CAROLINA GEOLOGICAL SOCIETY
FIELD TRIP GUIDEBOOK

SEPTEMBER 29-30, 1990

GEOLOGY OF GRENVILLE-AGE BASEMENT AND YOUNGER COVER ROCKS IN THE WEST CENTRAL BLUE RIDGE, NORTH CAROLINA

BY

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GEOLOGY OF GRENVILLE-AGE BASEMENT AND YOUNGER COVER ROCKS IN THE WEST CENTRAL BLUE RIDGE, NORTH CAROLINA

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INTRODUCTION

The region to be traversed during the 1990 Carolina Geological Society field trip is centrally located in the widest part of the Blue Ridge Province. The trip will focus on result from our geological mapping in the core of the province north and west of Asheville, North Carolina. Here, one may examine some of the region's oldest rocks and their relationships to the younger, flanking cover rocks. The field trip stops are selected to show: 1) the variable character of the high metamorphic grade, Grenville-age basement rocks; 2) relations at the faulted and folded basement-cover contact; and 3) the contrasting effects of Barrovian Paleozoic metamorphism on the basement and cover.

Most of the stops are at exposures north of Asheville in the Mars Hill and Barnardsville 7.5-minute Quadrangles and west of Asheville on the Sandymush, Canton, and Clyde 7.5-minute Quadrangles, where we have mapped in detail for a number of years. These two areas lie along strike and are separated by about twenty miles. In the following discussion we refer to the Mars Hill-Barnardsville region as the northern map area, and the Sandymush-Canton-Clyde region as the southern map area. There are many similarities between the rocks and geological relations from one region to the other, but there are also significant differences. We will elaborate on some of these as the trip progresses.

Our approach to Blue Ridge geology is that of the field mapper. We have recorded many outcrops on our field sheets while making cross-country traverses. We have some thin section control, but have not done intensive meso- or micro-scale structural studies. There are almost no geochemical studies covering the rocks in these quadrangles and within the area the age of only two map units has been determined by radiometric methods.

Other geologists have mapped in this region. The work of our predecessors provides a base to build upon or perhaps modify and that of our contemporaries provides new geologic maps and data to cross-check our work. All of this will be integrated by our successors into a more comprehensive picture. Listed in table 1 are the primary geologic maps and associated reports for the region along with a brief summary of important results of each study.

PHYSIOGRAPHIC SETTING

The mountainous area of western North Carolina and adjacent eastern Tennessee is part of the Blue Ridge physiographic province, a major geographic entity that extends for nearly 600 miles from southern Pennsylvania into Georgia. The width of the province in this vicinity is about 75 miles. The northwestern border virtually coincides with the westernmost sandstone and shale outcrops of the Chilhowee Group and Sandsuck Formation in eastern Tennessee and Virginia. The southeastern border with the Piedmont is at the base of the Blue Ridge Front, an erosional escarpment.

Hack (1982) presented a comprehensive geomorphic analysis of the Blue Ridge. Following the traditional pattern (Fenneman, 1938), Hack divides the area into a northern and a southern section. Hack's Southern Blue Ridge Province extends from the Roanoke River in Virginia south-westward to Pine Log Mountain near Cartersville in north Georgia. He further subdivides the Southern Blue Ridge Province into topographic subunits. Several subdivisions cover the area of the field trip. They are the southern Blue Ridge Highlands, the Asheville Basin, and the Waynesville- Canton Basin.

Lower, much more subdued landscapes characterize intermontane basins such as the Asheville Basin and the Waynesville-Canton Basin. Concordant elevations of low knobs and ridges and broad interfluves within these areas may mark old erosional levels. A distinctive soil, classified as Braddock by area soil scientists, is sometimes found at these places. Braddock soil develops on transported material rather than residual material. It is distinguished by a high sticky clay content, especially pronounced deep red color, and rounded quartz pebbles and cobbles in discrete layers. These features all suggest that Braddock soils are relic, very old, and deeply weathered fluvial deposits that originally were deposited on extensive, low-relief surfaces. Some of these deposits may be Tertiary in age, perhaps Miocene or possibly even much older.

The Asheville Basin, encompassing roughly 400 square miles, is the largest intermontane basin and is drained by the through-going French Broad River and its many tributaries. The basin, although well defined by contour levels between 2,300 to 2,400 feet, has a jagged, irregular border, because the basing floor protrudes far into many small tributary valleys and intervening ridges from the adjacent highlands extend some distance into the basin. Downstream from Asheville the French Broad River has become entrenched and is dissecting the old basin floor. Where it leaves the basin northwest of Marshall, the river and its tributaries are 400 to 500 feet below the remnants of the Asheville surface.

The smaller Waynesville-Canton Basin is drained prin-

Table 1. Primary geologic maps and associated reports covering field trip area.

Map and scale	Author and date	Important contribution
Asheville 30-minute Quadrangle, 1:125,000	Keith, 1904	Major pioneer geologist in area. Classic comprehensive maps and reports present an all-inclusive stratigraphic scheme and nomenclature. Discussion includes geologic structures and deformational features, describes physiography and geomorphic history, systematic descriptions of rock and mineral resources, as well as short discussions about water power and timber resources of the region.
Hot Springs area, 1:24,000	Oriel, 1950	Stratigraphy of the Paleozoic rocks and structure of the Hot Springs window. Includes description and geologic relations of the barite deposits, and of the older rocks rimming the window.
Eastern Great Smoky Mountains, 1:24,000 and 1:62,500	Hadley and Goldsmith, 1963	Through geologic map of the eastern Great Smoky Mountains region. Comprehensive descriptions of the Great Smoky and Snowbird Groups as well as the basement rocks. Structural features, both detailed and regional, are analyzed. Regional Barrovian metamorphism is carefully described and the temporal relation between metamorphism and deformation is discussed. Surficial deposits are briefly described.
North Carolina-Tennessee Blue Ridge 1:2,000,000 (approx.)	Carpenter, 1970	Presents regional map showing Paleozoic metamorphic isograds. Discusses relations between metamorphism, time of deformation, and region's intrusive rocks.
Leicester Quadrangle 1:24,000	Wiener, unpublished mapping	Preliminary map shows numerous lithologic basement units. Basement-Ashe boundary depicted; several trondhjemite bodies mapped.
Knoxville 1° x 2° Quadrangle, 1:250,000 and 1:1,000,000 (approx.)	Hadley and Nelson, 1971	Regional map based on compilation and rapid reconnaissance. Clearly distinguishes Middle Proterozoic basement from overlying cover sequences. Presents regional cross sections; shows isograd pattern and distribution of trondhjemite and Bakersville Metagabbro intrusives.
Mars Hill Quadrangle 1:24,000	Merschat, 1977	Mapped detailed subdivisions of the Middle Proterozoic basement rocks; mapped basement-cover contact. Identified granulite mineral assemblages in older rock units. Briefly summarized and tabulated area's mineral resources.
Mars Hill area	Kuchenbuch, 1979	Petrographic study confirmed presence of granulite-grade rocks and helped decipher complex mafic areas in Mars Hill area.
Mars Hill area	Fullagar and others, 1979	Presented Rb/Sr data which established Middle Proterozoic age of several basement units in Mars Hill area.
Barnardsville Quadrangle 1:24,000	Merschat, in preparation	Detailed map with lithologic subdivisions of basement rocks; folded trace of the Holland Mountain thrust fault shown on map; seven subunits of the Ashe Metamorphic Suite are distinguished. Includes metamorphic map showing distribution of Proterozoic and Paleozoic indicator minerals. Mineral resources summarized.
State Geologic Map 1:500,000 and 1:2,500,000	North Carolina Geological Survey, 1985	Regional compilation and reconnaissance map. Divides Proterozoic basement into three regionally extensive units. Ashe Metamorphic Suite nomenclature extended southwestward into central Blue Ridge area. Regional Paleozoic isograds and areas of Proterozoic granulite-facies metamorphism shown on small-scale auxiliary map.
Marshall area 1:24,000	Brewer, 1986	Mapped and described basement subunits. Presented an analysis of the Proterozoic deformational and metamorphic sequence.
Sandymush and Canton Quadrangles 1:24,000	Merschat and Wiener, 1988	Described and formalized several Middle Proterozoic basement units and mapped two lithologic divisions of the Ashe Metamorphic Suite. Mapped and named the Holland Mountain thrust fault, and mapped the kyanite-sillimanite isograd. Text discusses local effects of Proterozoic and Paleozoic metamorphism; mineral resources are inventoried.
Clyde Quadrangle 1:24,000	Merschat and Wiener, in progress	Proterozoic basement units being mapped. Cover sequences include Great Smoky Group and Ashe Metamorphic Suite. Kyanite-sillimanite isograd being closely located; search for Proterozoic metamorphic indicator minerals continuing.

cipally by the Pigeon River and its tributaries. This basin is defined by the 2,800- to 2,900-foot contour level and is being dissected. The peaks of low knobs as well as small, relatively flat areas away from the main stream still preserve the 2,800 to 2,900-foot level of the basin floor.

STRUCTURAL SETTING

The outcrop area of the Blue Ridge belt (King, 1955), or lithotectonic province, corresponds closely with the physiographic province of the same name. In North Carolina, the belt's south-eastern boundary is the Brevard fault zone. Rocks in the Brevard zone are characteristically mylonitic and record a sequence of dislocations including thrust faulting and strike-slip or oblique-slip movement (Edelman and others, 1987). At many places a steep-dipping, alter Paleozoic, brittle-style fault (i.e. the Rosman fault of Horton, 1982) sharply marks the change from rocks of the Blue Ridge belt to rocks of the Brevard zone and Chauga belt.

To the northwest, the Great Smoky thrust fault, a late Paleozoic structure, separates the Blue Ridge belt from the Valley and Ridge belt. The subsurface boundary of the Blue Ridge is the Great Smoky fault, or other closely related thrusts and decollements at relatively modest depth. Seismic data suggests the Blue Ridge is generally from three to six kilometers in thickness (Harris and others, 1981; Hatcher and others 1987).

Because the Blue Ridge generally has a central core of old basement rocks flanked to the northwest and southeast by younger cover rocks, the overall regional structure may be likened to an anticlinorium. However, in western North Carolina many of the contacts separating the major lithologic sequences are thrust faults and the regional structure is now commonly thought of in terms of stacked imbricate thrust sheets, or perhaps nested thrust sheets.

ROCK UNITS

Most rocks in the Blue Ridge belt are metamorphosed. They range from virtually unmetamorphosed sandstones and shales of the Lower Cambrian Chilhowee Group along the northwest margin of the belt through Proterozoic high-grade migmatitic and granulitic rocks that crop out at many places in the core of the Blue Ridge. The 1985 Geologic Map of North Carolina (North Carolina Geological Survey, 1985) groups Blue Ridge rocks into several large comprehensive map units. Nearly all the smaller, are really limited and restrictively defined lithologic units encountered in our detailed quadrangle mapping are readily placed into the State map stratigraphic scheme. The following rock descriptions are organized to follow the State map system and nomenclature (table 2).

A few Early Proterozoic dates have been obtained from rocks in the Blue Ridge belt. For example, in central Virginia, zircon grains from the Lovingston massif yield a 1,870 Ma (Sinha and Bartholomew, 1984), and whole-rock rubidium/strontium analysis provides a 1,815 Ma for granulite rocks on Roan Mountain, North Carolina (Monrad and Gulley, 1983). The geologic significance of these dates is not yet fully known; however, Early Proterozoic rocks and minerals must have been sources of precursors for subsequent rock units.

In the central part of western North Carolina, the oldest rocks of the Blue Ridge belt are Middle Proterozoic, massive to layered biotite-hornblende gneiss, biotite gneiss, biotite granitic gneiss, and granodioritic gneiss. Many have a plutonic or intrusive origin, but there is also certainly a sedimentary component as shown by rare, scattered exposure of marble. There is possibly an extrusive and volcano-clastic component as well. These basement rocks were metamorphosed in Proterozoic time, locally attaining granulite facies. Radiometric dates cluster at 1.2 billion years, but it is not entirely clear if the dates record the time of magmatic crystallization or the time of high-grade metamorphic homogenization and recrystallization. Subdividing these rocks into practicable map units is a major ongoing phase of our (and others') fieldwork.

Intrusive into the complex of gneisses are more massive plutonic rocks which are mostly granitic to granodioritic in composition. Additionally, some small gabbroic masses and dikes intrude the gneiss complex. In the central Blue Ridge these intrusive include the Max Patch Granite and the Bakersville Metagabbro. The age of the Bakersville Metagabbro is 734 Ma (Goldberg and others, 1986). Other local units are not yet dated, but must also be Proterozoic in age.

The Middle and Late Proterozoic basement rocks exhibit a mylonitic fabric at many places. Similar, widespread mylonitization is present in coeval units elsewhere in the North Carolina Blue Ridge belt. For example, in the Sherwood and Baldwin Gap Quadrangles (Bartholomew and Gryta, 1980; Bartholomew, 1983, respectively), Bartholomew divides each of several different plutonic bodies into a massive facies and a mylonitic facies. Each facies covers a broad, extensive area. Similarly, in the west central Blue Ridge, mylonitic rocks are not necessarily restricted to narrow linear zones, but are also present throughout large areas. Thus, in most cases it is incorrect, or at least a gross oversimplification to relate isolated or selected outcrops of mylonite in these basement rocks to single narrow faults or fault zones.

Throughout the Blue Ridge belt several different cover sequences succeed the Middle to Late Proterozoic basement rocks. In the field trip area two cover sequences are represented: the Ocoee Supergroup and the Ahse Metamorphic Suite. The Ocoee clearly has a sedimentary origin. The two constituent groups exposed in our southern map area, the Snowbird Group and the Great Smoky Group, are very Late Proterozoic in age. Field work by Hadley and Goldsmith

Table 2. Map units of the west central Blue Ridge belt.

	State geologic map	**Map area**
Paleozoic	Pegmatites	Pegmatites (most stops) (Intrusive)
	Trondhjemites	Trondhjemites (Stops 4,9) (Intrusive)
Late Proterozoic	Ocoee Supergroup	Ocoee Supergroup (Cover Rock)
	Great Smoky Group (Zgs)	Great Smoky Group (Stop 12)
	Snowbird Group (Zs)	Snowbird Group
	Ashe Metamorphic Suite	Ashe Metamorphic Suite (Cover Rock)
	Muscovite-biotite gneiss (Zatm)	Informal lithologic units (Stops 1,4,9)
	-Unconformity-	-Holland Mountain fault- (Stops 4,9)
	Bakersville Metagabbro	Bakersville Metagabbro (Stop 2b (?), 5) (Intrusive)
	Metaultramafic rock (PzZu)	Dunite (Mile 37.8) (Intrusive)
Middle Proterozoic	Biotite granitic gneiss (Ybgg)	Sandymush Felsic Gneiss and (Stops 2a, 2b, numerous informal rock units 7,11) (Basement)
	Biotite gneiss (Zybn)	Earlies Gap Biotite Gneiss, (Stops 8,9,10,13) (Basement) Richard Russell Formation and numerous informal units (Basement)
	Migmatitic hornblende-biotite gneiss (Ymg)	Numerous informal units (Stops 4,5,6) (Basement)

(1963) in the nearby Great Smoky Mountains National Park area convincingly shows that at some places the Ocoee overlies the basement rocks along a major unconformity. The Ashe Metamorphic Suite is usually described as a metasedimentary unit with variably abundant, concordant amphibloites which represent metamorphosed basaltic rock (Rankin and others, 1973; Abbott and Raymond, 1984; Gair and Slack, 1984). We generally agree but also suggest that a significant portion of the felsic layers within the Ashe may have originated as andesitic to rhyolitic pyroclastic material. Where we are familiar with the Ashe Metamorphic Suite, it is always in fault contact with the basement rocks and it is basal contact relations and depositional setting must be inferred.

