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GEOLOGY OF THE SANDYMUSH AND CANTON QUADRANGLES, NORTH CAROLINA

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by

Carl E. Merschat and Leonard S. Wiener

BULLETIN 90

NORTH CAROLINA GEOLOGICAL SURVEY

DIVISION OF LAND RESOURCES

DEPARTMENT OF NATURAL RESOURCES
AND COMMUNITY DEVELOPMENT

RALEIGH, 1988

Cover: Distinctly layered, heterogeneous, folded, and highly jointed gneisses and schists characteristic of the Earlies Gap Biotite Gneiss. Exposure is at the formation's type locality near Payne Chapel along Secondary Road 1394 west of its intersection with Secondary Road 1401, Sandymush Quadrangle, North Carolina.

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The Section conducts a number of basic and applied research projects in environmental geology, mineral resource exploration, mineral statistics, and systematic geologic mapping. Services constitute a major portion of the Section's activities and include identifying rock and mineral samples submitted by the citizens of the state and providing consulting services and specially prepared reports to agencies that require geological information.

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Jeffrey C. Reid
Chief Geologist

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GEOLOGY OF THE SANDYMUSH AND CANTON QUADRANGLES, NORTH CAROLINA

Bulletin 90

By Carl E. Merschat and Leonard S. Wiener

ABSTRACT

The bedrock geology of 122 square miles in the central Blue Ridge of North Carolina is the subject of this report. The rocks are mostly multi-deformed, amphibolite-facies gneisses and schists of Proterozoic age.

A Middle Proterozoic basement sequence underlies approximately 60 percent of the area and is divided into five map units. One is correlated with the Richard Russell Formation; four other units are here defined and formally named. They are the Earlies Gap Biotite Gneiss, the Sandymush Felsic Gneiss, the Spring Creek Granitoid Gneiss, and the Doggett Gap Protomylonitic Granitoid Gneiss. The Richard Russell Formation is dominated by discontinuous, well-foliated biotite gneiss layers. The biotite gneiss is commonly migmatitic and at places grades to metagraywacke. Interlayers of amphibolite are also present. The Earlies Gap Biotite Gneiss mostly contains well layered biotite gneiss with abundant interlayers of amphibolite and minor interlayers of calc-silicate granofels. Most felsic layers have granodioritic compositions. The formation is characterized by its wavy foliation and the common presence of thin layers of coarse-grained biotite flakes in the foliation planes. The Sandymush Felsic Gneiss is a very thick, heterogeneous sequence of layered rocks. Biotite granitic gneiss to quartz dioritic gneiss dominates. Interlayers of biotite schist, biotite gneiss, and amphibolite are common throughout the unit. Parts of the Sandymush Felsic Gneiss and the Earlies Gap Biotite Gneiss resemble each other very closely. The two units have a gradational boundary with each other and are essentially the same age. They may represent a related plutonic-volcanic accumulation with the protolith of the Sandymush Felsic Gneiss having originated as the more plutonic phase and the Earlies Gap representing the volcanic-dominated phase.

The Spring Creek Granitoid Gneiss is mostly a poorly foliated to foliated, coarse-grained biotite granitic gneiss. Mylonitic textures occur throughout the formation with approximately 15 percent of the unit consisting of mylonitic and protomylonitic interlayers. The Doggett Gap Protomylonitic Granitoid Gneiss is largely a distinctive, very coarse-grained gneissic granitic rock that has been extensively mylonitized. The Spring Creek and Doggett Gap protoliths were granitic bodies, here interpreted as having intruded the older Sandymush Felsic Gneiss.

Cover rocks, assigned to the Late Proterozoic, are locally represented by parts of the Ashe Metamorphic Suite and the Snowbird Group. The Ashe formed from a mixed assemblage of clastic sediments and minor volcanics. It is divided into two main subunits, one dominated by aluminous schist and the other dominated by metagraywacke to mica gneiss. Snowbird rocks are largely kyanite-garnet mica schist of pelitic origin interbedded with lesser metagraywacke and minor calc-silicate granofels. The Ashe overlies the basement rocks along a major thrust fault; the Snowbird nonconformably overlies the Spring Creek Granitoid Gneiss.

Small intrusive bodies are also present in the area. Included here are pegmatite, trondhjemite, dunite, and other altered mafic and ultramafic bodies.

Minor surficial deposits of alluvium occur in the flood plains and stream channels. Colluvial material, ranging from clay particles to huge boulders, covers much of the sloping land in the area.

A major, complex, deformational and metamorphic episode, correlated with the Middle Proterozoic Grenville orogeny, affected the older rocks in the area. Although later events have largely obliterated Grenville-age features, evidence for Proterozoic folding, amphibolite-grade metamorphism, intrusion of plutons, and regional mylonitization still remains. Paleozoic events, associated with the Taconic orogeny, include transposition of earlier features into the planes of a new pervasive regional foliation. Subsequently, a major tectonic feature, here named the Holland Mountain thrust fault, developed and the rocks with their contained

structures were then folded. Prograde Barrovian metamorphic effects are well displayed in pelitic units where porphyroblasts of staurolite, kyanite, or sillimanite are common. The kyanite-sillimanite isograd is closely located with its trace generally oblique to the regional structures. Therefore, much of the structural deformation must have preceded or, at the latest, been contemporaneous with the metamorphic peak. This Paleozoic metamorphic episode also had a retrogressive effect on some older, Middle Proterozoic rocks. Most notably, thin amphibolite layers were converted to biotite schist.

A mylonitic to protomylonitic fabric, likely developed in late Paleozoic time, is widely present. It occurs both as an overprint at various isolated outcrops and as more or less continuous zones up to a quarter mile wide and several miles long.

The orientations of several hundred joints were measured. The majority have a northwest-southeast trend and a lesser group has an east-west trend.

Mining has not been a major industry in the area. Mica, feldspar, sand and gravel, and stone were of greatest commercial value. Other commodities mined or prospected on a small scale include kaolin, soapstone, corundum (including sapphire), and olivine. During this study scheelite and monazite were discovered in many stream sediment samples. The scheelite is restricted to streams draining the Middle Proterozoic, amphibolite-bearing Earlies Gap and Sandymush Felsic Gneiss units. Monazite formed in the area's pelitic rocks where the metamorphic grade was sufficiently high.

INTRODUCTION

This report presents the results of a detailed study of the bedrock geology of the Sandymush and Canton 7 1/2-minute Quadrangles, North Carolina. The mapping project was prompted by the U.S. Department of Energy's announcement in early 1986 that a 105-square-mile area centered on the two quadrangles was one of a dozen sites in the eastern United States proposed as potentially acceptable for deep burial of high-level radioactive waste (U.S. Department of Energy, 1986). However, for this specific area no comprehensive geologic report had ever been prepared and the few existing geologic maps were only of reconnaissance nature. The present field-based investigation has resulted in the first detailed geologic maps and rock descriptions for the Sandymush-Canton area. The basic, factual data accumulated during the study reveal that local geologic conditions do not meet the Department of Energy's stated criteria for acceptability as a high-level radioactive-waste repository. (See the supplement to this report [Merschat and Wiener, 1988] for a discussion of the area's non-suitability as a repository.)

Location and Access

The study area covers parts of Buncombe, Haywood, and Madison Counties. It is bounded by latitudes 35°30' and 35°45' North, and longitudes 82°45' and 82°52'30" West. Canton, located in the southern part of the area, is the largest community and is the area's only incorporated town. Its population is about 4,700. Asheville, the largest city in the nearby region, is approximately 15 miles to the east (figure 1).

A major regional transportation corridor extends across the southern part of the two-quadrangle area. Included here are Interstate Highway 40, U.S. Routes 19, 23 and 74, and a line of the Norfolk Southern Railroad. State Highway 63 crosses the area's northern part and other state-maintained paved and unpaved roads extend into many valleys. Farm, logging, and development roads provide access to some of the ridges and hillsides. Much of the steeper ground and higher terrain, however, is best accessible by foot.

Physiographic Setting

The Sandymush-Canton area is centrally located within the widest part of the Blue Ridge province of the Appalachian highlands (Fenneman, 1938). In a major study encompassing the Blue Ridge, Hack (1982), divides the southern section of the province into several areas based on topographic similarities and differences. Portions of three of Hack's subdivisions are present in the Sandymush-Canton area. They are the Waynesville-Canton basin, the Asheville basin, and the Southern Blue Ridge highlands (figure 2).

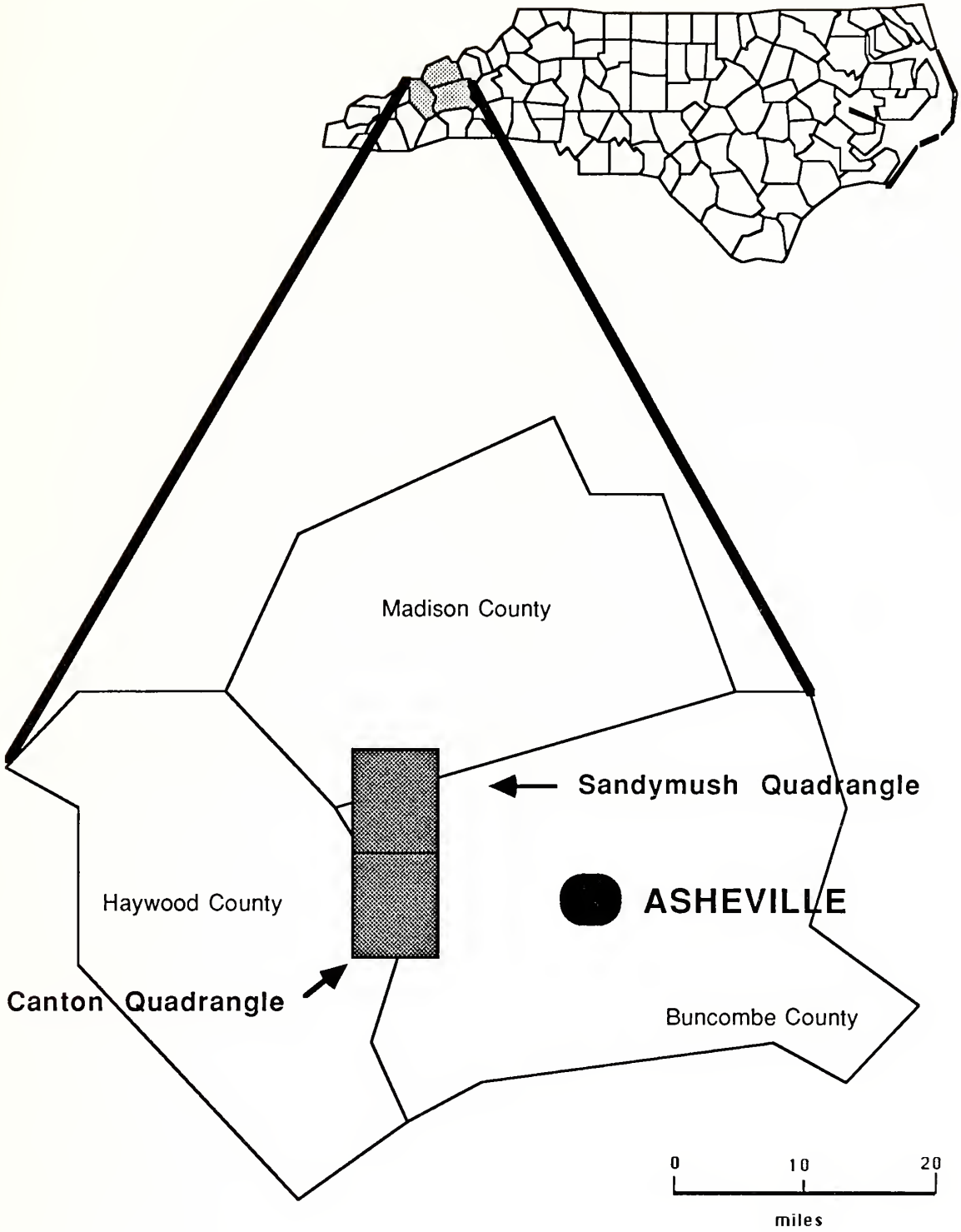


Figure 1. Location map for the Sandymush and Canton Quadrangles, North Carolina.

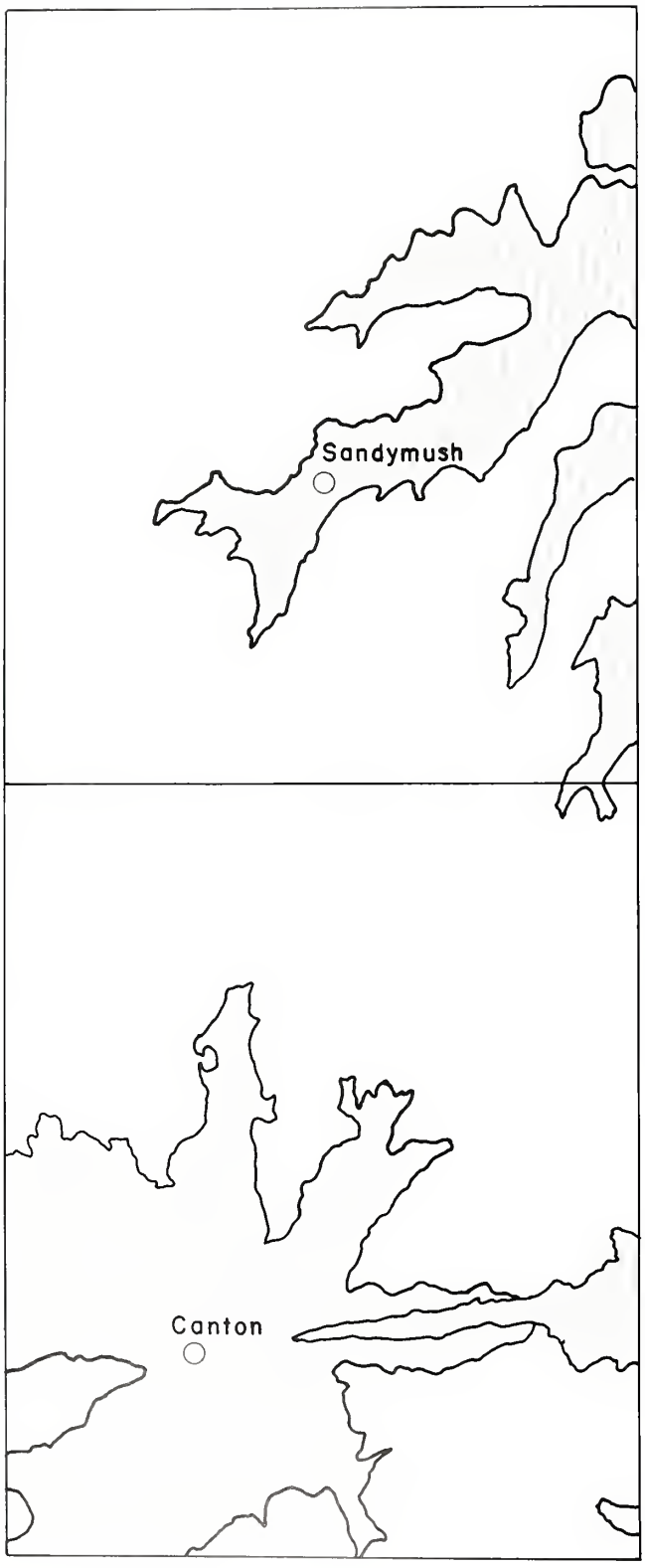


Figure 2. Physiographic subdivisions of the Sandymush and Canton Quadrangles after Hack (1982). Waynesville-Canton Basin (dotted), Asheville Basin (ruled), and Southern Blue Ridge Highlands.

The Canton-Waynesville basin is drained by the Pigeon River and its tributaries along with the upper reaches of Hominy Creek and several of its tributaries. The Pigeon River leaves the area at an elevation of about 2,540 feet; the low, rounded hills within the basin do not exceed 2,900 feet. The basin itself, especially its north and west margins, is fairly well delimited by the 2,800- to 2,900-foot contour interval. The basin floor was developed at about this level, but it is now being dissected with only the peaks of low knobs and ridges still preserving the 2,800- to 2,900-foot level.

Part of the Asheville basin extends finger-like into the Sandymush-Canton area. The basin is represented by valley areas along Sandymush Creek and some of its tributaries, especially North Turkey Creek, Sugar Creek, Willow Creek, and Little Sandymush Creek. The lowest elevation, about 2,000 feet, occurs where Sandymush Creek leaves the area. The basin floor gradually rises upstream to about 2,300 to 2,400 feet at which elevation the mountain hillsides are encountered. Low hills and rounded ridges, particularly from the vicinity of Canto westward to the Robinson Cove and Long Branch area, rise to elevations of 2,400 to 2,500 feet. (Canto is located along N.C. Highway 63 near the east edge of the Sandymush Quadrangle.) They seemingly mark the remnants of an old lowland that is now being dissected and consumed by Sandymush Creek.

The mountainous portion of the study area is included in Hack's (1982) Southern Blue Ridge highlands. Locally, the maximum elevation of 4,850 feet is on Little Sandymush Bald near the area's west edge. A number of other peaks and connecting ridges exceed 4,000 feet. Mountainside slopes of 40 to 50 percent are common throughout the area. Rock cliffs are present, but not dominant. The local relief is a thousand feet or more, typical of the Blue Ridge highlands.

Previous Work

Several earlier geologic maps include the

Sandymush and Canton Quadrangles. Those of the 19th century, notably Kerr's pioneer geologic map of North Carolina (1875), are now primarily of historical interest. About the turn of the century, the U.S. Geological Survey embarked on an ambitious, comprehensive topographic and geologic mapping effort in the Appalachian region. As part of this project, Arthur Keith mapped in the southern Appalachians in the early 1900's. His geologic map in the Sandymush-Canton area is at the intermediate scale of 1:125,000 (Keith, 1904). Keith's perceptive map and accompanying text remained the primary data source for many succeeding compilations including the 1958 Geologic Map of North Carolina (Stuckey, 1958).

In 1971, Hadley and Nelson published a new regional map at a scale of 1:250,000 (Hadley and Nelson, 1971). This map incorporated and set forth major changes in stratigraphic nomenclature and geologic interpretation. They compiled existing data and used much new information obtained from numerous road traverses and a few foot traverses.

In 1985, a major revision of the North Carolina State Geologic Map, scale 1:500,000, was published (North Carolina Geological Survey, 1985). Representation of the geology in the Sandymush-Canton area is based on the older maps, extrapolation of trends shown on all available published and unpublished work in nearby areas, and data from a few road traverses.

The three regional maps (Keith, 1904; Hadley and Nelson, 1971; North Carolina Geological Survey, 1985) have several stratigraphic elements in common. They all show a small area of metasedimentary rocks in the Little Sandymush Bald region. They also depict an area of granitic rocks in the northwestern part of the Sandymush Quadrangle. Aside from several small ultramafic bodies, the remainder of the two quadrangles is shown as underlain by a complex of gneisses and schists. These rocks have been interpreted and classified differently by the various authors.

Both Keith (1904) and Hadley and Nelson (1971) present cross sections that depict the geologic structure. However, these sections, especially those of Hadley and Nelson, are extremely generalized.

Several of the ultramafic bodies and corundum occurrences in the area are mentioned in Pratt and Lewis (1905), Hunter (1941), Penso (1981), and Hirt et al. (1987). Sketch maps of the large dunite body near Newfound Gap are in Hunter (1941, p. 66), Penso (1981), and Hirt et al. (1987).

A few pegmatite bodies located in the Sandymush and Canton Quadrangles have been prospected or exploited for muscovite mica or feldspar. The available statistics are tabulated by Lesure (1968, p. 90-93). Olson and Parker (1943) prepared a mine map of the Big Cove Mica Mine, the largest of these mines.

Several studies present small-scale maps showing the distribution of metamorphic index minerals in the Blue Ridge (Carpenter, 1970; Hadley and Nelson, 1971; North Carolina Geological Survey, 1985). These all show sillimanite in the southeastern part of the two quadrangles. Kyanite or kyanite-staurolite is shown occupying a broad band that trends diagonally across the center of the area. The northwestern corner of the Sandymush Quadrangle contains the lowest metamorphic-grade rocks of the study area.

Present Investigation

Geologic field work began in March, 1986 and was essentially completed in June, 1987. During the summer of 1986, stream sediment samples for a heavy mineral study were collected throughout the area. Much of December 1986, and January through March 1987 was spent doing laboratory work. During the summer and fall of 1987, additional traverses were made to provide more information in selected areas, and the remaining laboratory work was completed. Preparation of the map and text continued into 1988.

Standard field methods were used. The area was covered by a network of foot traverses, rock fabric orientations were measured with Brunton compasses, and field identification of rocks and minerals were based on hand-lens examination. Data were plotted directly on 7 1/2-minute field sheets, and pocket altimeters were useful aids in establishing field locations. The stream sediment samples were panned in the field and the concentrates were brought back for further concentration and study (see Appendix 1).

This investigation has resulted in the first detailed geologic maps and rock descriptions for the Sandymush and Canton Quadrangles. The present detailed work confirms the general distribution pattern for major rock classes shown on earlier maps. However, accurate location of the major unit boundaries is now established and subunits or minor units have been identified, delineated, and described. In addition, observations and interpretation of the area's geologic structures, metamorphic history, and economic mineral deposits are presented in this report.

ROCK DESCRIPTIONS

One result of past geologic investigations in the Blue Ridge has been the development of a stratigraphic framework for the area's rocks. It is now established that an old basement complex is overlain by younger groups of cover rocks. The cover rocks are largely metasediments; in contrast, the basement rocks appear to have a much greater plutonic and volcanic complement. At some places a profound unconformity separates the two, but at other places the boundary is a tectonic feature. Both sequences commonly contain monotonous and repetitive-looking rocks that do not contain fossils or other unique markers, thus severely hampering stratigraphic interpretations. In addition, they have a complex structure and exhibit an overriding, variable, and even multiple metamorphic imprint. Of the two, the distribution and internal stratigraphy of the cover rocks is better understood, at least in general terms. In the Sandymush and Canton Quadrangles, the cover is represented by parts of the Late Proterozoic Ashe Metamorphic Suite and the Snowbird Group.

The basement complex remains more difficult to decipher. These rocks are chiefly layered, biotite-bearing felsic gneisses and relatively massive granitoid gneisses, along with a substantial component of more mafic rocks. They are older than the cover rocks with many having Middle Proterozoic ages between 1.0 and 1.3 billion years. In this report, the more massive granitoid gneisses are interpreted as having intruded preexisting, layered gneisses. In the Sandymush and Canton Quadrangles five extensive basement rock units were distinguished during field work. One of these units is correlated with the Richard Russell Formation of Georgia; for the others new formational names were needed. The formational names here introduced are: the Earlies Gap Biotite Gneiss, the Sandymush Felsic Gneiss, the Spring Creek Granitoid Gneiss, and the Doggett Gap Protomylonitic Granitoid Gneiss (table 1).

Small intrusive bodies are also present. These include pegmatite, trondhjemite, dunite, other altered mafic and ultramafic bodies, and four small talc bodies presumed to be derived from ultramafic intrusives. In addition, there are also surficial deposits of alluvium and colluvium.

Rock descriptions, presented on the following pages, are based on routine observations in the field and petrographic examination of selected samples. Several standard terms are used throughout the descriptions to describe grain size and thickness of compositional layers. These terms and their quantitative limits are listed in table 2.

Petrographic study and modal analysis was greatly aided by use of thin sections selectively stained for both K-feldspar and plagioclase. Through staining, misidentification of the large proportion of untwinned feldspar grains was avoided. Rock names follow the plutonic rock terminology of the I.U.G.S. classification system (Streckeisen, 1976).

Table 1. *Names and type areas of newly defined formations (refer to figure 3 for road locations)*

Name	Source of Geographic Name	Type Locality	Names Used on Previous Reconnaissance Maps
Doggett Gap Proto-mylonitic Granitoid Gneiss	Doggett Gap, at the Buncombe County-Madison County boundary, Sandymush Quadrangle	Roadside outcrops along N.C. Highway 63, from 0.4 miles west of Doggett Gap to 0.7 miles east of Doggett Gap	Max Patch Granite (Keith, 1904); Max Patch Granite and Cranberry Gneiss (Hadley and Nelson, 1971); Biotite granitic gneiss (N.C. Geological Survey, 1985)
Spring Creek Granitoid Gneiss	Spring Creek community, Madison County, Spring Creek Quadrangle	Roadside outcrops along N.C. Highway 63, from 0.4 to 1.2 miles northwest of Doggett Gap	Cranberry Granite (Keith, 1904); Max Patch Granite and Cranberry Gneiss (Hadley and Nelson, 1971); Biotite granitic gneiss (N.C. Geological Survey, 1985)
Sandymush Felsic Gneiss	Sandymush community, Buncombe County, Sandymush Quadrangle	Outcrops along N.C. Highway 63, 2,000 feet west of confluence of Sandymush Creek and Little Sandymush Creek	Carolina Gneiss (Keith, 1904); Layered gneiss and migmatite (Hadley and Nelson, 1971); Biotite granitic gneiss (N.C. Geological Survey, 1985)
Earlies Gap Biotite Gneiss	Earlies Gap, Buncombe County, Sandymush Quadrangle	Extensive roadside outcrop along SR 1394, approximately 300 feet southwest of its junction with SR 1401	Carolina Gneiss and Roan Gneiss (Keith, 1904); Layered gneiss and migmatite (Hadley and Nelson, 1971); Biotite granitic gneiss (N.C. Geological Survey, 1985)

Richard Russell Formation

FIELD OCCURRENCE AND DESCRIPTION

The Richard Russell Formation was named by Gillon (1982) and formalized by Nelson and Gillon (1985) for usage in Georgia and North Carolina. Rocks correlated with the Richard Russell Formation crop out in the southwestern corner of the Canton Quadrangle. They underlie about five percent of the quadrangle and consist principally of biotite gneiss with lesser metagraywacke and amphibolite. Aluminous layers common to the Richard Russell in its type area in Georgia, about 75 miles to the southwest, are not present. Migmatization is locally present throughout.

Biotite gneiss layers make up 85 percent of the Richard Russell Formation. The unweathered rock is very light gray to medium light gray. Discontinuous layering is very prominent and varies from medium to thick. The biotite gneiss is commonly migmatitic with neosome pods and stringers composed chiefly of quartz and feldspar. Locally, the rocks have a high enough quartz content to resemble metagraywacke (see figure 4).

Table 2. *Grain size and layer thickness terms used in rock descriptions (grain size after Williams et al., 1954; layer thickness adapted from Ingram, 1954)*

Grain Size	Layer Thickness
Very Coarse	Very Thick
--- 3 cm ---	--- 1 meter ---
Coarse	Thick
--- 5 mm ---	--- 30 cm ---
Medium	Medium
--- 1 mm ---	--- 10 cm ---
Fine	Thin
	--- 1 cm ---
	Very Thin

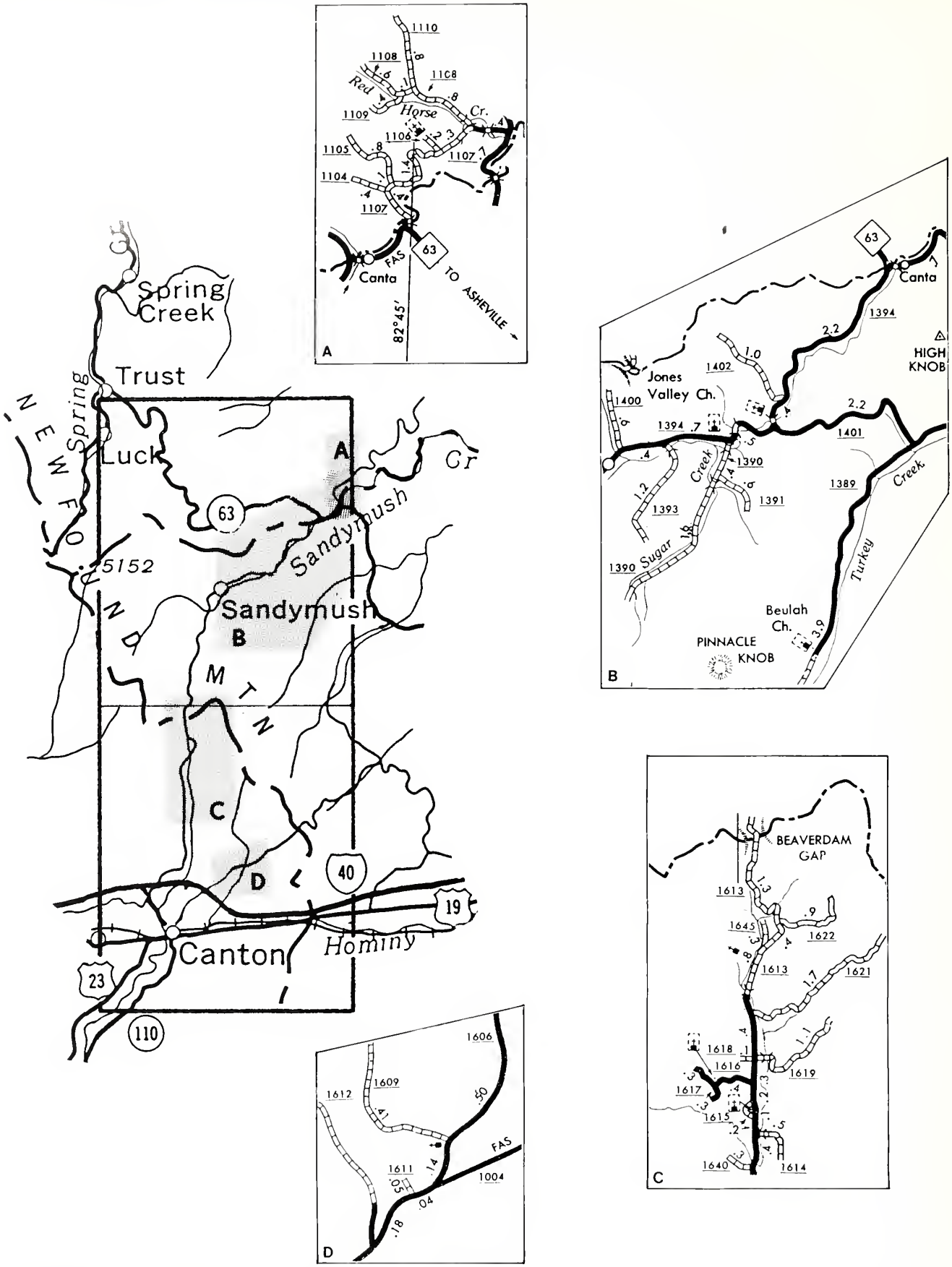


Figure 3. North Carolina Secondary Roads in parts of the Sandymush and Canton Quadrangles. *A*, Worley Cove section, Madison County. *B*, Earlies Gap-Payne Chapel-Sandymush area, Buncombe County. *C*, Wilson Cove-West Cove area, Haywood County. *D*, Hominy Grove area, Haywood County. Underlined four-digit numbers are Secondary Road numbers; decimal numbers show distance (in miles) between road intersections.

Amphibolite layers make up about 15 percent of the Richard Russell Formation on the Canton Quadrangle. They are interlayered with biotite gneiss and metagraywacke and have variable thicknesses ranging up to about ten meters. The amphibolite layers are commonly discontinuous to podiform in shape and are dark greenish gray to greenish black.

PETROGRAPHY

The biotite gneiss layers are well foliated at a scale from a millimeter to centimeters. The felsic portion of the gneiss has a granitic composition. The modal composition is shown in table 3. The garnet content is particularly variable and as estimated in the field, may be as much as 20 percent locally.

The amphibolite is well foliated and exhibits a nematoblastic texture. Mineralogically it is similar to amphibolites and hornblende-biotite gneisses in the Carolina Gneiss in the Dellwood Quadrangle (Hadley and Goldsmith, 1963).

AGE, CONTACT RELATIONSHIP, AND PROTOLITH

Radiometric age data are not available for the Richard Russell Formation in the Canton Quadrangle or indeed anywhere else. Nelson and Gillon (1985) class the Richard Russell as Late Proterozoic. Most previous workers have called these rocks Precambrian or Late Precambrian. The Geologic Map of North Carolina (North Carolina Geological Survey, 1985) classifies rocks along strike from the type Richard Russell as Late to Middle Proterozoic. However, in the study area a possible connection of the Richard Russell with the Earlies Gap beneath the Holland Mountain thrust sheet favors the Middle Proterozoic age assignment.

