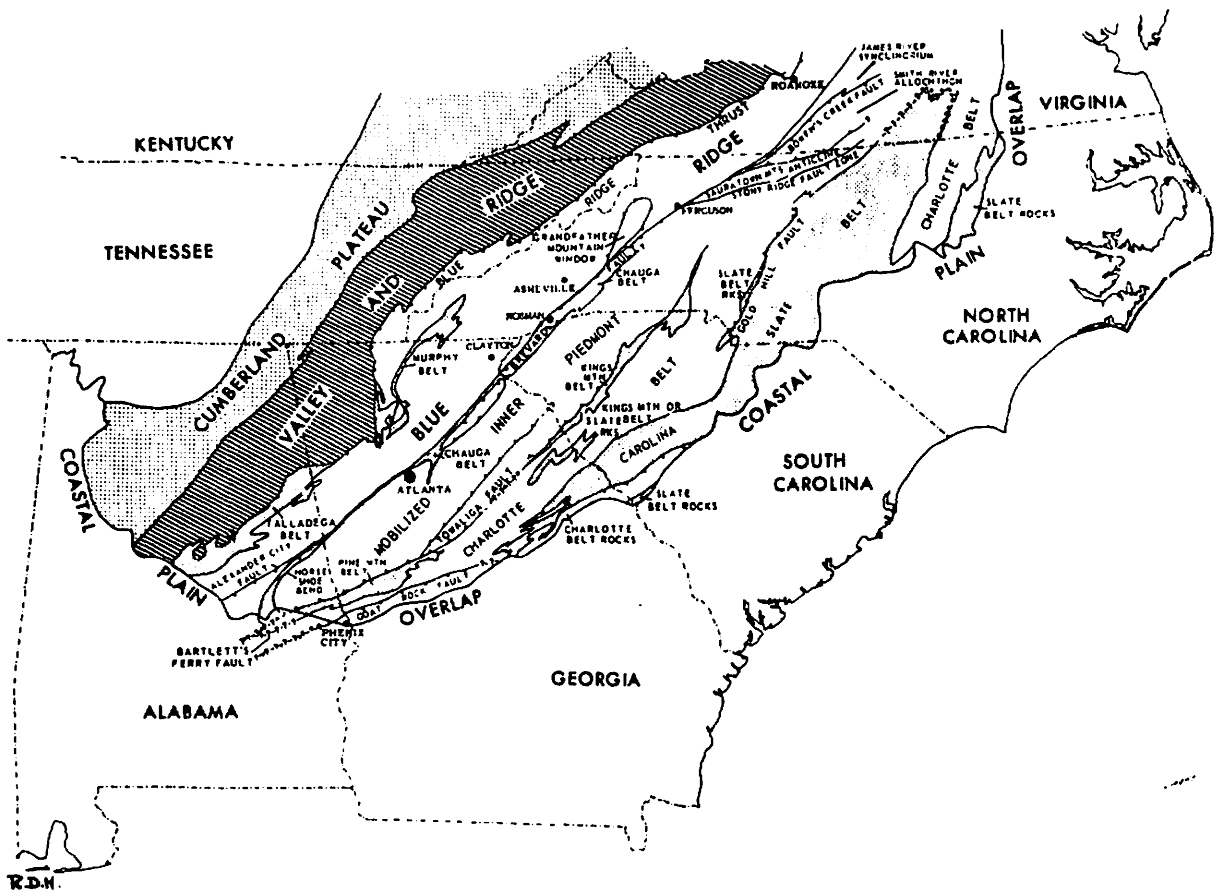
FIELD GUIDEBOOK TO THE GEOLOGY OF THE CENTRAL BLUE RIDGE OF NORTH CAROLINA AND THE SPRUCE PINE MINING DISTRICT

Revised Edition

by

Leonard S. Wiener and Carl E. Merschat



NORTH CAROLINA GEOLOGICAL SURVEY
DIVISION OF LAND RESOURCES

DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES

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DIVISION OF LAND RESOURCES

RALEIGH

1990

STATE OF NORTH CAROLINA

JAMES G. MARTIN, GOVERNOR

DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES
WILLIAM W. COBEY, JR., SECRETARY

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FIELD GUIDEBOOK TO THE GEOLOGY OF THE CENTRAL BLUE RIDGE OF NORTH CAROLINA AND THE SPRUCE PINE MINING DISTRICT

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GEOLOGIC HISTORY OF THE BLUE RIDGE OF NORTH CAROLINA

Introduction

The mountainous area of western North Carolina and adjacent eastern Tennessee is part of the Blue Ridge physiographic province, a major geomorphic entity that extends for nearly 600 miles from southern Pennsylvania into Georgia. In the vicinity of Asheville the province has its greatest width, about 75 miles. At this latitude the western edge of the province is in Tennessee along a line of high quartzite ridges which overlook the carbonate and shale lowlands of the Valley and Ridge province.

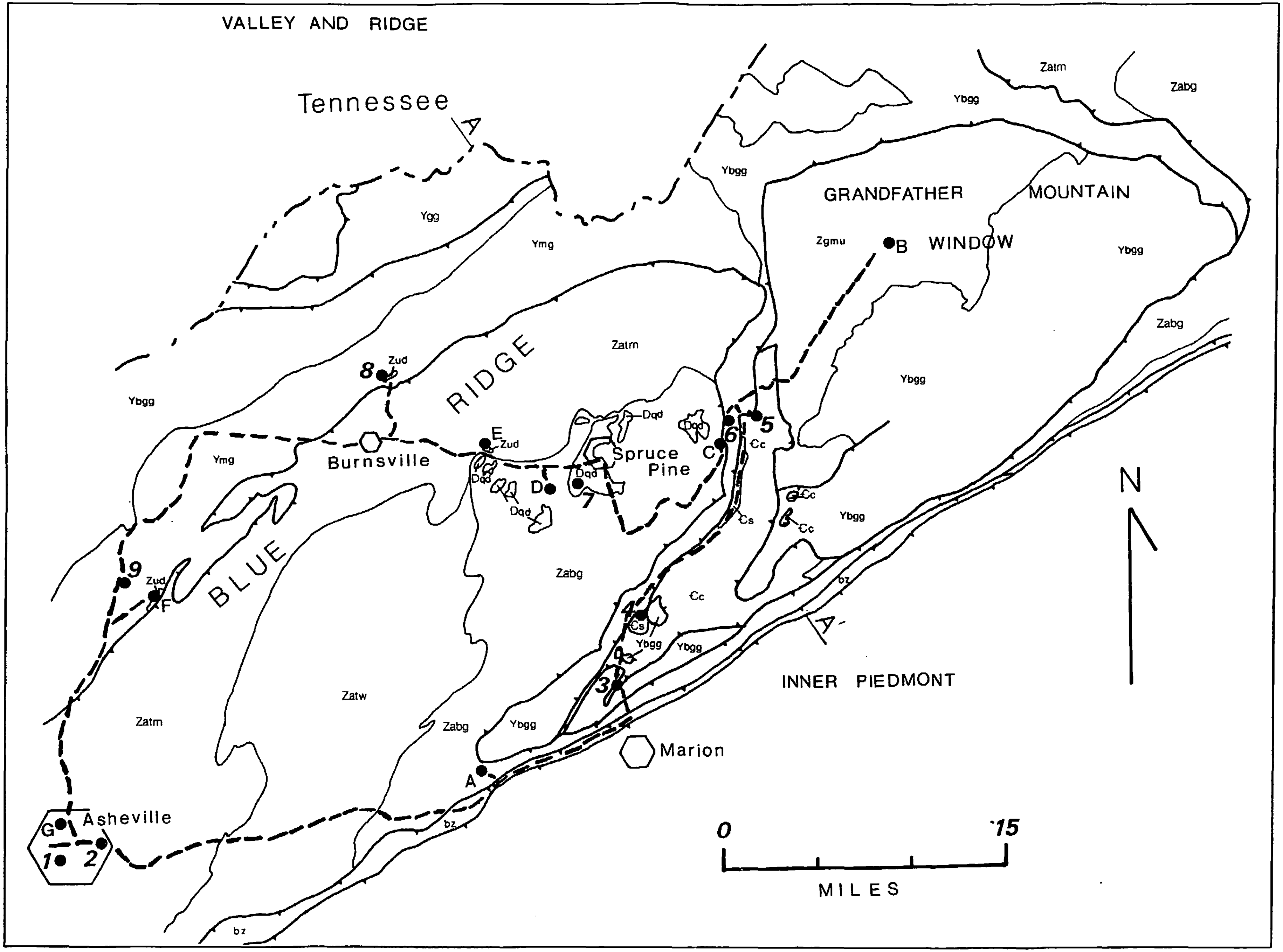
The eastern boundary of the Blue Ridge province is located at the base of the escarpment between the mountainous terrain to the west and the low-lying Piedmont province to the east. Although a number of restricted ranges and monadnocks, notably the Brushy Mountains and the South Mountains, are present in the Piedmont, the broad, rolling interfluve areas define a surface that is generally between 1,200 and 1,500 feet in elevation along the base of the Blue Ridge escarpment as it crosses North Carolina. Relief along the escarpment exceeds 2,000 feet at many places, and numerous peaks along the crest of the escarpment are more than one-half mile above the Piedmont surface. The crest is generally coincident with the Eastern Continental Divide; streams flowing eastward drain directly into the Atlantic, while the west-flowing streams follow a much longer course, ultimately draining into the Gulf of Mexico.

In addition to the peaks and ridges along the escarpment, the Blue Ridge province includes a dozen or more longitudinal and transverse mountain ranges. Mount Mitchell, the highest peak in eastern North America (elevation 6,684 feet), is located about 20 miles northeast of Asheville in the Black Mountain range. Asheville itself is situated in an intermontane basin whose floor is between 2,000 and 2,200 feet in elevation. Low hills project above the basin floor, and the major stream through the basin, the French Broad River along with its tributaries, is entrenched as much as 500 feet at the north end of the Asheville basin.