Other notable rock units in the map area include altered to unaltered ultramafic rock, trondhjemite dikes and sills, and very coarse-grained granitoid rock (pegmatite). The age and mode of emplacement of the ultramafic rocks have been widely debated over the years. Aside from accurately plotting locations of known bodies and many previously unrecorded ones, we have little new data to contribute to this continuing debate.

The Trondhjemite intrusions (felsic, potash-poor, soda-rich intrusive igneous bodies) are widely distributed, both in the basement and in the Ashe. The largest bodies, originally noted by Keith (1904), crop out a few miles northwest of Asheville. Elsewhere, trondhjemite occurs as post-metamorphic, crosscutting dikes and sills rarely more than ten feet thick.

Most of the hundreds of pegmatites in our map area are relatively small bodies. Only a few dozen are sufficiently large to have been mined or seriously prospected. Silurian to Devonian ages (435-390 Ma; Kish, 1983) are generally ascribed to the pegmatites. Many of the small bodies, however, appear to be related to Ordovician or even Proterozoic migmatization processes.

Migmatitic Biotite-Hornblende Gneiss

Migmatitic biotite-hornblende gneiss is a heterogeneous unit of the State Geologic Map (North Carolina Geological Survey, 1985). It is exposed for about 50 miles from northwest of Asheville to the area north of Roan Mountain. Along strike to the southwest, somewhat similar rocks are assigned to the State map's Biotite gneiss unit. If grouped with the

Migmatitic biotite-hornblende gneiss unit as proposed by Raymond and others (1989), the extent of the combined unit in North Carolina is about 125 miles.

Keith (1903, 1904, 1907a) did not distinguish the Migmatitic biotite-hornblende gneiss in his original mapping, but distributed the component rocks into parts of the Cranberry Granite, Roan Gneiss, and Carolina Gneiss. The terms Roan Gneiss and Carolina Gneiss are abandoned and the Cranberry Granite has been restricted and redefined. Hadley and Nelson (1971) included rocks of the Migmatitic biotite-horneblend gneiss in their larger Layered gneiss in their larger Layered gneiss and migmatite unit. Merschat (1977) first described and defined the Migmatitic-biotite-hornblende gneiss as it was later used on the 1985 State Geologic Map. Brewer (1986) mapped this same unit and informally called it the Amphibolitic basement complex. Merschat and Wiener (1988) extended the unit southwestward, and near Canton, North Carolina, subdivided it into two formal units, the Earlies Gap Biotite Gneiss and the Sandymush Felsic Gneiss. Raymond and others (1989) refer to this inclusive belt of rocks exposed from Georgia to the Roan Mountain area as the Cullowhee terrane and suggest that it may be an melange belt.

The Migmatitic biotite hornblende gneiss consists of layered mafic and felsic rocks interlayered and gradational at all scales. Thicknesses of the component rock types range from inches to mappable units of a thousand feet or more. The rocks have a low quartz content and contain almost no muscovite, kyanite, or sillimanite. They exhibit a nematoblastic to granoblastic to lepidoblastic texture. At least some parts of the unit were metamorphosed at granulite-facies conditions during the Proterozoic (Merschat, 1977; Kuchenbuch, 1979; Gulley, 1982; Monrad and Gulley, 1983; Gulley, 1985). Subsequently, the granulite rocks were variably retrograded by Taconic metamorphism (Gulley, 1985; Merschat and Wiener, 1988).

Included in the Migmatitic biotite-hornblende gneiss unit are layers and masses of diverse rock types including biotite granitic gneiss, amphibolite, calc-silicate granofels, rare marble, biotite gneiss, biotite-hornblende gneiss, hypersthene granitic gneiss, pyroxene granulite, hypersthene-plagioclase rock, and others (Merschat, 1977; Gulley, 1982; Brewer, 1986). In addition, areas of migmatization are locally common (Merschat, 1977; Brewer, 1986).

Amphibolite occurs as discontinuous layers, lenses, and pods throughout the Migmatitic biotite-hornblende gneiss unit. The amphibolite masses range in thickness from inches to tens or even hundreds of feet. Most amphibolites are concordant with surrounding layers, but locally, small dike-like bodies occur.

At least two different varieties of amphibolite occur. The most abundant variety is dark-green to greenish-black, equigranular, fine- to coarse-grained, well-foliated to massive, hornblende- and plagioclase-dominated rock.Areas mapped as amphibolite contain interlayers of calc-silicate granofels, biotite granitic gneiss, and biotite gneiss (Merschat, 1977; Wiener, unpublished mapping; Kuchenbuch, 1979; Brewer, 1986; Merschat and Wiener, 1988). The amphibolites were probably derived from either mafic volcanic and plutonic rocks or from retrograded melanocratic granulites. Much less likely, they have a sedimentary origin (Kuchenbuch, 1979).

Another amphibolite variety is mottled white and green, inequigranular, fine- to coarse-grained, poorly foliated to foliated, hornblende-actinolite and plagioclase rock. This variety has a relict igneous texture (Merschat, 1977; Kuchenbuch, 1979; Brewer, 1986). These amphibolites probably originate from metamorphic alteration of plutonic mafic rock, possibly the Bakersville Metagabbro (Merschat, 1977; Kuchenbuch, 1979; Brewer, 1986).

Biotite Gneiss

The Biotite gneiss unit of the 1985 North Carolina State Geologic Map extends southwest in a widening band from the Leicester and Weaverville 7.5-minute Quadrangles in Buncombe and Madison Counties to the North Carolina-Georgia Sate line. As indicated in the preceding discussion, the Biotite gneiss unit may be an along-strike continuation or correlative of the Migmatitic biotite gneiss unit.

In reconnaissance mapping, the Biotite gneiss unit rocks were mapped by Keith (1904, 1907b, and 1952) as part of the Carolina Gneiss. On the 1958 State Geologic Map, Stuckey and Conrad included the unit in their extensive Mica gneiss unit. Hadley and Nelson (1971) on the Knoxville 1°x2° sheet included the rocks of the Biotite gneiss in two units; a Layered gneiss and migmatite unit and a Biotite schist and gneiss unit. Hadley and Nelson’s Layered gneiss and migmatite is more varied in rock type than their Biotite schist and gneiss. Further south, Hatcher (1980) in the Prentiss Quadrangle and Eckert (1983) in the Wayah Bald Quadrangle correlate rocks of the Biotite gneiss belt with the Tallulah Falls Formation.

The Biotite gneiss unit is a medium-gray to medium-dark-gray, medium- to coarse-grained, medium- to thick-layered, well-foliated, biotite-quartz-plagioclase gneiss. The biotite-quartz-plagioclase gneiss is interlayered and intergraded with biotite-garnet gneiss, biotite schist, and amphibolite. Layering is commonly discontinuous. Locally the unit is migmatitic and contains areas of abundant quartz and alumino-silicate minerals. Although much of this band of rocks is at sillimanite grade or higher, sillimanite generally occurs in scattered, small lenses and pods (Hash and VanHorn, 1951). Amphibolite interlayers, lenses, and pods are locally abundant. Calc-silicate layers and lenses are widely scattered throughout. Granulite-facies metamorphic rocks occur in the Franklin (Force, 1976), Wayah Bald (Eckert, 1984), and Rainbow Springs (Hatcher and Butler, 1979; Absher and

McSween, 1985) 7.5-minute Quadrangles.

Detailed geologic mapping of the Sandymush and Canton Quadrangles (Merschat and Wiener, 1988) and current work on the Clyde Quadrangle enables us to portray this major unit more accurately than was done in reconnaissance for the 1985 State Geologic Map. In these quadrangles we now reassign some rocks of the Biotite gneiss unit (as shown on the State Geologic Map) to the Late Proterozoic Ashe Metamorphic Suite and place the rest in the Middle Proterozoic Earlies Gap Biotite Gneiss or the Richard Russell Formation. Merschat and Wiener's (1988) cross sections of the Canton Quadrangle suggest that at least part of the Richard Russell may connect with the Earlies Gap beneath the Holland Mountain thrust sheet. If so, the two formations would be at least partly correlative. However, as mapping continues in the Clyde Quadrangle, it may be necessary to define an additional unit of the Biotite gneiss.

Biotite Granitic Gneiss

In the central Blue Ridge belt most gneissic granitic rocks were originally named the Cranberry Granite by Keith (1903) for exposures at Cranberry, North Carolina. In addition to use the type area on the Cranberry 30-minute Quadrangle, Keith extended this term to rocks in the Asheville (1904), Mr. Mitchell (1905), Roan Mountain (1907a), and surrounding quadrangles. Later, Bayley (1923) reported that abundant gneiss, schist, and amphibolite layers occur within the Cranberry Granite. Bryant (1962) changed the name to the Cranberry Gneiss and described the unit as consisting of light-gray to gray and locally pink, layered to non-layered, quartzo-feldspathic gneiss with interlayers of amphibolite, epidote-biotite gneiss, and hornblende gneiss. Stuckey and Conrad (1958) also emphasized the metamorphic layering in the unit by calling it the Cranberry Granitic Gneiss on the 1958 State Geologic Map. The U.S. Geological Survey continued using the term Cranberry Gneiss on the Knoxville 1°x2° sheet (Hadley and Nelson, 1971). In 1984, Bartholomew and Lewis (1984) redefined the Cranberry Gneiss and further limited the range of rocks included under that name. Although the rocks labeled Biotite granitic gneiss herein were previously called Cranberry Granite or Cranberry Gneiss, those names are no longer applicable.

The Biotite granitic gneiss unit crops out in the Bryson City, Ela, and Straight Fork windows in Swain, Jackson, and Haywood Counties and extends from west of Asheville into Virginia. In the window areas, Hadley and Goldsmith (1963) mapped augen and flaser gneiss of granitic, quartz monzoinitic, and granodioritic composition with minor amounts of amphibolite and layered gneiss. In the Bryson City window Cameron (1951) mapped these rocks as granitic gneiss. In the central region, Merschat (1977), Brewer (1986), and Merschat and Wiener (1988) mapped the Biotite granitic gneiss as containing units of layered biotite granitic gneiss and more massive, intrusive, granitic gneiss. All of these rocks are interlayered with amphibolites, calc-silicates, and rare marble. In this region mylonitic phases of both the layered biotite granitic gneiss and the massive granitic gneiss are extensive enough to be mappable units.

The Biotite granitic gneiss of the central Blue Ridge is a heterogeneous map unit. The compositions range from granite to quartz diorite, with quartz monzonite being the most common. The rock is massive to thinly layered. Amphibolite layers, lenses, and pods occur throughout the Biotite granitic gneiss unit and range in thickness from a few inches to several feet to mappable bodies. The unit was metamorphosed during both Proterozoic and Paleozoic events. Proterozoic metamorphism approached or attained granulite grade (Merschat, 1977; Gulley, 1982). In the local area, peak intensity of the Paleozoic-age Taconic metamorphism was as high as upper amphibolite facies (North Carolina Geological Survey, 1985).

Mappable amphibolite units usually include interlayers of granitic gneiss, biotite gneiss, and calc-silicate granofels. The amphibolite occurs as discontinuous conformable layers, but has been observed locally to be dike-like. The amphibolite is dark green to black, equigranular, and poorly foliated to well foliated. Locally, the amphibolite bodies exhibit evidence of retrogressive metamorphism (Merschat and Wiener, 1988). Amphibole content varies; some bodies are composed almost entirely of hornblende. Protoliths for these amphibolite bodies are mafic volcanic rocks, most likely mafic pyroclastics, basaltic lava flows, and some intrusvie bodies.

Bakersville Metagabbro

The Bakersville Metagabbro was originally named the Bakersville Gabbro by Keith (1903) and assigned a Triassic age. He mapped metagabbro areas on the Cranberry (1903) and Mount Mitchell (1905) Quadrangles, but did not map them on the Roan Mountain Quadrangle (1907a). The latter quadrangle includes the type area and contains the thin metadiabase and metagabbro dikes and sills of the Bakersville-Roan Mountain area investigated by Wilcox and Poldervaart (1958). Bayley (1923) first reported these mafic rocks were metamorphosed and therefore could not be Triassic. Wilcox and Poldervaart (1958) delineated and defined the Bakersville Metagabbro as a dike swarm, petrographically characterized lithologic variations within the swarm, examined the metamorphic effects, and established the dikes' Precambrian age. Since then, the Bakersville Metagabbro was reported and studied in the central Blue Ridge near Mars Hill and Marshall in Madison County (Merschat, 1977; Burton, 1979; Kuchenbuch, 1979; Goldberg and others, 1986). Goldberg and others (1986) dated the Bakersville at 734±20 Ma. They concluded it is a rift-zone-related, tholeiitic, basaltic intrusive.

The Bakersville Metagabbro dike swarm is present in an area about 90 miles long and 20 miles wide from about the North Carolina-Virginia State line southward to just north of Asheville. Most of the dikes and sills are thin and small (1 inch to 60 feet wide).

The Bakersville Metagabbro is dominated by two distinct phases distinguished by grain size: a fine-grained diabasic phase and a coarse- to very coarse-grained gabbroic phase. Intermediate grain sizes are uncommon. The diabasic phase is dark greenish gray; the gabbroic phase is olive black to purplish black. Both phases range in texture from granoblastic to blastophitic and locally are blastoporphyritic. Chilled margins occur locally. The development of metamorphic foliation varies throughout the dike swarm. Where metamorphic fluids were deficient, metamorphic recrystallization was inhibited and original igneous textures still persist. Where more water was available, recrystallization occurred, thereby destroying original igneous textures. In some of the dikes metamorphic recrystallization is greater near the edges than in the center.

Ashe Metamorphic Suite

The Ashe Formation was named by Rankin (1970) and subsequently designated the Ashe Metamorphic Suite by Abbott and Raymond (1984). In the central Blue Ridge belt the dominant rock types are two-mica schist, metagraywacke, and mica gneiss. Amphibolite and calc-silicate granofels are present in minor amounts. No subunits of the Ashe Metamorphic Suite have yet been formalized. The unit is at least several thousands of feet thick; but to date, only a few subdivisions based on dominance of gneiss, schist, or amphibolite, have been practicable to use during individual quadrangle mapping. Rocks of the Ashe Suite are locally mylonitic and, where metamorphic conditions were sufficiently intense, they are migmatitic.

Schist of the Ahse Metamorphic Suite is medium to coarse grained, light to dark gray, and well foliated. Both biotite and muscovite are abundant, except where metamorphic grade is high enough for muscovite to be unstable. In the central Blue Ridge where we are mapping, kyanite and sillimanite are key Barrovian metamorphic indicator minerals. Porphyroblasts of garnet are common; pyrrhotite is variably present.

Metagraywacke is typically medium light gray to medium gray, and medium to thick layered. Most original sedimentary features have been obliterated or transposed, although metaconglomerate layers are locally discernible.

Muscovite-biotite gneiss to biotite gneiss of the Ashe Metamorphic Suite is typically medium gray to medium dark gray, think to medium layered, and is commonly sulfidic.

Metagraywacke, schist, and gneiss of the Ashe are repetitively and variably interlayered and intergradational with one another at all scales. The schist is distinguished by abundant mica and a lepidoblastic texture. The metagraywacke is distinguished by abundant quartz, medium to thick layers, and massive appearance. The gneiss is relatively feldspar-rich, containing less mica than the schist and less quartz than the metagraywacke. In the gneiss, layers of quartz and feldspar alternate with mica-rich layers at a scale of several inches. In contrast, the schist has thinner layers and the metagraywacke has a more massive, homogeneous character.

