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Geology of the Linville Falls Quadrangle North Carolina

GEOLOGICAL SURVEY BULLETIN 1161-B

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By JOHN C. REED, JR.

CONTRIBUTIONS TO GENERAL GEOLOGY

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A study of an area of complex structural and metamorphic history in western North Carolina

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GEOLOGY OF THE LINVILLE FALLS QUADRANGLE, NORTH CAROLINA

By John C. Reed, Jr.

ABSTRACT

The Linville Falls quadrangle, in northwestern North Carolina, includes most of the southwestern part of the Grandfather Mountain window and adjacent parts of the Blue Ridge thrust sheet to the west and the Inner Piedmont to the southeast.

In the Grandfather Mountain window, Precambrian granitic rocks are overlain unconformably by sedimentary and volcanic rocks of the Grandfather Mountain Formation, also of Precambrian age. These autochthonous rocks have been overridden by the Tablerock thrust sheet, composed of quartzite and phyllite of the Chilhowee Group of Early Cambrian(?) and Early Cambrian age and Lower Cambrian Shady Dolomite.

The Blue Ridge thrust sheet, which has moved relatively northwestward at least 30 miles along the Linville Falls fault, has overridden the rocks exposed in the Grandfather Mountain window. The sheet consists of Precambrian rocks, chiefly layered granitic gneiss, mica schist and gneiss, and amphibolite, that have been intruded by granodiorite and associated pegmatite of middle or late Paleozoic age.

The rocks of the Inner Piedmont are layered gneiss, mica schist, amphibolite, and granitic rocks of different aspect than the Precambrian rocks in the Blue Ridge thrust sheet. The age of most of the Inner Piedmont rocks is unknown except that they are probably older than middle Paleozoic. They are in contact with rocks of the Blue Ridge thrust sheet along the Brevard fault zone, a belt of blastomylonite and associated cataclastic and retrogressively metamorphosed rocks that probably marks a major strike-slip fault southeast of the Grandfather Mountain window.

The structural and metamorphic history of the area is complex. Correlation of metamorphic events in the various tectonic blocks, and the establishment of the complete structural and metamorphic chronology are hindered by structural complexity, lack of fossils, and the scarcity of absolute age determinations.

The Precambrian granitic rocks now exposed in the Grandfather Mountain window and in the Blue Ridge thrust sheet formed during an episode of plutonic metamorphism about 1,100 million years ago. The oldest granitic rocks in the Inner Piedmont may have been emplaced at this time, or they may be much younger.

During the middle or late Paleozoic (about 350 million years ago) medium-grade regional metamorphism of rocks now in the Blue Ridge thrust sheet took place and granodiorite and pegmatite were emplaced. At perhaps the same time, rocks of the Inner Piedmont were regionally metamorphosed to medium and high grade, and quartz monzonite and associated pegmatites were intruded.

Cambrian and upper Precambrian rocks in the Grandfather Mountain window were progressively metamorphosed under low-grade conditions probably during the early or middle Paleozoic; Precambrian basement rocks were sheared and retrogressively metamorphosed during the same episode.

Low-grade retrogressive metamorphism of medium-grade rocks along the edges of the Grandfather Mountain window in the Blue Ridge thrust sheet and in the Inner Piedmont probably took place during the middle or late Paleozoic. Movement along the major thrust faults probably occurred in the late Paleozoic, prior to movement along the Brevard fault zone.

Mica, feldspar, kaolin, and construction materials—including gravel, crushed stone, building stone, and flagstone—are currently mined and quarried in the quadrangle. Small quantities of manganese ore have been produced. Prospecting for zinc, lead, and uranium has not been fruitful.

INTRODUCTION

The Linville Falls [1] 15-minute quadrangle is in northwestern North Carolina about 45 miles northeast of Asheville and 75 miles northwest of Charlotte (pl. 1). It occupies an area of 242 square miles in parts of Burke, Caldwell, Avery, Mitchell, and McDowell Counties. Topographic maps covering the quadrangle have been published by the Geological Survey as the Linville Falls, Chestnut Mountain, Oak Hill, and Ashford 7½-minute quadrangles.

About 35 square miles in the northwestern part of the Linville Falls 15-minute quadrangle (pl. 2) lies in the Blue Ridge upland, a deeply dissected plateau ranging in altitude generally from 3,200 to 3,700 feet. Streams are incised as much as 600 feet below the upland surface, and hills rise 300–600 feet above it. Ball Ground Mountain (alt 4,240 ft), the highest point in the quadrangle, stands about 500 feet above nearby parts of the upland surface.

The central part of the quadrangle, occupying about 135 square miles, lies on the deeply dissected and heavily wooded southeastern flank of the Blue Ridge. Here, peaks and ridges stand at altitudes of 2,500–4,000 feet, and local relief is commonly 1,000–1,500 feet and reaches a maximum of 2,000 feet.

The remainder of the quadrangle, about 60 square miles, lies southeast of the Blue Ridge in the Morganton Basin, part of the Piedmont province. In this area the Piedmont surface has a general altitude of 1,200–1,300 feet, more than 2,000 feet lower than the

[1] On preliminary editions of the Geological Survey topographic map the quadrangle was called Table Rock, and it has been referred to by this name in Bryant (1962), Bryant and Reed (1962), Reed and Bryant (1960), and Reed and others (1961).

Blue Ridge upland. Streams are incised at most 200 feet into the plateau surface, leaving a series of concordant flat-topped interfluves. The lowest altitude is about 1,000 feet along the Catawba River near the southeastern corner of the quadrangle.

Most of the quadrangle is drained by the Catawba River and its tributaries, but part of the Blue Ridge upland in the northwestern part is drained by the North Toe River, a tributary of the Tennessee River. Lake James, a large storage reservoir partly in the southern part of the quadrangle, is impounded by earthfill dams across the Linville and Catawba Rivers.

Most of the area is thickly wooded with second-growth forest of pines and deciduous trees; commonly there is a dense understory of laurel and rhododendron. Habitations are sparse. Most of the few small farms are limited to level parts of the Blue Ridge upland and to the valley bottoms in the Piedmont and along the North Fork of the Catawba River. Many fields have been abandoned and are now overgrown with dense thickets of briers and scrubby pines.

GEOLOGIC INVESTIGATIONS

Kerr (1875) briefly described the geology of western North Carolina and mentioned the occurrence of "sandstones and quartzites of various degrees of metamorphism" on Linville Mountain and of "compact, light-colored and gray limestone" in the valley of the North Fork (of the Catawba River).

Keith and Sterrett (1954) studied the geology of the Morganton 30-minute quadrangle, of which the Linville Falls 15-minute quadrangle constitutes the northwestern quarter, but their results were never published. Keith also mapped the Cranberry 30-minute quadrangle (Keith, 1903), which lies north and northeast of the Linville Falls 15-minute quadrangle, and the Mount Mitchell 30-minute quadrangle (Keith, 1905), which lies to the west and southwest. In these three quadrangles, Keith delimited an extensive area of sedimentary and igneous rocks of low metamorphic grade to which he assigned a late Precambrian and Early Cambrian age; he believed that these rocks occupied a complex syncline bounded on the north and west and on part of its southeast side by faults along which Precambrian plutonic rocks had overridden the younger rocks. This structure was reinterpreted on the "Geologic Map of the United States" (Stose and Ljungstedt, 1932) as a window in a major overthrust sheet, now called the Grandfather Mountain window. This interpretation has been followed on subsequent maps (King and others, 1944; King, 1955) and is probably correct (pl. 1).

A small area in the northwestern part of the Linville Falls quadrangle was mapped from 1948 to 1953 by Kulp and Brobst (1956), as part of an investigation of the Spruce Pine pegmatite district. As a corollary study, Eckelmann and Kulp (1956) made a reconnaissance of the layered granitic gneisses between the edge of the Spruce Pine district and the Grandfather Mountain window.

The Linville Falls quadrangle is the southwestern quadrangle of a block of four 15-minute quadrangles currently being mapped in a study of the Grandfather Mountain window and adjacent areas. Fieldwork was done in 1957–60. The Linville quadrangle, which borders the Linville Falls 15-minute quadrangle to the north, has been mapped by Bryant (1962) as part of the project. His advice and assistance have been invaluable to me during the study of the Linville Falls quadrangle.

ROCK UNITS

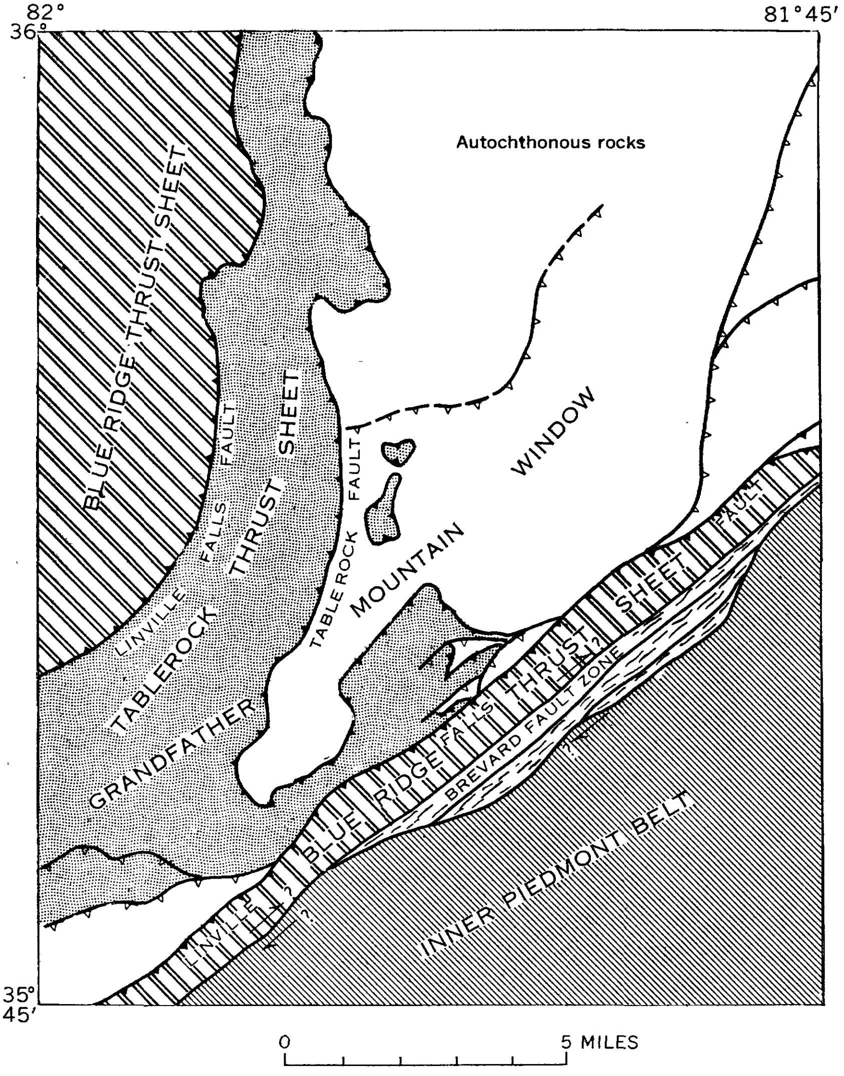
The rocks of the Blue Ridge in northwestern North Carolina and northeastern Tennessee (pl. 1) form a complex crystalline terrane composed chiefly of schist, gneiss, migmatite, and granite of Precambrian age locally intruded by mafic igneous rocks and by granodiorite and pegmatite of Paleozoic age. These rocks have been subjected to several episodes of retrograde thermal and dynamic metamorphism during Paleozoic time and have been involved in large-scale overthrusting, which has carried them northwestward for at least 30 miles over Precambrian granitic rocks and other Precambrian and Lower Cambrian rocks exposed below the thrust sheet in the Grandfather Mountain window and in the Unaka belt northwest of the Blue Ridge (King, 1955).

The rocks of the Inner Piedmont belt (King, 1955) are chiefly interlayered mica gneiss, schist, hornblende gneiss, and amphibolite, containing concordant intrusive bodies of augen gneiss and generally concordant bodies of younger quartz monzonite. This suite of rocks differs from that of the Blue Ridge thrust sheet (Reed and Bryant, 1960), and the relations between the two terranes are uncertain. Regional considerations and scattered radiometric age determinations in other areas (Long and others, 1959) suggest that most of the Piedmont rocks in the Linville Falls quadrangle are not younger than middle Paleozoic.

ROCKS OF THE GRANDFATHER MOUNTAIN WINDOW

AUTOCHTHONOUS ROCKS

The oldest rocks exposed in the Grandfather Mountain window in the Linville Falls quadrangle are foliated nonlayered granitic gneiss and rudely foliated granite of Precambrian age (fig. 1). Resting unconformably on these basement rocks is a thick sequence of Pre-



EXPLANATION

Major thrust faults between tectonic blocks	Other thrust faults	Brevard fault zone
Barbs on upper plate	*Barbs on upper plate. Dashed where inferred or approximately located*	*Arrows show inferred direction of movement*

FIGURE 1.—Outline map of the Linville Falls quadrangle, showing faults and major tectonic blocks.

cambrian sedimentary rocks, chiefly arkose, siltstone, and shale. In the Linville and Blowing Rock quadrangles various volcanic rocks are intercalated with the sedimentary rocks (Bryant, 1962, and oral communication, 1960). These rocks have been designated as the Grandfather Mountain Formation and tentatively correlated with rocks of the Ocoee Series (Bryant, 1962). Several isolated narrow belts of volcanic and sedimentary rocks in the Linville Falls quadrangle are clearly younger than the basement rocks which surround them, and may represent parts of the Grandfather Mountain Formation lower than the basal beds exposed in its main area of outcrop.