Hard, coherent bedrock commonly crops out along the entrenched streams; elsewhere in the basin a thick saprolite cover is widespread. Thus, the basin is not a depositional or structural feature, but rather is a topographic lowland resulting from a long period of chemical decay and erosion of the rocks. This conclusion, reached many years ago, provided the basis for early geologists naming the surface landform the "Asheville peneplain." Although not as extensive, similar erosional basins are present along other major drainages in the mountains and their surfaces are often correlated with the Harrisburg or Valley Floor surface of the Valley and Ridge province.

Blue Ridge Structural Province

The Blue Ridge structural province of North Carolina and adjoining Tennessee is composed of a great, three-dimensional mass of deformed and metamorphosed rocks. The province is bounded on the west by major thrust faults, and on the east by the Brevard zone (figure 1). In addition, rocks of the province are undoubtedly allochthonous, being underlain in the subsurface by the Linville Falls fault and other similar thrusts of Late Paleozoic age. The Blue Ridge rocks have been moved northwestward on these faults at least 30 miles and probably more than 125 miles. To the west, and also beneath the thrust sheet are Paleozoic sedimentary rocks of the Valley and Ridge province. To the east is the Inner Piedmont structural province which includes the Brevard zone, a long narrow belt characterized by intense mylonitization.


VALLEY AND RIDGE
Tennessee
A
A'
GRANDFATHER MOUNTAIN WINDOW
BLUE RIDGE
INNER PIEDMONT
Burnsville
Spruce Pine
Marion
Asheville
Zatm
Zabg
Ybgg
Ygg
Ymg
Zgmu
Zatw
Zud
Dqd
Cc
Cs
bz
A
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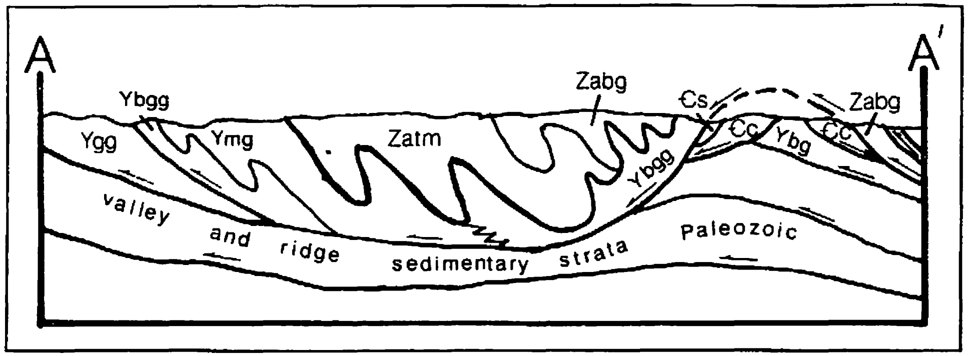
MILES



Schematic cross section along line A-A'.
(Vertical scale exaggerated for clarity.)

EXPLANATION

Pegmatites Lenticular to tabular dikes and sills, unfoliated; granitic to granodioritic. Too small to show on map.

Trondhjemite Postmetamorphic dikes and sills, weakly foliated to massive granodiorite to tonalite. Too small to show on map.

Dqd Alaskite plutons of the Spruce Pine area are medium- to coarse-grained quartz diorite to granodiorite.

Cs Shady Dolomite—light gray, fine grained, massive, locally thin bedded or ribboned. Includes thin beds of phyllite.

Cc Chilhowee Group—vitreous to feldspathic quartzite; interbedded with metasiltstone and metashale.

Zgmu Grandfather Mountain Formation—interlayered and gradational metagraywacke, meta-arkose, metasiltstone, and phyllite; locally interlayered with volcanic rock.

Bakersville Metagabbro Thin dikes and sills of metadiabase to metagabbro. Not shown on map.

Figure 1. Geologic map and fieldtrip stops.

Zud Dunite—dark green to yellowish green, massive; composed primarily of olivine and minor disseminated chromite, altered areas contain serpentine minerals, talc, and anthophyllite.

Zabg Alligator Back Formation—laminated to thin layered gneiss and schist; locally contains metagraywacke, metaconglomerate, and amphibolite.

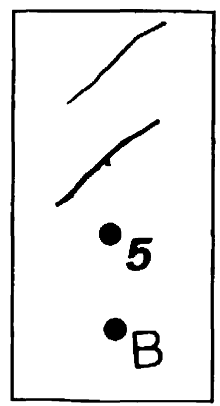
Zatw Ashe Metamorphic Suite—metagraywacke; interlayered with mica gneiss and schist, metaconglomerate, and rare graphitic schist.

Zatm Ashe Metamorphic Suite—muscovite-biotite gneiss; interlayered with mica schist, metagraywacke, and minor amphibolite.

Ygg Granodioritic gneiss—mylonitic to massive; epidote, sericite, and chlorite are common alteration minerals.

Ybgg Biotite granitic gneiss—massive to well foliated, granitic to quartz monzonitic; includes variably mylonitized orthogneiss and paragneiss, interlayered amphibolite, calc-silicate rock, and marble.

Ymg Migmatitic biotite-hornblende gneisses—interlayered mafic and felsic gneisses; locally contains relict granulite facies rock.



Contact

Thrust Fault

Stop

Optional Stop

Proterozoic and Paleozoic History

Our concepts of the geologic history of this area are continually being refined, modified and even radically changed as field mapping, radiometric studies, detailed petrographic work, and other geologic research progresses. However, the outline many geologists accept is that a complex of rocks, largely plutonic in nature but also containing sedimentary or volcanic components, formed the old "basement" for subsequent events in the Blue Ridge. Radiometric determinations, especially those of zircon and whole-rock samples from orthogneisses of the basement yield ages near or exceeding 1 billion years.

Overlying the old basement complex, at some places on major nonconformities and at other places on faults, are various cover sequences. In the central Blue Ridge the older of these cover sequences are the Tallula Falls Formation, Ashe Metamorphic Suite, and Alligator Back Formation. They represent great, but undetermined thicknesses of varied clastic sediments interspersed with lesser volcanic and plutonic material. The sediments were metamorphosed, mainly into a wide variety of muscovite-biotite gneisses. The associated volcanic and plutonic rocks were also metamorphosed, principally to feldspathic gneisses or amphibolite depending on their original composition. These cover rocks are all considered to be Late Proterozoic in age. About 20 miles west of Asheville near the Great Smoky Mountains National Park and also in the Grandfather Mountain area northeast of Asheville, the basement granitic gneisses and the overlying metasedimentary and metaigneous rocks are unconformably overlain by two other sequences of metamorphosed sediments. These younger sequences are the Ocoee Supergroup and the Grandfather Mountain Formation, respectively. They are partly coeval and are latest Proterozoic in age.

Basal Paleozoic strata (sandstones and shales of the Chilhowee Group and the conformably overlying Shady Dolomite) crop out extensively along the western margin of the Blue Ridge. These units are also exposed within the main mass of the Blue Ridge in half a dozen structural windows. The largest and easternmost of these structures is the Grandfather Mountain window (figure 1).

Most other rocks in the central part of the Blue Ridge are intrusive in orgin. They range from ultramafic dunite through felsic granitic and pegmatitic bodies. Although not a major component of the Blue Ridge, these bodies are economically important, yielding olivine, feldspar, flake mica, quartz, and kaolinite and halloysite clay. In addition, these magmatic rocks are the source of many prize mineral specimens.

Regional metamorphism has affected nearly all of the Blue Ridge rocks. Aside from the complicated physical and chemical aspects, important and only partially answered questions pertain to the number, intensity, and timing of the various metamorphic and deformational events.

The most recent syntheses provide the following Proterozoic and Paleozoic geologic scenario:

1. Early Proterozoic plutonism, possibly with associated metamorphism. A few radiometric dates exceeding 1.8 billion years indicate that some of the region's rocks must have an extremely archaic history.

2. Deformation, regional metamorphism up to granulite grade, and igneous activity in the Middle Proterozoic. Evidence for these old events is largely obscured or obliterated by subsequent Paleozoic metamorphism and deformation. However, highly deformed rocks, including granitic and mafic gneisses as well as rocks with relic granulite-facies mineral assemblages and textures are exposed in some areas of western North Carolina. This complex of high-grade metamorphic and tectonic events is correlated with the Grenville orogeny of eastern North America.

3. Folding, thrust faulting, and regional metamorphism occurred about Middle Ordovician. Most of the dominant structural and metamorphic elements seen in rocks of the southern Blue Ridge are attributed to this Middle Ordovician tectonism and are associated with the Taconic orogeny.

   These features were caused by long-term compressive stress acting upon rocks whose mechanical properties varied during an extensive period of heating and subsequent cooling. The heating first caused recrystallization and development of an overprinting metamorphic foliation along with rheological homogenization or a general "plasticizing" of the entire rock sequence. The initial rock weaknesses, incompetent stratigraphic units and bedding planes which had controlled formation of early structures, were commonly transposed into the new foliation planes.

Deformation under these conditions was dominated by flowage with folds, ductile faults, and interfolia displacements prevailing. As the thermal peak was reached, typical Barrovian porphyroblastic indicator minerals crystallized. Melting took place locally and was especially prevalent in the originally "wet" quartz-feldspar-clay sediments whose chemical composition approximated that of a granitic eutectic. The melts behaved magmatically, and some ultimately crystallized as pegmatitic veins or masses.

4. The late Paleozoic Alleghanian Orogeny resulted in emplacement and concomitant warping of the Blue Ridge thrust sheet to form major regional structures such as the Grandfather Mountain "dome", Spruce Pine synclinorium, and others. Retrogressive metamorphism—development of low-grade greenschist-facies minerals—appears to have been caused by this event of late Paleozoic age.

