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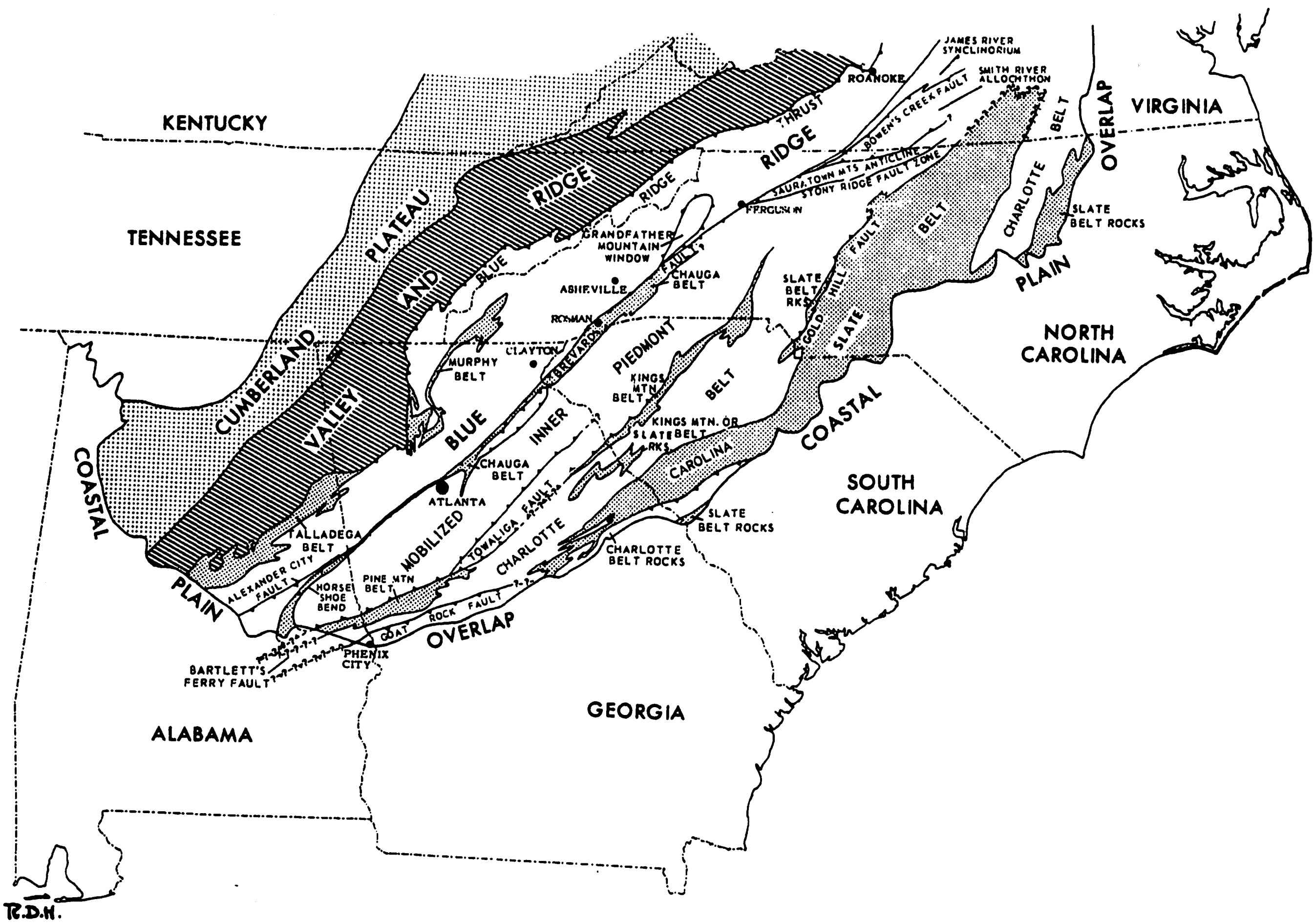
Asheville, North Carolina

Host: Stephen G. Conrad, State Geologist
North Carolina Department of Natural
and Economic Resources



Field Guidebook to the Geology of the Central Blue Ridge of North Carolina and the Spruce Pine Mining District

