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Field Trip Guidebook

Guide to the Geology of the Blue Ridge South of the Great Smoky Mountains, North Carolina

by

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Raleigh

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CAROLINA GEOLOGICAL SOCIETY

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CONTENTS

ILLUSTRATIONS

TABLES

AN APPRECIATION

Jarvis B. Hadley

(1909-1974)

Dr. Jarvis Hadley was to be one of the leaders of the 1975 Carolina Geological Society field trip. In November of last year he died of a heart attack while doing fieldwork in the Catoctin Mountains of Maryland.

Dr. Hadley's work in the Blue Ridge covered a span of over thirty years, starting with strategic mineral investigations during World War II and continued into the 1970's with regional geologic mapping. He was probably best known for his authoritative work on the geology of the eastern Great Smoky Mountains done in collaboration with Richard Goldsmith. He was one of the first geologists to recognize that radiometric dates on minerals taken from high grade metamorphic terranes probably reflects the time of uplift and cooling rather than a true igneous or metamorphic age.

He was a man of refreshing character, never forcing his views upon others and always willing to look at another person's interpretation of the facts. Although Dr. Hadley will not be on this field trip, it would not have been possible without his years of work in this area. Accordingly, this guidebook is dedicated to his memory.

CAROLINA GEOLOGICAL SOCIETY
Guidebook for 1975 Annual Meeting
Pages 1-28

GUIDE TO THE GEOLOGY OF THE BLUE RIDGE SOUTH OF THE GREAT SMOKY MOUNTAINS, NORTH CAROLINA

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INTRODUCTION

The Carolina Geological Society field trip for 1975 will focus on the geologic setting of the Blue Ridge area south of the Great Smoky Mountains. The trip will run parallel to the entire length of the Smokies; however, most of the stops will be in valley areas, south of the main divide.

Weather at this time of year is usually pleasantly crisp and clear; however, it is advisable to bring warm clothing for the early morning and late afternoon chill.

The field trip leaders have a varied interest in this region. Carl Merschat and Leonard Wiener are investigating the regional stratigraphy and structure between the Great Smoky Mountains and the Ducktown region. David Mohr has completed a detailed stratigraphic and metamorphic study in the eastern Fontana Lake region. Steve Kish is presently engaged in determining the timing of structural and metamorphic events in this portion of the Blue Ridge.

We hope that you will have an enjoyable and hopefully somewhat enlightening trip.

REGIONAL STRATIGRAPHY

The Blue Ridge province of western North Carolina is basically an anticlinorium, modified by large-scale thrust faulting. A basement complex of gneissic and granitic rocks with interspersed amphibolite forms the core of the anticlinorium (figure 1). Based on uranium-lead dating of zircons (Davis, Tilton, and Wetherill, 1962) and rubidium-strontium whole rock dating (Fullagar and Odom, 1973), the minimum age for plutonic gneisses of this complex is 1.1 b.y. Structural and metamorphic studies of basement units indicate at least two periods of deformation and metamorphism, one during the Late Precambrian (Grenville orogeny) and one during the Paleozoic (Hadley and Goldsmith, 1963, p. 23).

Unconformably overlying the basement complex are unfossiliferous, clastic metasediments of the Ocoee Series [Supergroup]. On the western side of the Great Smoky Mountains, units of the Ocoee Series are conformably overlain by the Lower Cambrian (?) and Lower Cambrian Chilhowee Group. Based upon this relationship, the Ocoee Series is assigned to the Late Precambrian (King, Hadley, Neuman, and Hamilton, 1958, p. 965).

The rocks of the Ocoee Series were metamorphosed during the Paleozoic. Metamorphic grade ranges from subgreenschist facies in the western portion of the Blue Ridge in Tennessee to upper amphibolite facies in North Carolina (Carpenter, 1970). The Ocoee Series is broken into a number of thrust sheets, making stratigraphic correlation difficult. The Ocoee has been divided into three major units, the Snowbird, Great Smoky, and Walden Creek Groups, with a total thickness of at least 12 kilometers. In the Great Smoky Mountains the Snowbird Group, consisting of fine-grained meta-arkose, rests nonconformably on basement gneiss and is overlain by the Great Smoky Group. Its thickness decreases rapidly to the south and east, so that in the vicinity of Sylva, North Carolina, the Great Smoky Group rests directly on basement. The Great Smoky Group occupies more than three-fourths of the known outcrop area of the Ocoee Series, ranging from northwest Georgia to the vicinity of Asheville, North Carolina. It has a thickness of approximately 5 kilometers; dominant rock-types include conglomeratic meta-arkose and feldspathic metasandstone. A distinctive marker unit for the upper portion of the Great Smoky Group is the Anakeesta Formation, a black, graphitic and highly sulfidic series of slate, phyllite and schist with minor units of impure dolomitic marble (Hadley and Gold-

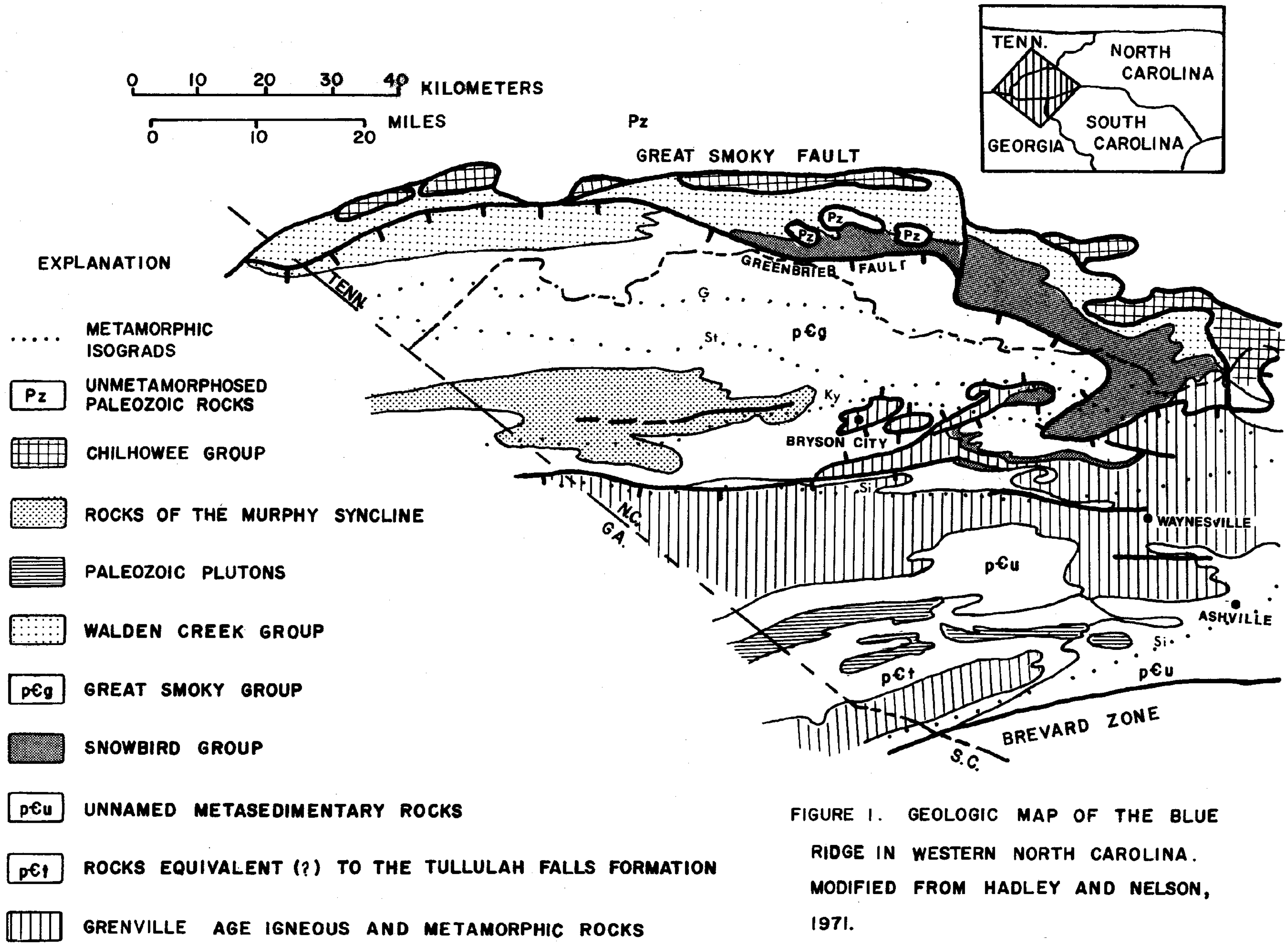


Figure 1. Geologic map of the Blue Ridge in Western North Carolina modified from Hadley and Nelson, 1971.

Table 1. Stratigraphic nomenclature for rocks south of the Great Smoky Mountains.

Nantahala quadrangle, N.C.-Tenn. (Keith, 1907)	Mineral Bluff quadrangle, Georgia (Hurst, 1955)	This Guide
		Murphy Group
	Mineral Bluff Formation	Mineral Bluff Formation
Nottely Quartzite	Nottely Quartzite	Nottely Quartzite
Andrews Schist	Andrews Formation	Andrews Formation
Murphy Marble	Murphy Marble	Murphy Marble
Valleytown Formation		
Brasstown Schist	Brasstown Schist	Brasstown Formation
		Nantahala Formation
Tusquitee Quartzite	Tusquitee Quartzite	Tusquitee Member
Nantahala Slate	Nantahala Slate	Lower Member
		Great Smoky Group
Great Smoky Conglomerate	Dean Formation	Dean Formation
	Hothouse Formation	Ammons Formation
	Hughes Gap Formation[1]	Anakeesta Formation
	Copperhill Formation[1]	Metasandstone, equivalent in part to the Thunderhead Sandstone
		Grenville granitic and layered gneiss
Carolina Gneiss		

[1]Stratigraphic correlation between these units and rocks of the Great Smoky Mountain region is not implied.

smith, 1963, p. 59). The Walden Creek Group, containing metaquartzite, dolomitic marble, metaconglomerate and pelitic metasandstone, is exposed in isolated thrust sheets in the western Blue Ridge of Tennessee. Since it overlies the Snowbird Group and is overlain by the Chilhowee Group, the Walden Creek Group is probably at least partially equivalent to the Great Smoky Group (Neuman and Nelson, 1965). Southwest of the Great Smoky Mountains, the Great Smoky Group is conformably overlain by rocks present in a major synclinal structure known as the Murphy belt. At the present time, no formal stratigraphic name has been applied to this sequence; they will be referred to informally as the Murphy Group. The rocks of the Murphy belt are distinctly different from those of the underlying Great Smoky Group, in that they include graphitic phyllite, clean metaquartzite and marble. Keith (1907) was the first to name and describe units within the Murphy Group (Table 1). He interpreted these rocks as overlying the Great Smoky Conglomerate (Great Smoky Group) and being correlative with the Cambrian Chilhowee Group to the west. Subsequent workers have agreed with Keith's basic stratigraphy, however, some of his stratigraphic terminology has been revised because it was based in part upon an incorrect interpretation of structure and lithologic facies changes (Power and Forrest, 1973; Hadley, 1970, p. 255).

The basal unit of the Murphy Group, the Nantahala Formation, was originally divided into two units, the Nantahala Slate and the Tusquitee Quartzite. Keith (1907) believed that the Tusquitee Quartzite was above all the dark pelitic units of the Nantahala Slate and that its repetition in outcrop pattern was due to folding. Hadley (1970, p. 255) subsequently has shown that the pelitic and quartzitic units are interbedded and should be considered a single formation. The Nantahala Formation is overlain by the Brasstown Formation, a sequence of dark, pelitic, and thinly bedded mica schist and light colored metasiltstone. The Murphy Marble, which overlies the Brasstown Formation, is the most thoroughly studied unit within the Murphy belt due to its importance as a source of building stone and its association with economically significant quantities of talc. The Murphy Marble consists of approximately 100 meters of bluish-gray, light gray and white marble and dolomitic marble (Van Horn, 1948). It