These upper Precambrian rocks were progressively metamorphosed during Paleozoic time, and at the same time the basement rocks were pervasively sheared and retrogressively metamorphosed. A conspicuous cleavage, striking northeast and dipping southeast, was imposed on both groups of rocks.

All the Precambrian rocks in the Grandfather Mountain window are probably autochthonous. These autochthonous rocks have been overridden by a thrust sheet composed principally of quartzite and phyllite of the Chilhowee Group of Early Cambrian (?) and Early Cambrian age and locally including the overlying Lower Cambrian Shady Dolomite. This tectonic unit, the Tablerock thrust sheet, occupies most of the western and southwestern parts of the Grandfather Mountain window in the Linville Falls quadrangle and forms klippen on the Chimneys and Tablerock Mountain.

PRECAMBRIAN GRANITIC ROCKS

WILSON CREEK GNEISS

Highly sheared plutonic gneisses constitute the bulk of the basement rocks exposed in the Grandfather Mountain window. These rocks were mapped together with the Cranberry Granite by Keith (1903), but because of their different lithology and tectonic position they were distinguished as a separate unit by Bryant (1962), who named them the Wilson Creek Gneiss, after the excellent exposures along Wilson Creek in the southeastern part of the Linville quadrangle and the northeastern part of the Linville Falls quadrangle.

The Wilson Creek Gneiss is a medium- to coarse-grained light- to medium-gray or greenish-gray biotite-quartz-feldspar gneiss. It generally has a conspicuous cataclastic foliation that is defined by folia of fine-grained biotite. The gneiss is generally not layered, but locally contains layers and pods of biotite schist and biotite-amphibolite. Dikes, pods, and irregular bodies of pegmatite composed of quartz, microcline, and albite, but containing little or no mica, are common in the gneiss. The pegmatite is slightly foliated, but its microscopic texture indicates that it has undergone the same cataclasis as the enclosing gneiss. Locally, the gneiss is cut by thin dikes of fine-grained light- to medium-gray quartz monzonite. These dikes show cataclastic effects similar to those in the coarser grained gneiss, but the foliation is commonly less conspicuous. The dikes cut some of the pegmatite bodies and are in turn cut by others.

Angular blocks of finely layered amphibole gneiss occur as xenoliths in a coarse pegmatitic phase of the Wilson Creek Gneiss on Upper Creek 0.5 mile above the mouth of Burnthouse Branch.

The typical gneiss is composed of porphyroclasts of microcline and microcline-microperthite, plagioclase, quartz, and biotite in a fine-grained matrix of reconstituted plagioclase, quartz, sericite, biotite, chlorite, and epidote. Zircon, apatite, orthite, magnetite, sphene, and leucoxene are common accessory minerals. The feldspar porphyroclasts range from a few millimeters to as much as 5 cm in diameter and have conspicuous tails of recrystallized quartz and plagioclase parallel to the cataclastic foliation. Most of the potassium feldspar is clear and unaltered, although much shows breaks sealed by fine-grained mosaics of quartz. The plagioclase porphyroclasts are sericitized and saussuritized, and many show bent and broken twin lamellae. They are pseudomorphosed by albite, and are commonly rimmed with clear albite. Porphyroclastic biotite occurs in ragged bent books, clouded by opaque inclusions and commonly containing sagenitic webs.

The reconstituted matrix consists of granoblastic quartz and albite (the grains ranging generally from 0.01 to 0.1 mm in diameter) interwoven with discontinuous folia of fine-grained new biotite and sericite which define the cataclastic foliation. In many specimens, the biotite has been largely chloritized. The intense cataclasis and accompanying sercitization of the feldspars make it difficult to determine the composition of the gneiss prior to the retrogressive metamorphism but, of a suite of 41 specimens, 4 were estimated to have been quartz diorite; 13, granodiorite; 19, quartz monzonite; and 5, granite. Large variations in composition occur within single outcrops, and the relations between rocks of different composition are not known.

An area of slightly foliated coarse-grained light-colored quartz monzonite in the Wilson Creek Gneiss is distinguished on the map near Rose Mountain. This rock has a partially recrystallized allotriomorphic granular texture and is composed mostly of quartz, potassium feldspar (microcline and microcline-microperthite), and plagioclase in subequal amounts; traces of fine-grained new sericite, biotite, and chlorite also occur.

Where shearing and retrogressive metamorphism was more pervasive, the gneiss was reduced to lustrous gray sericite phyllonite which weathers reddish brown. The phyllonite has transitional contacts with the enclosing gneiss and contains porphyroclasts and horses of pegmatite derived from the surrounding gneiss. Some of the phyllonite contains disseminated graphite and pyrite.

Tilton and others (1959) obtained discordant uranium/lead isotopic ages for zircon from the Wilson Creek Gneiss exposed in the quarry on the east side of Wilson Creek 0.7 mile northwest of the abandoned hamlet of Mortimer. They suggested that these ages indicate a Precambrian age of about 1,100 million years for the zircon and, hence, for the plutonic rocks, modified by loss of lead during a metamorphic episode about 375 million years ago.

BLOWING ROCK GNEISS

In the northeastern part of the quadrangle the Wilson Creek Gneiss passes into porphyroclastic quartz monzonite gneiss containing abundant microcline crystals 2–5 cm long. This rock was named the Blowing Rock Gneiss by Keith (1903) for its exposures near Blowing Rock in the Cranberry 30-minute quadrangle (Blowing Rock 15-minute quadrangle).

The microcline porphyroclasts in the Blowing Rock Gneiss are generally milky white and tabular or lentil shaped. They are in a fine matrix of quartz, albite, fine biotite, sericite, and epidote. Finely disseminated biotite colors the matrix a dark gray or black. Cleavage and lineation are well defined, and the feldspar porphyroclasts tend to lie with their long axes parallel to the lineation and their intermediate axes in the cleavage plane.

The Blowing Rock Gneiss commonly contains dikes and pods of pegmatite and of fine-grained quartz monzonite similar to those in the Wilson Creek Gneiss.

Tilton and others (1960) obtained a nearly concordant lead/uranium age of about 1,000 million years for zircon from the Blowing Rock Gneiss in its type area, indicating that the Blowing Rock Gneiss is of the same general age as the Wilson Creek Gneiss.

Contacts between the Wilson Creek and Blowing Rock are commonly gradational, but the fact that pods and blocks of Blowing Rock Gneiss occur locally in the Wilson Creek Gneiss suggests that some parts of the Wilson Creek Gneiss may be younger than the Blowing Rock.

BROWN MOUNTAIN GRANITE

The Brown Mountain Granite is here named for its exposures on Brown Mountain in the northeastern part of the Linville Falls 15-

minute quadrangle. The granite is faulted against Wilson Creek Gneiss and upper Precambrian sedimentary and volcanic rocks on the west and northwest; on the southeast it is bounded by the Linville Falls fault, which marks the southeastern boundary of the Grandfather Mountain window.

The granite is medium to coarse grained, light colored, and homogeneous. It is generally poorly foliated and nonlayered, but commonly has a distinct cataclastic lineation. It characteristically crops out in flat exfoliation slabs, which make measurement of foliation and lineation difficult.

The granite is composed of 35–40 percent quartz, 45–50 percent potassium feldspar, 10–15 percent plagioclase, and small amounts of biotite, muscovite, and epidote. Sphene, leucoxene, orthite, fluorite, and magnetite are the principal accessory minerals. The potassium feldspar is string perthite which occurs as porphyroclastic grains as much as 1 cm long. Quartz is largely recrystallized into a granoblastic interstitial mosaic but a few large grains of highly strained quartz remain as porphyroclasts. Albite forms occasional cloudy porphyroclasts, but occurs largely in clear reconstituted grains with quartz in the groundmass and in rims on the potassium feldspars. Original biotite occurs locally but is generally replaced by irregular clots of new biotite or by aggregates of epidote, muscovite, and opaque minerals. Muscovite occurs as small flakes in the quartz-albite mosaic. Fluorite occurs as small irregular grains in the mosaic and locally as thin coatings on joint surfaces.

Local thin zones of silvery medium-gray phyllonite occur in the granite, but no extensive phyllonite zones are known.

The Brown Mountain Granite is older than the Precambrian sedimentary and volcanic rocks to the west and northwest. Its relations to the Wilson Creek Gneiss and Blowing Rock Gneiss are undetermined, but it is inferred to be of the same general age.

UPPER PRECAMBRIAN ROCKS

GRANDFATHER MOUNTAIN FORMATION

The Grandfather Mountain Formation is a thick sequence of interlayered and intertonguing arkose, arkosic quartzite, siltstone, shale, and volcanic rocks which unconformably overlies Precambrian granitic rocks in the Grandfather Mountain window. The formation is extensively exposed in the Linville quadrangle, where it has been described by Bryant (1962) and named for the prominent exposures of the lower members on Grandfather Mountain. In its western outcrop areas in the Linville Falls quadrangle the formation consists almost entirely of sedimentary rocks; in the narrow outcrop belt farther to the east, volcanic rocks predominate. In the Linville quadrangle the thickness of the formation is at least 10,000 feet and is perhaps as much as 30,000 feet (Bryant, 1962). Only the lower members are exposed in the Linville Falls quadrangle, and the thickness of the formation there is much less.

There is no direct evidence as to the age of the Grandfather Mountain Formation because the formation is nowhere in stratigraphic contact with younger rocks. Bryant (1962) assigned the formation to the upper Precambrian on the basis of gross lithologic and stratigraphic similarities to parts of the upper Precambrian Ocoee Series of the Great Smoky Mountains and suggested that the intercalated volcanic rocks may indicate that it is a transitional facies between the Ocoee Series and the Mount Rogers Volcanic Group of southwestern Virginia.

Sedimentary rocks

The basal member of the Grandfather Mountain Formation in its western outcrop areas in the Linville Falls quadrangle is predominantly fine- to coarse-grained thin-bedded to massive light-green, tan, or gray sericitic arkose. The arkose contains interbeds of green sericite phyllite and a few lenses of conglomerate. Crossbedding is conspicuous in a few exposures, but graded bedding is scarce. Bedding is also marked by heavy-mineral streaks, phyllitic partings, and thin calcareous layers. In many exposures bedding is not apparent, and the only conspicuous structure is the regional cleavage marked by parallel orientation of fine green laminae of sericite.

The typical arkose consists of clastic grains of microcline, strained quartz, and plagioclase (pseudomorphosed by albite) in a matrix of fine-grained reconstituted quartz, albite, green sericite, and minor amounts of epidote and carbonates. The feldspar content generally ranges from 15 to 50 percent. The green sericite, unusually rich in iron (Foster and others, 1960), lends its color to the rock. Biotite occurs only rarely in the arkose. Accessory heavy minerals are ilmenite, zircon, sphene, leucoxene, and rutile.

The feldspar clasts range from a few millimeters to several centimeters in diameter. In general, the lower parts of the member are fine grained, and the upper parts tend to be coarser. Conglomerates are largely in the upper part of the unit; they contain deformed pebbles and cobbles of granitic rocks, quartz, potassium feldspar, quartzite, and felsic volcanic rocks, and angular fragments of silvery-gray, blue, green, and purple phyllite. The conglomerate bodies are lenses, a few feet to 50 feet thick, and are generally traceable along the strike for only a few hundred feet.

The contact of the arkose with the underlying Wilson Creek Gneiss is not well exposed and is obscured by shearing. It is interpreted as a folded unconformity, locally overturned.

The basal arkose member of the Grandfather Mountain Formation is overlain by medium- to dark-gray or greenish-gray siltstone, phyllite, and phyllitic schist, containing interbeds of graywacke, graywacke conglomerate, and fine-grained arkosic quartzite. The siltstone and phyllite are commonly calcareous and locally contain layers of sandy marble as much as 8 inches thick.

The fine-grained rocks, which compose the bulk of the unit, consist of recrystallized plagioclase and quartz, sericite, biotite, and chlorite. The micaceous minerals are commonly arranged in folia 0.5–1 mm thick parallel to a conspicuous bedding schistosity which is crumpled and offset by a closely spaced slip cleavage. Epidote and carbonate occur in some laminae. Some of the coarser siltstones contain clastic grains of quartz and plagioclase, occasional pebbles of granitic rocks, mashed fragments of dark phyllite, and sparse clastic grains of perthite.

Graywacke and graywacke conglomerate form thin lenses a few inches to a few tens of feet thick. The graywacke consists of angular clastic grains of quartz, plagioclase, dark phyllite, fine-grained volcanic rocks, and sparse grains of potassium feldspar in a fine-grained mosaic of quartz, plagioclase, and sericite. The conglomerate contains pebbles of quartz, feldspar, granitic rocks, and felsic volcanic rocks, and flattened fragments of dark-green and blue phyllite.

Volcanic rocks

West and northwest of Brown Mountain, intercalated volcanic and sedimentary rocks crop out in a narrow discontinuous belt extending from the eastern edge of the quadrangle north of Wilson Creek to a point southwest of Steels Creek. These rocks are principally felsic flows, crystal tuffs, and tuffaceous sedimentary rocks, associated with flows of amygdaloidal and porphyritic andesite, although basaltic greenstone, associated with steel-blue tuffaceous(?) phyllite and dark quartzite, is locally dominant. All these rocks are strongly foliated.