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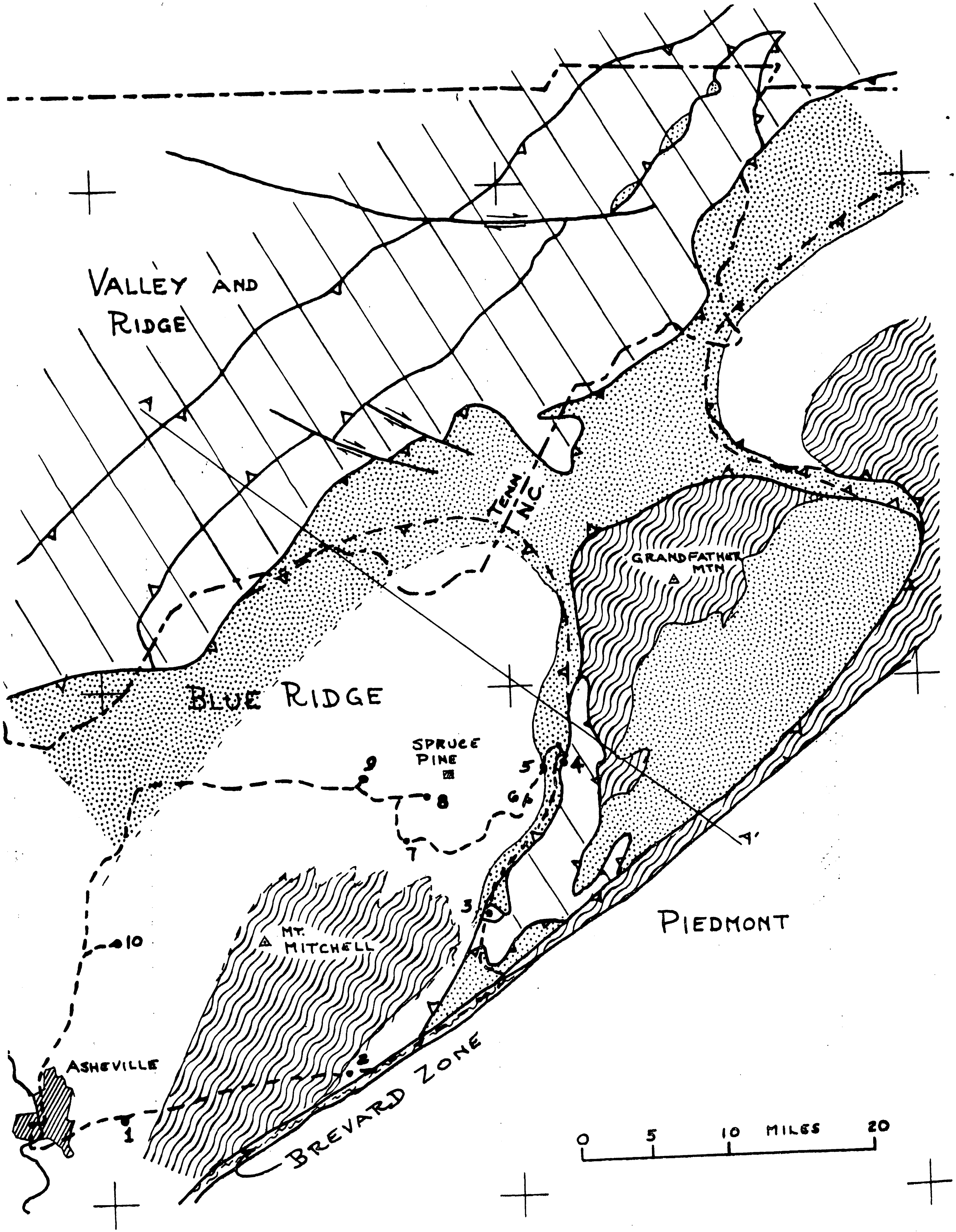
GEOLOGIC HISTORY OF THE BLUE RIDGE OF NORTH CAROLINA

Pre-Mesozoic History

The Blue Ridge structural province of North Carolina is limited on the west by the Great Smoky and associated thrust faults and on the east by the Brevard zone (see Figure 1). In addition, the rocks of the province are undoubtedly allochthonous, being underlain by the Great Smoky, Linville Falls, or other similar thrust fault system of Late Paleozoic age. All the rocks have been carried northwestward, at least 30 and possibly as much as 70 miles. Major elements of the Blue Ridge thrust sheet are the Spruce Pine and Ararat synclinoria which are separated by the crudely domal Grandfather Mountain structure. To the west, and also beneath the thrust sheet, is the Valley and Ridge province; to the east is the enigmatic Brevard zone, a long narrow belt characterized by intense cataclasis. It has variously been called a "fossil" subduction zone, a major strike slip fault (both right lateral and left lateral), a major thrust fault, a dejective zone, and many other terms.

Our concepts of the geologic history of this area are continually being refined, modified and even radically changed as field mapping and radiometric studies progress. However, in broad outline many workers generally agree that a complex of rocks, largely plutonic in nature but also perhaps containing a sedimentary component, formed the old "basement" for subsequent events in the Blue Ridge. The term "Cranberry Granitic Gneiss" has long been applied to this complex which is largely, but by no means entirely quartz monzonitic in composition. Radiometric determinations, especially those of zircon and whole-rock samples from the Cranberry and its associates yield ages near or exceeding 1 billion years. Deposited over the basement complex on a major nonconformity


VALLEY AND RIDGE
BLUE RIDGE
TENN
NC
GRANDFATHER MTN
SPRUCE PINE
MT. MITCHELL
PIEDMONT
BREVARD ZONE
ASHEVILLE
A
A'
1
2
3
4
5
6
7
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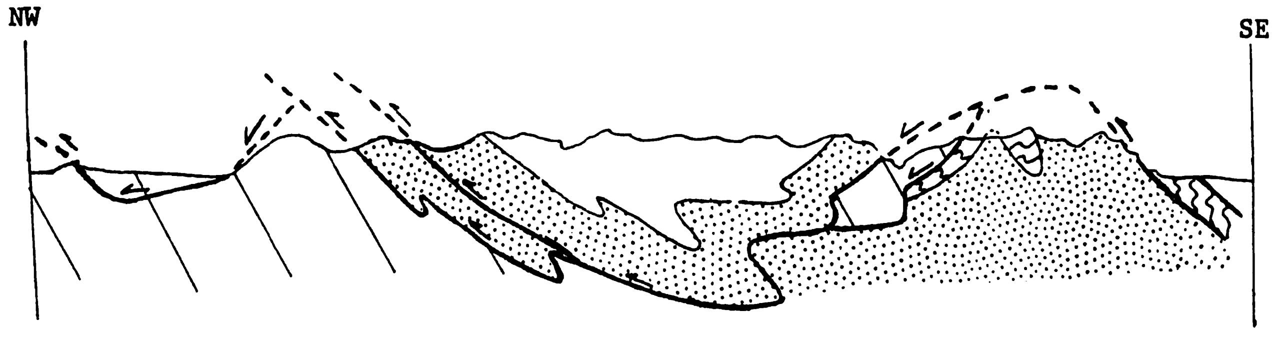
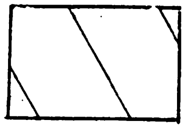
10
0 5 10 MILES 20

