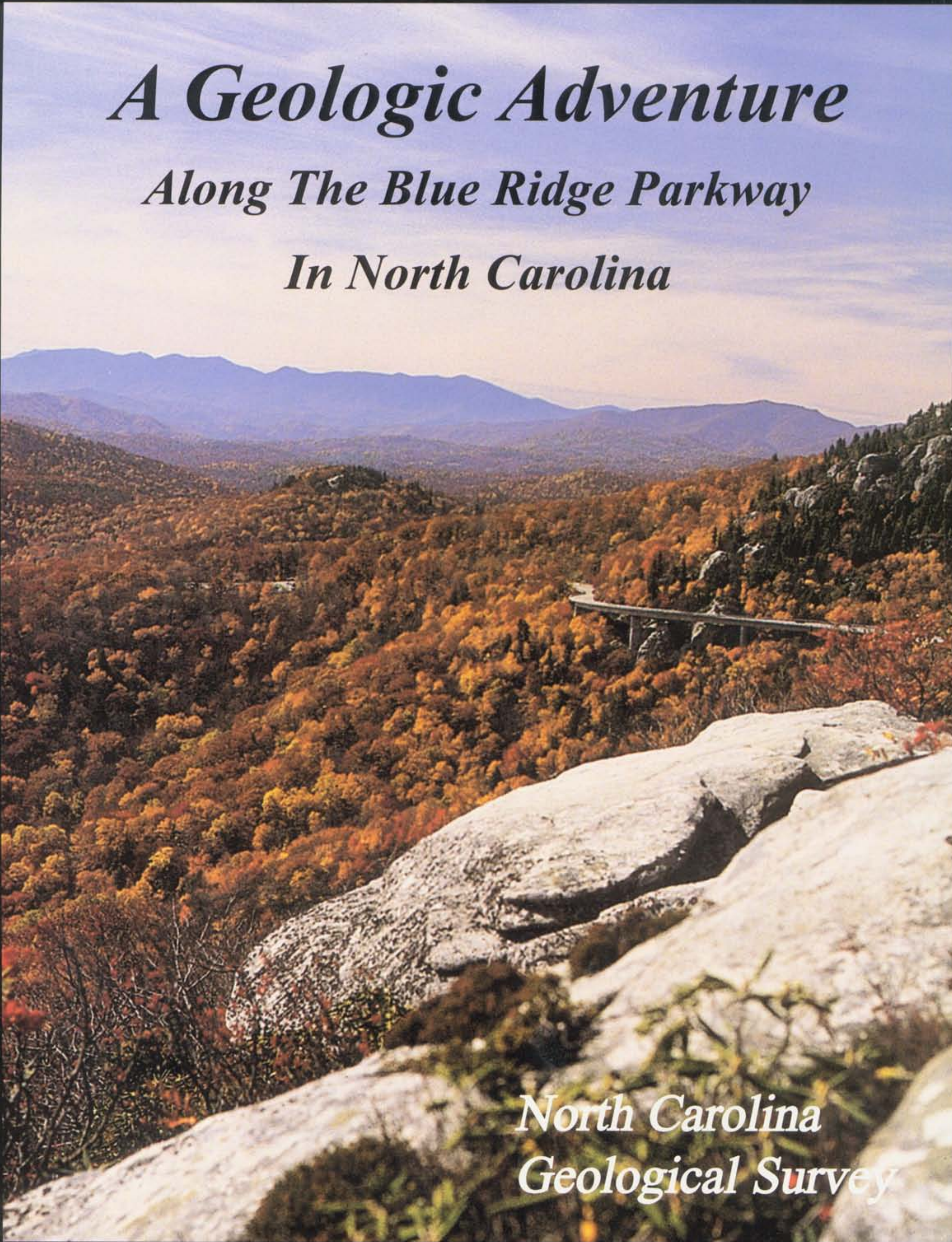
A Geologic Adventure

Along The Blue Ridge Parkway

In North Carolina



North Carolina
Geological Survey

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Front Cover: *Southwest view from Rough Ridge, near mile 302, overlooking the Linn Cove Viaduct, and the Black Mountains beyond. Rocks in the foreground are of the Grandfather Mountain Formation. Photography by Lillian McElrath, National Park Service.*

A Geologic Adventure
Along the Blue Ridge Parkway In North Carolina

Bulletin 98

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A GEOLOGIC ADVENTURE ALONG THE BLUE RIDGE PARKWAY IN NORTH CAROLINA

North Carolina Geological Survey
Division of Land Resources
North Carolina Department of Environment and Natural Resources

PREFACE

Have you ever wondered why mountains stand so tall, or how valleys are carved across the landscape, or why rocks cropping out along the roadside have a peculiar color and shape? Do you know how significant the Earth's geologic resources are to humankind, how the wide variety and locations of rocks determine the rest of the Earth's natural environment, or how certain rocks and minerals can affect the environment if disturbed by humans? These questions, and so many more, can be answered through the study of geology.