In the central Blue Ridge belt, amphibolite of the Ashe Metamorphic Suite occurs as local interlayers rather than as thick, widely extensive masses typically found further northeast. The paucity of amphibolite may indicate an original absence of basaltic volcanic activity or may be the result of omission of amphibolite units through faulting along the Holland Mountain thrust fault.

Calc-silicate granofels in the Ashe Metamorphic Suite is composed mostly of quartz, plagioclase, garnet, either hornblende or biotite, and clinozoisite or epidote. The abundance of quartz, the calcium-rich nature of the other minerals, and the weakly developed foliation of calc-silicate granofels suggest that it was derived from calcareous graywacke.

Amphibolites of the Ashe Suite were derived from basaltic to diabasic volcanic rocks. The origin of the felsic units is not always as clear. Most writer accept or infer a detrital sedimentary origin. However, as shown by modal analyses, felsic gneisses from the Mars Hill, Barnardsville, Asheville, Sandymush, and Canton Quadrangles, have low quartz content, little or no potassic feldspar, and relatively high plagioclase content. This leads us to suggest that some of the Ashe may have originated as felsic pyroclastic material.

In North Carolina, numerous quartz diorites to granites, some as old as 450-500 Ma (Fullagar, 1983), intrude the Ashe Metamorphic Suite, thereby limiting its minimum age. The Ashe also correlates with the Lynchburg-Catoctin sequence of Virginia (Rankin, 1970; Rankin and others, 1983); thus, the Ashe Metamorphic Suite is traditionally assigned a Late Proterozoic age.

Dunite

Scores of ultramafic bodies crop out in the central Blue Ridge belt. In our map area nearly all are dunite and occur within Middle Proterozoic basement rocks. In an economically oriented report Hunter (1941) described most of the largest bodies. Few of these exceed half a mile in any dimension.

High-magnesium olivine (Fo_{92}) is by far the most abundant primary mineral. Chromite occurs as disseminated octahedral grains, thin discontinuous layers or veins, or rare masses up to several feet across. Chromite typically makes up about one percent of each body. A minor amount of bronzite (Mg-rich orthopyroxene) is often reported. Alteration minerals include serpentine, magnetite, talc, anthophyllite, phlogopite, and vermiculite.

The age of the dunites is not known conclusively. Dunites of the central Blue Ridge belt are most frequently placed within a broad range from Late Proterozoic to Early Paleozoic (Hadley and Nelson, 1971; North Carolina Geological Survey, 1985). They were metamorphosed during Taconic events, thereby restricting their minimum age to Ordovician. Dunites do not occur in Cambrian or Ordovician rocks of the nearby Valley and Ridge, nor do they occur in the very Late Proterozoic Ocoee Supergroup or Grandfather Mountain Formation. Elsewhere in the Blue Ridge, altered dunites are present in the Ashe, Tallulah Falls, and Alligator Back Formations, all of Late Proterozoic age. Thus, the dunites probably6 originated sometime during the Late Proterozoic.

Where well exposed, western North Carolina dunites exhibit sharp contacts with the surrounding rock. From the field geologist's point of view, these relations are compatible with either tectonic emplacement of the dunites, or magmatic emplacement of the bodies.

Ocoee Supergroup

The Ocoee Supergroup is a thick monotonous sequence of non-volcanogenic, terrigenous, clastic sedimentary rock with minor intercalations of limestone and dolostone. The Ocoee is divided into three major groups; the Snowbird Group, the Great Smoky Group, and the Walden Creek Group (Kind and others, 1958). The composite thickness probably exceeds 40,000 feet. In the field trip area only small sections of the Snowbird and Great Smoky Groups are present.

Snowbird Group

The Snowbird Formation was named by Keith (1904) for outcrops on Snowbird Mountain northeast of the Great Smoky Mountains along the boundary between Haywood County, North Carolina, and Cocke County, Tennessee. King and others (1958) redefined the Snowbird Formation as the Snowbird Group. In the central Blue Ridge, Hadley and Goldsmith (1963) mapped and described four formations within the Snowbird Group. These are the basal Wading Branch Formation, the Longarm Quartzite, Roaring Fork Sandstone, and the Pigeon Siltstone.

The Snowbird Group is the oldest metasedimentary rock unit found above the granitic basement. At many places along the North Carolina-Tennessee State line the original nonconformable contact is still preserved. The material that makes up the Snowbird metasediments was derived from the granitic basement (Hadley and Goldsmith, 1963). In the west central Blue Ridge the Snowbird occurs only in a remote region straddling the boundary between the Sandymush (Merschat and Wiener, 1988) and Fines Creek Quadrangles. Kyanite-garnet-mica schist dominates; some metagraywacke and minor calc-silicate granofels are also present. We tentatively correlate the Snowbird strata here with the Wading Branch Formation.

Great Smoky Group

The Great Smoky Group, the middle unit in the Ocoee Supergroup, was given formal group status by Hurst (1955). Prior to this, Keith's (1895) original designation of the Great Smoky Conglomerate was used.

The Great Smoky Group is a thick, monotonous sequence of variably metamorphosed clastic sedimentary rocks. Originally, the dominant rock types were graywacke, conglomerate, siltstone, and shale. They are interbedded and intergraded at all scales. The rocks are commonly poorly sorted and graded bedding is widespread. Graded bedding, other diagnostic primary features, and cyclic sedimentation patterns interpreted as Bouma cycles, indicate the significance of turbidity deposits in the group as a whole.

Rocks of the Great Smoky Group, tentatively assigned to the Copperhill Formation, crop out in only two small areas in the Clyde Quadrangle. Here, many of the diagnostic features of the Great Smoky Group are difficult to observe because of high-grade metamorphism and limited outcrop area. The sedimentary and conglomeratic character or the Copperhill Formation is evident in some exposures. Tourmaline, a diagnostic heavy mineral of the Great Smoky Group, has been panned from stream sediments of both outcrop areas.

Pegmatite

Pegmatitic granitoid rocks occur throughout the central Blue Ridge. The pegmatitic rocks that intrude the Ashe Metamorphic Suite contain coarse muscovite. In contrast, those intruding the Middle Proterozoic rocks are generally muscovite-poor and biotite-rich. Pegmatite bodies are commonly crosscutting and lenticular to tabular in shape with thicknesses ranging from inches to several tens of feet. Contacts are usually sharp and well defined.

The pegmatitic granitoid rocks are white to mottled white and pink. Texturally they are coarse to very coarse grained. They contain plagioclase, potassic feldspar, quartz, biotite and/or muscovite in varying proportions. Other accessory minerals may occur in pegmatitic rocks.

Muscovite-bearing pegmatitic rocks in the Spruce Pine Mining District are about 390-435 Ma. (Kish, 1983). This age is widely accepted for similar bodies throughout the central Blue Ridge.

Trondhjemite

The term trondhjemite was first used on North Carolina maps by Hadley and Goldsmith (1963). They applied the name to several small dikes in the southeast corner of the Dellwood Quadrangle. Bryant and Reed (1970) reported trondhjemite north of the Grandfather Mountain window. A year later, Hadley and Nelson (1971) showed the distribution of abundant trondhjemite dikes on a small-scale inset map on the Knoxville 1° x 2° Quadrangle. Trondhjemite is widespread, but appears to be most abundant in upper amphibolite facies rocks.

Trondhjemites are generally too small to depict accurately at standard field-mapping scales. A few large bodies were mapped by Wiener (unpublished mapping) on the Leicester Quadrangle. Other mappable bodies are present on the Weaverville Quadrangle. Keith (1904) noted these rocks and mentions that crosscutting dikes, large enough to quarry for building stone, occur between Alexander and Asheville in the area encompassed by the Leicester and Weaverville Quadrangles.

Trondhjemite is light gray to medium light gray, fine to medium grained, and equigranular, although locally it may be porphyritic. The larger dikes are usually the most coarse grained. Trondhjemite occurs as dikes and sills that are massive to weakly foliated. Mortar structure is common in almost all trondhjemites. They range in composition from granodiorite to tonalite, but most are tonalites (Hadley and goldsmith, 1963; Merschat, 1977; Morrow, 1977; Yurkovich and Butkovich, 1982). Trondhjemite is characterized by a low potassium content and low color index. Potassic feldspar and muscovite are rare. Trondhjemites are intrusive and have sharp, crosscutting contacts with all bedrock units. They are not strongly metamorphosed, if at all, and are compositionally similar to the large Devonian-age intrusive quartz diorite bodies of the Blue Ridge belt. These relationships indicate a post-metamorphic, middle Paleozoic age for trondhjemite bodies.

Surficial Deposits

Throughout the Blue Ridge Mountains of western North Carolina, thin deposits of loose, unconsolidated, relatively recent surface debris cover extensive areas. These surficial deposits are divisible into two classes — alluvium and colluvium — based on their mode of transport.

Alluvium or alluvial deposits occur in stream valleys, both in their flood plains and channels. The largest alluvial deposits occur in the flood plains of the major streams. These large alluvial deposits underlie the most extensive flat areas and provide the best farming lands of the region.

Alluvial deposits consist of boulders, cobbles, pebbles, sand, silt, and clay-sized particles. Stream channel deposits include all of these different sized clasts, but the sediments are poorly sorted and not very extensive. Beyond the banks of a stream, flood plain deposits have accumulated as a result of periodic flooding. These deposits consist of poorly to well-sorted, stratified gravel, sand, silt, and clay. Alluvial deposits are rarely greater than 15 feet thick.

Colluvium or colluvial deposits mantle much of the sloping land in the highland areas. Compositionally, colluvial materials reflect the bedrock units from which they develop. Colluvial fragments range in size from clay particles to giant boulders. The larger clasts come from more resistant and more massive bedrock units. Quite commonly, where several huge colluvial boulders touch, they form cave-like openings. In some areas these openings are interconnected and create lengthy passageways. In steep terrain, colluvial accumulations include abundant coarser-sized material, no matter what the bedrock. In gently sloping terrain, only massive, resistant bedrock produces bouldery colluvium.

Colluvial deposits are classified according to their characteristic shapes. In fact, when the deposits are large and well developed, their distinctive form is easily recognized on topographic maps. Colluvial deposits include talus, block streams, blockfields, and colluvial tongues, sheets, or aprons. All of these colluvial forms are commonly modified and dissected by running water.

Erosion of the Blue Ridge has been occurring continuously since Paleozoic time, but no pre-Cenozoic surficial deposits are unknown. Some relic Tertiary deposits may still be preserved locally; however, most investigators infer that the bulk of the relatively ephemeral surficial deposits formed much more recently during interglacial and glacial intervals of the Pleistocene Epoch (e.g. King, 1964; Mills and others, 1987). Although glaciers certainly were not present in the local area, the climate was likely quite severe. This promoted rock disintegration and formation of extensive detrital accumulations. It is clear that colluvial deposits are currently being created and reworked, notably during occasional, high-energy storms. Thus, surficial deposits have been generated intermittently through time with the frequency of formation related to major climatic conditions. The alluvial and colluvial deposits are therefore classed as Quaternary and Tertiary om age.

METAMORPHISM

It has been well known for over a century that the North Carolina-East Tennessee Blue Ridge belt is part of an extensive terrane of metamorphosed rocks. Metamorphic intensity was known to increase in a west to east direction based mainly on the progression of rock types from fine-grained slate to the west through phyllite and into coarse-grained schist and gneiss to the east. However, it was some years before the standard Barrovian metamorphic indicator minerals and isograds were systematically mapped, even in small areas of the Blue Ridge (c.f. Hurst and Schlee, 1962; Hadley and Goldsmith, 1963; Hernon, 1964; King, 1964).

The first regional isograd map published for the East Tennessee-North Carolina Blue Ridge was prepared by Carpenter (1970). This map is based on mineralogic data obtained from more than 350 stream sediment heavy-mineral concentrates collected throughout the area. Shortly thereafter, Hadley and Nelson (1971), using their own independent data, prepared a small-scale isograd map to accompany their compilation and reconnaissance work on the Knoxville 1° x 2° sheet. These works reported the effects of Paleozoic metamorphism which Butler (1972) concluded was a Taconic (Ordovician) event. Butler later compiled a metamorphic map for the entire State (North Carolina Geological Survey, 1985). Butler's was the first regional map to show areas of Proterozoic granulite metamorphism in the Blue Ridge discovered by Merschat (1977; in preparation) and Gulley (1982). Butler also included a Paleozoic, hypersthene-bearing, granulite area described by Force (1976) in the Franklin area.

The effects of high-grade Middle Proterozoic metamorphism in the Southern Blue Ridge have been known for many years. For example, Watson and Cline (1916) described granulite-facies mineral assemblages in Virginia. Bartholomew and Lewis (1984) discussed high-grade rocks in the Virginia and northern North Carolina Blue Ridge, and McConnell and Costello (1984) described similarly metamorphosed rocks near the western edge of the Blue Ridge belt in Georgia. Radiometric ages of about 1,000 Ma are recorded from many of these rocks (Fullagar and Odum, 1973; Rankin and others, 1983). This combination of data from so extensive a geographic area is evidence to conclude that regional, high-grade metamorphism of this general age in eastern North America is commonly named Grenvillian and when coeval deformational and magmatic effects are included, use of the term Grenville orogeny is appropriate.

The area of the field trip includes the Proterozoic high-grade, granulite region around Mars Hill (Stops 2 and 5) and another granulite-grade region in the Fines Creek vicinity (Stop 11). In between, granulite-grade minerals and rock textures are not preserved. The questions raised are 1) were these intervening rocks ever metamorphosed above upper amphibolite facies, or 2) were they once at granulite grade but subsequently retrogressed, thereby losing their granulite aspect?

The principal Paleozoic metamorphism, ascribed to Taconic events of Ordovician age, follows the standard Barrovian pattern and increases in intensity from west to east across the area. It ranges from middle staurolite grade (Stops 11) well into sillimanite grade (Stops 1 and 13). An objective of this trip is to observe the prograde effects of Paleozoic metamorphism in the cover rocks as well as its retrograde effects in the basement rocks.

Subsequent to the peak of intense Taconic-age metamorphism one, or perhaps two, low-grade events affected the region. They may reflect Alleghenian and possibly Acadian activity.

Proterozoic Metamorphism in the Northern Section

Geologic mapping in the Blue Ridge belt of western North Carolina is revealing an ever increasing number or areas of Middle to Late Proterozoic granulite facies rocks. These granulite rocks occur within the more extensive, early Paleozoic amphibolite facies terrane. Hypersthene, a diagnostic mineral of the granulite facies, was first recorded by Merschat (1977) on the Mars Hill Quadrangle. He mapped and described the following hypersthene-bearing units: hypersthene-plagioclase rock, hypersthene granitic gneiss, hypersthene-biotite-hornblende gneiss and hypersthene metagabbro. (The latter unit was originally thought to be part of the Bakersville Metagabbro.) Subsequent mapping and stream sediment heavy mineral sampling in the late seventies on the adjoining Barnardsville Quadrangle (Merschat, in preparation) further substantiated the presence of hypersthene-bearing granulite units in the central Blue Ridge. In 1979, Kuchenbuch studied two of the large mafic units mapped on the Mars Hill Quadrangle and suggested that the easternmost area represents a mafic granulite body that was intruded by the Bakersville Metagabbro and later retrograded by Paleozoic metamorphism.

In 1982, Gulley established the existence of Proterozoic granulite metamorphism in the vicinity of Roan Mountain and later formalized two granulite map units (Gulley, 1985). One unit, the Carvers Gap Granulite Gneiss, consists of granulite gneiss (characterized by orthopyroxene), amphibolite gneiss, granitoid segregations, and metadiabase. The other unit, the Cloudland Granulite Gneiss, is characterized by garnetiferous alumino-silicate granulite gneiss.