The felsic volcanic rocks are fine to medium grained, light gray to dark bluish gray, and markedly foliated; they contain scattered angular phenocrysts of perthite, antiperthite, and plagioclase 0.5–3 mm in diameter and subrounded partially resorbed phenocrysts of blue or smoky quartz 1–3 mm in diameter. The groundmass consists of a mosaic of quartz and feldspar, generally 0.005–0.05 mm in diameter, scattered flakes of sericite, and sparse grains of epidote and biotite. Magnetite, orthite, zircon, stilpnomelane, and fluorite are common accessories. The foliation is defined by sericite folia and by elongate lenses and laminae of somewhat coarser grained quartz and feldspar in the fine-grained mosaic.

Because of the small size of many of the grains, it is difficult to determine the relative proportions of plagioclase and potassium feldspar in most of these rocks. A chemical analysis of one typical specimen showed it to be quartz latite, but there may be considerable variation in composition among the rocks described as felsites.

Intense shearing and recrystallization have obliterated almost all traces of original structures although, locally, faint color banding and differences in grain size may represent bedding or primary flow structure. In a few exposures, faint suggestions of crossbedding or local concentrations of lithic fragments indicate that the rocks were water-laid crystal tuffs or tuffaceous sediments. Adjacent to some of the andesite flows intricate convolutions of color banding and pseudointrusive relations between the felsic rocks and the andesite may indicate that the felsic material was unconsolidated at the time of the extrusion of the andesite. One 6-inch bed of tuff, similar to the felsic volcanic rocks near Brown Mountain, is interlayered with arkose near the base of the Grandfather Mountain Formation along the new Forest Service road northeast of Tablerock Mountain.

Small dikes and plugs of rocks identical in megascopic and microscopic appearance with the felsic volcanic rocks cut the Wilson Creek Gneiss in several places north and west of the belt of volcanic rocks. The striking similarity between the dike rocks and many of the felsic volcanic rocks suggests that at least some of the felsites were flows.

Flows of porphyritic and amygdaloidal andesite are interlayered with the felsic volcanic rocks, particularly near the northwestern edge of the outcrop belt. Several of these flows are well exposed along Wilson Creek above the mouth of Craig Creek. The andesite is now a fine-grained light greenish-gray to dark-blue-gray greenstone or greenschist composed of a microscopic mosaic of albite, which is clear and partially recrystallized, muscovite, epidote, chlorite, opaque minerals, and of abundant accessory sphene, leucoxene, and carbonates. The plagioclase occurs in laths, 0.1–0.2 mm long, which in some specimens have a relict volcanic texture, although in detail their outlines are ragged owing to recrystallization. In some outcrops saussuritized and sericitized plagioclase phenocrysts as much as 3 cm long are abundant. Epidote knots and amygdules filled with quartz, epidote, and chlorite are conspicuous in many of the andesites and are locally as large as 5 cm in diameter.

Greenstone and greenschist intercalated with lustrous blue or silvery phyllite and locally with thin beds of dark quartzite compose most of the strip between Upper Creek and the southern part of the ridge of Brown Mountain. The greenstone and greenschist are fine-grained green to blue-gray rocks composed of albite, muscovite, chlorite, epidote, and opaque minerals. They contain epidote knots and amygdules filled with epidote and quartz. They locally have relict volcanic texture and resemble the andesite flows intercalated with the felsic volcanic rocks. The phyllite is a very fine grained lustrous rock composed mostly of quartz, sericite, and opaque minerals; it contains minor amounts of epidote, sphene, and apatite and small angular clasts of plagioclase. Felsic volcanic rocks are locally intercalated with the mafic rocks and phyllite.

A second narrow discontinuous belt of similar blue phyllite and greenstone occurs along the southeastern contact of the Grandfather Mountain Formation between Buck Creek and Ripshin Ridge, and extends northeastward along the strike for a short distance northeast of Upper Creek. Along the northwestern edge of this belt, blue phyllite is interbedded with arkose, and some conglomerate beds in the arkose contain fragments of blue phyllite.

The structural relations of the volcanic rocks are uncertain, and it has not been possible to establish a stratigraphic sequence within the belt because of the lack of mappable marker horizons and the rarity of exposures exhibiting bedding or original flow structures.

LINVILLE METADIABASE

Dikes and sill-like bodies of greenstone and greenschist intrusive into the Grandfather Mountain Formation are assigned to the Linville Metadiabase (Keith, 1903; Bryant, 1962). The metadiabase is a medium- to fine-grained blue-green, green, or gray massive or schistose rock in which amphibole grains and plagioclase laths are visible on some weathered surfaces. Relict igneous textures are scarce in the bodies exposed in the Linville Falls quadrangle, but in larger bodies in the Linville quadrangle they are more common (Bryant, 1962).

The rock consists principally of fine-grained albite, actinolite, epidote, chlorite, magnetite, and sphene; it also locally contains minor amounts of muscovite, stilpnomelane, and biotite. Some of the coarser greenstone contains laths of albite 0.5–2 mm long, probably pseudomorphs after igneous plagioclase, and sieve-textured porphyroclasts of green hornblende 2–3 mm in diameter. In the more schistose rocks, chlorite and actinolite are rudely alined, defining the megascopic cleavage.

Relations of the metadiabase to the metabasalts of the Montezuma Member of the Grandfather Mountain Formation in the Linville quadrangle indicate that the diabase was the intrusive equivalent of the basalt and that the Linville Metadiabase is therefore of late Precambrian age (Bryant, 1962).

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ROCKS OF THE TABLEROCK THRUST SHEET

Beds of Early Cambrian(?) and Early Cambrian age compose the Tablerock thrust sheet, which is extensively exposed along the western edge of the Grandfather Mountain window and on Shortoff Mountain and in klippen on Tablerock Mountain and the Chimneys. The thrust sheet extends for at least 4 miles southwestward from the edge of the Linville Falls quadrangle into the Wood Mountain and Marion quadrangles and about a mile northward into the Linville quadrangle.

The Tablerock thrust sheet overrode the Wilson Creek Gneiss and the Grandfather Mountain Formation along the Tablerock fault. It was in turn overriden by Precambrian rocks of the Blue Ridge thrust sheet along the Linville Falls fault, which marks the boundary of the Grandfather Mountain window.

CHILHOWEE GROUP

The quartzite, arkosic quartzite, and phyllite which compose the bulk of the Tablerock thrust sheet are correlative with the Chilhowee Group (Early Cambrian(?) and Early Cambrian) of the Unaka belt. These rocks show abundant lithologic similarities to rocks of the Chilhowee Group in northeastern Tennessee (King and Ferguson, 1961), and they also lie stratigraphically below the Shady Dolomite of Early Cambrian age. Rocks of the Chilhowee Group in the Linville Falls quadrangle are unfossiliferous, except for a few occurrences of the worm tube, *Scolithus;* rocks of the Chilhowee Group elsewhere are only very rarely fossiliferous (Keith, 1903; King, 1949; King and Ferguson, 1961).

The Chilhowee Group in the quadrangle differs from the Grandfather Mountain Formation as follows: The arenaceous rocks are generally less arkosic; conglomerate is scarce and volcanic rocks are lacking; the stratigraphic units have greater continuity; the occurrence of detrital tourmaline, which is very scarce in arenaceous rocks of the Grandfather Mountain Formation, is widespread.

Rocks of the Chilhowee Group in the Tablerock thrust sheet have been subdivided into two quartzite units separated by a thin phyllite unit, which is the only mappable marker horizon in the sequence. Because of their isolated tectonic position, however, no attempt has been made to assign these rocks to formations known within the Chilhowee Group in the Unaka belt. Certainly part of or all the Erwin Formation of Early Cambrian(?) age is represented in the thrust sheet, and lower strata may be correlative with older formations of the Chilhowee Group.

Complexity of folding and discontinuity of exposures preclude an accurate estimate of the stratigraphic thickness of the Chilhowee

Group in the Tablerock thrust sheet. Estimates based on structural sections, however, indicate that at least 4,000 feet of Chilhowee beds are present.

LOWER QUARTZITE UNIT

The lowest unit of the Chilhowee Group is a sequence of quartzite, arkosic quartzite, and interlayered green sericite phyllite. It ranges in thickness from about 800 feet along the Linville River south of Shortoff Mountain to at least 2,200 feet on the east side of Linville Mountain opposite the Chimneys.

The unit consists of medium- and fine-grained white, gray, or greenish quartzite and arkosic quartzite containing numerous thin interbeds of green sericite phyllite. The quartzite is generally thin bedded, but massive beds as much as 30 feet thick of medium- and coarse-grained quartzite are common. Much of the quartzite is crossbedded and has dark-blue heavy-mineral streaks parallel to bedding and crossbedding. Angular clasts of pink feldspar as much as 5 mm in diameter are common in some beds. Beds of quartz-pebble conglomerate 6 inches to 5 feet thick occur in a few places near the base of the sequence. A few 10- to 20-foot beds of vitreous white or gray quartzite occur near the top of the unit.

The quartzite consists of a mosaic of recrystallized quartz enclosing detrital grains of strained quartz and angular microcline or microperthite. The feldspar content ranges from a trace to about 15 percent. Scattered flakes and discontinuous fine-grained green-sericite folia define a cleavage parallel to bedding. Accessory heavy minerals—chiefly tourmaline, zircon, sphene, and ilmenite—occur as scattered grains or are concentrated in thin laminae parallel to bedding or crossbedding. The phyllite consists predominantly of fine-grained green sericite but contains recrystallized quartz and small amounts of chlorite and biotite.

The lower few hundred feet of the lower quartzite unit forms prominent cliffs along the west side of the Linville Gorge and on Shortoff Mountain, Tablerock Mountain, and the Chimneys. The higher parts of the sequence generally form more rounded slopes without prominent cliffs.

PHYLLITE UNIT

The lower quartzite unit is overlain by a thin unit of dark phyllite and interbedded fine-grained quartzite. The phyllite unit ranges in thickness from a few feet to as much as 400 feet, but is generally less than 150 feet thick.

The phyllite is a lustrous finely laminated dark-blue, blue-gray, or blue-black rock consisting of folia of fine-grained sericite and thin lenses and laminae of granoblastic quartz, parallel to a strong bedding foliation. The rock contains minor amounts of biotite, chlorite, and opaque minerals and scattered grains of zircon and green tourmaline. The lepidoblastic mica fabric is commonly cut by a slip cleavage which produces minor crenulations on the foliation surfaces.

Interbeds ¼ to 6 inches thick of fine-grained light-gray or blue-gray sugary quartzite are common in the phyllite; locally, layers of blue or white vitreous quartzite 2 to 20 feet thick occur, especially where the phyllite is unusually thick.

Thin beds of similar blue phyllite are interlayered with quartzite in the upper part of the lower quartzite unit and throughout the upper quartzite unit.

UPPER QUARTZITE UNIT

The upper unit of the Chilhowee Group is a sequence of quartzite and arkosic quartzite ranging in thickness from 1,300 to perhaps 2,500 feet. The rocks are thin- to thick-bedded medium- to fine-grained white, greenish-gray, or bluish-gray quartzite and arkosic quartzite. Massive beds of fine-grained white and blue-gray vitreous quartzite are more common than in the lower unit, and phyllite is less common. Phyllite interbeds of this upper quartzite unit resemble the blue phyllite of the middle phyllite unit rather than the green phyllite of the lower quartzite unit.

Small-scale crossbedding is common in the quartzite. Conglomerate is absent. Near the summit of Bald Knob and in a few places on the slopes of Linville Mountain some quartzite beds contain slightly deformed *Scolithus* tubes similar to those common in rocks of the Chilhowee Group elsewhere (King, 1949; King and Ferguson, 1961).

The quartzite typically consists of fine-grained granoblastic quartz, scattered flakes and partings of green sericite, and rarely a few flakes of biotite. Detrital grains of microcline, perthite, and strained quartz 0.5–2 mm in diameter are common. A few beds contain feldspar clasts as large as 1 cm and quartz granules as large as 3 mm in diameter. Magnetite, ilmenite, sphene, zircon, and tourmaline are the chief accessory detrital minerals and are commonly concentrated in streaks parallel to bedding or crossbedding.

The contact of the upper quartzite unit with the overlying Shady Dolomite is exposed along the North Fork of the Catawba River about 1 mile north of Linville Caverns. In this exposure massive white quartzite passes up into 15–20 feet of thin-bedded quartzite and green sericite phyllite overlain by a 6-inch to 1-foot bed containing well-rounded quartz granules, 2–5 mm in diameter, in a calcareous matrix. This bed is directly overlain by Shady Dolomite.

These transitional beds may correspond to the Helenmode Formation of the Chilhowee Group (John Rodgers, oral communication, 1959).

QUARTZITE IN TECTONIC SLICES

Thin slices of quartzite and arkosic quartzite are intercalated with rocks of the Blue Ridge thrust sheet along the Linville Falls fault southeast of the Grandfather Mountain window, and similar slices are common in the Wilson Creek Gneiss south of Dobson Knob and west of Paddy Creek. The slices range from a few inches to 40 feet in thickness. Some can be traced for half a mile along the strike. All the slices in the schist and layered gneiss lie within a few hundred feet of the trace of the fault. Those in the Wilson Creek Gneiss apparently mark minor subsidiary faults.