In the Canton Quadrangle, the Richard Russell Formation has a minimum thickness of 2,000 feet. It is everywhere in fault contact with

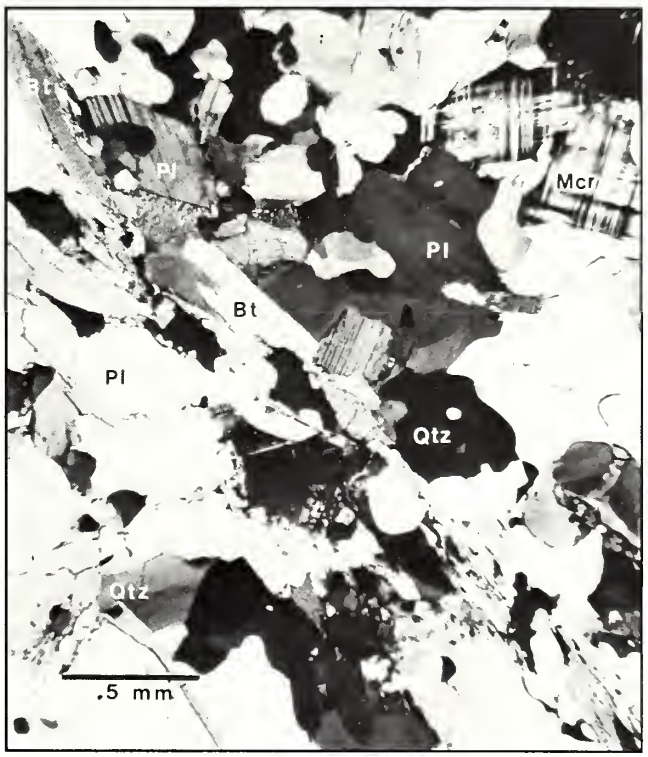


Figure 4. Richard Russell Formation. *Above*, Light-colored migmatitic biotite gneiss with prominent medium to thick layering. Outcrop is 3 miles southwest of Canton along N.C. Highway 215. *Below*, Photomicrograph of typical biotite gneiss showing granoblastic texture in felsic layers dominated by quartz (Qtz), plagioclase (Pl), and microcline (Mcr). Schistosity is marked by lepidoblastic biotite (Bt). Crossed polarizers, sample 2193.

Table 3. *Modal analyses (in percent) of Richard Russell Formation*

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Sericite
1768	663,350N; 867,900E	Biotite Gneiss	34.6	28.2	18.8	13.8	2.6	0.4	0.0	0.6	1.0
2189	665,000N; 853,350E	Biotite Gneiss	57.0	12.0	25.8	3.2	0.8	0.4	0.2	0.4	0.2
2193	659,850N; 848,150E	Biotite Gneiss	26.4	29.6	24.2	15.4	4.2	0.2	0.0	0.0	0.0
		Average	39.3	23.3	22.9	10.8	2.5	0.3	0.1	0.3	0.4
		Minimum	26.4	12.0	18.8	3.2	0.8	0.2	0.0	0.0	0.0
		Maximum	57.0	29.6	25.8	15.4	4.2	0.4	0.2	0.6	1.0
		Std Dev	15.8	9.8	3.7	6.6	1.7	0.1	0.1	0.3	0.5

the Ashe Metamorphic Suite and thus, its stratigraphic position with respect to other map units cannot be determined from the surface geologic map.

In the type area, the protolith of the Richard Russell Formation originated from clastic sediments (Gillon, 1982). In the Canton Quadrangle, the high feldspar content of some biotite gneisses may indicate a felsic volcanic component also. The interlayered amphibolites undoubtedly have a mafic volcanic origin, perhaps as tuffs or thin flows or sills.

Earlies Gap Biotite Gneiss

FIELD OCCURRENCE AND DESCRIPTION

The Earlies Gap Biotite Gneiss crops out over much of the northern half of the Canton Quadrangle and continues in a two-mile-wide band through the eastern half of the Sandymush Quadrangle. This two-mile-wide band is designated as the type area and contains most of the good accessible exposures discussed below. The type locality is in Buncombe County along the south side of SR 1394 west of its intersection with SR 1401. (The abbreviation, SR, is used in this report for Secondary Road; see figure 3 for location of Secondary Roads.) This exposure, an extensive road cut in the vicinity of Payne Chapel, typifies the distinctly layered, heterogeneous, migmatitic, folded, and highly jointed character of the map unit (see figure 5).

Smaller, isolated outcrops are characterized and dominated by any one or more of these features. Another exposure representative of the formation occurs at the intersection of SR 1394 and SR 1390, the road along Sugar Creek. Other good, easily accessible exposures are along SR 1401 for about 0.4 miles west from Earlies Gap. Nearly continuous bedrock exposures occur in the headwater streams of North Turkey Creek, in the steep drainages on Pinnacle Knob, and in the small, but steep stream channels that drain the ridge that trends southwest from Earlies Gap. In the Canton Quadrangle good exposures occur in the small steep stream valleys on the sides of Doubleside Knob.

The Earlies Gap Biotite Gneiss is a sequence, at least 4,000 feet thick, of well foliated, highly layered biotite gneiss. It is interlayered with thinly layered amphibolite, layered biotite granitic gneiss, and rare calc-silicate granofels or muscovite-biotite gneiss. The interlayering occurs at all scales from hand sample to outcrop to map scale. The Earlies Gap Biotite Gneiss is characterized by a diagnostic wavy foliation and thin layers of coarse-grained biotite flakes. The wavy foliations vary in thickness from about one millimeter to about a centimeter.

Rocks of the Earlies Gap Biotite Gneiss are locally migmatitic, most notably in the Canton Quadrangle near the southern end of the outcrop belt. The leucocratic neosome, composed chiefly 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, the dominant rock type, varies in color from very light gray to medium light gray; its color reflects the biotite content; that is,

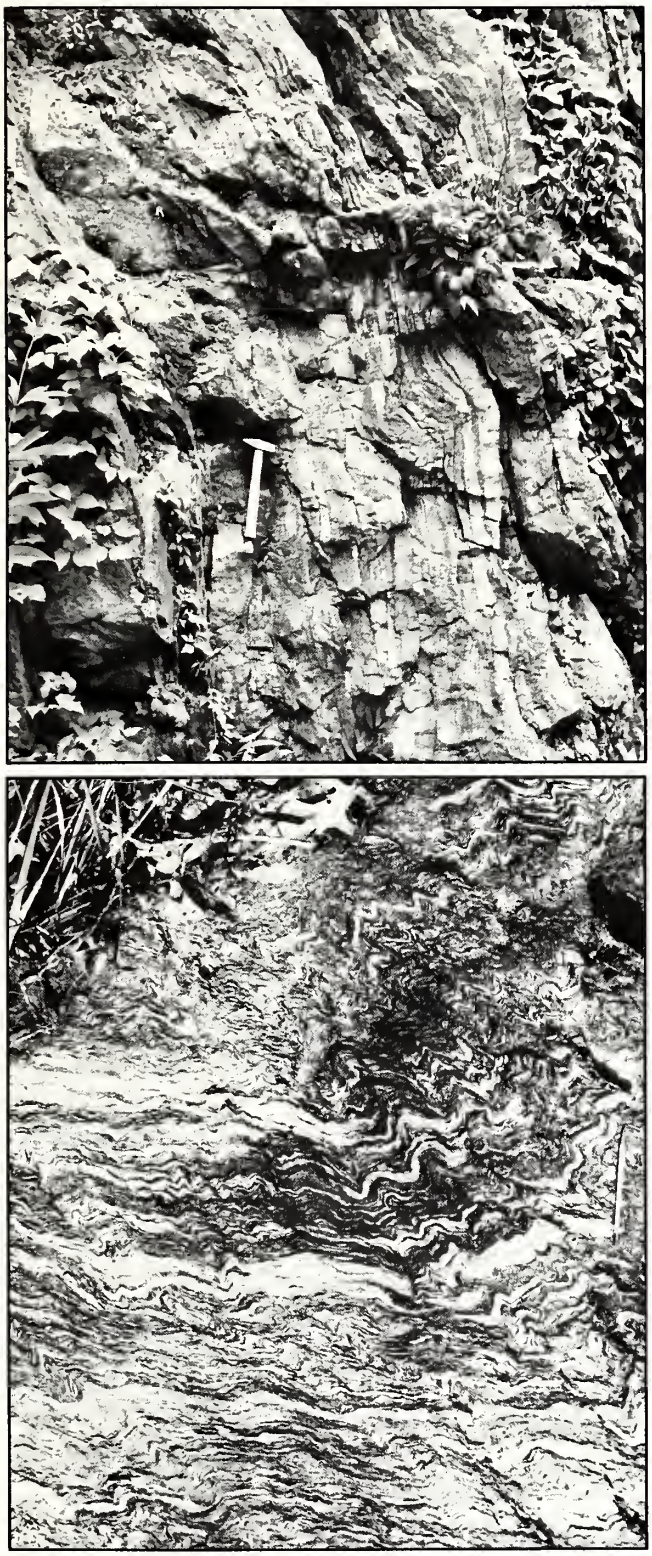


Figure 5. Earlies Gap Biotite Gneiss. *Above*, Medium- to thick-layered biotite gneiss. Three-foot-thick amphibolite is left of hammer. Outcrop is 500 feet southwest of Payne Chapel along SR 1394. *Below*, Well-foliated, distinctly layered biotite gneiss with abundant, highly wrinkled schistose layers. Pencil, upper center, is 6 inches long. Outcrop is 0.3 miles northeast of Payne Chapel along SR 1394.

the higher the biotite content, the darker the rock. It is well foliated on a millimeter to a centimeter scale. Layering ranges from centimeters to meters in thickness. As the biotite content increases, the foliation and layering become thinner and the gneissic character of the rock becomes more schistose. Interlayered with the biotite gneisses 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 is the second most abundant rock type in the Earlies Gap Biotite Gneiss, occurring as thin layers, lenses, and pods. They range in thickness from a few millimeters to meters and are 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 is mapped as an amphibolite-dominant phase and underlies about five percent of the quadrangle. Keith (1904) too, indicates abundant amphibolite in this area and shows it extending on to the northeast under the now abandoned term "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 of the rapid weathering of the dominant mafic layers in this unit. The best exposures occur along SR 1394, approximately one-half mile south of Canto on the Sandymush Quadrangle. Other good exposures occur on the northern slopes of High Knob near the eastern edge of the quadrangle. Interlayered calc-silicate granofels is much less abundant than amphibolite and occurs as pod-like masses.

PETROGRAPHY

In thin section, biotite gneiss exhibits a lepidoblastic to equigranular granoblastic texture. Lepidoblastic textures dominate as this unit has a high biotite content. Locally, mylonitic textures

are common. Modal analyses of various samples are given in table 4.

The felsic portion of the biotite gneiss ranges between tonalitic and granitic with the bulk of the felsic layers being granodioritic in composition (figure 6). The biotite content, naturally, is highest in the more schistose layers. The biotite content of these interlayers is estimated at over 80 percent. Rare pleochroic halos occur in the biotite.

Muscovite occurs in very minor amounts 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, thin layered to podiform. It is commonly interlayered and mapped with amphibolite. Only two small bodies of calc-silicate granofels are separately mapped within the Earlies Gap Biotite Gneiss. They both occur along North Turkey Creek near the eastern edge of the Sandymush Quadrangle. Calc-silicate granofels consists of plagioclase, K-feldspar, quartz, epidote-group minerals, diopside, and other alteration minerals. Characteristically, the diopside weathers rapidly to diagnostic spots of yellowish-brown limonite.

AGE, CONTACT RELATIONSHIP, AND PROTOLITH

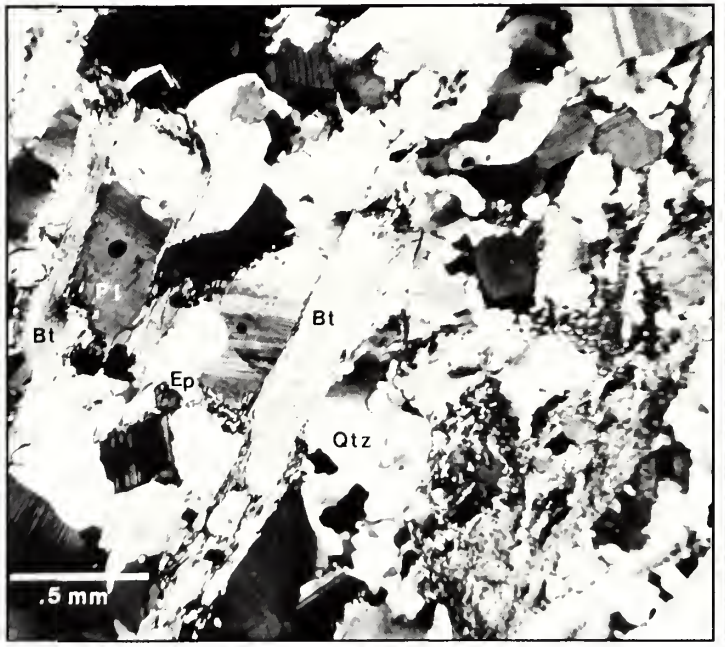
An absolute age for the Earlies Gap Biotite Gneiss has not been determined in the study area. Reconnaissance observations indicate the formation interfingers and correlates with rocks to the north and northeast on the Marshall, Mars Hill, and Barnardsville Quadrangles. It correlates well with portions of a biotite-hornblende migmatite unit on the Mars Hill Quadrangle (Merschat, 1977) whose granitic interlayers are dated at 1214 ± 83 million years (Fullagar et al., 1979; Rankin, 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). These rocks have an age of 1270 ± 44 million years (Fullagar, 1983). The Earlies Gap Biotite Gneiss may indicate downstrike lithologic changes resulting from original variations of the protolith and from a more thorough retrogression of some mafic rocks. 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 amphibolitic basement complex of the intervening Marshall Quadrangle (Brewer, 1986), and also less mafic than the biotite-hornblende migmatite unit of the Mars Hill Quadrangle. Based on the above described relations, the Earlies Gap Biotite Gneiss is most likely a Middle Proterozoic unit with an age of about 1.2 to 1.3 billion years.

The contact between the Earlies Gap Biotite Gneiss and rocks of the Ashe Metamorphic Suite is the Holland Mountain thrust fault. This contact is readily mapped on the basis that muscovite and aluminous minerals are virtually absent from the Earlies Gap Biotite gneiss, but are very common in the Ashe Metamorphic Suite. The presence or absence of muscovite and aluminous minerals makes this boundary one of the most easily distinguished contacts in the central Blue Ridge of western North Carolina. The contact between the Earlies Gap Biotite Gneiss and the Sandymush Felsic Gneiss is gradational in nature. Both formations contain similar rock types, thereby making the correct formational assignment of individual samples or some small outcrops uncertain.

The protolith for the Earlies Gap Biotite Gneiss is thought to have been a thick accumula-

Table 4. *Modal analyses (in percent) of Earlies Gap Biotite Gneiss*

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Carbonate
107	732,450N; 882,750E	Amphibolite	12.4	23.0	0.0	23.8	0.0	2.2	0.4	2.0	0.0	33.6	2.4	0.2	0.0
Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Carbonate
57	723,550N; 883,300E	Biotite Granodiorite Gneiss	35.0	35.0	15.4	13.8	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Carbonate
48	723,500N; 881,100E	Biotite Tonalite Gneiss	32.4	40.0	2.4	22.4	0.0	1.8	0.4	0.0	0.6	0.0	0.0	0.0	0.0
951	729,100N; 880,800E	Biotite Tonalite Gneiss	56.2	36.6	2.0	0.8	4.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
		Average	44.3	38.3	2.2	11.6	2.1	0.9	0.2	0.1	0.3	0.0	0.0	0.0	0.0
Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Carbonate
498	705,500N; 868,450E	Granitic Gneiss	43.8	29.6	25.0	0.0	0.0	0.8	0.0	0.8	0.0	0.0	0.0	0.0	0.0
Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Carbonate
516	688,000N; 664,750E	Mylonitic Amphibolite	1.8	49.6	0.0	14.6	0.0	0.2	0.0	0.4	0.4	31.8	1.2	0.0	0.0
Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Carbonate
513	688,100N; 664,200E	Mylonitic Biotite Gneiss	15.4	21.6	0.0	56.4	0.2	0.6	0.8	0.0	3.2	0.0	0.0	0.0	1.8



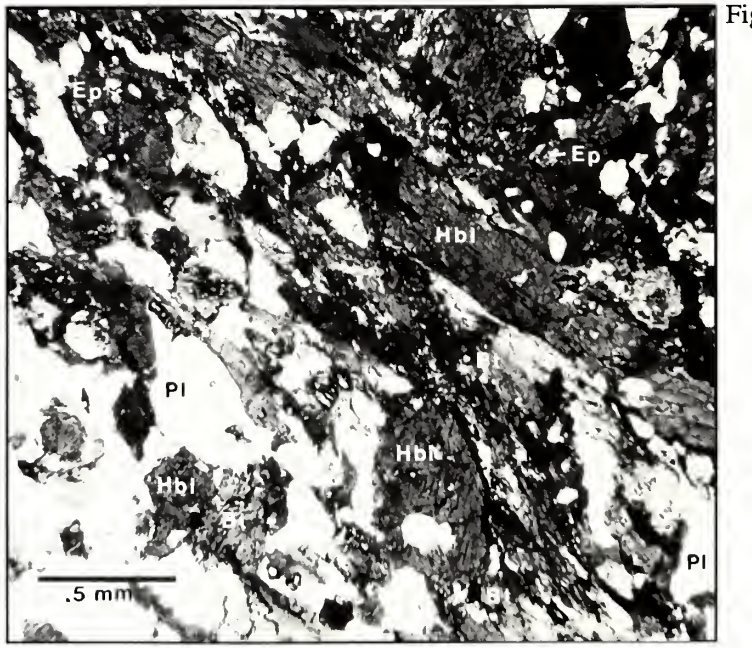


Figure 6. Earlies Gap Biotite Gneiss. *Left*, Biotite tonalite gneiss showing typical lepidoblastic texture. Mortar structure and granulation of some grains indicate incipient mylonitization. Composed mostly of plagioclase (Pl), biotite (Bt), quartz (Qtz), and minor epidote (Ep). Crossed polarizers, sample 48. *Right*, Amphibolite. Abundant untwinned plagioclase (Pl), hornblende (Hbl), biotite (Bt), epidote (Ep), opaques, and quartz (Qtz). Note biotite replacing hornblende. Crossed polarizers, sample 107.

tion of rapidly repeating thin mafic and felsic volcanic rocks. The well developed layering characteristic of the dominant biotite gneiss suggests a well layered protolith. The low quartz content tends to preclude a sedimentary origin, although rare interlayers of metasedimentary rock may exist locally.

Sandymush Felsic Gneiss

FIELD OCCURRENCE AND DESCRIPTION

The Sandymush Felsic Gneiss extends diagonally across the Sandymush Quadrangle and the northwest corner of the Canton Quadrangle. It underlies approximately 50 square miles of the two quadrangles. The type locality is on the south side of N.C. Highway 63 about 2,000 feet west of the confluence of Sandymush Creek and Little Sandymush Creek. Other easily accessible exposures are along SR 1394 from where Sugar Creek joins Sandymush Creek west to Clark Branch. The best exposures, however, occur in the steep valleys of small headwater tributary streams of Sandymush, Little Sandymush, and Willow Creeks.

The Sandymush Felsic Gneiss is a monotonous, repetitive sequence of layered rocks perhaps more than 15,000 feet thick. It consists 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, except calc-silicate granofels, are widespread and common throughout this heterogeneous map unit.

Biotite granitic gneiss to quartz dioritic gneiss layers are dominant. 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 biotite granitic- to quartz dioritic gneiss layers is variable. At some outcrops the layering is measured in millimeters, at others in centimeters, and at still others in meters. As the biotite content increases, the rock becomes schistose. Grain size varies from coarse to fine. The texture is equigranular, but where there has been local mylonitization it is inequigranular. Fresh color ranges from very light gray to very pale orange to medium light gray. The weathered color generally reflects the amount and degree of iron oxide staining. The felsic gneiss layers are repeatedly interlayered with amphibolite layers, many of which are very thin. Most amphibolite layers are continuous at the hand sample and outcrop scale, but are discontinuous at map scale (figure 7).

Locally, the thin amphibolite interlayers are retrograded. These retrograded layers have a high biotite content which makes them difficult to distinguish from other biotite-rich layers.

Calc-silicate granofels is relatively rare, but where observed it is associated and interlayered with amphibolite. The calc-silicate layers occur discontinuously and are abundant enough to distinguish separately at map scale only in one area along Willow Creek on the Sandymush Quadrangle.

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

PETROGRAPHY

The felsic layers have compositions ranging from quartz-rich granitoid to quartz diorite or tonalite but the majority have a granitic composition. The chief texture exhibited in the felsic layers is granoblastic or lepidoblastic depending on the biotite mica content. The dark colored, low-felsic bands have a high biotite content and are strongly lepidoblastic. Modal compositions are shown in table 5.

Amphibolites are very abundant within the Sandymush Felsic Gneiss. They occur as layers, lenses, and pods that vary in thickness from a few millimeters to meters. In several areas they are abundant enough to be mapped as separate units. Nematoblastic texture is dominant.

AGE, CONTACT RELATIONSHIP, AND PROTOLITH

The Sandymush Felsic Gneiss is one of the oldest rock units on the maps. Although not dated in the local area, it 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 have an age of 1214 ± 83 million years (Fullagar et al., 1979; Rankin, 1983). Granitic gneiss layers from the biotite granitic gneiss unit yield an age of 1270 ± 44 million years (Fullagar, 1983). The Sandymush Felsic Gneiss of the Sandymush and Canton Quadrangles is a little more felsic and less mafic than equivalent units to the north and northeast. The mafic layers are thinner, less abundant, and more altered 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. It is possible that the mafic character of rocks in the Sandymush and Canton Quadrangles was somewhat altered or obliterated by Paleozoic metamorphism. The amphibolites are mostly retrogressed to biotite gneisses and schists, thereby producing the apparent change in present character of these rocks to the southwest.

The boundary between the Sandymush Felsic Gneiss and the Earlies Gap Biotite Gneiss is a gradational stratigraphic contact. Felsic gneiss, including biotite granitic gneiss to quartz dioritic gneiss, dominates in the Sandymush Formation. In contrast, biotite gneiss dominates in the Earlies Gap. The disappearance of both coarse-grained biotite and the characteristic wavy foliation surfaces of the Earlies Gap help mark the boundary between it and the Sandymush Felsic Gneiss. To the northwest, the Spring Creek Granitoid Gneiss and the Doggett Gap Protomylonitic Granitic Gneiss are thought to be intrusive into the Sandymush Felsic Gneiss. However, the original relations are clouded by widespread transposition and mylonitization which mask and modify the true nature of the contacts.

The protolith for the Sandymush Felsic Gneiss was likely a thick plutonic-volcanic sequence of rocks. Felsic material dominated, in contrast to the mixed mafic and felsic volcanic protolith of the Earlies Gap Gneiss.

Spring Creek Granitoid Gneiss

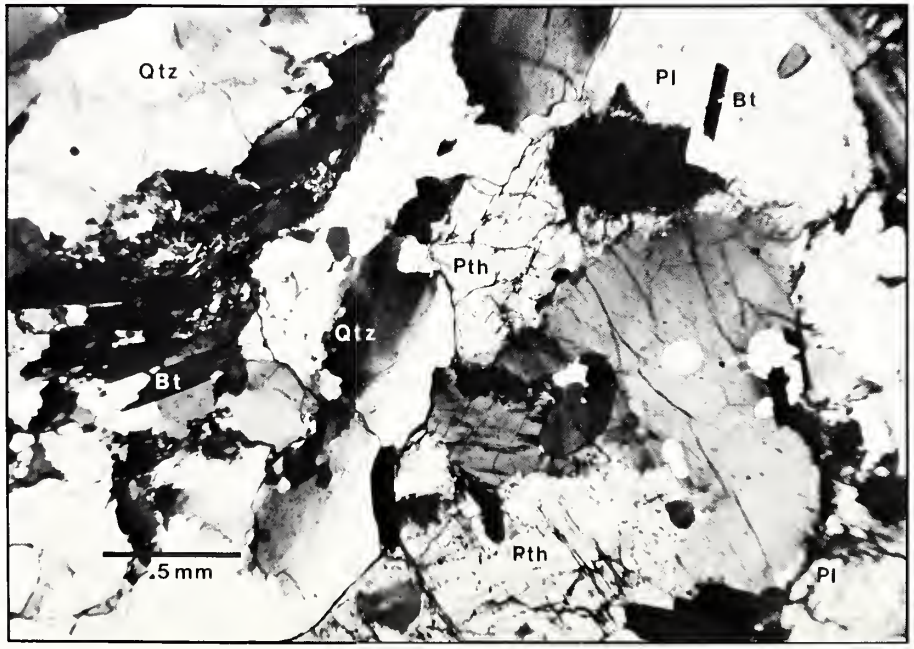
FIELD OCCURRENCE AND DESCRIPTION

The Spring Creek Granitoid Gneiss crops out in the northwest part of the Sandymush Quadrangle. It covers approximately 20 percent of the quadrangle. The type locality is along N.C. Highway 63 west of Doggett Gap where there are intermittent roadside exposures for approximately 0.8 of a mile. The exposures start approximately 0.4 of a mile northwest of Doggett Gap and continue along the highway to the vicinity of Mt. Pleasant Church. Other typical exposures are along N.C. Highway 209 in the northwesternmost corner of the Sandymush Quadrangle and the adjoining Spring Creek Quadrangle.

The Spring Creek Granitoid Gneiss, at the very least 4,000 feet thick, is composed primarily of coarse-grained biotite granitic gneiss (figure 8). Also present are interlayers of layered biotite granitic gneiss, protomylonitic to mylonitic granodioritic gneiss, amphibolite, and rare calc-silicate granofels.

The coarse-grained biotite granitic gneiss is light gray, mottled with pinkish gray to pale reddish brown. The gneiss is poorly foliated to foliated. Most outcrops exhibit very thick to medium layering. The coarse-grained biotite granitic gneiss makes up about 60 percent of the formation.

Layered biotite granitic gneiss is similar to the coarse-grained biotite granitic gneiss, except it is more highly foliated and exhibits less massive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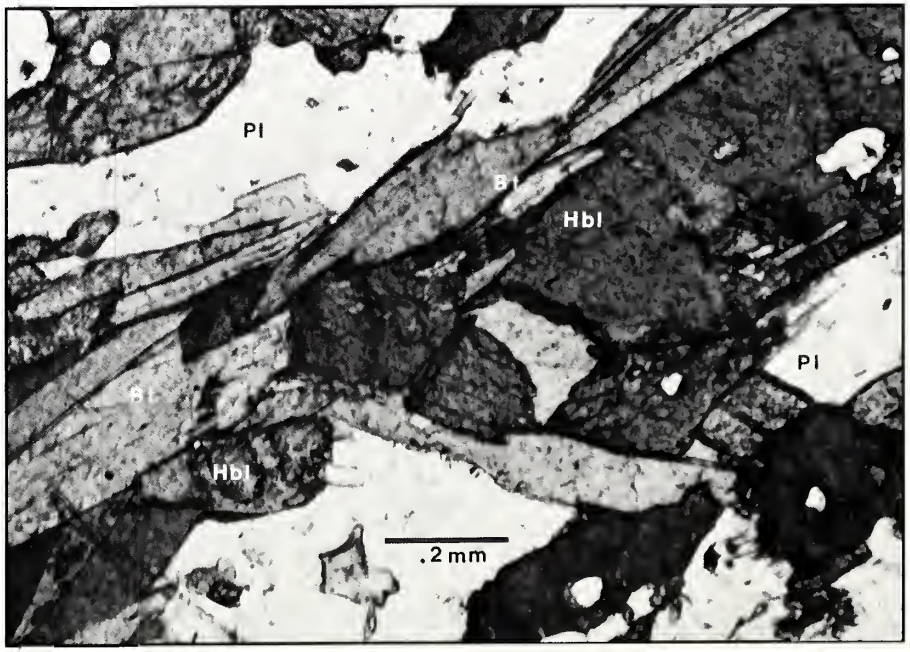
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Figure 7. Sandymush Felsic Gneiss. [Facing page] *Upper left*, Light-colored biotite granitic gneiss. Layering and a few foliation joints are nearly vertical. Roadside outcrop 0.6 mile east of Little Sandymush Church, N.C. Highway 63. *Lower left*, Photomicrograph of biotite granitic gneiss showing typical granoblastic texture. Plagioclase (Pl), quartz (Qtz) with undulatory extinction, perthite (Pth), and biotite (Bt). Crossed polarizers, sample 4. *Upper Right*, Massive amphibolite. Foliation is nearly vertical. Massive layer on right exhibits spheroidal weathering. Hammer rests on two well developed joint surfaces. Exposure in abandoned roadside quarry 0.8 miles southeast of Doggett Gap along N.C. Highway 63. *Lower right*, Photomicrograph of amphibolite with nematoblastic texture. Biotite (Bt) is replacing hornblende (Hbl); abundant untwinned plagioclase (Pl) is present. Crossed polarizers, sample 165-a.

Table 5. *Modal analyses (in percent) of Sandymush Felsic Gneiss*

Sample Number	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Chlorite
165-a	732,000N; 864,150E	Amphibolite	3.8	38.8	0.0	11.4	0.0	0.6	0.0	0.0	0.4	45.0	0.0	0.0	0.0
166	732,350N; 863,950E	Amphibolite	2.2	33.2	0.0	7.4	0.0	0.2	0.0	1.4	0.0	55.6	0.0	0.0	0.0
119	733,100N; 875,600E	Amphibolite	1.0	41.6	0.0	8.6	0.0	0.0	0.0	3.2	0.0	45.2	0.0	0.4	0.0
116	733,950N; 878,650E	Amphibolite	7.2	33.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	59.2	0.0	0.0	0.0
972	720,200N; 869,700E	Amphibolite	3.6	20.6	0.0	0.0	0.0	1.6	0.2	0.8	0.0	72.2	1.0	0.0	0.0
1365	748,100N; 885,150E	Amphibolite	7.0	35.8	1.2	4.2	0.0	4.0	0.4	3.6	0.0	43.8	0.0	0.0	0.0
		Average	4.1	33.9	0.2	5.3	0.0	1.1	0.1	1.5	0.1	53.5	0.2	0.1	0.0
		Minimum	1.0	20.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.8	0.0	0.0	0.0
		Maximum	7.2	41.6	1.2	11.4	0.0	4.0	0.4	3.6	0.4	72.2	1.0	0.4	0.0
		Std Dev	2.5	7.3	0.5	4.7	0.0	1.6	0.2	1.6	0.2	11.2	0.4	0.2	0.0

Sample Number	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Chlorite
34	722,850N; 873,350E	Biotite Granitic Gneiss	31.2	31.4	25.8	10.8	0.0	0.4	0.0	0.0	0.2	0.0	0.0	0.0	0.2
1880	730,250N; 862,150E	Biotite Granitic Gneiss	31.6	32.2	23.2	9.8	0.6	1.6	0.4	0.0	0.6	0.0	0.0	0.0	0.0
4	720,400N; 857,250E	Biotite Granitic Gneiss	33.4	29.4	25.0	11.4	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	0.0
		Average	32.1	31.0	24.7	10.7	0.2	0.8	0.1	0.1	0.3	0.0	0.0	0.0	0.1
		Minimum	31.2	29.4	23.2	9.8	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum	33.4	32.2	25.8	11.4	0.6	1.6	0.4	0.4	0.6	0.0	0.0	0.0	0.2
		Std Dev	1.2	1.4	1.3	0.8	0.3	0.7	0.2	0.2	0.3	0.0	0.0	0.0	0.1

Sample Number	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Chlorite
1876	731,050N; 860,650E	Quartz-rich Granitoid Gneiss	70.2	9.6	17.2	1.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Sample Number	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Chlorite
165	732,000N; 864,150E	Biotite Granodiorite Gneiss	20.4	56.8	6.0	14.8	0.8	0.6	0.0	0.0	0.0	0.0	0.2	0.0	0.4

Sample Number	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Chlorite
113	733,500N; 881,150E	Biotite Tonalite Gneiss	34.6	61.4	0.6	2.8	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1291	713,150N; 862,000E	Biotite Tonalite Gneiss	10.2	12.2	0.0	50.2	2.0	15.8	0.0	5.2	1.0	0.0	3.4	0.0	0.0
		Average	22.4	36.8	0.3	26.5	1.0	8.2		2.6	0.5		1.7		

Sample Number	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sphene	Apatite	Chlorite
2	720,200N; 854,000E	Protomylonitic Biotite Granitic Gneiss	15.8	33.4	22.4	21.2	0.6	5.2	0.0	0.2	1.0	0.0	0.0	0.2	0.0

layering. These interlayered gneisses make up about 20 percent of the Spring Creek Granitoid Gneiss.