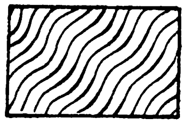


Schematic cross section along line A - A'.
(Vertical scale exaggerated for clarity)

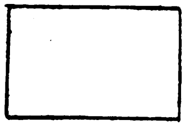
LEGEND



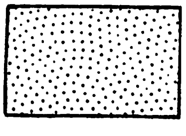
Paleozoic strata with Early Cambrian Shady Dolomite and Chilhowee Group at base



Later Precambrian, mostly metasedimentary including Ocoee Supergroup, Grandfather Mountain Formation, and possible correlatives



Earlier Precambrian metasedimentary and metaigneous rocks



Basement complex including the Cranberry Granitic Gneiss, Wilson Creek Gneiss, and other units

Figure 1. Schematic geologic map and cross section

is a sequence of great, but undeterminable, thickness of varied sediments interspersed with volcanic and plutonic material erupted or intruded intermittently during sedimentation. The sediments have subsequently been metamorphosed, mainly into a variety of biotite gneisses, and the igneous rocks, largely of mafic composition, have been metamorphosed, principally to metagabbro and amphibolite. These rocks are all considered to be Precambrian in age. About 20 miles west of Asheville near the Great Smoky Mountains National Park both these basement granitic gneisses and the overlying metasedimentary and metaigneous rocks are unconformably overlain by another sequence of now metamorphosed sediments called the Ocoee Supergroup. The Ocoee is usually thought of as being latest Precambrian in age. Whether or not units correlative with the Ocoee are also present in the cores of the Spruce Pine and Ararat synclinoria is not established, although many writers now accept this notion. Other rocks making up the terrane in the central part of the Blue Ridge are mostly intrusive, ranging from ultramafic dunite through felsic granitic and pegmatitic bodies. Although not a major component of the Blue Ridge, these bodies are of considerable economic importance, presently yielding forsterite olivine, dimension stone, feldspar, flake mica, kaolinite and halloysite clay, and quartz, in addition to being the source of many prize mineral specimens.

Regional metamorphism has obviously affected many 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 scenario:

1. Plutonism, possibly with associated metamorphism, a billion years ago.
2. Regional metamorphism in the Late Precambrian.

(Evidence for Precambrian metamorphic events is weak as subsequent Paleozoic metamorphism has largely obscured the early record.)

3. Folding and thrust faulting in Early Paleozoic time, likely coeval with regional metamorphism during the Middle to Late Ordovician. Presumably the folds produced at this time were isoclinal with well developed axial plane schistosity. The most obvious feature in most of the rocks, aside from differing compositional layers, is a pervasive foliation, developed primarily at this time. Folds of this foliation are common, having been produced during subsequent deformations.

4. Renewed deformation and metamorphism during the mid-Paleozoic. This event caused folding of all earlier structures and is associated with widespread pegmatite development.

Paleozoic metamorphism is a regional, Barrovian type with kyanite and sillimanite-bearing rocks of the upper amphibolite facies being common in the core of the Blue Ridge from about Spruce Pine southwestward. If two distinct Paleozoic events occurred, both must have been nearly coincident in space, with the later, mid-Paleozoic metamorphism having been more intense. Another interpretation is that metamorphism and deformation were not so episodic. Rather, what we see today has been 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 metamorphic foliation along with rheological homogenization or a general "plasticizing" of the entire rock sequence. As a result, the initial planes of weakness, incompetent stratigraphic units or bedding itself, which had controlled the formation of the earlier structures were gradually reduced in importance as foliation developed throughout the mass. Deformation under these conditions was dominated by shear folds and faults, including tectonic slides, as interfolia displacements prevailed. More or less synchronously with the thermal peak, metamorphism caused local melting, especially of the originally "wet" quartz-feldspar-clay sediments whose composition was near that of a granitic eutectic. These melts thereupon behaved magmatically, ultimately to intrude the country rock and crystallize as pegmatite and alaskite bodies. According to this alternate explanation, general uplift, cooling, and retrogression is related to the wane of thermal activity in the latter part of the Paleozoic.

5. Emplacement and warping of the Blue Ridge thrust sheet to form major regional structures such as the Grandfather Mountain "dome", Spruce Pine syncline, and others. Retrogressive metamorphic effects appear to date from this event of Late Paleozoic age.

Mesozoic to Recent History

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 occurs along the line of high ridges underlain by resistant quartzite of the Early Cambrian Chilhowee Group 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 monadnocks, including the Hickorynut and South Mountains, are present in the Piedmont, the broad, rolling interfluve areas define a surface that is generally between 1200 and 1500 feet elevation along the base of the Blue Ridge escarpment throughout North Carolina. Relief along the scarp exceeds 2000 feet at many places, and many peaks are more than a half a mile above the Piedmont surface. The crest of the scarp is generally coincident with the eastern continental divide; streams flowing eastward drain directly into the Atlantic, whereas the west flowing streams follow a much longer course, ultimately draining into the Gulf of Mexico.

In addition to the peaks and ridges of the escarpment the rest of the province is made up of a dozen or more longitudinal and transverse ranges. Mt. Mitchell, the highest peak in eastern North America (elevation 6684 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 mostly from 2000 to 2200 feet 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.