Geology is the branch of science that helps us to understand the Earth, and geologists are people who specialize in this science. By studying rocks and their features, geologists can piece together the physical character of our planet, its composition, and its history.

A great place to experience geology is along the Blue Ridge Parkway in the mountains of North Carolina. A venture along the Parkway winds the traveler across 252 miles of Blue Ridge mountain ranges, including Grandfather Mountain, the Black Mountains, the Great Craggies, the Great Balsams, and the Plott Balsams, all of which are only a part of the more extensive Appalachian Mountain System, which extends from Alabama to Nova Scotia.

This guidebook, "A Geologic Adventure Along The Blue Ridge Parkway In North Carolina" tells the story of these majestic mountains. Throughout its pages, travelers along the Parkway will be introduced to the basic laws and concepts of geology, and learn about the geologic history of western North Carolina. It is written in a road log style narrative; descriptions and explanations of rock exposures and geologically interesting vistas are keyed to Parkway mileposts, so it is designed to accompany visitors as they travel the Parkway.

The road log is divided into four segments. Each segment highlights a concept in geology that is most represented in the rock outcrops and vistas that will be encountered along that portion of the Parkway. "A Brief Introduction to the Geologic History of the Mountains" provides an overview of modern ideas about how these mountains came into existence. A glossary of common geologic terms used throughout this Bulletin is also included at the back of the road log starting on page 44 to assist laypersons in their geologic adventure along the Parkway. Readers are encouraged to review the glossary before reading this guidebook. Without doing so, some frequently used terms may be misunderstood. For example, "minerals" are more than gemstones; all rocks are made up of one or more minerals, and most rocks consist of a mixture of only three or four minerals.

Foremost, this book is intended to guide visitors to the Blue Ridge Parkway on an exciting and informative recreational journey through the mountains and valleys of this scenic area. In fact, the rocks and vistas that occur along the Parkway are themselves like pages in a book. When properly interpreted, the story that they reveal is a geologic history of mountain-building with rock formation, deformation, weathering, and erosion which had their beginnings more than 1 billion years before the existence of humankind. The rocks and vistas along the Blue Ridge Parkway await an adventurous audience!

Please note that rock and mineral collecting is NOT PERMITTED along the Parkway. The staff of the North Carolina Geological Survey hopes you have a pleasant experience.

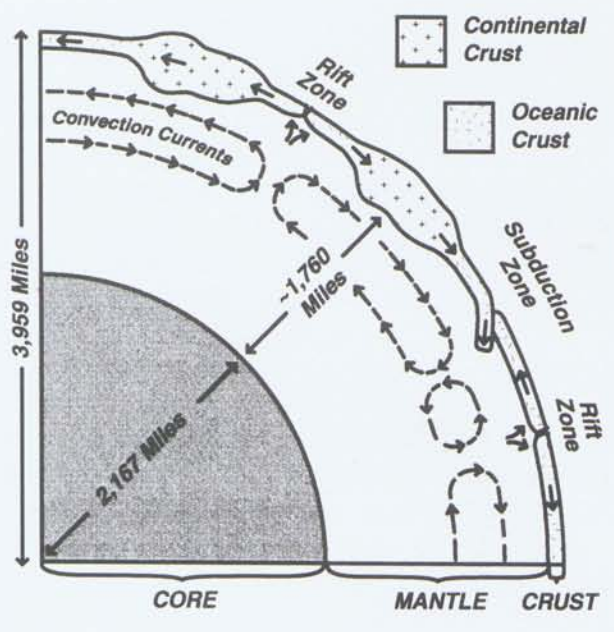
A BRIEF INTRODUCTION TO THE GEOLOGIC HISTORY OF THE MOUNTAINS

Geologists know much about the Earth and its history. Through careful field and laboratory observations around the world, they understand and interpret many of the events and forces which have shaped the Earth since its formation about 4.5 billion years ago.

LAYERS OF THE EARTH

The Earth is composed of a metallic core surrounded by a thick, very dense mantle of hot material that behaves much like cookie dough, and a thin, rigid outer crust. Its crust is broken into numerous "plates," which are composed of both huge masses of granitic material called continents, and oceanic material made up of a rock type called basalt. These massive plates are slowly driven across the face of the planet by internal convective forces within the mantle.