At the north end of our map area, the granulite rocks may be classified into two broad groups: 1) pyroxene granulites, and 2) quartzo-feldspathic granulites. The pyroxene granulites are medium to coarse grained and range from dioritic to gabbroic in composition. They have an equigranular, granoblastic texture and are usually massive to weakly foliated. The foliation, where discernible, results from a slight alignment of the mafic minerals. The plagioclase-rich pyroxene granulites will be referred to as felsic granulites, while those richer in mafic minerals will be referred to as mafic granulites. All these rocks contain pyroxene and plagioclase with accessory blue and smoky gray quartz, potassic feldspar, magnetite, ilmenite, zircon, garnet, and apatite. The orthopyroxene is hypersthene and the clinopyroxene is diopside. Plagioclase is well twinned, frequently antiperthitic, and of andesine composition. Retrograde minerals include hornblende and biotite which rim the pyroxene grains.

The quartzo-feldspathic granulites are medium to coarse grained and have a composition that ranges from granitic to granodioritic. They have an equigranular granoblastic texture and are massive to well foliated. They contain abundant feldspar with nearly equal amounts of orthoclase and plagioclase. The feldspars are commonly perthitic to antiperthitic.

Microcline is also present locally but is thought to reflect later Paleozoic metamorphism. The plagioclase feldspar is commonly oligoclase. Clinopyroxene is rare, except in the interlayered calc-silicate granofels where it occurs as both massive pods and disseminated grains. Grossularite and diopside occur in calc-silicate granofels in the Barnardsville Quadrangle (Merschat, in preparation). Hypersthene is rarely observed in this group because it is usually completely retrograded. Only one thin section from the quartzo-feldspathic granulite map units of the Mars Hill Quadrangle contains hypersthene. First-generation garnet is much more common than hypersthene and clinopyroxene. Accessory minerals include biotite, hornblende, magnetite, ilmenite, apatite, and zircon.

It is uncertain how uniform and homogeneous granulite-facies conditions were throughout this area during Grenville metamorphism. All the granulite rocks show some evidence of retrogression, albeit to varying degrees.

Early Paleozoic Metamorphism in the Northern Section

In the northern part of the map area, effects of post-Grenville, early Paleozoic metamorphism (Taconic) can be observed at the micro-, meso-, and megascopic scales. Depending on the previous history of the affected rocks, this metamorphism either retrograded or prograded the rocks. The Grenville-age granulites show retrogressive effects. Where metamorphic fluids were sufficient, the pyroxene granulites were altered to amphibolite, biotite-hornblende gneiss, and biotite granitic gneiss. Where metamorphic waters were sparse, evidence for retrogression is seen only in thin sections where hornblende and biotite rim and replace ortho and clinopyroxenes. At single exposures, this retrogression can also be documented where we find pyroxene granulite masses rimmed by amphibolite, or at map scale where we traverse from a core of mafic granulite outward into amphibolite. The water content variability in these rocks during retrogressive metamorphism caused diversity and intergrading of rock types.

In the quartzo-feldspathic rocks, retrogression is much more difficult to recognize. It is assumed that much of the microcline twinning is a result of retrograde metamorphism of orthoclase (or perthite), and that hornblende and biotite are retrograde alteration products of hypersthene and clinopyroxene.

Region-wide Taconic metamorphism of early Paleozoic age (Butler, 1972) produced northeast-southwest trending prograde Barrovian isograds in the aluminous cover rocks of our northern map area. On the Barnardsville Quadrangle all of the Ashe Metamorphic Suite is at kyanite grade. Monazite, another mineral whose distribution in pelitic rocks is controlled by metamorphic grade (Overstreet, 1967), also occurs throughout most of the Ashe on the Barnardsville Quadrangle.

Taconic metamorphism affected some of the region's intrusive rocks. For example, the Bakersville Metagabbro exhibits variable metamorphic effects. At many places the Bakersville retains much of its original texture and mineralogy, except for pyroxenes which show metamorphic clouding in thin section and minor alteration to hornblende and biotite around their edges. At these places, the original, magmatically formed subophitic texture of the Bakersville Metagabbro is virtually unchanged. At other places, we infer that water was somewhat more abundant during metamorphism because most of the pyroxene grains are completely altered to hornblende. In these rocks a granoblastic to nematoblastic texture with relict laths of plagioclase is dominant. Where even more water was available for completion of the metamorphic reactions, pyroxene is completely replaced by well crystallized, granular hornblende and minor biotite. Also, the feldspar is no longer in lath shapes but appears granular.

Proterozoic Metamorphism in the Southern Section

Reconnaissance mapping indicates that the Earlies Gap Biotite Gneiss and the Sandymush Felsic Gneiss of the Cylde, Sandymush, and Canton Quadrangles correlate northeastward along strike with the granulite-grade rocks of the northern section of our map area. However, rocks of the Sandymush and Canton Quadrangles, based on their mineral components, record metamorphism that did not exceed amphibolite facies conditions. The presence of widely scattered migmatitic areas suggests that these rocks reached at least upper amphibolite facies. The rocks are amphibolite, biotite gneiss, biotite granitic gneiss, tonalite gneiss, calc-silicate rock, and granitic gneiss. Hypersthene was not identified in the field, in thin section, nor in stream sediment samples.

West of the Sandymush Quadrangle on the Fines Creek Quadrangle is an area of pyroxene granulite (see later discussion at Stop 11). These hypersthene-bearing mafic rocks are similar to the granulite rocks in the northern section of our map area. The granulite rocks in our southern map area, found during reconnaissance work, have not yet been mapped in detail. They were first mentioned by Merschat and Wiener (1988). This occurrence further emphasizes the apparent irregular pattern of Proterozoic metamorphism.

Merschat and Wiener (1988) suggested three possible explanations for the metamorphic pattern.

1) Granulite-grade metamorphic conditions existed throughout the region, but locally the rocks are not of appropriate chemical composition to produce granulite index minerals. Chemical data are lacking, but it is unlikely that the chemical composition of similar-appearing rocks in the Sandymush-Canton area is much different from that in nearby and along-strike high-grade areas.

2) Granulite-grade metamorphic conditions existed in

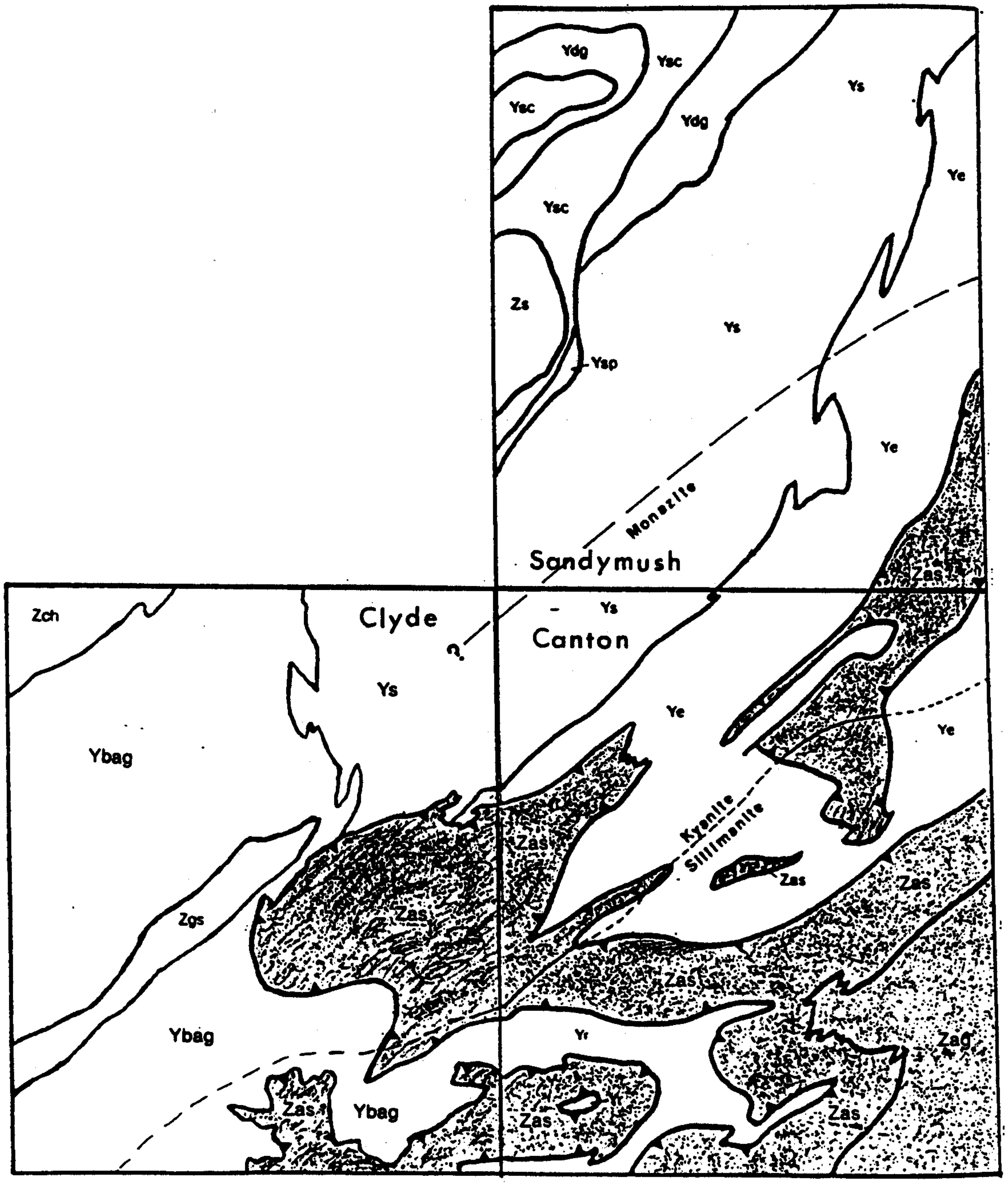

Figure 1. Outline map showing location of the sillimanite-kyanite isograd (short-dashed where approximately located) and distribution of monazite-bearing rocks, patterned area. Location of the monazite isograd, long-dashed line, is inferred based on its presence in the Ashe Suite and absence from the pelitic Snowbird Group. Symbols: Zgs = Great Smoky Group, undivided; Zch = Copperhill Formation; Zs = Snowbird Group; Zag and Zas = Ashe Metamorphic Suite; Ydg = Doggett Gap Protomylonitic Granitoid Gneiss; Ysc = Spring Creek Granitoid Gneiss; Ys = Sandymush Felsic Gneiss; Ye = Earlies Gap Biotite Gneiss; Yr = Richard Russell Formation; Ybag = unclassified basement gneisses on Clyde Quadrangle (discussion in text). Saw teeth on upper plate of Holland Mountain thrust fault.

the Sandymush-Canton area, but subsequent retrograde metamorphism destroyed pre-existing, diagnostic, high-grade minerals. As seen in the field some amphibolites are locally converted to biotite schist and gneiss. This replacement is confirmed in thin sections where biotite is seen replacing hornblende. However, it is doubtful that all traces of high-grade minerals would have been obliterated throughout the two-quadrangle area.

3) The Sandymush-Canton area never attained so high a metamorphic grade. With more detailed geologic mapping and petrologic studies it may become apparent that this lower-grade region is not anomalous, but actually fits well with an overall regional pattern.

Early Paleozoic Metamorphism in the Southern Section

In the southern section of the map area, Early Paleozoic metamorphism of the Middle Proterozoic basement rocks acted as a retrograde event. Evidence for this retrogression is especially notable in the amphibolites. In thin-section, biotite replaces existing hornblende. In the field, some of the thinner amphibolite layers are now altered to biotite schist and gneiss. The biotite flakes form a new surface or foliation which, though poorly developed, is slightly different from the compositional layering. This new foliation nearly parallels biotite-rich layers in the pre-existing biotite gneiss, biotite schist, and granitic gneiss.

In the Sandymush and Canton Quadrangles the contrast in metamorphic grade between Proterozoic and Paleozoic events was probably not as great as in the northern area, but the same pattern is present. In this area, unaltered hornblende in amphibolite and pyroxene grains in the calc-silicate rocks are relics from Middle Proterozoic metamorphism.

In the Ashe Metamorphic Suite, Snowbird Group, and Great Smoky Group Early Paleozoic metamorphism is a prograde event. The kyanite-sillimanite isograd crosses the Clyde and Canton Quadrangles diagonally from southwest to northeast with the highest grade rocks lying in the southeast part of the map (figure 1). The isograd's precise location and configuration as it crosses the less aluminous Earlies Gap Biotite Gneiss is not known because these rocks do not yield kyanite or sillimanite upon metamorphism. Thus, it is necessary to project the isograd across the Earlies Gap outcrop area.

Metamorphic monazite first appears in pelitic rocks in the higher-grade portion of the kyanite zone in a downgrade direction from the kyanite-sillimanite isograd (Overstreet, 1967). Based on stream sediment samples, monazite is present throughout the aluminous metasedimentary rocks of the Ashe Metamorphic Suite. Several miles northwest on the Sandymush Quadrangle the lower-grade Snowbird Group, also composed of pelitic metasedimentary rocks, does not contain monazite. The monazite isograd therefore lies between these two units. The intervening Middle Proterozoic rocks do not have the appropriate composition for monazite to develop and only an approximate location for a monazite isograd can be drawn. Figure 1 shows the distribution of monazite, the broad limits of an apparent monazite isograd, and relations to the kyanite-sillimanite isograd.

The northwest part of the Canton Quadrangle and most, if not all, of the Sandymush Quadrangle is at kyanite grade. Metamorphic intensity in the northwest corner of the Sandymush Quadrangle is uncertain because the non-pelitic, granitic rocks do not produce diagnostic alumino-silicate minerals upon metamorphism. However, both kyanite and staurolite are common in samples from meta-pelites of the Snowbird Group which extends to within three miles of the northwest corner of the quadrangle.

Mapping in the Clyde Quadrangle has further pinpointed the kyanite-sillimanite isograd. The southeastern one-fifth of the quadrangle is at sillimanite grade; the rest of the quadrangle is at kyanite grade. Kyanite is abundant in the Ashe Metamorphic Suite around Chambers Mountain near the corner of the Clyde Quadrangle and in the areas underlain by Great Smoky rocks. One of these areas is a narrow band northwest of Lake Junaluska; the other area includes the extreme northwest corner of the quadrangle.

Late Paleozoic Metamorphism

A post-Taconic, low-grade metamorphic event is commonly reported in the Blue Ridge belt (e.g. Butler, 1972). In our map areas there are also indications of a late, low-grade event. Chlorite, a mineral commonly associated with greenschist-facies metamorphism, is visible in amphibolite outcrops in the northwestern map area. It also occurs in a few thin sections of different gneiss varieties where it rims or replaces biotite and hornblende. This metamorphic event may be considered a low-grade, greenschist-facies, retrogressive metamorphism. The time of occurrence is poorly constrained by evidence in the local area; however, we infer the event may have occurred during the late Paleozoic Alleghenian orogeny.

SUMMARY

Table 3 summarizes and condenses the geologic history of the west-central Blue Ridge. It is based on knowledge gained through both detailed and reconnaissance mapping, thin section studies, heavy mineral analyses, and mineral resource investigations. It is further supplemented by our interpretation of a myriad of facts, thoughts, and ideas of current and previous workers in the central Blue Ridge of western North Carolina, eastern Tennessee, southwestern Virginia and northern Georgia.

Table 3. Summary of geology of west central Blue Ridge belt.

Quaternary. Erosion and formation of surficial deposits; continued regional uplift and joint development.

Tertiary and Mesozoic. Subaerial erosion; variably active epeirogenic uplift.