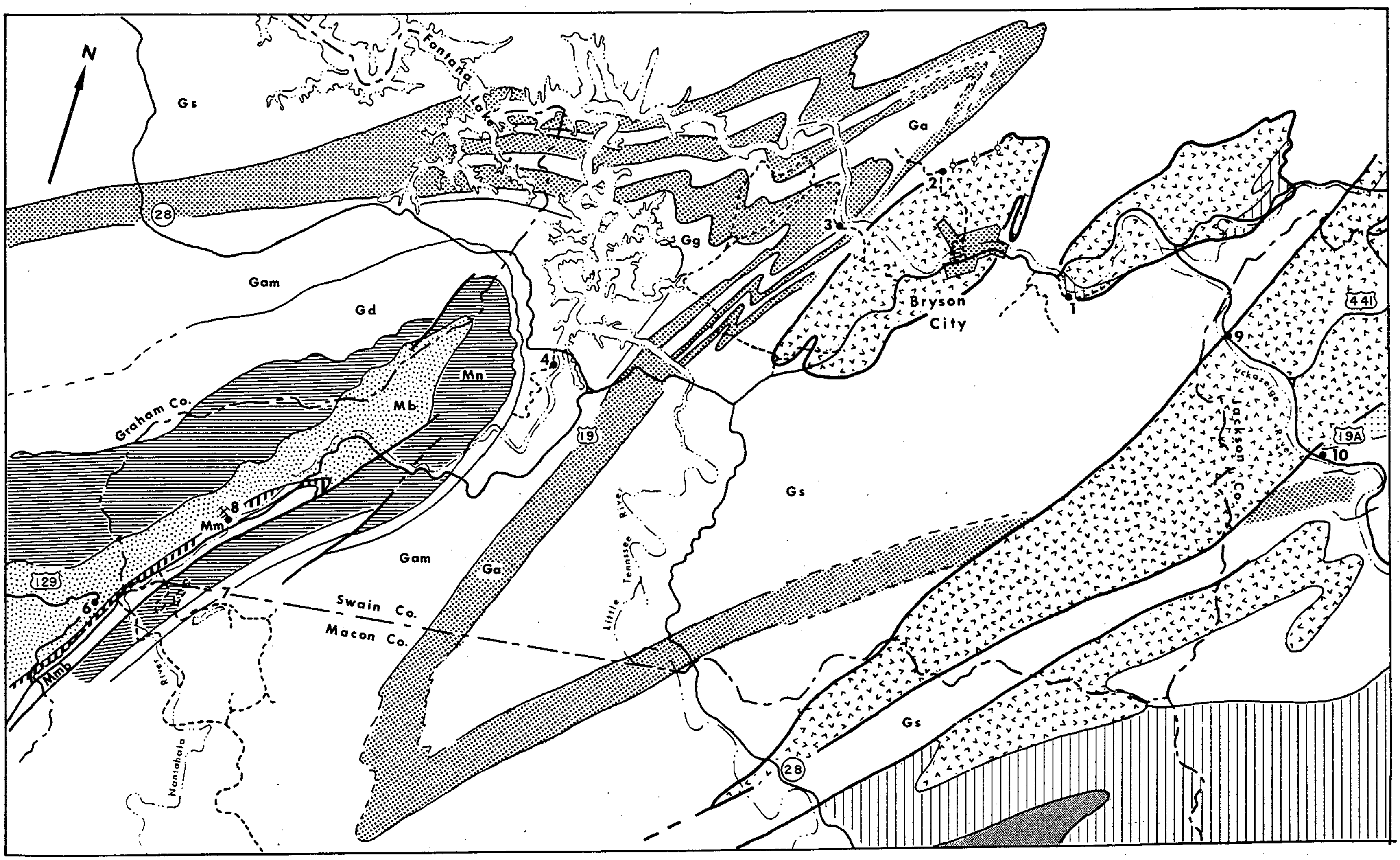
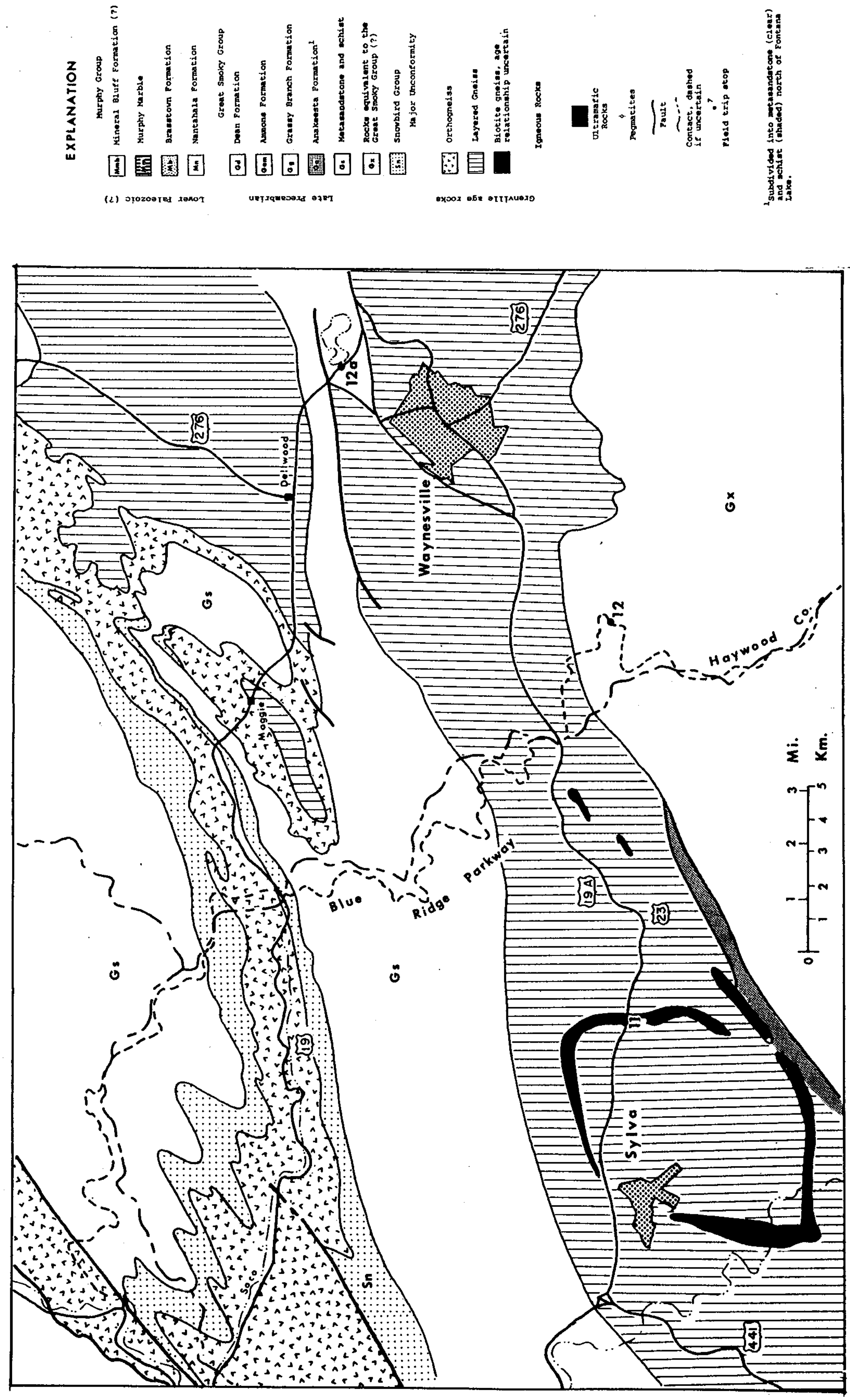


Figure 2. Geologic map of the region south of the Great Smoky Mountains. (Map continues on next page)


EXPLANATION
Lower Paleozoic (?)
Murphy Group
Mineral Bluff Formation (?)
Murphy Marble
Brasstown Formation
Nantahala Formation
Late Precambrian
Great Smoky Group
Dean Formation
Ammons Formation
Grassy Branch Formation
Anakeesta Formation[1]
Metasandstone and schist
Rocks equivalent to the Great Smoky Group (?)
Snowbird Group
Major Unconformity
Grenville age rocks
Orthogneiss
Layered Gneiss
Biotite gneiss, age relationship uncertain
Igneous Rocks
Ultramafic Rocks
Pegmatites
Fault
Contact, dashed if uncertain
Field trip stop
[1]Subdivided into metasandstone (clear) and schist (shaded) north of Fontana Lake.
Waynesville
Dellwood
Maggie
Sylva
Blue Ridge Parkway
Haywood Co.
Gs
Gx
Sn
Mi.
Km.

is overlain by the Andrews Formation, containing interlayered units of marble and mica schist. A thin quartzite, the Nottely Quartzite, overlies the Andrews Formation on the north limb of the Murphy Syncline, but is not present on the south limb. The highest unit exposed in the Murphy Group is the Mineral Bluff Formation (Hurst, 1955), a sequence of interlayered pelitic schist and quartzites, which appears to be restricted to the southern portion of the Murphy belt and is not recognized north of Andrews, North Carolina (Hadley and Nelson, 1971).

STRUCTURAL GEOLOGY

A detailed description of the structural and metamorphic history for the Blue Ridge is beyond the scope of this guide. Only the salient features of structure and metamorphism to be seen on the field trip will be discussed below. Table 2 is an attempt to synthesize the major structural elements and metamorphic features in the area south of the Great Smoky Mountains.

Structural studies in the Great Smoky Mountains (Hadley and Goldsmith, 1963; Hamilton, 1961) reveal that the earliest generation of folding (F_1) observed in post-Grenville rocks is characterized by nearly east-west trending, subvertical to recumbent similar folds having an axial-plane cleavage or schistosity. The only large macroscopic F_1 folds observed in the field trip area are two major synclinal folds in the Murphy belt and a major anticlinal fold which may extend from the Murphy belt to the Soco Valley area (see figures 2, 3, and 4). Metamorphism accompanying this generation of folding appears to have been restricted to the lower greenschist facies. The low-angle Greenbrier fault, having a possible displacement of 20 kilometers (Hadley and Goldsmith, 1963, p. 80), post-dates most F_1 structures. However, at outcrops adjacent to the Greenbrier fault, the S_1 schistosity appears to grade into the mylonitic foliation association with the fault. Major movement on the Greenbrier fault ceased before the peak of metamorphism. Metamorphic isograds cross the fault without offset.

A second generation of relatively open, asymmetric folds, trending north-northeast, has deformed earlier folds and the Greenbrier fault. Field trip stops 1 and 2 will attempt to demonstrate that the Bryson and Ela domes are windows in the Greenbrier thrust created by F_2 folding. Second-generation folds appear to be en echelon in nature; single macroscopic folds cannot be traced for more than a few kilometers; however, these folds appear to be nearly pervasive in their affect upon S_0 and S_1 surfaces (see figures 3 and 4). The interference patterns produced by the intersection of F_1 and F_2 fold systems varies from elongate S and Z patterns superimposed upon large F_1 folds (e.g., the F_1 Murphy syncline near Bryson City) to modified, elongate basin and dome patterns (e.g., the F_1 Soco anticline crossed by numerous $_2$ folds near Maggie – see figure 2). F_2 folds have an associated axial-plane slip cleavage; locally a true schistosity is present. Microscopic evidence indicates that most metamorphic porphyroblasts, including metamorphic index minerals, grew after the development of S_1 schistosity, but before the development of S_2 surfaces. Large pegmatites in the Bryson City area cut F_2 structures (Cameron, 1951). Rubidium-strontiu whole rock dating has established an age of 440 m.y. for one of these pegmatites (Kish and Fullagar, unpublished data). This age would establish a *minimum* date for the time of regional metamorphism and deformation.

At least two generations of slip cleavage and brittle-type deformation post-date the peak of metamorphism (see Table 2). Potassium-argon dating of retrograde sericite associated with the $_3$ surfaces observed by Power and Forrest (1971) yields ages of 280 m.y., nearly 100 m.y. younger than mineral ages from the surrounding rocks which are relatively unaffected by retrograde metamorphism (Kish, unpublished data). These structures may be associated with Late Paleozoic faulting in which a large portion of the Blue Ridge was thrust westward over unmetamorphosed rocks of the Valley and Ridge. The thrust faults are broken by strike-slip and normal faults. Folding of thrust sheets and subsequent erosion has created numerous windows through which unmetamorphosed Ordovician rocks are exposed (see figure 1).

The sequence of structural and metamorphic events just described appears to be recurrent throughout much of the Blue Ridge from northwestern North Carolina to northeast Georgia (Rankin et al., 1973; Stirewalt and Dunn, 1973; Butler, 1973; Hatcher, 1974).

Brevard zone geologists should note that the sequence of structural events associated with Greenbrier fault (isoclinal folding, mylonitization, second generation folding) is nearly identical to the sequence observed in the Brevard zone (Stirewalt and Dunn, 1973).

ROCK UNITS

Grenville Age Rocks

Layered Gneiss

The oldest rocks exposed in the area south of the Great Smoky Mountains are layered gneiss and schist, which are known to lie non-conformably beneath rocks of the Great Smoky and Snowbird Groups. These rocks were originally mapped as Carolina Gneiss by Keith (1904, 1907) and Hadley and Goldsmith (1963, p. 6). The use of the term Carolina Gneiss has been discontinued because it has been applied to rocks of various ages over a large area in the southern Blue Ridge and Piedmont.

The dominant lithology in these rocks is layered biotite gneiss with subordinate amounts of calc-silicate-rich muscovite gneiss and schist, hornblende gneiss, and amphibolites. The average composition of these gneisses is rather mafic. The quartz content in the biotite gneiss averages less than 30