As these plates have moved across the planet's surface through the course of time, they have bumped and ground into each other and produced distinct features on the planet's surface such as volcanoes and mountain ranges. Geologists refer to these plate movements and collisions as "plate tectonics." You may be able to envision that a present-day collision between Asia and India is lifting up the Himalayan Mountains in southern Asia, but can you envision that similar collisions throughout the eons have shaped the Blue Ridge Mountains in North Carolina?



Layers of the Earth. The outermost layer, called the crust, is composed of both continental masses and oceanic material. Continental crust is between 12 and 43 miles thick, whereas oceanic crust is only about 6 miles thick. The crust is broken into numerous "plates" which are bounded by rift zones and subduction zones. New crust is generated at rift zones, and older crust is destroyed at subduction zones. The plates are driven across the face of the Earth by convection within the upper part of the mantle (the thickness of the crust is exaggerated in this cross section through the Earth).

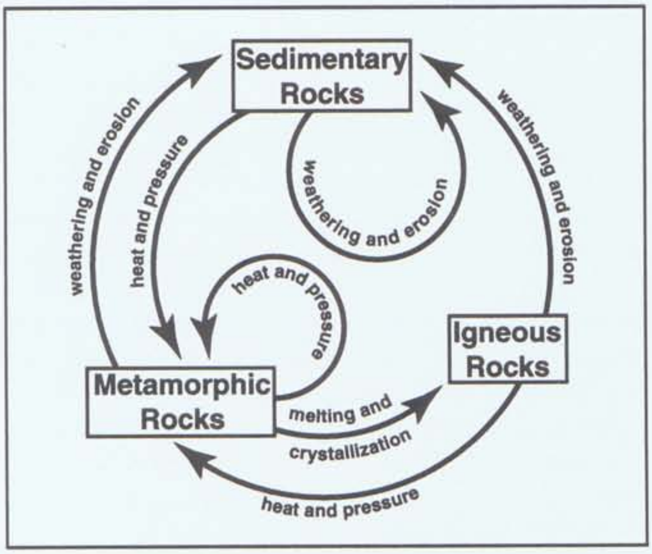
THE ROCK CYCLE

Collisions between these crustal plates not only produce visible features on the Earth's surface, they also leave behind distinct marks in the rock record. As mountain ranges are lifted up by plate collisions, heat and pressure is generated. This heat and pressure alters, or changes the original granitic and basaltic materials of the crustal plate to form new types of rocks called "metamorphic" rocks. If heat and pressure become so intense that original crustal material is melted, magma forms. When magma solidifies, or crystallizes in the Earth's crust, "plutonic igneous" rocks are produced. Other types of rocks, called "volcanic igneous" rocks, are formed when magma rises all the way to the surface and crystallizes.

Newly formed mountains are also worn down through the processes of weathering and erosion. Weathering breaks down existing rocks into smaller fragments and mineral grains, which are then eroded and carried away by wind or water elsewhere, and hardened into a third type of rock called "sedimentary" rocks. Of course, all three rock types can be altered by heat and pressure to form new metamorphic rocks, eroded to form new sedimentary rocks, or melted to form new igneous rocks. This cycle of rock formation is called the "rock cycle," and it has been in continual motion since the formation of the Earth more than 4 billion years ago.

GEOLOGIC TIME

Another geologic concept that is sometimes difficult for people to comprehend is the vastness of geologic time. A tall skyscraper is like geologic time in that traveling upwards from the basement to the roof represents traveling through the great expanse of Earth's history. The floor of the basement represents the time of the formation of the Earth. Comparatively, the tip of the flagpole on the roof represents the very short time that humans have inhabited the Earth. The successive floors of the skyscraper are comparable to each distinct moment or time interval throughout the Earth's history.



The rock cycle. Many Earth processes contribute to form the three common categories of rocks.

ERA	PERIOD	AGE in millions of years before present
Cenozoic	Quaternary	1.6
	Tertiary	66
Mesozoic	Cretaceous	144
	Jurassic	208
	Triassic	245
Paleozoic	Permian	286
	Carboniferous	360
	Devonian	408
	Silurian	438
	Ordovician	505
	Cambrian	570
Proterozoic	Late Proterozoic	900
	Middle Proterozoic	1600
	Early Proterozioc	

The geologic time-scale, showing the divisions of Earth's history and the time when they began.