The quartzite is a fine-grained white, gray, or light-green sugary rock containing dark streaks of heavy minerals and dark-green partings of sericite. Bedding and cleavage are parallel and are conformable with the foliation in the enclosing rocks. Small clastic grains of feldspar are visible in some outcrops, and in a few places small quartz pebbles are present. The quartzite consists of a mosaic of fine-grained quartz, green sericite, and minor amounts of feldspar. Angular to subrounded clasts of potassium feldspar (chiefly microcline and microperthite) generally compose 5–10 percent of the rock. A few clasts of twinned plagioclase occur in some specimens. In a few specimens small flakes of brown biotite are associated with the sericite.

The quartzite closely resembles the quartzite of the Chilhowee Group in the Tablerock thrust sheet, and the slices are interpreted as having been carried up from the buried part of the Tablerock thrust sheet along Linville Falls fault and its subsidiary faults.

SHADY DOLOMITE

Shady Dolomite of Early Cambrian age is exposed in several small areas near the head of North Cove and in the abandoned quarry about 0.5 mile north of Ashford. It may be present locally beneath the alluvial deposits along the North Fork of the Catawba River. It also crops out in the area southeast of Woodlawn in the adjacent Wood Mountain quadrangle, where it is well exposed in a large road-metal quarry about 2 miles west of the edge of the Linville Falls quadrangle.

The formation consists of fine-grained white, light-gray, blue-gray, or buff-gray crystalline dolomite, which is commonly massive or vaguely mottled but locally thin bedded or ribboned. Partings and thin beds of light-gray or green phyllite are common. In some areas the dolomite is silicified to a fine-grained white sugary or porcelaneous rock resembling quartzite. Near Linville Caverns, partially silicified dolomite contains small veinlets and irregular replacements of honey-yellow to black sphalerite accompanied by some chalcopyrite and pyrite.

Bedding is generally not visible in small natural outcrops but is conspicuous in large exposures, especially in the quarries. The small outcrop area of the formation and the complexity of the structure make it impossible to estimate accurately the stratigraphic thickness of the formation exposed in the quadrangle, but Keith (1905) estimated that at least 500 feet of dolomite is exposed near Woodlawn in the Mount Mitchell quadrangle.

No fossils have been discovered in the Shady Dolomite in the Grandfather Mountain window. The Shady is also unfossiliferous in northeastern Tennessee (King and Ferguson, 1961), but a few Early Cambrian fossils have been collected from the formation in southwestern Virginia (Resser, 1938, p. 24–25; Butts, 1940, p. 54–56). The dolomite in the Linville Falls quadrangle is correlated with the Shady Dolomite on the basis of its strong lithologic similarity to the Shady in Tennessee (Keith, 1905; John Rodgers, oral communication, 1959; R. A. Laurence, oral communication, 1958) and its stratigraphic position overlying *Scolithus*-bearing quartzite similar to that of the Erwin Formation of the Chilhowee Group.

ROCKS OF THE BLUE RIDGE THRUST SHEET

Precambrian crystalline rocks, locally intruded by light-colored granodiorite and associated pegmatite of middle or late Paleozoic age, are exposed west of the Grandfather Mountain window in the northwestern part of the quadrangle and southeast of the window between the Linville Falls and the Brevard faults. These rocks form a tectonic sheet which has ridden northwestward across the rocks of the window along the Linville Falls fault. Adjacent to the fault southeast of the window, thin tectonic slices of quartzite similar to quartzite in the Tablerock thrust sheet are intercalated in the overriding block. The Precambrian rocks are predominantly layered granitic gneiss, mica schist, mica gneiss, and amphibolite typical of the crystalline terrane of the Blue Ridge belt in northwestern North Carolina.

Keith (1903, 1905, 1907) mapped the mica schist and mica gneiss as Carolina Gneiss, the predominantly amphibolitic rocks as Roan Gneiss, and the granitic gneiss as Cranberry Granite. Because the terms Carolina Gneiss and Roan Gneiss were applied by Keith and by later workers (for example Keith and Darton, 1901) to similar but probably unrelated rocks in widely separated areas throughout the crystalline belt of the southern Appalachians, these terms have lost their usefulness and have been abandoned by the Geological Survey. The term Cranberry Granite has been modified to Cranberry Gneiss (Bryant, 1962) to better reflect the character of the unit at its type locality.

MICA SCHIST, MICA GNEISS, AND AMPHIBOLITE

The mica schist and amphibolite unit west of the Grandfather Mountain window consists predominantly of biotite-muscovite schist and gneiss but has subordinate amounts of interlayered amphibolite and amphibole gneiss. Locally, the amphibolite predominates over large enough areas to be distinguished on the geologic map.

The mica schist and gneiss are medium- to coarse-grained well-foliated light- to medium-gray rocks consisting of quartz, plagioclase, muscovite, biotite, and garnet, some chlorite and epidote, and accessory amounts of apatite, zircon, sphene, and opaque minerals. Muscovite and biotite flakes are from 0.2 to 10 mm long. The rocks commonly contain knots of pegmatite and porphyroclasts of feldspar. Schist and gneiss are similar in composition and are intimately intercalated in layers a few inches to a few tens of feet thick. A few thin layers are composed of quartz, plagioclase, and biotite or of epidote, quartz, and plagioclase. The strong foliation is generally parallel to the compositional layering and wraps around fold noses, but in a few places it cuts across layering in the noses of isoclinal folds.

Southeast of the Grandfather Mountain window, between the Linville Falls fault and the Brevard fault zone, schist is sheared and retrogressively metamorphosed and contains abundant lustrous sericite and fine-grained chlorite. Commonly bent books of muscovite 0.5–1 cm in diameter occur as porphyroclasts.

The plagioclase is oligoclase in most of the schist and gneiss. In the retrogressively metamorposed rocks southeast of the Grandfather Mountain window, however, albite is common, although relict grains of oligoclase occur locally. Staurolite and kyanite occur in similar rocks in a few places in the Linville quadrangle (Bryant, 1962), but have not been found in the Linville Falls quadrangle except in a few places in the belt between the Linville Falls fault and the Brevard fault zone. In a narrow belt adjacent to the contact with the Cranberry Gneiss west of the Grandfather Mountain window, the schist and gneiss contain albite or sodic oligoclase and abundant epidote and have conspicuous cataclastic features.

The amphibolite and amphibole gneiss are greenish-gray to dark-green rocks which occur in layers a few inches to more than 100 feet thick intercalated in all proportions with the schist and gneiss. They consist predominantly of hornblende and plagioclase (generally oligoclase) and locally contain abundant garnet and epidote. In the belt of lower grade rocks adjacent to the Cranberry Gneiss the plagioclase is albite, and epidote is more abundant.

Layering is marked by differences in proportions of hornblende and plagioclase and by thin intercalations of mica schist and gneiss. Hornblende generally is strongly oriented parallel to a foliation which is parallel to the layering.

The mica schist, mica gneiss, and amphibolite are intercalated in all proportions, and seem to be part of a single stratigraphic sequence (Eckelmann and Kulp, 1956). Metamorphism and deformation, however, have obliterated all details of the original relations between rock units.

CRANBERRY GNEISS

In the Linville Falls quadrangle the Cranberry Gneiss (Cranberry Granite of Keith, 1903) is a heterogeneous unit consisting of layered light- to medium-gray, pink, or pink and green cataclastic granitic gneiss intercalated with darker layers of biotite gneiss, fine-grained biotite-epidote schist, amphibole gneiss, and amphibolite. Locally, the gneiss contains layers and pods of poorly foliated nonlayered granitic rocks.

Layering is conspicuous in most outcrops. Some layers can be traced continuously for several hundred feet. Foliation, which is generally parallel to layering, is produced by orientation of fine-grained micas, mineral aggregates, and porphyroclasts. In a few places blocks of competent rocks, generally amphibolite, have been rotated so that layering in the blocks is at a high angle to layering and foliation in the enclosing gneiss.

The lighter colored, more granitic layers are composed of well-foliated, fine- to medium-grained muscovite-biotite gneiss ranging in composition from quartz diorite to granite but generally having a composition of quartz monzonite. The texture is conspicuously cataclastic and locally blastomylonitic or phyllonitic. The rocks consist of inequigranular mosaics of fine-grained granoblastic quartz, albite, sericite, biotite, epidote, and chlorite surrounding larger grains of microcline, cloudy plagioclase (pseudomorphosed by albite), quartz, and biotite. Porphyroclasts of pink or white microcline or microperthite 2–10 mm in diameter are conspicuous in most of the gneiss.

The darker layers consist of medium- to dark-gray biotite granodiorite or quartz diorite, biotite-hornblende gneiss, amphibolite, or fine-grained biotite-epidote schist.

Locally, the Cranberry Gneiss contains layers and pods of poorly foliated nonlayered medium- to coarse-grained light-colored biotite granite or quartz monzonite. One of these bodies just east of Doe Hill contains hornblende in addition to biotite.

West of the Grandfather Mountain window the contact of the Cranberry Gneiss with the overlying mica schist and amphibolite unit is marked by an abrupt transition from finely layered porphyroclastic granitic biotite gneiss to more thickly layered coarser grained muscovite-biotite schist and gneiss and amphibolite. In the southwestern part of the Linville quadrangle (Bryant, 1962), however, Cranberry Gneiss passes into layered amphibolite and amphibole gneiss of the overlying unit through a transition zone of migmatitic rocks.

Keith (1903) believed that the mica schist and amphibolite were intruded by the Cranberry. The contact was interpreted by Eckelmann and Kulp (1956) as a stratigraphic contact between two groups of isochemically metamorphosed rocks, but Bryant (1962) has shown that it can better be interpreted as a boundary between granitized and nongranitized rocks. Some of the nonlayered granitic bodies are probably of intrusive origin, as was suggested by Eckelmann and Kulp (1956).

Isotopic ages of zircons from Cranberry Gneiss in adjacent areas (Tilton and others, 1959) indicate that the plutonic metamorphism which produced the Cranberry Gneiss occurred 1,000–1,100 million years ago. The Cranberry Gneiss and the mica schist and amphibolite unit are therefore assigned to the Precambrian.

The Cranberry Gneiss in the Linville Falls quadrangle is continuous with the Cranberry Gneiss at its type locality in the Linville quadrangle (Keith, 1903; Bryant, 1962) and with rocks mapped as Henderson Granite by Keith (1905) in the Mount Mitchell quadrangle (Eckelmann and Kulp, 1956). The Henderson Granite mapped by Keith northwest of the Catawba River in the Mount Mitchell quadrangle is probably part of the Cranberry Gneiss.

GRANODIORITE AND PEGMATITE

The mica schist, gneiss, and amphibolite of the Blue Ridge thrust sheet are intruded by irregular stocks, pods, and sill-like bodies of medium- to coarse-grained white granodiorite (Spruce Pine Alaskite of Hunter and Mattocks, 1936, and subsequent workers) and by pods, lenses, and stringers of related muscovite pegmatite. These bodies have not been found in the adjacent Cranberry Gneiss or in rocks in the Grandfather Mountain window.

The granodiorite is composed of sodic oligoclase, microcline and microperthite, muscovite, and minor amounts of biotite, garnet, and apatite. Many rare minerals have been reported in small amounts from the pegmatite (Olson, 1944; Kulp and Brobst, 1956). All gradations from granodiorite to coarse-grained pegmatite occur. The granodiorite tends to be more uniform in composition than the pegmatite.

In the larger bodies the rock is weakly foliated, but in smaller bodies intense cataclastic foliation is conspicuous in outcrop and hand specimen. Porphyroclasts of potassium feldspar, plagioclase, and quartz and large books of bent muscovite are surrounded by mosaics of coarsely recrystallized plagioclase, quartz, microcline, and parallel flakes of muscovite. Partings of fine-grained green sericite occur along some of the foliation planes. Scattered red garnets, a few as large as 3 inches in diameter, are common in some of the pegmatite and granodiorite bodies.

The granodiorite and pegmatite have been sheared and partially recrystallized during the latest metamorphism under the same metamorphic conditions as the wallrocks. Keith (1903) recognized the polymetamorphic character of the wallrocks and concluded that the pegmatite had been intruded after the earliest metamorphism but prior to the latest; Kulp and Poldevaart (1956), however, failed to recognize the cataclastic character of the pegmatite.

Chemical age determinations on uraninite from pegmatite in the interior of the Spruce Pine district range from 330 to 365 million years (Eckelmann and Kulp, 1957), whereas nearly concordant lead-uranium isotopic ages range from 345 to 390 million years (Eckelmann and Kulp, 1957; Tilton and others, 1959). Potassium-argon ages of micas from the pegmatite and from the wallrocks average about 340 million years. These determinations date a major metamorphism during middle or late Paleozoic time. Because the effect of shearing and recrystallization on uraninite and other pegmatite minerals used for age determination is not yet well understood, it is not clear whether the pegmatite was intruded during the metamorphism, as is generally assumed, or whether it was intruded earlier and the contents of lead and uranium in the uraninite changed during the metamorphism.

GNEISS SOUTHEAST OF THE GRANDFATHER MOUNTAIN WINDOW

Between the Linville Falls fault southeast of the Grandfather Mountain window and the Brevard fault zone the Blue Ridge thrust sheet is composed predominantly of fine-grained generally nongranitic gneiss interleaved with biotite-muscovite schist. Most of the rocks in this belt are strongly sheared and retrogressively metamorphosed. Except for its retrogressive character, the schist resembles schist in the mica schist, mica gneiss, and amphibolite unit west of the Grandfather Mountain window, and where schist predominates it is mapped with that unit.

The gneiss resembles the Cranberry Gneiss in its layered character and in the composition of its more mafic layers, but overall it is less granitic and is therefore mapped as a separate unit. It is generally a fine- to medium-grained conspicuously layered rock with a prominent foliation parallel to the layering. Feldspar porphyroclasts 0.1–0.5 inch in diameter are common in most outcrops. Individual layers range from less than an inch to several feet in thickness.