Permian – Pennsylvanian. Alleghenian deformation. Major northwestward movement of the Blue Ridge allochthon on deep, subhorizontal faults, local low-grade metamorphism, and formation of mylonite zones.

Early Devonian – Silurian. Intrusion of pegmatite bodies and trondhjemite dikes and sills.

Early Paleozoic. Widespread orogenic deformation and metamorphism correlated with the Ordovician Taconic orogeny. Development of the pre- to synmetamorphic Holland Mountain thrust fault, major and minor folds, and pervasive foliation. Foliation or schistosity developed in the Ashe Metamorphic Suite and Ocoee Supergroup; existing foliation and layering of the older rocks was transposed and locally enhanced.

Metamorphic conditions attained sillimanite and kyanite levels. In the older rocks, most of which had undergone Grenville, high-grade Proterozoic-age metamorphism, retrograde metamorphism occurred. This retrogression is best expressed in the mafic units (i.e., pyroxene to hornblende to biotite).

Latest Proterozoic. Deposition of Ocoee Supergroup sediments.

Late Proterozoic. Intrusion of the Bakersville Metagabbro, deposition of Ashe Metamorphic Suite sediments and volcanic materials, and emplacement of ultramafic rocks.

Middle or Late Proterozoic. Mylonitization occurred.

Middle Proterozoic. High-grade metamorphism, migmatization, and deformation associated with the Grenville orogeny. The Migmatitic biotite-hornblende gneiss, Biotite gneiss, and Biotite granitic gneiss were metamorphosed to upper amphibolite and granulite facies. Undoubtedly, this major orogenic event involved wholesale recrystallization and metamorphic differentiation to produce banded and foliated gneissic rocks.

Middle (?) Proterozoic. Formation of the protoliths of the Migmatitic biotite-hornblende gneiss, Biotite gneiss, and the Biotite granitic gneiss. These were likely layered felsic and mafic volcanic materials with only minor sedimentary components.

ACKNOWLEDGEMENTS

We wish to thank our numerous colleagues, who were involved in our Survey's mapping programs in western North Carolina. Their efforts made our understanding of the geology of the west-central Blue Ridge less insurmountable. We would also like to express our appreciation to the many summer interns whose work greatly benefited our stream sediment heavy mineral studies. The manuscript was improved through a timely yet thorough review by Loren A. Raymond, Appalachian State University; J. William Miller, Jr., University of North Carolina, Asheville; Mike Quinn and Tim Davis, University of Tennessee; and Jeff Reid, Chief Geologist of the North Carolina Geological Survey. Sigrid Ballew assisted in all production phases of this report, including proofreading and presentation of material. In addition, she handled the manuscript layout in her usual most competent manner.

FIELD TRIP ITINERARY AND STOP DESCRIPTIONS

Road Log for First Day

Mileage	
0.0	Trip starts at the Holiday Inn West, 275 Smoky Park Highway (U.S. 19, 23, and 74), about five miles west of Asheville. Cautiously turn right (west) onto Smoky Park Highway, proceed 0.4 miles and enter I-40 eastbound towards Asheville.
1.8	From the left lane, take exit 46-B to I-240 and Asheville.
5.8	Cross the French Broad River. Continue east on I-240.
7.9	West end of road cut through Beaucatcher Mountain.
9.2	Leave I-240 at Exit 7 (U.S. 70). Stay in the left lane of the exit ramp and continue straight ahead passing under one traffic light. At the second light, turn left and then at the third light turn left again.
9.6	Continue straight ahead and rejoin I-240 westbound.
10.8	East end of Beaucatcher Mountain road cut.

STOP 1. Ashe Metamorphic Suite at Beaucatcher Mountain road cut. This major 10-million-dollar highway excavation completed in the late 1970's provides an excellent view of a portion of the Late Proterozoic Ashe Metamorphic Suite. The cut is oriented approximately east-west and is thus transverse to the local northerly trend of the rocks. The excavation is about 1,400 feet long and the pavement is about 275 feet below the original ridge peak. Approximately one million cubic yards of overburden and two million cubic yards of rock were removed during construction (Russell Glass, personal communications).

At this exposure, the rocks are mostly gneiss and mica schist, with lesser amounts of amphibolite, garnet and amphibole-biotite granofels, mylonite, and pegmatitic layers. The gneiss and mylonite contain plagioclase, quartz, and biotite with locally abundant K-feldspar, along with minor garnet, muscovite, and chlorite. The amphibolite consists primarily of hornblende and plagioclase with minor biotite and trace chlorite. Garnet granofels and garnet-feldspar-biotite schist have plagioclase and garnet as major minerals with varying minor K-feldspar, biotite, and sillimanite, kyanite, and sphene. Sillimanite is most abundant in the garnet-rich granofels. Thin sections of this rock show sillimanite rimming and replacing garnet. The amphibole-biotite granofels contains plagioclase with minor biotite, chlorite, hornblende, and cummingtonite. Plagioclase averages An_{25} in most rocks and may reach An_{47} in some amphibolites. Traces of zircon, apatite, and carbonate are widespread.

Opaques appear in amounts of two percent or less, with ilmenite and pyrrhotite the most common, and rutile, magnetite, hematite, geothite, chalcopyrite, and pentlandite found less frequently in trace amounts. Pentlandite was found only in the amphibolite, granofels, and garnet-feldspar-biotite schist.

These rocks have been subjected to upper amphibolite facies metamorphism with extensive recrystallization and varying degrees of mylonitization.

The gneiss and mylonite occur in extensive layers that show strong compositional banding and which have bulk compositions similar to clastic sedimentary rocks and rhyolite. The amphibolite, granofels, and garnet-feldspar-biotite schist occur in lens-shaped layers and have aluminum-rich and in some cases iron-rich basaltic compositions. Rankin and others (1973) and Abbott and Raymond (1984) have studied the Ashe elsewhere and interpret the gneisses and schist to be metasedimentary rocks, and the amphibolites to be metabasalts with possibly some metagabbro.

(The preceding description was contributed by J. William (Bill) Miller, Jr., UNC-Asheville, who have recently been studying the Ashe Metamorphic Suite in the local area.)

10.8 Continue driving west on I-240.

12.7 Exit onto U.S. 19 and 23 North, and U.S. 70 west toward Weaverville.

18.3 Cross the Holland Mountain fault, locally covered, between the Ashe Metamorphic Suite behind us, and the Migmatitic biotite-hornblende gneiss unit of the basement ahead of us.

21.1 Leave expressway following U.S. 70 West (and U.S. 25 North) toward Marshall.

26.8 Pass intersection of U.S. 25-70 with SR 1588 (Ivy Trails Road and Sprouse Town Road) and park on shoulder.

STOP 2A. Felsic granulite in the Mars Hill Quadrangle. This exposure is a large, unbenched road cut, 0.4 miles east of the bridge over Ivy Creek. Much of the cut is covered with fine talus making the slope difficult to climb – please be careful!

The exposed rock is mapped in the Biotite granitic gneiss unit and is an excellent example of felsic granulite (plagioclase-rich pyroxene granulite). The felsic granulites are characterized by a granoblastic texture, light-brown to grayish-red purple andesine, some blue quartz, and the presence of hypersthene. In our map area, they vary from massive to weakly foliated and from granoblastic to nematoblastic. They have the composition of diorite. Modal analyses of this rock are typically: 1 to 12 percent potassic feldspar, 65 to 70 percent andesine, 0 to 7 percent diopside, and 9 to 12 percent hypersthene. Minor accessory minerals include hornblende, biotite, magnetite and zircon. In thin section, alteration rims (coronas) of hornblende and biotite surround hypersthene and clinopyroxene.

At this exposure, overprinting effects of early Paleozoic metamorphism, which was at or near kyanite grade, are barely apparent. The foliation which dips gently to the west, atypical for the central Blue Ridge belt, is evidently a weakly developed Proterozoic feature. At the west end of the exposure there is a crosscutting, very fine-grained mafic dike. Mineralogic effects of the more recent Paleozoic metamorphism are limited to incipient alteration of the clino- and orthopyroxene grains.

26.8 Continue westward along U.S. 25-70.

27.2 East end of bridge over Ivy Creek.

STOP 2B. Road cut in rocks typical of the Migmatite biotite-hornblende gneiss. The rocks exposed near the east end of the bridge over Ivy Creek along U.S. 25-70 are typical of the Migmatitic biotite-hornblende gneiss unit in the northern part of the map area. However, at this stop they occur as a small, undifferentiated enclave within the Biotite granitic gneiss unit. Present here are interlayered and intergraded mafic and felsic layers that are folded and show the effects of migmatization and boudinage. Towards the east end of the cut the rocks are more mafic and represent a retrogressed mafic granulite. In thin-section, a textural and mineralogic transition from granulite to amphibolite is often recognizable in rocks such as these.

Near the center of the outcrop the more massive, coarse-grained granitic gneisses exhibit the equigranular granoblastic texture typical of Proterozoic metamorphism. Away from the central area, the rocks are strongly overprinted by the regionally prevailing Paleozoic metamorphism that locally produced the steeply dipping foliation. In the northern section of the area the early Paleozoic metamorphic overprint involves a combination of retrograde recrystallization and ductile mylonitization.

27.2 Cross the bridge over Ivy Creek; continue westward along U.S. 25-70.

27.6 Large outcrop on north side of road.

STOP 3. Layered biotite granitic gneisses in the vicinity of Ivy Dam. The rocks exposed in this large road cut on the north side of U.S. 25-70 are layered biotite granitic gneiss. Arthur Keith (1904) included this area as part of his Cranberry Granite and all mappers since Keith have agreed that the rocks in this vicinity are granitic in appearance. We now recognize them as retrograded quartzo-feldspathic granulites.

The biotite granitic gneiss ranges in color from very light gray to very light pinkish gray to light red and is fine to coarse grained. It is massive to well foliated and locally mylonitic. The gneiss exhibits a granoblastic texture in the quartzo-feldspathic layers and a lepidoblastic texture in the layers where biotite dominates. Mineralogic composition of the quartzo-feldspathic layers ranges from granitic to granodioritic. A typical mode is: 33 percent plagioclase (principally oligoclase), 27 percent potassic feldspar, 27 percent quartz, and 11 percent biotite with accessory epidote, clinozoisite, sphene, apatite, magnetite, and zircon. Notable is the presence of magnetite and the absence of muscovite, characteristic features of the basement in the central Blue Ridge. Muscovite, where present, usually appears to be secondary and results from later shearing or mylonitization. The rarity of muscovite and the absence of sillimanite or kyanite in the basement, except for a few isolated places (Gulley, 1985; Brewer, 1986), indicates that the protoliths were generally metaluminous rock types.

Interlayered with the granitic layers is amphibolite, which is more common at the southeast end of the outcrop. The amphibolite layers are either completely retrograded pyroxene granulite or are amphibolites of Grenville age that were not subjected to granulite-grade metamorphism.

In several places crosscutting mafic dikes containing minor sulfides occur. Steven Goldberg (personal communication, 1990) correlates these dikes with the Bakersville Metagabbro. The dikes are obviously altered as evidenced by the presence of various amphiboles and chlorite. Locally the dikes appear to have imparted a reddish color to the feldspars in the adjacent rocks. At Stop 5 we will see other Bakersville Metagabbro dikes that intrude more mafic rocks and are not nearly as altered.

Yellow-green veins and joint fillings of epidote occur throughout this road cut and throughout the basement. The epidote is thought to be late Proterozoic and may be associated with intrusion of the Bakersville Metagabbro.

27.6 Turn around and drive eastward on U.S. 25-70 towards Asheville.

29.6 Turn east (left) towards Red Oak School on Jupiter Road (SR 1756).

34.8 Continue straight ahead under U.S. 19-23. The road is now N.C. 197.

37.8 Intersection of Arrowood Road, SR 2155, and N.C. 197. We are in the highly serpentinized and deeply weathered Democrat-Morgan Hill dunite body (Hunter, 1941).

Intruding the dunite is a pegmatite, now highly weathered, that was mined in the past chiefly for halloysite. The overgrown pit northeast of the intersection of Arrowood Road and N.C. 197 is the abandoned Arrowood halloysite mine (Hunter and Hash, 1949).

In the deep saprolite road cut on the southwest side of the intersection and for a few hundred feet uphill along N.C. 197, garnierite (a green-colored, waxy appearing, hydrous nickel-bearing silicate mineral) can be found. Upon lateritic weathering of olivine, nickel is released and redeposited as garnierite. Many assays of olivine from the region show that it invariably contains about 0.2 percent nickel. These garnierite veinlets enrich the saprolite to the extent that the nickel content here is higher than at some commercial laterite deposits. However, the tonnage available locally is not sufficient to support a viable mining operation (Worthington, 1964).

38.8 Bridge over Ivy Creek.

38.9 Park near D and D Grocery store.

Stop 4. Basement-cover contact in the Barnadsville Quadrangle at Democrat; the northern section. A short west-to-east traverse past a series of small, locally covered, road cuts along the north side of State route 197 in the Democrat area helps illustrate the complexity of the contact between the Middle Proterozoic basement rocks and the cover rocks of the Ashe Metamorphic Suite. The contact is interpreted as a folded pre- to synmetamorphic thrust fault named the Holland Mountain fault (Merschat and Wiener, 1988). The folded nature of the contact in this area is illustrated by its irregular, deeply invaginated pattern and outlying allochthonous masses as shown on the Barnardsville Quadrangle (Merschat, in preparation) (figure 2). Strike and dip of the foliation in this vicinity are consistent with, and further define the folds outlined by the basement-Ashe contact. Occasionally, discontinuous bands of mylonitic rock are found paralleling this contact, both in the upper and lower

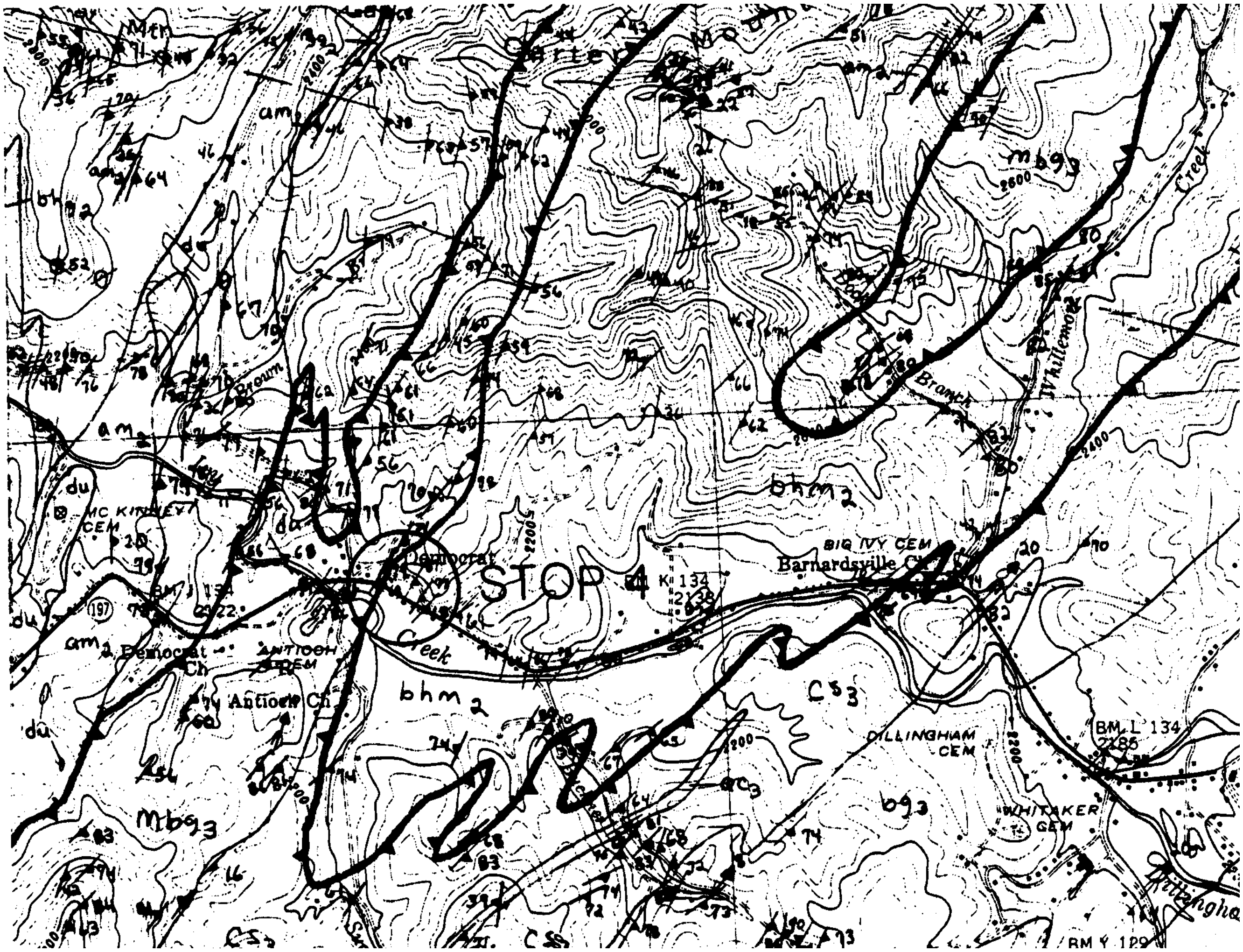

Figure 2. Basement – cover contact at Stop 4. Varnardsville 7.5-minute Quadrangle. The Holland Mountain thrust fault is shown as a heavy line with saw teeth on the upper plate. Basement map units designated by subscript 2; Ashe Metamorphic Suite map units designated by subscript 3; dunite designated by du. Scale approximately 1:24,000. Merschat (in preparation).

thrust plates. There may well be several generations of mylonite present, possibly representing Late Proterozoic, early Paleozoic, middle Paleozoic, or late Paleozoic deformation.