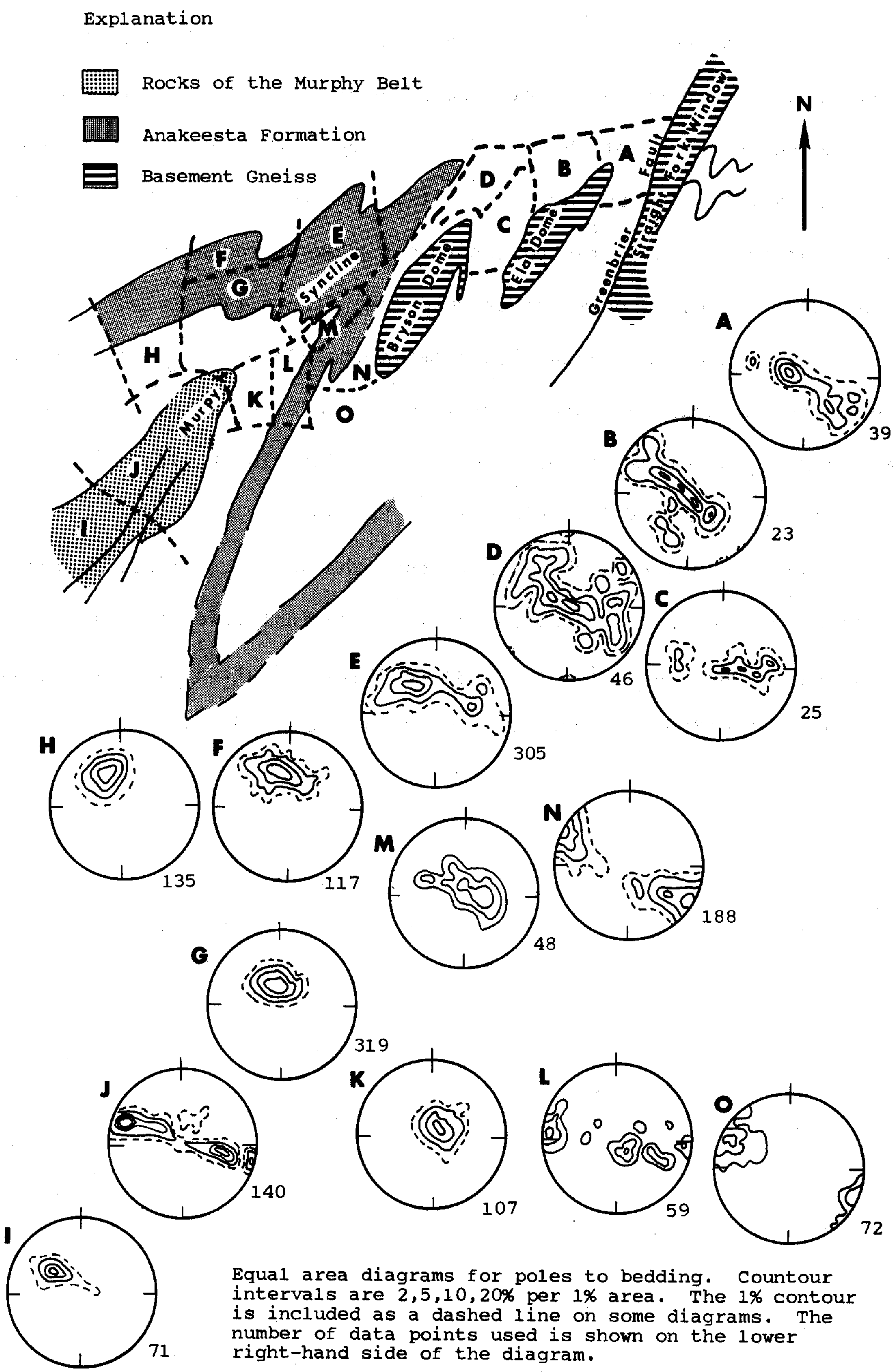
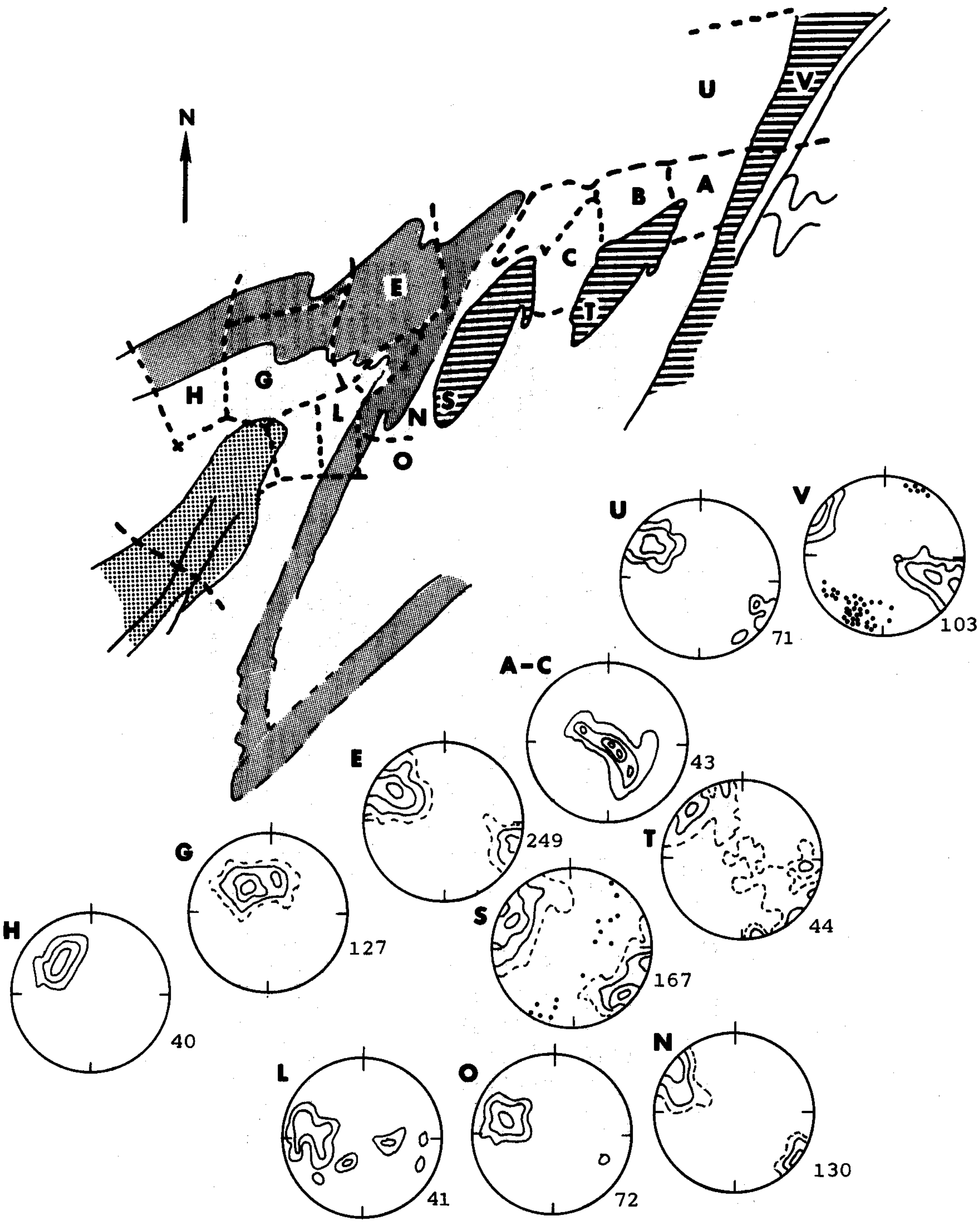


Figure 3. Orientation diagram for poles to bedding.



Equal area diagrams for poles to schistosity. Contour intervals 2,5,10,20% per 1% area. The 1% contour interval is included as a dashed line on some diagrams. The number of data points used is shown on the lower right-hand side of each diagram.

Small dots represent lineations in gneiss.

Diagrams U and V from Hadley and Goldsmith (1963).

Figure 4. Orientation diagrams for poles to schistosity.

Table 2. Structural elements for the rocks south of the Great Smoky Mountains.

Planar structures	Folds	Lineations	Other features
S_1 Development of pervasive schistosity in fine-grained metasandstone and schist above garnet grade. Slaty cleavage below garnet grade. S_1 foliation dips to the SE. and is subparallel to the axial planes of F_1 folds. Appears to develop into a mylonitic foliation adjacent to the Greenbrier fault zone.	F_1 Macroscopic Murphy synclinorium, Soco anticlinorium. Moderate to gentle SE. dipping axial surfaces which strike ENE. North of the main trace of the Greenbrier fault the folds trend E.-W. Mesoscopic folds are well-developed in interlaminated metasiltstone and schist.	Intersection of S_0 and S_1 produces a faint streaking lineation which appears as lines and grooves on S_1 surfaces. Elongate quartz pebbles within the S_1 surface.	Emplacement of mafic and ultramafic igneous bodies? Low grade metamorphic conditions. Formation of local quartz and pegmatite veins.
S_2 Development of slip and crenulation cleavage striking NNE. to N.E., subvertical cleavage surface. Locally transposes S_1 to form a true schistosity. Parallel to F_2 axial surfaces.	F_2 Macroscopic en echelon folds near Bryson City, Ravensford and Cataloochee anticlines. Bryson and Ela domes due to the folding of the Greenbrier thrust. F_2 mesoscopic folds are typically open with sub-axial surfaces striking NNE.	Crenulation formed on S_0 and S_1 surfaces by intersection with S_2. Crenulation axes plunge moderately NE. or SW. Some porphyroblasts form lineations within S_2 surfaces.	Peak of metamorphism probably pre-S_2. Porphyroblasts are broken and rotated (?) into S_2 surfaces. Some porphyroblasts may be synkinematic to S_2. Granitic pegmatites (440 m.y. old) and trondhjemite dikes and sills are post-F_2.
S_3 Crenulation and slip cleavage striking E.-W., subvertical surface.	F_3 With the possible exception of broad warps no major folds have been observed.	Intersection of S_3 with S_0-S_1 produces a prominent crenulation which plunges SE. due to SE. dip of S_0-S_1.	Development of retrogressive assemblages: quartz-chlorite-sericite-magnetite. Emplacement of quartz-car bonate-chlorite veins.
S_4 Slip cleavage with a gentle SE. dip.	F_4 Open folds and kinks with subhorizontal axial surfaces.	Crinkles with variable trend. Intersection of S_4 with S_3 on S_0-S_1 produces basin and dome pattern.	The temporal relationship between S_4 (?) and S_3 (?) is uncertain.

percent and potassium feldspar is also quite low (Hadley and Goldsmith, 1963, p. 8-9). These rocks were probably formed from a quartz-poor graywacke or from volcanic deposits of intermediate composition.

The well-defined layering in the gneisses may be in part relict sedimentary or volcanic beds, but the present texture is in large part due to the segregation of mafic and felsic components into migmatite-like layers

The age of these gneisses is uncertain. Layered gneisses in a similar geologic setting in northwestern North Carolina yield uranium-lead ages from zircon of 1.3 b.y. (Davis, Tilton, and Wetherill, 1962). However, these zircons could be detrital in origin and as such would only place an upper limit on the age of these gneisses. Plutons, dated at 1.1 b.y. establish a minimum age for these units.

Plutonic Rocks

Coarse-grained plutonic rocks are present in anticlinal folds and in windows in the Greenbrier thrust sheet (see figure 2). These plutons range from granite to diorite in composition, with granodiorite and quartz monzonite making up 75 percent of the exposed bodies (Hadley and Goldsmith, 1963, p. 13). Most of these rocks are now well foliated and for flaser and augen gneisses; most are concordant with the surrounding layered gneiss. Hadley and Goldsmith (1963, p. 107) observed that to the northwest, layered gneisses became increasingly migmatitic, grading gradually into uniform plutonic rocks, presumably derived through the process of partial melting and local mobilization.

Rubidium-strontium whole rock dating of quartz monzonite gneiss in the northern portion of the Bryson Dome (field trip stop 2) establishes an approximate age of 1.1 b.y. for this body. The relatively high initial Sr^{87}/Sr^{86} value for this pluton (0.7065 ± 0.001) supports Hadley and Goldsmith's suggestion that these rocks are anatectic in origin.

Great Smoky Group

Metasandstone and Schist

The lowest stratigraphic units of the Ocoee Series present south of the Great Smoky Mountains are light to dark gray metasandstone, which typically occurs in thick to massive beds. Individual beds are commonly graded; the base of each bed usually contains pebble size, rounded grains of blue and white quartz and feldspar; the tops of the beds are marked by thin layers of muscovite schist. A distinctive feature of this metasandstone is the presence of thin lenses and ellipsoidal masses of carbonate rich metasiltstone. These bodies are generally referred to as concretions although their large size (up to 1 meter thick) and extensive distribution suggest they may be primary in origin. At high metamorphic grades these bodies form a distinctive cal-silicate mineral assemblage (quartz-plagioclase-garnet-hornblende-clinozoisite) commonly referred to as "pseudodiorite" in allusion to the granoblastic, igneous-like appearance of this rock. Units of muscovite-biotite schist up to 50 meters thick are interbedded with the metasandstone. North of Bryson City these units have been called the Thunderhead Sandstone, but no formal name has been applied to metasandstone to the south.

Anakeesta Formation

To the west of Bryson City a 1,200-meter thick section of highly graphitic and sulfidic black schist is present on both limbs of the Murphy syncline. Mohr (1973, p. 54) was able to subdivide the formation into five subunits of subequal thickness. The lower, middle, and upper units are dominated by massive beds of black to dark gray muscovite schist. Above the kyanite isograd porphyroblasts of plagioclase, biotite, and kyanite are present. Bedding is not visible in units of massive schist, but is usually traceable when the schist contains thin metasiltstone layers. Minor rock types associated with the black schist are black tremolite schist or para-amphibolite and dark tremolitic marble (Mohr, 1973, p. 53). Two major units of thin-bedded felsic metasandstone are present between the black schist units.

These units of black schist have been correlated with similar lithologies present in the Anakeesta formation in the Great Smokies. However, these units appear to be 1,800 meters higher in the stratigraphic section than the Anakeesta Formation exposed on Clingmans Dome and about 330 meters higher than the base of the Anakeesta Formation at its type locality (Hadley and Goldsmith, 1963, p. 63-64). A complex intertonguing relationship of schist and metasandstone was proposed to explain the wide stratigraphic interval of the black schist units. Until the completion of mapping between the type area of the Anakeesta and the schist near Bryson City, the name Anakeesta Formation should be applied to these rocks only in a provisional manner.

Grassy Branch Formation

The Grassy Branch Formation is composed of 100 to 300 meters of felsic metasandstone and laminated schist. The type area for the formation is along a tributary stream of Alarka Creek, 6 kilometers west of Bryson City (Mohr 1973, p. 54-55). The formation can be divided into a 100- to 150-meter thick lower, gray metasandstone and schist. The metasandstone is similar to the unnamed strata exposed above the Anakeesta Formation near Clingmans Dome. Graded bedding and calcareous nodules and lenses are common in the metasandstone. The upper unit is composed of 10 to 150 meters of thinly bedded to laminated schist containing abundant biotite porphyroblasts. The Grassy Branch Formation appears to thin southward and has not been recognized south of the Noland Creek quadrangle.

Ammons Formation

The Ammons Formation is a 1,200- to 1,500-meter thick sequence composed of relatively clean metasiltstone and fine- to medium-grained metasandstone interbedded with thin beds of non-graphitic muscovite schist. The type section for the Ammons is along the bank of the Little Tennessee River just north of the field trip stop 4. Graded beds, soft-sediment slump features, and cross bedding are prominent in many metasandstone beds. A dark, sulfidic mica schist and laminated metasandstone interbedded with a lighter colored metasandstone and bluish-white quartzite form a restricted lithology within the Ammons, mapped as the Horse Branch Member by Mohr (1973, p. 57). Merschat and Wiener (1973) have correlated the Ammons Formation with the Hothouse Formation of Hurst (1955).

Dean Formation

The uppermost formation of the Great Smoky Group consists of thick units of greenish-gray sericite schist and arkosic metasandstone, present in roughly equal proportions. Metasandstone is present in units 10 to 50 meters thick, which are interbedded with schist. The metasandstone has thick to massive beds often containing conglomeratic layers which display crude to well developed graded bedding. Pebbles within the conglomeratic units are subrounded clasts of blue quarts and white feldspar. Schist units are thick to massive; bedding is poorly preserved. Locally bedding is accentuated by the presence of laminae of fine-grained metasiltstone. Keith (1907, p. 12) placed these units at the base of his Nantahala Slate, but subsequent workers have placed these units within the Great Smoky Group. Mohr (1973) has correlated these units with the Dean Formation of Hurst (1955).

The contact between the Dean Formation and the Nantahala Formation is gradation over an interval of 10 to 50 meters. Usually metasandstone or schist of the Dean Formation becomes finer-grained and darker upsection, and finally is replaced by thinly bedded phyllite and metasiltstone of the Nantahala Formation.

Murphy Group

Nantahala Formation

A major portion of the Nantahala Formation is exposed along the Nantahala River in the vicinity of Wesser, North Carolina. The formation is divided into two parts, a lower metasiltstone and schist member and an upper member containing interbedded metaquartzite and metasiltstone. The total thickness of the Nantahala Formation is estimated to be at least 600 meters.

The lower pelitic member of the Nantahala Formation, the Nantahala Schist (Mohr, 1973), contains thinly bedded or laminated, dark-gray, fine-grained metasiltstone, phyllite and metaquartzite. Current structures and ripple-drift lamination are present throughout the lower member. Fine-grained quartz, feldspar, sericite and sulfides are abundant accessory minerals. Garnet and biotite porphyroblasts, generally less than 1 millimeter in diameter, are locally observed in the sericite-biotite-quartz matrix. Thin bands of calc-silicates are locally present in the Nantahala Schist.