Protomylonitic to mylonitic granodioritic gneiss interlayers occur throughout the formation. The mylonitic interlayers do not appear to be concentrated in local areas or associated with major regional structures. These layers are well foliated and are mostly thin to thick layered. Much of the mylonitic gneiss is porphyroclastic, but the porphyroclasts are much smaller than those in the Doggett Gap Protomylonite. The porphyroclasts range from about 0.5 centimeter to 1 centimeter in size. These mylonitic rock types make up approximately 15 percent of the Spring Creek Granitic Gneiss.

Amphibolite occurs as thin interlayers in the Spring Creek Granitoid Gneiss. In only one small area in the Sandymush Quadrangle are the interlayers abundant enough to distinguish as a mappable subunit. The amphibolite is dark greenish gray to greenish black, containing mostly hornblende and plagioclase. The rocks are foliated, especially where retrogression has been most intense. Amphibolite makes up approximately four percent of this unit.

Calc-silicate granofels interlayers occur, but are quite rare. Where observed in the field, they occur with amphibolites in layers and pods. Calc-silicate granofels is very light gray to greenish gray in color on fresh surfaces, and is massive to slightly foliated with thin to thick layering. Locally it grades into amphibolite. Calc-silicate granofels layers make up about one percent of the outcrop area.

PETROGRAPHY

The coarse-grained granitic gneiss of the Spring Creek exhibits an equigranular granoblastic texture to an inequigranular lepidoblastic texture. Locally, mylonitic textures are observable. The gneiss has the composition of a granite. Modal analyses are listed in table 6.

The interlayered biotite granitic gneiss is distinguished from the granitic gneiss by its better developed lepidoblastic texture and its higher biotite content.

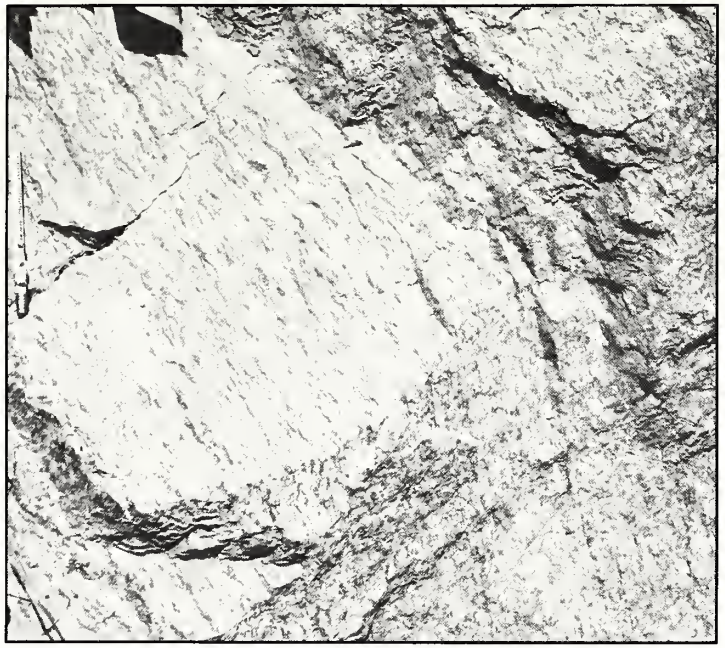
Amphibolites of the Spring Creek Granitoid Gneiss are equigranular nematoblastic in texture.

The calc-silicate granofels layers have an equigranular granoblastic to nematoblastic texture. They consist of plagioclase, K-feldspar, amphibole, epidote-group minerals, and other accessory minerals including biotite, sphene, and opaques.

AGE, CONTACT RELATIONSHIP, AND PROTOLITH

The absolute age of the Spring Creek Granitoid Gneiss is not precisely known as no attempt has yet been made to date the formation. The area underlain by the Spring Creek was included in the extensive Cranberry Granite of Keith (1904). It is now correlated with or included in the Elk Park Plutonic Suite (Rankin et al., 1972, 1983), the Cranberry granitic basement complex of Brewer (1986), and the biotite granitic gneiss of the 1985 Geologic Map of North Carolina (N.C. Geological Survey). Collectively, this large granitic rock unit is approximately 1.1 billion years old (Fullagar and Odum, 1973; Fullagar et al., 1979; Fullagar, 1983).

The Spring Creek Granitoid Gneiss is considered to be intrusive into the Sandymush Felsic Gneiss. However, the contact is not well exposed and is commonly overprinted by mylonitization and thus its true nature is not obvious. A magmatic origin for the Spring Creek is suggested by its massive, very thick to thick layering, weak foliation, and granitic composition. Rocks of the Spring Creek Granitoid Gneiss may represent an intrusive pluton within the very complex and multi-origin basement complex of western North Carolina.



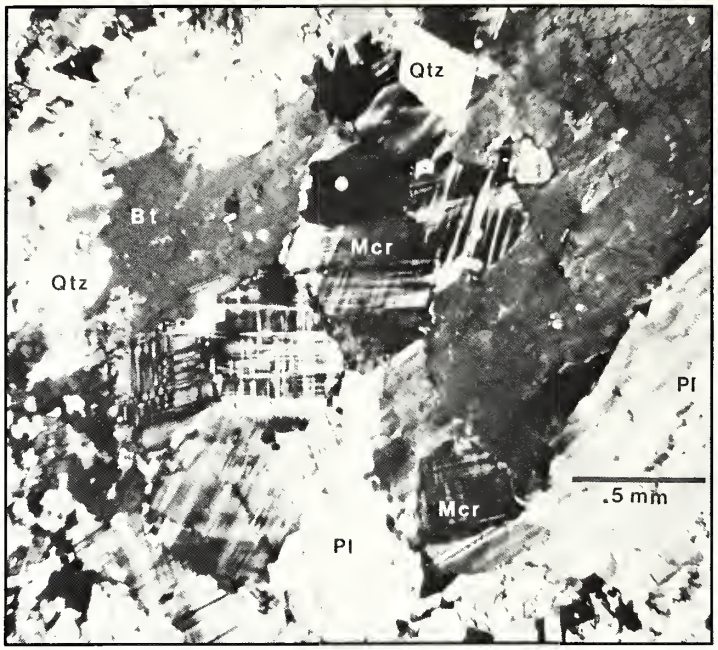


Figure 8. Spring Creek Granitoid Gneiss. *Left*, Granitoid gneiss showing well developed protomylonitic structure. Outcrop along N.C. Highway 209 opposite Lusk Chapel, Madison County. *Right*, Photomicrograph of biotite granitic gneiss showing granoblastic texture with some polygonized grains. Abundant microcline (Mcr), with plagioclase (Pl), quartz (Qtz), and minor biotite (Bt). Crossed polarizers, sample 1734.

Table 6. *Modal analyses (in percent) of Spring Creek Granitoid Gneiss*

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plag.	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sericite	Sphene	Apatite	Talc
1807-a	747,500N; 859,000E	Amphibolite	0.6	55.8	0.0	0.0	0.0	16.4	0.0	3.0	0.0	23.8	0.0	0.0	0.4	0.0
1807-b	747,500N; 859,000E	Amphibolite	0.4	20.6	0.0	0.0	0.0	7.0	0.0	0.2	0.0	69.2	1.2	1.0	0.0	0.4
		Average	0.5	38.2	0.0	0.0	0.0	11.7	0.0	1.6	0.0	46.5	0.6	0.5	0.2	0.2
Sample No.	N.C. Coordinates	Rock Name	Quartz	Plag.	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sericite	Sphene	Apatite	Talc
1734	731,800N; 855,850E	Biotite Granitic Gneiss	26.2	25.4	37.0	3.8	6.2	0.2	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.0
200	741,200N; 859,900E	Biotite Granitic Gneiss	30.6	25.2	34.4	6.8	2.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
		Average	28.4	25.3	35.7	5.3	4.2	0.4	0.0	0.1	0.5	0.0	0.0	0.0	0.1	0.0
Sample No.	N.C. Coordinates	Rock Name	Quartz	Plag.	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Hornblende	Sericite	Sphene	Apatite	Talc
1575	743,450N; 861,500E	Protomylonitic Granodioritic Gneiss	16.4	33.6	3.8	45.4	0.0	0.4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0

Doggett Gap Protomylonitic Granitoid Gneiss

FIELD OCCURRENCE AND DESCRIPTION

The Doggett Gap Protomylonitic Granitoid Gneiss forms two narrow bands in the northwest quarter of the Sandymush Quadrangle. The largest band is about 5 miles long and 1 mile wide. The smaller band is folded and is about 5.5 miles long and from 0.5 to 0.1 mile wide. North Carolina Highway 63 cuts across the largest band at Doggett Gap and this section is designated the type locality. Outcrops along the road occur intermittently for about 0.4 mile west of the gap and 0.7 mile east of the gap. Other exposures in the type area occur both northeast and southwest of Doggett Gap in the grass fields and pastures along a northeast-trending ridge. This two and one-half mile-long ridge extends from Robinson Rough in the southwest to Mikes Knob in the northeast. These outcrops are dominated by very coarse-grained protomylonite that characterizes the Doggett Gap Protomylonitic Granitoid Gneiss.

The Doggett Gap Protomylonitic Granitoid Gneiss is a sequence of mylonitized granitic rocks interlayered with biotite granitic gneiss, biotite tonalite gneiss, and amphibolite. It is approximately 5,000 feet thick. The very coarse-grained granitic protomylonites which characterize the unit (figure 9) make up approximately 70 percent of the formation.

The protomylonitic layers are distinctly megacrystic. They are light gray to medium light gray to very pale orange and are poorly foliated to well foliated. The layers range from medium to very thick.

Biotite granitic gneiss to biotite tonalite gneiss interlayers are common, but are not very thick; layering varies from thin to medium. This lithologic type comprises about 25 percent of the entire map unit.

Amphibolite of the Doggett Gap is present as thin interlayers to small, locally mappable bodies. At most places it is mylonitized and commonly shows the effects of retrogressive metamorphism.

PETROGRAPHY

Protomylonites of the Doggett Gap are inequigranular (megacrysts range from 0.5 centimeter to 4 centimeters), mylonitic, and poorly layered to layered. Layer thicknesses range from centimeters to meters. The composition of the characteristic protomylonites is granitic. Interlayers of biotite granitic gneiss to biotite tonalite gneiss are granoblastic to lepidoblastic (table 7).

The amphibolites are mostly medium- to coarse-grained, nematoblastic to weakly lepidoblastic, and commonly mylonitic. Retrogression is indicated by the common occurrence of biotite replacing hornblende.

AGE AND CONTACT RELATIONSHIP

A radiometric age for the Doggett Gap Protomylonitic Granitoid Gneiss has not been determined. The protolith of the Doggett Gap Protomylonitic Granitoid Gneiss is interpreted to have intruded its adjacent formations; the Spring Creek Granitoid Gneiss and the Sandymush Felsic Gneiss. It is thus presumed to be younger than both of these units. The Doggett Gap has also been affected by Middle to Late Proterozoic mylonitic deformation. Thus, the Doggett Gap Protomylonitic Granitoid Gneiss is reasoned to be latest Middle Proterozoic in age.

Keith (1904) recognized and mapped coarse-grained granitic rocks in this region as part of his Max Patch Granite. However, general differences in appearance and composition, along with uncertainties of cross-strike correlation of these various metamorphosed plutonic bodies have led subsequent geologists to limit application of the term "Max Patch" to rocks in and around the type area (North Carolina Geological Survey, 1985).

The Doggett Gap Protomylonitic Granitoid

Figure 9. Doggett Gap Protomylonitic Granitoid Gneiss. *Left*, Characteristic megacrystic protomylonite. Diameter of coin is about 1.5 centimeters. Outcrop is along the South Prong of Little Pine Creek about 1.3 miles east of Little Pine Gap, Madison County. *Right*, Photomicrograph showing part of a microcline megacryst (Mcr) in a much finer grained mylonitic matrix. Note elongate polygonized grains. Crossed polarizers, sample 1449.

Table 7. *Modal analyses (in percent) of Doggett Gap Protomylonitic Granitoid Gneiss*

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Opaques	Clinozoisite	Hornblende	Sphene	Apatite
177	733,550N; 864,450E	Biotite Granitic Gneiss	27.8	13.6	45.4	10.4	0.4	1.6	0.0	0.8	0.0	0.0	0.0

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Opaques	Clinozoisite	Hornblende	Sphene	Apatite
1449	748,150N; 871,850E	Protomylonitic Granitic Gneiss	21.6	28.0	40.2	7.2	1.4	1.2	0.0	0.0	0.0	0.2	0.2
1450	748,050N; 871,650E	Protomylonitic Granitic Gneiss	28.2	26.2	31.0	11.8	1.0	0.8	0.0	1.0	0.0	0.0	0.0
		Average	24.9	27.1	35.6	9.5	1.2	1.0	0.0	0.5	0.0	0.1	0.1

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Opaques	Clinozoisite	Hornblende	Sphene	Apatite
1448	748,250N; 872,050E	Amphibolite	4.2	36.4	0.8	0.0	0.0	1.2	1.8	0.0	55.2	0.4	0.0

Gneiss may be equivalent to Brewer's (1986) Indian Grave metagranite mapped about ten miles to the northeast. However, the large mylonitic "eye" structures, or augen, in the Doggett Gap are not entirely monomineralic as in the Indian Grave metagranite. In the Doggett Gap, the augen are composed chiefly of coarse-grained granitic material. The equivalency, therefore, will remain uncertain until the area in between is more thoroughly mapped. Brewer (1986) tentatively correlated his Indian Grave unit with the Beech Granite of the Crossnore Suite. However, until further study, this correlation must be considered even more speculative.

Talc Body

FIELD OCCURRENCE AND DESCRIPTION

Four small talc bodies occur in the northwest quarter of the Sandymush Quadrangle. The deposits are shown by Keith (1904) under the grouping "soapstone, dunite, and serpentine". These bodies are very small with exposures consisting of only a few small outcrops and some associated float material. Precise locations are listed in Appendix 3. The talc bodies are surrounded by granitic and layered granitic gneisses and are evidently isolated masses. They are not associated with amphibolite or any other altered mafic or ultramafic rock. They have a very pronounced foliation that may be related to Proterozoic mylonitization and to a subsequent, subparallel Taconic metamorphic overprint. The bodies appear to be podiform, possibly resulting from large-scale, extensive boudinage.

PETROGRAPHY

No thin sections were made of these talcose rocks. Hand sample examination, however, shows they are composed primarily of talc and a little chlorite. The proportions are variable both within each body and from one body to the next, although talc is always the dominant mineral.

AGE, CONTACT RELATIONSHIP, AND PROTOLITH

The absolute age of the talc bodies is not known. Similar deposits are present northeastward through Madison County for at least twenty miles. The protolith for these talc bodies is uncertain. A sedimentary origin was suggested by Bentzen and Wiener (1973) based principally on a spatial association with nearby marble layers. Bohannon (1975) proposed an intrusive origin, citing high trace-element values of nickel and chromium, indicating derivation from ultramafic igneous rock. In the Sandymush Quadrangle their apparent sharp contact with the surrounding granitic gneiss favors an intrusive origin. The talc bodies would thus be younger than the granitic gneiss host. Initially they may have been intruded as ultramafic rocks and later were altered to talc-rich bodies. This alteration may have happened during the Grenville metamorphic event, but it is unlikely. High-temperature Grenville metamorphism would have driven off most of the water needed for hydration and subsequent formation of talc. A more likely time for steatization was during the Late Proterozoic mylonitization event or possibly during Paleozoic metamorphism.

Similar talc bodies do not occur within the Late Proterozoic Ocoee Supergroup, Grandfather Mountain Formation, or the Paleozoic strata in the nearby Valley and Ridge of East Tennessee. Thus, a Paleozoic age is doubtful and a Proterozoic age is more consistent with the known facts.

Ashe Metamorphic Suite

The Ashe Formation was named by Rankin (1970) and subsequently retermed the Ashe Metamorphic Suite by Abbott and Raymond (1984). The Ashe Metamorphic Suite is a mixed assemblage of clastic sediments and mafic volcanic rocks. The dominant rock types in the Sandymush and Canton Quadrangles include two-mica schist, metagraywacke, and two-mica gneiss. Minor amphibolite and calc-silicate granofels are also

present. In these quadrangles, the Suite is divided into two major units, one in which schist dominates, and one in which metagraywacke and gneiss dominate (figures 10 - 12).

SCHIST

Field Occurrence and Description — The schist-dominated unit underlies the southeast corner of the Sandymush Quadrangle and four areas on the Canton Quadrangle. The northernmost area on the Canton Quadrangle is an extension of the outcrop area on the Sandymush Quadrangle. This area is allochthonous and separated from the main body of the Ashe Metamorphic Suite. It covers about five percent of the two quadrangles. Another, much smaller allochthon is in the center of the Canton Quadrangle. It is about 1.5 miles long and averages about 0.2 mile wide. The largest area of Ashe schist forms an irregularly shaped band that runs diagonally through the Canton Quadrangle from its northeast corner to its southern and western borders. This large area covers about 35 percent of the Canton Quadrangle. The fourth area of schist is in the southwest corner of the quadrangle and extends into the adjoining Clyde Quadrangle. It too, is allochthonous and covers about three square miles.

The most accessible exposures are found near the west border of the Canton Quadrangle along Crabtree Road, from approximately 0.5 mile to 1.0 mile southeast of Crabtree Gap. The best exposures occur along the crest and sides of Holland Mountain. Good exposures also occur along the southwest side of Newfound Mountain between Big Butt Mountain and Rockyface Mountain, and along the southeast slopes of Buck Cove Mountain.

The Ashe schist unit is characterized by muscovite-biotite schist which underlies more than 60 percent of the outcrop area. The muscovite-biotite schist is light gray to medium light gray and is thin to medium layered. Kyanite or sillimanite is a key accessory mineral depending on metamorphic grade. All schist layers are variably garnetiferous and sulfidic. Repetitively and variably interlayered with the schist is metagraywacke, muscovite-biotite gneiss to biotite gneiss, amphibolite, and rare calc-silicate granofels. All rock types may be mylonitic or migmatitic in local areas.

Interlayered metagraywackes are medium light gray to medium gray, and are commonly medium to thick layered. Any original sedimentary features have been obliterated or transposed. The metagraywackes are distinguished from the muscovite-biotite gneisses chiefly by their higher quartz and lower feldspar content. Metagraywackes make up about 20 percent of the map unit. However, in only two areas are metagraywackes abundant enough to distinguish as a sub-unit on the geologic map (see plate 2).

Interlayers of muscovite-biotite gneiss to biotite gneiss are medium gray to medium dark gray. Layering varies from medium to thick. These mica gneiss interlayers make up approximately 15 percent of the Ashe schist.

Widely scattered amphibolite interlayers occur in the Ashe schist. They are dark greenish gray to greenish black and thin layered and are rarely, if ever, interlayered with calc-silicate granofels. They make up less than five percent of the outcrop area. Only two areas are extensive enough and contain sufficient amphibolite interlayers to be mapped separately. These areas are on the southeast side of Potato Knob near the south border of the Canton Quadrangle and about 0.4 mile south of Newfound Gap.

The thin-layered calc-silicate granofels that occur within the Ashe schist are calcareous metagraywackes. They have the appearance of metagraywacke, but have a very high quartz content. In addition, garnet and an amphibole mineral are invariably present.

Petrography — The Ashe schists are medium- to coarse-grained, finely foliated micaceous rocks that exhibit a strong lepidoblastic texture.

The schists are variably porphyroblastic ranging from 0 to 15 percent. The porphyroblasts are of garnet and kyanite and are commonly poikiloblastic. Kyanite porphyroblasts are occasionally kinked, while the garnets are commonly fractured. Where sillimanite replaces kyanite, the porphyroblastic character of the schists disappears.

The mineral composition of the Ashe schist is quite variable over the map or even across an outcrop. For example, there are garnet-muscovite-biotite schists, garnet-kyanite-muscovite-biotite-schists, garnet-sillimanite-kyanite-muscovite-biotite schists, garnet-sillimanite-muscovite-biotite schists, and sillimanite-biotite schists. The mineral composition of several samples is shown in table 8.

Metagraywacke layers are weakly foliated and exhibit a granoblastic to lepidoblastic texture. The higher the original clay content, the greater the mica content and the better developed the lepidoblastic texture. The composition of the metagraywacke in the Ashe schist is quite variable.

Mica gneiss, ranging from muscovite-biotite gneiss to biotite gneiss, is interlayered throughout the schist unit. The gneiss is weakly foliated to foliated and exhibits a granoblastic to lepidoblastic texture. It is very similar in appearance to the metagraywackes and is distinguished on the basis of a higher feldspar-to-quartz ratio. As the mica content increases the lepidoblastic texture becomes better defined. One thin section analyzed yielded a tonalitic composition (see table 8, figure 10).

Amphibolite layers within the Ashe schist are composed mostly of hornblende and plagioclase. They appear to be similar in composition to those mapped in the biotite gneiss and schist unit and the biotite-plagioclase-quartz gneiss unit of the adjoining Cruso Quadrangle (Morrow, 1977).

Rare calc-silicate granofels found in the Ashe schist are similar to those described by Morrow (1977) in his biotite gneiss and schist unit. The calc-silicate rocks are composed mostly of quartz, feldspar, garnet, and either an amphibole or biotite.

GNEISS

Field Occurrence and Description — The gneiss-dominated map unit of the Ashe Metamorphic Suite is present in the southeast part of the Canton Quadrangle. It underlies about 15 percent of the quadrangle. The best and most accessible exposures occur in road cuts on the north side of Interstate-40 from approximately 0.3 mile to 1 mile west of the Buncombe-Haywood County line.

Metagraywacke is the dominant rock type followed by mica gneiss. Typically, the metagraywacke contains over 50 percent quartz. Mica gneiss, ranging from muscovite-biotite gneiss to biotite gneiss, contains less quartz, but is higher in feldspar and a little higher in micaceous minerals. The rock types grade into each other with fresh samples being difficult to distinguish because of the similarity of quartz and feldspar grains. However, weathering accentuates the feldspar by causing it to lighten in color, thereby making it feasible to make accurate field classifications.

The Ashe gneiss contains approximately 50 percent metagraywacke. Metagraywacke is light gray to medium dark gray on the fresh surface. The thickness of the layers ranges from a few centimeters to several meters. The metagraywacke layers are commonly migmatitic.

Interlayered with metagraywacke in the Ashe gneiss are muscovite-biotite gneiss to biotite gneiss, kyanite-garnet-muscovite-biotite schist, sillimanite-kyanite-garnet-muscovite-biotite schist, amphibolite, and calc-silicate granofels. Muscovite-biotite gneiss to biotite gneiss is the second most abundant rock type, making up about 40 percent of the map unit.

Interlayered sillimanite-kyanite-garnet-mica schist makes up over five percent of the unit. It closely resembles other schists in the Ashe Metamorphic Suite.

Calc-silicate granofels is very sparingly present as thin layers and pods less than a meter in

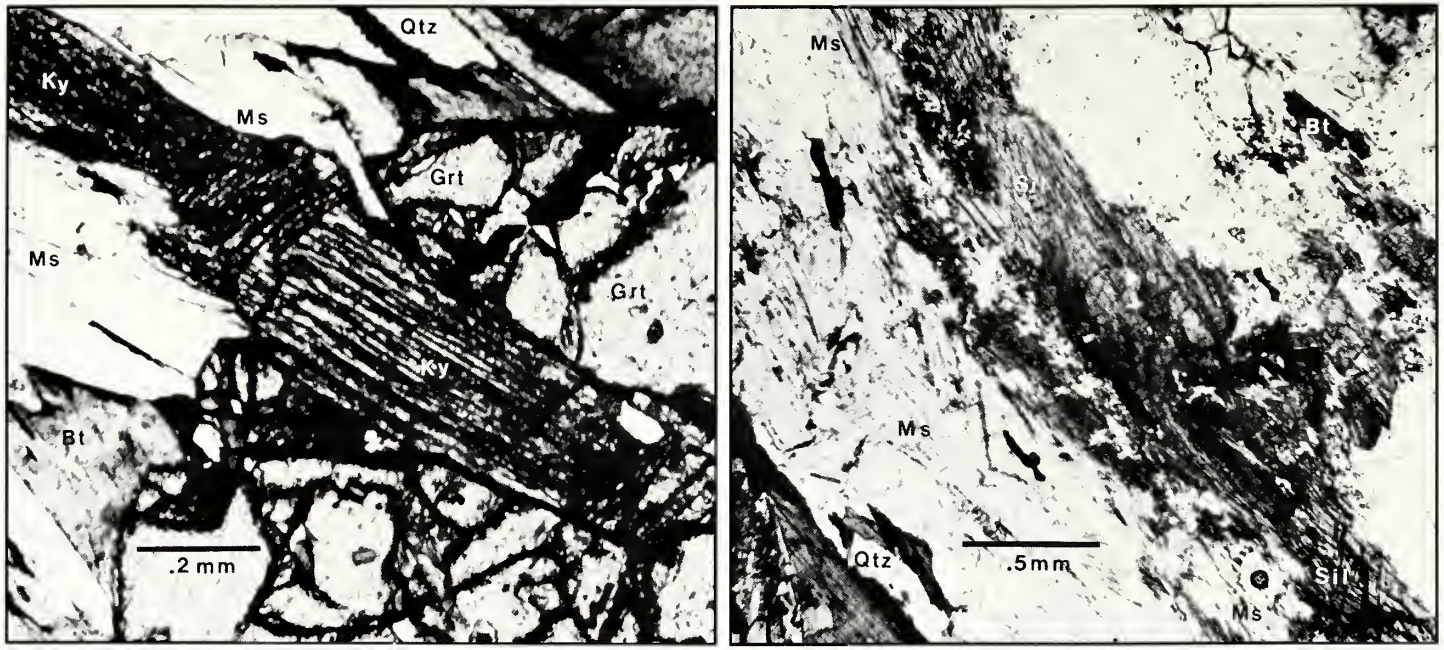


Figure10. Schist unit of the Ashe Metamorphic Suite, photomicrographs. *Left*, Kyanite (Ky) penetrating fractured garnet (Grt). Quartz (Qtz), muscovite (Ms), and biotite (Bt) also present. Plane polarized light, sample 580-a. *Right*, Sillimanite (Sil) porphyroblast in contact with muscovite (Ms). Biotite (Bt), quartz (Qtz), and opaques also present. Crossed polarizers, sample 2372-b.

Table 8. *Modal analyses (in percent), Schist unit of the Ashe Metamorphic Suite*

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Clinozoisite	Kyanite	Sillimanite
1983	676,150N; 872,900E	Sillimanite-Kyanite-Garnet Schist	41.4	14.2	0.0	12.0	11.4	0.0	8.4	0.0	0.0	12.4	0.2
2372-b	677,100N; 859,100E	Sillimanite-Kyanite-Garnet Schist	13.8	5.8	0.0	40.8	20.6	0.0	15.0	0.4	0.0	2.4	1.2
2372-a	677,100N; 859,100E	Kyanite-Sillimanite-Garnet Schist	2.8	0.2	0.0	53.0	16.0	0.0	15.8	0.8	0.0	4.6	6.8
580-a	688,700N; 848,950E	Kyanite-Garnet Schist	16.0	11.6	0.0	22.0	38.4	0.0	7.0	1.6	0.0	3.4	0.0
642	687,250N; 851,250E	Muscovite-Biotite Gneiss	39.0	14.2	1.6	21.4	11.0	0.0	6.8	3.0	0.0	3.0	0.0
782	698,600N; 875,550E	Metagraywacke	49.2	21.6	0.0	25.2	3.8	0.0	0.0	0.2	0.0	0.0	0.0
857	685,050N; 882,950E	Metagraywacke	65.4	0.8	0.0	4.0	27.6	0.4	1.2	0.6	0.0	0.0	0.0
580-b	688,700N; 848,950E	Mylonitic Metagraywacke	62.0	8.6	21.6	6.0	1.4	0.0	0.0	0.4	0.0	0.0	0.0
330	692,200N; 894,950E	Biotite Tonalite Gneiss	24.4	35.2	2.8	32.8	3.0	0.0	1.0	0.6	0.2	0.0	0.0

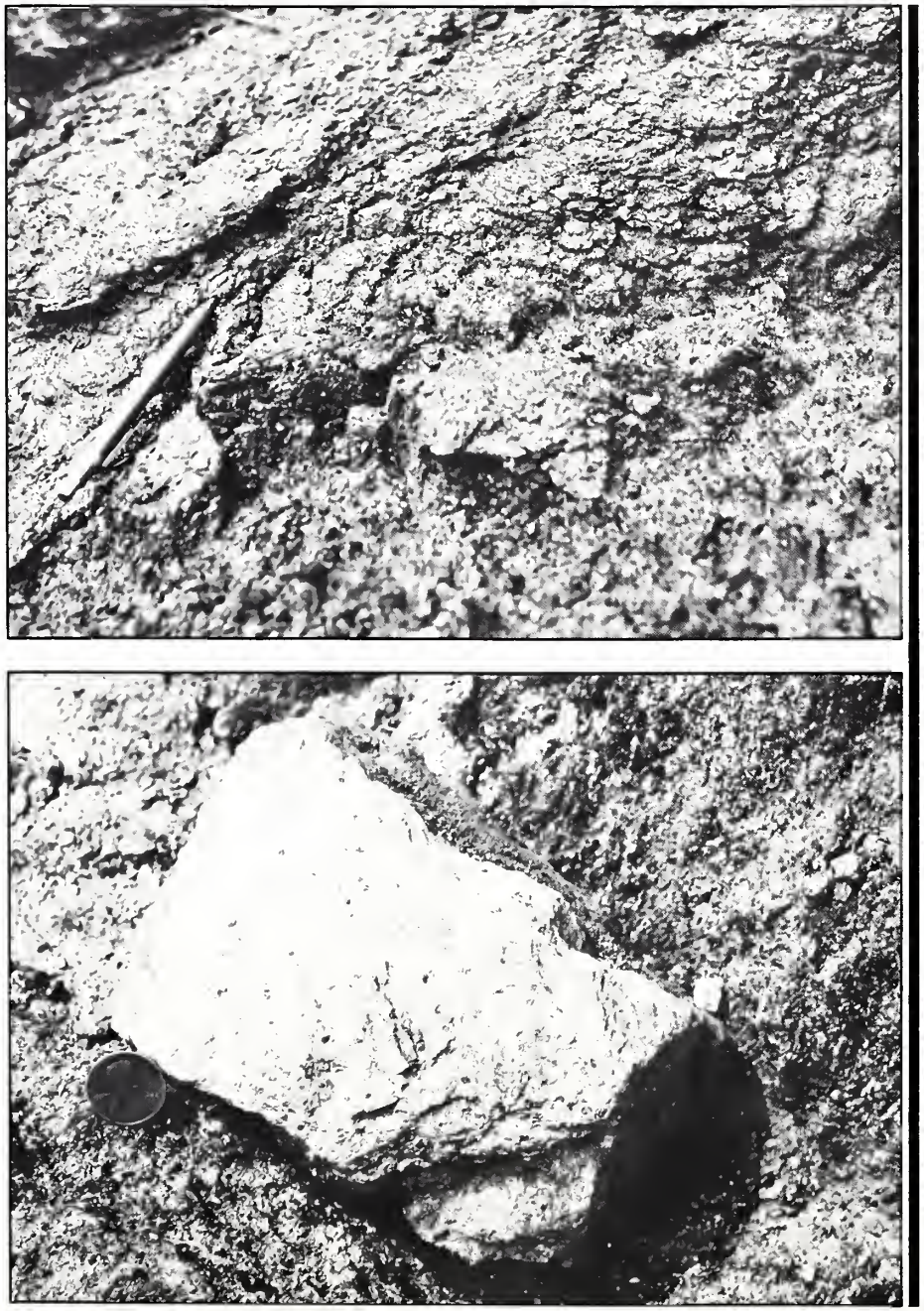


Figure 11

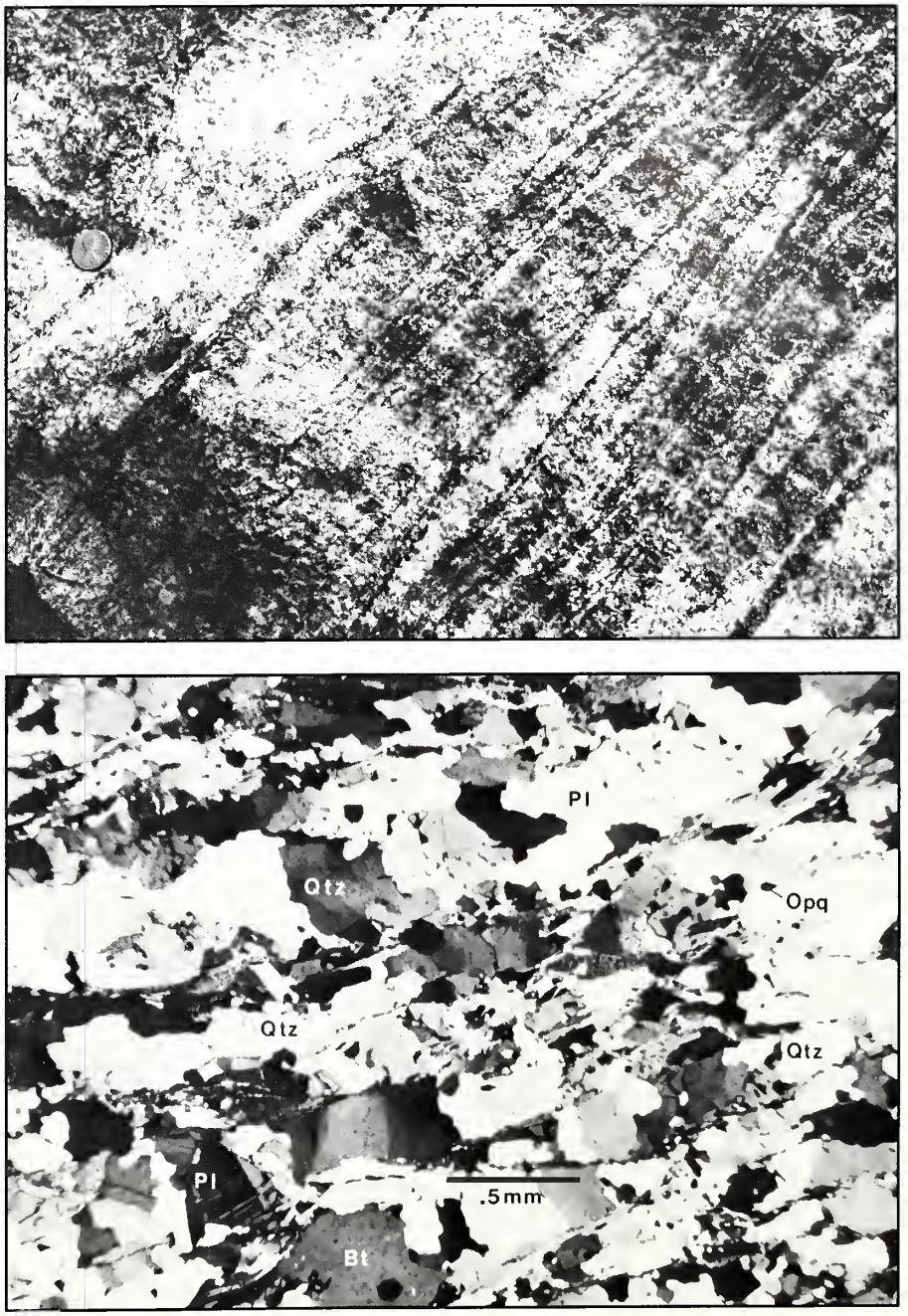


Figure 12

Figure 11. Ashe Metamorphic Suite, Schist unit (on facing page, left side). *Above*, Mica schist with abundant porphyroblasts of muscovite up to 4 centimeters across. Tip of pencil points to one porphyroblast. *Below*, Kyanite-garnet schist. Several lath-like kyanite porphyroblasts, up to 2 centimeters long, and numerous 2- to 3-millimeter garnets are present on foliation surfaces. Exposures are along private road near Beaverdam Creek, 0.6 miles southwest of Beaverdam School, Canton Quadrangle.