The lighter colored layers are composed of quartz and plagioclase in various proportions and subordinate amounts of biotite, muscovite, epidote, and chlorite. In the darker layers biotite is predominant, and chlorite and epidote are abundant. The chief accessory minerals are garnet, sphene, apatite, and opaque minerals. In a few specimens small relict grains of kyanite, now largely replaced by sericite, have been found.

Most of the biotite and muscovite appear to have formed during the latest episode of shearing and retrogressive metamorphism, but older bent porphyroclastic grains are common. Chlorite appears to have formed at a late stage of the retrogressive metamorphism, largely at the expense of biotite and garnet.

The feldspar porphyroclasts are chiefly albite or sodic oligoclase with bent or broken twin lamellae, but locally more calcic plagioclase occurs. Some specimens also contain small porphyroclasts of potassium feldspar. The fine-grained plagioclase is albite.

The gneiss commonly contains thin layers and pods of dark fine- to medium-grained amphibolite and quartz-plagioclase-hornblende gneiss. The layered gneiss and the interleaved schist locally contain abundant pods and layers of medium- to coarse-grained highly cataclastic muscovite pegmatite, having quartz dioritic to quartz monzonitic composition. A few of the larger pegmatite bodies are as much as 15 feet thick, but most are less than 1 foot. They are strongly foliated and appear to have been sheared at the same time as the enclosing rocks.

ROCKS OF THE BREVARD FAULT ZONE

The Brevard fault zone (fig. 1) is a narrow belt of thoroughly sheared rocks that separates rocks of the Blue Ridge thrust sheet on the northwest from rocks of the Inner Piedmont belt on the southeast. In the Linville Falls quadrangle the fault zone ranges in width from a few hundred to more than 5,000 feet and contains blastomylonite and strongly retrogressively metamorphosed schist and gneiss of different aspect than the adjacent rocks. Elongate bodies of layered gneiss, similar to gneiss in adjacent parts of the Inner Piedmont belt, occur within the fault zone. They are probably tectonic slices and are therefore described with the Inner Piedmont rocks.

PHYLLONITIC SCHIST AND GNEISS

Sheared and retrogressively metamorphosed mica schist with interlayered fine-grained biotite gneiss form a distinctive unit within the Brevard fault zone. These rocks are more thoroughly retrograded than the adjacent gneiss and schist, and lack the pegmatite layers and pods which are abundant both in rocks of the Blue Ridge thrust sheet and the Inner Piedmont belt.

The schist is a lustrous green or silvery-gray rock containing abundant sericite, fine-grained chlorite, and porphyroclasts of bent muscovite largely altered to sericite aggregates. In outcrop, these aggregates resemble large fish scales scattered on the foliation surfaces. Locally, garnets 0.1–0.2 inch in diameter are abundant in the schist; in some places they are unaltered and display rhomb dodecahedral faces, but more commonly they are partially or completely replaced by chlorite.

The rock is composed chiefly of sericite, chlorite, quartz, and muscovite, and smaller amounts of biotite and very sparse plagioclase (albite or sodic oligoclase). Garnet, tourmaline, epidote, apatite, and opaque minerals are common accessories. In thin section, the rock displays a lepidoblastic texture. Folia of fine sericite, chlorite, and synkinematic biotite interleaved with laminae of recrystallized quartz define a strong foliation. Muscovite porphyroclasts, or sericite aggregates replacing them, are generally parallel to the foliation, but some are broken and rotated and a few are bent nearly double. Many of them display flattened rhombic cross sections. Garnet occurs in idioblastic sieve-textured grains, many of which display helicitic structure.

The schist commonly contains layers of fine-grained light- to dark-gray conspicuously layered gneiss. Locally, gneiss composes the bulk of the unit. The gneiss consists principally of biotite, plagioclase, and quartz in various proportions and contains small amounts of garnet, epidote, and chlorite. It contains a few muscovite porphyroclasts similar to those in the schist. Locally, the gneiss and schist contain thin layers of fine-grained recrystallized feldspathic quartzite and quartz-epidote rock. Fine-grained amphibolite forms small pods and layers, but amphibolite is much less abundant in this unit than in the adjacent rocks.

The source of the schist and gneiss in the Brevard fault zone is not clear. The rocks differ from the rocks adjacent to the fault zone anywhere in the Grandfather Mountain area, and are therefore probably a tectonic lens of rocks derived from outside the area.

BLASTOMYLONITE AND RELATED ROCKS

The blastomylonite is very fine-grained or aphanitic flinty rock that is generally gray, greenish gray, buff, or pink and that is characterized by a dull, waxy luster. Many specimens superficially resemble slightly metamorphosed fine-grained volcanic rocks. Feldspar porphyroclasts 0.5–1 cm in diameter are common and, locally, they are as much as 1 foot in diameter. The larger porphyroclasts were probably derived from pegmatite. The rocks are composed of fine-grained mosaics of quartz and feldspar containing scattered flakes and wavy folia of sericite, biotite, and chlorite. Foliation is well defined in most specimens by lentils of coarser and finer grained mosaic, quartz segregation laminae, and by the micaceous folia. The feldspar porphyroclasts are microcline, patch perthite, and oligoclase. Porphyroclasts of muscovite are common in some specimens. Some of the rocks are breccia in which angular fragments of microcrystalline pseudoisotropic mylonite are set in the more coarsely recrystallized matrix. The microcrystalline fragments and coarser granoblastic mosaic are cut by anastomosing zones of quartz-feldspar mortar and microbreccia. Blastomylonite derived from more mafic rocks contains abundant chlorite and epidote, and some has small porphyroclasts of hornblende and sphene.

The blastomylonite has generally well-defined foliation but some is nonfoliated. Layering is scarce. In general, the foliation is parallel to the contacts of the blastomylonite zone and to foliation in the enclosing rocks, but local variations are common. Cataclastic gneiss and schist are intimately associated with the blastomylonite, and the contacts of the zone are transitional. Thin layers of blastomylonite are found in the schist and gneiss on either side of the main blastomylonite zone, but they are not large enough to distinguish on the map; they generally are parallel to the main blastomylonite belt and to the foliation in their wallrocks.

ROCKS OF THE INNER PIEDMONT

The rocks southeast of the Grandfather Mountain window form a complex metamorphic terrane of layered biotite and hornblende gneiss, amphibolite, muscovite and muscovite-biotite schists, and large concordant sheets of cataclastic augen gneiss. Several pods of ultramafic rock occur in the layered gneiss and schist, and near the southeastern corner of the quadrangle the layered gneiss has been invaded by irregular semiconcordant plutons of biotite-quartz monzonite.

All these rocks except the biotite-quartz monzonite are polymetamorphic. Throughout most of the Inner Piedmont part of the quadrangle the latest metamorphism was of medium or high grade, but adjacent to the Brevard fault zone medium-grade rocks were sheared and retrogressively metamorphosed under low-grade conditions.

The age of most of the Inner Piedmont rocks is unknown, and rocks of widely different ages may be present. The youngest granitic rock is probably of Paleozoic age. Keith and Sterrett (1954) mapped the schist and gneiss as Carolina Gneiss and believed them to be Archean. The rocks, however, differ from the rocks mapped as Carolina Gneiss by Keith (1903, 1905) in the Blue Ridge thrust sheet, and the correlation of the two groups of rocks is unlikely.

Similar rocks in other areas in the western part of the Piedmont contain micas, which on the basis of potassium-argon age determinations, are about 350 million years old (Long and others, 1959; Kulp and Eckelmann, 1961). This indicates that the last episode of metamorphism of the Inner Piedmont rocks occurred during middle or late Paleozoic time (Kulp, 1961). Farther to the southeast, however, there is evidence that the latest period of metamorphism occurred in late Paleozoic time, about 250 million years ago.

GNEISS AND SCHIST

Biotite-plagioclase gneiss intercalated in all proportions with muscovite and muscovite-biotite schist is the most abundant rock type in the Inner Piedmont. Contacts between areas of predominant schist and predominant gneiss are gradational, exposures are scarce, and colluvium, thick. Contacts indicated on the map are diagrammatic at best.

The typical gneiss is a fine-grained well-layered light-, medium-, or dark-gray rock consisting of quartz, plagioclase, biotite, and subordinate muscovite, epidote, hornblende, potassium feldspar, and garnet. Common accessory minerals are zircon, sphene, orthite, tourmaline, pyrite, magnetite, and ilmenite. Textures are granoblastic and lepidoblastic. Quartz and plagioclase form an inequigranular sutured granoblastic mosaic ranging from 0.05 to 0.3 mm in grain size. Biotite occurs in scattered flakes and discontinuous wisps which define a foliation which generally is parallel to layering, but which locally transects layering at high angles. Porphyroclasts of plagioclase 5–10 mm in diameter are common in some layers. Porphyroclastic sheaves and bent flakes of muscovite as long as 10 mm are also widespread. Garnet occurs both as small grains in the quartz-plagioclase mosaic and as larger skeletal grains which may be porphyroblasts. Potassium feldspar occurs locally, both as porphyroclasts and as small recrystallized grains; it is especially common in the layered gneiss near the contacts with Henderson Gneiss and the quartz monzonite.

Layers range from less than an inch to several feet in thickness. In areas of good outcrops layers and groups of layers can be traced for several hundred feet along the strike without significant variations in thickness. Differences in color and texture between layers are mainly due to variations in the proportions of quartz, feldspar, and biotite. A very light gray or white fine-grained rock composed of quartz, plagioclase, and epidote forms local layers a few inches to several tens of feet thick.

The mica schist is a fine- to coarse-grained medium- to dark-gray or greenish-gray rock composed of muscovite, biotite, quartz, and plagioclase. The rock commonly contains garnets 0.15–15 mm in diameter. Coarse muscovite and biotite flakes are strongly oriented in wavy folia and layers separated by irregular laminae of finer grained granoblastic quartz and plagioclase and containing small flakes of new biotite and muscovite. Scattered porphyroclasts of plagioclase are common in the schist. The schist occurs as thin layers intercalated in all proportions with the gneiss and also as fairly homogeneous bodies containing only occasional layers of gneiss.

Amphibolite and hornblende gneiss layers ranging from less than an inch to at least 50 feet in thickness are interlayered with the gneiss and schist, but nowhere are amphibolite layers large enough to be delineated on the map. The amphibole-bearing rocks are fine- to medium-grained and medium- to dark-green or gray-green. They consist of nematoblastic-granoblastic mosaics of green hornblende and interstitial granoblastic plagioclase and quartz, and commonly contain skeletal garnets and poikilitic grains and aggregates of epidote. One specimen of amphibolite from near the southeastern corner of the quadrangle contains abundant grains of diopsidic augite that appear to be contemporaneous with the hornblende.

Quartz schist, fine-grained gray micaceous quartzite, calcareous quartz-mica schist, and thin layers of marble rarely form intercalations in both schist and gneiss. Thicker layers of marble occur near Marion southwest of the Linville Falls quadrangle (Conrad, 1959).

Sillimanite, kyanite, and staurolite occur in the gneiss and schist at a few localities (pls. 2, 3), but these minerals are so widely scattered that it has not been possible to map isograds. Sillimanite is confined to an area between Grandview Church and Willow Tree School in the southeastern part of the quadrangle. Staurolite and kyanite occur farther to the northwest and are present at a few localities adjacent to the Brevard fault zone. They seem to be synkinematic or postkinematic in relation to the last deformation southeast of the fault zone, but near the zone they are jacketed with sericite or occur as relict grains in sericite aggregates and appear to have formed before shearing and retrogressive metamorphism along the Brevard.

In the southeastern part of the quadrangle, to within less than a mile of the Brevard fault zone, plagioclase in the schist and gneiss is generally andesine or calcic oligoclase. Farther to the northwest the plagioclase is generally albite or sodic oligoclase, although more calcic plagioclase occurs locally, especially in rocks containing kyanite or staurolite. Epidote, chlorite, and sericite are widespread in these rocks, and cataclastic textures and retrogressive metamorphic effects are conspicuous.

ULTRAMAFIC ROCKS

Several small pods of magnesian schist derived from ultramafic rock occur in the schist and layered gneiss. The largest of these is about 0.7 mile long and 0.1 mile wide and lies about 1 mile northeast of Zion Church on North Carolina State Route 181.

The magnesian schists are lustrous fine- to medium-grained dark gray-green rocks containing knots (0.5–1 cm in diameter) of light-green or gray amphibole that are conspicuous on weathered surfaces. Schistosity is generally well defined, but near the centers of some of the bodies the rocks are nonfoliated. The magnesian schists are largely composed of tabular aggregates of prochlorite(?) interleaved with magnetite and small flakes and aggregates of talc. Colorless to light-green amphibole occurs in ragged prisms and poikilitic grains and in tiny needles interwoven with chlorite. Relict poikilitic grains of clinopyroxene (diopside?) occur in most specimens. Several specimens also contain relict grains of olivine that are partially replaced by aggregates of antigorite(?).

The relative ages of the ultramafic rocks, the Henderson Gneiss, and quartz monzonite are not well established. At one locality on the south side of the Linville Arm of Lake James, 1.5 miles southeast of the mouth of the Linville River, a small body of biotitized and feldspathized ultramafic rock occurs adjacent to a body of Henderson Gneiss; this evidence suggests that the ultramafic body is the older.