The upper member of the Nantahala Formation, the Tusquitee Member, contains alternating metaquartzite and metasiltstone units. Four major metaquartzite units, 5 to 50 meters thick are present within the Tusquitee Member. The lower and most prominent metaquartzite is exposed along the Nantahala River, 0.1 kilometers west of Wesser, additional units are exposed along streams on the north rim of the Nantahala Gorge. Bedding within the metaquartzite varies from thin to massive. A prominent longitudinal jointing may be mistaken for bedding in the more massive units. Individual beds of the Tusquitee Member contain white to light bluish-gray metaquartzite and metasubarkose composed of medium- to fine-grained, recrystallized, subrounded quartz and feldspar with very minor amounts of metamorphic white mica and biotite. Small grains of zircon and tourmaline are present in some beds. A brownish-gray, arenitic unit present in the upper portion of the Tusquitee Member contains pebble size, subangular clasts of blue quarts, K-feldspar and plagioclase. Phyllite present as chips and slabs within this unit probably represents shale clasts formed by penecontemporaneous sediment movement.

Metapelitic units, which are interbedded with metaquartzite of the Tusquitee Member, are similar in appearance to those of the Nantahala Schist, however both graphite and sulfides are less abundant.

The contact between the Nantahala Formation and the overlying Brasstown Formation is gradational over a range of 10 to 50 meters. The uppermost portion of the Nantahala Formation is a graphitic metasiltstone and metaquartzite that passes upward into light brownish-gray phyllite and metasiltstone of the Brasstown Formation.

Brasstown Formation

The Brasstown Formation is exposed along a single outcrop belt located on the northern rim of the Nantahala Gorge (see figure 2). The formation is absent on the south limb of the Murphy syncline due to faulting. The total thickness of the Brasstown Formation is estimated to be approximately 250 meters.

The Brasstown Formation contains interlayered units of very fine-grained metasiltstone and phyllite. In many exposures the phyllite resembles the pelitic portion of the Nantahala Formation, however, phyllite of the Brasstown Formation is more micaceous, with the mica being coarser grained. Graphite and sulfides are usually absent or present in very minor amounts. The lower one-half of the Brasstown Formation is dominated by interlayered metaarkose, metagraywacke, and phyllite. Metagraywacke is dark-brown, highly micaceous and contains medium- to coarse-grained recrystallized quartz and feldspar. Locally, metaarenite interlaminated with phyllite displays graded bedding on the scale of 1 to 3 millimeters. The phyllite is dark gray and composed of fine-grained white mica, biotite, and quartz with minor amounts of graphite.

The upper portion of the Brasstown Formation contains light-gray, fine- to medium-grained metasiltstone, which ranges from metasubarkose to metaquartzite in composition. These units, 15 to 20 meters thick, are interlayered with dark-gray phyllite containing laminae of metaquartzite. Garnet-staurolite-biotite schist and calc-silicate layers reported in the Brasstown Formation to the south (Power and Forrest, 1971, p. 5) are not present in the northern portion of the Murphy syncline.

The contact between the Brasstown Formation and the overlying Murphy Marble appears to be gradational. In the vicinity of the Nantahala Talc and Limestone Company quarry at Hewitt, dark-gray, interlaminated phyllite and metaquartzite of the Brasstown Formation intertongues with and grades upward into a dark bluish-gray arenitic marble forming the base of the Murphy Marble. The transition takes place over an interval of less than 5 meters. South of Hewitt a dark-gray, fine-grained quartz-sericite-chlorite phyllite forms the contact between the two formations.

Murphy Marble

The Murphy Marble is exposed along a single outcrop belt on the northwest limb of the Murphy syncline; due to faulting the formation is absent on the southeast limb. The Murphy Marble is approximately 115 meters thick in the vicinity of Hewitt (Van Horn, 1948, p. 11); however, deformation may have increased the thickness of the marble at this location.

Exposures of the Murphy Marble are limited because of a thick saprolitic cover associated with the marble. In exposures at the Nantahala Talc and Limestone Company quarry at Hewitt, a large variety of carbonate lithologies are present. Gray and bluish-gray calcareous and dolomitic marble, black graphitic marble, and white dolomite marble are present as distinctive units. Actinolite, tremolite, biotite or phlogopite, chlorite and pyrite are common accessory minerals within the marble. Large, lens-shaped bodies of talc are locally present in the marble and have been mined on a commercial scale in the vicinity of Talc Mountain.

The quartzite-marble-phyllite sequence of the Murphy Group has been correlated with the Chilhowee-Shady-Rome sequence of the Valley and Ridge (Keith, 1907; Hadley, 1970; Mohr, 1973). However, McLaughlin and Hathaway (1973) report fossils (possibly as young as Middle Ordovician) in the Murphy Marble (field trip stop 8), which would seem to prevent a correlation with the Early Cambrian sequence of the Valley and Ridge. If the Murphy Marble is younger than Early Cambrian, a major unconformity must be present in the Murphy Group to explain the absence of a thick Cambrian-Ordovician carbonate sequence, which is required on the basis of regional stratigraphy.

The relationship of the Murphy Marble to overlying units is poorly defined due to the absence of exposures. Southwest of Hewitt units of the Andrews Formation and locally the Nottley Quartzite have been mapped as overlying the Murphy Marble (Van Horn, 1948). Northeast of Hewitt, the marble appears to be overlain conformably by dark-brown, medium-grained metasiltstone possibly belonging to the Mineral Bluff Formation.

Andrews Formation – Nottely Quartzite

South of Hewitt, North Carolina, the Murphy Marble is overlain by the Andrews Formation, which contains impure marble and calcareous schist. The Andrews Formation is overlain by the Nottely Quartzite, a white, fine-grained metaquartzite, 5 to 15 meters thick. Both units have been mapped as far north as Hewitt (Keith, 1907; Van Horn, 1948), but appear to be absent to the northeast, either due to faulting or nondeposition.

Mineral Bluff Formation

The Mineral Bluff Formation (Hurst, 1954) is the youngest recognized stratigraphic unit within the Murphy Group. The formation occupies the central portion of the Murphy Syncline in northernmost Georgia. Power and Forest (1971) show the Mineral Bluff Formation extending as far north as Andrews, North Carolina.

The extent of the Mineral Bluff Formation north of Andrews is uncertain. Dark-gray to brownish-gray fine-grained metasandstone exposed on the lower slopes of Briertown Mountain in the Nantahala Gorge appears to overlie the Murphy Marble in stratigraphic continuity, and is probably part of the Mineral Bluff Formation, however, a major fault is present in this area and units believed to be the Mineral Bluff Formation may include units of the Brasstown Formation in fault contact with Murphy Marble.

Igneous Rocks

Mafic intrusives

Intrusive dikes and sills of diorite composition intrude rocks as young as the Brasstown Formation in the Murphy Group. These rocks are usually highly altered by metamorphism and now contain mineral assemblages such as actinolite-plagioclase-chlorite and hornblende-plagioclase-sphene. A crude belt of scattered metadiorite sills extends 26 kilometers southwest from Clingmans Dome to Hazel Creek near Fontana Dam (Hadley and Goldsmith, 1963, p. 69). Van Horn (1948, p. 15) has mapped similar metadiorite sills in the Murphy Group. One metadiorite body exposed in the Nantahala Gorge (the Hewitt sill) has a poorly preserved ophitic texture. Saussuritized plagioclase laths (0.1 to 0.5 mm long) are surrounded by patches of biotite and chlorite, which have formed from the original mafic minerals. Some samples from the sill contain dark-green, porphyroblastic actinolite.

Ultramafic rocks

A large number of tabular to lenticular bodies of relatively unaltered dunite and olivine-pyroxene ultramafic rocks are exposed in the eastern portion of the field trip area (see figure 2). Most of the major ultramafic bodies form a linear belt, which is located just east of a major fault (possibly the Greenbrier fault) mapped by Hadley and Nelson (1971). The ultramafic rocks have been deformed by folding and some bodies are intruded by pegmatites.

Pegmatites

Pegmatites in this portion of the Blue Ridge are of two types. The most common type is thin, pegmatitic layers (1 to 10 cm thick), which are almost always parallel to the layering in the adjacent rock. The second type of pegmatite ranges from 0.1 to 3 meter wide dikes to tabular and lens-like masses 150 meters long and 50 meters wide (Cameron, 1951). These bodies are clearly intrusive in origin. Both types of pegmatites appear to be restricted to areas above the kyanite isograd (Lesure, 1968). In the Bryson City district, the largest pegmatites are concentrated on the northwest margin of the Bryson dome, apparently due to some type of structural control. Most of the larger pegmatites appear to be associated with fractures formed along the crest of second-generation asymmetric folds (Cameron, 1951, p. 23). Both the pegmatites and fold axes plunge steeply to the southwest. The pegmatites are usually zoned, with the outer zones being rich in plagioclase and the inner zones rich in perthite.

These pegmatites appear to post-date the last major folding and prograde metamorphic events in this portion of the Blue Ridge. Long, Kulp and Eckelman (1950) report a 340 m.y. potassium-argon age for muscovite from the Deep Creek Number 1 Mine near Bryson City. This age is nearly identical to potassium-argon ages from micas of the Spruce Pine district. Most geologists have accepted these ages as

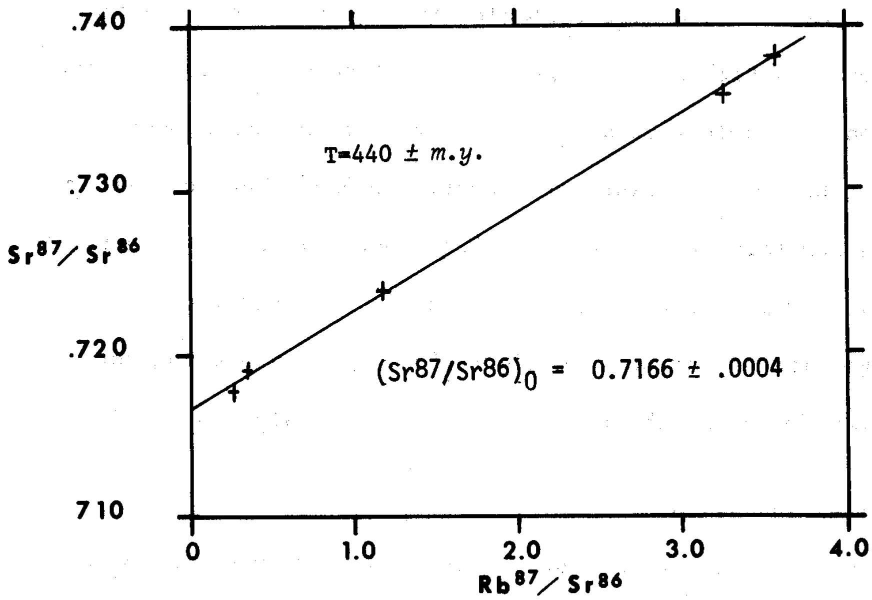


Figure 5a. Preliminary rubidium-strontium whole rock isochron for the Cox Number 1 Pegmatite.

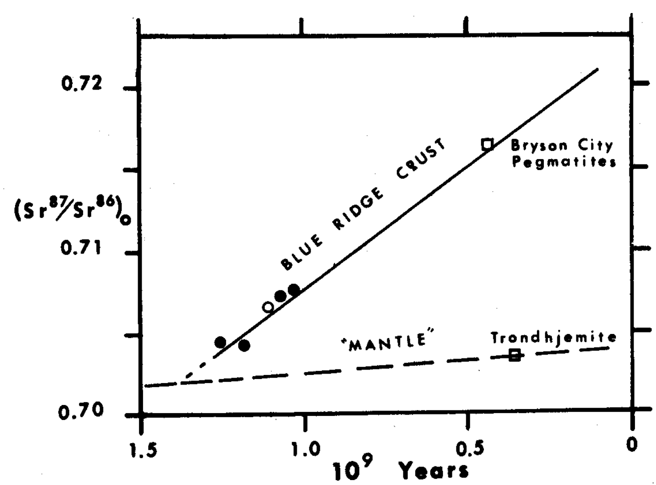


Figure 5b. Curves showing the apparent change in Sr^{87}/Sr^{86} initial ratios with geologic time. Black dots represent values taken from Fullagar and Odom (1973). Blue Ridge curve represents material with high Rb/Sr ratios – typical of upper crustal material. Lower curve represents materials with low Rb/Sr ratios (i.e., mantle). Note that the two types of Paleozoic intrusions have distinctly different initial Sr^{87}/Sr^{86} ratio suggesting derivation of one type from the upper crust (pegmatites) and the other from the mantle (trondhjemites).

approximating the time of regional metamorphism (Bryan and Reed, 1970; Rankin, 1970; Hurst, 1973). However, within the past two years it has been recognized that mineral ages from high-grade metamorphic terranes may be tens of millions of years younger than the true time of metamorphism or igneous intrusion (Hurley et al., 1962; Hadley, 1964; Armstrong, 1966; Harper, 1967; Dewey and Pankhurst, 1970; Butler, 1972). The low age is a result of the slow cooling of deep-seated, high-grade rocks and the low temperatures (around 200º C) at which micas quantitatively retain the products of radioactive decay.

In order to establish a more reliable date for the intrusion of the larger pegmatites, Kish and Fullagar (unpublished data) have obtained a rubidium-strontium whole rock age of 440 m.y. for the Cox Number 1 pegmatite of the Bryson City district (see figure 5a). The initial Sr^{87}/Sr^{86} value for this pegmatite (0.7166 ± 0.0004) is nearly identical to the probably average value of Sr^{87}/Sr^{86} in the Blue Ridge crust at the time of pegmatite formation (see figure 5a). This would suggest the pegmatite was formed by the partial melting of crustal material.

Trondhjemite dikes and sills

The youngest igneous bodies observed in this portion of the Blue Ridge are small dikes and sills of trondhjemite (leucocratic alkali granodiorite). These rocks are distributed over a wide area of the Blue Ridge. They have been reported north of the Grandfather Mountain window (Bryant and Reed, 1970) and as far south as the Blue Ridge of Georgia (Hatcher, 1974, p 16). The dikes and sills are most abundant in a 16-kilometer-wide belt extending 80 kilometers northeast from Waynesville, North Carolina (Bryant and Reed, 1970, p. 215). The trondhjemite is generally present in 0.1 to 0.1 meter thick sills and subordinate dikes. The trondhjemite is light gray and usually contains 1 to 5 millimeters long phenocrysts of Na-plagioclase in a fine-grained groundmass of quartz, plagioclase and biotite. These rocks are similar in composition to the "alaskites" of the Spruce Pine plutonic group of Rankin et al. (1973, p. 25). Both groups have low potassium, iron, and magnesium contents; both are peraluminous, containing accessory muscovite; and both appear to have been emplaced after the peak of regional metamorphism. Preliminary rubidium-strontium whole rock dating of one trondhjemite body indicates an age of at least 400 m.y.