These road cuts are east of the previous stops in Grenville basement. In the partially covered cuts are interlayers of biotite gneiss, muscovite-biotite gneiss, and protomylonite. The exposures are within a unit mapped locally on the Mars Hill (Merschat, 1977) and Barnardsville (Merschat, in preparation) Quadrangles. The unit, informally named Muscovite-biotite gneiss, consists mostly of interlayered and intergraded biotite gneiss and muscovite-biotite gneiss. Minor interlayers of amphibolite and calcsilicate granofels are also present. The dominant biotite gneiss is light gray to medium dark gray to dark gray and well foliated to locally mylonitic. It is lepidoblastic and typically contains 29 to 42 percent plagioclase feldspar, 12 to 40 percent quartz, 9 to 54 percent biotite, 8 to 13 percent potassic feldspar, 0 to 27 percent hornblende, 1 to 4 percent epidote, 0 to 1 percent muscovite and trace garnet. The interlayered muscovite-biotite gneisses are medium gray to dark gray, well foliated, lepidoblastic, and contain 38 to 61 percent quartz, 17 to 37 percent plagioclase feldspar, 9 to 20 percent biotite, 3 to 6 percent muscovite, less than 1 percent opaques, and a trace of garnet. This map unit is assigned to the Ashe Metamorphic Suite because of the presence of muscovite, the relatively high quartz content, and the scarceness of both mafic rocks and potassic feldspar – characteristic features of the Ashe Metamorphic Suite locally and throughout much of the central Blue Ridge belt.

Stream sediment heavy mineral studies, thin section analysis, and hand-sample identification show this area is at kyanite grade.

At the western end of these outcrops the Ashe Suite is intruded by an unmetamorphosed trondhjemite dike.

According to the regional pattern, one would expect to continue deeper into the Ashe as we move eastward past a

Table 4.* Physical properties of mafic rocks observable in the northern section of our map area.

Bakersville Metagabbro			Mafic granulite	Amphibolite
	gabbro	**amphibolite**		
Color	dark brown-purplish black	dark green-black	dark brown-black and white (salt and pepper)	dark green-black and white
Color index	43-62	60-74	30-53	60-76
Relict original textures	subophitic-porphyritic	igneous plagioclase laths	absent	absent
Metamorphic textures	blastophitic-blastoporphyritic	nematoblastic spotted amphibolite	granoblastic to weakly foliated	gneissic to granoblastic
Grain size	medium to coarse	fine to medium	medium	medium to fine
Grain shape	lath plagioclase, subhedral pyroxene	euthedral to anhedral amphibole	equigranular anhedral to subhedral	equigranular euhedral mafics
Effects of weathering	spheroidal boulders	shaly layers	spheroidal boulders	shaly to blocky
Color of soil	red brown-brown	red brown-brown	brown-light brown	red brown-brown

*Modified from Kuchenbuch (1979).

250-foot-wide covered area (occupied by a Country Food Store/ Eblen gas station). However, exposures just east of the store are well-foliated to locally migmatitic biotite granitic gneiss to granodioritic gneiss with interlayered amphibolite. Two modal analyses made on rocks from a very similar nearby exposure show 27 to 33 percent plagioclase, 7 to 27 percent potassic feldspar, 19 to 22 percent quartz, 11 to 33 percent biotite, 0 to 10 hornblende, and 4 to 7 percent epidote and other accessory minerals. These rock types (granitic to granodioritic gneiss) and modes (notably the high potassic feldspar content, low quartz content, and virtual absence of muscovite) are characteristic of large parts of the Middle Proterozoic basement.

The interpretation of this short traverse is that we started in the Ashe Metamorphic Suite, moved eastward across the locally covered Holland Mountain fault, and ended in Middle Proterozoic basement rocks. Figure 2 is a geologic map of this vicinity that depicts the folded nature of the Holland Mountain fault as revealed by quadrangle mapping.

As noted above, a trondhjemite dike intrudes the Ashe. Also, in the basement gneiss exposures, at least two other crosscutting trondhjemites are present. Similar relations are found elsewhere and indicate that the Ashe Metamorphic Suite was emplaced over the basement prior to injection of the post-metamorphic trondhjemite dikes, thereby putting a pre-trondhjemite age constraint on the Holland Mountain fault.

38.9 Turn around and drive westward on N.C. 197 retracing route to U.S. 19-23.

429 Turn north (right) onto U.S. 19-23 towards Johnson City.

44.7 Turn right at Stockton Road (SR 2148) and then make a left turn onto SR 2207 towards Forks of Ivy.

44.9 Park in front of the prominent outcrop.

STOP 5. Mafic granulite, south of Forks of Ivy. This road cut contains the largest and freshest exposure of mafic granulite, the two-pyroxene-rich granulite, in the Mars Hill Quadrangle. This area was originally mapped by Keith (1904) as metagabbro and later was mistakenly grouped with dunites on the 1958 State Map (Stuckey and Conrad, 1958). Hadley and Nelson (1971) grouped the rocks in this area with “Amphibolite, metadiabase, metagabbro, and related mafic intrusive rocks” of Paleozoic age. Merschat (1977) mapped these rocks as part of a coarse-grained, hypersthene-bearing metagabbro body that is amphibolitized at its outer edge. Kuchenbuch (1979) recognized that the mafic areas mapped by Keith, Hadley and Nelson, and Merschat are actually a complex of more than one rock type, age, and metamorphism.

The rock is a dark brown to black and white (salt and pepper texture), massive to weakly foliated, medium- to coarse-grained, granoblastic, mafic granulite. The effects of Taconic retrograde metamorphism can be seen in thin section, where pyroxenes are rimmed by hornblende and minor biotite. A typical modal analysis of this mafic granulite is: 26 percent hypersthene, 15 percent clinopyroxene, 34 percent plagioclase feldspar, 9 percent biotite, 9 percent hornblende, 4 percent black opaques, and others. Elsewhere, this mafic granulite body is locally and irregularly retrograded to amphibolite. The mafic granulite weathers spheroidally.

Another mafic component of this area is a series of Bakersville Metagabbro dikes. In the central section of the exposure (just north of the painted area) are several dark-black, dense, fine-grained dikes that contain mesoscopic feldspar laths and exhibit subophitic microscopic texture. The Bakersville has an age of 734± 20 Ma (Goldberg and others, 1986). In this region, dikes range in thickness from inches to tens of feet. On the Barnardsville Quadrangle (Merschat, in preparation), with the exception of one small body, they are too small to map accurately at the 1:24,000 scale. At this particular exposure, the mafic granulite has a granoblastic texture with no obvious foliation, thereby making the intrusive and crosscutting nature of the Bakersville dikes somewhat obscure.

Bakersville Metagabbro dikes were also altered in varying degrees by Taconic metamorphism. Kuchenbuch (1979) listed four levels of metamorphic recrystallization in the Bakersville dikes. The dikes range from those with clearly recognizable igneous textures to those that are now amphibolites in which original textures and minerals have been completely obliterated or replaced.

The exposures here and at Stops 2 and 3 show the amphibolites in this area have varied origins. They are either retrograded pyroxene granulites, metamorphosed Bakersville dikes or relic Proterozoic amphibolites that never attained granulite grade. Table 4 lists the common physical characteristics of the different rocks within the mafic areas in the northern section of our mapping area.

44.7 Return to U.S. 19-23. A safe turn-around is at the Forks of Ivy Plaza just beyond the north end of the mafic granulite exposure.

45.2 Carefully turn onto U.S. 19-23 southbound.

51.1 Take exit ramp and leave expressway. Join U.S. 25 North and U.S.70 West towards Marshall.

51.7 At stoplight turn left onto Monticello Road, SR 1727.

54.5 Junction with N.C. 251 at the French Broad River. Turn right and follow N.C.251 to the north and downstream.

55.5 Park near bridge and large outcrop.

STOP 6. Migmatite. This road cut is located on the east side of North Carolina 251 directly opposite a bridge over the French Broad River. The stop is one-half mile northwest of the Alexander Post Office on the Weaverville Quadrangle. Although no detailed geologic mapping yet exists for this quadrangle, we have done reconnaissance work in the area and the exposure is convenient for examining the migmatitic and lithologic character of the Grenville basement in an intermediate geographic position as we traverse southwestward across the map area.

The mafic character of the rocks has been recognized sine Keith (1904) mapped the area as underlain by Roan Gneiss. Hadley and Nelson (1971) included the rocks in their Layered gneiss and migmatite unit. The 1985 State Geologic Map (North Carolina Geological Survey, 1985) designated the area as part of a basement unit called Migmatitic biotite-hornblende gneisses. Brewer (1986) mapped about five miles to the northwest on the Marshall Quadrangle and recognized very similar lithologic types. The outcrop here resembles and is along strike of Brewer's (1986) Amphibolitic basement complex.

The Middle Proterozoic basement rocks are very similar to those at Stop 2b, and consist mostly of interlayered and intergraded amphibolite, biotite-gneiss, biotite-hornblende gneiss, and calc-silicate granofels. The more mafic rocks dominate and are more intensely migmatized than seen at previous stops in the basement. The age of this migmatization is uncertain. It is obvious that in our map area there were two high-grade metamorphisms, one in the Proterozoic (Stops 2,5,11), and one in the Paleozoic (Stops 1,12). Both metamorphic events were intense enough to produce some local melting. Therefore it is quite probable to have multiple migmatizations at some basement outcrops.

The amphibolite layers are highly contorted and boudinaged, and locally amphibolite layers appear to be floating in the neosome.

Raymond and others (1989) described some aspects of this outcrop, noting at least three phases of intrusion and two grades of amphibolite-facies metamorphism in the amphibolite.

55.5 Turn onto SR 1634 and cross the bridge over the French Broad River.

56.8 In front of the French Broad Elementary School turn left onto SR 1620 towards Leicester.

61.1 Bear right at road junction of Sluder Branch Road (SR 1620) and Martin Branch Road (SR 1610) and continue to southwest.

61.7 Turn right onto Leicester Highway, N.C. 63. Continue northwest on N.C. 63.

69.5Stop on road shoulder at series of roadside outcrops.

STOP 7. Type area of the Sandymush Felsic Gneiss. Stop 7 is at the northwestern end of a series of small road cuts along N.C. Highway 63 that make up the type locality of the Sandymush Felsic Gneiss (Merschat and Wiener, 1988). Although not dated in the local area, the unit correlates with rocks to the northeast that have been dated radiometrically. The Sandymush Felsic Gneiss correlates at least in part with either the Biotite-hornblende migmatite or the Layered biotite granitic gneiss units of the Mars Hill Quadrangle (Merschat, 1977) and the Amphibolitic basement complex of Brewer (1986). Granitic gneiss layers from the Biotite-hornblende migmatite unit are 1214 ± 83 Ma (Fullagar and others, 1979; Rankin and others, 1983). Granitic gneiss layers from the Biotite granitic gneiss unit yield an age of 1270 ± 44 Ma (Fullagar, 1983).

The Sandymush Felsic Gneiss of the Sandymush and Canton Quadrangles is a little more felsic than equivalent units to the north and northeast. The mafic layers are thinner, less abundant, and more retrograded than those of the Mars Hill Quadrangle. Many of the mafic rocks in the Mars Hill Quadrangle still contain relic minerals and textures indicative of granulite grade metamorphism. In the Sandymush and Canton Quadrangles the amphibolites are mostly retrogressed to biotite gneisses and schists, thereby producing apparent differences between the mafic rocks of the two areas.

As illustrated at these outcrops, the Sandymush Felsic Gneiss is a thick, monotonous, repetitive sequence of layered rocks. It is composed dominantly of biotite granitic gneiss to quartz dioritic gneiss interlayered and intergraded with biotite gneiss, biotite schist, amphibolite, and very minor calc-silicate granofels. These various lithologic types are widespread and all, except calc-silicate, occur quite commonly throughout this heterogeneous map unit.

The biotite granitic to quartz dioritic (tonalite) gneiss layers dominate; the other lithologic types are so interlayered, intergraded, and thin that they can be mapped as separate units in only a few areas. The thickness of the biotite granitic to quartz dioritic gneiss layers is variable. Layers range from a fraction of an inch to several feet in thickness. Grain size ranges from coarse to fine. The fabric is equigranular, but where local mylonitization occurred, it is inequigranular. Color of the fresh rock ranges from very light gray to very pale orange to medium light gray.

The felsic gneiss layers are repeatedly interlayered with generally thin amphibolite layers. Commonly the amphibolite interlayers are retrograded and thus have a high biotite content. Most amphibolite layers are continuous in hand sample and outcrop scale. Only in a few areas does continuity of amphibolite layers extend to map scale.

Calc-silicate granofels layers are relatively rare and are found associated and interlayered with amphibolite. The calc-silicate layers are discontinuous at map scale.

Rocks of the Sandymush Felsic Gneiss are locally migmatitic. The quartz and feldspar neosome commonly crosscuts the gneissic layering

The felsic layers are mostly granitic, but range from quartz-rich granitoid to quartz diorite or tonalite. Granoblastic or lepidoblastic textures dominate in the felsic layers depending on the biotite content. The dark-colored, low-felsic bands have a high biotite content and are strongly lepidoblastic. Modes range from 0-23 percent potassium feldspar, 12 to 63 percent plagioclase, 2 to 50 percent biotite, with minor epidote, clinozoisite, garnet, sphene and black opaques.