Mesozoic and Cenozoic History

The Alleghanian, last of the great orogenies to have affected this region, closed out the Paleozoic Era. The geologic story from then until the present—a 250-million-year time span—seems extremely mild by comparison. It is principally one of continued epeirogenic uplift and concomitant subaerial erosion. Since the beginning of the Mesozoic we estimate that perhaps some 9,000 feet of Blue Ridge rock have been eroded away. Some of the detritus from this lengthy and continuing period of denudation now make up part of the Atlantic and Gulf Coastal Plain sedimentary accumulations. The differentially sculptured terrain left behind in the Blue Ridge makes up our present-day mountain landscape. Its geomorphic history is exceedingly difficult to determine, in large part because it is the result of evidence-destroying erosional processes. The broad outline of the area's erosional history is presented in table 1; elaborating and adding detail to this spare frame is a difficult and challenging task.

SPRUCE PINE MINING DISTRICT

The Spruce Pine district, the principal feldspar producing area in North America, covers approximately 300 square miles in the mountains of western North Carolina. Feldspar, muscovite mica, kaolin, quartz, and olivine provide the bulk of the material extracted from the region. Other minerals have also been produced in much smaller amounts. These include anthophyllite asbestos, halloysite, chromite, vermiculite, kyanite, soapstone, columbite, and samarskite. The area is a favorite of many rockhounds; emerald and aquamarine are among the more unusual specimens found.

The earliest mining was by Indians who worked surface outcrops and made shallow tunnels and pits searching for sheet muscovite well before the arrival of the early European settlers. Feldspar mining also has a long history. Early production took place in the 18th century when, it has been said, the local Indians mined and sold partially kaolinized feldspar to make ceramics prior to 1744. The first recorded feldspar shipment from North Carolina was in 1911 when ore was sent to Ohio. All early production for both feldspar and sheet mica was from the very coarse-grained pegmatites which could readily be handcobbed and sorted. More than 700 pegmatite mines and prospects are known in the Spruce Pine district and probably as many more are unlisted.

Research on feldspar and mica separation by froth flotation, mainly by the U.S. Bureau of Mines, started in 1937 and culminated in construction of the world's first commercial feldspar and mica flotation plant in the Spruce Pine district in 1946. To supplement the Bureau's pioneering work, North Carolina's Minerals Research Laboratory at Asheville anwered many specific technical difficulties associated with treating ores of this district. By 1950 three companies were operating flotation plants and the mills were an economic success. This major development in beneficiation technology permitted a great increase in feldspar production. Miners' attention therefore turned away from the highly variable, labor-intensive pegmatite bodies as a source of ore to much larger and more uniform alaskite bodies also found in this district. Alaskite, as the term is used locally, is medium- to coarse-grained, leucocratic, feldspar-quartz-muscovite rock. Its composition averages about 40 percent oligoclase (soda-spar), 25 percent quartz, 20 percent microcline (potash-spar), and 15 percent muscovite. Biotite, garnet, and others are minor accessories.

The first commercial sheet mica production was in 1868 and 1869. As late as June 1962, it was still hand-worked from the pegmatites when a federal program of buying mica for the Nation's

Table 1. Summary of Erosional History of the Central Blue Ridge of North Carolina

Event	Evidence	Age
Development of recent alluvium and other young surficial deposits; dissection of older deposits and erosion of saprolite; important climatological variations.	Presence of multi-age alluvial and colluvial deposits; gullying action of streams and exposure of older deposits; remnant spruce-fir northern forest species.	Quaternary (present to 2 million years ago)
Tilting and regional uplift, likely episodic; rejuvenation and incising of west-flowing streams; dissection of earlier-formed saprolite.	Major streams, especially in their lower reaches, are incised through saprolite and are now flowing in bedrock gorges. Presence of rare high terrace deposits. Uplifts in mountains likely correlate with changes in Coastal Plain sedimentation and terrace development.	Pleistocene through Middle Miocene (2 million to 16 million years ago)
Main streams develop wide valleys and straths (the Asheville surface) on which they tend to meander. Within these valleys and other low-gradient areas saprolite develops extensively.	Presence of incised meanders. *In situ* kaolin deposits of the mountain region, developed by deep chemical weathering of bedrock, are associated with the major straths. A plot of the elevations of these deposits lies on a smooth curve which includes the elevations of known Late Cretaceous lignitic and bauxitic deposits in the Valley and Ridge.	Middle Miocene through Cretaceous (16 million to 100 million years ago)
Orogenic uplift and profound subaerial erosion; initiation of the region's landscape development.	Cessation of marine deposition in Appalachian basin; late Paleozoic tectonism. Local continental deposits are preserved in Late Triassic extensional basins. Oldest exposed Coastal Plain sediments in North Carolina are gravel and coarse sand of the Late Cretaceous Cape Fear Formation; Early Cretaceous and Late Jurassic (?) strata are recognized in the subsurface.	From Late Cretaceous well into Late Paleozoic (100 million to more than 250 million years ago)

strategic stockpile came to an end. Sheet mica is still split, trimmed, and fabricated at two plants in the district, but the raw material is now imported, principally from India. Cuttings and trimmings from the early sheet mica operations provided the original source of "scrap" mica. Later, simple washing and screening was used to recover mica flakes from deeply weathered alaskite bodies. Currently, almost all mica in the district is recovered by froth flotation, either as a principal product from weathered alaskite or as an important byproduct from feldspar mines in the hard-rock alaskite bodies.

In the past, quartz cores from some of the pegmatites were hand cobbed on a sporadic basis to provide small quantities of quartz. For example, the 200-inch mirror of the Mount Palomar, California telescope was made partly of quartz mined from the Chestnut Flats pegmatite mine in 1933. In recent years, the increased demand for high-quality quartz prompted the mining companies to add quartz recovery and purification circuits to their processing plants. Much of the Spruce Pine material is used to make crucibles in which electronic-grade quartz crystals are grown.

Today, three companies mine alaskite and have a combined capacity of about 100 to 125 tons of ore per hour, fairly evenly divided between the three. They all use froth flotation, generally following the flowsheet shown in figure 2.

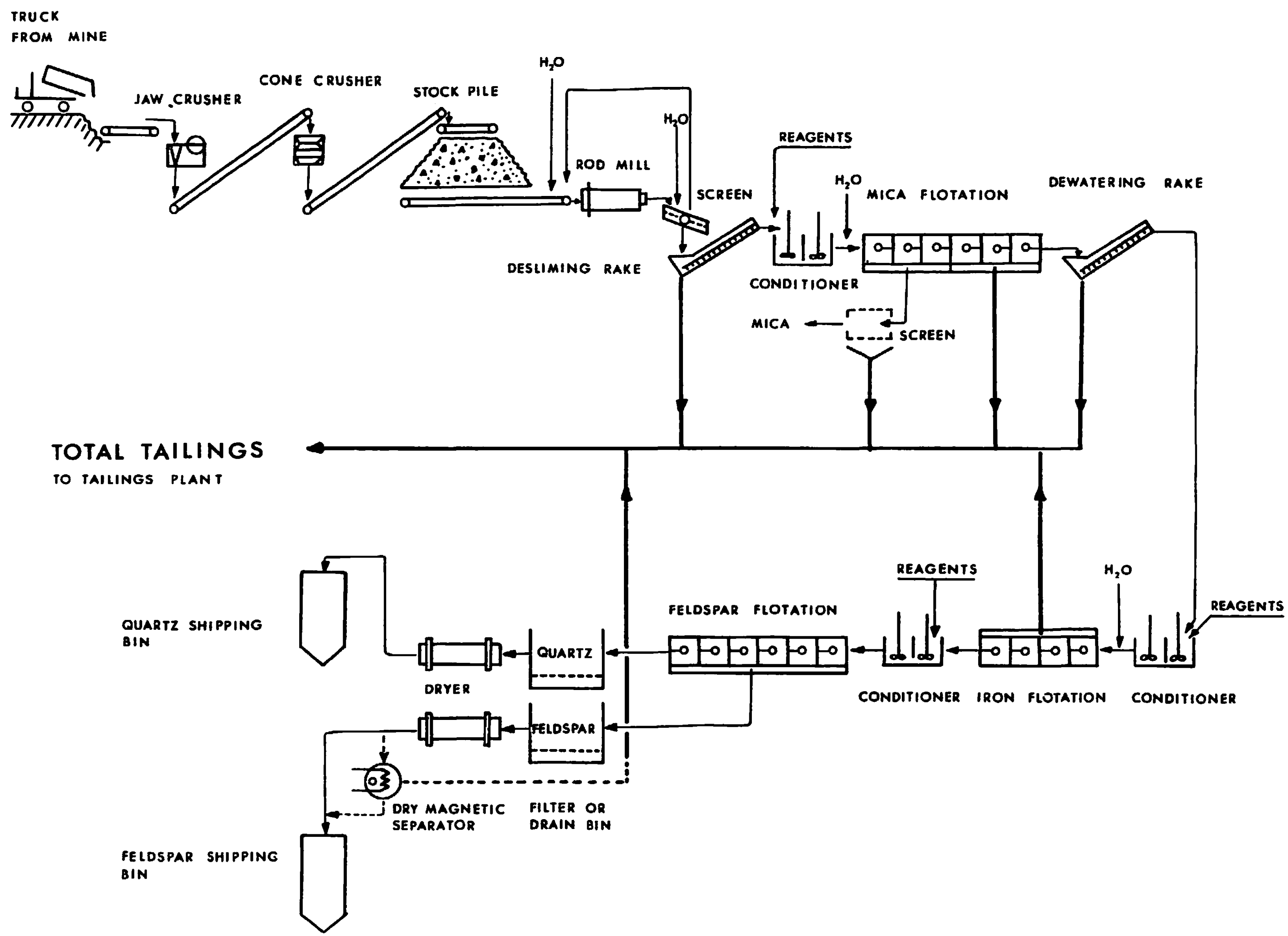


FIGURE 2 FLOWSHEET OF SPRUCE PINE FELDSPAR PLANTS

Figure 2. Flowsheet of Spruce Pine Feldspar Plants

Two companies mine alaskite saprolite to recover flake mica; one of these companies also recovers kaolinite and halloysite clay and quartz.