By studying the successive rock layers, fossils within the rock, and by determining the extent of radioactive decay within minerals, geologists have been able to piece together a geologic "time-scale" for the Earth's history. It's like a ruler that measures time instead of distance. Keep in mind that as you travel the Blue Ridge Parkway and observe the rocks and features that occur within them, you are, in a sense, traveling back in time to witness the vestiges of major geologic events that happened over the course of time.

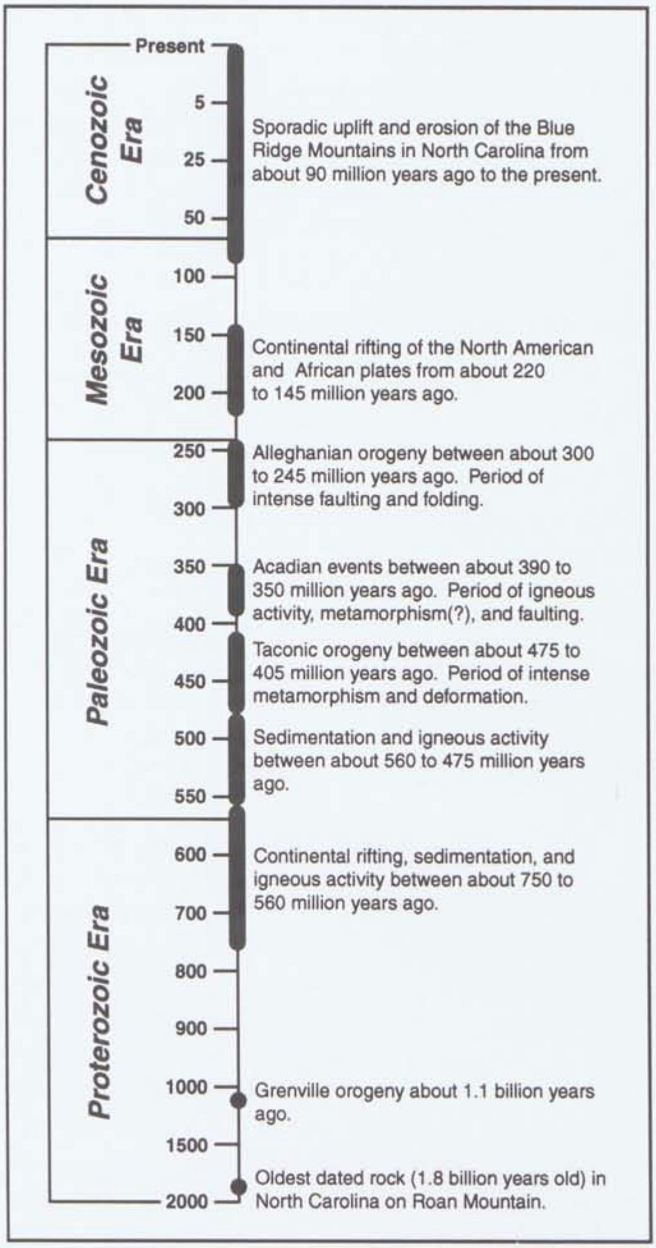
EARLIEST GEOLOGIC HISTORY

The geologic history of the rocks that crop out along the Blue Ridge Parkway is complex and extremely ancient. Geologists have concluded that the oldest rocks which occur in the North Carolina mountains were originally formed during a geologic time-period called the Early Proterozoic, almost two billion years ago. Because they are so old, few details are known about their origin. There is evidence that during that time, the continental landmasses that we now observe on our planet's surface were arranged quite differently. In fact, most geologists believe that the continent we now call North America was clumped together with parts of other modern continents into a larger "supercontinent."

Then about 1.1 billion years ago, during the Middle Proterozoic time-period, the rock record tells of the first great geologic event to affect some of the rocks that crop out along the Parkway. Geologists hypothesize that a collision between the old supercontinent and another initiated an episode of mountain-building that metamorphosed all of the pre-existing older rocks.

Episodes of mountain-building spawned by plate collisions are called "orogenies," and this billion-year-old event is named the Grenville orogeny. The metamorphic rocks which it formed are collectively called "basement" rocks, because they constitute the lowest level of the rock record. You can observe some of these old Grenville basement rocks along the Parkway at the Thunder Hill Overlook, mile 290.4, and at the Woodfin Valley Overlook, mile 446.