Amphibolite is abundant within the Sandymush Felsic Gneiss. It occurs as layers, lenses, and pods that range in thickness from less than an inch to several feet. Locally amphibolite layers are abundant enough to be mapped as separate units. Nematoblastic texture is dominant.

69.5 Turn around and return eastward on N.C. 63.

70.1 Turn right onto SR 1401.

72.7 Pass Payne Chapel Methodist Church and cross Sandymush Creek. Turn right at junction of SR 1401 and SR 1394.

72.8 Park along shoulder of SR 1394 in front of large outcrops.

STOP 8. Type area of the Earlies Gap Biotite Gneiss. The type locality of the Earlies Gap Biotite Gneiss is an extensive road cut along the south side of SR 1394 west of its intersection with SR 1401 (Merschat and Wiener, 1988). This exposure typifies the distinctly layered, heterogeneous, migmatitic, and commonly folded character of this unit.

An absolute age for the Earlies Gap Biotite Gneiss has not been determined. Reconnaissance observations indicate the formation interfingers and correlates with rocks north and northeast on the Marshall, Mars Hill, and Barnardsville Quadrangles. The Earlies Gap correlates well with portions of a Biotite-hornblende migmatite unit on the Mars Hill Quadrangle (Merschat, 1977) whose granitic interlayers are 1214±83 Ma (Fullagar and others, 1979; Rankin and others, 1983). It also correlates well with some of the biotite-rich portions of the Biotite granitic gneiss unit of the Mars Hill Quadrangle (Merschat, 1977) which are 1270±44 Ma (Fullagar, 1983). The Earlies Gap biotite Gneiss is a little less felsic than most of the Biotite granitic gneiss unit of the Mars Hill Quadrangle. It is less mafic than the Amphibolite basement complex of the intervening Marshall Quadrangle (Brewer, 1986), and also less mafic than the Biotite-hornblende migmatite unit of the Mars Hill Quadrangle. The Earlies Gap Biotite Gneiss may therefore indicate a downstrike lithologic change resulting from original variations of the Protolith and from a more thorough retrogression of the mafic rocks.

The Earlies Gap Biotite Gneiss sequence, at least 4,000 feet thick, is well-foliated, highly layered biotite gneiss interlayered with thinly layered amphibolite, layered biotite granitic gneiss, and rare calc-silicate granofels or muscovite-biotite gneiss. Interlayering occurs from hand sample to map scale. The Earlies Gap Biotite Gneiss has a diagnostic wavy foliation and thin layers of coarse-grained biotite flakes. The gneissic layers range up to several inches in thickness.

The Earlies Gap Biotite Gneiss is locally migmatitic, especially in the Canton Quadrangle near the southern end of the outcrop belt. The leucocratic neosome, composed of quartz and feldspar, commonly crosscuts the gneissic foliation. Locally, the migmatitic areas show the effects of later shearing and folding. Mylonites also occur in the Earlies Gap Biotite Gneiss.

Biotite gneiss, the dominant rock type, varies in color from very light gray to medium light gray. It is well foliated with layers ranging up to several feet in thickness. As the biotite content increases, the layering becomes thinner and the rock becomes more schistose. Interlayered with the biotite gneiss are thin repetitive layers of amphibolite and lesser calc-silicate granofels. The amphibolite is commonly retrograded, thereby making some thin amphibolites difficult to distinguish from biotite gneiss.

Amphibolite, the second most abundant rock type in the Earlies Gap Biotite Gneiss, occurs as thin layers, lenses, and pods that range in thickness from less than an inch to a few feet. Amphibolite is interlayered at all scales with the biotite gneiss. To the northeast, on the Sandymush Quadrangle, amphibolite crops out extensively and dominates at most exposures. This area, mapped as an amphibolite-dominant phase, underlies about five percent of the quadrangle. Keith (1904) too, indicated abundant amphibolite in this area and showed it extending northeastward under the now abandoned unit "Roan Gneiss". Several other smaller amphibolite-dominated areas are also mapped on both the Sandymush and Canton Quadrangles. Good exposures of amphibolite are uncommon because the dominant mafic layers weather rapidly. Interlayered calc-silicate granofels is much less abundant than amphibolite and occurs as pod-like masses.

Biotite gneiss exhibits a lepidoblastic to equigranular granoblastic texture. Lepidoblastic textures dominate because of the high biotite content. Locally, mylonitic textures are common.

The felsic portion of the biotite gneiss ranges between tonalitic and granitic with most of the felsic layers being granodioritic in composition. The biotite content, ranging up to 80 percent, is highest in the schistose layers. Rare pleochroic halos occur in the biotite. Muscovite is a minor accessory in the gneiss. Field observations indicate that the muscovite content increases ever so slightly in the southeastern outcrop area of the Canton Quadrangle.

Amphibolite is equigranular nematoblastic in texture, but grades to lepidoblastic where retrogressive metamorphism has been thorough. It is poorly foliated to well foliated, depending partly on the proportion of amphibole present and partly on the thoroughness of retrogression. The higher the amphibole content, the better developed the foliation. The more thorough the retrogression, the higher the biotite content and the more distinct the foliation.

Calc-silicate granofels is equigranular granoblastic to lepidoblastic, massive to foliated, and thin layered to podiform. It is commonly interlayered and mapped with amphibolite. Calc-silicate granofels is composed of plagioclase, K-feldspar, quartz, epidote-group minerals, diopside, and other alteration minerals. Diopside weathers rapidly to diagnostic spots of yellowish-brown limonite.

72.8 Turn around, and bearing right, drive past junction of SR 1394 and SR 1401. Continue uphill on SR 1401.

75.0 Junction with North Turkey Creek Road, SR 1389. Continue east (to left) on Turkey Creek Road.

76.4 Turn right (southbound) onto N.C. 63 and continue back toward Asheville.

87.6 Junction with U.S. 19, 23, and 74. Turn right and continue west.

90.4 Holiday Inn West. End of first day's trip.

Road Log for Second Day

Mileage

0.0 Leave motel parking lot turning right onto Smoky Park Highway, U.S. 19, 23, and 74. Stay in the right lane and proceed 0.2 miles to the first entrance ramp to I-40. Turn right onto I-40 westbound towards Canton.

8.3 Beginning of a 1.3-mile-long series of road cuts in the Ashe Metamorphic Suite through the southwest end of Holland Mountain. As mapped on the Canton Quadrangle, most exposures are included in an informal gneiss unit in which biotite gneiss and metagraywacke dominate over schist. This area is east of the sillimanite isograd.

11.3 Cross Holland Mountain fault. Ashe is to the southeast, behind us; the Earlies Gap Biotite Gneiss is to the northwest.

13.2 Leave Interstate at exit 31 and take N.C. 215 southbound (to left) towards Canton.

13.9 Turn right onto Old Thickety Road, SR 1513.

14.5 Cross I-40 on narrow bridge.

14.6 At road junction continue straight ahead on SR 1549.

15.1 At road junction bear left onto SR 1509 (Crabtree Road).

16.2 Pavement ends. Continue northwestward on gravel road.

16.9 Private driveway enters Crabtree Road from the left. Park in this vicinity.

STOP 9. Holland Mountain thrust fault – a basement-cover contact near Crabtree Gap on Canton Quadrangle. In the southern map area a series of small outcrops along the east side of SR 1509 (Crabtree Road) and along the west side of an adjoining private driveway illustrate relations along the Holland Mountain fault (figure 3). The fault contact is

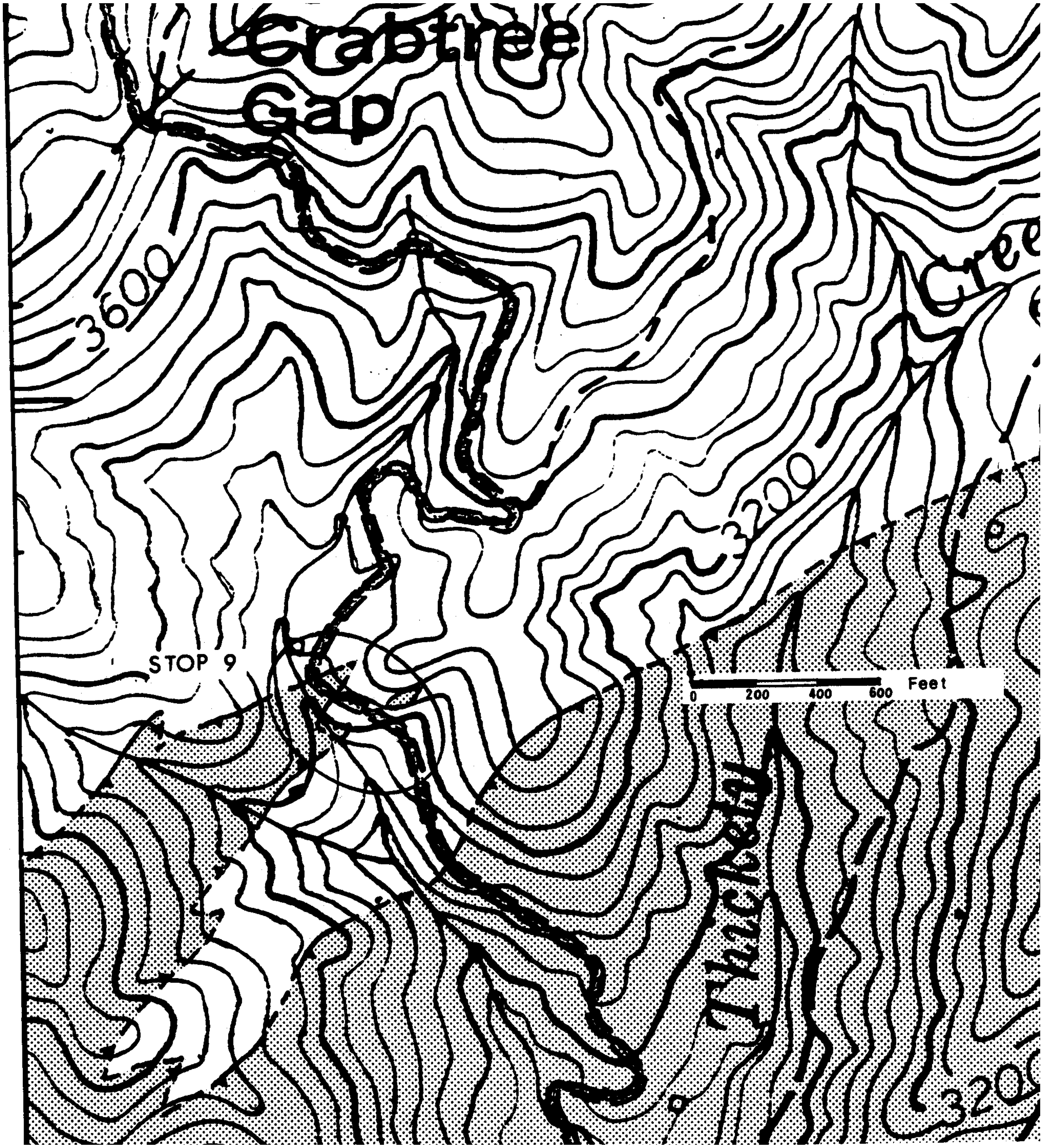

Figure 3. Basement-cover relations at Stop 9, Canton 7.5-minute Quadrangle. Patterned area – Ashe Metamorphic Suite; unpatterned area – Earlies Gap Biotite Gneiss. Saw teeth on upper plate of Holland Mountain thrust fault. Trace of fault dashed where approximately located.

exposed in a small driveway cut near the west side of SR 1509, approximately 2,000 feet south of Crabtree Gap.

The extreme northeast end (approximately 50 feet) of the driveway exposures is in layered biotite felsic gneiss that contains thin, wispy, dark ultramylonitic layers. The rock is composed of potassic feldspar, plagioclase and biotite. Rare, thin wavy muscovite is also present. Tight folds with attenuated and truncated limbs, a phenomenon common to the basement rocks, occur in the biotite felsic gneiss. These basement rocks are within the Earlies Gap Biotite Gneiss.

The outcrops along the driveway to the southwest are typical kyanite-bearing garnet-biotite-muscovite schist and gneiss of the Ashe Metamorphic Suite.

In the driveway cut the basement-cover contact appears to be a straightforward, steeply dipping, northeast-striking feature. However, examination of the nearby surrounding area, shows that relations are more complex. Rocks to the northwest of the driveway exposure are in basement. Traversing downhill along the road to the southeast, we cross about 250 feet of Ashe strata and re-enter basement gneiss. Then about 750 feet southeast of the driveway we cross back into the Ashe. We explain this in terms of tight, post-fault folding. A folded pattern for the contact in this local area mimics the quadrangle-scale folded nature of the contact revealed by detailed mapping. Dips in this area are very steep, but in the first part of the road traverse foliation and compositional layering in the Ashe dip inwardly in the fashion of a tightly appressed synform which concurs with the local synformal structure of the Holland Mountain fault indicated by the map pattern (figure 3).

Again in this area, unmetamorphosed trondhjemite dikes crosscut both basement rocks and cover rocks on either side of the Holland Mountain fault.

In saprolite of the Earlies Gap Biotite Gneiss along Crabtree Road we can see thin amphibolite layers containing retrogressive biotite.

At this stop mylonites are most prominent in the Earlies Gap. Yet in mapping the Sandymush and Canton Quadrangles (Merschat and Wiener, 1988) we found that near the Holland Mountain fault, mylonites were generally more common in the Ashe Metamorphic Suite. Some of the mylonites are located near or along the Holland Mountain thrust, but many other mylonitic zones are well within rocks of the footwall and hanging wall far from the actual contact.

16.9 Continue driving uphill on Crabtree Road.

17.7 Crabtree Gap, elevation about 3,700 feet.

19.0 Crabtree Bald, elevation 5,340, is straight ahead. This peak is at the southwest end of an area underlain by an isolated downfold of Snowbird Group rocks.

20.2 Immediately after crossing Liner Creek turn left onto the paved road, SR 1503.

22.5 Junction with N.C. Highway 209 at Crabtree-Iron Duff School. Turn right onto N.C. 209 and continue north.

22.9 Park on shoulder in front of road cuts.

STOP 10. Aluminous rocks in the basement. Rock cut exposures along renovated North Carolina Highway 209 consist of metasedimentary-looking, sulfidic, garnet-muscovite-biotite gneiss and schist that are locally migmatitic. These rocks resemble the Ashe Metamorphic Suite, but are a considerable distance northwest of the Holland Mountain thrust and are interlayered or surrounded by biotite gneiss and biotite felsic gneiss of the Middle Proterozoic basement. This is one of many similar muscovite-biotite gneiss occurrences mapped in this part of the Clyde Quadrangle (Merschat and Wiener, in progress). If the exposed rocks are part of the Ashe Suite, they are infolds or downfaulted blocks. If the rocks are part of the Middle Proterozoic basement then we must rationalize their metasedimentary aspect and the presence of white mica. Thus we have a perplexing stratigraphic or structural problem. The rocks appear devoid of kyanite, while the Great Smoky to the northwest and the Ashe to the southeast carry abundant kyanite. Our heavy mineral sampling may yet yield kyanite, but this significant mineral was not obvious in hand samples examined during routine mapping. The absence of kyanite suggests that these rocks are not as aluminous as typical cover rocks. On the other hand, their intricate interlayering and association with nearby basement rocks indicates that there may be compositional changes in the basement strata so that in this part of the central Blue Ridge, white-mica-bearing rocks become a constituent of the Earlies Gap Biotite Gneiss, the Richard Russell Formation, or a new basement unit.

Our present inclination is to accept the stratigraphic explanation that there are areas of white-mica-bearing rocks in the basement in the southern part of our mapping area. Unfortunately, this greatly reduces the reliability of using the presence or absence of muscovite to discriminate between cover sequence rocks and basement rocks.