Forsterite olivine, an excellent refractory material, is the other commodity currently mined and processed in the district by one company. The olivine comes from ultramafic dunite bodies, hundreds of which are found throughout the Blue Ridge of North Carolina.

ACKNOWLEDGEMENTS

Several of our colleagues read a draft version of this report and passed along many pertinent and useful comments. We are pleased to acknowledge the helpfulness of Mike Linden, U.S. Forest Service, and Pat Gallagher and Jeffrey Reid of the North Carolina Geological Survey. Mr. Joe Turner and his staff at AIMCOR's Day Book operation kindly provided information about the company's olivine ore body and its mining and processing. The lengthy, painstaking task of converting our rough handwork into a polished document ready for the printer was taken care of by Sigrid Ballew. Her work, as usual, was done in a most competent and capable manner.

FIELDTRIP ROAD LOG

Cumulative Miles

0.0 Road log starts in West Asheville at the junction of Hilton Inn Drive and access loop road to Interstate-240 and U.S. 19-23. Proceed south on access road, following signs to I-240 West. Stay in left lane, underpass U.S. 19-23 and merge with I-240.

For the first 30 miles the trip will be through Middle Proterozoic metasedimentary and metavolcanic rocks of the Ashe Metamorphic Suite and Alligator Back Formation (figure 1). Between here and the vicinity of Swannanoa (mile 17.3) the rocks belong to the muscovite-biotite gneiss unit of the Ashe Metamorphic Suite. Beyond that point, the original sedimentary character of the strata is more obvious; these strata are assigned to the metagraywacke unit of the Ashe Metamorphic Suite.

The first part of the route lies in the French Broad and Swannanoa River valleys. Both rivers are variably entrenched into the Asheville erosion surface.

2.0 Exit from I-240 at Brevard Road (N.C. 191) following signs to Speedway.

2.2 At traffic light at end of the exit ramp turn left, cross the Interstate, and turn left again to enter I-240 East. Stay in right-hand lane.

2.6 Exit from I-240 onto Amboy Road and continue eastward on Amboy Road.

The route here is in the flood plain of the French Broad River. The flood plain in this area is the site of several small businesses, the Asheville Speedway (a half-mile oval race track), and two "sand-dipping" operations. One of the sand operations is at mile 2.6; the other is at mile 3.2. Mining and processing is very simple and direct. A single cable spanning the river is anchored on both sides and supports a drag-line bucket which is winched back and forth across the river. During each return trip, the bucket drags material from the river bottom and raises it to an elevated hopper where the bucket discharges. Processing is a matter of washing the sand down through screens beneath the hopper. The oversize includes rock fragments and abundant twigs, cans, and trash. It has little value except for use as low-quality fill. The sand product is used in local construction work, principally in jobs where specifications are not too exacting. At the scale of these operations, the river-bottom ore body is virtually an inexhaustible, constantly renewed resource! One of the operators, however, remarked that the reduction of farm activity over the years has noticeably reduced the amount of sand the river normally carries.

3.6 **STOP 1. Saprolite and recent fluvial deposits.** Turn into paved driveway at Biltmore Oil Company sign. Please park out of the way of company traffic.

The base of this excavation is slightly above flood plain level of the nearby French Broad River; here at an elevation of about 1,980 feet. Remnants of the floor of the Asheville basin are preserved by the low hilltops and interstream areas with their elevations between about 2,100 and 2,200 feet. The river and its tributaries are gradually incising themselves and dissecting the basin.

The great unconformity between Proterozoic metamorphic bedrock and unconsolidated Quaternary fluvial deposits is intermittently exposed for about a mile along the north side of Amboy Road. At this excavation, a subhorizontal, 1- to 2-foot-thick layer of quartz boulders and cobbles, set in a yellow-colored clayey matrix, overlies and truncates biotite gneiss of the Ashe Metamorphic Suite. Above the bouldery layer and below the present-day surface are twenty feet or more of nearly structureless, clayey, sandy material. Within this mass are several isolated, gently trough-shaped layers of angular quartz pebbles and cobbles. They are as much as 3 feet wide and are 6 to 12 inches thick. Exposed in cross section, they have the appearance of small channel deposits.

Most of the exposed bedrock is converted to saprolite. Saprolite, or "rotten rock", results from a long period of in-place chemical decay. Saprolitization reduces the original rock's bulk density by thirty to fifty percent and decreases its strength to the point where it may be dug with hand tools. However, the saprolite still retains nearly all structural features of the unweathered, original rock and one can easily see and measure layering, fold orientations, mineral lineations, and so forth. Determination of the parent rock type can usually be made at most saprolite exposures based on the nature of the weathered material (table 2). At this particular location one can confidently relate the saprolite to a medium-grained muscovite-biotite gneiss, with minor calc-silicate layers and some thin quartzo-feldspathic migmatitic to pegmatitic segregations. Washing and panning the material would also readily provide a sample of its resistate heavy mineral suite. Based on results from correlative rocks nearby, we expect to find at least epidote, ilmenite, monazite, rutile, sillimanite, sphene, and zircon.

Leave the pit area and resume driving east on Amboy Road.

4.1 Cross bridge over the French Broad River. At the stoplight and "T" junction of Amboy Road with Lyman Avenue, turn left and continue driving downstream along the river's right bank.

5.3 Turn left just past the cafe onto Riverside Drive and continue northward. (Don't cross the railroad tracks.)

6.0 Riverside Drive goes underneath the Railroad bridge. During the great flood of July 1916, this bridge was nearly inundated, with floodwaters reaching within eight feet of the rails. In an effort to save the bridge from being destroyed, loaded coal cars were parked on the bridge. The added mass was hoped to counteract buoyancy and toppling forces of the floodwaters.

6.3 Entrance to Expressway and Interstate routes. Turn right and follow signs to Expressway and I-240 East.

6.7 Merge with I-240, eastbound.

7.3 Beaucatcher Mountain is straight ahead.

Table 2. Relations Useful in Field Correlation Between Saprolite and Parent Rock

Unweathered Parent Bedrock		Resultant Saprolite	
Rock Type	Component Minerals	Preserved Weathering Products	Structure and Texture
Mica gneiss, mica schist, granitoid	Feldspar	White clay (kaolinite)	Layered; original gneissic or schistose structure is retained.
	Quartz	Quartz	
	Biotite	"Hydrobiotite", vermiculite, iron oxides.	Granitoid-derived saprolite is light-colored to tan, gritty or sandy, readily disaggregated.
	Muscovite	Muscovite, sericite, illite.	
Amphibolite, hornblende gneiss	Hornblende	Iron-rich clay (including allophane), iron oxides.	Generally massive to blocky, non-gritty, red to ocherous sticky clay.
	Feldspar	Clay (kaolinite).	
Dunite	Olivine	Iron oxides, iron-rich clay, precipitated silica.	Massive, structureless, deep red clay residiuum with chalcedony fragments and flakes or masses of talc.
	Talc	Talc	

8.4 to 8.7 **STOP 2. Road cut through Beaucatcher Mountain.** This major 10-million-dollar highway excavation completed in the late 1970's provides an excellent view of some rock types and structural features common in the central Blue Ridge. The cut itself is oriented approximately east-west and is thus transverse to the local northerly trend of the rocks. The excavation is about 1,400 feet long and the pavement is about 275 feet below the original ridge peak. Approximately 1 million cubic yards of overburden and 2 million cubic yards of rock were removed during construction.

The rocks are part of the Late Proterozoic Ashe Metamorphic Suite; a metasedimentary and metavolcanic sequence that overlies the billion-year-old basement complex.

The outcrop is dominated by biotite- and quartz-rich rocks which resulted from high-grade metamorphism of a poorly sorted, dominantly clastic sequence. Metagraywacke is interlayered with and locally gradational to garnet-sillimanite-biotite schist, calc-silicate granofels, garnet-rich layers and masses, possible metachert, and other types. Small pegmatite bodies and stringers are also present.

The most obvious feature is the rock's layering which reflects original sedimentary compositional differences. Foliation, presumably of Taconic age, is well developed, folds are common, and in some places refolding can be seen. Mylonitic textures are locally present and small offsets, or faults, occur throughout the exposure.

The presence of sillimanite here and in the surrounding area indicates that upper amphibolite facies metamorphism affected the rocks.

9.7 Extensive road cuts in the Ashe Metamorphic Suite.

10.5 Cross the Swannanoa River.

Continue on I-240 and follow signs to I-40 East (towards Statesville).

12.2 Merge with I-40 East (I-240 ends).

12.5 to 12.7 Large road cut in the Ashe Metamorphic Suite. In quadrangle mapping this outcrop was included in a local subunit of the Ashe and was informally termed "biotite-plagioclase-quartz gneiss." The dominant rock type at this exposure is light- to dark-gray, medium-grained, thinly layered to massive gneiss or metagraywacke. It is interlayered with minor muscovite-biotite schist, calc-silicate granofels and other rock types. Accessory minerals include garnet, sillimanite, chlorite, calcite, and pyrrhotite. Pegmatite and aplite are also present in the outcrop.

13.6 Panorama of the Great Craggy Mountains to the north and the Black Mountains to the northeast. Mount Mitchell, elevation 6,684 feet, is approximately 17 miles to the northeast at the crest of the Black Mountains.

14.0 Exit 55 provides access to the Folk Art Center on the Blue Ridge Parkway, located about 1.5 miles to the northwest.

17.3 Contact (not exposed along highway) marking a major subdivision of the Ashe Suite. To the west is the muscovite-biotite gneiss unit and to the east is the metagraywacke unit. Included in the metagraywacke unit are metaconglomerate, metasandstone, garnetiferous mica schist and gneiss, and graphitic schist.