Figure 12. Ashe Metamorphic Suite, Gneiss unit (on facing page, right side). *Above*, Metagraywacke with light-colored quartz-rich layers and thin, dark-colored biotite-bearing layers. Outcrop is 0.5 miles west of the Haywood-Buncombe County line along Interstate-40. *Below*, Photomicrograph of metagraywacke showing weakly developed lepidoblastic texture. Quartz (Qtz), some with undulatory extinction, dominates. Plagioclase (Pl), biotite (Bt), and opaques (Opq) also common. Crossed polarizers, sample 1946.

thickness. Calc-silicate granofels is composed mostly of quartz, plagioclase, garnet, and either hornblende or biotite.

Petrography — Throughout the Ashe gneiss, lepidoblastic texture dominates, but a granoblastic texture is also common, especially in the metagraywacke layers (figure 12).

The mica gneiss layers differ principally in feldspar and quartz content from the metagraywacke layers. In metagraywacke, quartz is more abundant; in the gneiss, feldspar is prevalent. In both types biotite is generally more abundant than muscovite. Modal analyses are given in table 9. No modal analyses were made of the interlayered schist or calc-silicate granofels. Hand sample examination, however, indicates they are very similar to schist and calc-silicate granofels elsewhere in the Ashe Metamorphic Suite.

AGE AND CONTACT RELATIONSHIP

The most frequently cited age for the Ashe Metamorphic Suite is Late Proterozoic or Late Precambrian. This assignment is supported by stratigraphic correlation with the Lynchburg-Catoctin sequence of Virginia (Rankin, 1970). Zircons from the Catoctin and presumed correlative units have been dated by Rankin et al. (1969) at 820 million years. Another age constraint is provided by relations with the Bakersville Gabbro. A whole rock Rb/Sr isochron from eight Bakersville dikes is 734 ± 24 million years (Goldberg et al., 1986). Field relations show that the Bakersville does not intrude the Ashe. This evidence suggests that the Ashe is younger than 734 million years. Numerous granitoid plutons intrude the Ashe in the Southern Blue Ridge (North Carolina Geological Survey, 1985) and thereby limit the minimum age. The Whiteside, Looking Glass, and Pink Beds plutons have Rb/Sr whole rock isochrons of about 390 million years. The Rabun Gneiss also intrudes the Ashe and is assigned an age of 450-500 million years (Fullagar, 1983). However, zircon-based ages obtained by T.W. Stern of the U.S. Geological Survey are 373-351 million years (A.E. Nelson, written communication, 1988). Alaskites and pegmatites also intrude the Ashe and are 390 to 435 million years old. Metamorphism, dated at 470-430 million years (Butler, 1973) has affected the Ashe Suite. The Ashe is therefore younger than 734 million years and no more recent than Early or Middle Ordovician. Consequently, a Late Proterozoic age is accepted for the unit.

The schist unit of the Ashe Metamorphic Suite overlies Middle Proterozoic rocks along the Holland Mountain thrust fault.

The internal boundary between the schist unit and the gneiss unit is evidently a normal

Table 9. *Modal analyses (in percent), Gneiss unit of the Ashe Metamorphic Suite*

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques
1946	659,850N; 874,500E	Metagraywacke	51.4	16.0	9.8	12.2	9.8	0.4	0.0	0.4
2318	672,700N; 877,150E	Metagraywacke	55.8	33.2	0.0	8.6	0.8	0.4	0.6	0.6
2325	672,000N; 871,500E	Metagraywacke	37.0	39.4	0.0	20.4	0.0	0.4	1.2	1.6
		Average	48.1	29.5	3.3	13.7	3.5	0.4	0.6	0.9
		Std Dev	9.8	12.1	5.7	6.0	5.4	0.0	0.6	0.6

depositional, stratigraphic contact. This contact is somewhat arbitrarily located because both units are composed of very similar rock types. In the field, the unit assignment is based on whether schist dominates or metagraywacke to mica gneiss dominates.

The upper limit of the Ashe Suite is not present in the Sandymush or Canton Quadrangles. In the type area, the Ashe is conformably overlain by the Alligator Back Formation (Rankin et al., 1973).

Dunite

FIELD OCCURRENCE AND DESCRIPTION

No dunites crop out in the Sandymush Quadrangle; however, eight small dunite bodies are present in the Canton Quadrangle. The two largest and best known are the Newfound Gap and Hominy Grove bodies (Pratt and Lewis, 1905; Hunter, 1941). The Newfound Gap body is located a few hundred feet east of Newfound Gap along the Buncombe-Haywood County line. The Hominy Grove body is located near the Harmony Grove Church, approximately 400 feet west of the intersection of SR 1609 with SR 1606. Smaller bodies occur in the vicinity of each of these larger bodies. A small dunite body occurs 600 feet north of Newfound Gap. An additional tiny body, too small to show at map scale, crops out about 100 feet north of this body (Hirt, 1987). At Hominy Grove a small body is located about 2,000 feet west of the larger dunite body.

Elsewhere in the quadrangle two small bodies are located west of Beaverdam Creek on the southeast slopes of Sassafras Ridge. Another small dunite body is located on the south side of Interstate-40, approximately 2,000 feet from the west edge of the Canton Quadrangle. The last small dunite body crops out on the southeast side of the ridge between Wilson and West Coves, about 4,500 feet northeast of the intersection of SR 1613 and SR 1619.

Many of these small bodies are represented by only one or two outcrops. Their extent is determined by float materials and soil characteristics. Float materials include both olivine and the common hydrous alteration minerals such as talc, anthophyllite, and vermiculite. The dunites weather to a nickeliferous saprolite and a dark-red soil that contains residual chalcedonic fragments.

All the dunites, except the one between Wilson and West Coves, are surrounded by Grenville-age rocks. The one exception, only a few hundred feet away from the Earlies Gap, is tectonically emplaced into a mylonitized zone of the Ashe schist. The dunites normally occur very close to the contact between the Earlies Gap Biotite Gneiss and the overlying Ashe Metamorphic Suite. A similar relationship exists on the nearby Mars Hill (Merschat, 1977), Barnardsville (Merschat, in progress), and Leicester Quadrangles (Wiener, unpublished mapping).

The dunites, where unaltered, are composed mostly of olivine (Fo_{92}). The unaltered dunite is pale olive to dusky yellow green and is dusky yellow when weathered. It is usually fine- to coarse-grained, granular, and locally friable. Black crystals and blebs of chromite also occur; however, they make up only one or two percent of the rock. The altered dunites are variably serpentinized. Hydrous alteration minerals that occur, other than serpentine minerals, include talc, anthophyllite, chlorite, tremolite, and vermiculite. Much of the hydrous alteration occurs along fractures in the olivine bodies and in tiny fractures that cut individual grains. During serpentization magnetite is formed. This alteration has proven to be useful in mapping the extent of altered olivine bodies with a magnetometer (Hirt, 1987; Perez, 1979).

PETROGRAPHY

A thorough investigation of the dunites was not within the scope of this report and thus only hand samples were examined. However, numerous petrologic studies have been completed on

many similar dunite bodies in western North Carolina. Studies on the Newfound Gap deposit have been made by Palmer et al. (1977), Perez (1979), Penso (1981), and Hirt (1987). They record samples containing various amounts of olivine, chromite, serpentine, anthophyllite, tremolite, talc, vermiculite, magnetite, and chlorite.

AGE AND CONTACT RELATIONSHIP

The age of the dunites is not known conclusively. Dunites of the central Blue Ridge are most frequently placed within a broad range from Late Precambrian to Early Paleozoic (Hadley and Nelson, 1971; North Carolina Geological Survey, 1985). They have been metamorphosed during the Taconic, thereby restricting them to being Early Ordovician or older. Dunites do not occur in any Cambrian or Ordovician rocks of the nearby Valley and Ridge province, nor do they occur in the very Late Proterozoic Ocoee Supergroup or Grandfather Mountain Formation. Elsewhere in the Blue Ridge, dunites are present in the Ashe, Tallulah Falls, and Alligator Back Formations, all of Late Proterozoic age. Thus, the dunites probably originated sometime during the 330-million-year span of the Late Proterozoic.

The dunite bodies of the Canton Quadrangle, except one, occur in the Earlies Gap Biotite Gneiss. Their contacts with the Earlies Gap are covered. However, since better exposed western North Carolina dunites exhibit sharp contacts, it is expected that contacts in the local area should also be quite sharp.

Altered Mafic and Ultramafic Rock

FIELD OCCURRENCE AND DESCRIPTION

Two bodies of massive amphibolite and talc-bearing amphibolite crop out in Worley Cove in the northeast corner of the Sandymush Quadrangle. The largest body occurs beneath a low ridge separating the two drainages that head up in Worley Cove to form Worley Creek. The smaller body occurs on the east side of the cove approximately 3,000 feet north of the intersection of SR 1110 with SR 1108.

Both bodies lie within a large amphibolitic unit of the Earlies Gap Biotite Gneiss. The bodies are distinctive in that they are much more massive and contain a higher percentage of amphibole than the surrounding country rock amphibolites. In addition, talc, as pod-like alteration masses, occurs within each of these bodies and does not occur with the enclosing amphibolites.

PETROGRAPHY

In hand sample these rocks are greenish black to brownish black and are quite massive. They display a medium- to coarse-grained nematoblastic texture. Compositionally they are over 90 percent amphibole (hornblende) with lesser plagioclase and epidote-group minerals. The talc-bearing rocks are light greenish gray to greenish gray and are foliated.

AGE, CONTACT RELATIONSHIP, AND PROTOLITH

An absolute age is not available for the altered mafic and ultramafic rock unit. The unit must be younger than the amphibolites of the Earlies Gap Biotite Gneiss because it apparently intrudes them. The unit has been metamorphosed, thus requiring that it be older than the major metamorphism that occurred in the Taconic. Most likely it is Middle Proterozoic to Early Paleozoic in age.

The contact between these two rock bodies and the amphibolites of the Earlies Gap Biotite Gneiss is not exposed. Evidence suggesting that these bodies actually intrude the Earlies Gap Biotite Gneiss is their north to northwest trend which is oblique to trends in the country rocks.

These altered mafic and ultramafic rocks may represent any of the following intrusive rocks: gabbro, pyroxenite, or dunite. The talc pods may represent original compositional differences in the intrusion that were more susceptible to alteration.

Snowbird Group

FIELD OCCURRENCE AND DESCRIPTION

The Snowbird Group underlies a small area along the western edge of the Sandymush Quadrangle along the Buncombe-Madison County line. It covers less than five percent of the Sandymush Quadrangle and does not crop out in the Canton Quadrangle. The most easily accessible outcrops lie along Bald Creek. The best exposures, however, are along the Buncombe-Madison County line for about one mile northeast of Little Sandymush Bald.

In the Sandymush Quadrangle the Snowbird Group consists of an interlayered sequence of clastic metasedimentary rocks dominated by kyanite-garnet-mica schist and metagraywacke. Cross sections based on outcrop width and attitude of relic bedding suggest that 4000 feet of metasediment are present. The schist layers make up over 65 percent of the map unit. The schist is medium gray to medium dark gray on freshly broken surfaces and it is thin to medium layered. At many exposures, relic bedding is indicated by compositional variations from layer to layer.

Metagraywacke interlayers make up over 30 percent of the formation. They are medium light gray to medium gray in color and are locally conglomeratic with granules and pebbles of both quartz and feldspar. Graded bedding was seen at only two outcrops.

Calc-silicate granofels forms minor interlayers within the metagraywacke. On fresh surfaces these medium to thin layers are medium gray to dark gray.

PETROGRAPHY

The schist (figure 13) is finely foliated and has a pronounced lepidoblastic texture. Garnet and kyanite occur as porphyroblasts and exhibit a poikiloblastic texture. Some of the kyanite porphyroblasts are as much as 1.5 centimeters in length. Kyanite is occasionally kinked and the garnet is commonly fractured. Mineral composition of the schist is variable from sample to sample.

Metagraywacke interlayers are poorly foliated to foliated and granoblastic to lepidoblastic in texture. This textural variation reflects the variation in mica content which, in turn, reflects the clay content of the original sediment. Modal composition of several samples is shown in table 10.

Calc-silicate granofels in the Snowbird Group is a compositional and mineralogic variation of metagraywacke. It has a granoblastic to nematoblastic texture. The more calcareous the original sediment, the more amphibole present and the better developed the nematoblastic texture. As noted during field traverses, mineral composition of the calc-silicate granofels is variable.

AGE AND CONTACT RELATIONSHIP

The metasedimentary rocks of the Little Sandymush Bald region are here assigned to the Late Proterozoic Snowbird Group of the Ocoee Supergroup. Previously they had been classed with other parts of the Ocoee -- the Great Smoky Group (North Carolina Geological Survey, 1985; Hadley and Nelson, 1971) or the Great Smoky Conglomerate and Hiwassee Slate (Keith, 1904). There are several reasons for reassigning the rocks to the Snowbird. First, graded beds of metagraywacke and graphitic schist or slate, very common in the Great Smoky, are rare to virtually absent in the Little Sandymush Bald area. Second, tourmaline, a very abundant, almost diagnostic accessory mineral in the Great Smoky (Hadley and Goldsmith, 1963), is only sparingly present in the rocks of the local area (figure 18 and Appendix 2). Third,

Figure 13. Snowbird Group. *Left*, Kyanite-garnet schist with prominent 1- to 3-millimeter garnets concentrated along compositional layers. Sample from along Bald Fork, 1.2 miles south of Little Sandymush Bald. *Right*, Photomicrograph showing crinkled layer of mica (mostly muscovite), kyanite (Ky) and garnet (Grt) porphyroblasts, and quartz, plagioclase, and epidote (Ep). Plane polarized light, sample 1739.

Table 10. *Modal analyses (in percent) of Snowbird Group.*

Sample No.	N.C. Coordinates	Rock Name	Quartz	Plagioclase	K-Feldspar	Biotite	Muscovite	Epidote	Garnet	Opaques	Hornblende	Kyanite
1705	731,250N; 851,150E	Feldspathic Metagraywacke	64.6	15.8	6.4	6.6	6.2	0.2	0.0	0.2	0.0	0.0
1738	729,650N; 855,000E	Conglomeratic Metagraywacke	71.0	14.4	4.2	7.8	2.6	0.0	0.0	0.0	0.0	0.0
1739	729,500N; 854,900E	Kyanite-Garnet Schist	12.8	10.2	0.6	8.4	42.6	0.0	12.8	0.6	0.0	12.0
1744	729,350N; 854,400E	Calc-Silicate Granofels	57.4	27.8	0.0	0.0	0.0	0.2	5.4	1.4	7.8	0.0

at many nearby places it is the Snowbird that nonconformably overlies granitic "basement" rocks (Hadley and Goldsmith, 1963), just as is the case in the local area.

In and around its type area, the Snowbird Group is a sequence of clastic marine sediments that were deposited directly onto granitic basement. In the nearby Pigeon River Gorge the Snowbird Group is divided into four formations (Hadley and Goldsmith, 1963). The lowermost is the Wading Branch Formation followed by the Longarm Quartzite, the Roaring Fork Sandstone, and the Pigeon Siltstone. Insufficient data is available to warrant subdividing the Little Sandymush Bald rocks. However, because of their occurrence immediately above the granitic basement and the dominance of dark-gray, fine-grained rocks, they are most likely correlative with the Wading Branch Formation.

The lowermost contact, as previously discussed, is a nonconformity. In the Sandymush Quadrangle, the Snowbird was deposited on an old erosion surface developed over the Spring Creek Granitoid Gneiss. The upper limit of the Snowbird is not present on the quadrangle.

Mylonite and Protomylonite

FIELD OCCURRENCE AND DESCRIPTION

Mylonite and protomylonite, formed during Late Paleozoic deformation, is present at many places in the area. The larger, more continuous bodies are shown as separate units on the accompanying maps (plates 1 and 2). At many other more or less isolated exposures, mylonitic fabric overprints the country rock to varying degrees. These places are shown on the maps by a colored pattern. Interestingly, almost none of the road cuts in the area contain exposures of mylonite. The most accessible outcrops are on the Canton Quadrangle and occur intermittently along slopes of the ridge separating West Cove from Wilson Cove.

Mylonite itself is dense, compact to somewhat flinty in texture, and locally approaches ultramylonite. The mylonites and protomylonites are interlayered with each other at the scale of centimeters. The mylonites are distinctive and are characteristic of the unit. Many of the protomylonites closely resemble the interlayered gneiss. At many places gneiss, similar to the enclosing map unit, is interlayered with the mylonite and protomylonite. Thin interlayers of amphibolite and mylonitized amphibolite also occur within mylonite and protomylonite units.

PETROGRAPHY

No modal analysis was made of the mylonite and protomylonite. Hand samples are medium gray to dark gray on fresh surfaces; the more thorough the mylonitization the darker the color. Mylonitic to gneissic and variably porphyroclastic (less than 1 millimeter to 1 centimeter) textures are observable in hand sample. Mineralogic composition of the mylonites reflects the map units from which they were derived. For example, mylonite derived from the aluminous Ashe Metamorphic Suite commonly contains abundant muscovite (figure 15).

AGE AND CONTACT RELATIONSHIP

The mylonites are Middle or Late Paleozoic in age. Locally, they obliterate or truncate the trace of the Holland Mountain thrust fault, crosscut unit boundaries, and truncate the Paleozoic foliation of the Ashe Metamorphic Suite and the Earlies Gap Biotite Gneiss. The truncation of the Paleozoic foliation and the Holland Mountain fault is most obvious around Williams Mountain and Big Butt Mountain in the northern part of the Canton Quadrangle (see plate 2). The minimum age of the mylonite and protomylonite is uncertain, but regional considerations make it quite unlikely to be post-Paleozoic.

Trondhjemite

FIELD OCCURRENCE AND DESCRIPTION

Thin trondhjemite dikes and sills occur sparingly in the southeastern part of the Sandymush Quadrangle and most of the Canton Quadrangle. They appear to be most abundant in the southeast half of the Canton Quadrangle where the Paleozoic metamorphic grade is highest. The dikes and sills range in thickness from several centimeters to a meter and are rarely traceable beyond the limits of a single outcrop. Nowhere in the study area are the bodies large enough to warrant mapping.

In hand sample, trondhjemite is very light gray to medium light gray to very pale orange in color. It is unfoliated; however, a few samples show some alignment or streaking of minerals. This is attributed to original magmatic flow or may possibly record a weak deformation event.

PETROGRAPHY

Thin sections were not made of trondhjemite from the Sandymush and Canton Quadrangles. Samples of trondhjemite from nearby areas are somewhat varied (Yurkovich and Butkovich, 1982; Merschat, 1977; Morrow, 1977; Hadley and Goldsmith, 1963). Textures are porphyritic to granoblastic and mortar structure is common. Grain size ranges from fine to medium grained. Modal analyses range from granodiorite to tonalite; however, most samples are tonalites. Plagioclase and quartz normally make up more than three-fourths of the rock. Minor biotite is present; K-feldspar and white mica rarely total more than six or seven percent.

AGE AND CONTACT RELATIONSHIP

An absolute age for the trondhjemite is not available. Although attempted, radiometric dating has not been satisfactorily accomplished. Trondhjemite is intrusive into all of the bedrock map units, except pegmatites. This observation, and the fact they are not strongly foliated, indicates a post-metamorphic, Middle Paleozoic age. Further support for a Middle Paleozoic age derives from the fact that compositionally the trondhjemites resemble many of the large intrusive bodies of the Blue Ridge. These bodies, for example, the Whiteside, Stone Mountain, and Mount Airy plutons, are of established Silurian or Devonian age. The compositional similarity suggests a close genetic and therefore temporal relationship.

Trondhjemite is intrusive and exhibits sharp, commonly discordant contacts with all the highly foliated metamorphic rock units on these quadrangles.

Pegmatite

FIELD OCCURRENCE AND DESCRIPTION

Pegmatite occurs throughout the Canton Quadrangle and much of the Sandymush Quadrangle. Pegmatites that intrude the Ashe Metamorphic Suite contain coarse muscovite. Those intruding the Earlies Gap Biotite Gneiss, Sandymush Felsic Gneiss, and other Middle Proterozoic rocks are generally muscovite-poor and biotite-rich. Pegmatite is commonly crosscutting and lenticular to tabular in shape. Thickness varies from a centimeter to a few tens of meters. Although very thin pegmatites are locally abundant, it was practical only to record the larger pegmatites on plates 1 and 2. Because the pegmatites weather and decay so thoroughly, their orientation is often difficult to determine.

PETROGRAPHY

Thin sections were not made of pegmatite. Because of the coarse-grained nature of a pegmatite, a hand-sample description is adequate. Pegmatite is white to mottled white and pink in color. Its texture is coarse grained to very coarse grained. It contains plagioclase, K-feldspar, quartz, biotite,

and/or muscovite. Other accessory minerals may occur in pegmatite.

AGE AND CONTACT RELATIONSHIP

Muscovite-bearing pegmatites in the Spruce Pine Mining District have an age of about 390-435 million years (Kish, 1983). Although the Sandymush and Canton Quadrangles are 50 miles southwest of Spruce Pine, the Spruce Pine pegmatite age is accepted for similar pegmatites in this area.

The pegmatite bodies have sharp, well-defined contacts with the surrounding country rocks. Pegmatite is the youngest bedrock unit on the quadrangle as it intrudes and crosscuts all other bedrock units on the map.

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 based chiefly on their mode of transport — alluvium and colluvium. Alluvium is formed by running water depositing clastic material in stream channels and flood plains. Colluvium is the coarse- to fine-grained material mantling hillsides and slopes that has been moved downward mainly by gravity. Although not shown on the accompanying bedrock maps, alluvial and colluvial deposits occur throughout the two quadrangles. These surficial deposits, along with soils and vegetation, mask the bedrock geology of the quadrangle. A detailed map of the surficial deposits is beyond the scope of this project.

ALLUVIUM

Alluvium or alluvial deposits occur in stream valleys, both in their flood plains and channels. Significant accumulations exist at only one or two places in each quadrangle. Commonly, the largest alluvial deposits occur in the flood plains of the major streams. On the Sandymush Quadrangle the largest flood plain deposit occurs where Willow Creek joins Sandymush Creek. This large alluvial deposit provides the largest flat area and the best farming land in the quadrangle. A similar area is found on the Canton Quadrangle along the Pigeon River in the southwestern corner of the map in the vicinity of the Plott Farms Addition. These large flood plain deposits represent deposition that took place during flood stages when the streams were out of their banks.

Alluvial deposits of the Sandymush-Canton Quadrangles consist of boulders, cobbles, pebbles, sand, silt, and clay-sized particles. Deposits within the stream channels contain all of these different sized sediments, but they are poorly sorted and not very extensive. Beyond the banks of a stream, flood plain deposits may build up as a result of flooding. These deposits consist of poorly to well-sorted, stratified gravel, sand, silt, and clay. The deposits are rarely greater than 15 feet thick.

COLLUVIUM

Colluvium or colluvial deposits mantle much of the sloping land throughout both quadrangles. The material is a product of weathering (mass wasting), sloping land, and gravity. In steep terrain, colluvial accumulations include abundant coarser-sized material, no matter what the bedrock material. In gently sloping terrain it requires a more massive bedrock to produce a more bouldery colluvium. Colluvial materials range in size from clay particles to giant boulders larger than houses. Quite commonly, where several huge colluvial boulders are touching, they form cave-like openings. In some areas these openings are interconnected and create lengthy passageways.

Colluvial deposits are classified according to their characteristic shapes. In fact, when they are large and well formed, their distinctive form is easily recognized on topographic maps. The collu-

vial deposits observed on the Sandymush and Canton Quadrangles include talus, block fields, and colluvial tongues, sheets, or aprons. All of these colluvial forms are commonly modified and dissected by running water.

Compositionally, colluvial materials reflect the bedrock units from which they develop. The more resistant rock types produce the more abundant particles. The more massive rock units produce the larger colluvial particles.

AGE

Alluvium and colluvium are deposits of clastic material released by local erosion of the surrounding mountains. Erosion of the Blue Ridge has been going on since at least Mesozoic time, over a quarter of a billion years ago, but it is almost inconceivable that remnants of detritus this archaic are still present in the area. Those materials must have long since been transported far out of the area. Most investigators infer the bulk of the relatively ephemeral surficial deposits formed much more recently during glacial intervals of the Pleistocene Epoch (e.g. King, 1964; Mills et al., 1987). Although glaciers certainly were not present in the local area, the climate was likely quite severe, thereby promoting the formation of extensive detrital accumulations. It is also clear that these deposits are currently being created and reworked, notably during occasional, high-energy storms. Thus, the deposits have been generated intermittently through time with the frequency related to major climatic conditions. The alluvial and colluvial deposits are therefore classed as Quaternary in age.

GEOLOGIC STRUCTURE

At virtually every outcrop in the area one may readily observe features of rock deformation. Planar surfaces and relic layers, that is, lithologic contacts and beds as well as foliation surfaces, are tilted, warped, or folded. Structural discontinuities, or faults of the layers are common, and mylonite zones, from microscopic to map scale, are widespread. In addition, fractures and cracks, or joints, are ubiquitous. Based on analysis of these deformation structures and supplemental mineral and rock radiometric ages, a historical deformational sequence may be constructed (table 11). Many similar studies have been done throughout the Appalachians with the cumulative, integrated evidence showing that a series of rock-deforming and metamorphic episodes spanning a billion years or more have occurred.

In the southern Appalachian Blue Ridge it is widely accepted that three principal episodes of deformation and metamorphism, or orogenies, have affected the region. They are the Middle Proterozoic Grenville orogeny, about 1.2 to 1.0 billion years ago, the Early to Middle Paleozoic Taconic orogeny, approximately 470 to 430 million years ago, and the Late Paleozoic Alleghenian orogeny about 300 to 280 million years ago. Each of these lengthy and complex episodes affected the then extant rocks in its own peculiar manner. In addition, events of lesser intensity have also left their mark on the rocks in the region.

Proterozoic Structures

The oldest, or Grenville event, affected rocks throughout eastern North America. It has been studied most extensively in eastern Canada and the Adirondack area of New York State where these highly deformed and metamorphosed rocks are widely exposed. In the southern Appalachians, Grenville-age rocks form the core of the Blue Ridge and crop out intermittently as far south as Georgia. However, subsequent Paleozoic-age deformation and metamorphism profoundly overprinted and largely obliterated features produced by Grenville events.

In the local area, strata existing about a billion years ago are now represented by five formations. Three of these consist mostly of layered rocks; the other two are more massive units.

Table 11. *Geological development of the Sandymush and Canton area*

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 Taconic orogeny. Development of the pre-metamorphic Holland Mountain thrust fault, major and minor folds, and pervasive foliation. Foliation or schistosity developed in the Ashe and Snowbird formations; 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, some retrogression occurred. This retrogression is expressed mainly in the mafic units (i.e., hornblende to biotite; olivine and pyroxene to serpentine and anthophyllite).

Latest Proterozoic. Deposition of Snowbird Group sediments.

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

Middle or Late Proterozoic. Mylonitization occurred. It is especially pronounced or well preserved in the Doggett Gap Protomylonitic Granitoid Gneiss. Steatization of protoliths of the talc bodies in north part of area also took place.

Middle Proterozoic. High-grade metamorphism and deformation associated with the Grenville orogeny. The Doggett Gap, Spring Creek, Sandymush, Earlies Gap, and Richard Russell Formations were metamorphosed, at least into the upper amphibolite facies. Undoubtedly, this major orogenic event involved wholesale recrystallization and metamorphic differentiation to produce banded and foliated gneissic rocks. Granitic material intruded and crystallized to form protoliths of the very coarse-grained Doggett Gap unit and the coarse-grained Spring Creek Granitoid Gneiss. Mafic material also intruded to form protoliths of the talc bodies and the more massive mafic and ultramafic rocks.

Middle (?) Proterozoic. Formation of the protoliths of the Sandymush Felsic Gneiss, Earlies Gap, and the Richard Russell Formations. These were likely layered felsic and mafic volcanic materials with only minor sedimentary components.

The layered units are the Sandymush Felsic Gneiss, Earlies Gap Biotite Gneiss, and the Richard Russell Formation. Their layering, although certainly long since transposed into foliation surfaces, likely reflects original compositional variations.

The massive units, the Spring Creek Granitoid Gneiss and the Doggett Gap Protomylonitic Granitoid Gneiss, originally were granitic plutonic bodies. They may have been medium- or very coarse-grained phases of one pluton, or they may represent two separate magmatic bodies. We interpret these to have intruded the presumably older, layered units. However, contacts are now so overprinted by subsequent tectonic events that it is virtually impossible to determine the original relationships at field exposures. Both plutonic units contain an internal tectonic and metamorphic fabric. The Spring Creek Granitoid body is gneissic with some mylonitic elements. The Doggett Gap has a ubiquitous protomylonitic fabric that locally grades to mylonitic or gneissic texture.