HENDERSON GNEISS

The Henderson Gneiss is a fine- to medium-grained biotite-quartz monzonite augen gneiss that occurs in concordant bodies enclosed in the layered gneiss and schist. The gneiss is strongly foliated and lineated but is generally nonlayered except near the contacts, where a rude layering is defined by differences in grain size and amounts of biotite and feldspar porphyroclasts. Along the contacts, and especially near the ends of the larger bodies, the gneiss is interlayered with fine-grained layered gneiss and schist. Reconnaissance shows that most of the rock mapped by Keith (1905, 1907) as Henderson Granite in its type area in Henderson County, N.C., is identical with the quartz monzonite augen gneiss in the Linville Falls quadrangle, although some layered granitic gneiss and even-grained granitic rocks were included in the unit. The name Henderson is therefore applied to the augen gneiss in the Linville Falls quadangle, but the lithologic designation is changed from granite to gneiss to better describe the lithology of the unit.

The gneiss is a light- to medium-gray rock containing abundant gray or white feldspar porphyroclasts 0.2–0.8 inch long. The porphyroclasts are generally lentil shaped and are strongly alined parallel to the regional northeastward-trending lineation. In a few places the gneiss contains porphyroclasts as much as 8 inches long, probably derived from pods and layers of pegmatite. Locally, porphyroclasts are absent in the gneiss, perhaps owing to intense cataclasis.

The bulk of the rock consists of an inequigranular granoblastic-lepidoblastic mosaic of quartz, plagioclase (chiefly calcic oligoclase), potassium feldspar, biotite, muscovite, epidote, and small amounts of chlorite, garnet, and green hornblende. The grains in the mosaic are 0.01–0.1 mm in diameter. Foliation is defined by segregation lamellae of quartz and feldspar and by diffuse folia of biotite and muscovite. Biotite occurs in small irregular flakes and grains and appears to be largely late synkinematic and partly postkinematic. Muscovite appears to be largely contemporaneous with the biotite, but a few specimens contain large bent porphyroclasts of old muscovite. Epidote occurs as scattered grains and poikilitic grains and aggregates; some have orthite cores. Some specimens contain small skeletal garnets.

The feldspar porphyroclasts are chiefly microcline and microcline-microperthite, but some twinned plagioclase porphyroclasts occur. The potassium feldspar porphyroclasts have ragged outlines and are jacketed by mosaics of quartz, plagioclase, myrmekite, and recrystallized potassium feldspar in which the grains are slightly coarser than in the adjacent groundmass. Commonly, the porphyroclastic grains have been broken and the fractures healed by the mosaic.

The chief accessory minerals in the gneiss are magnetite, sphene, apatite, and light-pink or orange zircon. The zircon occurs in euhedral elongate prisms, some as long as 0.5 mm.

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QUARTZ MONZONITE

Irregular sill-like bodies of medium-grained biotite quartz monzonite invade the schist and layered gneiss near the southeastern corner of the quadrangle. The quartz monzonite is a light- to medium-gray rock which ranges in character from uniform, nonlayered, and weakly foliated to strongly gneissic and well foliated. It typically contains biotitic schlieren and scattered feldspar megacrysts as much as 1 inch in diameter.

The quartz monzonite bodies are generally concordant with the structural trends of the enclosing rocks but are locally discordant. Foliation in the quartz monzonite is parallel or subparallel with the contacts. Near contacts, the quartz monzonite is intimately intercalated with the enclosing rocks, and locally contains inclusions of schist, gneiss, and amphibolite. Amphibolite inclusions are surrounded by biotitic reaction selvages 0.5–1 inch thick.

The quartz monzonite consists of an allotriomorphic granular mosaic of quartz, microcline, plagioclase (calcic oligoclase), biotite, muscovite, and small amounts of epidote. The quartz and feldspar grains average 1–3 mm in diameter. Biotite and muscovite occur as fresh stubby flakes and irregular poikilitic grains, generally without noticeable preferred orientation but strongly oriented in some specimens. Some sericite occurs as tiny inclusions in feldspar, and as fringes on the ends of larger muscovite flakes against feldspar.

Heavy minerals consist of abundant light-amber euhedra of xenotime, small colorless and light-pink prisms of zircon, euhedral or subhedral orange or yellow-orange grains of monazite, and broken smoky-gray prisms of tourmaline.

The quartz monzonite has not been found in contact with the Henderson Gneiss, but its general lack of cataclastic textures and structures and its local discordance with the regional structural trends suggest that it is younger. The quartz monzonite is similar in composition, structural habit, and heavy-mineral content to the Toluca Quartz Monzonite in the Shelby area (Griffiths and Overstreet, 1952; Overstreet and Griffiths, 1955) and occurs along the strike of bodies of Toluca Quartz Monzonite southeast of Morganton described by Overstreet and Griffiths (1955). However, the correlation between the rock in the Linville Falls quadrangle and the Toluca Quartz Monzonite at its type locality remains to be proved by detailed mapping of the intervening area. Recent radiometric age determinations on minerals from the Toluca Quartz Monzonite at its type locality (Jaffe and others, 1959; Davis and others, 1962) show that it is of early Paleozoic age, probably Ordovician, and the quartz monzonite in the Linville Falls quadrangle is therefore assumed to be early Paleozoic.

PEGMATITE

Pods and layers of quartz-feldspar pegmatite are common in most of the rocks of the Inner Piedmont, but nowhere are the pegmatite bodies large enough to distinguish on the geologic map. Most of the bodies are parallel to the foliation of the enclosing rocks. They range in thickness from a few inches to several tens of feet, and a few can be traced along the strike for as much as a hundred feet. Adjacent to the Brevard fault zone, many exhibit advanced cataclastic textures, and some appear to be boudins derived from original dikes or sill-like bodies.

The pegmatite consists of variable proportions of quartz, oligoclase, and potassium feldspar and generally contains small amounts of muscovite, epidote, and biotite. In the coarser pegmatite, feldspar grains are 2–6 inches in diameter. Muscovite occurs as stubby prisms or bent sheets which seldom exceed 2 inches in diameter.

The pegmatite contains euhedral amber xenotime, euhedral to subhedral orange to yellow-orange monazite, and euhedral prisms of zircon. This heavy-mineral suite is nearly identical with that of the quartz monzonite and is unlike that recovered from any other rock in the area. These pegmatite bodies, and presumably most of those in this part of the Inner Piedmont, are therefore inferred to be related to the quartz monzonite. Because most of the pegmatite bodies are sheared and boudinaged, the emplacement of the pegmatite probably occurred slightly before the intrusion of the quartz monzonite.

SURFICIAL DEPOSITS

RESIDUAL AND COLLUVIAL DEPOSITS

Deep chemical weathering has produced saprolite and residual soils mantling most of the bedrock. Because these materials are so widespread, they have not been distinguished from the bedrock units on the geologic map. Saprolite is present on almost all bedrock types but is most abundant on feldspar-rich rocks such as the quartzofeldspathic gneisses and the more feldspathic schists and arenites. Quartz-rich rocks, such as the cleaner quartzite in the Tablerock thrust sheet, and highly micaceous rocks, such as phyllite and phyllonite, are the most resistant to the formation of saprolite. Saprolite is most widespread in the Inner Piedmont, but it occurs at all altitudes, and is present throughout the mountainous parts of the quadrangle, especially on the level parts of the Blue Ridge upland. On the Blue Ridge front, it is confined to ridge crests and to pockets on the gentler slopes. The exposed thickness of the saprolite blanket ranges from a few inches to more than 50 feet, but the blanket may be thicker than 100 feet on the level interfluves of the Piedmont.

Formation of saprolite in a quartzofeldspathic rock typically begins with alteration of the feldspar grains to a chalky white appearance. Plagioclase is attacked before potassium feldspar and is reduced to white clay pseudomorphs. At this stage biotite and hornblende remain fresh, so that although the rock is friable or even completely unconsolidated it retains nearly its original color. At a later stage, decomposition of the potassium feldspar to clay is completed, biotite is leached to a bronze color, and hornblende is reduced to a rusty limonitic boxwork. The saprolite is stained yellow, orange, brown, or red by the liberated iron oxides. It retains undisturbed linear and planar structures of the parent rock although finer textural details are lost.

Where the soil has not been transported, the saprolite passes upward with gradual loss of structure into clayey residual soil, generally containing angular fragments of vein quartz and small mica flakes. In the Inner Piedmont, residual soils are brick red, but at higher elevations they are generally brown.

Many of the soils overlying saprolite have evidently been transported by colluvial or alluvial processes, for in many exposures the red clay soil is separated from the underlying saprolite by a thin layer of angular quartz gravel or by a layer of rounded alluvial gravel.

Parizek and Woodruff (1957) discussed such stone layers, which they concluded reflect a period of runoff (perhaps during the Pleistocene) that resulted in extreme dissection of the steeper slopes and the formation of extensive stone-covered surfaces on gentler slopes. This period was followed by a period of different erosional conditions during which the clay soil overlying the stone layers was transported by colluvial processes.

ALLUVIAL DEPOSITS

ALLUVIAL FAN DEPOSITS

Alluvial fans are widespread in the mountainous parts of the quadrangle, but they are shown on the geologic map only where they cover extensive areas or obscure contacts between bedrock units. The fan deposits consist of coarse rudely stratified angular debris, locally containing blocks as much as 40 feet in diameter. The blocks are generally in a matrix of sandy silt or clay. Locally, however, the fine interstitial material has been removed, and a chaotic jumble of boulders is left. Organic remains have not been found in any of the fan deposits.

Many fans grade into talus slopes or boulder trains at their heads, and pass smoothly downvalley into coarse flood-plain alluvium. The fan surfaces slope as much as 2,000 feet per mile near their heads, but the slope decreases downvalley to less than 200 feet per mile at the distal edges of large fans. The surfaces are gently convex in transverse section, and streams commonly flow along the edges of the fans between the fan material and the valley sides. Many fans are trenched by narrow gullies having nearly vertical sides, some as deep as 40 feet. Most of the fans are less than 50 feet thick, but more than 100 feet of fan materials is exposed west of Dobson Knob and on the west side of the valley of the North Fork between Linville Caverns and Ashford. The fan deposits commonly rest on saprolite derived from rocks similar to those which compose unweathered boulders in the fan. This suggests that some of the fans have been deposited subsequent to the formation of the saprolite beneath them.

On the western side of the North Fork about 1 mile south of Linville Caverns, streamcuts expose fan materials in which the component gneiss and schist boulders are completely saprolitized. These ancient fan deposits have no recognizable topographic expression, and rise as low hills and ridges above the surface of younger fans in which boulders are fresh or slightly weathered.

The alluvial fans clearly indicate a long and complex depositional history. Some of the deposits may be pre-Quaternary, though others are undoubtedly of Recent age.

HIGH-LEVEL GRAVELS

Well-rounded alluvial gravels cap terraces along some of the major streams and a few interfluves in the Piedmont near the base of the Blue Ridge.

The largest of the high-level gravel deposits on the Piedmont interfluves are south and southeast of Dobson Knob and on the ridge east of Paddy Creek around Longtown. The surface of the gravel deposit south of Dobson Knob extends to an altitude of about 1,700 feet; near Longtown it is at an altitude of about 1,400 feet. Scattered pebbles and thin sandy pockets on the flat ridges near Oak Hill and southeast of Willow Tree School may be remnants of similar deposits.

The gravel on these terraces and interfluves consists exclusively of weathered cobbles and boulders of quartzite derived from quartzites in the Tablerock thrust sheet. The deposits close to the foot of the Blue Ridge contain boulders as much as 5 feet in diameter; near Longtown the size of the gravel ranges from 6 inches to about 2 feet. Some of the gravel deposit near the foot of Dobson Knob may be as much as 100 feet thick, but the base is not exposed and its position is obscured by downslope creep of the overlying gravel. Near Longtown roadcuts expose a 5-foot gravel layer resting on saprolitized bedrock and overlain by 5–10 feet of red clay soil. Cobbles in the gravel layer have weathered rinds of friable sand as much as 2 inches thick. The matrix of the gravel is mottled red and gray clayey sand. The weathered condition of this gravel and the position of the gravel on interfluves as much as 150 feet above the present flood plains indicate that the gravel is one of the oldest alluvial deposits in the quadrangle and that it may be of pre-Quaternary age.

High-level terraces have been mapped along many of the major streams. These terraces occur at various altitudes as much as 80 feet above the present flood plains. They are discontinuous and exhibit no particular concordance in level, even along a single master stream. They are generally floored by slightly weathered gravel (commonly quartzite or vein quartz) which rests on bedrock or bedrock saprolite and which is overlain by yellow, gray, or white alluvial sand, silt, and clay. The terrace deposits are generally less than 20 feet thick. They are commonly overlain by a red clayey soil, probably partly derived from weathering of the terrace materials and partly of colluvial origin.

The generally less weathered condition of most of the terrace gravel, its thinner cover of red clay, and its direct relation to the present drainage show that it is younger than the gravel on the interfluves. The terrace gravel probably represents flood-plain remnants of various ages.

FLOOD-PLAIN DEPOSITS

Except in areas of extreme local relief, most streams in the quadrangle are flanked by broad, gently sloping flood plains into which they are incised to depths of as much as 20 feet. In the mountains, the flood-plain materials consist predominantly of rudely stratified coarse gravel and sand, locally overlain by a thin layer of fine sand and silt.

