor Mountain Formation with each other and interlayering of the Henderson Gneiss with the Poor mountain sequence.

Late Precambrian metasediments are present in the Blue Ridge adjacent to the Brevard cataclastic zone throughout a large segment of northwesternmost South Carolina. The rocks of the Chauga River Formation in South Carolina do not physically resemble these metasediments northwest of the Brevard cataclastic zone in this area. The Chauga River rocks do, however, resemble some of the Ocoee metasediments adjacent to the Brevard zone in the Black Mountain area of North Carolina. Similar graphitic schist and carbonate (although more impure than that in the Chauga River sequence) occur in the Ocoee series of that area. Because of the similarity of the Chauga River sequence to some of the rocks of the Ocoee series, it ti thought that the age of the Chauga River-Poor Mountain Group could also be Late Precambrian, or possibly, Early Cambrian.

Structure

Mesoscopic Structures and their Relationship to Macroscopic Structure

The coaxial trend of mesoscopic isoclinal folds (F_1), open folds (F_2), and crinkle lineations (L_2) would imply a similarity oriented stress field for all these structures (Figure 5; Plate 2). It could be concluded, but with less certainty, that the isoclinal folds, open folds, and crinkles are all of the same age. However, in exposures where both isoclinal and open folds amy be observed, the open folds are invariably superimposed onto the isoclines in the low rank belt (Plate 18). V. S. Griffin (personal communication) has found similar relationships to be true in the high rank Inner Piedmont. It is thought by the writer that both sets of folds, and crinkle lineations, were formed by operation of the same stress filed. The isoclines were formed, then the open folds were super-

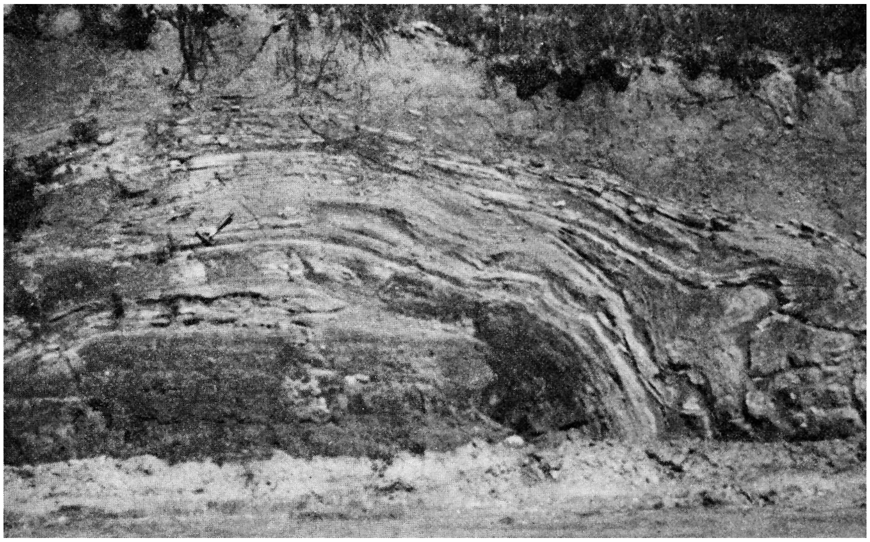

Plate 18. Mesoscopic fold in feldspathic quartzite of the poor Mountain Formation on U. S. 76 in the Holly Springs Quadrangle. This isoclinal recumbent fold has an upright open fold superimposed on it.

imposed upon the former by a slight reorientation of the stress field. This may have been accomplished by crowding of an isocline after it had moved forward to the limit of available space for release of stress through isoclinal folding.

The uniformity of direction and plunge and geometry of all types of mesoscopic folds n the low rank belt suggests that folding is cylindrical (see Figure 2). The poles to foliation and compositional folding plotted in Figure 2 best fit a great circle of the equal area net. This further supports the notion that folding is cylindrical. If conical folding were dominant in the area the poles to foliation and compositional layering would best fit a small circle (Whitten, 1966, p. 63). If the mesoscopic folds are cylindrical, it is highly probable that the macroscopic structure involves cylindrical folding as well. Moreover, more mesoscopic folds plunge northeastward that southwestward perhaps indicating that the major macroscopic folds likewise plunge in northeastward. Further support of this idea is present in Figure 2 where it can be observed that there is much greater population of N10 ^{o}W to N30 ^{o}S strikes and northeast dips than there are southwest dips with the same northwest strikes.

Tectonic sliding is an important structural feature related to the isoclinal folding process in the low rank belt, along the high rank-low rank boundary, and Blue Ridge (Figure 6). Although no tectonic slides have been mapped thus far by this writer in the Blue Ridge of South Carolina, McKniff (1967) has mapped a large thrust in the Highlands-Cashiers area of North Carolina which would probably qualify as a tectonic slide. Extension of the common limb between an isoclinal anticline and syncline is common in hand specimen and mesoscopic exposures in the low rank belt (see Plates 15, 16, and 17), as mentioned above. Occurrences of tectonic slides of rocks of this area would indicate that after or during isoclinal folding of the ricks of this area shearing stresses were great enough to carry the isoclinal folding process to an extreme and thrust the attenuated common limb. This material was probably still in a highly attenuated viscous plastic state so that folding and tectonic sliding occurred as an extension of the same process.