In the northwest corner of the Sandymush Quadrangle the outcrop pattern and internal fabric of the Doggett Gap Protomylonite define a large fold (see plate 1). The axis of this structure trends northeast-southwest. However, the Spring Creek Granitoid Gneiss comprises both the outer flanks and inner core of the fold. This unusual condition requires that the rocks were folded twice. First, the Doggett Gap and surrounding strata, including the Spring Creek, were tightly and perhaps even isoclinally folded. Second, the sequence was later refolded into a relatively open structure to produce the present pattern (see plate 1 and section A-A'). The northeast-southwest trend of the second or later fold parallels regional structural trends and regional foliation directions. We therefore infer that the second fold developed at the same time as did the dominant regional structure. There is little argument that overriding regional structural trends resulted from Taconic deformation and are of Paleozoic age. For convenient reference, the two fold events are designated F_1 (earlier) and F_2 (later). As the mylonitic fabric is likewise folded by the Paleo-

zoic F_2, the mylonitic fabric must also be an older feature. We infer that the mylonitization and F_1 folding record complex Proterozoic, Grenvillian orogenic deformation.

It is tempting to consider that the tight, nearly isoclinal folding of the Doggett Gap and development of its protomylonitic fabric were contemporaneous. However, no additional or conclusive evidence pertaining to their genetic relationship was discovered. Elsewhere in the Grenville-age rocks other mylonitic areas were observed and mapped. As these mylonites resemble those in the Doggett Gap, we infer that they too are Proterozoic in age.

Throughout the area contacts between the several Middle Proterozoic units are commonly curved and inflected, indicating at least one episode of folding. (See plates 1 and 2.) Because the regional Early Paleozoic Taconic foliation variably and non-systematically trends across these contacts, it is concluded that the foliations postdate at least some of the folding recorded by the curved, inflected contacts. This folding is therefore also correlated with the Grenville-age, F_1 folding previously discussed.

Early Paleozoic Structures

In contrast to the just-described relations between foliation trends and Middle Proterozoic rock-unit contacts, foliation trends and lithologic contacts of the younger Snowbird and Ashe Formations obviously have systematic, geometrical relationships. (See plates 1 and 2; figure 14.) For example, near the west edge of the Sandymush Quadrangle, Snowbird Group rocks occupy a broad southwest plunging syncline. Measurements of schistosity in the Snowbird reveal an axial planar trend and in cross section the schistosity defines a divergent cleavage fan. (See section B-B', plate 1.) Divergent fans, on both theoretical and observational grounds, are understood to develop during folding of a relatively incompetent layer between competent layers (cf. Ramsey and Huber, 1983, p. 181). With regard to the adjacent quartzo-feldspathic gneisses, the dominantly schistose Snowbird which hosts the divergent fan is clearly incompetent. The conclusion is that folding of the Snowbird and development of its northeast-striking schistosity occurred during the same deformation.

Within the Ashe Metamorphic Suite, geometrical relations between foliation orientations and map-scale folds are also suggestive of axial plane foliation. This relation is most clearly shown at several places on the Canton Quadrangle (see plate 2). The locations are west of Beaverdam Creek valley in the vicinity of Rocky Knob and Rough Creek, in the area approximately three-fourths of a mile west of Newfound Gap, and at the south end of Holland Mountain along the schist-gneiss contact of the Ashe Suite. At these places, foliation in the Ashe is generally parallel to mapped trends and limbs.

The folding just described probably formed during the Paleozoic Taconic orogeny. Almost all modern studies of geologic structures in the southern Blue Ridge conclude that this was a complex deformational event. There was an early isoclinal folding phase with attendant development of metamorphic foliation and transposition of existing planar elements, such as bedding, or igneous contacts into the plane of foliation. Transposition is considered to have been extreme enough to have obliterated nearly all the closures, or noses, of the early isoclines. Observations in the Sandymush-Canton area are quite consistent with this interpretation. At both outcrop and thin-section scales, foliation and compositional layering are essentially parallel and fold closures attributable to early folding are rare to virtually absent.

However, non-isoclinal, open to tight folds of foliation and the parallel compositional layering are abundant. They are well defined at map scale and are readily observable at many outcrops throughout the area. These folds of foliation must have formed subsequent to the foliation itself. This sequence, development of a principal metamorphic foliation that is parallel to compositional lay-

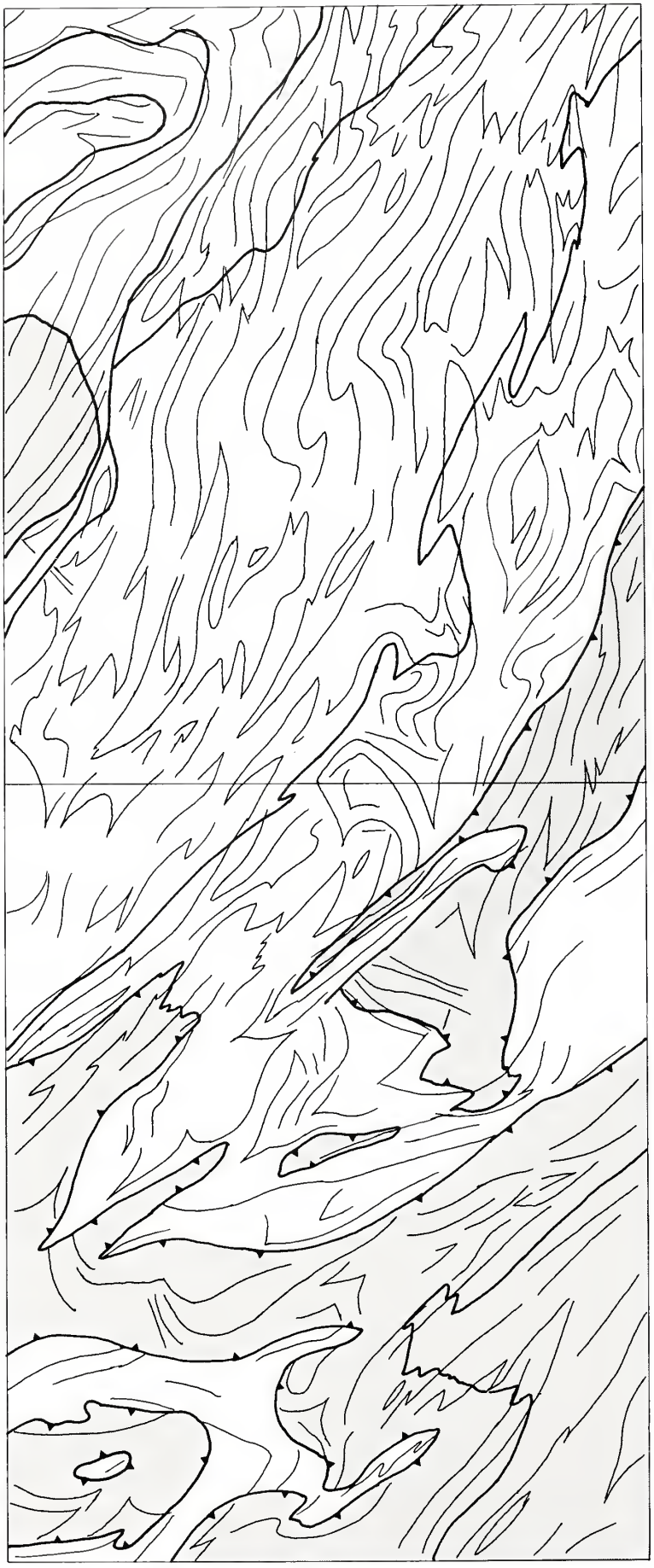


Figure 14. Map showing foliation trends, Sandymush and Canton Quadrangles. Heavy lines are formation boundaries; saw teeth are on upper plate of Holland Mountain thrust fault. Late Proterozoic Ashe Metamorphic Suite and Snowbird Group are shaded.

The Snowbird Group, central left on the Sandymush Quadrangle, is cut by axial planar schistosity which is co-planar with foliation that variably crosscuts formation contacts between Middle Proterozoic units. At some places, the Holland Mountain thrust truncates foliations in both upper and lower plates. However, as the fault does not displace the kyanite-sillimanite isograd (see plate 2 and figure 19), the fault must be syn- to late metamorphic in age.

ers followed by folding of the foliation itself, is characteristic of many orogenic belts throughout the world (e.g. Turner, 1968).

An important feature in the region is the contact underlying the Ashe Metamorphic Suite. The nature of this boundary is open to question as the known pertinent evidence is not definitive. First, there is certainly a great hiatus between the Late Proterozoic Ashe Suite and the underlying Middle Proterozoic Earlies Gap Biotite Gneiss. Either a fault or an unconformity could cause this relationship; however, at no place on the Canton, Sandymush, or nearby quadrangles have clasts of older units been observed in the overlying Ashe Suite. The absence of such clasts argues against an unconformity. Second, detailed mapping of the nearby quadrangles (Merschat, 1977; Merschat, in preparation; Wiener, unpublished mapping) shows that different rock units abut the contact from both above and below. This relation is suggestive of truncation by faulting. Finally, current regional interpretations for the Blue Ridge place major thrust faults between distinctly different groups of lithic units (cf. Mies et al., 1987; Nelson, 1985; Higgins et al., 1984). A fault below the Ashe is in agreement with this regional model. Based on this evidence the contact is interpreted as a fault and is here named the Holland Mountain thrust fault. Holland Mountain is a long, prominent ridge on the east side of the Canton Quadrangle that is underlain by the fault.

Examination of the geologic map shows that the Holland Mountain fault has the appearance of a folded, low-angle thrust. It has an irregular trace and several klippen are present. This folding has also affected foliation in the Ashe Suite. Foliation trend lines mimic the folding shown by the Holland Mountain thrust (figure 14), thereby demonstrating that the thrust existed prior to folding. Additionally, the metamorphic foliation and transpositional fabric appear to be truncated by the fault. This evidence suggests the fault to be post-foliation in age. Significantly, the fault predates the region's metamorphic thermal peak as the closely located kyanite-sillimanite isograd obliquely crosses the Holland Mountain thrust without detectable offset (see plate 2). Thus, based on several lines of evidence, the Holland Mountain thrust fault is a pre- to syn-metamorphic structure. A number of other faults in the southern Blue Ridge exhibit similar relations; two of the better known ones are the Greenbrier fault (Hadley and Goldsmith, 1963) and the Hayesville fault (Hatcher et al., 1979).

To summarize, the following sequence occurred during the Taconic episode. Regional foliation developed and transposition took place followed by faulting and open to tight folding. Finally, a thermal peak, represented by development of porphyroblastic minerals such as staurolite, kyanite, and sillimanite, overprinted the deformed rocks.

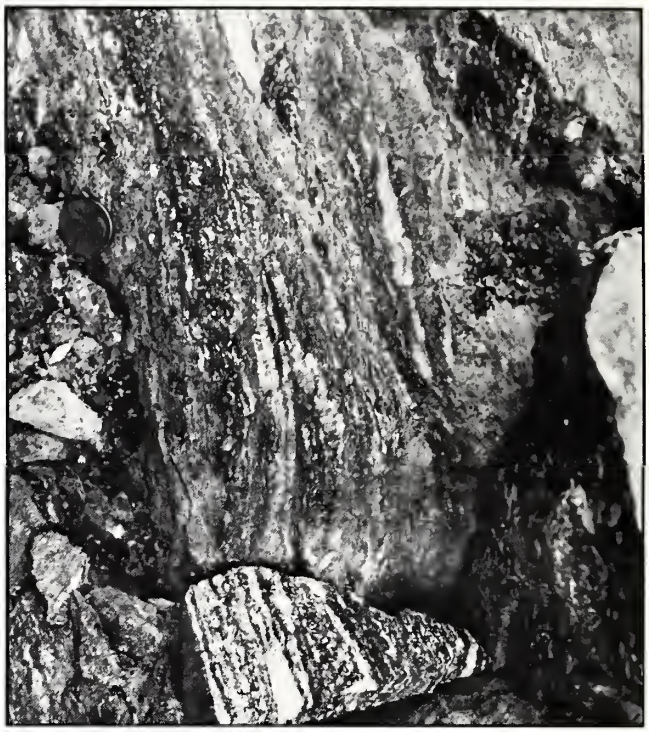
Later Paleozoic Deformation

In the Sandymush-Canton area Taconic structures are cut by mylonite zones, small trondhjemite dikes, and pegmatite intrusions. However, no crosscutting relations between these features were discovered and thus relative ages with respect to each other are not conclusively established.

Locally, the pegmatites are thin tabular bodies that are commonly discordant with regard to foliation and compositional layering of the enclosing rocks. Butler (1972) points out that regionally the muscovite-bearing pegmatites tend to appear in the kyanite and sillimanite metamorphic zones. He also notes that contact metamorphic effects are absent from around the boundaries of the pegmatites. Observations on the relatively few pegmatites in the Sandymush-Canton area are in agreement with Butler's. There is, therefore, concurrence with his conclusion that the pegmatites intruded during the waning phases of a metamorphic event. The age of Blue Ridge pegmatites is cited as 390-435 million years, or Silurian-Early Devonian (North Carolina Geological Survey, 1985).

The few small exposures of trondhjemite found in the Sandymush-Canton area have the form of thin, crosscutting, unfoliated dikes. A regional study by Yurkovich and Butkovich (1982) reports on the orientation of some six dozen trondhjemite dikes and sills. They found the intrusives are mostly parallel to the northeast trend of the Blue Ridge with a lesser number perpendicular to this trend. Paucity of well-exposed dikes in the Sandymush-Canton area precludes the present study from adding to their data. Anderson's widely accepted explanation of dike formation (Anderson, 1951) states that dikes are intruded into zones perpendicular to the direction of minimum compressive stress. Thus, Yurkovich and Butkovich's (1982) regional information suggests that the minimum compressive stress was oriented northwest-southeast at the time of trondhjemite intrusion. This, however, was the orientation of maximum compressive stress during Taconic deformation. Perhaps the low-stress zones which controlled the trondhjemite intrusions resulted from relaxation of the northwest-directed compressive stress field in post-Taconic time.

In addition to the old Proterozoic mylonitization previously discussed, the effects of a more recent mylonitization are locally present (see figure 15). As is quite clear from field relations in the central part of the Canton Quadrangle around the Williams Mountain-Big Butt area, Taconic-age folds and the Holland Mountain fault are truncated by a major mylonite unit (see plate 2). Half a mile northwest of this area in the region of Wilson Cove, Williams Cove, and Turkey Creek Gap, this same mylonitization is developed mostly in aluminous, muscovite-bearing rocks of the Ashe Metamorphic Suite. In this region a small dunite body is anomalously present in the midst of the Ashe-derived mylonite. In the central Blue Ridge dunite normally occurs only in rocks much older than the Ashe. Its anomalous presence in the Ashe-derived mylonite suggests that the dunite has been emplaced by the same kinematic processes responsible for the formation of the mylonite itself. These processes must therefore have involved considerable dip slip in the planes of mylonitization.



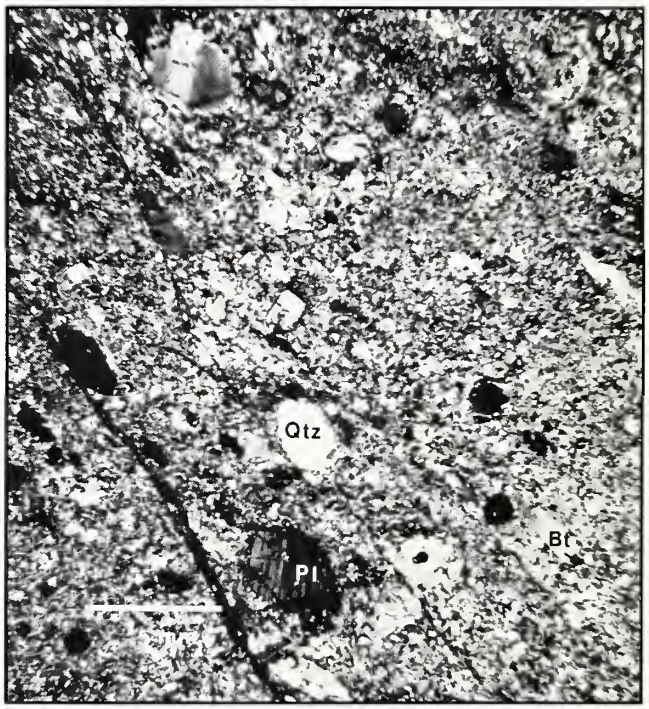


Figure 15. Mylonitization. *Above*, Mylonite of the Ashe Metamorphic Suite. Later Paleozoic fluxion structure obliterates most earlier features. Coarse muscovite porphyroblasts are common. Coin is 1.5 centimeters across. Outcrop is along tributary stream to West Cove, 3200 feet northwest of Big Butt Mountain, Canton Quadrangle. *Below*, Photomicrograph of mylonite of the Earlies Gap Biotite Gneiss. A few porphyroclasts of plagioclase (Pl), biotite (Bt), and quartz (Qtz) remain in a fine-grained ground mass. Crossed polarizers, sample 513.

Other areas of mylonite and protomylonite are also present. They are most notable in schistose rocks of the Ashe Metamorphic Suite, both within the body of the unit and at many places along its boundary with gneisses of the Earlies Gap Biotite Gneiss. It is tempting to infer a genetic association between these mylonites and development of the Holland Mountain thrust fault. However, as previously described, the fault itself is truncated by a mylonite zone in the Williams Mountain-Big Butt area, thereby demonstrating that the two deformational features are not necessarily related in a genetic sense. Thus, the mylonitization event must postdate the Taconic deformation and metamorphism as do the trondhjemite and pegmatite dikes.

About seven miles north of the Sandymush Quadrangle is the Hot Springs window. Exposed in this structure are unmetamorphosed Paleozoic sedimentary rocks surrounded by major thrust faults (Oriel, 1950). These faults are part of a regional thrust system that evidently underlies the entire Blue Ridge to make it a huge allochthonous mass. Seismic reflection data (Harris et al., 1981; Cook et al., 1983; Hatcher et al., 1987) suggest that the thrust is nearly horizontal beneath the Blue Ridge. The most recent work (Hatcher et al., 1987) concludes that the fault is from two to five kilometers below the surface in the eastern Blue Ridge. Geologic relations to the west in the Valley and Ridge Province establish the age of this faulting. It is associated with the Alleghenian orogeny and is of Late Paleozoic age. Although not exposed at the surface in the local area, the undoubted presence at depth of this major thrust, or thrust system, adds another dimension to the region's geologic structure. In fact, the Late Paleozoic mylonitic zones and possibly other features may be related to emplacement of the Blue Ridge allochthon during the Alleghenian deformational event.

Mesozoic and Cenozoic Structures

The Mesozoic and Cenozoic tectonic history of the southern Appalachians is mainly one of variably active epeirogenic uplift. Associated with this is concomitant subaerial erosion. Other than joints, specific Mesozoic- or Cenozoic-age structures are not known, or at least not identified in North Carolina's Blue Ridge.

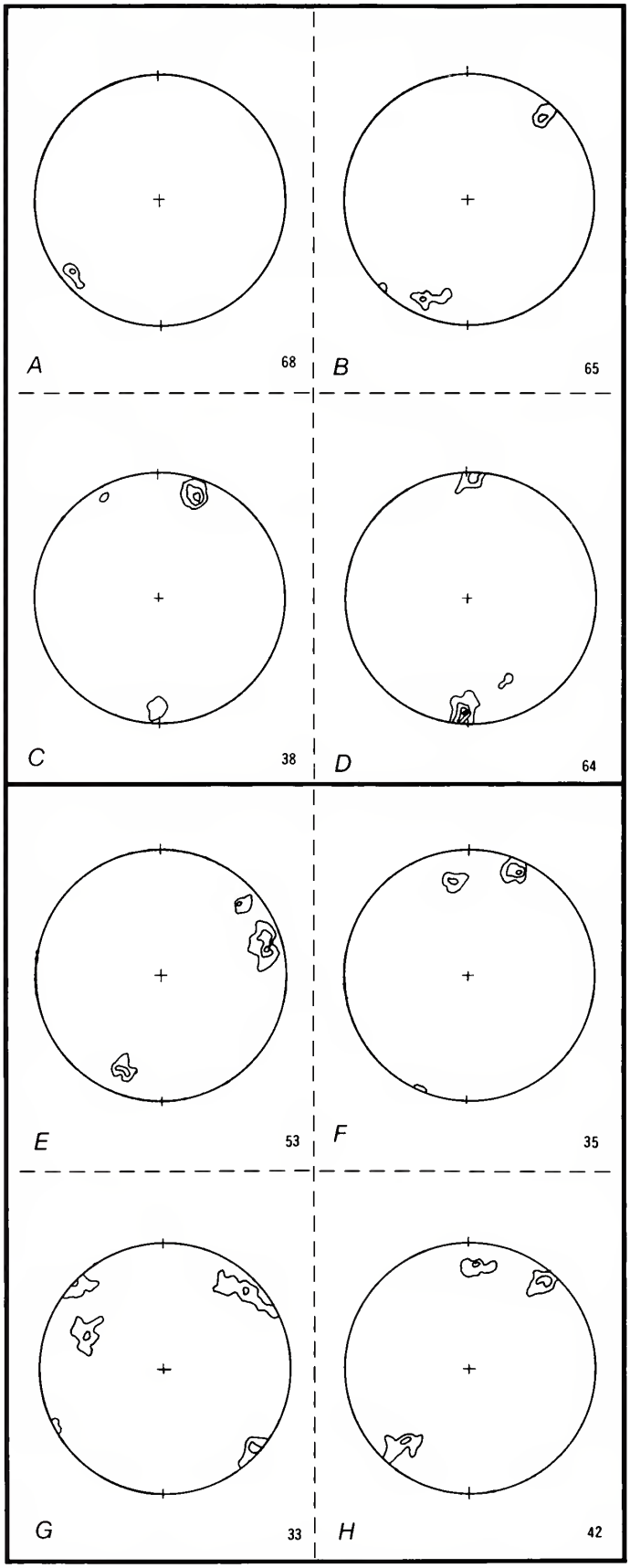
The most recent structures in the Sandymush-Canton area are fractures or joints that are present in virtually every outcrop. These fractures may be grouped or classified in several different ways. More or less curved joints that tend to parallel the topographic surface are locally present. Many of these come under the category of sheet, or exfoliation joints. They are well displayed at the rounded bare rock knobs and hillsides underlain by the massive Doggett Gap Protomylonitic Granitoid Gneiss or the Spring Creek Granitic Gneiss.

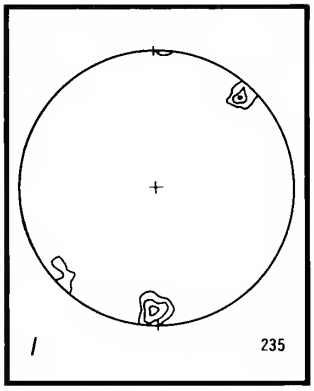
At many places joints coincide with foliation surfaces. These breaks in the integrity of the rock mass are analogous to features called bedding joints in sedimentary rocks.

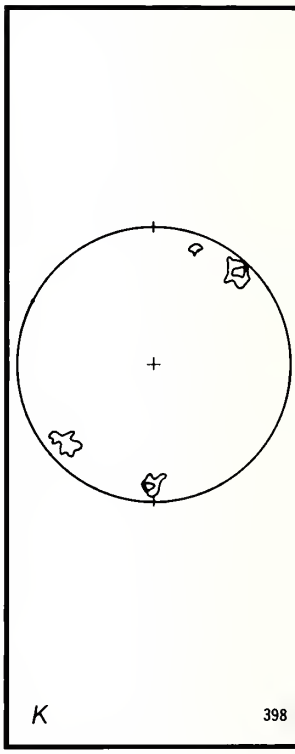
Other joints are present which are not obviously sheet joints or foliation-surface joints and have diverse orientations. Several hundred of these joints were measured and recorded. These data were entered into a standard computer program and recovered as contoured equal-area stereographic plots. The plots are presented in figure 16. Figure 17 presents a graphic summary of the data in terms of small, quarter-quadrangle domains, individual quadrangles, and by the full, two-quadrangle area.

Apparently, the smaller the area, the less the diversity of joint orientations and the higher the degree of concentration in each joint orientation maximum. Conversely, plots for data composited over the larger one- or two-quadrangle area show an increasing scatter of orientations and a lowering of the degree of concentration in each orientation maximum. Perhaps this tendency is a reflection of the overall geologic non-homogenous nature of the area.

The joint maxima diagrams reveal a general northwest-southeast trend for the majority of the







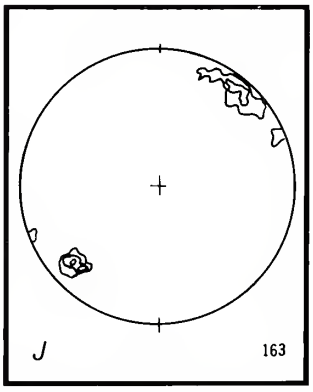


Figure 16. Contoured stereoplots of joint orientations, Sandy mush and Canton Quadrangles. Lower hemisphere projection of poles to joints, equal area net.

A-H - Data plotted by quadrants.

I and *J* - Data for each full quadrangle.

K - Composite of all joints, both quadrangles.

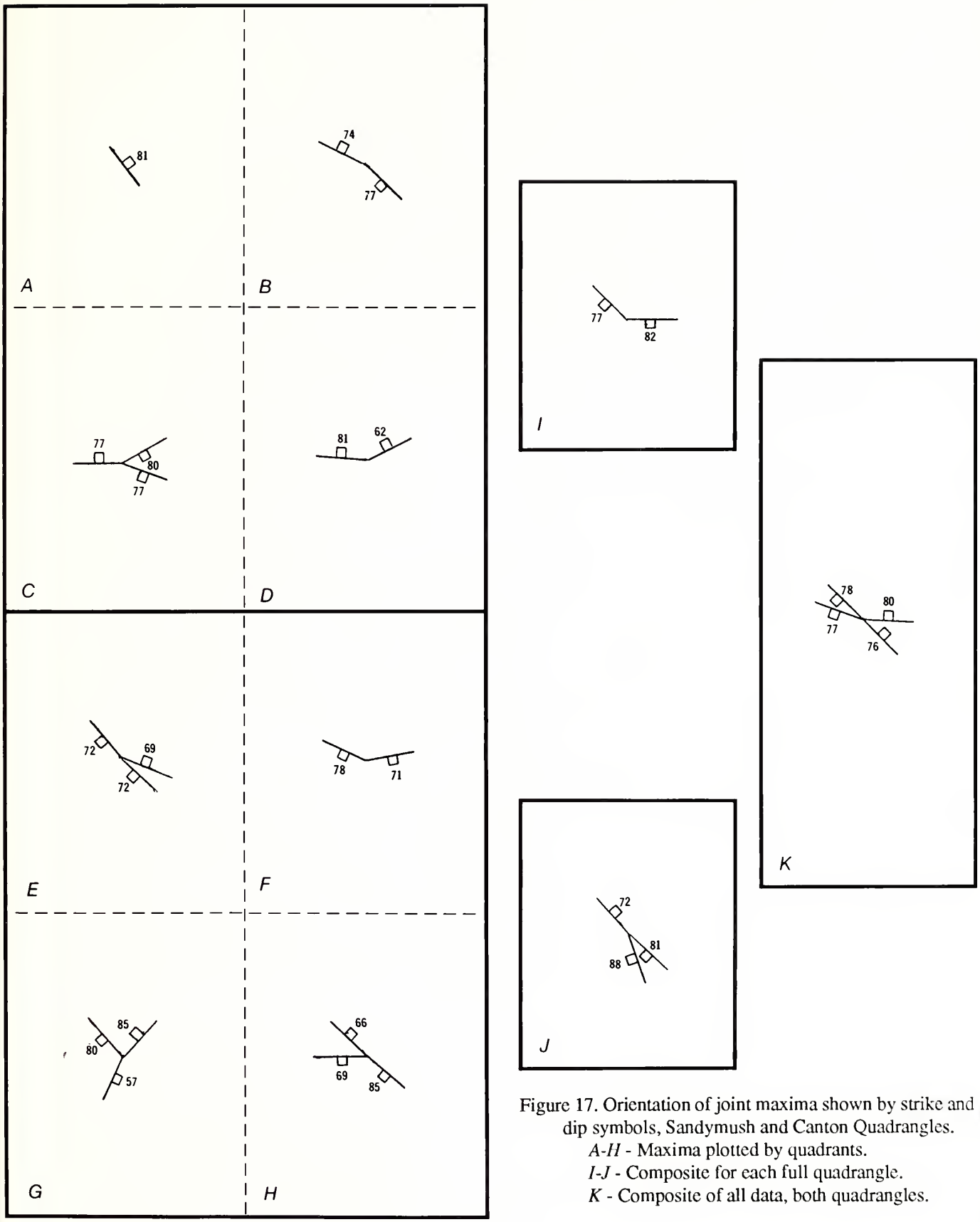


Figure 17. Orientation of joint maxima shown by strike and dip symbols, Sandymush and Canton Quadrangles.
A-H - Maxima plotted by quadrants.
I-J - Composite for each full quadrangle.
K - Composite of all data, both quadrangles.

measured joints with a subsidiary, nearly east-west trend. These principal trend directions undoubtedly have some underlying regional tectonic explanation. However, considerably more study will be necessary to explain this aspect.

As the present investigation was necessarily limited to surface exposures, no first-hand information was obtained on the subsurface extent of any jointing. Daniel (1987) made a regional statistical study of more than 6,200 water wells drilled in the Piedmont and Blue Ridge of North Carolina. His data show that significant amounts of exploitable water are available 1,200 feet or more below the surface at some places. This information certainly indicates that joints are present and act as water conduits at considerable depth in the Piedmont and Blue Ridge. Similar deep joints may also be present in the Sandymush-Canton area.

METAMORPHISM

Deciphering completely the long, complex metamorphic history of the rocks of the Sandymush and Canton Quadrangles is well beyond the scope of this study. The synthesis presented here incorporates our own observations with data and conclusions of others from work elsewhere in the Blue Ridge.

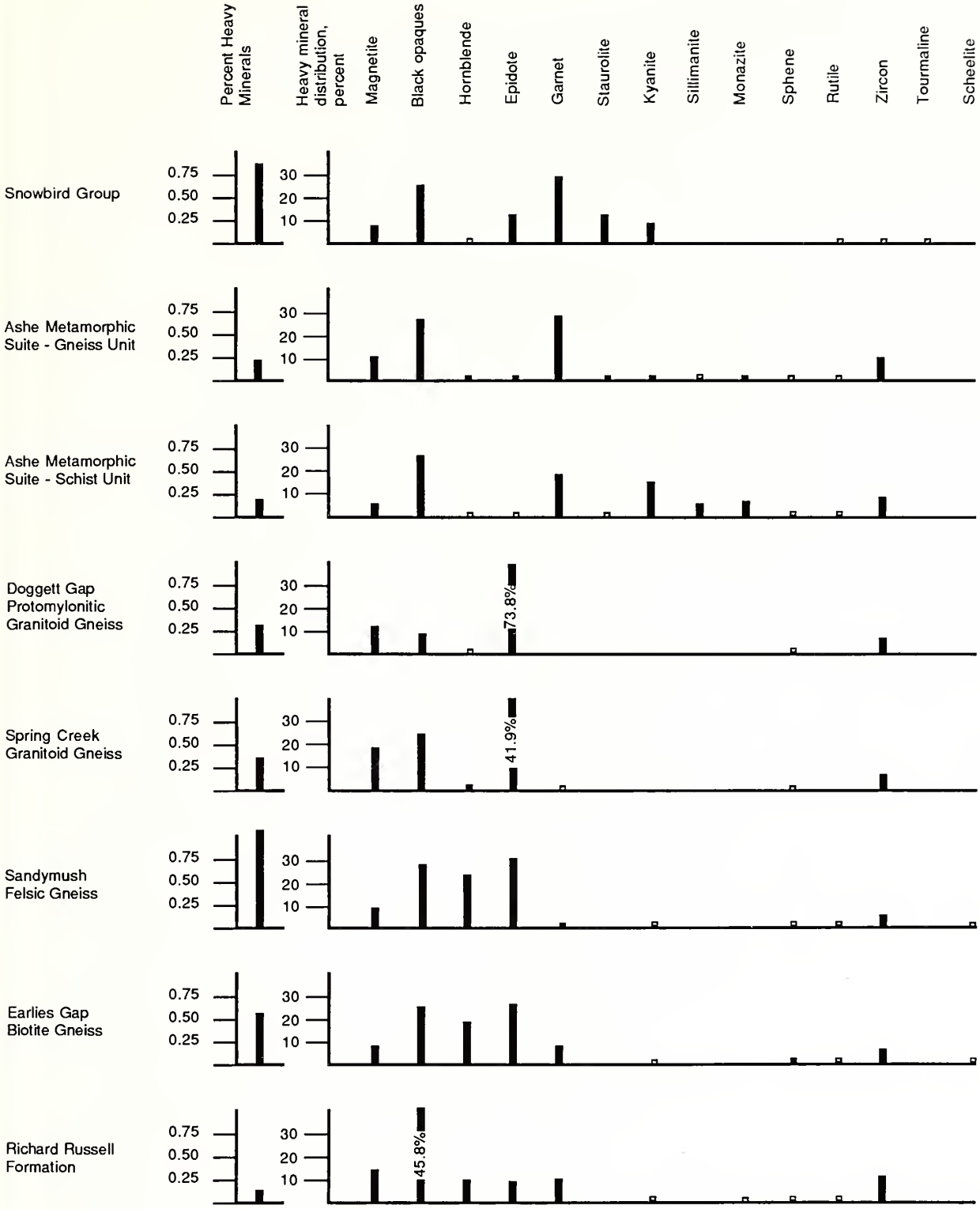
The areal distribution of metamorphic index minerals is important in elucidating the region's metamorphic history. Primary control in the two-quadrangle area is mainly based on 149 stream-sediment samples (figure 18; Appendix 2). Hand-sample examination during field traverses and subsequent thin-section study of selected samples provided important additional data.