In some locations trondhjemite dikes cut granitic pegmatites (optional stop on

). A sample taken from a trondhjemite sill at field trip stop 132 has a present day Sr^{87}/Sr^{86} value of 0.7039 ± 0.0005. This value is too low for the rock to have originated by the melting of crustal material. The trondhjemitic magma was probably derived from a subcrustal source (see figure 5b).

SATURDAY, NOVEMBER 8, 1975

Buses will leave from in front of the Fryemont Inn at 8:00 a.m.

Mileage

0.0 Mileage starts at the intersection of U.S. 19 (Main St.) and Everett St. (S.R. 1364). Drive east on U.S. 19.

0.5 Exposures on the right are saprolitic gneiss of the Bryson dome. The contact between the gneiss and the surrounding metasediments of the Great Smoky Group is approximately 300 meters to the east.

0.7 Exposures on the left, across the Tuskasegee River are well-bedded metasandstone of the Great Smoky Group, which is overturned to the west. The sequence of strata between the Bryson and Ela domes appears to be continuous, suggesting either the rocks on the east side of the Bryson dome are much higher in the stratigraphic sequence than rocks on the west flank of the Ela dome or that the dominant folds in this area (F_2) are nearly isoclinal.

1.6 Small quarry on right is in highly deformed metasandstone and kyanite-garnet-muscovite schist.

1.8 Turn right onto S.R. 1168; U.S. 19 continues acros Tuckasegee River.

2.4 **STOP 1 (60 minutes):** Intersection of S.R. 1168 and the Bryson City by-pass, which is under construction. We will leave the buses and walk about 0.5 mile along road cuts on the by-pass. The buses will move to the terminus of the walk.

This stop is located on the southern margin of the Ela dome. Grenville age augen gneiss and paragneiss underlie the broad valley to the north, while metasandstone of the Great Smoky Group forms the ridges which encircle the valley. Proceed west.

Lower cut. The dominant lithology in this cut is a biotite-plagioclase paragneiss. Biotite and plagioclase-quartz alternate in layers from a few millimeters up to several centimeters thick. Accessory garnet and epidote are present as clear, anhedral grains, generally less than a millimeter in size. The low quartz content and virtual absence of potassium feldspar (see Table 3) in this gneiss suggest it was probably derived fro either a quartz poor graywacke or a volcanic rock of andesitic composition. The dominant foliation in the paragneiss, formed by the gneissic layering, dips gently to the south. Locally, small isoclinal folds are present and their axial plans are subparallel to gneissic layering. A large body of amphibolite, 3 to 5 meters thick, is present in the upper portion of the cut. The body is roughly concordant with the layering in the surrounding gneiss; however, the extensive boudinage present around the margin of the body suggests the concordance may be due in part to tectonic transposition during isoclinal folding. The amphibolite is composed of coarse-grained, brownish-green hornblende (60%), brown biotite (20%), plagioclase (15%), and accessory sphene, opaques, and carbonate. The presence of clinopyroxene in the cores of hornblende grains suggest the body may have originated as a diorite or gabbro dike or sill.

Middle cut. The migmatite exposed here is composed of paragneiss interlayered with igneous-like layers containing coarse-grained plagioclase and quartz. Note the apparent offset and "draping" of many layers. There is some suggestion of a large scale, recumbent fold in the upper portion of the cut. The timing of migmatization is uncertain, however no migmatites of this scale are present in the surrounding rocks of the Late Precambrian Great Smoky Group. This would suggest this migmatite probably formed during a Precambrian (Grenville) metamorphic event.

Upper cut. Between the middle cut and the crest of this hill we have crossed from paragneiss into

Table 3. Selected modes for rocks to be seen on the field trip.

	A	B	C	D	E	F	G	H
Quartz	10.3	23.0	37.7	18.5	34.3	32.3	29.7	50.1
Plagioclase	50.3	36.0	29.3	26.7	55.5	60.4	58.5	32.1
K-Feldspar	1.7	34.0	29.7	29.5	tr.	0.8	3.5	--
Biotite	32.4	4.0	1.2	16.5	8.5	5.3	7.1	16.0
White Mica	--	--	1.8	2.8	1.4	1.1	0.9	0.3
Garnet	1.4	--	--	--	--	--	--	1.0
Epidote	2.5	2.0	0.3	4.9	--	--	--	tr.
Opaques	0.4	0.2	tr.	0.4	tr.	tr.	tr	.0.2
Sphene	0.7	tr.	--	tr.	--	--	--	--
Apatite	0.3	0.6	tr.	0.7	tr.	tr.	0.2	--
Carbonate	tr.	tr.	--	--	--	--	--	--

A. Dark-gray paragneiss, stop 1.
B. Bryson gneiss, stop 2.
C. Leucocratic, fine-grained gneiss, stop 2.
D. Dark-gray, biotite gneiss containing microcline augen, stop 2.
E. Fine-grained trondhjemite, stop 12.
F. Slightly coarser-grained trondhjemite dike in contact with sample E.
G. Relatively coarse-grained trondhjemite sill, stop 12.
H. Light-gray metasandstone, stop 12.

[1]All modes are based on a count of 1,500 points per thin section.

metasandstone and schist of the Great Smoky Group. These units tend to be more aluminous and potassic compared to the basement gneiss. Quartz, plagioclase, and potassium feldspar are the most abundant phases in metasandstone. The schist is composed of slightly pleochroic muscovite (40%), biotite (20%), quarts (30%), plagioclase (10%), and accessory amounts of subhedral, clear garnet. The schist near the basement contact has a distinct banded or ribbon-like appearance. Close inspection reveals this texture is produced by 1 to 5 millimeter segregations of quartz-plagioclase and muscovite-biotite, which have been accentuated by small isoclinal folds. Larger layers probably represent original sedimentary layering.

The most prominent foliation in these rocks (here interpreted as S_0 parallel to S_1) strikes northeast with a moderate to steep dip to the northwest. A secondary, crenulation cleavage (S_2) striking N. 15º E. and dipping steeply to the southeast produces a wavy appearance in the banded schist. Associated with this foliation are open to tight concentric folds (F_2), which have axial surfaces dipping steeply to the southeast. At the northwest end of this roadcut a prominent mesoscopic isoclinal fold (F_1) is refolded by this generation of folds. Also present are deformed pegmatite-like veins of quartz-plagioclase-kyanite. The kyanite is deep blue in color and is present in blades up to 5 centimeters long. The kyanite appears to have been kinked by the S_2 cleavage.

3.8 Continue to buses at the base of the hill. Head north on S.R. 1166. Metasandstone and schist of the Great Smoky Group are exposed on the right.

4.2 Turn right (north) onto U.S. 19. Return to Bryson City.

5.6 Turn right (north) onto Everett St. (S.R. 1364).

8.1 Exposure of quartz monzonite gneiss on north side of road.

8.8 Sherill Gap. Contact between basement gneiss and rocks of the Great Smoky Group.

8.9 **STOP 2 (45 minutes):** Tectonic contact between Bryson Gneiss and the Great Smoky Group. We will unload from the buses at the west end of Sherill Gap.

This stop is located on the western margin of the Bryson City dome. Based upon stratigraphic relationships to the west, it appears that several hundred and perhaps several thousand meters of metasandstone are missing between the east limb of the Murphy Synclinorium and the Bryson dome.

The west end of the exposure contains a distinctive kyanite-staurolite-garnet two-mica schist. Clear euhedral garnets the size of pinheads make up 20 percent of the schist. Staurolite encloses some garnet grains and contains poikiloblastic inclusions of quartz and plagioclase, which form trails parallel to schistosity. Kyanite has been extensively altered to a randomly oriented white mica. Going eastward the schist is interlayered with thin- to medium-bedded metasandstone. Small-scale isoclinal folds are visible in freshly broken pieces of the more micaceous beds. The west end of the gap contains 0.1 to 0.1 meter thick beds of medium-gray metasandstone. Quartz and feldspar pebbles within the metasandstone have been intensively flattened and recrystallized. Length to width ratios of pebbles observed in thin-section vary from 5:1 to 10:1. Thin lenses of calc-silicates (pseudodiorite) are present in metasandstone beds on the south side of the road. The mineral assemblage present in these lenses (quartz, plagioclase, hornblende, garnet, and clinozoisite) is characteristic of medium to upper amphibolite facies metamorphism. On the north side of the road a prominent crenulation cleavage (S_2) strikes N 20º E and dips steeply to the southeast.

The contact between the metasandstone and basement gneiss is approximately 3 meters west of a weathered pegmatite present on the north side of the road. The contact, present in saprolite, is sharp with little or no intercalation between the two units. The gneiss immediately adjacent to the contact has a very distinctive appearance produced by a strong foliation. The 50 meters of gneiss exposed here consist of alternating biotite and quartz-feldspar gneiss in layers 0.1 to 5 meters thick. Biotite-rich portions of the unit contain abundant microcline augen ranging from 0.1 to 1.0 centimeter in length. Also present are wispy bands and lenses of fine-grained (0.1 mm) aggregated grains of quartz and feldspar. The texture resembles a blastomylonite or a recrystallized protomylonite. The quartz-feldspar gneiss contains fine-grained quartz, plagioclase, and potassium feldspar, which have smooth to slightly curved grain boundaries producing a granoblastic texture. Large microcline augen are locally present. This gneiss is similar in composition to the coarse-grained Bryson Gneiss exposed 200 meters to the east. The present texture would indicate that the rock underwent a reduction in grain size (presumably by intense deformation) followed by recrystallization. At the east end of this outcrop the dominant foliation is deformed by tight folds having axial planes which strike N 20º E and dip 70º southeast. The axes associated with these folds plunge 55º, N. 35º E. These folds are interpreted as being F_2 structures, associated with the crenulation cleavage observed in the metasandstone.

Cameron (1951, p. 11) termed this distinctive gneis the “border gneiss” because of its restriction to the margin of the Bryson dome. The border gneiss is most prominent along the northern portion of the Bryson dome but rocks of similar lithologic character are present along much of the dome’s margin. Cameron (1951, p. 11) states that the thickness of the border gneiss varies from 20 to 60 meters and at some locations the biotite and quartz-feldspar gneiss is intercalated with hornblende-biotite and actinolite schist. Rubidium-strontium whole rock dating of both the biotite gneiss and the quartz-feldspar gneiss indicate they were derived from rocks approximately 1.1 b.y. old (Kish and Fullagar, unpublished data). The general setting of the border gneiss (always at the basement-Great Smoky Group contact) and the mylonitic nature of the gneiss suggest the basement contact is tectonic in nature, and is probably a thrust fault or tectonic slide. In this case the Bryson and Ela domes would be structural windows formed along the crest of a series of en echelon F_2 folds. This situation is almost identical to the structural sequence observed to the northeast where the Greenbrier thrust is exposed along the F_2 Ravensford anticline (Hadley and Goldsmith, 1963). The “border gneiss” and immediately adjacent rocks in the Great Smoky Group probably represent the main Greenbrier fault zone or a related fault above the main thrust. Continue east. The broad valley to the south is underlain by orthogneiss of the Bryson dome; the peaks of the Alarka Mountains (approx. elev. 4,600 ft./1,400 m) are upheld by metasandstone on the south flank of the dome. Just past the border gneiss outcrop a jeep road leads uphill to a prospect pit in a small quartz-plagioclase pegmatite.

9.3 Exposure of relatively undeformed Bryson Gneiss. The gneiss has the composition of a quartz monzonite (see Table 3). The gneiss is slightly porphyritic; microcline is present in flattened phenocrysts up to 1 centimeter in length. Biotite is the main mafic mineral although large, euhedral (up to 3 cm) crystals of dark green hornblende are locally present, especially in coarse-grained, pegmatite-like veins of the gneiss. Preliminary rubidium-strontium whole rock dating of this portion of the Bryson Gneiss yields an age of 1.09

± 0.05 b.y. and a Sr^{87}/Sr^{86} initial ratio of.7065 (Kish and Fullagar, unpublished data).

If time permits we will visit the Cox Number 1 pegmatite, which starts directly across from S.R. 1365. The Cox Number 1 is typical of the granitic pegmatites of the Bryson City district. The pegmatite is roughly zoned, containing an outer zone of fine-to-coarse-grained quartz and plagioclase with minor perthite and biotite. An intermediate zone contains coarse-grained plagioclase and quartz with varying amounts of perthite. Euhedral grains of a brownish-black fluorite up to 2 centimeters in width are present in this zone. The inner zone of the pegmatite consists of coarse-grained perthite-quartz and a 1- to 3-meter quartz core, which appears to plunge approximately 50º, N. 70ºW (Cameron, 1951, p. 84).

9.3 Reboard buses. Return to Bryson City.

10.9 Turn right on Gibson St. (S.R. 1321).

11.0 Turn left on Shope St. (S.R. 1323). Cross railroad tracks and the Tuckasegee River

11.3 Turn right (south) onto U.S. 19. Exposures of Bryson Gneiss are on the opposite side of the road.

12.4 Turn right (north) onto S.R. 1320. The Bryson Gneiss exposed on the side of U.S. 19 is cut by several dike-like bodies of foliated porphyritic quartz monzonite.

12.5 Turn right (north) onto S.R. 1311.

13.5 Cross railroad. Railroad cuts are in saprolite of the Bryson Gneiss.

14.0 Contact between basement gneiss and rocks of the Great Smoky Group.

14.5 **STOP 3 (40 minutes):** Upper metasandstone and black schist of the Anakeesta Formation. Unload at the east end of the outcrop. Structural features of two major folding episodes are present here. The general low angle of dip at many portions of this outcrop is due to our location in the trough of the F_1 Murphy syncline. A large macroscopic second generation fold has produced the tight, upright folds visible in outcrop. The s-shaped asymmetry of many of these folds suggest a major synclinal fold to the west. At this location the s-surface associated with F_2 folds in a well-developed schistosity rather than a crenulation cleavage such as seen at stops 1 and 2. Careful inspection at some locations reveals tight crenulations rather than true schistosity.

Proceed west. Nearly vertical beds of feldspathic metasandstone. Small graded beds indicate younger beds are to the west.

14.55 Black muscovite schist. The dark color is due to high graphite content. The dip of bedding (S_0) is gentle; schistosity (S_2) is nearly vertical, striking N. 40º E.