19.3 to 20.0 To the north is the valley of the North Fork of the Swannanoa River. For many years, Grove Stone and Sand Branch of B. V. Hedrick Company mined alluvial and colluvial material in the valley. These surficial deposits have largely been depleted, and the company is now operating an open pit quarry in bedrock. This mine is the major supplier of aggregate in the market area from Asheville eastward.

Further up the valley, beyond the mine and reclaimed gravel pits, is the Burnett (Asheville) Reservoir and water purification plant. A watershed of about 20,000 acres on the heavily forested slopes of the Great Craggy and Black mountains supplies the reservoir.

The Black Mountain Range is about 10 miles north of the Interstate. The name comes from the dark, somber appearance of the spruce and fir dominated forest that covers the higher ground. The balsam firs are generally found above 5,000 feet. The transmitting tower is on Clingman's Peak, elevation about 6,540 feet, near the south end of the range.

24.1 to 24.4 Graphitic schist crops out in low exposures to the north. The principal rock type is graphite-muscovite-biotite schist. It is lustrous, medium dark gray to light gray, and fine grained with scattered porphyroblasts of garnet, biotite, and kyanite. Locally staurolite is present. These beds also contain abundant iron sulfide, in places more than 10 percent.

25.8 Cross contact (not exposed along the Interstate) between the Ashe Metamorphic Suite to the west and the succeeding Alligator Back Formation to the east.

26.4 Swannanoa Gap, elevation 2,786 feet. The crest of the Blue Ridge escarpment and the Eastern Continental Divide, coincident in this area, cross the route at this point. Exposed here is part of the Alligator Back metasedimentary sequence.

For the next 3.5 miles the Interstate winds down the Blue Ridge escarpment. A four-lane road was built along the present route in the 1950's, bypassing two older, narrow, twisty roads. However, along the new road, recurring slides of colluvium, saprolite, and rock, as well as deterioration of the original fills created significant and ongoing maintenance problems. Many of the failure surfaces coincided with foliation planes and the parallel compositional layering. In the late 1970's when the road was incorporated into the Interstate system, alignment and grade were locally adjusted and the roadway was widened. Reconstructed fills were economically retained using reinforced earth techniques. Much potential slide material was removed from cut slopes, and rock bolts and wire mesh were installed for safety and stabilization of rock faces.

The origin of the prominent Blue Ridge escarpment, an expanse of rough, rugged terrain between the crest of the Blue Ridge and the much lower Piedmont, is not at all well understood. Although several theories have been presented to explain just why there is so abrupt a change in both elevation and appearance between the two adjacent provinces, the paucity of data leaves our explanations in the category of speculation. The three principal ideas are: 1) a fault-controlled scarp; 2) a wave-cut scarp of marine origin; and 3) an erosional scarp created and maintained by the great difference in distance to base level of the streams on either side of the scarp. Tangible evidence for either of the first two ideas is not very convincing. The third concept may be presented in classic peneplain terms or in more modern slope retreat terms and is perhaps most widely accepted. Though intellectually attractive and most generally accepted, the concept is not supported in this area with much concrete evidence.

Whatever the origin of the escarpment, it is clear that the Blue Ridge front provides the setting for a zone of intense erosional activity. Headwaters of oceanbound streams, such as the Catawba and Linville Rivers, cascade down from the crest of the Blue Ridge creating and extending indentations and deep gorges into the front. As a result the Piedmont surface is expanding westward as the Blue Ridge becomes consumed by vigorous erosional processes.

26.7 Pisgah National Forest Boundary

27.3 Contact (not conveniently exposed along highway) between the Alligator Back metasedimentary sequence to the west and intensely mylonitized rocks to the east. It is commonly very difficult to confidently determine the protolith of highly mylonitized rocks such as these. The interpretation shown in figure 1 is that these mylonitized rocks are continuous with metasediments of the Alligator Back.

Headwaters of the Catawba River, a major stream of the Piedmont, have developed the valley beneath us forming a prominent indentation into the Blue Ridge front. The peaks of Hicks Mountain, a spur from the Blue Ridge front, lie in front of us across the valley.

30.2 Pisgah National Forest Boundary. Views of the Blue Ridge front and the Inner Piedmont.

30.5 Cross contact between mylonitic units to the west and rocks of the Brevard fault zone to the east. The Brevard fault zone marks the boundary between two structural provinces with the Inner Piedmont to the east and the Blue Ridge to the west of the Brevard fault zone. The nature of the zone has long been in question; to date at least seventeen different explanations have been offered. At a field conference in 1974, a list of properties of the Brevard zone was compiled by investigators with special experience along different segments of the structure. Its more significant attributes are: 1) it is a remarkably straight feature from Alabama to Virginia with only a few short, slightly curved segments; 2) the zone changes character at both its northeast and southwest ends by "splaying out"; 3) it appears likely that the same or quite similar stratigraphic units are either parallel to or are present in the zone from Alabama to Virginia, although no single unit can be traced from one end to the other; 4) the zone is characterized by mylonitic rocks throughout; 5) the zone now contains greenschist-facies mineral assemblages which have been derived by retrogression from earlier, higher-grade, Barrovian-type assemblages.

Results from subsequent work along the Brevard zone further south support a multiple displacement-deformation history. According to this interpretation the Brevard zone was initiated as an early Alleghanian low-angle, right-lateral, strike-slip shear zone. The orientation was partly controlled by original stratigraphic weaknesses and earlier, Taconic (or possibly Acadian) structures. Later there was thrust reactivation along the regional subhorizontal zone associated with emplacement of the Blue Ridge allochthon. Finally, during a late Alleghanian phase, a more steeply dipping thrust or family of thrusts developed as "splays" off the major Blue Ridge thrust. These late displacements are marked by fault breccias, indicative of brittle-style deformation, and are collectively called the Rosman fault. It is this structure, in fact, which commonly marks the sharp contact between the Inner Piedmont and the Blue Ridge structural provinces.

Locally, rock types such as the following are present in the Brevard zone: mylonitic schist (sometimes called "fish-scale schist" or "button schist" for distinctive curved mica flakes or masses), phyllonite, mylonite gneiss, porphyroclastic mylonite, amphibolite, graphitic schist, and occasionally marble.

30.6 Leave I-40 at Exit 72. Follow U.S. 70 towards Old Fort.

31.8 Center of Old Fort. The town is located on the site of one of the early, pre-revolutionary forts along the then western frontier of the colonies. This fort was built in 1756 to protect the European settlers from the Cherokee Nations who lived in the lands to the west.

32.7 The route is now in the Catawba River valley. The elevation here is about 1,400 feet. To the far southeast are low hills and in the distance are the Hickorynut Mountains, monadnocks on the Piedmont surface with peaks near 3,300 feet. To the northwest is the Blue Ridge front or escarpment with peaks along its crest approaching 5,000 feet. Quite a few manufacturing plants are in this valley. Two of North Carolina's traditional economic bases—textiles and furniture manufacturing—are represented here.

33.6 Bridge over Curtis Creek. The headwaters of Curtis Creek are within a National Forest Wildlife Management area. Through intensive management and control in recent years the wild turkey and white-tailed deer populations have been replenished in this area.

33.7 Junction of Curtis Creek Road to northwest, and Greenlee Road to southeast.

OPTIONAL STOP A. Exposure of mylonitic rocks. Turn left onto Curtis Creek Road (SR 1227) and travel 1.6 miles to a 700-foot-long road cut.

These outcrops display the effects of Brevard mylonitization. Locally, the zone is about 2 miles wide; we are near its northwest limit. Protomylonite dominates and locally grades to mylonite. A few scattered phyllonite layers are also present. The most abundant minerals are plagioclase, quartz, and biotite; potassic feldspar is present, but not common. Other minerals include sericite, epidote, and garnet. The protolith is thought to be metasediments of the Alligator Back Formation.

Folding of the mylonitic layering is apparent, with folds ranging from open to tight. Axial planes range in dip from about 50 to 80 degrees southeast and have gentle southwest plunges. Some of the mylonite's small folds and crinkles exhibit crenulation cleavage. In hand specimen, the oldest tectonic surface clearly observable is the mylonitic foliation. Several miles along strike to the southwest, microscopic studies reveal traces of an older surface preserved within some of the porphyroclasts. From one end to the other of this exposure there is a gradual change in strike from about N5W to N45E which perhaps indicates very late regional warping.

Detailed petrographic work has not been done at this outcrop; however, megascopic garnet and biotite indicate that the area is at least in upper greenschist metamorphic facies.

Retrace route back to junction of Curtis Creek Road and U.S. 70. Turn left and resume traveling northeast on U.S. 70. (A convenient turn-around for busses or large vehicles is 0.8 miles further north on Curtis Creek Road.)

40.3 Junction of N.C. 80 with U.S. 70. Continue traveling northeast on U.S. 70.

41.4 Bridge over the Catawba River. Much of this area has been worked for sand and gravel. Bouldery and cobbly sandy alluvium from the river flood plain provides raw material for the mining operations, typical of many in the Piedmont province.

42.1 Leave U.S. 70. Turn onto the U.S. 221 North, towards Spruce Pine and Linville.

42.4 Bridge over the Catawba River.

42.7 Northwest limit of the Brevard zone. Small, scattered exposures upstrike and downstrike from this location reveal brecciated and locally silicified mylonite. These are interpreted to indicate late-stage Alleghanian brittle deformation superposed on earlier mylonitic rocks resulting from ductile deformation.

42.8 to 43.2 Scattered saprolite exposures of a layered gneissic-appearing unit in between the Grandfather Mountain window and the Brevard zone. The gneiss is thought to be derived from argillaceous sandstone or graywacke of the Alligator Back Formation.

43.2 Cross into the Grandfather Mountain window. Rocks lying southeast of the Grandfather Mountain window are thrust onto the Wilson Creek Gneiss within the window. Wilson Creek is the name used for the biotite granitic gneiss unit that constitutes the major portion of the much deformed and metamorphosed billion-year-old basement within the window.

For the next 6.4 miles we will travel through the "tail" of the window. The rocks in this area make up a series of overlapping fault slices. Although the general structural arrangement is fairly well understood, details of the slices are subject to varying interpretations.