Proterozoic Metamorphism

In the southern Appalachian Blue Ridge several recent radiometric analyses of rock and mineral samples have yielded unexpectedly old ages. Sinha and Bartholomew (1984) report a 1870-million-year age for zircon grains from the Lovingston massif in central Virginia. Monrad and Gulley (1983), using whole-rock rubidium/strontium methods, determined a 1815-million-year age for rocks on Roan Mountain, North Carolina, about fifty miles northeast of the Sandymush-Canton area. These archaic, Early Proterozoic dates are by far the oldest reported in the entire region and their significance is not yet clear. They may indicate a time of magmatic activity or they may reflect a period of extreme metamorphic reconstitution of crustal material. One may assume that rocks and minerals dating back to this time are precursors or sources for subsequent lithic units.

Documentation of high-grade Middle Proterozoic metamorphism is more extensive. For example, as long ago as 1916, Watson and Cline (1916) described granulite-grade mineral assemblages in Virginia. Bartholomew and Lewis (1984) discuss high-grade rocks in the Virginia and North Carolina Blue Ridge. McConnell and Costello (1982, 1984) describe similarly metamorphosed rocks near the western edge of the Blue Ridge in Georgia. Radiometric ages of about 1,000 million years are recorded from many of these rocks (Fullagar and Odum, 1973; Rankin et al., 1983). This combination of data from so extensive a geographic area is firm evidence for concluding that regional, high-grade metamorphism occurred during Middle Proterozoic time in the Blue Ridge. High-grade metamorphism of this general age in eastern North America is commonly named Grenvillian. When coeval deformational and magmatic effects are included, use of the term Grenville orogeny is appropriate.

On the Mars Hill Quadrangle, located about fifteen miles northeast of the Sandymush-Canton area, Merschat (1977) shows the presence of granulite-facies mineral assemblages. He provides detailed mapping and descriptions of hypersthene-plagioclase rock, hypersthene-biotite-hornblende gneiss, and hypersthene granitic gneiss. Kuchenbuch (1979) also examined rocks in the Mars Hill area and supported and extended Merschat's observations.



Note: Open symbol indicates less than 2 percent abundance; refer to Appendix 2 for exact values.

Figure 18. Graphs showing average abundance of heavy minerals in stream-sediment samples for individual formations.

Reconnaissance mapping indicates these units correlate along strike with parts of the Earlies Gap and Sandymush Formations. Fullagar et al. (1979) report a Middle Proterozoic age of 1214 million years (data recalculated by Rankin, 1983) for some Mars Hill rocks based on rubidium/strontium whole-rock analysis. The Middle Proterozoic age determined by Fullagar et al. (1979) in conjunction with Merschat's (1977) and Kuchenbuch's (1979) field and petrographic information is evidence for intense, granulite-grade, Middle Proterozoic metamorphism near the Sandymush-Canton area. Additionally, our own reconnaissance mapping a few miles west of the Sandymush Quadrangle in the Fines Creek area revealed hypersthene-bearing mafic rocks similar to the granulite rocks of the Mars Hill area.

However, the Middle Proterozoic rocks of the intervening Sandymush and Canton Quadrangles, based on their mineral components, record metamorphism that does not exceed amphibolite facies. In addition, the presence of local, but widespread, migmatization places the rocks in at least upper amphibolite facies. As seen today, the rocks are amphibolites, biotite gneisses, biotite granitic gneisses, tonalite gneisses, calc-silicate rocks, and granitic gneisses. Hypersthene was not identified in the field nor was it found in thin section. Also, it is not present in any of the stream sediment samples. Thus, an apparent anomaly in the metamorphic pattern exists; a lower-grade area lies between two higher-grade areas.

Three possible explanations are:

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

2) Granulite-grade metamorphic conditions existed, but subsequent metamorphism retrograded and destroyed once-present diagnostic high-grade minerals. As discussed elsewhere in this report, evidence for retrogression exists at many places. For example, in the field some amphibolites are locally converted to biotite schist and gneiss, and in thin sections biotite replaces hornblende (see figures 6,7). However, it is very doubtful that all traces of high-grade minerals would have been obliterated throughout the two-quadrangle area by retrogression.

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 contrast to the many uncertainties of Proterozoic Grenville metamorphism, Paleozoic metamorphism is well documented and has been widely studied at many places in the Blue Ridge. The major metamorphic interval was between 470 and 430 million years ago (Butler, 1973). This event produced the dominant foliation now seen in the rocks as well as a classical Barrovian prograde metamorphic sequence. The sequence ranges from chlorite or sub-chlorite along the west margin of the Blue Ridge into sillimanite grade in the central Blue Ridge of western North Carolina (Hadley and Nelson, 1971).

The kyanite-sillimanite isograd crosses the Canton Quadrangle diagonally from southwest to northeast with the highest grade rocks lying in the southeast part of the map (see plate 2 and figure 19). The isograd's precise location and configuration as it crosses the Earlies Gap Biotite Gneiss is not known because these rocks do not have the proper composition to produce kyanite or sillimanite upon metamorphism. Thus, it is necessary to project the isograd across the Earlies Gap outcrop area.

In the Canton Quadrangle an area of transi-

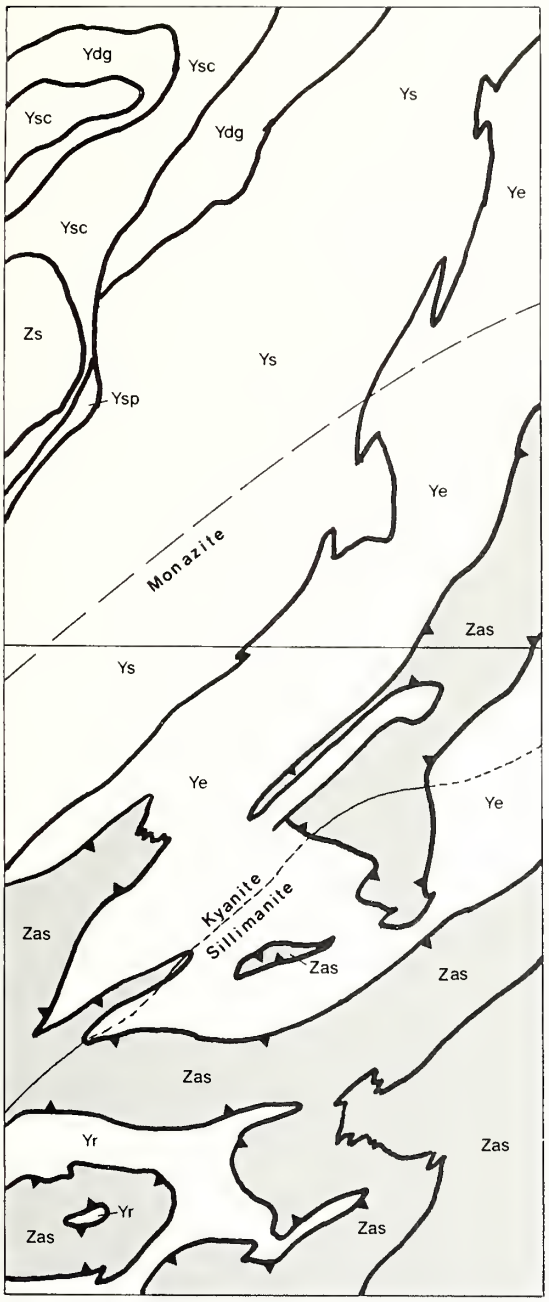


Figure 19. Outline map showing location of the sillimanite-kyanite isograd (short-dashed where approximately located) and distribution of monazite-bearing rocks, patterned area. Location of the monazite isograd, long-dashed line, is inferred based on its presence in the Ashe Suite and absence from the pelitic Snowbird Group. Overstreet (1967) has shown that upon sufficiently high regional metamorphism, monazite develops in aluminous, metasedimentary rocks. Symbols: Zs=Snowbird Group; 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. Saw teeth on upper plate of Holland Mountain thrust fault.

tion exists between kyanite-bearing rocks and sillimanite-bearing rocks. As observed in the field, this transition area is characterized by the presence of coarse-grained white mica (muscovite), which is pseudomorphic after kyanite (see figure 11). The coarse-grained mica appears to have developed abruptly at the expense of kyanite. Southeastward, towards higher grade areas, the porphyroblastic, white-mica pseudomorphs gradually disappear and sillimanite appears. The width of the transition area is variable, but averages several thousand feet. The applicable theoretical explanation for this transition area is not known to us. It may have resulted from one or more of the following: 1) Local falling temperatures during unloading (Turner, 1968). 2) fluctuations in water pressure connected with melting and freezing of a neosome in migmatitic areas (Turner, 1968). 3) Increase of oxidation ratios causing the amount of biotite and garnet to decrease with a complementary increase in muscovite and iron oxides (Chinner, 1966).

Another mineral whose distribution in pelitic rocks is controlled in part by metamorphic grade is monazite (Overstreet, 1967). Monazite first appears in the higher-grade portion of the kyanite zone downgrade from the kyanite-sillimanite isograd. In the Sandymush-Canton area only an approximate location for the monazite isograd can be drawn. Based on stream sediment samples, monazite is present throughout the aluminous metasedimentary Ashe Metamorphic Suite. Several miles northwest the lower grade Snowbird Group, which is also composed of pelitic metasediments, does not contain monazite. The monazite isograd therefore lies between these two units. The intervening Middle Proterozoic rocks, however, do not have the appropriate composition for monazite to develop and thus only an approximate location for a monazite isograd can be drawn. Figure 19 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 as the non-pelitic, granitic rocks in that region do not produce diagnostic aluminosilicate minerals upon metamorphism. However, both kyanite and staurolite are common in samples from the meta-pelites of the Snowbird Group which extends to within three miles of the northwest corner of the quadrangle.

RETROGRESSION

The Paleozoic metamorphism was a regional prograde event that had different effects on different rocks in the area. For example, the relatively aluminous Ashe and Snowbird Group rocks exhibit minerals and textures indicative of typical, Barrovian, upper amphibolite facies metamorphism.

On the other hand, the much older rocks of the Earlies Gap, Sandymush, Spring Creek, and Doggett Gap Formations had already been metamorphosed in the Proterozoic with development of biotite, hornblende, and various other metamorphic minerals. In these units, the Paleozoic metamorphism acted as a retrograde event. Evidence for this retrogression is especially notable in the Middle Proterozoic amphibolites. In thin-section, biotite replaces previously existing hornblende (figures 6,7). 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 gneisses, biotite schists, and granitic gneisses.

Additional evidence favoring the concept of Paleozoic metamorphism having retrogressive attributes exists along strike to the northeast in rocks of the Mars Hill Quadrangle (Merschat, 1977; Kuchenbuch, 1979) and Barnardsville Quadrangle (Merschat, in progress). In these quadrangles, certain mafic bodies have a core of coarse-grained, granoblastic, mafic granulite rock. Towards the outer margins these bodies become progressively more amphibolitic until at their edges they are medium- to fine-grained amphibolites. Thus, the cores preserve the old, Proterozoic, granulite-facies metamorphic suite while the exterior portions contain the Paleozoic, amphibolite-facies metamorphic suite. The lack of complete amphibolitization is attributed in part to the dry, water-poor character of these rocks. In the Sandymush and Canton Quadrangles the contrast in metamorphic grade between the Proterozoic and the Paleozoic events was probably not as great, but the same pattern is present. In this area, unaltered hornblende in amphibolites and pyroxene grains in the calc-silicate rocks of the Earlies Gap, Sandymush, Spring Creek, and Doggett Gap units are relics from the Middle Proterozoic metamorphism. The alteration of amphibolite to biotite schist and gneiss is the result of the younger, Paleozoic metamorphism. Alteration of the dunite bodies is also attributed to this major, Paleozoic metamorphic event. In them, primary olivine and pyroxene are locally altered to serpentine, talc, anthophyllite, and perhaps even chlorite or vermiculite.

TIMING

As previously mentioned, Taconic metamorphism took place about 470 to 430 million years ago (Butler, 1973). It was a regional dynamothermal event that was episodic in character. During the earliest stage existing planar features, such as compositional layering, were transposed into the plane of a newly forming regional foliation. A dynamic event, emplacement of the Holland Mountain thrust fault, took place after the foliation was well developed. Evidence for this is especially striking near Big Butt Mountain in the central part of the Canton Quadrangle where foliation trends in the Ashe Suite are abruptly truncated (see plate 2). After faulting, or at least after major displacement along the fault, the rocks and the thrust fault were both folded.

The final Taconic metamorphic episode was a regional thermal peak during which porphyro-

blastic indicator minerals such as kyanite and sillimanite crystallized. This thermal peak occurred after faulting had ceased as shown by the lack of offset along the kyanite-sillimanite isograd where it crosses the Holland Mountain fault (see plate 2). It was also during this thermal peak that local migmatization occurred over a widespread area in the Ashe Metamorphic Suite.

Late Paleozoic Metamorphism

A post-Taconic, low grade metamorphic event is commonly reported in the Blue Ridge (e.g. Butler, 1973). In the study area there also are indications of a late, low-grade event. Chlorite, a mineral commonly associated with greenschist-facies metamorphism, is visible in amphibolite outcrops in the northwestern part of the Sandymush Quadrangle. It also occurs in a few thin sections of various gneiss varieties from across the area. Thin sections containing chlorite are from the Sandymush Felsic Gneiss (4 sections), and Earlies Gap Biotite Gneiss (3 sections). 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.

MINERAL RESOURCES

Nowhere on the Sandymush or Canton Quadrangles has there ever been a major mining operation. Mining and prospecting occurred on a relatively small scale, but currently all mining properties are inactive and abandoned. An inventory of the area's mines, pits, prospects, and occurrences is presented in Appendix 3.

Past production data are minimal; however, mica was probably of greatest commercial value, followed by feldspar, sand and gravel, and crushed stone. Local residents reported that kaolin was mined from one locality near Wilson Cove in the Canton Quadrangle. Soapstone for local use was excavated from shallow pits in the northern part of the Sandymush Quadrangle. Also, a locality in the central part of the Canton Quadrangle once prospected for industrial corundum, is now open to mineral collectors on a fee basis.

Several dunite bodies, most notably the ones near Newfound Gap and Harmony Grove Church on the Canton Quadrangle, were prospected for olivine and associated corundum, vermiculite, and chromite.

Scheelite, an important ore of tungsten, unexpectedly was discovered to be a component in many stream sediment samples (seeAppendix 2). The scheelite-bearing samples all come from streams draining the Earlies Gap and Sandymush formations. Previously, scheelite had been found by Mr. James Stewart, a local prospector, in only one small area in the southeast part of the Sandymush Quadrangle (Stewart, 1986, oral communication). Hand samples provided by Stewart contain scheelite grains and aggregates up to 3 millimeters across. The host rock is medium-grained amphibolite to calc-silicate rock. The samples exhibit metamorphic alteration, or retrogression, as coarse biotite flakes are abundant on some foliation surfaces.

Monazite was not previously recorded from this area. However, it is widely present in stream sediment samples from the south and east part of the area (Appendix 2). It is most abundant in samples draining the schist portion of the Ashe Metamorphic Suite (figure 19).

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The several community clubs and organizations of Sandymush, Beaverdam Valley, and Crabtree strongly endorsed our efforts and we wish especially to thank all the members and officers of these organizations.

During the summer of 1987, Clay Haldeman and Terry Kicinski, geology students at Western Carolina University, collected, panned, and did preliminary mineralogic work on heavy mineral stream sediment samples. Results from this work add an important body of factual data that significantly helps our geologic understanding and interpretation of the area. The authors also wish to add a personal appreciation of Terry. His life was senselessly taken before this report was completed. He was a good person who worked hard and played well. He vigorously enjoyed life's activities and brightened the lives of his acquaintances. We miss him as a person; our science, and humanity, is the poorer for his absence.

Arthur Nelson examined some of the area's outcrops during a field excursion in the spring of 1987. Later, he guided us through parts of the Greenville Quadrangle especially to show and discuss rocks of the Helen Group and Richard Russell Formation. After field work was completed, he and Ken Gillon reviewed drafts of the Sandymush and Canton geologic maps and subsequently examined the manuscript for this report. Both offered many acute comments which have helped us improve the maps and the text. We are grateful for their thoughtful assistance and thorough reviews.

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APPENDIX 1. HEAVY MINERAL PROCEDURE.

In Field

1. Collect a standard-size stream-sediment sample from the gravelly portion of stream bed. Nominal weight, 13.6 kilograms.

2. Pan sample on site using standard 16-inch gold pan. Discard very coarse material. Resulting pan concentrates mostly weighed between 50 and 300 grams.

In Processing Laboratory

3. Screen pan concentrate at 0.6 mm (No. 30 sieve). Store oversize.

4. Perform heavy liquid separation using tetrabromoethane, specific gravity 2.96. Bag and save light fraction.

In Mineralogic Laboratory

5. Fluorescent and radioactive mineral examination:

a. Using short-wave and long-wave ultraviolet illumination, scan heavy mineral concentrate, noting especially scheelite and zircon.

b. Using a scintillometer, scan heavy mineral concentrate. Only samples especially rich in monazite had readings of even twice background.

6. Using an alnico hand magnet, remove all magnetic material. Weigh and record the magnetic portion as magnetite.

7. Petrographic Examination:

a. Successively split non-magnetic portion to a convenient size and mount grains on a microscope slide using standard 1.67 index of refraction oil. Store remainder.

b. Scan entire slide to note all mineral species present.

c. Systematically traverse slide counting and identifying about 200 grains.

8. Perform calculations and tabulate data (see Appendix 2).

APPENDIX 2. HEAVY MINERAL ANALYSES OF PANNED CONCENTRATES, CANTON AND SANDYMUSH QUADRANGLES.

Notes:

1. Sample locations are shown on plates 1 and 2 by red circles with appropriate sample numbers.
2. Formation symbols: Zs=Snowbird Group; Zag=Ashe Metamorphic Suite, Gneiss unit; Zas=Ashe Metamorphic Suite, Schist unit; Ydg=Doggett Gap Protomylonitic Granitoid Gneiss; Ysc=Spring Creek Granitoid Gneisss; Ys=Sandymush Felsic Gneiss; Ye=Earlies Gap Biotite Gneiss; Yr= Richard Russell Formation. Use of multiple formation symbols indicates drainage area sampled includes more than one formation. Parenthesis indicates formation comprises a very minor portion of drainage area.
3. 'Trace' indicates mineral observed in sample, but not not encountered during grain-counting proceedure.
4. Black opaque grains are mostly ilmenite.
5. Mineral abbreviations: MAG.=magnetite; HBLD.=hornblende; STAUR.=staurolite; KYAN.=kyanite; SILL.=sillimanite; TOUR.=tourmaline; SCH.=scheelite; UNIDENT.=unidentified.

APPENDIX 2. HEAVY MINERAL ANALYSES OF PANNED CONCENTRATES, CANTON AND SANDYMUSH QUADRANGLES.

SAMPLE	N.C. COORD. NORTH	N.C. COORD. EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
11	722,350	852,850	Zs	0.71	11.0	22.0	0.5	0.0	37.0	19.5	7.5	0.0	0.0	0.0	1.5	0.5	0.5	0.0	0.0
19	726,100	855,400	Zs	0.26	6.0	22.5	1.0	18.5	34.0	9.0	5.5	0.0	0.0	0.0	1.5	2.0	0.0	0.0	0.0
71	732,300	850,450	Zs	1.43	2.0	35.5	trace	17.5	14.5	13.0	14.5	0.0	0.0	trace	1.0	2.0	0.0	0.0	0.0
			Average	0.80	6.3	26.7	0.5	12.0	28.5	13.8	9.2	0.0	0.0	0.0	1.3	1.5	0.2	0.0	0.0

SAMPLE	N.C. COORD. NORTH	N.C. COORD. EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
136	675,750	880,950	Zag	0.10	11.0	28.0	0.0	0.0	34.5	1.0	1.5	2.5	8.0	0.0	0.5	13.0	0.0	0.0	0.0
145	668,500	882,900	Zag	0.23	9.0	26.5	1.0	0.0	21.0	13.5	12.0	1.0	7.0	0.0	2.0	7.0	0.0	0.0	0.0
146	663,150	878,350	Zag	0.53	23.0	11.5	14.5	16.0	6.5	0.0	0.5	trace	trace	3.0	0.5	24.5	0.0	0.0	0.0
147	658,950	882,200	Zag	0.13	13.5	24.0	0.5	0.0	27.5	5.5	1.0	1.0	9.0	2.5	0.0	15.5	0.0	0.0	0.0
148	662,550	882,250	Zag	0.04	3.0	33.0	0.0	0.5	54.5	0.5	1.0	0.5	0.5	0.0	0.0	6.5	0.0	0.0	0.0
149	657,450	877,200	Zag	0.30	8.5	37.0	0.0	0.5	31.0	2.5	1.5	trace	1.5	0.0	2.5	15.0	0.0	0.0	0.0
			Average	0.22	11.3	26.7	2.7	2.8	29.2	3.8	2.9	0.8	4.3	0.9	0.9	13.6	0.0	0.0	0.0

SAMPLE	N.C. COORD. NORTH	N.C. COORD. EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
39	705,250	883,550	Zas	0.22	1.0	20.5	0.5	3.5	5.0	0.0	58.0	0.0	9.5	0.0	0.0	2.0	0.0	0.0	0.0
42	702,300	880,500	Zas	0.40	1.5	5.0	1.0	0.5	3.5	0.0	78.0	0.0	7.0	0.0	0.0	3.5	0.0	0.0	0.0
44	697,200	874,200	Zas	0.28	3.0	28.5	5.0	7.5	12.5	0.0	28.0	0.0	3.5	1.0	0.5	10.5	0.0	0.0	0.0
92	684,050	848,850	Zas	0.10	2.0	25.5	1.0	4.0	37.0	trace	21.0	0.0	1.5	0.5	trace	7.5	0.0	0.0	0.0
94	681,450	848,450	Zas	0.68	2.5	37.5	5.0	1.5	19.0	trace	15.0	0.0	3.5	1.0	0.5	14.5	0.0	0.0	trace
99	661,050	849,650	Zas	0.07	4.0	15.0	0.5	0.0	25.0	trace	1.5	10.5	15.5	0.5	9.0	18.5	0.0	0.0	0.0
102	660,800	859,900	Zas	0.10	2.0	30.5	1.5	0.0	30.5	0.0	0.5	5.5	10.5	0.5	4.5	14.0	0.0	0.0	0.0
103	659,550	858,750	Zas	0.20	1.5	24.0	1.5	0.0	42.5	trace	trace	2.5	12.0	3.0	2.0	11.0	trace	0.0	0.0
104	660,200	866,750	Zas	0.12	4.0	41.5	6.0	0.5	20.0	0.0	3.0	1.0	2.5	0.0	trace	21.5	0.0	0.0	0.0
126	675,150	869,450	Zas	0.09	5.5	27.0	0.0	0.0	22.0	8.5	15.0	8.0	10.0	0.0	0.0	4.0	0.0	0.0	0.0
129	666,500	864,500	Zas	0.04	3.0	18.5	0.0	0.0	11.5	trace	1.5	4.0	26.0	3.5	4.5	27.5	0.0	0.0	0.0
131	663,400	872,950	Zas	0.39	8.0	44.0	0.5	0.0	26.5	1.5	7.0	0.0	4.0	0.0	1.0	7.5	0.0	0.0	0.0
138	675,650	863,800	Zas	0.03	26.0	25.5	1.5	0.0	2.0	8.5	4.0	1.0	10.5	0.0	1.5	19.5	0.0	0.0	0.0
140	675,700	855,850	Zas	0.10	13.0	34.5	0.0	0.0	0.5	5.0	11.5	2.5	13.5	0.0	1.0	18.5	0.0	0.0	0.0
143	673,750	871,850	Zas	0.22	10.0	33.0	1.5	0.0	35.0	0.5	5.5	1.5	2.5	0.5	0.5	8.5	0.0	0.0	1.0
			Average	0.20	5.8	27.4	1.7	1.2	19.5	1.6	16.6	2.4	8.8	0.7	1.7	12.6	0.0	0.0	0.1

SAMPLE	N.C. COORD. NORTH	N.C. COORD. EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
65	745,150	752,000	Ydg	0.46	11.5	5.0	2.5	73.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	7.0	0.0	0.0	0.0
66	745,500	853,300	Ydg	0.13	10.0	6.5	0.5	74.5	0.0	0.0	0.0	0.0	0.0	0.0	trace	8.5	0.0	0.0	0.0
			Average	0.30	10.8	5.8	1.5	73.8	0.0	0.0	0.0	0.0	0.0	0.5	0.0	7.8	0.0	0.0	0.0

APPENDIX 2 (continued). HEAVY MINERAL ANALYSES OF PANNED CONCENTRATES, CANTON AND SANDYMUSH QUADRANGLES

SAMPLE	N.C. COORD. NORTH	EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
60	741,700	860,350	Ysc	0.10	22.5	18.5	6.0	41.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0
62	749,800	860,000	Ysc	0.75	19.0	36.0	2.0	34.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	7.5	0.0	0.0	0.0
63	745,100	758,100	Ysc	0.79	4.5	56.0	13.5	20.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	4.5	0.0	0.0	0.0
64	748,850	755,750	Ysc	0.16	22.0	13.0	1.0	58.5	trace	0.0	0.0	0.0	0.0	0.5	trace	5.0	0.0	0.0	0.0
67	741,700	753,600	Ysc	0.15	18.0	9.0	2.5	53.0	2.5	0.0	0.0	0.0	0.0	0.5	0.0	14.5	0.0	0.0	0.0
68	734,250	855,800	Ysc	0.21	33.0	6.5	1.5	44.0	3.0	0.0	0.0	0.0	0.0	0.5	0.0	10.5	0.0	0.0	1.0
			Average	0.36	19.8	23.2	4.4	41.9	1.3	0.0	0.0	0.0	0.0	0.6	0.0	8.7	0.0	0.0	0.2

SAMPLE	N.C. COORD. NORTH	EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
1	717,100	870,650	Ys	12.80	26.5	22.5	38.0	9.5	1.0	0.0	0.0	0.0	0.0	0.5	0.0	2.0	0.0	0.0	0.0
4	704,750	857,850	Ys	3.55	9.0	15.0	45.5	19.5	4.5	0.0	0.0	0.0	0.0	3.0	2.0	1.5	0.0	0.0	0.0
5	708,100	859,950	Ys	1.09	8.5	22.0	22.5	33.0	4.0	0.0	0.0	0.0	0.0	1.5	3.5	5.0	0.0	0.0	0.0
6	713,050	862,700	Ys	0.17	14.0	9.0	21.5	53.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0
7	714,350	859,650	Ys	0.82	7.5	29.5	25.5	24.0	9.0	0.0	0.0	0.0	0.0	0.5	2.0	2.0	0.0	0.0	0.0
8	717,150	859,350	Ys	1.59	14.5	38.0	14.5	23.5	5.0	0.0	0.0	0.0	0.0	0.0	1.5	3.0	0.0	0.0	0.0
9	722,750	860,200	Ys	1.08	13.0	4.0	57.5	15.5	8.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	trace	0.0
10	715,350	855,050	Ys	0.40	12.5	24.5	19.0	32.0	10.5	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0
16	715,550	871,750	Ys	0.65	13.0	43.0	13.0	17.5	2.0	0.0	0.0	0.0	0.0	0.0	1.0	9.5	0.0	trace	1.0
18	713,850	867,950	Ys	1.81	9.5	24.5	51.5	9.0	0.5	0.0	0.0	0.0	0.0	1.0	0.0	4.0	0.0	0.0	0.0
20	727,150	859,450	Ys	0.38	20.0	18.5	20.0	31.5	4.0	trace	0.5	0.0	0.0	1.5	0.0	4.0	0.0	trace	0.0
21	725,600	868,000	Ys	0.51	6.0	48.0	23.5	15.5	2.5	0.0	0.0	0.0	0.0	0.5	0.5	3.0	0.0	trace	0.5
22	725,350	865,900	Ys	1.37	13.5	24.0	29.5	24.5	2.5	0.0	trace	0.0	0.0	1.5	0.5	4.0	0.0	0.0	0.0
23	720,400	863,300	Ys	0.52	6.5	36.0	6.0	37.0	4.5	0.0	2.0	0.0	0.0	1.5	0.0	6.5	0.0	trace	0.0
28	727,900	874,700	Ys	0.03	10.0	25.0	9.5	41.0	1.5	0.0	0.0	0.0	0.0	1.0	0.0	12.0	0.0	0.0	0.0
50	738,300	879,850	Ys	0.44	8.0	50.0	6.5	26.0	1.5	0.0	0.0	0.0	0.0	0.5	0.5	7.0	0.0	trace	0.0
51	734,350	875,550	Ys	0.21	7.0	49.0	1.0	32.0	1.5	0.0	0.0	0.0	0.0	0.5	0.0	9.0	0.0	0.0	0.0
52	736,900	874,150	Ys	0.14	10.0	43.5	7.0	26.0	5.0	0.0	0.0	0.0	0.0	0.5	trace	8.0	0.0	0.0	0.0
53	732,900	879,200	Ys	0.80	8.5	53.5	9.5	21.0	3.0	0.0	0.0	0.0	0.0	0.0	1.5	2.5	0.0	trace	0.5
74	744,550	880,550	Ys	0.17	1.0	13.0	14.0	60.5	1.5	0.0	0.0	0.0	0.0	0.0	0.5	9.5	0.0	0.0	0.0
75	749,000	880,250	Ys	0.06	3.0	10.5	5.0	68.5	1.5	0.0	0.0	0.0	0.0	1.0	0.0	10.5	0.0	0.0	trace
77	744,450	874,700	Ys	0.12	2.0	46.0	12.0	32.0	0.5	0.0	0.0	0.0	0.0	0.5	1.0	6.0	0.0	trace	0.0
79	747,350	876,700	Ys	0.08	5.0	32.0	9.5	45.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	7.0	0.0	trace	0.0
81	706,850	852,800	Ys	0.64	8.0	30.5	19.5	32.5	6.0	0.0	0.0	0.0	0.0	1.0	0.5	2.0	0.0	trace	0.0
82	708,400	850,350	Ys	0.25	2.0	56.5	25.0	10.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	trace	0.0
83	705,900	850,950	Ys	0.43	7.0	17.5	12.5	48.0	4.0	0.0	0.0	0.0	0.0	3.5	0.5	7.0	0.0	0.0	0.0
84	703,100	851,550	Ys	0.60	9.5	26.0	15.5	32.5	7.0	0.0	0.0	0.0	0.0	0.5	0.5	8.5	0.0	trace	0.0
85	704,700	853,400	Ys	0.21	16.0	20.5	12.0	46.0	2.0	0.0	0.0	0.0	0.0	0.0	0.5	3.0	0.0	trace	0.0
86	697,050	850,450	Ys	0.20	6.0	30.5	24.5	33.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	4.5	0.0	trace	0.0
87	698,500	851,850	Ys	1.60	2.0	38.5	32.5	17.0	5.0	0.0	0.0	0.0	0.0	1.0	0.0	4.0	0.0	trace	0.0
88	694,950	847,250	Ys	1.06	3.0	21.0	36.0	26.0	5.0	0.0	0.0	0.0	0.0	3.5	1.0	4.5	0.0	0.0	0.0
89	702,250	849,750	Ys	1.13	8.0	13.0	16.5	52.0	1.5	0.0	0.0	0.0	0.0	3.0	0.0	6.0	0.0	0.0	0.0
			Average	1.09	9.1	29.2	20.5	31.1	3.4	0.0	0.1	0.0	0.0	0.9	0.6	5.0	0.0	trace	0.0