The principal lineation of the area (L_1) is the crystallization lineation described earlier (Figure 3). Reed and Bryant (1964) describe this lineation in great detail and separate it from the northwest-trending a lineation that they state dominates within the Blue Ridge thrust sheet (Reed and Bryant, 1964, p. 1188). They also state that this northwest trending cataclastic *a* lineation swings a clockwise in both the Blue Ridge thrust sheet and Grandfather Mountain window until it is parallel to the trend of the Brevard zone. They interpret this lineation and the similar trending crystallization within and southeast of the Brevard zone to likewise be a cataclastic *a* lineation and thus interpret the Brevard zone to be a major zone of right-lateral strike-slip faulting (Reed, *et al.*, 1961; Reed and Bryant, 1964) or. More recently, of left-laterial strike-slip movement (Reed, *et al.*, 1968).

Having examined the rocks of the Brevard zone, Blue Ridge thrust sheet, and Grandfather Mountain window in the Black Mountain-Marion, North Carolina area (in company of J. R. Butler), this writer concludes that the same lineation that Reed and Bryant call their cataclastic a lineation is the dominant lineation of the low rank belt and high rank Inner Piedmont of northwest South Carolina. Griffin (1967b) suggested that the major northwest trending lineation in the Six Mile area may be related to the lineation in the Brevard Zone. This same northeast-trending lineation, but with a northeast, rather than a northwest, trend is present in the basement Wilson Creek Gneiss of the footwall inside the

Grandfather mountain window and in a slice of Erwin quartzite at the Lake Tahoma Dam. The same lineation with a dominant but less persistent northeast trend is also present in the Clemson area of South Carolina, some 25 miles from the Brevard cataclastic zone.

Another interesting aspect of the major lineation of this area is the precise parallelism and coaxiality with the major set of mesoscopic fold axes (Figures 3 and 5). It is this parallelism and presence of this lineation not only in the Blue Ridge thrust sheet, an intermediate slice, the footwall rocks of the Grandfather Mountain window, and the Brevard zone, of North Carolina and the low rank and high rank Inner Piedmont of South Carolina that led this writer to conclude that this lineation is not a cataclastic *a* lineation but a regional *b* lineation related to the major episode of isoclinal and open folding. There are at least two possible ways in which this lineation could have had its origin as a b lineation: (1) as a synmetamorphic crystallization by growth of quartz, etc., along the lines of intersection of the primary foliation of layering of the rock material and the axial plane foliation resulting from isoclinal folding ($L_{SO} + F_1$); or (2) as a synmetamorphic crystallization along lines of intersection of the axial plane foliation of the isoclinal folds and a secondary foliation of slip cleavage developed in association with open folds ($L_{F1} + F_2$). If either of these interpretations is correct the lineation would have to be a *b* lineation and would have been produced during the early to middle Paleozoic metamorphic-folding episode as an intersection of two stress fields.

The relative movement on faults mapped toward the northwest side of the low rank belt and in the Brevard cataclastic zone is not clearly discernable. The present interpretation of the lineation takes away the strongest evidence for strike-slip movement on the faults of this area. The primary component of movement in the Blue Ridge is northwestward. The faulting and shearing that produced the Brevard zone and associated faults is synchronous with or very slightly later than the movement on the Blue Ridge fault (since there is incomplete retrogression of all cataclastic minerals to greenschist conditions implying a still moderate pressure and temperature). Either a strike-slip or a dip-slip movement or combination of both could produce the outcrop pattern displayed on the geologic map (Plate 1). Most of the large thrusts of the Valley and Ridge have had an oblique-slip component of movement, but are predominantly dip-slip faults. The Blue Ridge thrust is also a dip-slip fault. The writer postulates that the Brevard zone and associated faults had a similar movement history.

The persistence of the Brevard cataclastic zone is almost the same stratigraphic position across oconee County, South Carolina and probably across Habersham County, Georgia for some 55 miles leads the writer to conclude that along this segment there is considerable control of the cataclastic zone by stratigraphy. There exist the possibility that the Brevard zone is the back-limb portion of the principal Blue Ridge thrust. If the Brevard is a thrust zone and the rocks within and southeast of the Brevard zone are Late Precambrian to lower Cambrian age thrusting would have moved younger rocks over older rocks.

Low Rank-High Rank Boundary

The boundary between the low rank belt and the high rank Inner Piedmont has been mapped in detail across most of northwestern South Carolina. It is a fundamental structural and metamorphic boundary across which the metamorphic rank rapidly increase southeastward. The rate of change of metamorphic rank across the boundary varies along strike as well. In the Salem and Walhalla area in the amphibolites close to the boundary there appears to be only an increase in grain size southeastward. To the southwest, along U. S. 76 (see Plate 1) migmatites are encountered not far to the southeast of the boundary. This is accompanied by a greater increase in grain size.

Difficulties arise in placement of the boundary, particularly if it must be placed within an amphibolite. In general, the Poor Mountain amphibolite is finer grained, contains more green minerals (chlorite, epidote, and an actinolite hornblende or hornblende actinolite), and commonly contains interlayers of the Brevard-Poor Mountain transitional lithology and laminae of feldspathic quartzite. However, these latter may be absent from the Poor Mountain amphibolite in some areas. The Poor Mountain amphibolite is commonly laminated with thin interlayers of feldspathic quartzite and weathers to thin chips whereas the amphibolite of the high rank Inner Piedmont is commonly more massive, non-laminated, and weathers to a blocky residual material (prior to complete breakdown into a soil).