14.57 Bedding is vertical.

14.60 Prominent kyanite-rich black schist. Kyanite is present in 5 to 10 centimeter long, dark gray blades, which lie within the S_2 schistosity. Small plagioclase porphyroblasts contain helicitic trails of inclusions, which probably define preserved S_1 surfaces. The high pyrrhotite content of this schist results in intense weathering, producing "rotten rock", highly iron stained surfaces, and deposition of hydrous iron sulfate efflorescence on dry surfaces.

14.66 A black quartz-tremolite "para-amphibolite" is present as a large boudin at the top of the exposure.

14.68 Large shear zone trending nearly north-south.

14.70 Boudin of black "para-amphibolite". This rock is composed of 1 to 10 millimeter long, euhedral tremolite (75%), 1 to 3 millimeter, euhedral grossularitic garnet (5%), calcic plagioclase (8%), and quartz (5%) with minor amounts of graphite, carbonate, and sphene. Diopside and the magnesium chlorite, amesite, have been reported in some of these bodies (Hadley and Goldsmith, 1963, p. 104). The rock is interesting in thin section and it would be worth collecting a *small* sample.

14.8 Reboard buses.

15.6 Junction of S.R. 1311 and S.R. 1312. Stay on S.R. 1311.

16.0 Leave Bryson City quadrangle and enter Noland Creek quadrangle.

16.4 Exposure of the upper black schist of the Anakeesta Formation.

17.2 Indian Grave Gap. Exposures of highly sulfidic black schist and boundinaged black tremolitic para-amphibolite.

18.1 Junction with S.R. 1312. Contact between upper black schist of the Anakeesta Formation and the lower metasandstone of Grassy Branch Formation.

19.1 Upper schist of the Grassy Branch Formation. S.R. 1311 changes to S.R. 1309. We are now traveling down the stratigraphic section.

19.6 Exposures of the upper and middle black schist members of the Anakeesta Formation.

20.7 Railroad underpass. Cross the west limb of a macroscopic F_2 syncline (see figure 2).

21.0 West limb of macroscopic F_2 anticline.

22.0 East limb of macroscopic F_2 anticline. Reenter the Bryson City quadrangle.

22.5 Turn right onto S.R. 1304.

23.0 Turn right onto U.S. 19.

23.2 Leave Bryson City quadrangle-enter Wesser quadrangle.

24.7 Cross Little Tennessee River. Exposures of Great Smoky Group metasandstone and schist in road cuts and along the river

25.6 Lower and middle black schist members of the Anakeesta Formation.

26.2 Upper black schist member of the Anakeesta Formation.

27.1 Junction of U.S. 19 and N.C. 28. Continue on N.C. 28.

27.7 View of Round Top (3,211 ft./979 m) The mountain is capped by gently dipping quartzites of the upper portion of the Nantahala Formation. This is the northernmost occurrence of the rocks of the Murphy belt.

27.8 Cross Nantahala River-Fontana Lake. During low water an extensive section of westward dipping metasandstone of the Ammnons Formation is visible to the north.

27.9 Turn left onto Watia Rd. (S.R. 1121).

28.1 **STOP 4 (20 minutes):** Metasandstone of the Ammons Formation. Bedding is dipping at moderate angles to the west. S_1 schistosity in this area dips gently to the east. This relationship plus the apparent "opening-up" of the Murphy syncline in the vicinity of Round Top Knob is probably produced by the refolding of the northwest limb of the nearly isoclinal Murphy syncline by an upright, open F_2 syncline. The true hinge of the F_1 Murphy syncline is located about a kilometer to the southeast.

The principal rock type exposed here is a medium gray, feldspathic metasandstone in medium to thick beds. The metasandstone is generally medium- to fine-grained; conglomeratic layers are rare. We are below the staurolite isograd at this location. Most of the larger detrital grains in the metasandstone have not been extensively deformed or recrystallized. The ubiquitous detrital blue quartz found in the Great Smoky Group at lower grades is sparingly present in some beds.

28.3 Turn right onto N.C. 28, return to U.S. 19.

29.1 Turn right (south) only U.S. 19. The road parallels the contact between the Ammons and Anakeesta Formation.

29.8 Nantahala Lodge.

30.2 Panoramic view of the crestline of the Great Smoky Mountains, 16 miles (26 kilometers) away. Clingmans Dome (6,643 ft./2,615 m), the highest peak in the Smokies is slightly east of due north.

32.0 Collins Gap. View of the Briertown Mountains to the west and the Nantahala Mountains to the southwest.

32.6 Wesser Creek Road. Dark-green, crossed biotite schist of the Dean Formation is exposed on the left.

33.3 Cross contact between the Dean Formation (top of the Great Smoky Group) and the Nantahala Formation (base of the Murphy Group).

33.5 Prominent exposures of dark-gray, sulfidic and graphitic metasiltstone of the lower portion of the Nantahala Formation.

33.7 Lowest and most prominent quartzite of the Tusquitee member of the Nantahala Formation.

34.0 Second quartzite.

34.4 Third quartzite. This unit contains significant amounts of feldspar and slate fragments.

35.0 Cross major high-angle fault. Rocks of the Brasstown Formation are exposed across the river.

35.2 Trough of the Murphy syncline. Beds of the Brasstown Formation, exposed across the river, dip gently to the southwest.

35.6 Exposure of dark-gray, micaeous metasiltstone of the Brasstown Formation.

36.1 Leave Wesser quadrangle and enter the Hewitt quadrangle.

36.8 Float of the "Hewitt sill" is present on the road bank to the left.

37.1 Blowing Spring on left emerges from slightly below the base of the Murphy Marble.

37.4 Exposures of siliceous, bluish-gray Murphy Marble across from roadside parking area.

38.6 Cross the Nantahala Gorge.

40.0 Nantahala.

40.6 Exposure of siliceous marble in streambed on right.

40.7 Swain-Macon county line.

41.0 Leave the Nantahala Gorge.

41.6 Exposure of Murphy Marble on right.

43.7 Red Marble Gap. Turn right onto U.S. 129.

43.7 Red Marble Gap; bridge over Southern Railroad tracks; enter Graham County. Continue northwesterly on U.S. 129 to lunch stop. In the afternoon we shall examine selected outcrops as we work our way back upsection (southeast) along this same route.

62.7 Junction S.R. 1146 and U.S. 129. Turn left to Cheoah Point Recreation Area

62.85 Turn left to Cheoah Point Campground.

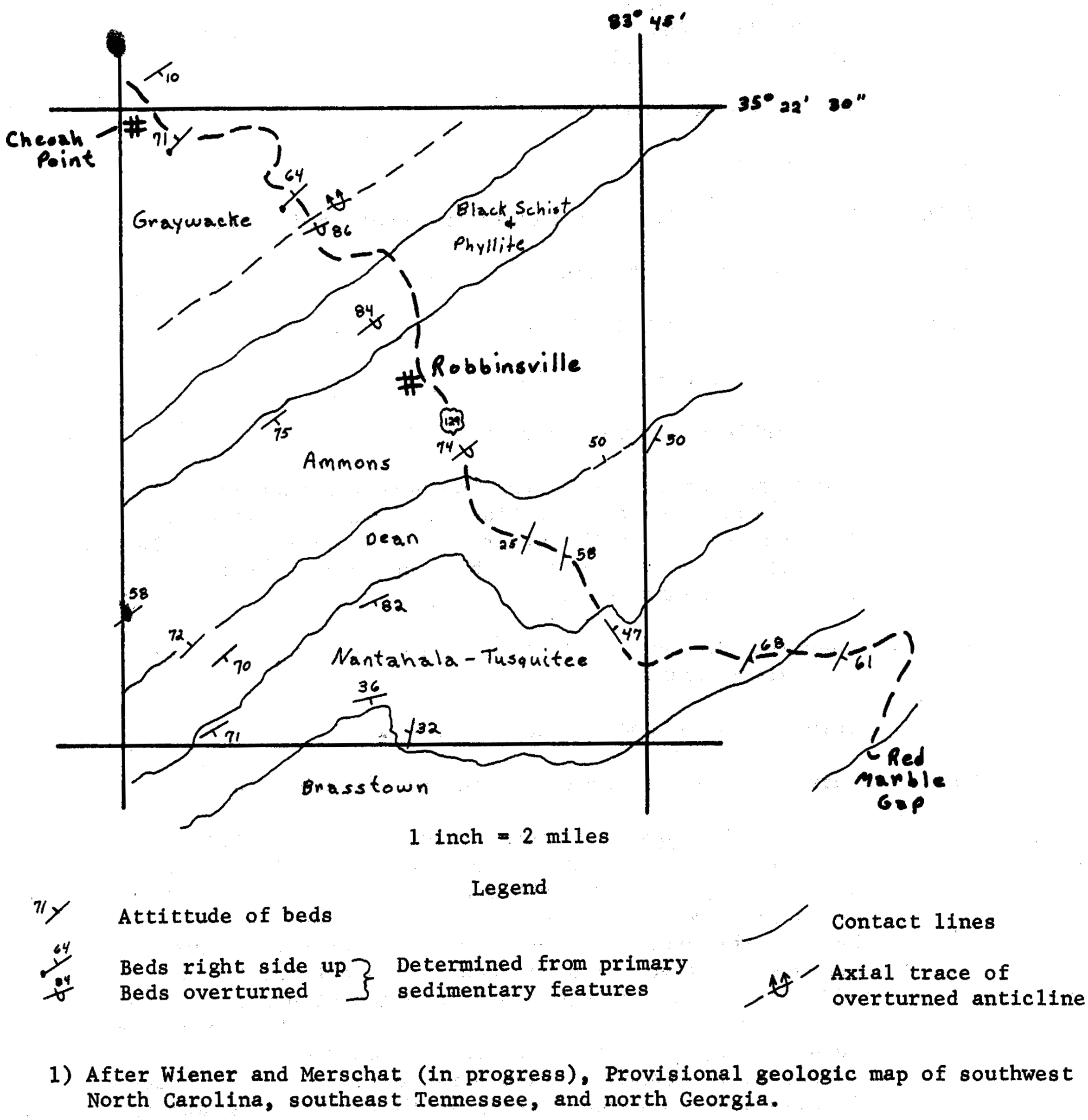


Figure 6. Geological map of the Robbinsville quadrangle and adjoining areas.

63.5 Turn right onto gravel road at boat launching area.

STOP 5 (90 minutes): Cheoah Point Recreation Area, Santeetlah Lake. Prominent exposures in this vicinity are coarse-grained to pebbly metagraywacke of the Great Smoky Group with occasional finer-grained layers. Many of the beds are poorly sorted, matrix-rich, homogeneous, massive units as much as 10 feet thick; in addition, graded beds may be discerned at numerous places in this area. Pebbles, many of which exceed 10 mm in diameter, are prominent with the bulk of the grains in the coarse sand to granule range (1/2 to 4 mm). Modes from 10 samples taken further south in this same strike belt average:

quartz	50%	opague*	1
plagioclase	17 c	carbonate	½
biotite	14	chlorite	½
muscovite	13	epidote, garnet, rutile, zircon	trace
K-spar	4		

*opaques include pyrrhotite, ilmenite, magnetite, graphite

Pebbles are composed of milky, smoky and blue quartz, feldspar, and some intraformational slaty fragments.

Ellipsoidal masses are also present in some of the beds. These are calcareous concretions, evidently formed during diagenesis. Frequently chips of slate are found in their cores. Modes from one concretion in this area are (data by Stephen Kish):

	Central portion	Outer ri
quartz	30%	29%
carbonate	30	22
biotite	12½	20
plagioclase	16	18
white mica	8	5
K-feldspar	3½	6
opaque	trace	–

Regional maps (Carpenter, 1970, p. 751; Hadley and Nelson, 1971) indicate that the Cheoah Point area is underlain by garnet grade rocks; detailed work elsewhere in the Great Smoky Group shows that recrystallization of the calcareous concretions begins to occur midway between the garnet and staurolite isograds. The recrystallized concretions form "pseudodiorite" or calc-silicate granofels, composed mainly of quartz, plagioclase, hornblende, clinozoisite or epidote, garnet, sphene, and traces of other minerals. In practice it is possible to map a "pseudodiorite isograd".

The beds in this area strike about N. 25º E. and dip moderately northwest; graded bedding shows the sequence here to be right-sided up. A pervasive cleavage is the most obvious planar structural element and is oriented about N. 45º E., 70º SE. Parallelism of the secondary mica minerals best defines the foliation. The primary sedimentary concretions are flattened in this plane as are some of the pebbles and granules. However, the coarse grains in other beds are not obviously deformed and still appear to retain their original detrital shapes. This may be due to a cushioning or insulation effect as a result of abundant matrix material in some beds.

Volumetric calculations indicate about 60 percent of the Great Smoky Group as now defined and mapped from the National Park southwestward into Georgia is composed of coarse-grained strata similar to the beds exposed here. Their common occurrence and wide distribution prompted the original grouping under the term "Great Smoky Conglomerate" by Arthur Keith (1904). Mapping and subdivision of the Great Smoky has proceeded sporadically since Keith's early work. The rocks exposed at Cheoah Point are down strike from units correlated with the Thunderhead Sandstone of modern usage (Hadley and Goldsmith, 1963, pl. 1; Mohr, 1975). Merschat and Wiener (1973) however, imply that use of the term Thunderhead outside of the strike belt of its type locality is not at all firmly established and may well be unwarranted, especially in areas such as this where detailed mapping is generally lacking.

Retrace route back to U.S. 129.

64.05 Cheoah Point access road joins S.R. 1146.

64.2 Junction U.S. 129 and S.R. 1146. Turn right only U.S. 129 (towards Robbinsville). Coarse-grained units including some dark, fine-grained beds of the Great Smoky Group are well exposed in extensive road cuts for next 0.3 mile. Dips here are towards northwest; strata are right side up.

65.1 Scenic overlook; view of Santeetlah Lake with the Unicoi Mountains of the Unaka's in the background. This terrain is underlain by Great Smoky Group rocks. Elevation of the lake at full pool is 1,940 feet (591 meters); the peaks range up to nearly 5,500 feet (1,676 meters).

68.1 Santeetlah Lakes Country Club.

68.4 Cross-axial area of a large overturned fold. Axial plane dips steeply to the northwest.

69.8 Bridge over Cheoah River embayment.

69.9 Scattered exposures in this vicinity and for about the next 1.1 miles are mainly dark, fine-grained schist and phyllite with massive metagraywacke interlayers. These rocks are continuous with a similar sequence mapped on the Noland Creek quadrangle and are there correlated with the Anakeesta Formation of the National Park (Mohr, 1975).