22.9 Continue north on N.C. 209.

27.5 Approximate location of contact between Middle Proterozoic basement behind us and Late Proterozoic Great Smoky rocks ahead of us. Downstrike in the National Park area, this contact is depicted as an unconformity (Hadley and Goldsmith, 1963).

28.3 At road junction in front of Ferguson's store and trout pond leave N.C. 209 and continue straight ahead on SR 1334 following sign to I-40.

28.4 Cross out of Great Smoky and re-enter basement rocks.

28.9 After crossing bridge over Fines Creek turn left onto SR 1338 (Lower Fines Creek Road) towards I-40.

31.1 Park in front of machinery shed opposite house and barn with concrete silo.

STOP 11. Pyroxene granulite on the Fines Creek Quadrangle. Small outcrops on the north side of SR 1338, in the nearby pastures, and in Fines Creek are pyroxene granulite. The pyroxene granulite is an olive-black to brownish-gray, massive to weakly foliated, medium-grained, granoblastic rock that consists of plagioclase feldspar (andesine), hypersthene, diopside, and quartz. It weathers in a characteristic spheroidal fashion. These outcrops, located in reconnaissance mapping of the Fines Creek Quadrangle, are near the center of a mafic granulite unit. These, as well as other nearby hypersthene-bearing rocks, are the southwesternmost area of granulite metamorphism known to occur in the Middle Proterozoic basement of our central Blue Ridge mapping area. Detailed mapping and thorough heavy-mineral stream sediment sampling shows that hypersthene is not present to the east on the adjacent Canton and Sandymush Quadrangles (Merschat and Wiener, 1988). This indicates that Middle Proterozoic basement was either not uniformly at granulite grade over the entire central Blue Ridge or that the diagnostic granulite minerals were destroyed irregularly by later retrogressive metamorphism.

Based on projecting Paleozoic isograd trends as mapped by Hadley and Goldsmith (1963) on the Cove Creek Gap Quadrangle, less than a mile to the west, this field trip stop is between the garnet and staurolite isograds. There are no major structural complications or faults between the two on-strike areas. Thus, the presence of the Fines Creek granulite-grade rocks within this Paleozoic low-grade area is further evidence that two metamorphic events affected the rocks. The first was the Grenville-age granulite metamorphism, and the other was the better known Paleozoic Barrovian event.

31.1 Continue driving west on SR 1338.

32.4 In front of large road cut on northwest side of road, turn left onto SR 1355 (Panther Creek Road).

33.2 Cross poorly exposed contact between basement rocks behind us and Great Smoky ahead of us.

34.8 Enter Panther Creek Baptist Church parking area on SR 1384. Follow driveway and make a sharp left turn into upper parking lot.

34.9 Park in front of outcrop serving as a retaining wall.

STOP 12. Great Smoky Group at Panther Creek Church. The rocks exposed here are continuously traceable southwestward across the Pigeon River into the Great Smoky Group of the National Park. Based largely on the regional pattern, the strata in this vicinity are assigned to the Group's Copperhill Formation (North Carolina Geological Survey, 1985).

The exposure alongside the Church parking lot is dominated by staurolite-kyanite-garnet-biotite-muscovite schist with thin interlayers of metagraywacke and minor calc-silicate granofels (pseudodiorite). Whether or not to call the schist and the metagraywacke units, beds or compositional layers, depends on one's judgment as to how much transposition of original bedding has occurred.

The most obvious foliation surfaces are subhorizontal and axial planar with respect to the local folds. This foliation clearly cross cuts the steeply dipping schist and metagraywacke layers. Thus, this outcrop is evidently at the nose of a large recumbent fold. Here, F_1 folds S_0, and S_1 is axial planar to F_1. Discordance between foliation and bedding is common in Great Smoky Group rocks (and other units of the Ocoee Group), but is almost never found in other Blue Ridge rocks. As seen previously, both in the layered basement gneisses and in the Ashe Metamorphic Suite, the principal metamorphic foliation is parallel to the compositional layers at virtually every outcrop. The nearby ubiquitous occurrence of S_0 parallel to S_1, leads most geologists to infer the existence of innumerable F_1 isoclines. F_1 fold noses, however, are exceedingly difficult to find. Their rarity is usually attributed to shearing out of the fold hinges during transposition of S_0 into S_1.

At this outcrop, hand lens observation reveals the pervasive schistosity is tightly wrinkled and at many places is so tight that a "slip cleavage" is developed.

34.9 Leave parking lot. Turn left and continue driving on SR 1355.

37.8 Leave the Great Smoky and cross back into basement rocks.

39.1 Abandoned crushed stone quarry to left. Hadley and Goldsmith present a photograph from this quarry and identify the rock as migmatitic biotite-quartz-plagioclase gneiss (Hadley and Goldsmith, 1963, figure 6B and table 2).

40.6 Junction of SR 1355 with N.C. 209. Turn right onto N.C. 209.

40.7 Pass exposures of Stop 10 and continue south on N.C. 209.

43.6 Turn right onto entrance ramp to I-40 eastbound towards Asheville.

46.8 Leave the Interstate taking exit 27 towards U.S. 19-23 and Clyde.

48.0 From the right lane take exit labeled 19-23 North; 74 East to Clyde.

48.9 Turn right into parking lot at the Clyde Post Office. Outcrops are behind the building.

STOP 13. Basement rocks behind the Clyde Post Office. Variably weathered bedrock and large boulders behind the Clyde Post Office reveal some small-scale complexities found in the area. We correlate these rocks with the Middle Proterozoic basement.

Biotite gneiss and amphibolite are most abundant. Minor interlayers of muscovite-biotite gneiss are also present. Many of the amphibolite layers occur as disconnected blocks and some of the blocks display dismembered folds. At some places the rocks are locally migmatitic or megacrystic, which is undoubtedly attributed to high-grade metamorphic conditions. Here and elsewhere in the region, particularly near or beyond the sillimanite isograd, feldspathic megacrystic zones grade into pegmatitic neosomes. In these exposures the pegmatites commonly crosscut foliation and contain kinked or bent muscovite. Although we are very close to the Paleozoic kyanite-sillimanite isograd there is no kyanite or sillimanite visible here—a fact supporting our interpretation that these are basement rocks. Our experience has been that at extensive exposures of the Ashe, we almost always are able to find some calc-silicate pods or layers. The absence of calc-silicate rocks here suggests that the rocks do not belong to the Ashe Metamorphic Suite, thereby making a basement correlation more likely.

Mylonites, common in these exposures, truncate foliation and thus must be relatively young.

Perhaps the latest structures are small-scale faults. The fault surfaces are characterized by slickenslides and some are covered with the greenschist mineral chlorite.

49.0 Leave parking lot and turn left retracing route on U.S. 19-23-74. Stay in right lane.

49.4 Turn right following signs to I-40.

50.2 From right lane continue following signs to I-40 towards Asheville.

67.2 Leave I-40 at exit 44, labeled U.S. 19-23 towards West Asheville.

67.5 Stay in left lane and at end of exit ramp; turn left onto Smoky Park Highway.

67.8 From center of Smoky Park Highway turn left into the Holiday Inn parking lot. End of field trip.

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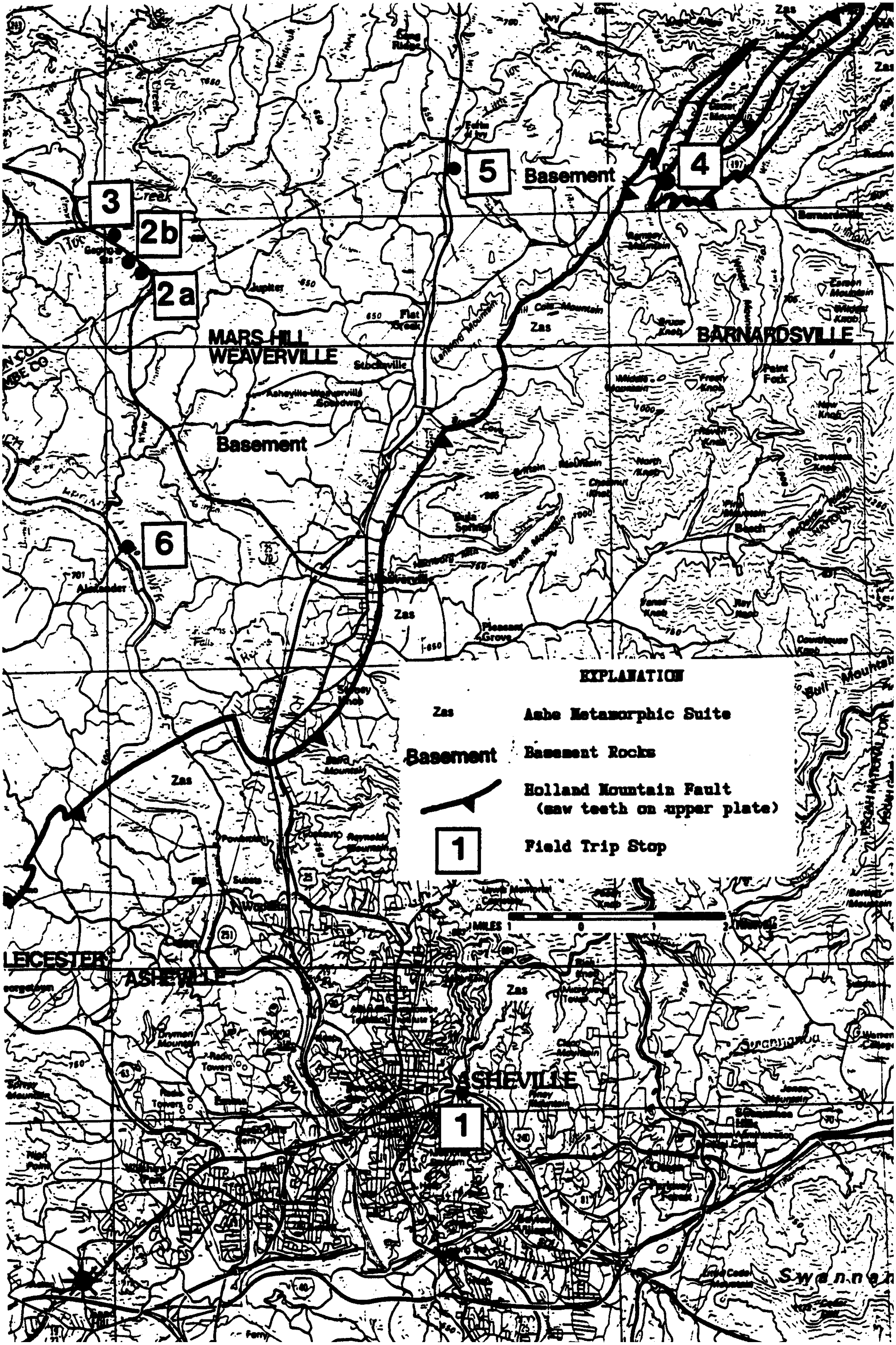
EXPLANATION
Zas Ashe Metamorphic Suite
Basement Basement Rocks
Holland Mountain Fault (saw teeth on upper plate)
1 Field Trip Stop
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2b
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Jupiter
Flat Creek
Stocksville
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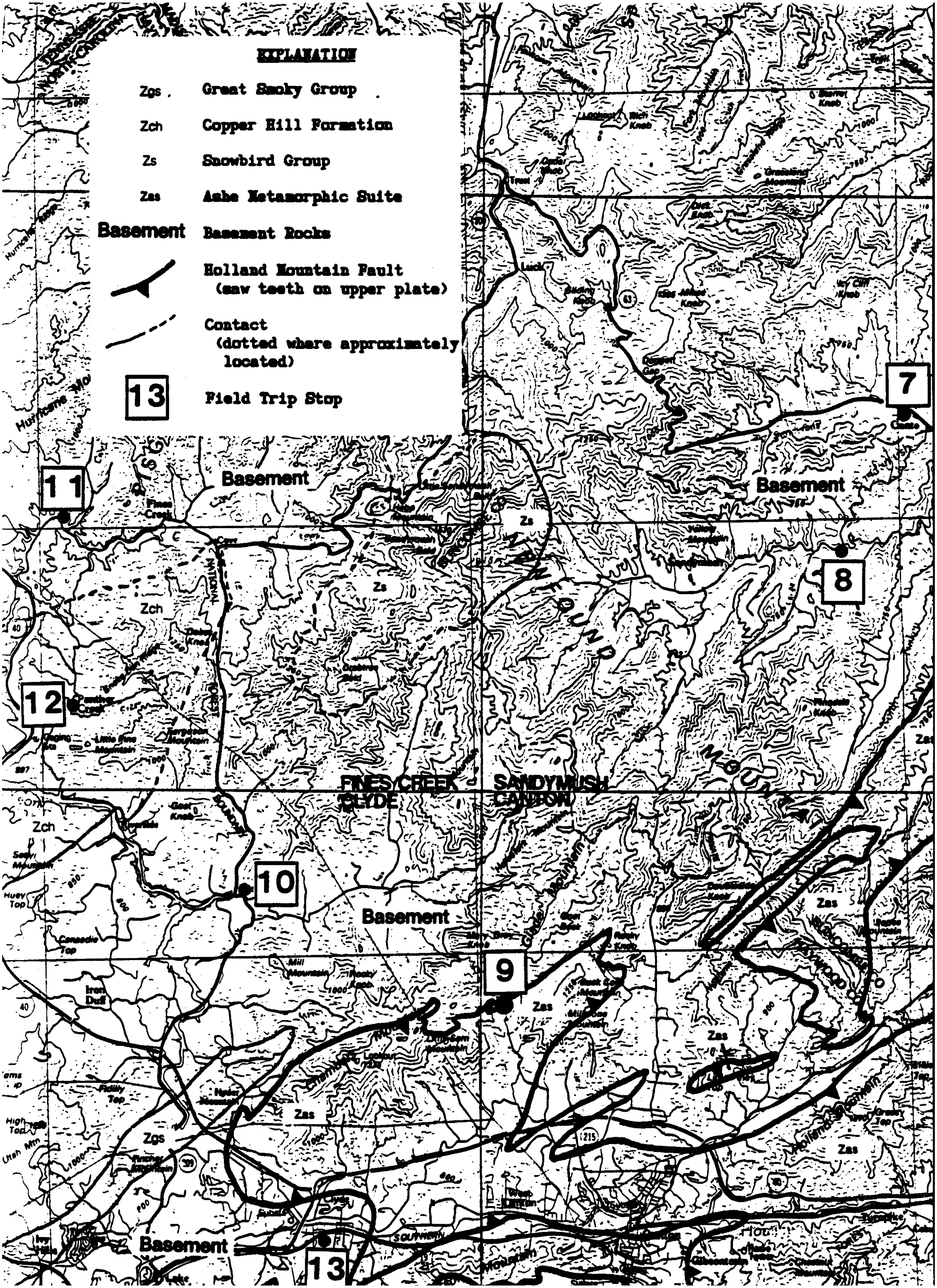
EXPLANATION
Zgs Great Smoky Group
Zch Copper Hill Formation
Zs Snowbird Group
Zas Ashe Metamorphic Suite
Basement Basement Rocks
Holland Mountain Fault (saw teeth on upper plate)
Contact (dotted where approximately located)
13 Field Trip Stop
7
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FINES CREEK
CLYDE
SANDYMUSH
CANTON
NORTH CAROLINA
TENNESSEE
Hurricane Mountain
Fines Creek
Panther Creek
Holland Mountain
Chambers Mountain
Clyde
Iron Duff
Utah Mtn
High Top
Huey Top
Mill Mountain
Rocky Knob
Coleman Mountain
Gibson