Some of the fine-grained Henderson gneiss of the southeastern part of the low rank belt very closely resembles some of the biotite granitic gneiss southeast of the boundary. However, the biotite granitic gneiss commonly contains thin interlayers of blocky-weathering coarse amphibolite and biotite schist, which do not occur in the Henderson. Moreover, pegmatites abruptly appear to the southeast very close to the boundary where they may be on either side of it. They are very rare throughout the remainder of the low rank belt and become common near the boundary, except in the very coarse Henderson gneiss belt northeast of Salem where they are fairly common. Most of the pegmatites occurring along the boundary and in the Henderson belt to the northeast are small discontinuous, often lenticular pods and relatively few actual dikes. They are thought to be largely synkinematic pegmatites that have been generated locally during the metamorphic-folding event.

The high rank-low rank boundary truncates structures in the low rank belt in several places. The outcrop trace of the boundary consists of a few relatively straight segments and

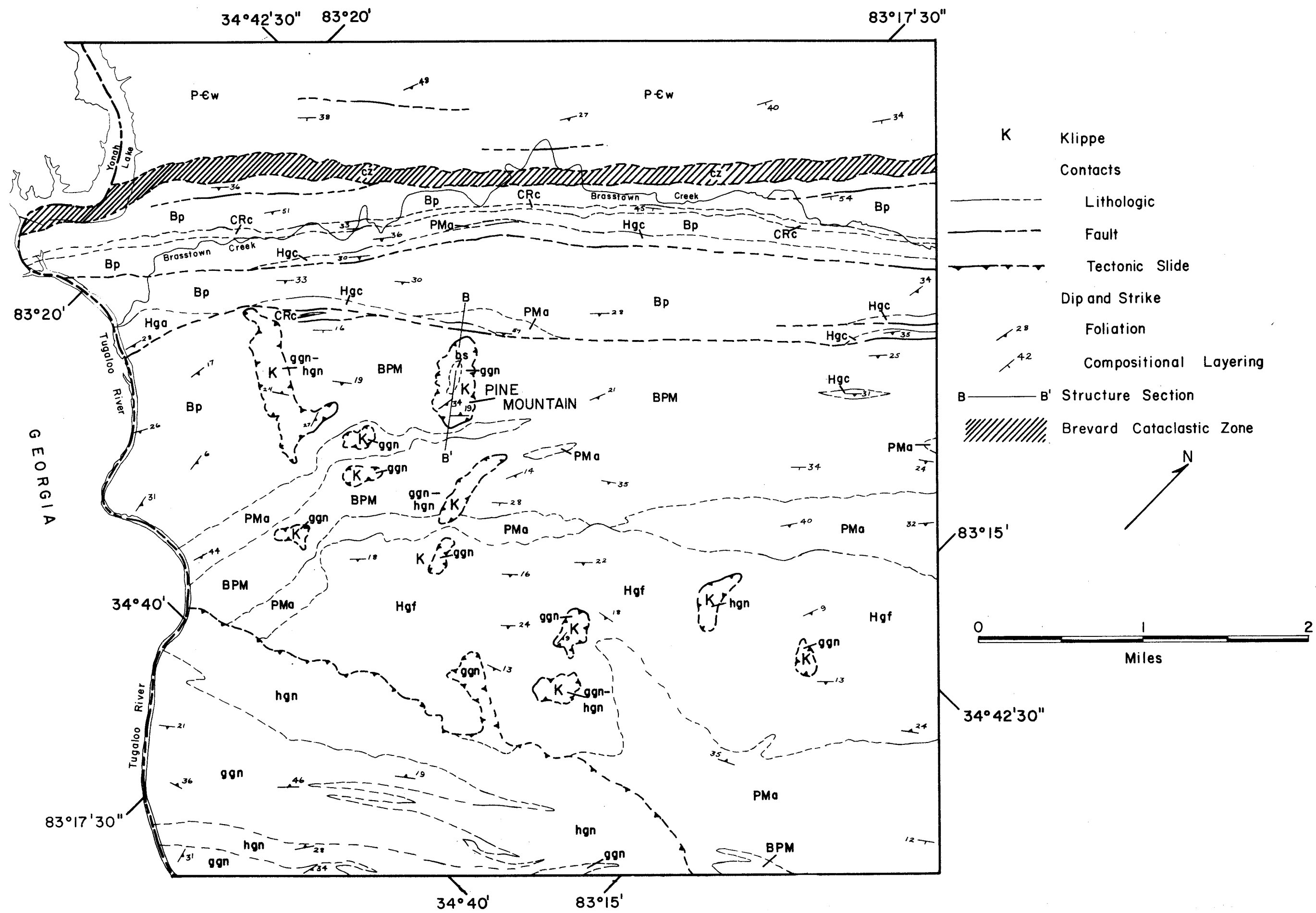

Figure 8. Geologic map of a portion of the Tugaloo Lake Quadrangle.