71.0 Base of the Ammon Formation, contact not exposed along highway.

71.1 Junction with S.R. 1106, main street of Robbinsville.

71.8 Five Points intersection, Sweetwater Road to north. Well-exposed rock in roadcut is the Ammons Formation; it dips steeply to the northwest but is overturned as indicated by graded bedding.

73.0 Ammons Formation – Dean Formation contact, not exposed along highway.

73.1 Weathered outcrops behind blue corrugated metal building are staurolite mica schist, coarse-grained. This rock type is characteristic of the lowermost beds of the Dean Formation at its contact with the Ammons Formation.

75.3 Exposures of "cross-biotite" schist of the Dean Formation.

76.0 Dean Formation – Nantahala Formation contact, not exposed along highway. This conformable contact marks the top of the Great Smoky Group and the base of the Murphy belt sequence. Several scattered exposures of typical black, sulphidic, metasiltstone and slate of the Nantahala occur along the highway for the next 1.5 miles.

76.7 Leave Robbinsville quadrangle, enter Hewitt quadrangle.

77.6 Nantahala – Tusquitee contact, not exposed along highway

78.5 **OPTIONAL STOP.** Outcrops of Tusquitee Quartzite.

79.0 Tusquitee Quartzite – Brasstown Formation contact, not exposed along highway.

79.1 Entrance to Bear Creek Station on the Graham County Railroad.

81.0 Prominent outcrops of the Brasstown Formation.

81.1 **STOP 6 (20 minutes):** Brasstown Formation and view of the Nantahala Gorge. The Brasstown Formation exposed here is composed of fine-grained brownish-gray schist, which contains thin laminae of metasiltstone. Locally the metasiltstone has a distinct gradation in grain size, possible representing microturbidites. At this outcrop bedding and schistosity (S_1) are subparallel, striking N. 30ºE. and dipping 60 º SE. The intersection of S_0 and S_1 produces a gently plunging, southwest trending lineation. No structures associated with F_2 folding have been observed at this location. A moderate to strongly developed crenulation and slip cleavage (S_3?) strikes east-west and is nearly vertical. The intersection of this s-surface with S_1 produces prominent crenulations, which plunge 40º, N. 80º E. A subhorizontal crenulation cleavage (S_4) and associated open folds intersect with $_3$ to produce culminations and depressions on the S_0-S_1 surface. Two well developed joint sets (N. 25º W, 55º E.; N. 5º E., 70º W.) combined with the schistosity allow large blocks to break off the rock face.

The view from the parking area is quite spectacular on a clear day. The Cheoah Mountains, forming the north rim of the Nantahala Gorge, have a maximum relief of over 3,000 feet (1,000 meters). Briertown Mountain on the south side of the Gorge has a maximum relief of 1,800 feet (590 meters). The Cherokee word Nantahala means “land of the noonday sun” in allusion to the steep (up to 50º) walls of the gorge which cut out the morning and afternoon sun. At this location we are looking at almost a complete cross-section of the main Murphy syncline. The north rim of the gorge is formed by dip slopes of the Nantahala and Brasstown Formations. The Murphy Marble is located on the low slopes on the north side of the gorge. The Nantahala River appears to follow either a fault or a nonresistant lithology located in the hinge zone of the syncline. The south rim of the gorge is located on the opposite limb of the Murphy syncline, and contains overturned beds of the Nantahala Formation. The peaks visible in the distance, south of the gorge, are high peaks of the Nantahala Mountains. Wayah Bald (5,342 ft./1,752 m) and Wine Springs Bald (5,445 ft./1,660 m) are approximately 10 miles (16 kilometers) away.

83.1 Red Marble Gap. Cross railroad bridge and follow U.S. 19 northeast (left). Exposures on the east side of valley are the uppermost beds of the Brasstown; the succeeding Murphy Marble, Andrews Formation, Nottely Quartzite, and Mineral Bluff Formation underlie the gap and west side of the valley.

85.8 Turn right onto S.R. 1310, enter the upper portion of the Nantahala Gorge. This is on the southeastern limb of the Murphy syncline. Overturned beds of metasiltstone of the Nantahala Formation are exposed in ledges on the opposite side of the Nantahala River.

86.1 Overturned beds of the lower portion of the Nantahala Formation.

86.2 Contact between the Nantahala Formation and dark-green schist of the Dean Formation. Approximately 75 to 100 meters of Dean Formation is exposed here. Stratigraphically below the Dean are dark-gray beds of biotite rich metasandstone, probably correlative with the Ammons Formation.

88.4 Large waterfall on opposite side of the river.

89.6 Cross the crest of a major anticlinal fold. Note the nearly horizontal attitude of beds in the river.

89.8 Leave the Nantahala Gorge.

90.3 Turn left onto S.R. 1412.

94.9 **STOP 7 (45 minutes):** Gradational contact between the Dean Formation of the Great Smoky Group and the Nantahala Formation of the Murphy Group. Buses will unload at the Queens Creek dam. We will walk down the Winding Stairs road to observe the lithologies forming the uppermost portion of the Great Smoky Group. The buses will rejoin us at the end of the walk. Distances given below are from the parking area by the dam

0.7 Medium to thick beds of light-gray metasandstone, which is locally a clean metaquartzite. Just past the large curve beds, beds become darker and more micaeous; bedding is thick to massive.

0.2 Dark-green sericite schist containing biotite porphyroblasts which cut across the schistosity.

0.3 Interlayered schist and medium-grained to conglomeratic metasandstone. In the conglomeratic units beneath the powerline graded bedded indicates the beds are overturned to the north. Metasandstone grades upward into a light greenish-gray biotite-garnet-sericite schist. Biotite is present in 1 to 5 millimeter porphyroblasts, garnet is euhedral containing inclusions sub-parallel to the dominant schistosity. Locally, prominent crenulations are produced by the intersection of a widely spaced slip cleavage (S_2) with the dominant schistosity (S_1). In some beds staurolite and kyanite (?) have grown within the slip surfaces producing a pseudocurrent bedding. Thin lenses of calc-silicates are present in both metasandstone and schist.

0.4 More metasandstone with graded bedding. Note the current bedding within schist units.

0.5 Contact between the Dean Formation and the Nantahala Formation. Over a stratigraphic interval of 10 meters, the rocks of the Dean Formation change from a light greenish-gray, laminated and highly micaeous schist into a darker, less micaeous rock containing more quartzofeldspathic interlaminations and appreciable amounts of sulfides. The increasingly dark color is probably due to the presence of graphite. The base of the Nantahala Formation is placed at the highest prominent green schist bed. Biotite porphyroblasts are sparingly present in the lower few meters of the Nantahala Formation.

0.6 Tight to isoclinal folds (interpreted to be F_1) are exposed on fracture surfaces. These folds have a northwest vergence and when viewed from the north they have a counterclockwise sense of rotation. This is consistence with their formation during the development of the main Murphy syncline. At stop 8 we will be on the opposite limb of the syncline. At that location isoclinal folds have a clockwise sense of rotation when viewed from the north. Late stage tectonic features including kink folds (F_4?) with subhorizontal axial surfaces and fault zones with phyllitic gouge are exposed 100 meters downhill. The view to the west is across the Nantahala Gorge towards the Cheoah Mountains. Cheoah Bald (5,062 ft./ 1,543 m) is slightly west of due north. The prominent low ridges across the gorge are supported by units of the Brasstown Formation.

95.5 Reboard buses. Continue down the Winding Stairs. The road passes through a very thick section of the lower Nantahala Formation; probably repeated due to faulting. The upper portion of the Nantahala Formation as well as the Brasstown Formation are absent on this side of the syncline.

97.5 Large landslide is visible across Queens Creek.

97.9 Enter Swain County, cross the Nantahala River.

98.1 Turn right onto U.S. 19.

99.6 Turn left only S.R. 1101.

99.8 **STOP 8 (45 minutes):** Crushed stone quarry in the Murphy Marble operated by the Nantahala Talc and Limestone Company. Unload from buses at the east end of the quarry. This is an active quarry; please do not go near faces or rubble piles which look unstable. The quarry is on a dip slope of the Murphy Marble. At one time this area was actively mined for talc, mainly by underground mining. Several thousand tons of talc have been mined from Talc Mountain, just east of this quarry (Van Horn, 1948, p. 50). Proceed along old road at east end of quarry. Caved-in adits of talc workings are visible uphill.

Along the lower portion of the road are exposures of highly weathered limonitic schist and quartz-rich marble, probably equivalent to the Andrews Formation. Principle lithologies exposed in the old quarry include a black, highly graphitic, laminated marble; white and pink mottled marble; bluish-gray marble; and white dolomitic marble. The marble is interlayered with a dark-gray biotite schist which contains thin metasiltstone layers. A large-scale isoclinal fold (F_1) can be seen high on the southeastern face of the old quarry. Open, concentric folds (F_2) are present in the schist which is interlayered with the marble. Large masses of white to light green tremolite are present in dolomitic layers but usually specimens can only be found in areas of recent quarrying.

100.0 Turn left onto U.S. 19.

114.1 Town square, Bryson City

SUNDAY, NOVEMBER 9, 1975

Transportation for today will be by automobile. Departure time from the Fryemont Inn will be 8:30 a.m. Mileages may change due to road construction.

Mileage

0.0 Town square Bryson City. Head east on U.S. 19.

2.0 Cross Tuckasegee River

2.1 Terrace gravels on the left are resting on saprolite of basement gneiss

2.6 Terrace gravels on left. View across valley to the location of stop 1. Alarka Mountains rise above the valley floor.

3.5 Exposures of augen gneiss on left.

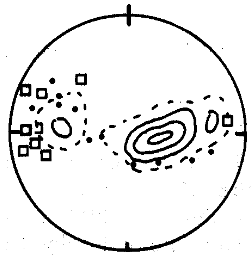
4.1 Ela.

5.1 Turn right on U.S. 19A.

5.5 Enter Whitter quadrangle, leave Bryson City quadrangle.

5.6 Cross from basement gneiss of the Ela dome into

Optional stop (milage 21.6)

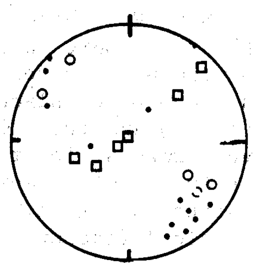


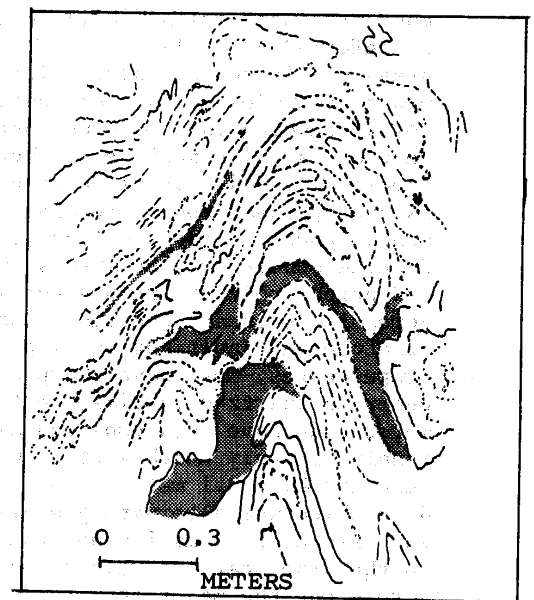
Dots are poles to foliation around a single F_2 fold.

Squares are poles to pegmatite dikes

Poles to foliation are contoured in intervals of 1,5,10,20% per 1% area.

Alternate stop 12.





Fold interference pattern stop 12A.

Dots are poles to foliation.
Open circles are poles to axial surfaces.
Open squares are fold axes.

Figure 7. Structural features of selected field trip stops on Sunday.

metasandstone of the Great Smoky Group.

6.5 Enter Jackson County.

6.9 Whitter.

7.1 Exposures of overturned beds of metasandstone.

7.4 **STOP 9 (20 minutes):** Greenbrier fault zone. If the shoulder on the right side of the highway is too soft for parking we will park on old U.S. 19A at the northwest end of the roadcuts. The Greenbrier fault exposed here is located along the west margin of the Straight Fork window. The main portion of the window was produced by folding of the Greenbrier fault by the F_2 Ravensford anticline. At this location other folds, particularly the Cataloochee anticline, were also involved in folding of the fault.

Do the rocks in this outcrop look familiar? At the eastern end of the rock cuts a coarse-grained augen gneiss, similar in lithology to the Bryson Gneiss, grades into a fine-grained well-foliated gneiss which has a banded appearance. Microcline is present as small (1-10 mm) augen composed of numerous subgrains. Quartz and plagioclase are present in lens shaped masses 0.1 to 1.0 millimeters in length. These lenses contain aggregate subgrains less than 0.05 millimeters in length. The banding or foliation, apparently mylonitic in nature, is oriented N. 35º E., 50º SE. The foliation is deformed by relatively open folds having axial planes oriented N. 45º E., 60º SE. The asymmetry of these folds indicate we are located on the west limb of an overturned antiformal structure, probably the Ravensford or Cataloochee anticline. West of the banded gneiss a biotite-plagioclase gneiss is present. This gneiss is similar in composition to the paragneiss of the stop 1, however, the prominent layering is not present. The small- to medium-size (1-10 mm) augen which are present are polymineralic, being composed of plagioclase, quartz, epidote, and minor potassium feldspar. If layering was originally present, it probably was destroyed by extension and boundinage of individual layers. The fine-grained biotite groundmass contains thin bands of polygonized quartz, typical of fluxion structure in mylonites. This rock could probably be classified as a protomylonite or mylonite.

Thin beds of muscovite-biotite metasandstone and schist of the Great Smoky Group are exposed in the road cut and drainage channel in the next hill to the west.

8.5 Detour (0.8 mile).

9.3 Resume route on U.S. 19A-23.

10.2 Exposure on layered gneiss on left. Prominent folds are probably associated with the Cataloochee anticline.

10.6 Cross Greenbrier fault on the east limb of the Cataloochee anticline.

10.8 **STOP 10 (20 minutes):** Lower portion of the Great Smoky Group. Pull off on the right-hand side of the road. We are near the base of the Great Smoky Group; units of the Snowbird Group are exposed just to the north. Dominant lithologies here include clean to moderately feldspathic metasandstone containing calc-silicate layers and coarse-grained kyanite-graphite muscovite schist. Conglomeratic units are rare. A large, relatively tight concentric fold, with parasitic folds on both its limbs is present in the mica schist. The fold asymmetry indicates we are on the east limb of an antiformal structure. Where the schist is crinkled by F_2 folds, kyanite blades are kinked and warped around crinkle hinges. A later subhorizontal foliation is also present in this exposure.