Although hard, coherent bedrock rarely crops out away from the entrenched streams, the presence of a thick, ubiquitous saprolite demonstrates that the basin is not a depositional feature, but rather is the result of a long period of erosion and chemical decay of the rocks. This conclusion, reached many years ago, provided the basis for naming the surface landform the "Asheville peneplain." Similar, though not as extensive erosional surfaces are present along the other major drainages in the mountains; these surfaces are often correlated with the Harrisburg, or Valley Floor, surface of the Valley and Ridge province.

The erosional history of this central portion of the Blue Ridge province is briefly summarized in Table I.

TABLE I. Summary of Erosional History of the Blue Ridge of Central 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.	Late Cenozoic (present to 10 million years ago)
Tilting and regional uplift, likely episodic; rejuvenation and incising of west-flowing streams with accompanying 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 correlates with changes in Coastal Plain sediments and terrace development.	Tertiary (10 million to 70 million years ago)
Main streams by now have developed wide valleys and straths (the Asheville surface) on which they tend to meander. Within these valleys and other low-gradient areas saprolite developed extensively.	Presence of incised meanders. *In situ* kaolin deposits of the mountain region developed by deep chemical weathering of highly feldspathic bedrock are associated with the major straths. A plot of the elevations of these deposits lie on a smooth curve which also includes the elevations of known Late Cretaceous lignitic and bauxitic deposits in the Valley and Ridge.	Late and Middle Cretaceous (70 million to 100 million years ago)
Uplift and profound subaerial erosion with development of the main elements of the mountain landscape.	Cessation of marine deposition in Appalachian basin; local continental deposits in Late Triassic tensional basins. Oldest exposed coastal plain sediments are gravel and coarse clastics of the Cretaceous Tuscaloosa Formation.	Possibly as old as Late Paleozoic and lasting until Middle Cretaceous (70 million to more than 200 million years ago)

SPRUCE PINE MINING DISTRICT

The Spruce Pine district, the principal feldspar producing area in North America, covers approximately 300 square miles in the northwestern mountains of North Carolina. Muscovite mica, feldspar, and kaolin provide the bulk of the material extracted from the region. In addition, there is current production of olivine; anthophyllite, asbestos, chromite, vermiculite, kyanite, quartz, soapstone, samarskite, and other minerals have also been produced in varying amounts. The area is a favorite of many rockhounds; emerald and aquamarine are among the more unusual specimens found.

The first mining was evidently by the native Indians who worked surface outcrops and made shallow tunnels and pits searching for sheet muscovite well before the arrival of the early white settlers. The first commercial mica production was in 1868 and 1869. Feldspar mining has a similar history, early production extends back into the early 18th century, when, it has been said, the Indians mined and sold partially kaolinized feldspar prior to 1744. The first recorded feldspar shipment from the State was in 1911 when ore was mined and sent to Ohio. More than 700 mines and prospects are known in the district and probably as many more are unlisted. All the early production for sheet mica and feldspar was from the coarse-grained pegmatites where material could readily be hand-cobbed and sorted. Research by the U. S. Bureau of Mines culminated in the building of the world's first commercial feldspar and mica froth flotation plant in the Spruce Pine district in 1946. In addition to the Bureau's work, North Carolina's Minerals Research Laboratory at Asheville found answers to many of the specific technical difficulties associated with treating ores of this district and the mills have become an economic success. This major development permitted a great increase in feldspar production, and as a result, attention turned away from the highly variable pegmatite bodies as a source of ore in favor of the much larger and more uniform alaskite bodies. Alaskite, as the term is used locally, is a medium- to coarse-grained, leucocratic, feldspar-quartz-muscovite rock. The average composition is about 40 percent oligoclase, 25 percent quartz, 20 percent microcline, and 15 percent muscovite. Biotite, garnet, epidote, apatite, pyrite, and others are minor accessory minerals.

Sheet mica, however, was still hand-worked from the pegmatites until as late as 1962 when the federally supported mica buying program came to an end. Sheet mica is still processed in the district, but the raw material is now imported from India and Brazil. Cuttings and trimmings from sheet mica operations, as well as mica recovered from the chemically weathered alaskite bodies provided the original source of "scrap" or "flake" mica; presently, by-product mica from the feldspar plants constitutes an important additional source.

Today, there are three companies mining alaskite in the district; their combined capacity is in the order of 100 tons of ore per hour, fairly evenly divided between the three. They all use froth flotation, generally following the flowsheet shown in Figure 2.

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

Forsterite olivine, an excellent refractory material, is the other commodity presently being quarried in the district. It comes from almost monomineralic dunite bodies, hundreds of which are found throughout the Blue Ridge of North Carolina.

The last four stops of the field trip will provide an opportunity to examine the geology at some of these different types of deposits.