44.2 Approximately 60 feet of fault-bounded Chilhowee Group quartzite are exposed in weathered road cuts and a small quarry immediately east of the highway. Fossils have been found at the type area of the Chilhowee on the east side of the Valley and Ridge in Tennessee, and the Chilhowee is confidently assigned an Early Cambrian age. The quartzite preserved here is a thin remnant of the Table Rock thrust sheet, one of the larger slices within the window.

45.5 **STOP 3. Flagstone quarry.** This roadside quarry is typical of some dozen or more small pits found throughout this area.

The rock being mined at this pit is quartzite of the Chilhowee Group. The quartzite's original bedding fissility has been enhanced by recrystallization of the rock's clay component to sericite. Subsequent mylonitization also increased the rock's fissility.

Working these deposits is very labor-intensive. After overburden removal, low-fragmentation blasting is used to loosen the rock. Some slabs have to be pried out with bars. An effort is made to salvage the thicker pieces by splitting them with a chisel and hammer. The most desirable stones are as wide as possible and about one to two inches thick. The flat flagstones are collected and hand-piled in compact, cyclindrical stacks of about 1 to 1.5 tons. Wire mesh is commonly wrapped and stapled around each load to reduce spillage during shipping and handling.

46.3 Outcrop of light-colored, weathered Chilhowee along road banks and driveway to east. At this locality, medium-gray phyllonite to sericitic schist (exposed along Hicks Chapel Road, 0.1 miles south) overlies silty metasandstone of the lower portion of the Chilhowee. The phyllonite has been assigned to the Wilson Creek Gneiss and the contact between the two units is shown as a fault. This area has been mapped slightly differently by various workers; the interpretation followed on the 1985 State Geologic Map and used in figure 1 is that the Wilson Creek occupies a small window through one of the smaller thrust faults within the overall Grandfather Mountain structure.

46.9 Pisgah National Forest Woodlawn Work Center to the west.

47.4 To the east is an extensive area of well exposed Chilhowee quartzite. Chemical analysis of a composite, representative sample showed a silica content of more than 98 percent. The area is considered to have potential as a high-silica resource.

48.2 At the Woodlawn Community turn right (east) onto American Thread Road (SR 1556).

48.4 Entrance to Explosive Supply Company's crushed stone quarry. Turn right and check in at plant office.

STOP 4. Shady Dolomite. The Explosive Supply Company's Woodlawn quarry is developed in thickly bedded, light- to dark-gray dolomite with abundant white calcite veinlets. Thin phyllite layers and films are also present. These strata are correlated with the Early Cambrian Shady Dolomite, better known from outcrops in the Valley and Ridge province more than 30 miles to the northwest. The Shady is the first and oldest of the major carbonate units of the Appalachian basin and stratigraphically overlies the Chilhowee Group. At its type area the Shady Dolomite is about 1,000 feet thick; here at Woodlawn the upper part of the formation is absent because of faulting and the full stratigraphic sequence is not present. In the quarry the beds generally dip gently except where local folds or warps are present. Although primary facing features have not been discovered here, the Shady must be overturned at this location because it dips beneath the older Chilhowee units.

Regional studies show that this portion of the window is at greenschist-grade metamorphism with biotite being the highest-grade metamorphic indicator mineral. In the quarry, however, only the sericite sheen on foliation surfaces provides an indication that the rocks have been metamorphosed.

The exposure here of Early Cambrian strata is compelling evidence that the Blue Ridge is allochthonous and shows that at least 30 miles of horizontal displacement have occurred. Interpretation of seismic data further indicates that thrusting of the Blue Ridge allochthon may well exceed 125 miles.

Leave quarry and retrace route back to U.S. 221.

48.7 Turn right onto U.S. 221 and continue north.

49.4 Junction of U.S. 221 and N.C. 226. Continue north on U.S. 221.

49.7 to 50.8 Scattered outcrops of biotite granitic gneiss of Middle Proterozoic age. Between the last exposures of Shady Dolomite near the quarry and the first exposures of biotite granitic gneiss we have crossed out of the Grandfather Mountain window, over the bounding Linville Falls fault, and into the allochthonous Blue Ridge province.

51.0 View of Dobson Knob to the east. It is underlain by resistant, ridgemaking quartzites of the Chilhowee Group. Our route now closely follows the trace of the Linville Falls fault; outcrops to the west are of the biotite granitic gneiss basement, and those to the east are of the Chilhowee.

54.6 View of Hawksbill Mountain (elevation 4,020 feet) directly ahead (northeast). Hawksbill is underlain by strata of the Grandfather Mountain Formation, a later Proterozoic metasedimentary unit probably coeval with the Snowbird Group in the western part of the Blue Ridge. The Grandfather Mountain Formation is estimated to be between 10,000 and 30,000 feet thick. It is composed predominantly of metasiltstone, metasandstone, metagraywacke, meta-arkose, and minor intercalated metavolcanic rocks. The formation overlies, with great nonconformity, the billion-year-old basement complex within the window. The elevation in this valley is about 1,600 feet.

57.4 Linville Falls fault, not exposed. We are now crossing from the Blue Ridge back into the window.

59.7 Intermittent exposures of bouldery colluvium and bedrock outcrops of the Chilhowee quartzite.

60.6 Entrance to Linville Caverns. The cave network consists of connected solution cavities developed in the Shady Dolomite. Roadside exposures here are Chilhowee.

61.0 Outcrops of Shady Dolomite (not visible from road during summer) near the base and lower slopes of the prominent cliff to the west contain disseminated sphalerite associated with small amounts of cuprite, chalcopyrite, and pyrite. The area was prospected and drilled by at least two mining companies. Evidently, commercial mineralization was not discovered.

62.0 to 62.2 Shady Dolomite exposed in road cuts to the east.

62.3 The route now recrosses the Linville Falls fault from the window back into the Blue Ridge. Roadside exposures are biotite granitic gneiss of the allochthonous Blue Ridge. A mylonitic fabric is well developed here. The rocks dip gently, about 15 to 20 degrees to the west or northwest off the dome-like core of the window.

63.9 Linville Falls community (elevation 3,300 feet). Enter Avery County, "Shrubbery Capital of North Carolina".

64.5 Leave U. S. 221 and turn right onto the Blue Ridge Parkway. Follow Parkway northbound (to left).

65.2 Cross the Linville Falls fault (locally covered) and re-enter the Grandfather Mountain window.

65.4 Bridge over the Linville River.

65.6 Turn right towards Linville Falls parking area and campground and follow access road south to Linville Falls parking area. Excellent exposures along the access road are mostly quartzite and some slate or metashale of the upper part of the Chilhowee Group.

67.1 Parking area and visitor center. To reach Stop 5, walk to the upper falls, approximately one-half mile away. Please remember this is a National Park; collecting or otherwise disturbing the flora, fauna, or rocks is not permitted.

The trace of the Linville Falls fault parallels the south-flowing Linville River and crosses the parking area from end to end. Exposed in the river just upstream from the footbridge near the parking area is biotite granitic gneiss of the Blue Ridge. Thus, the fault may conveniently be mapped under the east pier of the bridge. We will be walking southward, generally parallel to the trace of the fault. All exposures between here and Stop 5 are biotite granitic gneiss in the window's overriding thrust plate.

STOP 5. Type area of the Linville Falls fault. Approximately 150 feet upstream from the overlook are excellent exposures of the Linville Falls fault. Crudely foliated Middle Proterozoic basement biotite granitic rock overlies feldspathic metasandstone and metasiltstone of the upper part of the Early Cambrian Chilhowee. About 18 inches of mylonite and blastomylonite are along the fault plane. The mylonitic rock has been differentially eroded to produce the overhang. The fault dips gently westward in this vicinity. The biotite granitic gneiss forms the upper falls with the fault at the base of the falls.

Wrinkled and folded Chilhowee makes the floor of the overlook. The fold axes strike about N 45 E, forming a b lineation (lineation in the plane of movement perpendicular to the direction of movement). Elongated clasts and streaks of mineral grains are aligned forming an a lineation (lineation parallel with the direction of tectonic transport) and strike northwest.

Walk back to the parking area. Drive back along the access road to its junction with the Blue Ridge Parkway.

68.6 Rejoin Blue Ridge Parkway. Turn left (southbound) to continue towards Spruce Pine area.

OPTIONAL STOP B. View of Grandfather Mountain, Linn Cove Viaduct, and outcrops of the Grandfather Mountain Formation. Turn right (northbound) onto the Blue Ridge Parkway. A scenic 12-mile drive reaches the Linn Cove parking area and visitor center located on the southeast flank of Grandfather Mountain (at Parkway mile point 304.4). From the parking area and visitor center one may walk along several trails that go under and around the unique Linn Cove Viaduct. The trail winds over and between huge colluvial boulders of meta-arkose and metaconglomerate of the Grandfather Mountain Formation.

Good places for viewing Grandfather Mountain are at the Parkway's Grandfather Mountain overlook (Parkway mile point 306.6) and the Beacon Heights parking area at Parkway mile point 305.3.

The metaconglomerate is well exposed in low road cuts along the access road between the Parkway and U.S. 221 (Parkway mile point 305.1).

69.0 Leave Grandfather Mountain window crossing the Linville Falls fault (locally covered) for the last time. We are now driving generally southwest away from the domal window structure and into the synclinal structure of the Spruce Pine area.

69.7 Interchange with U. S. 221. Continue driving west on the Parkway.

70.6 **STOP 6. North Toe River Valley overlook.** We are looking down the Brushy Creek Valley, a headwater tributary of the North Toe River which drains the Spruce Pine mining district. Visible in the foreground are pits and tailings of the Unimin Corporation. Mining here is principally for kaolin-group clay minerals (kaolinite and halloysite), flake mica, and quartz. Kaolin mining in this valley started in 1937. The ore is a thick saprolite formed by thorough *in situ* chemical weathering of feldspathic alaskite bodies in the Brushy Creek Valley. Large, commercially important deposits such as these are considered to have formed throughout the district on valley terraces or straths developed mainly during Late Cretaceous or early Tertiary time.