11.0 Wilmont.

11.6 Exposures of medium- to fine-grained metasandstone and biotite schist.

14.9 Exposures of graphitic and sulfidic muscovite schist.

15.8 Cross from the Great Smoky Group into layered gneiss of the basement. The nature of the basement contact at this location is uncertain. Hadley and Nelson (1971) mapped the contact as an unconformity. If this is the case, the Greenbrier fault must now be located within the basement rocks, rather than following the Great Smoky Group as a zone of detachment.

16.0 Outcrops on right of highly deformed layered gneiss.

17.4 Layered gneiss on left.

20.3 View of the Plott Balsam Mountains. The valley is underlain by layered gneiss; the high peaks, Yellow Face (6,032 ft./1,838 m) and Waterrock Knob (6,292 ft./1,918 m) are upheld by metasandstone of the Great Smoky Group. The relief between this valley and ridgeline is over 4,000 feet (1,219 meters).

21.6 **OPTIONAL STOP (35 minutes):** Layered gneiss, multiply folded and faulted, cut by multiple igneous intrusions. Park on right side of road.

This gneiss is similar to the paragneiss of stop 1. The most prominent foliation is gneissic layering. This layering is deformed by small (0.1 to 0.5 meter) isoclinal folds. In areas unaffected by later folding, these folds plunge at moderate angles to the northeast. Large (5-10 meters) open folds trending in a more northerly direction and having nearly vertical axial planes deform both the gneissic layering and isoclinal folds. At the east end of this exposure the gneiss is cut by shear zones trending N. 40º E., 83º SE. These zones appear to have been active while the rocks were in a ductile condition, the shears are accompanied by drag folds and porphyroblasts are present within the zone of displacement. Some of the shears contain veins and pods of pegmatite. Other fracture and fault surface appear to have formed at lower temperatures, most have sharp contacts at the fracture surface. Numerous quartz-oligoclase-perthite pegmatites 0.1 to 1.0 meter wide have been emplaced along subvertical fractures running roughly north-south. One of these pegmatites is in turn cut by a 0.1-meter wide, fine-grain trondhjemite dike which was alternately emplaced along gneissic layering and fractures. Small xenoliths of biotite gneiss are visible in the dike near its western edge. The dike can be traced across one of the major open folds without any major deflection.

22.6 **STOP 11(30 minutes):** Webster-Addie ultramafic body. Park on the right side of the road, be careful of soft shoulder. The Webster-Addie body is one of the largest ultramafic bodies in the eastern United States. It is exposed as an elliptical-shaped ring having a long axis of 6 miles and a short axis of 3.5 miles (9.7 by 5.6 kilometers), with an outcrop width ranging from 50 to 1,500 feet (15 to 450 meters). Due to this elliptical shape, the Webster-Addie body has been frequently called a "ring-dike" (Hunter, 1941, p. 82), however, this term is a misnomer; the body is generally concordant with the surrounding gneiss. The body is actually a sill-like intrusion which has been deformed into an antiform or dome. Similar structural relationships are present in the Lake Chatuge ultramafic body of north Georgia (Hartley and Penley, 1974).

This outcrop is located on the northeast portion of the Webster-Addie body. The dominant lithology is greenish-brown medium-grained dunite. The dunite is slightly serpentinized, serpentine and brownish brucite form thin layers around individual olivine grains. The prominent laminations in the dunite may be related to original igneous layering (note the parallel chromite-rich bands) but they are probably partly tectonic in nature. In the road cut along S.R. 1709 these lamination are deformed by small folds. The dunite is cut by prominent veins of alteration products which run parallel and across laminations. Alteration products include serpentine, talc, anthophyllite-cummingtonite, and clinochlore. On the north side of U.S. 19A-23 the dunite is intruded by a 10-meter wide pegmatite. A few weathered dunite xenoliths in the pegmatite (please leave intact) contain biotite and a bright emerald-green hornblende (edenite or pargasite).

23.3 S.R. 1456 on left leads 0.5 miles downhill to the Harbison-Walker Refractory Company quarry in altered dunite.

23.8 Massive amphibolite.

24.7 Enter Hazelwood quadrangle and leave Sylva North quadrangle.

25.2 Massive amphibolite and layered biotite-hornblende gneiss, complexly folded and intruded by small veins of pegmatite-like quartz and plagioclase.

27.4 Balsam Gap dunite deposit is to the left on Judaculla Mountain.

27.8 Large landslide on left.

28.0 View of Steestachee Bald (5,640 ft./1,603 m) upheld by muscovite metasandstone and garnet mica schist.

28.8 Balsam Gap, elevation 3,360 feet (1,024 meters), enter Haywood County. Large landslide on left.

29.1 Turn left onto the entrance road to the Blue Ridge Parkway. If the Parkway is closed we will proceed on U.S. 19A-23 to an alternate stop.

29.6 Turn left onto the Blue Ridge Parkway.

30.0 Balsam Gap overpass.

31.6 Standing Rock Overlook (elev. here 3,715 ft./1,312 m). Exposure of layered biotite-plagioclase gneiss. Standing rock is at the base of a large debris slide. Plott Balsams are visible across the valley.

32.1 View of Waynesville (elev. here 4,110 ft./1,253 m). The layered gneiss, exposed on right, strikes N. 30º E. and dips 80º NW.

32.7 Approximate contact between layered gneiss and overlying metasandstone and schist.

32.9 View of the Village of Saunook (4,375 ft./1,334 m). Gently dipping garnet mica schist is exposed on the right.

33.1 Enter tunnel.

33.3 Exit tunnel.

34.6 **STOP 12:** Cove Field Overlook (4,620 ft./1,408 m). Exposures of unnamed metasandstone and schist intruded by trondhjemite dikes and sills. The metasandstone exposed here has lost most of its sedimentary aspects. The thin, 1 to 10 millimeter layers of mica and quartz-feldspar are probably due to metamorphic segregation and tectonic transposition. The 0.1 to 2.0 meter layering, calc-silicate layers, and porphyroclasts (pebbles in a graded bed?) are probably remnants of original sedimentary features. The composition of the metasandstone is similar to a quartz-rich graywacke (see Table 3). Calc-silicate layers are very abundant in the metasandstone; thin discontinuous layers of amphibolite are locally present. Large elliptical calc-silicate masses are best exposed near the portal of the tunnel below the parking area. Garnet-mica schist is present in separate layers ranging from 0.5 to 10 meters thick. In some layers large (3-8 mm), euhedral garnets make up to 40 percent of the rock. Sillimanite is present in minor amounts as small, fibrous bundles.

The stratigraphic position of these rocks is uncertain. In both their mineralogy and relative stratigraphic position - directly above basement gneisses, these rocks are very similar to the Great Smoky Group exposed in the Plott Balsams, only 5 kilometers away. However, Hadley and Nelson (1971) placed these units (labeled mica schist and gneiss on the Knoxville quadrangle) unconformably beneath the Great Smoky Group and unconformably above Grenville age gneisses. Hatcher (1974, p. 12), working with rocks of

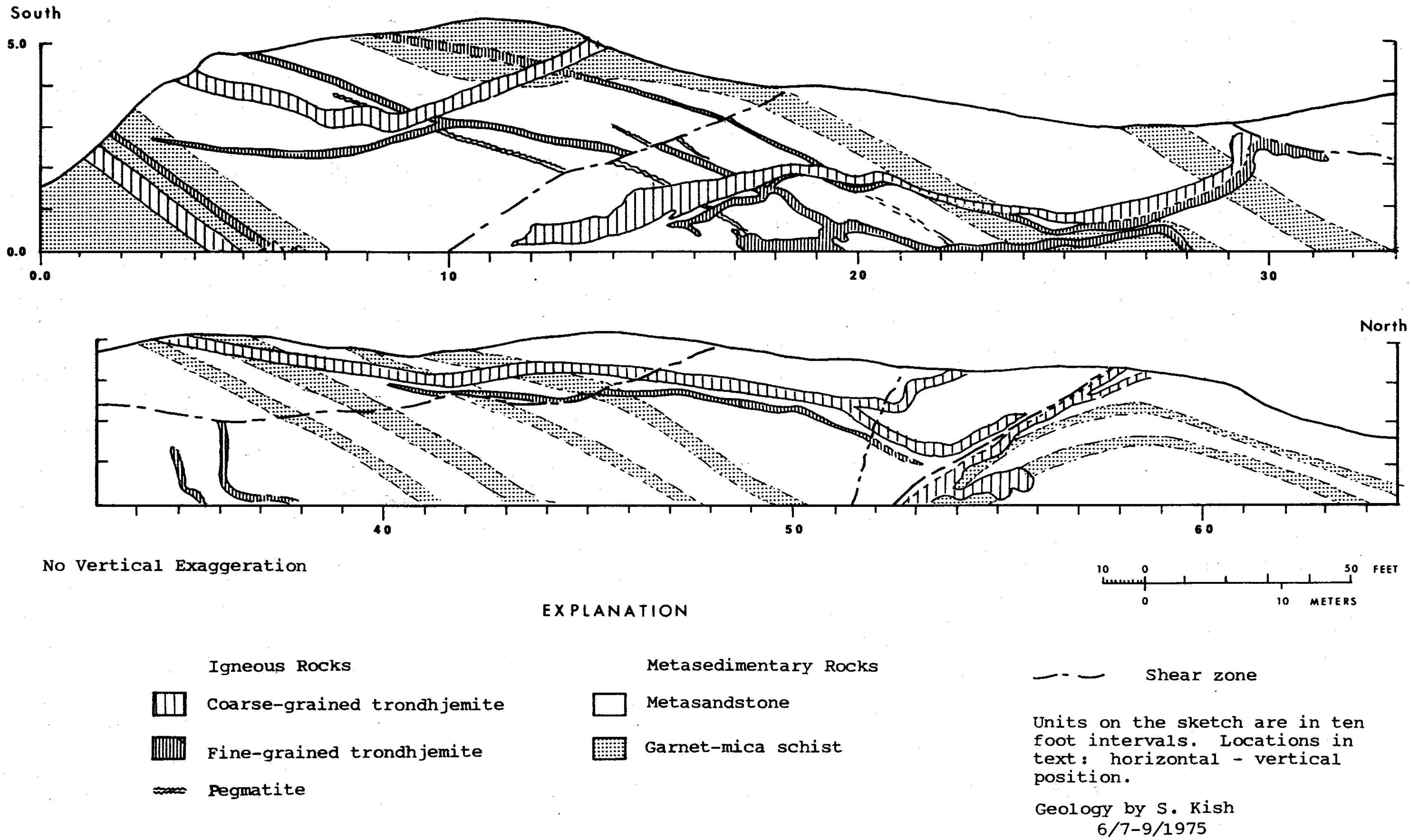


Figure 8. Geologic sketch of the outcrop at stop 12.

similar aspect along strike in north Georgia, placed his units high in the stratigraphic section (above the Tullulah Falls Formation) and assigned them the informal name Coweeta Group. Rankin (1975, p. 314) correlated these unnamed unites with the Ashe Formation of northwestern North Carolina. Additional work in intervening areas is needed before any firm correlation can be established.

Numerous light gray trondhjemite (leucocratic tonalite) dikes are sills, 0.2 to 2.0 meters wide, cut the metasediments (see
8). These intrusive rocks are composed almost entirely of quartz and oligoclase with minor biotite and muscovite (see Table 3). The trondhjemite is present in two distinct grain sizes. A fine-grained variety contains 1 to 3 millimeter, zoned plagioclase phenocrysts. The coarser variety (1-3 mm grains) is composed of roughly equidimensional quartz and plagioclase plus slightly larger plagioclase phenocrysts. Neither variety appears to have chill margins; however, the fine-grained dikes contain parallel bands of slightly coarser material (location 12.8–0.2, figure 8) probably due to multiple intrusions along a single fracture. Contact relationships, although not always clear, suggest the coarser-grained dikes and sills cut the finer-grained bodies. Both textural evidence and contact relationships suggest the dikes and sills were derived from a magma body crystallizing a depth, with the first intrusions being mostly melt plus a few phenocrysts. Crystallization continued in the main magma body, later intrusions contained proportionally less melt and more coarse-grained crystals. The trondhjemite bodies are generally concordant with the layering in metasediments but dikes are present. Most bodies are relatively unmetamorphosed but most contain a faint foliation and a distinct lineation formed by the parallel orientation of biotite grains. At location 10.5-2.05 (figure 8) a trondhjemite sill and adjacent pegmatite layers appear to be displaced along a small fault. At locations 26.0-2.50 and 50.0-2.00 (figure 8) sills are either deformed adjacent to shear zones or were intruded along the surfaces of displacement. At an outcrop 500 meters to the southeast, a trondhjemite body forms a phacolith-like intrusion in the crest of a tight F_2 (?) fold.

This is the end of the formal field trip. Persons returning to Tennessee and eastern North and South Carolina should return to U.S. 19A and drive east to Waynesville to reach I-40. Persons wishing to return to Georgia should return to Sylva and take U.S. 441.

Route to Alternate Stop 12.

Mileage

29.1 Continue east on U.S. 19A-23.

30.2 Exposures of layered biotite-plagioclase gneiss.

32.3 Exposures of sulfidic muscovite schist on left. This may be a down-faulted sequence of lower Great Smoky Group. Muscovite schist is exposed in the road cuts for the next 0.5 mile.

33.3 Large, 3-meter wide granodiorite dike cutting layered gneiss. The margins of the dike are finer-grained and more leucocratic.

33.7 View of Eaglenest Mountain on left (4,942 ft./1,506 m). The top of the ridge is upheld by metasandstone of the Great Smoky Group.

35.8 Turn right onto U.S. 276 N.

37.4 Turn right onto U.S. 19-23.

37.5 **ALTERNATE STOP 12:** Migmatitic gneis deformed by polyphase folding. Turn left and park across the road at the Lake Junaluska Assembly; limited parking is available at the east end of the outcrop adjacent to the Lake Junaluska golf course. Please be careful when crossing the highway!

The gneiss exposed here is composed of 1 to 5 centimeter bands of quartz-plagioclase and biotite. Small plagioclase porphyroblasts are abundant. The most striking feature of this outcrop is the tight, nearly isoclinal folds, which are pervasive on all exposed surfaces. Locally, small tectonic discontinuities separated the limb of one fold from another. These folds are refolded by somewhat more open folds which trend approximately N. 40º E. The interference pattern formed by these folds has the appearance of a flopped over mushroom. This pattern is also visible on the macroscopic scale in the Dellwood area. An excellent exposure of this interference pattern is located at the west end of the outcrop, about 8 meters above the highway. The second fold generation present here is probably equivalent to the open folds at the optional stop of this morning. Does anyone care to find evidence of Precambrian folding?

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