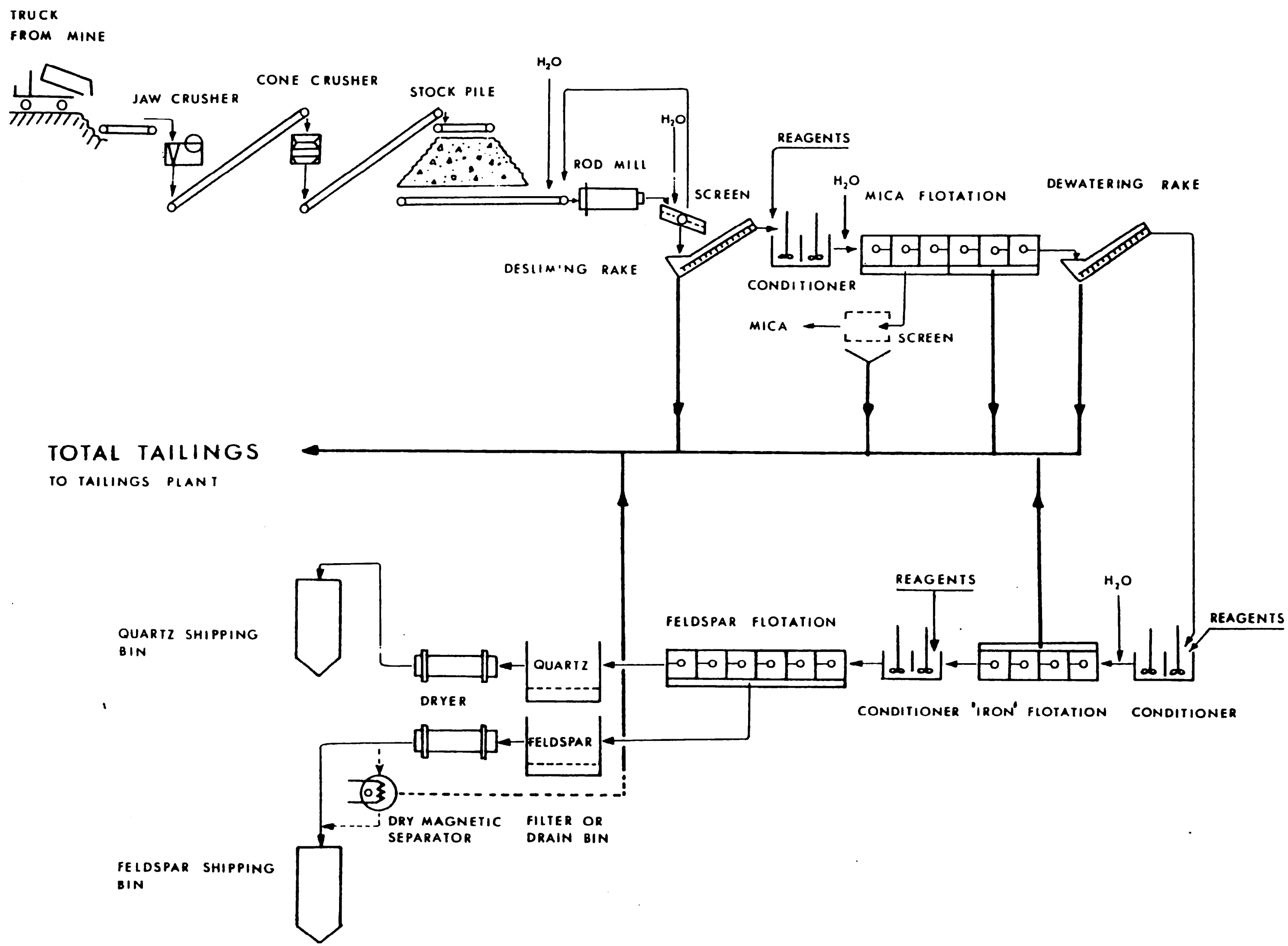


FIGURE 2. FLOWSHEET OF SPRUCE PINE FELDSPAR PLANTS

ROAD LOG

Cumulative Miles

00.0 Road log starts in West Asheville at the junction of Hilton Inn Drive and N. C. 191, 0.3 mile south of the Great Smokies Hilton. Proceed south on N. C. 191, underpassing U. S. 19-23.

For the first 25.4 miles, as indicated on figure 1, the trip will be through Precambrian metasedimentary and metaigneous rocks. Between here and the vicinity of Swannanoa (mile 14.7) the rocks belong to the earlier Precambrian sequence. Beyond that point, the original sedimentary character of the strata is much more obvious; these strata are frequently assigned to the later Precambrian and are tentatively correlated with part of the Ocoee Supergroup. Recently, however, it has been proposed that all the metasedimentary rocks east of Asheville should be assigned to the Late Precambrian Ocoee. This idea has considerable merit, but critical data are not yet available to either prove or disprove the concept.

This part of the route lies in the French Broad and Swannanoa River valleys which are variably entrenched into the Asheville erosion surface.

3.2 Bridge over French Broad River. Biltmore Estate to the south (right).

6.8 Cross U. S. 25 at Biltmore exit. The Swannanoa Mountains lie before us. The high point of this range, Flattop Mountain, is at 4,360 feet elevation, more than 2,000 feet higher than the adjacent Swannanoa River valley.

9.9 Stop 1 Extensive roadcut exposing one of the many varieties of biotite gneiss found in the Precambrian metasedimentary sequence. In quadrangle mapping this local unit has simply been given a lithologic name; biotite-plagioclase-quartz gneiss. It is a light- to dark-gray, medium-grained, thin-layered to massive gneiss interlayered with minor muscovite-biotite schist. Accessory minerals include garnet, sillimanite, chlorite, and calcite. Pegmatite and aplite are also found in the unit.

14.0 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.

14.7 Contact (not exposed along highway) between earlier Precambrian to the west, and later Precambrian metasedimentary rocks to the east. These later Precambrian rock types include metaconglomerate, metasandstone, garnetiferous mica schist and gneiss, and graphitic schist.

18.3 To left is State Road 2472 which leads to Grove Stone and Sand Branch of B. V. Hedrick Company. Alluvial and colluvial material is excavated from the valley of the North Fork of the Swannanoa River, trucked to the plant where it is crushed, washed, sorted and stockpiled. This is the major supplier of aggregate from Asheville eastward.

Further up the valley, beyond the 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.

24.5 Swannanoa Gap, elevation 2,786 feet. The crest of the Blue Ridge escarpment and the eastern continental divide, coincident in this area, cross our route at this point.

25.4 Contact (not conveniently exposed along highway) between the Precambrian metasedimentary sequence to the west and a mappable unit characterized by numerous zones of intense cataclasis to the east.