several curved reaches (Plate 1). In the area southwest of Walhalla the boundary has a more northerly trend where it truncates a belt of fine-grained Henderson gneiss. Farther southwestward the boundary begins to swing northwest and continues this trend into Georgia. This may reflect the development of major cross folds in both belts in this area (see Plate 2) as well as greater topographic relief upon which the low angle nature of the boundary may be expressed. East of the Yonah Lake there are several klippen of high rank granitic gneiss and amphibolite resting upon rocks of the low rank belt (Figure 8). The northwesternmost of these in South Carolina is only some 3,000 feet from the Brevard cataclastic zone and rests upon Brevard phyllite and Poor Mountain amphibolite. The best exposed of these klippen, that on Pine Mountain, consists principally of high rank granitic gneiss with some amphibolite (Figure 8). On the top of the mountain is some button phyllite which is very similar to that in the low rank belt but could be a button phyllite developed in the high rank Inner Piedmont rocks. Haller (1962) described an area in East Greenland where the metamorphic rank

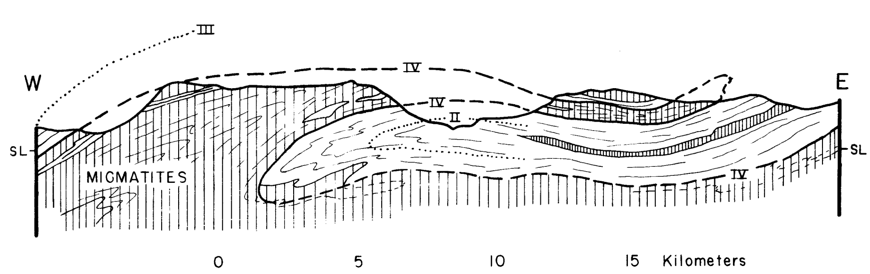

Figure 9. Geologic cross section through a portion of the East Greenland Caledonides (after Haller, 1962).

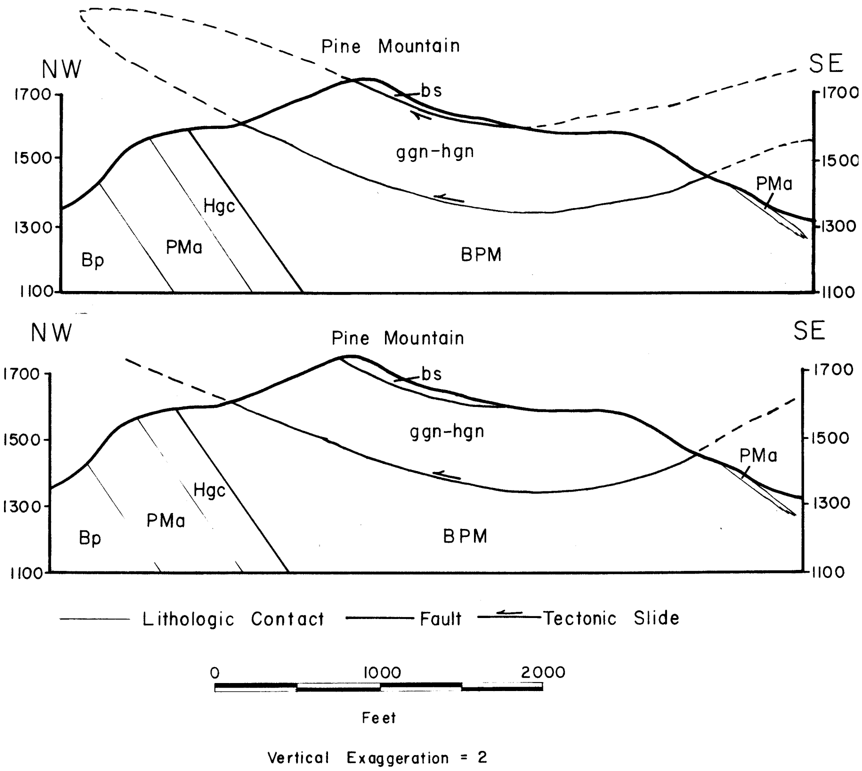

Figure 10. Two possible interpretations of the structure of Pine Mountain in the Tugaloo Lake Quadrangle (Figure 8 and Plate 1). Note the similarity to Haller´s cross section in Figure 9. However, the writer prefers the interpretation in the lower cross section. Bp-Brevard phyllite. Pma-Poor Mountain amphibolite. BPM-Brevard-Poor Mountain transitional. Hgc-cataclastic Henderson gneiss. bs-button schist. ggn-hgn-granitic gneiss-hornblende gneiss.

increases vertically. He termed this an "inverted succession of metamorphic stages." Here, as in East Greenland, the metamorphic rank changes vertically from lower rank near the base of Pine Mountain (and the other klippen as well) to higher rank gneisses, etc., on tops of the mountains. Haller (1962) also has observed areas where migmatites have forced their way as a nappe-like tongue into the lower rank rocks of the superstructure of East Greenland (Figure 9). If the button phyllite on top of Pine Mountain is actually a part of the low rank belt, the structure of Pine Mountain is probably not very different from the nappe-like tongue that Haller described. If however, the button phyllite proves to be a part of the high rank assemblage (as is presently suspected), it is simply another klippe. None of the other klippen mapped thus far have any button phyllite in the higher elevations (Figure 10).