In the Piedmont, the deposits typically consist of a layer 6 inches to 5 feet thick of rudely stratified sand and gravel, commonly underlain by saprolite and overlain by clay and sandy clay containing scattered pebbles. The clay is dark blue or blue gray at its base and passes upward through shades of gray into yellow or brown clay at the top. The blue-gray clay locally contains thin peaty layers and wood fragments near the base. The fact that the entrenched streams commonly expose bedrock or bedrock saprolite indicates that the flood-plain deposits rarely exceed 20 feet in thickness. The flood plains are commonly flanked by low terraces underlain by similar materials, which are mapped with the flood-plain deposits.

STRUCTURE AND METAMORPHISM

Each of the major tectonic blocks in the Linville Falls quadrangle has a complex structural and metamorphic history. Correlation of events which have affected rocks in different tectonic blocks is hindered by structural complexity, lack of fossils, and scarcity of absolute age determinations, and so it is not yet possible to establish a complete structural and metamorphic chronology. The structural and metamorphic features of each tectonic block are therefore discussed separately but are summarized in table 1 and plate 3.

AUTOCHTHONOUS ROCKS IN THE GRANDFATHER MOUNTAIN WINDOW

STRUCTURE

All the autochthonous rocks in the Grandfather Mountain window exhibit a similar structural pattern (fig. 1 and pl. 3). A well-defined regional cleavage strikes northeast and dips on the average 40°–50° SE. Intense cataclastic lineation, marked by elongation of mineral grains and aggregates, plunges southeastward down the dip of the cleavage throughout most of the window, but in a narrow belt adjacent to the southeastern edge of the window the trend of the lineation swings to the south. A few variations from the regional pattern occur locally in other parts of the window, but they are uncommon and apparently have no regional significance.

In the plutonic gneiss of Precambrian age, the regional cleavage is a cataclastic foliation marked by the folia of new mica and segregation laminae and lenses of feldspar and recrystallized quartz. In the overlying upper Precambrian rocks, it is a flow cleavage or slip cleavage marked by orientation of mica parallel to the axial planes of tight asymmetric folds overturned to the northwest. Axes of minor folds and crenulations and bedding-cleavage intersections strike northeast, parallel to the strike of the cleavage and normal to the cataclastic lineation.

METAMORPHISM

Discordant lead / uranium ages of zircon show that the Wilson Creek Gneiss formed during a Precambrian plutonic episode 1,000–1,100 million years ago and that lead was lost from the zircon 350–400 million years ago (Tilton and others, 1959). The upper Precambrian rocks had not been deposited at the time of the Precambrian metamorphism.

The upper Precambrian rocks have been progressively metamorphosed to the assemblages of the greenschist facies. Rocks containing excess potassium are characterized by new biotite, sericite, and albite; potassium-deficient rocks contain chlorite, actinolite,

TABLE 1.—*Summary of principal metamorphic events in the Linville Falls quadrangle, North Carolina*

Unit	Geologic age	Event	Absolute age
BLUE RIDGE THRUST SHEET	Late(?) Paleozoic	Thrusting along Linville Falls fault	Absolute age unknown
	Middle or late Paleozoic	Low-grade retrogressive metamorphism of Cranberry Gneiss	Absolute age unknown
	Middle or late Paleozoic	Medium-grade regional metamorphism. Emplacement of pegmatites and granodiorite	About 350 my
	Precambrian	Plutonic metamorphism. Formation of Cranberry Gneiss	About 1,100 my
GRANDFATHER MOUNTAIN WINDOW	Late(?) Paleozoic	Thrusting along Tablerock fault	Absolute age unknown
	Early or middle Paleozoic	Low-grade progressive metamorphism of Cambrian and upper Precambrian rocks and retrogressive metamorphism of Precambrian granitic rocks	Absolute age unknown
	Precambrian	Plutonic metamorphism. Formation of Wilson Creek Gneiss and Blowing Rock Gneiss. Emplacement of Brown Mountain Granite	About 1,100 my
INNER PIEDMONT	Late Paleozoic(?)	Movement along Brevard fault; formation of blastomylonite; low-grade retrogressive metamorphism adjacent to fault zone	Absolute age unknown
	Early (?) Paleozoic	Middle- and high-grade regional metamorphism; emplacement of syntectonic quartz monzonite and pegmatite	Absolute age unknown
	Precambrian or early Paleozoic	Emplacement of rock later metamorphosed to Henderson Gneiss. (Regional metamorphism of gneiss and schist?)	Absolute age unknown

epidote, and albite. The Precambrian plutonic rocks have been metamorphosed retrogressively to a similar grade. They contain new biotite, sericite, albite, and epidote, accompanied by porphyroclasts of potassium feldspar, plagioclase, and biotite which are relics of the plutonic metamorphism. Except for evidence that it occurred after deposition of the upper Precambrian rocks probably during the early or middle Paleozoic, the low-grade metamorphism has not been dated. Perhaps the lead loss from zircon in the Wilson Creek Gneiss at 350–400 million years was concurrent with the episode of low-grade metamorphism.

The structural and petrographic relations show that the regional pattern of cleavage, fold axes, and cataclastic lineation were impressed on the autochthonous rocks during the episode of low-grade metamorphism. The phyllonite zones in the gneiss of Precambrian age and the thrust faults of small displacement which bound the belts of upper Precambrian rocks in the gneiss were probably formed late in this metamorphic episode.

TABLEROCK THRUST SHEET

STRUCTURE

Most of the small- and medium-scale folds in the Tablerock thrust sheet are isoclinal, or nearly so, and are overturned to the northwest or north. The fold axes generally trend northeast, but locally east-trending axes predominate. In several areas, especially on the north and northwest slopes of Linville Mountain southeast of Ashford and on the west slopes of Dobson Knob, similar folds with north- or northwest-trending axes are common. It is not clear whether north-trending folds are superimposed on older northeast- or east-west-trending folds or whether the north-trending axes are due to local warping or rotation of the older structures.

Cleavage, marked by orientation of fine-grained mica, is generally parallel to bedding in the limbs of the folds. However, in the noses bedding is transected by flow cleavage or slip cleavage in the phyllitic layers and by rude fracture cleavage in the more massive quartzite layers. Cataclastic lineation, marked by elongation of clastic quartz grains, grooving, and streaking of mineral aggregates on the bedding and cleavage planes, trends northwest-southeast parallel to the cataclastic lineation in the autochthonous rocks and has low plunges in either direction. A swing to more southerly lineation trends takes place adjacent to the southeastern boundary of the Grandfather Mountain window.

The Tablerock thrust sheet forms a broad, nearly symmetrical arch whose northeast-trending axis passes through the Pinnacle and southeast of the Chimneys (sections *B–B′*, *C–C′*, pl. 2). Southeast of this axis, bedding and cleavage are parallel, and dip is 15°–40° SE. Medium- and small-scale folds are scarce. Northwest of the axis, axial planes and most fold limbs dip west or north, and complex folds with vertical or overturned limbs are common. In most exposures cleavage appears parallel to bedding, but overall the bedding is highly contorted and dips more steeply than cleavage.

A shallow syncline in the thrust sheet emerges from beneath the Linville Falls fault near Camp Creek and extends northeastward into the Linville quadrangle (Bryant, 1962).

METAMORPHISM

Rocks in the Tablerock thrust sheet have been progressively metamorphosed under dynamothermal conditions to assemblages of the greenschist facies. Detrital textures have been partly destroyed by recrystallization of quartz. The arenaceous and argillaceous layers contain abundant sericite and locally small amounts of biotite, chlorite, and albite. The Shady Dolomite has been recrystallized and locally contains partings of sericite phyllite.

There are no geologic or radiometric data that indicate the date of the folding and metamorphism of the rocks of the Tablerock thrust sheet, except that the event must have occurred after deposition of the Lower Cambrian Shady Dolomite. The absence of the regional northeast-trending cleavage that characterizes the overridden autochthonous rocks and the strong structural discordance with them indicate that the metamorphism and folding took place largely before the thrust sheet reached its present position, perhaps contemporaneously with the low-grade metamorphism of the autochthonous rocks.

BLUE RIDGE THRUST SHEET

STRUCTURE

In the northwestern part of the Tablerock quadrangle, foliation and layering in the rocks of the Blue Ridge thrust sheet are generally parallel and have a low regional dip to the west, toward the axis of the Spruce Pine synclinorium. Local variations in strike and reversals in dip are common. In the noses of folds, foliation generally transects layering. Southeast of the Grandfather Mountain window, foliation and layering dip moderately to steeply southeast.

Small isoclinal folds having northwest-trending axes are present in many of the layered rocks. Superimposed on these are more open folds which have north- or northeast-trending axes and are overturned to the west or northwest. Most of the rocks exhibit a northwest-trending cataclastic lineation marked by alined mineral grains and aggregates on the foliation planes. The lineation is most conspicuous in the Cranberry Gneiss but occurs locally in the mica schist and mica gneiss and in the pegmatite and granodiorite.

METAMORPHISM

The earliest metamorphic event recorded in the rocks of the Blue Ridge thrust sheet is the plutonic metamorphism during which the Cranberry Gneiss was formed. Recent lead/uranium age determinations on zircons from the Cranberry Gneiss and related rocks in nearby areas indicate that the Cranberry Gneiss formed 1,000–1,100 million years ago, probably during the same plutonic episode associated with the formation of the Wilson Creek Gneiss (Tilton and others, 1959; Bryant and Reed, 1962).

An episode of medium-grade dynamothermal metamorphism during the middle or late Paleozoic has produced the assemblage oligoclase-muscovite-biotite-garnet in the mica schist and mica gneiss, and hornblende-oligoclase in the amphibolite. Staurolite, kyanite, and monoclinic pyroxene have been reported from similar rocks in the Linville quadrangle (Bryant, 1962) and in nearby parts of the Spruce Pine District (Kulp and Brobst, 1956). Potassium/argon ratios of micas from the Spruce Pine district indicate that the medium-grade regional metamorphism occurred about 350 million years ago (Long and others, 1959). The pegmatite and granodiorite were probably emplaced during this event.

The Cranberry Gneiss has been retrogressively metamorphosed under conditions which produced the new assemblage albite-epidote-sericite-biotite-chlorite, characteristic of the greenschist facies. Cataclastic textures were impressed on the rocks and locally phyllonite and blastomylonite were produced. The northwest-trending cataclastic lineation in the Cranberry Gneiss and some of the northwest-trending folds probably formed during this low-grade retrogressive metamorphism.

The boundary between the low-grade rocks and the medium-grade rocks is approximately along the contact between the Cranberry Gneiss and the mica schist, mica gneiss, and amphibolite unit west of the Grandfather Mountain window (pl. 3). Adjacent to the boundary, the medium-grade rocks have been crushed and contain retrogressive mineral assemblages. This evidence indicates that the low-grade metamorphism of the Cranberry Gneiss occurred after the medium-grade metamorphism of the rocks to the west (Bryant, 1962). The rocks between the Linville Falls fault and the Brevard fault zones southeast of the Grandfather Mountain window have been retrogressively metamorphosed under similar low-grade conditions but locally contain relics of medium-grade minerals such as staurolite, kyanite, and oligoclase.

No radiometric age determinations are available which might indicate the date of the low-grade metamorphism. West of the window this metamorphism may have occurred during the waning stages of the middle or late Paleozoic regional metamorphism, or it may date from an early phase of the thrusting along the Linville Falls fault. Southeast of the window, low-grade retrogressive metamorphism probably occurred both during movement along the Linville Falls fault and during movement along the Brevard fault.

INNER PIEDMONT

STRUCTURE

In the Inner Piedmont the schist and layered gneiss are in a series of rootless isoclines which are overturned to the northwest and which have gentle plunges to the northeast or southwest. Foliation is parallel to layering in the limbs of the isoclines but locally transects layering in the noses. The regional strike is northeast, and the dip is generally 30°–60° SE. Axes of minor folds and crenulations and elongated mineral grains and aggregates are parallel to the northeast-trending fold axes. Petrographic data show that the rocks have been deformed at least twice, but it has not been possible to distinguish generations of lineations related to the several deformations.

METAMORPHISM

The earliest recorded metamorphic-plutonic event in the Inner Piedmont is the emplacement of the rock which was metamorphosed to form the Henderson Gneiss, but the date of this event is unknown.

An episode of medium- and high-grade regional metamorphism, during which the assemblage muscovite, biotite, and oligoclase-andesine was formed in the schist and gneiss and sillimanite, kyanite, and staurolite were formed locally in rocks containing excess aluminum, reached its peak intensity either slightly later or much later than the emplacement of the parental rock of the Henderson Gneiss. Andesine, hornblende, and—locally monoclinic pyroxene formed in rocks of appropriate composition. The distribution of sillimanite suggests that the metamorphic grade was highest toward the southeast. The tight folding of the schist and layered gneiss sequence probably took place during this episode, but folding also may have occurred earlier. The biotite-quartz monzonite and associated pegmatite were probably emplaced during this episode, because the pegmatite bodies are boudin shaped even in the rocks of sillimanite grade and the quartz monzonite displays some foliation. Potassium/argon ages of micas from other parts of the Inner Piedmont (Long and others, 1959; Kulp and Eckelmann, 1961) suggest that the medium- and high-grade metamorphism occurred during middle or late

Paleozoic time, perhaps at the same time as the medium-grade regional metamorphism of the rocks of the Blue Ridge thrust sheet.

Some of the rocks display cataclastic textures and structures. During or shortly after this deformation, new biotite, muscovite, garnet, and oligoclase were formed, and some of the aluminum-silicate minerals were partially replaced by muscovite. Some of these effects might be attributed to a retrogressive phase of the main regional metamorphism during middle or late Paleozoic and some to incipient effects of a later regional metamorphism of lower grade. The possibility of another episode of metamorphism of medium grade and local extent cannot be ruled out.