25.6 Stop 2 Exposed at the west end of the overlook is a unit mapped locally as cataclastic gneiss. The interpretation shown on figure 1 is that this unit is continuous into the main body of billion-year old basement granitic gneiss; however, detailed mapping and radiometric studies in the critical, intervening areas are only now being done. This interpretation demands that the contact crossed at mile 25.4 is a major nonconformity or perhaps a major fault. The rock itself resembles coarse, feldspathic metasandstone to metaconglomerate. If this is the case, then the unit best fits as part of the later Precambrian metasedimentary sequence, and the controversal contact at mile 25.4 would best be considered a stratigraphic contact between succeeding depositional units.

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.

The origin of the prominent Blue Ridge front, in this area an expanse of rough, rugged terrain between the crest of the Blue Ridge and the much lower levels of the Piedmont, is not at all well understood. Although several theories have been presented to explain just why there is so marked a change in both elevation and appearance between the two adjacent provinces, the paucity of data leaves all explanations in the category of speculation. The three principle ideas are: 1) a fault controlled scarp, 2) a wave-cut scarp of marine origin, 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 theory terms and is perhaps most widely accepted; however, though intellectually attractive and most generally accepted, the concept has not been substantiated in this area with firm evidence.

Whatever the origin of the escarpment, it is quite clear that the Blue Ridge front provides the setting for a zone of intense erosional activity. Ocean-bound streams, such as the Catawba and Linville Rivers, cascade down from the Blue Ridge creating indentations and deep gorges along the front with the result that the Piedmont surface is now expanding westward as the Blue Ridge becomes consumed by vigorous erosional processes.

26.2 Recurrent landsliding of colluvium, saprolite, and bedrock boulders. The slide occurs along the parallel foliation and compositional planes of the later Precambrian metasediments.

27.8 Sand pile to aid in the safe stopping of run-away busses and trucks.

28.3 Cross contact between cataclastic gneiss unit to west and Brevard zone to the east. The Brevard zone marks the boundary between two structural provinces with the Inner Piedmont to the east of the Brevard and the Blue Ridge structural province to its west. The nature of the zone has long been in question; to date at least seventeen different explanations have been offered. At a recent field conference, a list of properties of the Brevard zone was compiled by investigators with special experience along different segments of the structure. The 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 occur within 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 cataclastic rocks throughout. 5) The zone presently contains greenschist-facies mineral assemblages which have been derived by retrogression from earlier, higher grade, Barrovian-type assemblages.

29.5 Railroad overpass. Exposures on either side of the overpass are in the Brevard zone cataclastic complex. Locally, rock types such as the following are present: cataclastic schist (sometimes called "fish-scale schist" or "button schist" for distinctive curved mica flakes or masses), phyllonite, mylonite, mylonite gneiss, porphyroblastic mylonite, amphibolite, and occasionally marble.

29.9 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.

31.5 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.

31.6 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.

39.5 Bridge over the Catawba River. To the north is a sand and gravel operation of the Boyd Stone Company. Bouldery and cobbly sandy alluvium from the river flood plain provides the raw material for this operation, typical of many in the Piedmont province.

40.7 Cross the Catawba River again. To the west is another sand and gravel plant.

41.1 We have generally been following a valley developed largely on Brevard zone rocks but have by now crossed back into the Blue Ridge structural province. Saprolite exposures here are of a layered gneissic unit lying between the Grandfather Mountain window and the Brevard zone. The gneiss is thought to be derived from argillaceous sandstone or graywacke.

41.6 Linville Falls fault (not exposed). The layered gneiss lying southeast of the Grandfather Mountain window is thrust onto the Wilson Creek Gneiss within the window. The Wilson Creek constitutes the major portion of the much deformed and metamorphosed billion-year old basement found inside the window. The Linville Falls fault has been mapped continuously around the window and therefore is its bounding surface.

For the next 6.1 miles (til mile 47.7) we will travel through the "tail" of the window. The rocks in this area are present in a series of overlapping fault slices lying structurally beneath the Linville Falls fault. Although the general structural arrangement is fairly well understood, details of the fault slices are subject to varying interpretations.

42.7 Roadcut exposures of Chilhowee quartzite. The oldest known fossils in the Appalachians have been found at the type area of the Chilhowee on the east side of the Valley and Ridge in Tennessee, and the Chilhowee therefore is confidently assigned an Early Cambrian age. The quartzite preserved here is a thin remnant of one of the slices beneath the Linville Falls fault.

42.8 Wilson Creek Gneiss.

44.0 Upper Chilhowee quartzite.

44.6 Hicks Chapel to east (right). Weathered exposures in low cut to west are in the lower part of the Chilhowee. The strata here dip moderately to the southwest. As we continue northward in an up-dip direction for the next 3.1 miles, successively younger strata crop out; therefore the stratigraphic sequence in this fault slice must be overturned.

46.6 Stop 3 Woodlawn quarry. The quarry is developed in thickly-bedded, light- to dark-gray dolomite with abundant white calcite veinlets. It is part of the Early Cambrian Shady Dolomite, better known from outcrops in the Valley and Ridge province more than 25 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 is about 1,000 feet thick; here at Woodlawn the upper part of the Formation is absent because of faulting and a lesser thickness is present. The Shady is part of the slice which began at Hicks Chapel (mile 44.6). As it is the stratigraphically youngest unit in the slice, but dips southeastward beneath the older Chilhowee units, we have further proof that all the strata in this particular slice are overturned.

The quarry is owned and intermittently operated by the North Carolina Department of Transportation for crushed stone.