This writer has concluded that the high-rank-low rank boundary is a greatly extended tectonic slide for the following reasons: (1) there is a rather abrupt change in metamorphic grade across the high rank-low rank boundary; (2) structures in the low rank belt are truncated at the boundary; (3) klippen of high rank rocks resting upon lower rank rocks; (4) the folds of the high rank zone appear to be highly appressed against the boundary (Plate 1 and Figure 7); (5) the boundary has a sinuous outcrop pattern in some areas. The dip of the discontinuity surface is estimated to be 20 degrees or less. Folds to the southeast of the boundary would not extend uninterrupted to great depths because of their genesis in a plastic medium and also because the tectonic slide would be encountered at depth for at least a few miles southeast of the outcrop of the boundary.

SUMMARY OF CONCLUSIONS

1. A mappable stratigraphic succession is present in the Blue Ridge, Brevard zone, and low rank belt of northwestern South Carolina.
2. Early progressive regional metamorphism and later cataclastic retrogressive phases are both recognizable and separable in the Blue Ridge, low rank belt, and high rank Inner Piedmont belts of this area.
3. Early isoclinal and isoclinal recumbent folding with tectonic sliding dominates the deformation accompanying early progressive regional metamorphism. Faulting (probably thrusting) and cataclasis dominate the later metamorphism.
4. Equivalence of the Chauga River and Poor Mountain formations is suggested by similarity of rock type and

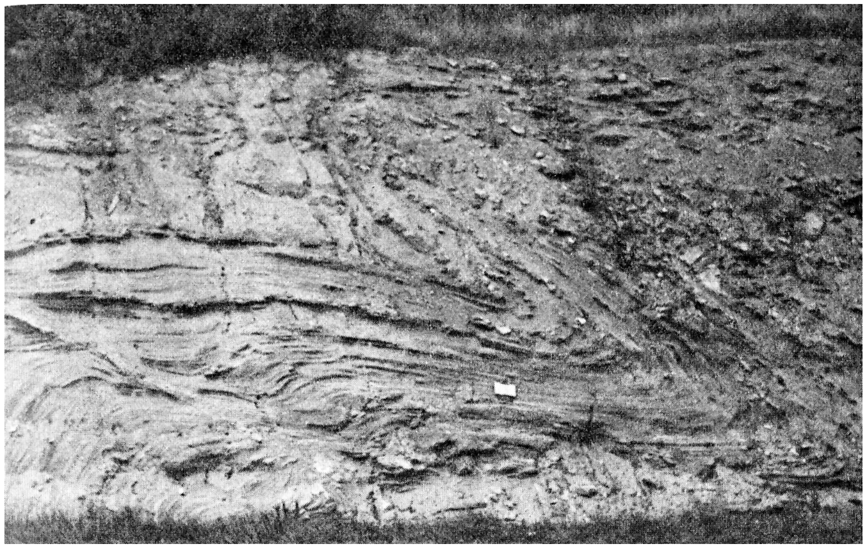

Plate 19. Mesoscopic fold in biotite gneiss of the high rank Inner Piedmont on U.S. 76 near the crossing of the Chauga River.

repetition of similar sequences. Sedimentary facies changes are thought to be responsible for differences in the two formations. The Henderson Gneiss is thought to be a stratigraphic unit.

5. A Late Precambrian and/or Early Cambrian age is proposed for the rocks of the Chauga River-Poor Mountain Group. Late Precambrian metasediments, the Whetstone Group, have been recognized northwest of the Brevard Zone.
6. Major isoclinal and open folds are thought to have originated under influence of the same stress field. The principal lineation of this area is thought to be a regional lineation developed in association with the major folding episode and is a *b* lineation.

REFERENCES

Acker, L. L., and Hatcher, R. D., Jr., in press, Relationships between topography and structure in northwesternmost South Carolina: Div. of Geology, S. C. State Development Board, Geol. Notes.

Burchfiel, B. C., and Livingston, J. L., 1967, Brevard zone compared to Alpine root zones: Am. Jour. Sci., v. 265, p. 241-256.

Burchfiel, B. C., and Livingston, J. L., 1968, Brevard zone compared to Alpine root zones, Reply: Am. Jour. Sci., v. 266, p. 219-220.

Cazeau, C. J., 1967, Geology and mineral resources of Oconee Country, South Carolina: Div. of Geol., S. C. State Devel. Board, Bull. 34, 38 p.

Dunn, D. E., Butler, J. R., and Justus, P. S., 1968, Brevard zone compared to Alpine root zones, Discussion: Am. Jour. Sci., v. 266, p. 215-219.

Fleuty, M. J., 1964, Tectonic slides: Geol. Mag., v. 101. p. 452-456.

Griffin, V. S., Jr., 1967a, Folding styles and migmatization within the Inner Piedmont Belt in portions of Anderson, Oconee, and Pickens Counties, South Carolina: Div. of Geol., S. C. State Devel. Board, Geol. Notes, v. 11, no. 3, p. 37-52.

Griffin, V. S., Jr., 1967b, Geology of the Six Mile Quadrangle, South Carolina: Div. of Geol., S. C. State Devel. Board, MS-14.

Griffin, V. S., Jr., 1968, Structural styles within a portion of the Inner Piedmont of western South Carolina (Abstract): Geol. Soc. America Southeastern Sect. Ann. Mtg., Durham, N.C.

Griffin, V. S., Jr., 1969, Migmatitic Inner Piedmont belt of northwestern South Carolina: Div. of Geol., S. C. State Devel. Board, Geol. Notes, v. 13, no. 4, p. 85.