APPENDIX 2 (continued). HEAVY MINERAL ANALYSES OF PANNED CONCENTRATES, CANTON AND SANDYMUSH QUADRANGLES

SAMPLE	N.C. COORD. NORTH	EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
25	718,900	881,100	Ye	0.10	22.0	9.0	12.0	25.0	10.0	0.0	0.0	0.0	0.0	0.5	0.5	21.0	0.0	0.0	0.0
29	724,800	879,350	Ye	0.68	21.0	19.5	7.0	42.5	1.5	0.0	0.5	0.0	0.0	1.5	2.5	4.0	0.0	0.0	0.0
32	707,750	876,800	Ye	0.49	5.0	39.5	9.5	29.0	7.0	0.0	0.0	0.0	0.0	1.0	0.5	8.5	0.0	trace	0.0
33	703,700	873,950	Ye	0.37	6.0	39.0	22.0	18.0	6.5	0.0	0.0	0.0	0.0	1.5	trace	7.0	0.0	trace	0.0
34	702,950	871,850	Ye	0.55	4.0	47.5	14.5	13.0	14.5	0.0	0.0	0.0	0.0	0.0	0.5	6.0	0.0	trace	0.0
36	722,300	884,950	Ye	0.95	7.0	44.0	15.5	24.5	3.0	0.0	trace	0.0	0.0	0.0	1.0	5.0	0.0	0.0	0.0
48	697,850	884,750	Ye	0.89	2.0	9.0	42.5	29.0	5.5	0.0	0.0	0.0	0.0	4.0	trace	8.0	0.0	0.0	0.0
91	689,550	851,050	Ye	0.40	18.0	21.0	19.0	21.0	7.5	0.0	0.0	0.0	0.0	3.0	0.5	10.0	0.0	trace	0.0
107	699,800	863,950	Ye	0.82	1.5	12.5	35.0	36.5	4.5	0.0	0.0	0.0	0.0	7.0	trace	3.0	0.0	trace	0.0
108	698,550	867,350	Ye	0.81	1.5	41.0	24.0	12.0	16.5	0.0	0.0	0.0	0.0	2.5	0.5	2.0	0.0	trace	0.0
111	687,350	863,250	Ye	0.28	6.0	10.0	15.5	41.5	5.5	0.0	0.0	0.0	0.0	12.0	0.0	9.5	0.0	0.0	0.0
137	693,300	862,550	Ye	0.08	7.5	42.0	11.0	19.0	11.0	0.0	0.5	0.0	0.5	2.0	trace	6.5	0.0	0.0	0.0
			Average	0.54	8.5	27.8	19.0	25.9	7.8	0.0	0.1	0.0	0.0	2.9	0.5	7.5	0.0	trace	0.0

SAMPLE	N.C. COORD. NORTH	EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
95	670,400	848,600	Yr	0.08	4.0	29.0	14.0	16.0	15.5	0.0	trace	trace	1.5	1.0	1.5	17.5	0.0	0.0	0.0
139	669,700	855,300	Yr	0.03	23.5	62.5	3.0	0.5	2.0	0.0	trace	0.0	trace	2.0	0.0	6.5	0.0	0.0	0.0
			Average	0.06	13.8	45.8	8.5	8.3	8.8	0.0	trace	0.0	0.8	1.5	0.8	12.0	0.0	0.0	0.0

SAMPLE	N.C. COORD. NORTH	EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
43	697,700	872,900	Pzm,Ye,Zas	0.55	8.0	36.5	13.5	17.5	7.5	0.0	2.0	0.0	1.0	1.5	trace	12.5	0.0	trace	trace
56	735,550	867,800	Ydg,Ys	0.25	7.0	30.5	26.5	28.0	2.0	0.0	0.0	0.0	0.0	1.5	0.0	4.5	0.0	trace	0.0
58	736,500	861,050	Ydg,Ysc	0.26	8.5	25.0	9.0	41.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	trace	0.0
61	746,150	861,750	Ydg,Ysc	0.18	11.0	27.5	4.0	49.0	2.0	0.0	0.0	0.0	0.0	trace	0.0	6.5	0.0	0.0	0.0
70	736,850	850,900	Ydg,Ysc	0.12	3.0	3.0	0.0	60.0	2.0	0.0	trace	0.0	0.0	0.0	0.0	32.0	0.0	0.0	0.0
78	747,750	870,200	Ydg,Ysc	0.28	20.0	48.0	5.5	11.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	14.0	0.0	0.0	0.0
13	717,650	875,650	Ye,Ys	2.23	23.0	2.0	57.0	15.0	2.5	0.0	0.0	0.0	0.0	trace	0.5	0.0	0.0	trace	0.0
30	727,850	878,650	Ye,Ys	0.35	16.0	29.0	12.0	34.5	3.0	0.0	0.0	0.0	0.0	0.0	0.5	5.0	0.0	0.0	0.0
31	729,300	884,450	Ye,Ys	1.00	9.0	20.5	25.0	39.5	0.5	0.0	0.0	0.0	0.0	0.5	1.0	4.0	0.0	0.0	0.0
72	744,050	886,250	Ye,Ys	0.10	10.0	53.0	10.0	15.5	1.5	0.0	trace	0.0	0.0	0.0	trace	10.0	0.0	0.0	0.0
73	739,850	884,950	Ye,Ys	0.10	11.0	54.0	6.5	16.5	0.5	0.0	0.0	0.0	0.0	0.0	trace	11.5	0.0	trace	0.0
113	693,950	857,100	Ye,Ys	1.22	14.5	14.0	27.5	25.5	5.5	trace	1.0	0.5	0.0	0.5	2.0	9.0	0.0	0.0	0.0

APPENDIX 2 (continued). HEAVY MINERAL ANALYSES OF PANNED CONCENTRATES, CANTON AND SANDYMUSH QUADRANGLES

SAMPLE	N.C. COORD. NORTH	EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
35	703,150	875,100	Ye,Zas	0.09	2.5	31.5	28.0	10.5	23.0	0.0	0.0	0.0	0.0	0.5	0.0	4.0	0.0	0.0	0.0
93	683,700	853,100	Ye,Zas	0.08	5.0	43.0	6.5	14.5	14.0	0.0	trace	0.0	0.0	1.0	0.5	15.5	0.0	0.0	0.0
116	691,550	885,400	Ye,Zas	0.09	8.0	28.0	19.5	10.5	8.0	1.0	3.5	0.5	2.5	4.5	0.5	13.5	0.0	0.0	0.0
117	689,500	882,700	Ye,Zas	0.09	9.0	42.0	6.5	5.5	11.0	0.0	2.5	0.0	5.0	1.0	0.5	17.0	0.0	0.0	0.0
119	684,300	877,650	Ye,Zas	0.22	4.0	27.0	3.0	0.5	37.0	4.0	5.5	trace	4.0	0.0	1.5	13.5	0.0	0.0	0.0
120	688,550	872,650	Ye,Zas	0.21	6.0	18.5	9.0	4.5	30.5	trace	8.5	4.0	12.5	0.0	1.0	5.5	0.0	0.0	0.0
121	689,950	869,000	Ye,Zas	0.62	14.0	13.5	2.0	2.5	47.5	0.0	4.5	trace	9.5	0.0	trace	6.5	0.0	0.0	0.0
122	682,550	872,000	Ye,Zas	0.49	8.0	34.0	17.0	1.0	14.5	0.0	6.0	0.5	4.0	1.5	2.5	11.0	0.0	0.0	0.0
124	681,700	866,100	Ye,Zas	0.03	13.0	23.0	13.5	0.5	16.5	0.0	2.5	0.0	8.0	3.5	trace	19.5	0.0	0.0	0.0
127	680,350	863,300	Ye,Zas	0.10	7.0	26.5	10.5	1.5	10.0	0.0	6.0	0.0	9.0	4.0	0.5	24.5	0.0	0.0	0.5
128	679,850	855,750	Ye,Zas	0.27	8.0	50.0	0.5	0.0	3.5	0.0	3.5	0.0	8.0	0.5	0.5	25.5	0.0	0.0	0.0
114	687,850	858,350	Ye,Zas (Pzm)	0.23	5.0	24.0	8.5	12.5	13.5	0.0	15.0	0.0	4.0	3.5	0.0	14.0	0.0	0.0	0.0
112	684,850	862,850	Ye (Yas)	0.63	29.5	17.5	1.0	2.0	21.5	1.0	3.5	1.0	3.5	0.0	0.5	19.0	0.0	0.0	0.0
26	711,500	879,150	Ye (Ys)	0.25	19.0	14.0	14.0	42.0	3.5	0.0	0.0	0.0	0.0	2.0	trace	5.5	0.0	0.0	0.0
27	724,050	876,850	Ye (Ys)	0.59	34.0	40.5	2.5	15.5	0.5	0.0	0.0	0.0	0.0	0.5	trace	6.5	0.0	0.0	0.0
49	734,000	883,300	Ye (Ys)	0.09	10.0	22.0	11.0	30.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	25.5	0.0	trace	0.0
109	698,400	861,550	Ye (Ys)	0.44	16.0	17.0	17.5	27.0	5.5	0.0	0.0	0.0	0.0	2.5	1.0	13.5	0.0	trace	0.0
24	719,850	884,050	Ye (Zas)	0.29	6.0	24.5	3.5	28.0	6.5	0.0	10.0	0.0	0.0	1.0	1.5	19.0	0.0	trace	0.0
115	683,600	859,550	Ye (Zas)	0.26	14.0	20.5	4.0	24.0	2.5	0.0	1.0	0.0	0.0	4.0	1.0	29.0	0.0	0.0	0.0
118	688,350	881,450	Ye (Zas)	0.15	9.0	41.0	4.0	2.0	15.0	0.0	2.0	trace	9.0	0.0	1.0	16.5	0.0	0.0	0.5
141	677,250	853,650	Ye (Zas)	0.22	4.5	53.5	0.0	0.0	2.5	0.5	27.5	0.0	4.5	0.5	0.5	6.0	0.0	0.0	0.0
76	744,250	873,300	Ys,Ydg	0.23	10.5	33.0	17.0	28.0	0.5	0.0	trace	0.0	0.0	0.5	0.0	10.5	0.0	0.0	0.0
14	711,850	869,200	Ys,Ye	0.68	19.0	24.5	32.0	15.0	3.5	0.0	0.0	0.0	0.0	3.0	2.0	1.0	0.0	trace	0.0
80	747,900	887,000	Ys,Ye	0.26	3.5	53.5	7.5	27.0	2.5	0.0	0.0	0.0	0.0	0.0	0.5	5.5	0.0	0.0	0.0
106	701,850	862,550	Ys,Ye	0.30	24.0	39.0	11.5	14.5	3.5	0.0	0.0	0.0	0.0	trace	0.5	7.0	0.0	trace	0.0
54	736,000	870,900	Ys (Ydg)	0.14	17.0	37.0	14.5	20.5	2.5	0.0	0.0	0.0	0.0	0.5	0.0	7.5	0.0	trace	0.5
55	732,550	867,650	Ys (Ydg)	0.36	16.0	21.0	30.5	22.0	4.5	0.0	0.0	0.0	0.0	1.0	0.0	5.0	0.0	trace	0.0
57	730,000	863,450	Ys (Ydg)	0.24	11.0	30.0	13.5	32.0	2.0	0.0	0.0	0.0	0.0	0.5	0.0	10.0	0.0	0.0	1.0
2	705,350	863,350	Ys (Ye)	0.74	30.5	16.5	20.5	26.5	2.5	0.0	0.0	0.0	0.0	0.0	0.5	3.0	0.0	trace	0.0
3	708,050	862,900	Ys (Ye)	1.01	28.5	11.0	28.0	24.5	2.0	0.0	0.0	0.0	0.0	0.5	1.0	4.5	0.0	trace	0.0
15	716,100	874,750	Ys (Ye)	0.27	16.0	20.0	26.5	31.5	1.5	0.0	0.0	0.0	0.0	1.0	1.0	2.5	0.0	trace	0.0
17	714,300	870,500	Ys (Ye)	0.46	8.0	20.5	40.0	17.0	8.5	0.0	0.0	0.0	0.0	2.0	2.5	1.5	0.0	trace	0.0
12	719,050	852,400	Ys (Zs)	0.57	5.0	29.5	2.5	12.0	23.5	8.0	14.0	0.0	0.5	0.0	0.0	4.5	0.5	0.0	0.0
59	739,600	862,750	Ysc,Ydg	0.09	18.0	33.5	5.5	22.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	18.0	0.0	0.0	0.0
69	736,150	850,150	Ysc (Zs)	0.72	2.0	20.0	0.0	18.0	30.0	13.5	7.5	0.0	0.0	0.0	trace	9.0	0.0	0.0	0.0
132	670,950	872,100	Zag,Zas	0.26	1.5	29.5	23.0	1.0	24.0	0.5	4.5	0.5	5.5	0.5	0.0	9.5	0.0	0.0	0.0

APPENDIX 2 (continued). HEAVY MINERAL ANALYSES OF PANNED CONCENTRATES, CANTON AND SANDYMUSH QUADRANGLES

SAMPLE	N.C. COORD. NORTH	EAST	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
134	677,500	882,650	Zag (Zas)	0.15	5.0	29.5	0.5	0.0	21.5	7.5	12.5	2.0	8.0	2.0	2.0	9.5	0.0	0.0	0.0
142	673,900	878,700	Zag (Zas)	0.06	4.0	17.0	0.0	0.0	38.0	4.5	2.0	5.5	15.0	0.0	1.5	12.0	0.0	0.0	0.5
144	669,950	880,850	Zag (Zas)	0.12	5.0	37.0	0.0	0.0	24.0	1.5	5.0	trace	8.5	0.0	2.0	17.0	0.0	0.0	0.0
46	700,250	880,800	Zas,Pzm,Ye	0.32	1.0	5.5	1.0	2.0	59.5	0.0	25.0	0.0	5.0	0.0	0.0	1.0	0.0	trace	0.0
45	696,500	878,150	Zas,Ye	0.41	3.0	10.5	40.0	8.0	18.0	0.0	8.5	0.0	1.0	1.5	trace	9.5	0.0	0.0	0.0
47	702,850	884,750	Zas,Ye	0.15	2.0	16.0	14.0	12.5	17.5	0.0	23.5	0.0	6.0	0.0	1.5	7.0	0.0	0.0	trace
90	688,200	849,050	Zas,Ye	0.24	3.0	31.0	14.0	20.0	11.5	0.0	4.0	0.0	1.5	4.0	trace	11.0	0.0	trace	0.0
123	680,300	873,250	Zas,Ye	0.26	3.0	29.0	1.0	0.5	40.0	7.0	12.0	2.0	4.0	0.0	trace	1.5	0.0	0.0	0.0
110	695,300	868,100	Zas,Ye (Pzm)	0.45	1.0	13.5	36.5	9.0	31.5	0.0	3.5	0.0	0.0	3.0	trace	2.0	0.0	trace	0.0
96	674,300	851,750	Zas,Yr	0.28	5.0	39.0	0.0	5.5	8.0	1.5	19.0	1.0	6.5	1.5	trace	13.0	0.0	0.0	0.0
105	659,600	871,050	Zas,Zag	1.38	2.0	42.5	26.0	8.5	12.0	0.0	0.5	0.0	0.5	0.0	1.0	7.0	0.0	0.0	0.0
135	679,900	882,900	Zas,Zag	0.31	4.0	33.0	0.0	0.0	16.0	5.5	12.0	1.0	13.5	0.0	1.0	14.0	0.0	0.0	0.0
40	706,050	880,900	Zas (Pzm)	0.30	2.0	15.5	4.5	10.5	12.0	0.0	43.5	0.0	3.5	0.0	3.5	5.0	trace	0.0	0.0
41	704,250	880,250	Zas (Pzm)	0.34	0.5	13.5	0.0	3.5	17.0	0.0	55.0	0.0	10.5	0.0	trace	trace	0.0	0.0	0.0
37	710,750	884,750	Zas (Ye)	1.26	4.0	37.5	8.5	12.5	6.0	0.0	18.5	0.0	3.0	0.5	1.0	8.5	0.0	0.0	0.0
38	708,450	880,900	Zas (Ye)	0.13	3.0	50.5	0.5	11.0	5.5	0.0	16.0	0.0	1.0	0.5	trace	12.0	0.0	trace	0.0
125	678,150	869,450	Zas (Ye)	0.27	4.0	22.5	0.0	0.0	37.5	10.0	12.5	2.0	6.5	0.0	1.0	4.0	0.0	0.0	0.0
97	665,600	853,600	Zas (Yr)	0.23	2.0	16.5	0.5	0.5	29.0	0.5	0.0	4.5	25.0	0.5	0.5	20.5	0.0	0.0	0.0
98	663,750	852,300	Zas (Yr)	0.55	5.0	22.5	1.5	0.0	18.5	0.5	1.0	3.5	15.0	2.0	2.5	28.0	0.0	0.0	0.0
100	663,250	857,450	Zas (Yr)	0.26	5.0	52.5	1.5	0.5	6.5	0.5	0.5	3.0	13.0	0.0	0.5	16.5	0.0	0.0	0.0
101	662,150	862,650	Zas (Yr)	0.09	5.0	22.0	0.0	0.0	40.5	1.0	1.0	trace	13.5	0.5	3.0	13.5	0.0	0.0	0.0
130	664,950	867,450	Zas (Yr)	0.14	10.0	26.0	0.0	0.0	16.0	5.0	8.0	4.0	10.0	0.0	2.0	19.0	0.0	0.0	0.0
133	683,100	885,800	Zas (Zag)	0.25	5.0	22.5	0.0	0.0	26.0	17.5	9.0	1.5	5.5	0.0	2.5	10.5	0.0	0.0	0.0

SUMMARY

	FORMATION	% HEAVY MINERALS	MAG.	BLACK OPAQUE	HBLD.	EPIDOTE	GARNET	STAUR.	KYAN.	SILL.	MONAZITE	SPHENE	RUTILE	ZIRCON	TOUR.	SCH.	UNIDENT.
Average	Zs (3)	0.80	6.3	26.7	0.5	12.0	28.5	13.8	9.2	0.0	0.0	0.0	1.3	1.5	0.2	0.0	0.0
Do.	Zag (6)	0.22	11.3	26.7	2.7	2.8	29.2	3.8	2.9	0.8	4.3	0.9	0.9	13.6	0.0	0.0	0.0
Do.	Zas (15)	0.20	5.8	27.4	1.7	1.2	19.5	1.6	16.6	2.4	8.8	0.7	1.7	12.6	0.0	0.0	0.1
Do.	Ydg (2)	0.30	10.8	5.8	1.5	73.8	0.0	0.0	0.0	0.0	0.0	0.5	0.0	7.8	0.0	0.0	0.0
Do.	Ysc (6)	0.36	19.8	23.2	4.4	41.9	1.3	0.0	0.0	0.0	0.0	0.6	0.0	8.7	0.0	0.0	0.2
Do.	Ys (32)	1.09	9.1	29.2	20.5	31.1	3.4	0.0	0.1	0.0	0.0	0.9	0.6	5.0	0.0	trace	0.0
Do.	Ye (12)	0.54	8.5	27.8	19.0	25.9	7.8	0.0	0.1	0.0	0.0	2.9	0.5	7.5	0.0	trace	0.0
Do.	Yr (2)	0.06	13.8	45.8	8.5	8.3	8.8	0.0	trace	0.0	0.8	1.5	0.8	12.0	0.0	0.0	0.0

APPENDIX 3. SUMMARY OF MINES, PITS, PROSPECTS, AND OCCURRENCES.

Name; Quadrangle, Map Number Location by North Carolina Coordinates	Dimensions	Remarks
Mica		
C. B. Wells Spar mine; Sandymush, 1 720,450N; 886,250E	200-foot-long cut, 20-30 feet deep.	This was primarily a feldspar mine with production coming from a zoned pegmatite. Scrap mica was also recovered; principal activity was in the 1950's (Lesure, 1968).
Lum Sprouse (Reeves) mine; Sandymush, 2 729,150N; 867,450E	Several shallow pits and cuts, less than 5 feet deep.	Lesure (1968) noted this pegmatite produced feldspar and scrap mica, mainly in 1928 and 1942. The mica is stated to be bent, locky, cracked, and with biotite intergrowths.
Big Cove mine; Canton, 1 683,700N; 883,250E	A series of cuts, pits, adits, drifts, and stopes are present in an area about 600 feet long and 200 feet wide.	The weathered, zoned pegmatite was worked from 1915-23, intermittently from 1932-43, and in 1952. Production was greenish-brown sheet mica, perhaps as much as 500 pounds (Lesure, 1968). A mine map (Olson and Parker, 1943) shows the pegmatite trends N45E and has a vertical to very steep southeast dip. The pegmatite is at least 300 feet long and up to 30 feet thick.
Mica mine, name unknown; Canton, 2 664,000N; 882,750E	A series of trenches and shallow pits. The two largest excavations are 50 to 75 feet long and 25 to 30 feet wide.	No records are known for this mine and present local residents know little of its history. Small bent books of mica are on the dumps suggesting that the primary output was scrap mica.
H. A. Hipps prospect; Canton, 3 697,950N; 876,250E	40-foot-long cut, up to 12 feet deep.	A small amount of cracked, stained, or bent mica was recovered with most, if not all activity in 1943 (Lesure, 1968).
L. L. West prospect; Canton, 4 685,050N; 879,450E	---	During 1938-1940, a small amount of ruby-colored sheet mica was produced (Lesure, 1968).
Frank Medford prospect; Canton, location uncertain, not shown on plate 2; Coordinates approximated from Lesure (1968): 697,000N; 855,000E	10-foot-long prospect pit.	A small amount of rum-colored, "A" structure, stained sheet mica was taken from a 4-foot-thick pegmatite (Lesure, 1968). This prospect was not found during the present study.

Mica (continued)

Champion Fibre Co. prospect; Canton, location uncertain, not shown on plate 2; Coordinates approximated from Lesure (1968): 673,500N; 853,500E	35-foot-deep shaft, short drifts.	A small amount of light ruby, "A" structure, bent, reeved, ruled, and clay-stained sheet mica was recovered from a weathered, quartz-cored pegmatite with most activity probably taking place during World War II (Lesure, 1968). Recent construction and development around the town of Canton has encroached on this area and the prospect was not relocated during the present study.

Olivine

Newfound Gap deposit; Canton, 5 685,950N; 878,850E	Crops out in an oval area about 700 feet long by 300 feet wide.	This dunite body has been known and prospected intermittently since the 19th century. Hunter (1941) conservatively estimates more than 6 1/2 million tons of serpentinized dunite and about 1 1/3 million tons of relatively unserpentinized granular olivine are present above local stream level.
Hominy Grove deposit; Canton, 6 680,550N; 868,500E	Outcrops and float indicative of dunite are present in an area several hundred feet across.	Hunter (1941) evidently considered this outcrop area near Harmony Grove Church to connect with dunite at locality 10, about 2,000 feet to the west. With this interpretation he estimated more than 20 million tons of serpentinized dunite and one million tons of granular olivine to be present; however, it is not likely that the deposit is nearly so large.
Olivine occurrence; Canton, 7 686,600N; 878,250E	Several outcrops of dunite are present here.	Geophysical work by Hirt et al. (1987) indicates that two masses of dunite are in this locale. The largest was determined to be about 350 feet long, 230 feet wide, and to extend no deeper than 350 feet.
Olivine occurrence; Canton, 8 683,300N; 859,500E	----	Scattered pieces of altered ultramafic material, dominantly talc-anthophyllite rock, are present in a red, clayey soil, and indicate the presence of an unexposed dunite body.
Olivine occurrence; Canton, 9 682,250N; 857,100E	A 25-foot-wide exposure.	The outcrop is composed of altered ultramafic rock that contains talc, serpentine, anthophyllite, chlorite, and vermiculite.

Olivine (continued)

Olivine occurrence; Canton, 10 680,500N; 866,350E	A 10-foot-wide exposure.	A small roadside outcrop of serpentinized dunite occurs here. Hunter (1941) apparently considered this outcrop to be part of the Hominy Grove olivine deposit.
Olivine occurrence; Canton, 11 678,500N; 849,600E	---	A small outcrop of altered ultramafic rock was exposed during construction of Interstate 40 during the late 1960's (J. Philip McElrath, personal communication). A few pieces of float are now scattered about the area.

Feldspar

Feldspar mine, name unknown; Canton, 12 691,100N; 849,350E	One large pit and several small trenches. The pit is about 75 feet long, 40 feet wide, and with walls 25 to 30 feet high.	The dumps contain abundant clean quartz, weathered feldspar, and minor biotite.
Feldspar prospect, name unknown; Canton, 13 703,050N; 862,200E	The prospect excavation here has a 12-foot-high face.	A 25-foot-thick pegmatite contains feldspar and quartz with minor biotite and traces of muscovite.
C. B. Wells Spar mine; Sandymush, 1 720,450N; 886,250E	---	See previous discussion of this mine.

Sand and Gravel

Sand and gravel pit, name unknown; Canton, 9 660,750N; 850,200E	---	Sand and gravel have been recovered from deposits in the flood plain of the Pigeon River in this vicinity.
Sand and gravel pits, Sandymush, locations uncertain, not shown on plate 1. Coordinates are very approximate: Caldwell pit: 731,000N 869,000E Canto pit: 733,500N 877,500E	---	Notes on a small-scale map in the files of the N.C. Geological Survey indicate that sand and gravel have been produced from flood plain material along Little Sandymush Creek at two localities prior to 1969. There is little remaining sign of mining activity in the area now. The material was likely used in local road construction.

Crushed Stone

Crushed stone quarry, name unknown; Sandymush, 9 723,550N; 881,100E	---	Stone from this small roadside quarry, developed in biotite gneiss of the Earlies Gap Biotite Gneiss, was likely used for fill and subgrade in local road construction.
Crushed stone quarry, name unknown; Sandymush, 10 732,300N; 863,950E	---	Stone from this small roadside quarry, developed in amphibolite of the Sandymush Felsic Gneiss, was likely used for fill and subgrade in local road construction.

Corundum

Presley mine; Canton, 15 684,750N; 866,300E	Two or three shafts are reported. Presently an exposed face in a hillside excavation is about 150 feet long and 25 feet high.	Blue to bluish-gray corundum occurs in pegmatite dikes that crosscut biotite gneiss interlayered with amphibolite. Pratt and Lewis (1905) state that the corundum occurs in rough crystals and fragments, some of which weighed 6 to 10 pounds. This is a popular location for mineral collectors who are charged a fee for entry.
Corundum (?) prospect; Canton, 16 697,200N; 879,500E	30-foot-long trench with an adit.	The property owner had been told that these diggings were for corundum. Rocks in the area are largely amphibolite; the adit and small dump contain massive actinolitic rock. No corundum was observed during this study.

Kaolin

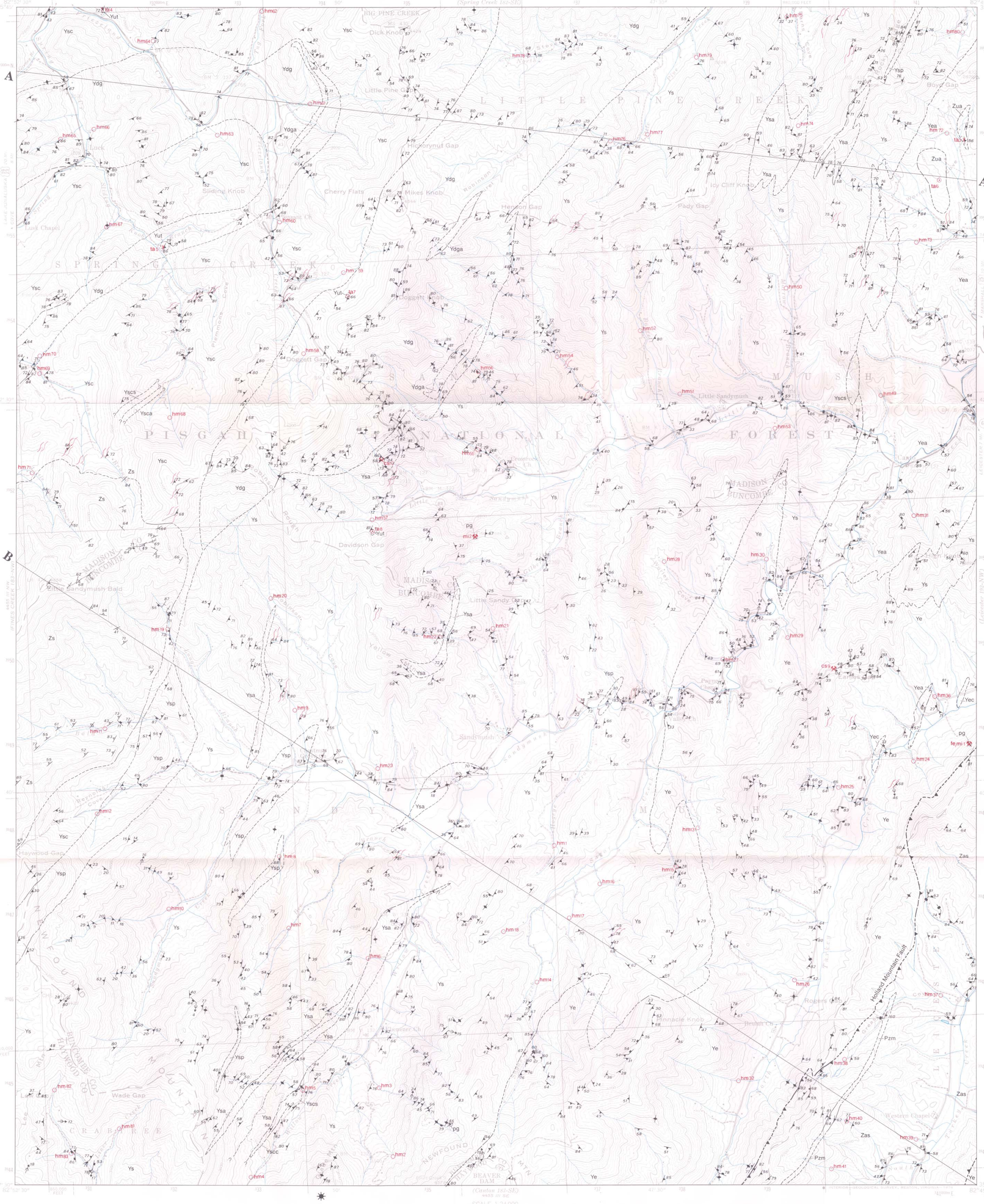
Kaolin prospect, name unknown; Canton, 17 692,750N; 862,350E	---	Local residents report that kaolin was prospected or mined on a small scale in this locality before World War II. Subsequent road construction has obliterated all signs of mining; however, kaolinized pegmatite is exposed in the present road cuts at this site.

Talc

Talc prospect; Sandymush, 3 743,750N; 886,900E	Shallow hillside excavation, 25 feet long, 15 feet wide, 10-foot-high face.	Talcose rock, or soapstone, dips 56 degrees NE; an 8-foot width is exposed in the face. The landowner reports this material was cut into blocks, primarily for local use in hearths and chimneys.

Talc (continued)

Talc prospect; Sandymush, 4 750,100N; 853,800E	Shallow sidehill cut, 40 feet long. Face at end of cut is 8 feet high.	A 10-foot thickness of talcose rock, or soapstone, is exposed. This locality has been prospected intermittently for many years, as recently as the early 1980's The material has been used locally in fireplace and chimney construction.
Talc prospect; Sandymush, 5 740,850N; 855,850E	Several small, shallow collapsed pits are present on the crest and southeast side of a small spur. One of the pits contains an outcrop of soapstone about 2 feet wide and 3 feet high.	Soapstone from this shallow pit has apparently been used in local fireplace construction.
Talc occurrence; Sandymush, 6 742,250N; 885,900E	Outcrops and float are scattered about an area several hundred feet across.	Talcose and chloritic rocks are present at this site.
Talc occurrence; Sandymush, 7 738,750N; 862,800E	----	Keith (1904) maps two small soapstone bodies in this vicinity. A search of the area revealed only a few outcrops and float of soapstone.
Talc occurrence; Sandymush, 8 729,550N; 863,450E	----	Keith (1904) maps a soapstone body here; however, a search of the area revealed only a small outcrop and float of talcose and chloritic rock.