Chalk Mountain, in the middle background, is composed almost entirely of alaskite and is the principal ore body for the Feldspar Corporation.

In the far distance are peaks of the Black Mountains.

Outcrops across the Parkway from the overlook are slightly mylonitic Middle Proterozoic biotite granitic gneiss; note the dip is gently to the southwest, away from the Grandfather Mountain window.

72.0 Contact between Middle Proterozoic rocks of the basement complex and the much younger metasedimentary rocks of the Alligator Back Formation. At this exposure the basement is represented by layered biotite gneiss with a mylonitic overprint containing various amounts of feldspar along with minor layers of amphibolite and calc-silicate units. It is overlain by pyrrhotite-bearing biotite-muscovite gneiss or metagraywacke and schist containing small pegmatites. Metamorphism has blurred the original nature of the contact; however, in this area the contact is mapped as a northwesterly dipping fault.

73.0 ***OPTIONAL STOP C. Chestoa View overlook.*** Turn left onto access road to reach parking area. From the parking area walk a few hundred feet down the path and steps to the overlook. The view eastward across the North Fork of the Catawba River valley is into the Grandfather Mountain window. Across the valley is Linville Mountain with a local peak, Laurel Knob, in front of us. Resistant quartzite units of the Chilhowee underlie the mountain. Linville Caverns, developed in the Shady Dolomite, is approximately 1,500 feet vertically below us in the valley. Hawksbill Mountain, underlain by the Grandfather Mountain Formation, is in the far background.

74.4 View of Table Rock Mountain. Table Rock is a klippe of lower Chilhowee resting on top of allochthonous basement within the Grandfather Mountain window.

75.3 Bear Den overlook. The Black Mountains are the high peaks straight ahead (west) with Mount Mitchell towards the southern end of the range. To the southeast we can observe irregularities in the Blue Ridge front caused by uneven headward erosion of tributaries to the Catawba River.

In the road cuts opposite the overlook are exposures of biotite-muscovite gneiss of the Alligator Back Formation.

80.6 Apple orchard. Apples, one of the cash crops in the mountains, are commonly grown on the slopes between about 2,500 and 3,500 feet elevation.

83.1 Gillespie Gap. Leave the Parkway and turn right onto access road towards N.C. 226.

83.2 Junction with N.C. 226. Directly ahead is the Parkway's Museum of North Carolina Minerals. The displays feature rocks and minerals from Spruce Pine and other mining districts in the State.

87.3 View to the north of alaskite mines of Unimin, Indusmin, and Feldspar Corporation.

87.9 Junction with U.S. 19-E. Turn left (west) and follow U.S. 19-E southbound.

89.7 Entrance to Chalk Mountain mine. The gate to the mine is normally open until 3:30 p.m. on weekdays. Permission to enter the property must be obtained from the Feldspar Corporation. Please remember that this is an operating mine; <u>watch for loaded ore trucks!</u>

STOP 7. Chalk Mountain alaskite mine. This mine, located about 2 miles southwest of Spruce Pine, is operated by the Feldspar Corporation. Pegmatite workings for mica existed here in the early and middle 1900's. Currently alaskite is being mined on the southern and northern flanks of the hill.

The alaskite's crude foliation results from rough parallelism of muscovite flakes and some orientation of the quartz and feldspar. The most common accessory mineral is garnet. As can be seen, alaskite such as this is desirable flotation head feed material; there is great mineralogic uniformity throughout the ore body and liberation size is relatively coarse. Reserves are obviously immense; no shortage of feldspar resources is anticipated in this area. Noteworthy at these exposures are xenoliths of country rock. Most are coarse-grained biotite schist.

To the north are the other active alaskite pits in the district.

Leave the mine and return to U.S. 19-E. Resume trip going west (left).

91.4 Junction with Hoot Owl Road, SR 1157.

OPTIONAL STOP D. Hoot Owl pegmatite mine. Turn left onto Hoot Owl Road and drive 0.4 miles. The pavement continues left as SR 1156; turn right onto the gravel road which is still SR 1157. Continue 0.8 miles to its end. The private road leading to the mine continues straight ahead. Note it is surfaced with pegmatite gravel. A convenient parking place is 0.7 miles beyond the end of SR 1157. Walk along the trail a few hundred feet past the dumps to the mine.

The Hoot Owl mine, one of the larger pegmatite mines in the district, yielded feldspar and mica. It was worked chiefly from 1937 through World War II. Sheet mica is reported to have been mined intermittently to as late as 1962. The connected cut and stopes at this site are about 500 feet long and up to 250 feet wide; workings went as deep as 150 feet. The mine is now abandoned and partly flooded.

Foliation of the enclosing muscovite-biotite gneiss and schist and minor amphibolite is cross cut by the pegmatite. A few country-rock inclusions or xenoliths are visible in the pegmatite body.

Based on information averaged from pegmatite mines in this district, it is estimated that of the total rock mined about 1.6 percent was recovered as block mica. Sheet mica pieces larger than 1.5 by 2 inches probably made up only about 10 percent of this, or less than 0.2 percent of the rock mined. Feldspar recovery from the mined rock usually averaged from 20 to 30 percent. About 2 man-hours of labor were required to mine and handle each ton of pegmatite at the site.

Retrace route to U.S. 19-E. Turn left and continue driving west on U.S. 19-E.

94.9 Bridge over the South Toe River. Deneen Mica Company's plant is to the right. Deneen's saprolite ore body is across the road to the south. The tailings dam is prominently exposed alongside the South Toe River. This company extracts flake mica from alaskite saprolite by washing, classifying, and flotation.

95.1 Junction with N.C. 80.

OPTIONAL STOP E. Newdale dunite body. Four-tenths of a mile to the north along N.C. 80 is the inactive, flooded, Newdale olivine quarry. The Newdale deposit is one of many dunite masses found in the Blue Ridge. This one is about 1,800 feet long and 500 feet wide in outcrop and was estimated to contain approximately 7 million tons of altered and unaltered olivine above local stream level. The ore from this quarry was hauled 8.5 miles to the processing plant at Day Book.

Retrace route back on N.C. 80 to U.S. 19-E and resume driving west south towards Burnsville.

95.5 Approximate location of contact between Alligator Back Formation to the east, and the Ashe Metamorphic Suite to the west.

96.0 The abandoned scrap mica pit to the south is in the Micaville deposit. During its life this mine is reported to have produced more scrap mica than any other in this district. Part of the old workings are now being used as a stockyard for locally produced flagstone and fieldstone.

100.3 Intersection with N.C. 197. Turn right onto N.C. 197.

102.0 Mine Fork valley is ahead of us. In the far distance is the spruce and fir covered crest of Unaka Mountain (elevation 5,185 feet) on the North Carolina-Tennessee boundary.

103.6 Contact between the Ashe Metamorphic Suite to the southeast and the Middle Proterozoic migmatitic biotite-hornblende gneiss to the northwest. This contact is interpreted as a major pre- to synmetamorphic thrust fault.

104.0 to 104.2 Dunite exposed in low road cuts to west.

104.3 **STOP 8. Day Book dunite body**. Olivine mine and mill of Applied Industrial Minerals Corporation (AIMCOR). The plant office is at the junction of N.C. 197 and Clearmont School Road (SR 1416).

The ultramafic body cropping out in this area, named for the nearby Day Book community, is representative of scores of similar bodies found in western North Carolina. At the surface the body is about 1,300 feet long and about 700 feet wide; limited drill information suggests the body dips to the southeast (figure 3).

High-magnesian olivine (Fo_{92}) is by far the most abundant primary mineral. Chromite is present as disseminated octahedral grains, thin discontinuous veins, or rare masses up to several feet across, and makes up about 1 percent of the body. A minor amount of bronzite (Mg-rich orthopyroxene) has been reported also. Secondary, or alteration minerals include serpentine, magnetite, talc, anthophyllite, phlogopite, and vermiculite.

Taconic regional metamorphism is widely thought to have promoted alteration of the olivine to serpentine with minor exsolved magnetite. Subsequent hydrothermal activity, notably along margins of the body and interior channel ways, but especially adjacent to several pegmatite intrusions, caused the development of anthophyllite, talc, and phlogopite. Chemical weathering in the near-surface environment results in the formation of an iron-rich clayey residuum containing diagnostic fragments or masses of chemically stable talc, chalcedony, and vermiculite. The chalcedony results from atmospheric dehydration of silica leached from the body and precipitated as opal; the vermiculite comes from weathering of the phlogopite in a Mg-rich environment.

This ultramafic body was prospected for chromite about 1901 and later, in 1917 and 1918, about 25 tons were shipped. Vermiculite was prospected in a sporadic manner, probably most intensively about 1950. However, no production is recorded from this deposit. The first workings for olivine were begun in the mid-1930's. Some twenty to thirty years later the olivine operations were rejuvenated and thereafter production followed an irregular, but mostly increasing curve. In 1941 it was calculated that the deposit contained approximately 10 million tons above local stream level. Two-thirds were estimated to be serpentinized dunite with the remainder being relatively unaltered, granular olivine.