Haller, J., 1962, Structural control of regional metamorphism in the East Greenland Caledonides: Proc. Geol. Soc. London, v. 21, no. 1594, p. 21-27.

Hamilton, W. B., 1957, Polymetamorphic rocks of the Blue Ridge front near Old Fort, N. C.: Am. Jour. Sci., v. 255, p. 568-573.

Hatcher, R. D., Jr., 1969a, Stratigraphy and petrology of the Brevard-Poor Mountain-Henderson belt of northwest South Carolina (Abstract): Geol. Soc. America Abstracts with programs for 1969, Part 4, Southeastern Section.

Hatcher, R. D., Jr., 1969b, Structure of the low rank belt of northwest South Carolina (Abstract): Geol. Soc. America Abstracts with programs for 1969, Part 4, Southeastern Section.

Hurst, V. J., and Crawford, T. J., 1964, Exploration of mineral deposits in Habersham County, Georgia: U. S. Dept. Commerce Area Redevel Geol. Atlas, Folio 147, 8 p.

Keith, A., 1907, Description of the Pisgah Quadrangle, U. S. Geol. Survey Geol. Atlas, Folio 147, 8 p.

Livingston, J. L., 1966, Geology of the Brevard zone and Blue Ridge in southwestern Transylvania County, North Carolina: unpublished Ph. D. Thesis, Rice Univ,. 117 p.

McKniff, J. M., 1967, Geology of the Highlands-Cashiers area, North Carolina, South Carolina, and Georgia: unpublished Ph. D. Thesis, Rice Univ., 100 p.

Overstreet, W. C. And Bell, H., 1965, The crystalline rocks of South Carolina: U. S. Geol. Survey, Bull. 1183, 119 p.

Rankin, D. W., 1969, The Fries fault: a major thrust in the Blue Ridge Province of southwestern Virginia (Abstract): Geol. Soc.

American Abstracts with programs for 1969, Part 4, Southeastern Section.
Reed, J. C., Johnson, H. S., Jr., Bryant, B., Bell, H., III, and Overstreet, W. C., 1961, The Brevard fault in North and South Carolina: U. S. Geol. Survey Prof. Paper 424-C, p. C67-C70.
Reed, J. C., Jr., and Bryant, B., 1964, Evidence for strike-slip faulting along the Brevard zone in North Carolina: Geol. Soc. America Bull., v. 75, p. 1177-1196.
Reed, J. C., Jr., and Myers, W. B., 1968, The Brevard zone in the Grandfather Mountain window area, North Carolina: a reinterpretation (Abstract), Geol. Soc. America Southeastern Section Ann. Mtg., Durham, N. C.
Shufflebarger, T. E., 1961, Notes on relationships of Piedmont metasedimentary rocks with emphasis on the Poor Mountain-Chauga River area, Oconee County, South Carolina: Div. of Geol., State Development Board. Geol. Notes, v. 5, p. 31-38.
Sloan, E., 1908, Catalogue of the mineral localities of South Carolina: S. C. Geol. Survey, Bull. 2, 4th Ser., 505 p.
Turner, F. J., 1968, Metamorphic petrology, McGraw-Hill Book Co., New York, 403 p.
Whitten, E. H. T., 1966, Structural geology of folded rocks, Rand

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1969 Annual Meeting
Pages 33-35

Carolina Geological Society 1969 Field Trip

October 4-5, 1969

Northwestern South Carolina

STOP 1 (Hatcher):

Metasediments of the Whetstone Group. Location: U. S. 76, 3,000 feet southeast of the junction of country road 96 and U. S. 76 at Long Creek Community (Rainy Mountain Quadrangle).

Exposed in the several roadcuts here are coarse muscovite schist and metagraywacke of the Whetstone Group. These lithologies are well interlayered and the metagraywacke does not appear to be highly deformed. However, the schist exhibits the button structure of the Chauga River-poor Mountain phyllites. This stop is only some 1,000 feet from the Brevard cataclastic zone and some shearing effects could be expected here. However, the button structure is characteristic of the schist across the entire outcrop belt (Plate 1). The metagraywacke does not normally exhibit any megascopic evidence of shearing except where it has been caught up in the cataclastic zone.

STOP 2 (Hatcher):

Brevard phyllite, cataclastic Henderson gneiss and Poor Mountain Formation. Location: U. S. 76, on curve 1,200 feet northwest of the intersection of the Spy Rock Road and U. S. 76 (Whetstone Quadrangle).

Exposed on the curve in the highway is some cataclastic Henderson gneiss. Northwest (across the road) is the Brevard phyllite member of the Chauga River Formation. This contact is thought to be a conformable stratigraphic contact. Note the slickensides in the Brevard phyllite across the highway from the Henderson exposure. Up the hill (to the southwest) a contact zone is exposed which brings together the Henderson gneiss and the Poor Mountain Formation. This is thought to be a fault contact (presently thought to be a high angle thrust). Southeastward (up the hill) the Brevard-Poor Mountain transitional member is exposed and is interlayered with some feldspathic biotite quartzite. Just beyond the crest of the hill is the contact between the Brevard-Poor Mountain transitional member and the amphibolite member of the Poor Mountain Formation.