Base topographic map by USGS-TVA 1941
10,000-foot grid based on North Carolina rectangular coordinate system

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

UTM GRID AND 1987 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

MAP LOCATION

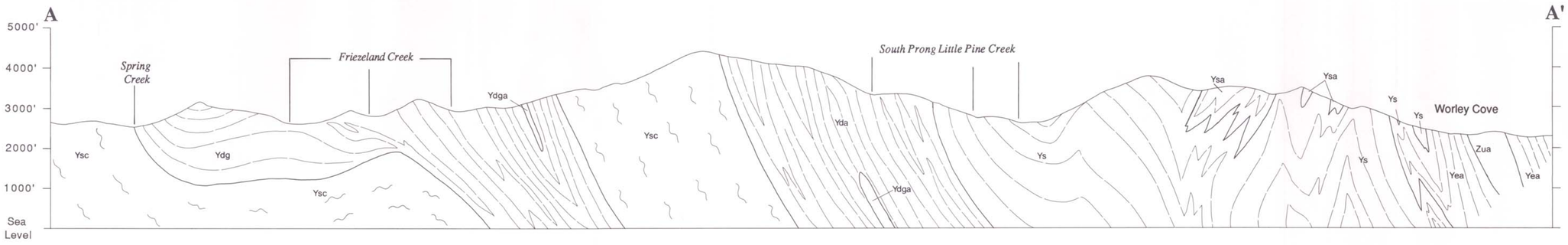
Geology mapped in 1986-87.

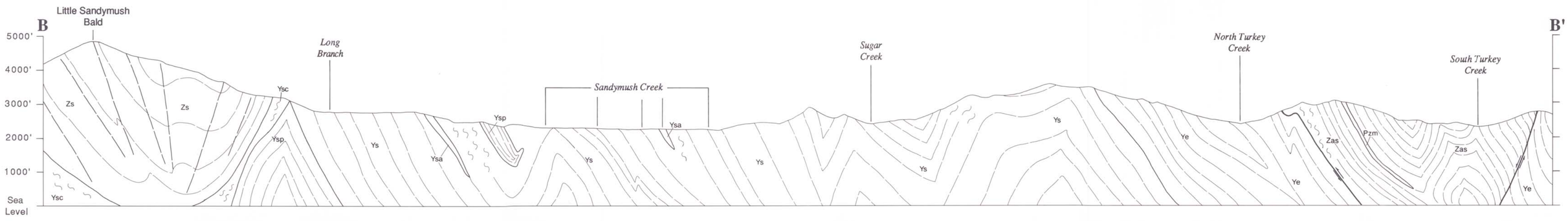
GEOLOGIC MAP OF THE SANDYMUSH QUADRANGLE, NORTH CAROLINA

By

Carl E. Merschat and Leonard S. Wiener

1988





MAP UNITS

QUATERNARY
- Alluvium
- Colluvium

PALEOZOIC
- pg — Pegmatite

Trondhjemite
- Pzm — Mylonite and Protomylonite. Large bodies mapped separately; isolated outcrops indicated by pattern:

LATE PROTEROZOIC
- Zs — Snowbird Group
- Zua — Altered mafic and ultramafic rock
- Zas — Ashe Metamorphic Suite

Unconformity

The following map units have been subjected to Proterozoic mylonitic deformation. Large bodies of mylonite and protomylonite are mapped separately; isolated outcrops are indicated by pattern:

MIDDLE PROTEROZOIC
- Yut — Talc Body
- Ydg, Ydga — Doggett Gap Protomylonitic Granitoid Gneiss (Ydg); interlayers of amphibolite (Ydga)
- Ysc, Ysca, Yscc — Spring Creek Granitoid Gneiss (Ysc); interlayers of amphibolite (Ysca); interlayers of calc-silicate granofels (Yscc)
- Ys, Ysp, Ysa, Yscs — Sandymush Felsic Gneiss (Ys); interlayers of protomylonite (Ysp); amphibolite (Ysa); calc-silicate granofels (Yscs)
- Yea, Yec — Earles Gap Biotite Gneiss(Ye); interlayers of calc-silicate granofels (Yec); grades northeastward to an amphibolite-dominant phase (Yea)

DESCRIPTION OF MAP UNITS

Alluvium - Composed of poorly to well-stratified gravel, sand, silt, and clay, generally less than 3 meters thick. Found in present-day stream valleys and older terrace deposits. Not mapped.

Colluvium - Composed of unstratified, poorly sorted boulders, cobbles, and pebbles in a finer-grained matrix. Commonly dissected and modified by fluvial processes. Locally present as hillside block fields, which commonly merge with valley fill in stream courses, and as talus or fan deposits at the base of steep slopes. Successive deposits of more than one age may be present. Not mapped.

Pegmatite - White to mottled-white and pink; coarse-grained; dominantly crosscutting; lenticular to tabular; thicknesses range from centimeters to meters. Composed of plagioclase feldspar, K-feldspar, quartz, biotite, and muscovite. Only larger bodies recorded; location is shown by "o", location and trend by "ø".

Trondhjemite - Very light-gray to medium-light-gray to very pale-orange; fine- to medium-grained; mostly unfoliated thin dikes and sills; thickness ranges from several centimeters to a meter. Composition varies from granodiorite to tonalite. Individual bodies too small and discontinuous to show at map scale.

Mylonite and Protomylonite - Medium-gray to dark-gray; very fine-grained to medium-grained; mylonitic to lepidoblastic, variably megacrystic (less than 1 mm to 1 cm); layers are a centimeter up to a few tens of centimeters thick; composition reflects the major map unit in which they are found; those of the Ashe Metamorphic Suite usually contain muscovite megacrysts. Mylonitization is variable throughout; local areas of unmylonitized rock occur.

Snowbird Group - An interlayered sequence of metasedimentary rocks dominated by kyanite-garnet-mica schist and metagraywacke with minor calc-silicate granofels. Mica schist is medium gray to medium dark gray; lepidoblastic; finely foliated; thin- to medium-layered; composed of muscovite (42%), garnet (13%), quartz (13%), kyanite (12%), plagioclase (10%), biotite (8 %), K-feldspar (1%) and opaques. Metagraywacke is medium light gray to medium gray; medium- to coarse-grained, locally conglomeratic; granoblastic to lepidoblastic; poorly foliated to foliated; medium- to thick-layered. Mineral content varies; quartz (65- 71%), plagioclase (14 -16%), K-feldspar (4-6%), biotite (7 -9%), muscovite (3-6%), and accessory epidote and opaques. Calc-silicate granofels form very minor interlayers within the metagraywacke. They are medium gray to dark gray; granoblastic; poorly foliated and consist of quartz (57%), plagioclase (28%), hornblende (8%), garnet (5%), opaques (1%), and a trace of epidote.

Altered mafic and ultramafic rock - Two small bodies of massive amphibolite and talc-bearing amphibolite are mapped in the amphibolite phase of the Earles Gap Biotite Gneiss. These rocks were probably intruded as gabbro, pyroxenite, or dunite and have since been metamorphosed. The amphibolite is greenish black to brownish black; medium- to coarse-grained; nematoblastic; massive and composed of 80 to 90 percent amphibole and lesser amounts of plagioclase and epidote group minerals. The talc-rich bodies are light greenish gray to greenish gray and foliated.

Ashe Metamorphic Suite - A heterogeneous metasedimentary unit composed of repetitive layers of kyanite-garnet-mica schist, metagraywacke, biotite gneiss, and amphibolite. On the Sandymush Quadrangle kyanite-garnet-mica schist dominates. It is light gray to medium light gray; medium- to coarse-grained; finely foliated; thin- to medium- layered; composed of muscovite (38%), biotite (22%), quartz (16%), plagioclase (12%), garnet (7%), kyanite (3%), and opaques. Metagraywacke, second in abundance, is medium light gray; granoblastic to lepidoblastic; medium to coarse grained; weakly foliated; medium to thick layered; composed of quartz (49-65%), muscovite (4-28%), biotite (4-25%), plagioclase (1-22%), minor epidote group minerals, and opaques. Biotite gneiss layers are medium gray to medium dark gray; granoblastic to lepidoblastic; medium grained; weakly foliated; medium- to thick-layered; composed of plagioclase (35%), biotite (33%), quartz (24%), K-feldspar (3%), muscovite (3%), garnet (1%), minor epidote group minerals, and opaques. Amphibolite, likely originating as mafic volcanic material, is present as rare, thin interlayers and is composed mostly of amphibole and plagioclase.

Talc body - Very pale-green to grayish-green; well foliated to massive; podiform to lens-shaped; composed almost entirely of talc and chlorite with minor magnetite.

Doggett Gap Protomylonitic Granitoid Gneiss - Light-gray to medium light-gray to very pale-orange; inequigranular (megacrysts range from 0.5cm to 4 cm); mylonitic to granoblastic to lepidoblastic; poorly layered to layered, thicknesses vary from centimeters to meters; granitic in composition, K-feldspar (31 - 40%), plagioclase (26 - 28%), quartz (22 - 28%), biotite (7 - 12%), accessory minerals include muscovite, epidote, opaques, clinozoisite, sphene, and apatite. Interlayered rock types include biotite granitic gneiss, biotite tonalite gneiss, and amphibolite.

amphibolite - dark greenish-gray to grayish olive-green, medium- to coarse-grained; nematoblastic; weakly foliated to mylonitic; thin- to medium-layered; composed of hornblende (55%), plagioclase (36%), quartz (4%); accessory minerals include epidote group minerals, opaques, sphene, and K-feldspar.

Spring Creek Granitoid Gneiss - Biotite granitic gneiss interlayered with protomylonitic granodioritic gneiss, amphibolite, and rare calc-silicate granofels. Biotite granitic gneiss is light gray, mottled with pinkish gray, to pale reddish brown; equigranular granoblastic to inequigranular lepidoblastic; locally mylonitized; poorly foliated to foliated; medium layered to massive; composed of K-feldspar (34-37%), quartz (26-31%), plagioclase (25%), biotite (4-7%), muscovite (2-7%), and minor epidote-group minerals, garnet, and a carbonate mineral. Protomylonitic granodioritic gneiss interlayers are composed of biotite (45%), plagioclase (34%), quartz (16%), K-feldspar (4%), epidote group minerals (1%), and opaques.

amphibolite - dark greenish-gray to greenish-black; equigranular nematoblastic; medium- to coarse-grained, well foliated, thin- to medium-layered; composed of hornblende (24 - 70%), plagioclase (21 - 56%), epidote (7 - 16%), opaques (0 - 3%), quartz (0 - 1%), and sphene, sericite, apatite, and talc.

calc-silicate granofels - very light-gray to greenish-gray to dark greenish-gray; equigranular granoblastic to nematoblastic; massive to foliated; thin- to thick-layered; composed of plagioclase, K-feldspar, amphibole, epidote group minerals and minor biotite, sphene, and opaques.

Sandymush Felsic Gneiss - The Sandymush Felsic Gneiss is a thick, monotonous, repetitive sequence of layered rocks dominated by biotite granitic gneiss to quartz dioritic gneiss. Intergraded and interlayered biotite schist, amphibolite, and protomylonite are common and widespread; calc-silicate granofels is a very minor constituent. Biotite granitic gneiss to quartz dioritic gneiss is very light gray to pale orange to medium light gray; equigranular granoblastic to lepidoblastic; inequigranular where mylonitized; thicknesses of layers range from millimeters to meters; composed of quartz (10-70%), plagioclase (10-62%), K-feldspar (1-26%), biotite (1-50%), epidote group minerals (0-17 %), muscovite (0-2%), opaques (0-5%), and garnet, sphene, apatite, and zircon.

protomylonite - derived from and interlayered with other rock types of the Sandymush Felsic Gneiss. Protomylonite is medium gray to very pale orange; inequigranular (megacrysts range from 0.5 to 2.5cm) to equigranular; mylonitic to lepidoblastic to granoblastic; layered to poorly layered, thicknesses range from less than a centimeter to meters; composition is granitic to granodioritic; plagioclase (24-33%), K-feldspar (22-39%), quartz (22-39%), biotite (3-21%), epidote (0-5%), and muscovite, garnet, opaques, clinozoisite, apatite, sphene, and chlorite.

amphibolite - interlayered with other rock types of the Sandymush Felsic Gneiss. Amphibolite is dark greenish gray to greenish black; equigranular; nematoblastic to lepidoblastic; poorly foliated to well foliated; layering ranges from several centimeters to meters in thickness; composed of hornblende (44-72%), plagioclase (21-42%), biotite (0-11%), quartz (1-7%), epidote group minerals (0-4%), and K-feldspar, opaques, garnet, sphene, and apatite.

calc-silicate granofels - interlayered with other rock types of the Sandymush Felsic Gneiss. Calc-silicate granofels is very light gray to greenish gray; equigranular granoblastic; massive to poorly foliated; thin- to medium- layered to podiform; composed of plagioclase, K-feldspar, quartz, epidote group minerals, diopside, and accessory and alteration minerals including hornblende, biotite, sphene, and garnet. Characterized by yellowish-brown limonite spots resulting from rapid weathering of diopside.

Earles Gap Biotite Gneiss - Includes numerous varieties of biotite gneiss and biotite granitic gneiss interlayered with abundant amphibolite, rare calc-silicate granofels, and muscovite-biotite gneiss. Biotite granodiorite gneiss to biotite tonalite gneiss is dominant; biotite granitic gneiss to quartz dioritic gneiss is very similar to portions of the Sandymush Felsic Gneiss. The "wavy" appearance of the layers of coarse-grained biotite granodiorite gneiss to biotite tonalite gneiss is distinctive of this unit. The gneisses are very light gray to medium light gray; lepidoblastic to equigranular granoblastic; locally mylonitic; well foliated; layer thicknesses range from centimeters to meters; locally migmatitic to highly migmatitic; composed of plagioclase (22-40%), quartz (15-44%), biotite (0-50%), K-feldspar (0-25%), epidote group minerals (0-2%), and muscovite, opaques, garnet, apatite, chlorite, and a carbonate mineral.

calc-silicate granofels - interlayered with amphibolite and other rock types of the Earles Gap Biotite Gneiss. Calc-silicate granofels is very light gray to greenish gray; equigranular granoblastic to lepidoblastic; massive to foliated; thin layered to podiform; composed of plagioclase, K-feldspar, quartz, epidote group minerals, diopside, and alteration and accessory minerals including hornblende, biotite, sphene, and garnet. Characterized by yellowish-brown limonite spots resulting from the rapid weathering of diopside.

amphibolite - interlayered with other rock types of the Earles Gap Biotite Gneiss. Amphibolite is dark gray to greenish black; equigranular nematoblastic to lepidoblastic; poorly foliated to well foliated; layering ranges from several centimeters to several meters in thickness; composed of hornblende (34%), biotite (altered from hornblende, 24%), plagioclase (23%), quartz (12%), epidote group minerals (2%), sphene (2%), opaques (2%), and garnet and apatite.

STRUCTURAL FEATURES

[The intersection of combined structural symbols marks the point of observation]

CONTACTS AND FAULTS [Solid line - well located; long-dashed - approximately located; short-dashed- inferred; queried- existence is uncertain]

Contact

Thrust Fault - *saw teeth on upper plate*

PLANAR FEATURES

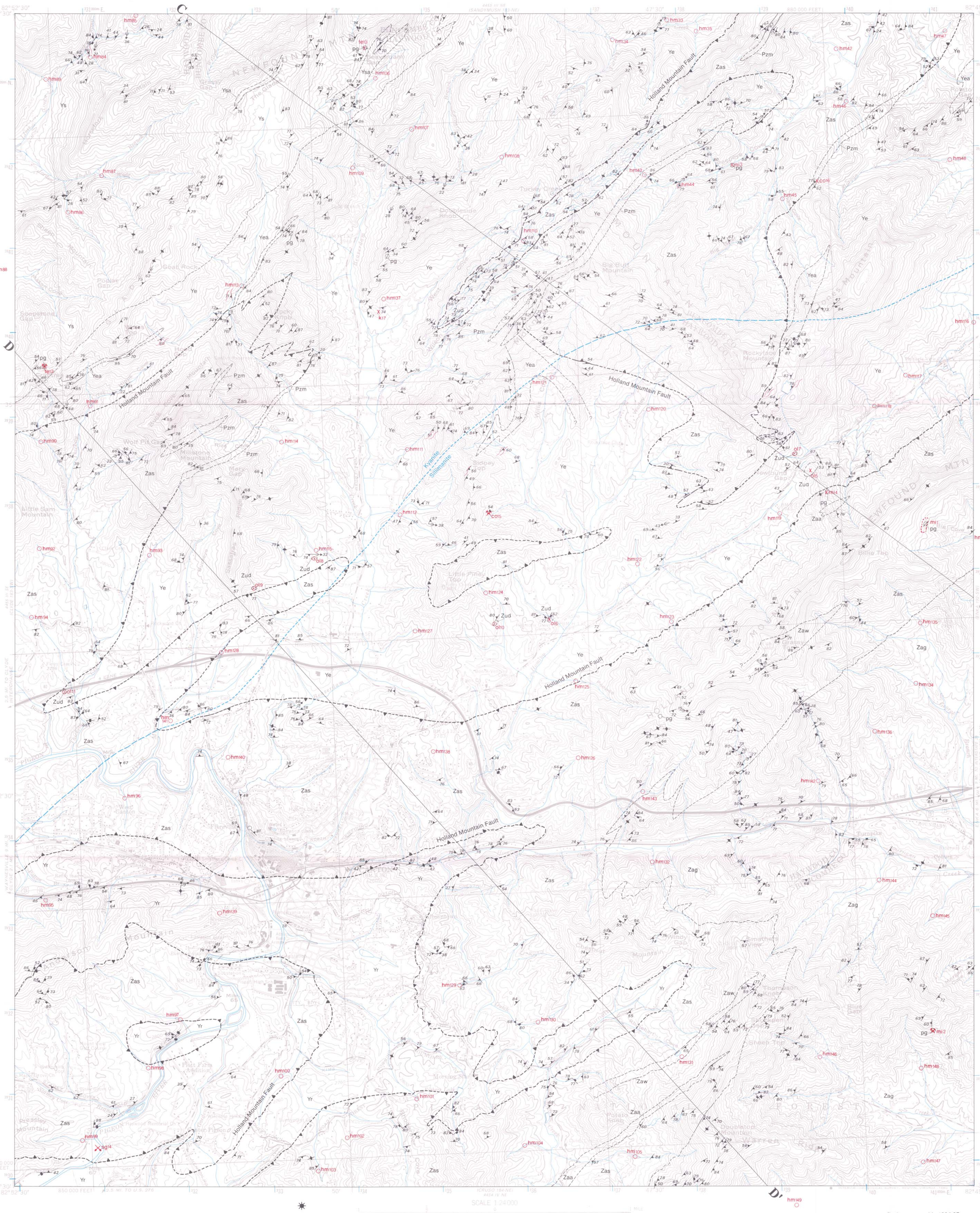
- Inclined beds
- Inclined, top of beds known from graded bedding
- Vertical beds
- Inclined schistosity
- Vertical schistosity
- Inclined foliation
- Vertical foliation
- Horizontal foliation
- Inclined joints
- Vertical joints

FOLDS

- Bearing and plunge of axes of small folds
- Horizontal small folds

MINERAL RESOURCES

- Inactive quarry
- Prospect
- Occurrence
- Heavy mineral sampling site
- cs Crushed stone
- fe Feldspar
- hm Heavy mineral
- mi Mica
- ta Talc
- 38 Map number refers to text description



Base topographic map by USGS-TVA 1967, photorevised 1979
10,000-foot grid based on North Carolina rectangular coordinate system
1000 meter Universal Transverse Mercator grid ticks, zone 17, shown in blue

UTM GRID AND 1987 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

N. C.
MAP LOCATION

Geology mapped in 1986-87.

GEOLOGIC MAP OF THE CANTON QUADRANGLE, NORTH CAROLINA

By

Carl E. Merschat and Leonard S. Wiener

1988

MAP UNITS

QUATERNARY
- Alluvium
- Colluvium

PALEOZOIC
- pg — Pegmatite
- Trondhjemite
- Pzm — Mylonite and Protomylonite. Large bodies mapped separately, isolated outcrops indicated by pattern:

LATE PROTEROZOIC
- Zud — Dunite
- Zag, Zas, Zaa, Zaw — Ashe Metamorphic Suite: gneiss (Zag); schist (Zas), with amphibolite (Zaa) or metagraywacke (Zaw)

The following map units have been subjected to Proterozoic mylonitic deformation. Local areas of mylonite indicated by pattern:

MIDDLE PROTEROZOIC
- Ys, Ysa — Sandymush Felsic Gneiss (Ys); with interlayers of amphibolite (Ysa)
- Ye, Yea — Earlies Gap Biotite Gneiss (Ye); with interlayers of amphibolite (Yea)
- Yr — Richard Russell Formation [stratigraphic position uncertain]

DESCRIPTION OF MAP UNITS

Alluvium - Composed of poorly to well-stratified gravel, sand, silt, and clay, generally less than 3 meters thick. Found in present-day stream valleys and older terrace deposits above present drainage levels. Not mapped.

Colluvium - Composed of unstratified, poorly sorted boulders, cobbles, and pebbles in a finer-grained matrix. Commonly dissected and modified by fluvial processes. Locally present as hillside block fields, which commonly merge with valley fill in stream courses, and as talus or fan deposits at the base of steep slopes. Successive deposits of more than one age may be present. Not mapped.

Pegmatite - White to mottled-white and pink; coarse-grained; dominantly crosscutting; lenticular to tabular; thicknesses range from centimeters to meters. Composed of plagioclase feldspar, K-feldspar, quartz, biotite, and muscovite. Only larger bodies mapped; location is shown by "o", location and trend by "ø".

Trondhjemite - Very light-gray to medium-light-gray to very pale-orange; fine- to medium-grained; mostly unfoliated thin dikes and sills; thickness ranges from several centimeters to a meter. Composition varies from granodiorite to tonalite. Individual bodies too small and discontinuous to show at map scale.

Mylonite and Protomylonite - Medium-gray to dark-gray, very fine-grained to medium-grained; mylonitic to lepidoblastic, variably megacrystic (less than 1 mm to 1 cm); layers are a centimeter up to a few tens of centimeters thick; composition reflects the major map unit within which they are found; those of the Ashe Metamorphic Suite usually contain muscovite megacrysts. Mylonitization is variable throughout; local areas of unmylonitized rock occur.

Dunite - Pale olive to dusky yellow-green; dusky yellow when weathered; unaltered to highly altered. Unaltered dunite is composed of olivine (forsterite - Fo_{90-95}) and minor chromite, whereas altered dunite contains various amounts of serpentine minerals, talc, anthophyllite, vermiculite, and opaques. Deeply weathered areas are characterized by a nickeliferous saprolite and a dusky-red to very dark-red soil with residual chalcedonic fragments.

Ashe Metamorphic Suite - A heterogenous metasedimentary unit consisting of repeated interlayers of mica schist, metagraywacke, biotite gneiss, minor calc-silicate granofels, and rare amphibolite. On the Canton Quadrangle the Ashe Suite is subdivided into two major units, one in which schist dominates and the other in which gneiss and metagraywacke dominate.

gneiss - composed of biotite gneiss to metagraywacke interlayered with sillimanite-kyanite-garnet-mica schist, and calc-silicate granofels. The biotite gneiss to metagraywacke is light gray to medium dark gray; dominantly lepidoblastic with some equigranular granoblastic layers; thicknesses of layers range from a few centimeters to several meters; composed of quartz (37-56%), plagioclase (16-39%), biotite (9-20%), muscovite (0-10%), K-feldspar (0-10%), and minor epidote, garnet, and opaques. Interlayers of sillimanite-kyanite-garnet-mica schist are similar to those described below; calc-silicate granofels is sparingly present and occurs as thin layers and pods less than one meter thick. It is composed mostly of quartz, plagioclase, a mafic mineral (either an amphibole or biotite), and garnet.

schist - composed of repetitive layers of sillimanite-kyanite-mica-garnet schist, metagraywacke, biotite gneiss, and rare, thin amphibolite interlayers. Sillimanite-kyanite-mica-garnet schist dominates and is light gray to medium light gray; medium- to coarse-grained; finely foliated; thin- to medium-layered; composed of quartz (24-41%), biotite (12-53%), muscovite (11-21%), garnet (8-16%), plagioclase (0-14%), kyanite (2-13%), sillimanite (0-7%), and opaques. Metagraywacke is medium light gray; granoblastic to lepidoblastic; medium- to coarse-grained; weakly foliated; medium- to thick-layered; composed of quartz (49-65%), muscovite (4-28%), biotite (4-25%), plagioclase (1-22%), minor epidote group minerals, and opaques. Biotite gneiss layers are medium gray to medium dark gray; granoblastic to lepidoblastic; medium grained, weakly foliated; medium- to thick-layered; composed of plagioclase (35%), biotite (33%), quartz (24%), K-feldspar (3%), muscovite (3%), garnet (1%), minor epidote group minerals, and opaques. Amphibolite, likely originating as mafic volcanic material, is present as rare, thin interlayers and is composed mostly of amphibole and plagioclase.

Within the schist unit of the Ashe Metamorphic Suite several areas are especially abundant in metagraywacke and in amphibolite: **Zaw** - metagraywacke-rich area; **Zaa** - amphibolite-rich area.

Sandymush Felsic Gneiss - The Sandymush Felsic Gneiss is a thick, monotonous, repetitive sequence of layered rocks dominated by biotite granitic gneiss to quartz dioritic gneiss. Intergraded and interlayered biotite schist and amphibolite are common and widespread. Protomylonite and calc-silicate granofels are minor constituents in the Canton Quadrangle. Biotite granitic gneiss to quartz dioritic gneiss is very light gray to pale orange to medium light gray; equigranular granoblastic to lepidoblastic; inequigranular where mylonitized; thicknesses of layers range from millimeters to meters; composed of quartz (10-70%), plagioclase (10-62%), K-feldspar (1-26%), biotite (1-50%), epidote group minerals (0-17%), muscovite (0-2%), opaques (0-5%), and minor garnet, sphene, apatite, and zircon. Interlayers of protomylonite are medium gray to very pale orange; inequigranular (megacrysts range from 0.5 to 2.5cm) to equigranular; mylonitic to lepidoblastic; thicknesses of layers vary from less than a centimeter to several meters; composition is granitic to granodioritic; plagioclase (24-33%), K-feldspar (22-39%), quartz (22-39%), biotite (3-21%), epidote (0-5%), and muscovite, garnet, opaques, clinozoisite, apatite, sphene, and chlorite. Calc-silicate granofels is sparingly interlayered with other rock types of the Sandymush Felsic Gneiss and is very light gray to greenish gray; equigranular granoblastic; massive to poorly foliated; thin- to medium-layered to podiform; composed of plagioclase, K-feldspar, quartz, epidote group minerals, diopside, and accessory and alteration minerals including hornblende, biotite, sphene, and garnet. Characterized by yellowish-brown limonite spots resulting from rapid weathering of diopside.

amphibolite - interlayered with other rock types of the Sandymush Felsic Gneiss. Amphibolite is dark greenish gray to greenish black; equigranular; nematoblastic to lepidoblastic; poorly foliated to well foliated; layering ranges from several centimeters to meters in thickness; composed of hornblende (44-72%), plagioclase (21-42%), biotite (0-11%), quartz (1-7%), epidote group minerals (0-4%), and K-feldspar, opaques, garnet, sphene, and apatite.

Earlies Gap Biotite Gneiss - Includes numerous varieties of biotite gneiss and biotite granitic gneiss, interlayered with abundant amphibolite and rare calc-silicate granofels and muscovite-biotite gneiss. Biotite granodiorite gneiss to biotite tonalite gneiss is dominant; biotite granitic gneiss to quartz dioritic gneiss is very similar to portions of the Sandymush Felsic Gneiss. The "wavy" appearance of the layers of coarse-grained biotite granodiorite gneiss to biotite tonalite gneiss is distinctive of this unit. The gneisses are very light gray to light gray; lepidoblastic to equigranular granoblastic; locally mylonitic; well foliated; layer thicknesses range from centimeters to meters; locally migmatitic to highly migmatitic; composed of plagioclase (22-40%), quartz (15-44%), biotite (0-56%), K-feldspar (0-25%), epidote group minerals (0-2%), and muscovite, opaques, garnet, apatite, chlorite, and a carbonate mineral. Calc-silicate granofels is interlayered with amphibolite and other rock types of the Earlies Gap Biotite Gneiss. Calc-silicate granofels is very light gray to greenish gray; equigranular granoblastic to lepidoblastic; massive to foliated; thin layered to podiform; composed of plagioclase, K-feldspar, quartz, epidote group minerals, diopside, and alteration and accessory minerals including hornblende, biotite, sphene, and garnet. Characterized by yellowish-brown limonite spots resulting from the weathering of diopside.

amphibolite - interlayered with other rock types of the Earlies Gap Biotite Gneiss. Amphibolite is dark gray to greenish black; equigranular nematoblastic to lepidoblastic; poorly foliated to well foliated; layering ranges from several centimeters to several meters; composed of hornblende (34%), biotite (altered from hornblende, 24%), plagioclase (23%), quartz (12%), epidote group minerals (2%), sphene (2%), opaques (2%), and garnet and apatite.

Richard Russell Formation - Composed of biotite gneiss with interlayers of amphibolite; commonly migmatitic. The dominant biotite gneiss has thin alternating dark-colored biotite-rich layers and light-colored quartz and feldspar-rich layers; thicknesses range from a millimeter to several centimeters; layers are locally discontinuous. The biotite gneiss is very light gray to medium light gray; equigranular granoblastic to lepidoblastic; composed of quartz (26-57%), plagioclase (12-30%), K-feldspar (10-26%), biotite (3-15%), muscovite (1-4%), and other minerals including epidote, garnet, opaques, and sericite. The dark greenish-gray to greenish-black amphibolite is composed mostly of hornblende and plagioclase. Amphibolite interlayers are also locally discontinuous and have variable thicknesses ranging up to about ten meters.

STRUCTURAL FEATURES

[The intersection of combined structural symbols marks the point of observation]

CONTACTS AND FAULTS [Solid line - well located; long-dashed - approximately located; short-dashed- inferred; queried- existence is uncertain]

- Contact
- Thrust Fault - *saw teeth on upper plate*
- Isograd - *based on 76 heavy mineral samples, 18 thin sections, and field observations*

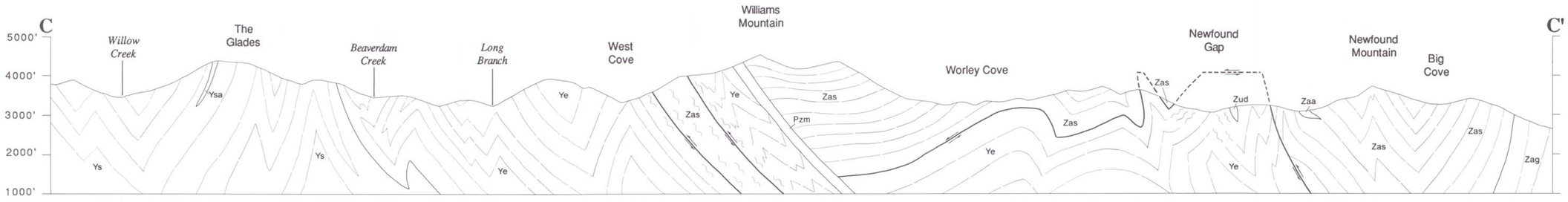
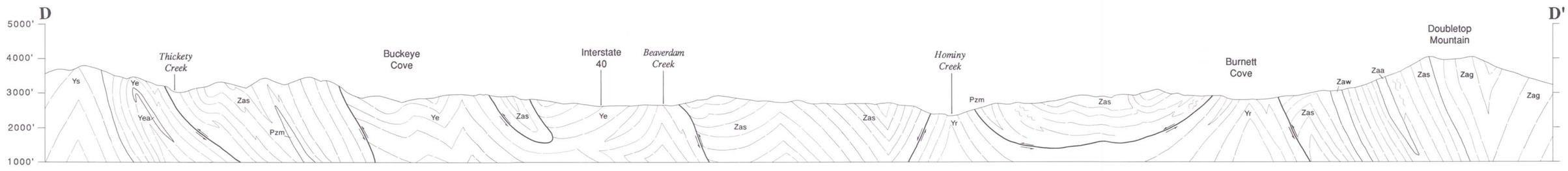
PLANAR FEATURES

- Inclined foliation
- Vertical foliation
- Horizontal foliation
- Inclined joint
- Vertical joint

FOLDS

- Bearing and plunge of axes of small folds
- Horizontal small folds

MINERAL RESOURCES

- Abandoned mining area
- Abandoned mine
- Abandoned pit
- Prospect
- Occurrence
- Heavy mineral sampling site (Sites 88, 116, 133, and 149 are over edge on adjacent quadrangles)
- Map number refers to description in text

- co Corundum
- fe Feldspar
- hm Heavy mineral
- k Kaolin
- ol Olivine
- mi Mica
- sg Sand and gravel