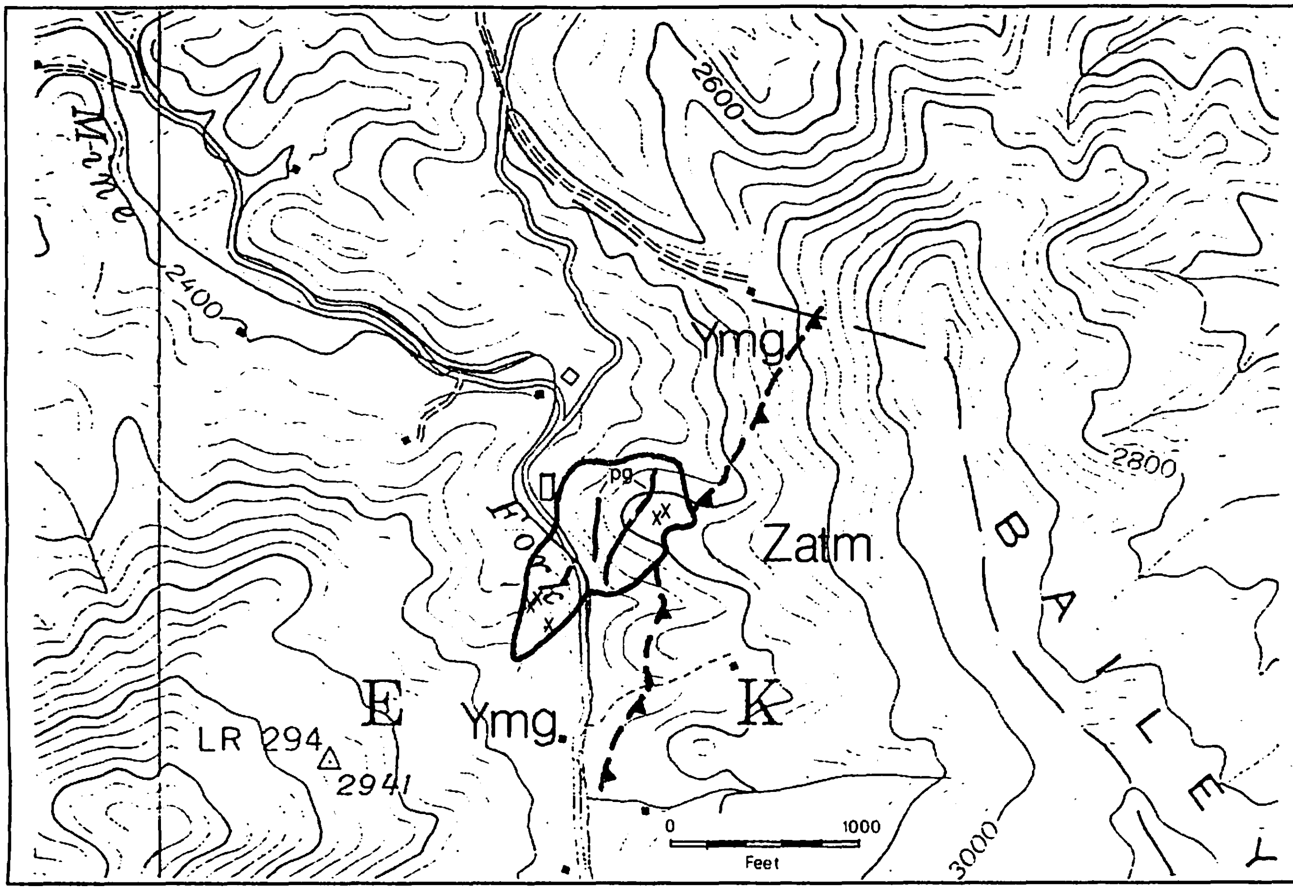


Figure 3. Geologic sketch map of Day Book dunite body and vicinity. Within the dunite body prospect symbols show location of abandoned chromite pits and heavy lines labeled "pg" are intrusive pegmatites. Outside the dunite heavy dashed line is a pre- to synmetamorphic thrust fault (sawteeth on upper plate); Zatm = Ashe Metamorphic Suite; Ymg = Migmatitic biotite-hornblende gneisses. Geology modified from Kulp and Brobst (1954) and North Carolina Geological Survey (1985). Base map enlarged from Burnsville 7.5-Minute Quadrangle (1939), contour interval = 40 feet.

Olivine is used principally as a refractory material. The hydrous alteration minerals are separated and discarded during processing. Several beneficiation techniques and different types of equipment were used as the milling process evolved. Considerable success is now achieved by using screens, several washing steps, classification, and specific gravity-based separators. The olivine product is dried and sized to meet consumer requirements with the finished product packed in bags for shipment. It is trucked about 5 miles to the nearest railroad for shipping.

Retrace route south on N.C. 197 back to U.S. 19-E.

108.3 Junction of N.C. 197 and U.S. 19-E. Turn right onto U.S. 19-E and continue westward.

109.5 U.S. Forest Service Toecane Ranger Station on south side of road.

112.1 Contact between the Ashe Metamorphic Suite to the east, and the migmatitic biotite-hornblende gneiss to the west. Occasional roadside exposures for about the next 27 miles are in the Middle Proterozoic migmatitic biotite-hornblende gneiss map unit. This very heterogeneous unit is characterized by layered mafic and felsic rocks which are interlayered with each other at all scales. Many different rock types are present including biotite granitic gneiss, amphibolite, biotite-hornblende gneiss, biotite gneiss, pyroxene granulite, hypersthene-plagioclase rock, hypersthene granitic gneiss, calc-silicate granofels, and others including rare marble. These rocks are intruded by thin dikes of the Bakersville Metagabbro, dated at 734 million years old. The more mafic units, as well as the Bakersville, commonly exhibit retrogressive effects resulting from Taconic metamorphism in the Paleozoic.

115.2 Junction with U.S. 19, U.S. 19-W, and Possum Trot Road. Continue driving west on U.S. 19.

119.8 Madison County-Yancey County line at Ivy Gap. Route re-enters the French Broad drainage basin.

126.1 Junction with U.S. 23. Turn south (left) onto U.S. 19-23 towards Asheville.

130.3 At the intersection, carefully turn left to cross the highway. Turn left again onto SR 2207 towards Forks of Ivy and park opposite the prominent road cut located 0.1 miles north of the intersection.

STOP 9. Mafic granulite. This road cut was made during expansion of U.S. 19-23 in the 1970's. Although now partly obscured by lespedeza and paint, these are some of the best and freshest exposures in the area of archaic gabbro metamorphosed to pyroxene granulite during Proterozoic Grenville events.

Pyroxene granulite makes up most of the exposure. It is a greenish-brown to dark brown, massive to poorly layered, fine- to coarse-grained, granoblastic rock. It is composed of plagioclase feldspar, hypersthene, monoclinic pyroxene, biotite, hornblende, garnet, and magnetite and ilmenite. Thin section examination reveals that the hypersthene is rimmed to completely replaced by hornblende—good evidence for post-Grenville retrogressive metamorphism. At outcrops elsewhere the retrogressive alteration is so complete that the entire rock has been converted to amphibolite. Where continuous outcrops exist one may observe a progression from only slight retrogression in the granulite body's central area to completely amphibolitized rock at the edges of the body.

Intrusive into the rocks here are a few thin dikes of Bakersville Metagabbro. The dikes are mostly in the south half of the exposure.. The Bakersville is usually darker and finer grained than the pyroxene granulite and normally exhibits an ophitic to subophitic texture.

Return to U.S. 19-23. (A safe turn-around is at the Forks of Ivy Plaza just beyond the north end of the exposure.) Continue south on U.S. 19-23.

132.2 Interchange with N.C. 197.

OPTIONAL STOP F. Lateritic nickel deposit and Arrowoood halloysite mine. Exit to N.C. 197; turn east towards Barnardsville and drive 3.0 miles. Stop at Arrowood Road, SR 2155.

This locality is within the Democrat-Morgan Hill dunite body. The rock, however, is not suited for olivine production because it has been thoroughly serpentinized and thus does not yield good refractory material.

Intruding the dunite is a pegmatite, now highly weathered, that was mined in the past chiefly for halloysite. The overgrown pit across the road to our east is the inactive Arrowood halloysite mine.

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

Return on N.C. 197 westward to the interchange with U.S. 19 and 23. Rejoin U.S. 19 and 23 southbound towards Asheville.

136.2 View of the Pisgah Mountains. These mountains are approximately 20 miles away. The pyramidal-shaped peak with the television transmitting station is Mt. Pisgah (elevation 4,758 feet).

139.2 Contact (locally covered) between the Middle Proterozoic migmatitic biotite-hornblende gneiss of the basement and the younger Ashe Metamorphic Suite. In this region the boundary between the two units is interpreted as a folded pre- to synmetamorphic thrust fault.

140.2 Exposures of metasedimentary rocks of the Ashe Suite.

142.1 View of the Asheville skyline. The French Broad River lies to the west (right).

142.8 Exit ramp to N.C. 251 and University of North Carolina-Asheville.

OPTIONAL STOP G. Crosscutting trondhjemite dikes. Leave the Expressway *via* the N.C. 251 exit ramp. At the stop light at the end of the ramp, continue straight ahead (south) for 0.5 miles to Pearson Bridge Road. Turn right onto Pearson Bridge Road and cross the French Broad River. Park well off the road and be especially careful of traffic coming around the sharp curve. In road cuts along the curve at the west approach to the bridge you can see well exposed crosscutting dikes up to a few feet thick of trondhjemite. Trondhjemite is characterized by the virtual absence of potassic feldspar. It is light colored and composed mostly of quartz, plagioclase, and minor biotite. These bodies are relatively young Paleozoic rocks as they are not metamorphosed and cross cut rock units and structures in the Blue Ridge . The country rock at this locality belongs to the Ashe Metamorphic Suite and is mostly garnetiferous muscovite-biotite gneiss and schist.

To rejoin the trip route cross back over Pearson Bridge. Turn right (to south) onto Riverside Drive and continue 1.0 miles to the next entrance to the Expressway. Turn left following signs to I-26 and West Asheville. Stay in right-hand lane and join trip route at mile 144.8.

144.8 Complex road junction; I-240, U.S. 19, 23, 70, and 74. Westbound and southbound to Hilton Inn Drive — keep right, cross the bridge over the French Broad River and stay in the right-hand lane.

145.6 Hilton Inn Drive; end of trip.

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GEOLOGIC TIME CHART

Terms and boundary ages used in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~ 240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~ 330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~ 570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				
		3800?			
pre-Archean[2]					4550

[1] Rocks older than 570 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.