STOP 3 (Hatcher):

Poor Mountain amphibolite, feldspathic quartzite, and the Henderson augen gneiss. Location: U. S. 76, 2 miles west of where the highway crosses the Chauga River (Holly Springs Quadrangle).

Typical fine-grained laminated Poor Mountain amphibolite is exposed in the first cut along the highway southeast of the parking area. Some Brevard-Poor Mountain transitional lithology also occurs here as interlayers in the amphibolite. The dip of the amphibolite here is anomalously steep (50-60 degrees) and several small isoclinal folds with steep southeast-dipping axial surfaces may be observed.

In the next cut is exposed the mesoscopic fold shown in Plate 18 of the text. This is an isoclinal recumbent fold in the feldspathic quartzite of the Poor Mountain Formation. At least two garnet-rich layers may be traced around the culmination of the fold. Note also that this isoclinal recumbent fold has a secondary upright open fold superimposed upon it.

A few feet to the northwest near the top of the cut is a small mass of Henderson augen gneiss. This is a very isolated mass, for it cannot be traced away from the cut. The quartzite here is not the typical Poor Mountain quartzite that normally occurs at the top of the Poor Mountain Formation. However, presence of Henderson gneiss just above the quartzite (although in somewhat dislocated condition) has led the writer to conclude that the structure observed here were developed in the axial portion of a local synclinal fold.

The high rank-low rank boundary is some 2,000 feet southeast of this exposure.

STOP 4 (Hatcher):

Fold and migmatite of the High Rank Belt. Location: U. S. 76, 800 feet northwest of the Chauga River (Holly Springs Quadrangle).

This exposure contains a large mesoscopic antiform and synform in granitic gneiss (Plate 19). Southeastward (toward the river) foliation traces become difficult to follow due to migmatization of the rocks in this part of the cut.

STOP 5 (Hatcher):

Exposure of the high rank-low rank boundary. Location: Country road 3,500 feet east of Crossroads No. 2 Church, 300 feet east of where Ramsey Creek crosses the county road (Holly Springs Quadrangle).

The boundary tectonic slide is exposed in the road-cut with granite gneiss of the high rank Inner Piedmont thrust against fine-grained Henderson gneiss. The quartzofeldspathic gneisses on both sides od the boundary are quite similar but that southeast of the boundary is slightly coarser (somewhat resembles some of the Henderson augen gneiss with sheared out augen) and contains some thin silvers of amphibolite. Note the sudden appearance of small pegmatite pods at the boundary and the absence of them to the northwest (walk across the bridge and look at the fine-grained Henderson gneiss).

STOP 6 (Hatcher):

Poor Mountain and Henderson Rocks. Location: Rich Mountain Road, 2 miles north of the intersection of Rich Mountain Road with Cobb Bridge Road (Holly Springs Quadrangle).

Exposed along this segment of the Rich Mountain Road are amphibolite and calcareous quartzite of the Poor Mountain Formation and Henderson augen gneiss. The road lies just beneath the gently undulating contact between the Henderson gneiss and rocks beneath. To the north, the road crosses into the Henderson and out again, passing from Poor Mountain amphibolite into quartzite into Henderson into quartzite and back into the amphibolite again. This crossing of contacts is accomplished not by crisscrossing it by movement in a horizontal direction but gaining elevation.

The quartzite exposed here contains no calcite at the present time. However, alignment of solution cavities on the surface of the quartzite reveal a lineation (N40° E) which is present in the rock here.

Abundant tourmaline in vein quartz may be observed in several places at this stop.

These are the most accessible exposures close to the Poor Mountain type locality (Plate 1) and have in them the same rocks originally described by Sloan (1908) with the exception of the Poor Mountain marble.

STOP 7 (Hatcher) -- Lunch Stop:

Chauga River Formation. Location: Blackwell Bridge crossing of Chauga River by county road 193 (Whetstone Quadrangle).

This stop involves walking for some 1,000 feet up a creek to observe the Chauga River formation and an optional additional walk to observe a carbonate slice present in the Brevard cataclastic zone in this area (Plate 1). Although this is not a particularly difficult walk it perhaps should not be made by someone in ill health.

Exposed on the Chauga River at the mouth of the tributary stream is some cataclastic Henderson gneiss. The first exposures up this tributary creek are in the upper Brevard phyllite member and consist of Brevard phyllite and interlayered metagraywacke. Some 400 feet upstream from the mouth is the carbonate member of the Chauga River Formation. The upper Brevard phyllite member appears to be a abnormally thin here and the contact between upper Brevard phyllite and overlying Henderson Gneiss is thought to be a fault contact (see Plate 1). This is one of the few places in this area where a fault is thought to separate the cataclastic Henderson from the main Chauga River sequence.

Proceeding up the creek through the carbonate member into the lower Brevard phyllite member, thin mylonite zones become more common. This lower phyllite member consists of muscovite chlorite phyllite, graphitic phyllite and minor amounts of metagraywacke. The graphitic phyllite is more common toward the base of the sequence and could be the unit along which movement in the Brevard zone is localized (provided there is stratigraphic control of the Brevard zone). Upstream the distinction between the cataclastic zone and the local portions of the sequence become less clear.Those who wish to do so may take the optional walk to the carbonate slice. This lithology is unlike any of the other carbonates in this area (contrast Plates 3, 4, 5, 6, and 10). It has been sheared and granulated and contains streaks of carbonaceous material. Any comments on the origin or the source of the carbonate would be appreciated.