47.7 Outcrops of Cranberry Granitic Gneiss. Between the last exposures of Shady Dolomite near the quarry and these first exposures of Cranberry we have crossed out of the window, over the Linville Falls fault, and into the allochthonous Blue Ridge province.

49.9 View of Dobson Knob to the east. It is underlain by resistant, ridge-making quartzites of the Chilhowee Group. For the next 3.7 miles our route parallels the trace of the Linville Falls fault; outcrops to the west are of the Cranberry Granitic Gneiss and those to the east will be of the Chilhowee.

52.7 View of Hawksbill Mountain directly ahead (northeast). Hawksbill is underlain by strata of the Grandfather Mountain Formation, a later Precambrian metasedimentary unit correlative with the lower part of the Ocoee Supergroup 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 metasandstone, metagraywacke, metaarkose, and metasiltstone. The Formation overlies, with great nonconformity, the billion-year old basement complex within the window.

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

55.2 Village of Ashford, elevation 1,750 feet.

55.6 Bridge over North Fork of the Catawba River.

58.8 Entrance to Linville Caverns. The cave network consists of connected solution cavities developed in the Shady Dolomite.

59.8 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 has been prospected and, in the mid-1940's, drilled by the New Jersey Zinc Company. Evidently, commercial mineralization was not discovered.

60.3 Shady Dolomite exposed in roadcuts to the east.

60.4 We are now recrossing the Linville Falls fault from the window back into the Cranberry Granitic Gneiss of the Blue Ridge.

61.1 Linville Falls post office (elevation 3,300 feet).

63.7 Bridge over the Linville River.

63.8 Recross back into the Grandfather Mountain window.

63.9 Access road to Linville Falls parking area. The excellent exposures along the access road are mostly quartzite and some slate or metashale of the upper part of the Chilhowee.

65.5 Parking area. From here it is a half mile walk to the upper falls and stop 4. Please remember that this is a National Park; disturbing the flora, fauna, or rocks is not permitted.

The Linville Falls fault crosses the parking area from end to end closely parallel to the river. Exposures in the river just upstream from the footbridge at the south end of the parking area are of the Cranberry Granitic Gneiss; the fault may conveniently be placed 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 4 are of the Cranberry.

Stop 4 Type area of the Linville Falls fault. Approximately 150 feet upstream from the overlook are excellent exposures of the

Linville Falls fault. Crudely foliated basement granitic rock, the Cranberry Gneiss, overlies feldspathic metasandstone and metasiltstone of the upper part of the Early Cambrian Chilhowee. About 18 inches of mylonite and blastomylonite occurs along the fault plane. The cataclastic rock has been differentially eroded to produce the overhang. The fault dips gently westward in this vicinity. The granitic gneiss forms the upper falls with the fault at the base of the falls.

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

Return to busses in parking area on Parkway.

67.0 Enter picnic area on flood plain of Linville River.

-- LUNCH --

68.3 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.

70.1 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 dumps of the Harris Mining Company. Mining here is principally for kaolin group clay minerals (kaolinite and halloysite) from thick saprolite formed by thorough <u>in situ</u> chemical weathering of feldspathic alaskite bodies adjacent to Brushy Creek. In addition, flake mica is also recovered. Large, commercially important deposits such as these are considered to have formed throughout the district on valley straths developed mainly in the Cretaceous or early Tertiary.

Chalk Mountain, in the middle background, is composed almost entirely of alaskite and is the principal ore body for the Feldspar Corporation of Spruce Pine. At present, mining activity is on the southern and southwestern flanks of the mountain.

In the far distance are the peaks, including Mount Mitchell, of the Black Mountains.

Outcrops across the Parkway from the overlook are of the Cranberry; note that they are dipping gently to the west, away from the Grandfather Mountain window.

71.0 Panoramic view of Grandfather Mountain (elevation 5,938 feet) to the northeast and Hawksbill Mountain to the southeast. Both these peaks are underlain by the Grandfather Mountain Formation.

71.6 Stop 5 Contact between the plutonic granitic rocks of the basement complex and the later Precambrian metasedimentary rocks of the Blue Ridge. At this exposure, layered biotite gneiss containing various amounts of feldspar along with minor layers of amphibolite and calc-silicate units are overlain by biotite-muscovite gneiss and schist containing small pegmatites. Metamorphism has blurred the original nature of the contact; however, in this area it is believed to be a nonconformity.

72.6 Stop 6 Chestoa View overlook. We are looking eastward across the North Fork of the Catawba River valley. Across the valley is Linville Mountain with a local peak, Laurel Knob, in front of us. Resistant units of the Chilhowee underlie the mountain. The Linville Caverns area is approximately 1,500 feet vertically below us in the valley. Hawksbill Mountain is in the far background.

74.1 View of Table Rock Mountain. Table Rock is a klippe of lower Chilhowee resting on top of autochthonous basement within the window.

75.0 Overlook. The Black Mountains are the high peaks straight ahead (west) with Mount Mitchell at the south end of the range. To the southeast we can observe irregularities in the Blue Ridge front caused by uneven headward erosion of tributaries of the Catawba River.

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

77.9 At these outcrops foliation and compositional banding are dipping towards the east. One interpretation of this change in dip direction is that we are now some distance away, both vertically and horizontally, from the direct domal influence of the window structure, and that the dips we see here are associated with smaller-scale wrinkles and folds within the Blue Ridge sheet.

80.4 Apple orchard; apples are an important cash crop in the mountains and are frequently grown on the slopes between about 2,500 and 3,500 feet elevation.