Adjacent to the Brevard fault zone the rocks have been cataclastically deformed and retrogressively metamorphosed under low-grade conditions. Albite, epidote, sericite, biotite, and chlorite have been formed; potassium feldspar, oligoclase, and muscovite have remained as porphyroclasts. Kyanite and staurolite occur locally as porphyroclastic grains now largely replaced by sericite aggregates. The shearing and low-grade metamorphism in this area probably occurred during movement along the Brevard fault.

THRUST FAULTS

The Tablerock fault, named for its exposures in the klippe on Tablerock Mountain, carried Lower Cambrian(?) and Lower Cambrian rocks of the Tablerock thrust sheet over autochthonous rocks in the Grandfather Mountain window. The fault is parallel to the bedding and cleavage in the overriding block and in most places truncates cleavage and bedding in the underblock. Where the Wilson Creek Gneiss is adjacent to the fault, the fault is marked by a zone of lustrous phyllonite and highly cataclastic gneiss ranging from a few inches to more than 50 feet in thickness. Cleavage in the phyllonitic zone adjacent to the fault plane is parallel to the fault plane and concordant with the structures in the overriding block; farther beneath the fault it curves to become parallel with the regionol cataclastic foliation in the underblock. In a few places thin slices of quartzite derived from the overblock and of arkose derived from the underblock are intercalated with phyllonite and sheared gneiss. Between the Linville River and Longarm Mountain, arkose of the Grandfather Mountain Formation forms the underblock, and the fault is marked by finely laminated siltstone and calcareous phyllite—probably a tectonic slice derived from the siltstone of the Grandfather Mountain Formation. Farther to the north the fault is poorly exposed, but structural discordance is apparent between the quartzite in the overriding block and the siltstone and phyllite of the Grandfather Mountain Formation. The fault extends northward about a mile into the Linville quadrangle where it is truncated by the Linville Falls fault south of Crossnore (Bryant, 1962).

The Tablerock fault carried younger rocks over older rocks. Nevertheless, the presence of intercalated slices from the overriding and overridden blocks in the phyllonite along the fault and the different structural patterns in the two blocks indicate that the feature is a fault of considerable magnitude, rather than an unconformity along which there has been minor movement.

The Linville Falls fault, named for its exposure near Linville Falls, forms the boundary of the Grandfather Mountain window. It carried Precambrian rocks of the Blue Ridge thrust sheet over autochthonous rocks in the Grandfather Mountain window and over the Cambrian(?) and Cambrian rocks in the Tablerock thrust sheet. The fault west of the Grandfather Mountain window in the Linville Falls quadrangle has been traced continuously around the northern end of the window to the fault which bounds the window on the southeast in the Linville Falls quadrangle. Thus, the fault on the southeast was found to be a continuation of the fault on the west. Branches of the Linville Falls fault cut the Tablerock fault east of Shortoff Mountain. (See section *B–B′*, pl. 2). Imbricate faults mapped south of Dobson Knob, one of which carried Wilson Creek Gneiss over quartzite of the Tablerock thrust sheet, are probably branches of the Linville Falls fault (section *C–C′* pl. 2).

The fault plane is generally parallel to layering and foliation in the overriding block and to bedding and cleavage in the Tablerock thrust sheet. Discordance is not discernible between structures in the Blue Ridge thrust sheet and those in the Tablerock thrust sheet, but along the west and north sides of the Grandfather Mountain window in the Linville quadrangle, where the fault brings the Blue Ridge thrust sheet against autochthonous rocks, Bryant (1962) described marked structural discordance. Southeast of the window the fault is parallel to cleavage and foliation in the adjacent rocks.

The fault is best exposed on the west side of the Linville River 100 yards upstream from the end of the trail to the head of Linville Falls. At this location rudely layered Cranberry Gneiss overlies green sericitic quartzite of the Tablerock thrust sheet. The contact, which dips gently west, is marked by 6–18 inches of white to green finely laminated blastomylonite which is parallel to bedding in the quartzite and to foliation in the gneiss. Several other thin blastomylonite layers occur in the quartzite 100–200 feet south of the exposure of the main fault.

On the west side of the valley of the North Fork of the Catawba River about 0.3 mile north of Linville Caverns, the fault plane separating the gneiss above from the Shady Dolomite beneath is exposed near the base of a prominent cliff of Cranberry Gneiss. Near the fault the gneiss has been reduced to a dark-green siliceous blastomylonite. The fault is marked by a 6-inch quartz vein. The Shady Dolomite is shattered and silicified in a 1- to 2-foot zone below the fault. The fault plane is parallel to the layering and foliation in the gneiss; bedding is not apparent in the dolomite.

The fault is also exposed southeast of the window in a small quarry and in an adjacent roadcut on North Carolina State Route 181 on the east side of Steels Creek about 1 mile north of Smyrna Church. In this exposure, layered biotite gneiss overlies felsic metavolcanic rocks. The fault plane is marked by a 10- to 20-foot quartzite slice; several other thin slices are intercalated with the gneiss of the overriding block within a few feet of the fault. In the roadcut a single 2- to 3-foot quartzite slice separates gneiss from the underlying felsic volcanic rock.

Similar thin slices of quartzite, probably derived from the Tablerock thrust sheet, are commonly found along the main fault plane southeast of the Grandfather Mountain window and intercalated in rocks of the Blue Ridge thrust sheet as much as a quarter of a mile southeast of the trace of the fault. They are absent in the underblock northwest of the fault in most places, although similar slices are numerous in the Wilson Creek Gneiss south of Dobson Knob. Quartzite slices have not been found along the fault west of the window in the Tablerock quadrangle, but Bryant (1962) described similar quartzite slices along the Linville Falls fault and along subsidiary faults west and north of the window in the Linville quadrangle.

At least 30 miles of movement has occurred along the Linville Falls fault, as estimated on the basis of the distance between the southeastern edge of the Grandfather Mountain window and the probable emergence of the fault plane in northeastern Tennessee, (Bryant and Reed, 1962). The direction of movement of the Blue Ridge thrust sheet is inferred to have been northwestward, parallel to the regional cataclastic lineation in the Grandfather Mountain window and in the Cranberry Gneiss adjacent to the fault and perpendicular to the regional structural trend of the southern Appalachians.

The large-scale thrusting in the Grandfather Mountain area is inferred to have occurred during the late Paleozoic. As no major metamorphism has taken place since the thrusting, the faulting must have occurred after the 350-million-year-old metamorphic event which affected rocks of the Blue Ridge thrust sheet. West of the Great Smoky Mountains, 60 miles west of the Linville Falls quadrangle, movement along the Great Smoky fault, a similar postmetamorphic fault, occurred probably not before Mississippian time.

BREVARD FAULT ZONE

The Brevard fault zone separates rocks of the Blue Ridge thrust sheet from rocks of the Inner Piedmont belt. The zone extends as a narrow belt of rocks of low metamorphic grade (the Brevard belt) for at least 375 miles, from central Alabama, where it disappears beneath Coastal Plain deposits, to near Mount Airy, N.C. Its extension northeastward into Virginia has not been located.

Jonas (1932) recognized that the low grade of the rocks in the belt was due to retrogressive metamorphism and suggested that the belt marks a major thrust fault. Recent reconnaissance observations in North Carolina, South Carolina, and northwestern Georgia (Reed and Bryant, 1960; Reed and others, 1961) confirm Jonas' interpretation of the retrogressive character of the rocks. The relatively straight trace of the belt and the subhorizontal mineral lineation in the rocks along it suggest that the belt marks a major strike-slip fault rather than an overthrust as suggested by Jonas (1932). Relations between the Linville Falls fault and the Brevard fault zone, southwest of the Linville Falls quadrangle near Marion (pl. 1), and change in orientation of the regional cataclastic lineation in rocks of the Grandfather Mountain window and Blue Ridge thrust sheet near the zone suggest that the displacement has been right lateral.

The amount of movement along the fault zone is unknown, but regional considerations suggest that the relative movement amounted to many miles. Movement along the fault must have occurred after thrusting along the Linville Falls fault, but before emplacement of unmetamorphosed diabase dikes of probable Triassic age which cut rocks in the fault zone in the Lenoir quadrangle.

ECONOMIC GEOLOGY

ZINC AND LEAD

Disseminated sphalerite associated with small amounts of cuprite, chalcopyrite, pyrite, and some secondary copper minerals is found in the Shady Dolomite near Linville Caverns. The ore minerals, associated with quartz and calcite, occur in veinlets and as irregular replacements in dolomite. One small prospect trench has been opened on the hillside, and in 1943–44 four holes were diamond drilled. No further exploration work has been done since that time.

Galena, in euhedral cubes as much as 5 mm across, and small amounts of chalcopyrite and sphalerite were found in a 25- to 30-

foot-thick vein of granular quartz on the north side of Upper Creek about 1 mile west of the east edge of the quadrangle. The vein strikes northeastward, parallel to the foliation of the enclosing schist and gneiss. It is exposed in several prospects pits over a distance of about 200 feet; however, no recent work has been done, and the pits are slumped and overgrown. The galena reportedly carries small quantities of silver.

Reports of the occurrence of native lead in the area are widespread, but no specific localities are mentioned. Such reports have a long history, for Elisha Mitchell, who visited the area in 1828, records in his diary (Mitchell, 1905): "Such in substance is the account that I received in so many different places and from so many different persons that I am ready to knock down the man who shall tell the tale again."

MANGANESE

Botryoidal psilomelane, clayey pyrolusite, and ocherous wad occur in alluvial and colluvial clay which caps a small quartzite knob 0.5 mile S. 20° W. of the village of North Cove (formerly Pitts Station). The clay contains lenses of gravel. D. A. Brobst (written communication, 1950) estimated that the manganiferous clay is at least 30 feet thick and that it is covered by a soil mantle 5–10 feet thick. Some prospecting and development work was done on the deposit between 1943 and 1950, and several carloads of ore were shipped. Brobst (written communication, 1950) visited the deposit in 1950 and estimated that manganiferous clay would yield manganese concentrate at a ratio of 10 to 1. By 1959, all the open cuts and small adits described by Brobst were caved, and the workings were partly overgrown.

URANIUM

Considerable prospecting for uranium in the Wilson Creek Gneiss was done from 1954 to 1956. The most promising areas are found on North Harper Creek at the north edge of the quadrangle and along North Carolina State Route 181 on Ripshin Ridge. Some stripping and trenching were done in both areas, and some diamond drilling was done at the prospect on North Harper Creek, but no minable deposits were found.

The richest uranium mineralization occurs in scattered uraninite-filled joints in pegmatite in phyllonite zones in the Wilson Creek Gneiss. The uraninite-filled joints are commonly perpendicular to the northwest-trending regional lineation in the wallrocks. The phyllonite zones are discontinuous, and the uranium mineralization is spotty.

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MICA AND FELDSPAR

Sheet and scrap muscovite and feldspar are mined from pegmatite bodies in the Blue Ridge thrust sheet in the northwestern part of the quadrangle. This area is part of the Spruce Pine district. Most of the productive pegmatite bodies occur in the mica schist and mica gneiss and the amphibolite units, but some are in the granodiorite. They are absent from the Cranberry Gneiss. Most of the pegmatite bodies are concordant lenses and pods, the largest a few hundred feet long and several tens of feet thick. Some are rudely zoned, but most exhibit no conspicuous zoning. The smaller pegmatite bodies have conspicuous cataclastic textures, and their muscovite books are bent and ruled. Cataclastic effects are less common in the larger bodies, but thin sericitic films bearing the northwest-trending cataclastic lineation are common in most of the pegmatites in the quadrangle.

Pegmatite bodies in the Spruce Pine district, including most of the economically important ones in the Linville Falls quadrangle, were described by Maurice (1940), Kesler and Olson (1942), Olson (1944), Parker (1953), and Kulp and Brobst (1956).

KAOLIN

Kaolin is mined from granodiorite saprolite along the north side of Brushy Creek in the northwestern part of the quadrangle. The deposits were opened in 1937, and several large open-pit mines are currently being operated. Scrap muscovite is recovered as a by-product.

Parker (1946) stated that the kaolin is as much as 60 feet thick and is overlain in part by terrace gravels averaging 16 feet in thickness and in part by residual soil and stained kaolin averaging 6 feet in thickness. He estimated that the reserves in 1942 were between 1½ and 3 million tons of washed kaolin. No records of production or estimates of current reserves are available.

CONSTRUCTION MATERIALS

Road metal has been quarried from the Wilson Creek Gneiss along Wilson Creek and along North Carolina State Route 181. The largest operating quarry is south of Route 181 near Cold Springs, where the gneiss is quarried for road metal and building stone. Shady Dolomite has been quarried for track ballast near Ashford. Building stone and flagstone have been quarried in small operations from several of the quartzite slices along the Linville Falls fault between Steels Creek and Upper Creek.

Gravel for road construction is obtained from several extensive pits on the flood plain of the Linville River above the head of Lake

James and on the flood plain of Paddy Creek south of Longtown. The gravel is poorly sorted and consists of rounded quartzite pebbles and cobbles ranging from 1 inch to 3 feet in diameter in a matrix of gray sandy clay. The gravel ranges in thickness from 4–10 feet and rests on bedrock or saprolite. It is overlain by 2–5 feet of gray, yellow, or brown sandy clay containing scattered pebbles and cobbles and passing upward into brown organic soil.

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