STOP 8 (Hatcher):

Brevard-poor Mountain transitional lithology. Location: State Highway 28, 1,500 feet south of the intersection of State Highway 28 and country road 226.

This is an optional stop (time permitting) to show the Brevard-Poor Mountain transitional lithology 3 miles southeast of the Brevard zone. This is the same belt as the Poor Mountain type locality (Plate 1).

STOP 9 (Griffin):

Recumbent isoclines developed in amphibole gneiss. This road cut is an unusually excellent exposure showing mesoscopic recumbent folds in the Walhalla nappe. The fold development here is comparable to stage D in Figure 7. Low amplitude antiforms and synforms are superimposed on the fold limbs. Down toward the Creek, near the fold closure behind the small pine tree, large crenulations occur on the recumbent fold limb. The crinkles may have resulted from late movement along a slip cleavage direction.

STOP 10 (Griffin):

A macroscopic anticlinal closure within the northwestern boundary fold. This quartz muscovite schist-quartzite lies within the core of the western boundary fold of the Walhalla nappe and grades southwest into biotite gneiss and biotite schist. The quartz muscovite schist at the top of the hill, directly across from the abandoned house, is younger. Both units, separated by amphibolite, are strikingly similar here. The younger quartzite closes across the highway about one quarter mile northeast of here, then swings back south where it outcrops along the highway we just traveled from Stop 9.

SUNDAY TRIP

STOP 11 (Griffin):

Macrobuttons or "tectonic fish" within the biotite gneiss-biotite schist unit of the Six Mile nappe. Similarities with the example in figure 4 of the text may be recognized here. On careful inspection, some of these macrobuttons show remnant recumbent fold closures. At the southwest end of the road cut, a nappe-like fold in the biotite schist can be seen. This recumbent fold has a distinct root zone. Sillimanite occurs widely in this area.

STOP 12 (Griffin):

Contact with biotite gneiss-biotite schist unit and the migmatite complex below. The author believes this boundary is the sole of the Six Mile nappe. The contact here can be traced for miles along strike (see Plates 1 and 2). The biotite gneiss contains augen of potash feldspar. The writer believes that these augen may have developed through migration of potassium from the lower migmatite complex. C. Q. Brown (personal communication) notes that augen commonly occur in biotite gneiss near granite contacts throughout Pickens County. Note the mesoscopic recumbent folds in the biotite schist near the boundary.

STOP 13 (Griffin):

Agmatite in the migmatite complex of the Walhalla nappe. This locality and similar ones have been previously described, "...Thick blocks of boudins of undigested mafic – occasionally quartzite-material ("paleosome") occur immersed within the acidic neosome in some migmatitic zones. Sederholm..... first recognized such eruptive developments in similar migmatitic zones in southwestern Finland, and he named them ´agmatite.´

"In the Inner Piedmont agmatite zones the paleosome blocks were pulled apart along pre-existing joint surfaces and swirled about in the highly mobile acidic neosome. Reaction of these blocks with the neosome is indicated by rims of biotite – now weathered to vermiculite – developed along the interface between the two contrasting phases. Biotite schlieren drawn out into the prevailing foliation occur also in these agmatite zones." (Griffin, 1967a, p. 48).

As we return up the hill, toward Stop #12, notice the dikes and sills of alaskite on your left below the contact. The dikes appear to be essentially postkinematic, although minor displacement effects can be seen.

STOP 14 (Griffin):

A typical "good" exposure if the muscovite biotite schist. The high muscovite content imparts a brilliant, sparkling aspect to this rock in hand specimen. The sillimanite content is high, which is typical for this rock type. Exposures of the unit are usually not very outstanding. Probably this is due to its atmospherically stable mineral composition (e.g., muscovite, quartz and sillimanite) and to the almost flat, sheet-like exposure of the schist over the entire Six Mile Quadrangle. The muscovite biotite schist plays essentially the same geomorphic role as a flat well-indurates sandstone horizon; both act as resistant caps upholding high areas. Six Mile Mountain, seen in the distance, contains many simple pegmatite veins cutting the schist. This concentration of coarser, stable minerals may account for the existence of the monadnock on the plateau. The muscovite-biotite schist occupies the core of the Six Mile nappe (Figure 5).

STOP 15 (Griffin):

An outstanding exposure showing together many features unique to the migmatitic Inner Piedmont belt. As we start up the hill note the amplitude folds. Beyond this, a reverse fault may be seen occupied by a simple pegmatite. Note the extreme drag (?) folding in the foot wall amphibolite. The amphibolite in the hanging wall is extensively granitized. The granitizing agents favored the foliation dragged normal to the pegmatite emplacement, which probably was their source. Extreme plastic folding is observed beyond this. Beaded structures of alakite occur within thinly interlayered amphibolite and biotite schist, suggestive of sedimentary lamination.

We return down the hill and walk out onto the point in Hartwell Lake. The greenschist you see here is composed of Chlorite and actinolite. This is an example of the magnesian schist briefly discussed in the author´s paper. Salient questions pertaining to the origin of these rocks are:

1. What original rock type were they, ultramafic intrusives or impure dolomites?
2. What permits chlorite and actinolite to coexist with rocks approaching and within the sillimanite grade of metamorphism?
3. Do structural discontinuities separate these anomalous bodies from the surrounding rocks?