83.0 Gillespie Gap. Museum of North Carolina Minerals.

88.0 Alpine Village, "1,000 acres of fine mountain homes and home-sites".

89.3 Upper pits of the McKinney pegmatite mine.

89.5 Stop 7 McKinney Pegmatite Mine. This pegmatite has been mined intermittently between 1924 and 1962 almost entirely for sheet mica and feldspar. The body, as are most in the district, is mostly concordant with the local foliation although in some places it is strongly discordant. The pegmatite itself is zoned, both texturally and mineralogically. The wall zone is medium-grained, composed of plagioclase, quartz, and muscovite; the intermediate zone is coarse-grained and composed of plagioclase, quartz, and perthite; and the core is coarse-grained, containing quartz and perthite. The mica here is usually greenish, "A"-structured, often stained, and contains garnet inclusions. Accessory minerals include garnet, beryl, pyrite, chalcopyrite, samarskite, columbite, autunite, torbernite, epidote, and many others in small quantities.

Recently, some local entrepreneurs have started using the dump material as feed for a small crushed stone operation. Their product is used for local construction purposes.

91.0 Small sand and gravel pit now being converted into a trout pond. This stream, Crabtree Creek, has supplied sand and gravel locally for many years.

93.4 View of Chalk Mountain straight ahead (east). The mountain receives the name from its white-colored rocks and white, chalky saprolite.

95.8 Entrance to the Chalk Mountain mine.

Stop 8 Chalk Mountain Mine. This mine, located about 2 miles southwest of Spruce Pine is operated by the Feldspar Corporation. The original workings were for mica in the early and middle 1900's. Presently mining is being conducted on the southern flank of the hill.

The alaskite is slightly to moderately foliated as a result of rough parallelism of muscovite flakes and some orientation of the quartz and feldspar. The most common accessory minerals are garnet and biotite.

Especially noteworthy at these exposures are xenoliths of country rock. The xenoliths are mostly coarse-grained biotite schist. As can be seen, alaskite such as this is desirable flotation head feed material; there is great uniformity in the body and liberation size is relatively coarse. Reserves are immense; no shortage of feldspar resources is anticipated in this area.

To the north are the other two active pits in the district. These supply ore for International Minerals and Chemical Corporation and Lawson-United Feldspar and Mineral Company.

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

101.3 Stop 9 Newdale olivine quarry. The Newdale deposit, owned by International Minerals and Chemical Corporation, is one of many dunite bodies found in the Blue Ridge. This one is about 1,800 feet long and 500 feet wide in outcrop, and is estimated to contain close to 7 million tons of altered and unaltered olivine above local stream level. The olivine here is generally pale green to pale yellow and fine-grained. Octahedrons of chromite are scattered through the dunite. Beneficiation of the ore is by gravity methods; both Humphrey Spirals and shaking tables have been used to separate the unaltered, refractory olivine from the associated hydrous alteration minerals, serpentine, anthophyllite, and talc. The major use of olivine is as molding or casting sand.

103.5 Abandoned soft ore (saprolite) pit to the south. Probably mined for scrap mica or a kaolin group clay.

103.9 Micaville, North Carolina.

107.8 Intersection with N. C. 197. Three and one half miles north is the Daybook mine and mill of International Minerals and Chemical Corporation. Olivine from the Newdale mine is trucked to and processed at this mill.

111.4 View of the Walnut and Bald Mountains.

111.9 Ivy Gap; Madison-Yancey County line. Entering the French Broad drainage basin.

129.4 Exposures to the west (right) are in the later Precambrian Bakersville Hypersthene Metagabbro which outcrops discontinuously for the next 2.4 miles. It is intrusive into a biotite-hornblende migmatite unit of the Blue Ridge thrust sheet. This body has been metamorphosed; however, it still exhibits an igneous texture (ophitic to subophitic) and a slightly altered gabbroic mineral assemblage. The lack of complete metamorphic alteration is attributed to water deficient conditions during metamorphism. Other Bakersville Metagabbro bodies in the area show a progression from slightly altered metagabbro to amphibolite at their edges. Where water was more readily available during metamorphism, the gabbroic bodies are completely altered to amphibolite.

130.6 Excellent exposure of the Bakersville Hypersthene Metagabbro to the east (left).

131.8 End of the hypersthene metagabbro; contact with the biotite-hornblende migmatite is concealed.

132.7 Exit to N. C. 197; turn east towards Democrat and Barnardsville.

133.3 Outcrops to the south (right) and north (left) contain 2-inch to 2-foot thick dikes and sills of trondhjemite (quartz diorite). Trondhjemite is characterized by the absence of potassic feldspars. The bodies are thought to be Paleozoic in age because they are relatively unmetamorphosed and apparently cut all rock types in the Blue Ridge except the pegmatites.

135.5 Stop 10 This stop is within the Democrat-Morgan Hill dunite body, an ultramafic composed almost entirely of olivine. However, this body is not well suited for the production of olivine, because most of it has been thoroughly serpentinized and thus does not make good refractory material. Chromite in non-commercial amounts occurs with the olivine.

Intruding this dunite is a pegmatite, now highly weathered, that has been mined in the past chiefly for halloysite. The pit to our east is the inactive Arrowood halloysite mine.

In the deep saprolite road cut on the southwest side of the intersection, garnierite (a nickel serpentine mineral) can be found. Upon weathering of the olivine, which contains approximately 0.2% nickel in its lattice, nickel is released and redeposited as garnierite.

These garnierite enriched veinlets in the saprolite make the nickel content here higher than some of the commercial laterite deposits; however, the tonnage is not sufficient to open a new deposit.

142.2 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).

146.4 View of the Asheville skyline and the French Broad River to the west (right).

149.5 Bridge over the French Broad River.

The Great Smokies Hilton

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