As mountains were pushed up during the Grenville orogeny, it is important to remember that the processes of weathering and erosion were working at the same time to wear them down. You can think of these processes, mountain-building, and weathering and erosion, as being in a continual state of competition. If the landscape is uplifted faster than weathering and erosion can wear it down, mountains are formed. If weathering and erosion act more quickly than the mountains are uplifted, however, the high peaks are reduced to gently rolling hills. This competition between mountain-building, weathering, and erosion continues today, as it has throughout geologic time.

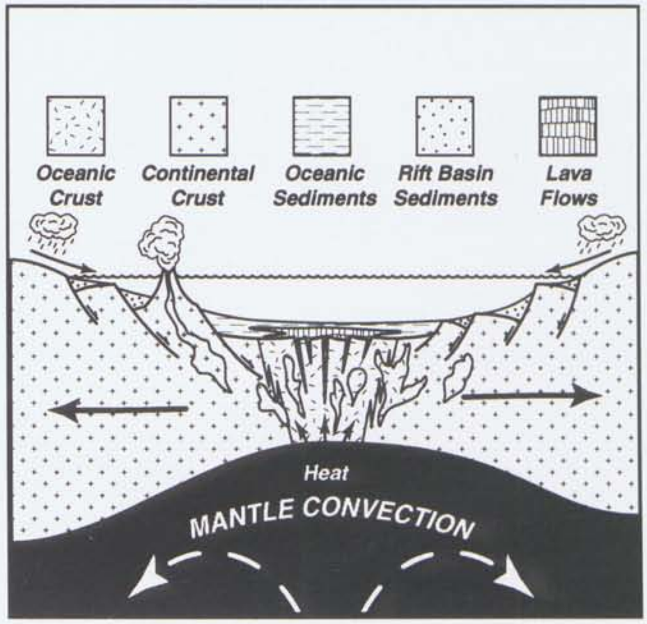


Time-line showing significant events in the geologic history and evolution of the mountains in western North Carolina.

Little can be deciphered from the rock record for the next 400 million years after the Grenville orogeny. Then, in the Late Proterozoic time-period about 700 to 800 million years ago, the next major geologic event occurred. The Earth's internal convective forces began to break apart the old supercontinent by a process called continental rifting.

You can think of continental rifting much like pulling apart a piece of taffy. The taffy represents a continental landmass. As you slowly pull the taffy "continent" apart, the taffy between your hands begins to neck down and sag, and eventually breaks. In much the same way as our taffy model, continental landmasses also thin during continental rifting. A deep trough develops between the two masses of continental material. Erosion washes weathered material from the edges of the trough, or rift, into the basin. These sediments eventually turn into sedimentary rocks. Just like our taffy example, continued rifting breaks the continent apart. Basalt, a type of volcanic igneous rock, swells up in the intervening cracks in the Earth's crust to form new ocean floor. Volcanoes sometimes develop along the margins of the rift too, and spew molten volcanic rock across the landscape.

Geologists find modern examples of continental rifting today. The Red Sea between Africa and Arabia is the product of those two crustal plates breaking apart within the last 25 million years of Earth's history.



A rift zone. A rift zone is formed when convection currents (shown by large white arrows) within the mantle pull a continent apart. A deep basin forms by tension (shown by large black arrows) between the pulled apart pieces of continental crust. Large blocks of continental material drop down along normal faults along the edges of the rift zone. Sediment from the continental land masses wash down and accumulate in these basins. Heat generated from the mantle convection generates igneous activity. As rifting continues, new oceanic crust is formed in the rift basin. Sediments washed down onto the new crust are interbedded with lava flows.

As the old supercontinent broke apart to form an ancient ancestor of the modern Atlantic Ocean, sediments which eroded from the Grenville basement rocks began to accumulate in water-filled rift basins close to the edge of the continent, and farther offshore. These sedimentary accumulations, composed of sandy, gravelly, and muddy (silt and clay) material, gradually increased in thickness to as much as three or four miles. Some sedimentary rock sequences contain volcanic igneous rocks which formed intermittently during sedimentation. Most of the rocks that you will encounter along the Parkway are metamorphosed sedimentary and volcanic rocks that were formed at this time.

At a few places along the Parkway, you can find well preserved, hardened layers of gravel called conglomerate. Upon close examination, it is apparent that some of the pebbles within these conglomerates match exactly some of the distinctive rock types found in the older basement rocks exposed at the surface. That's because these sedimentary rocks were derived from, and deposited directly on top of, the old weathered basement rocks. These older surfaces of weathering and erosion are called "unconformities."

This period of sedimentation lasted for about 250 million years. As fragments of the old supercontinent slowly moved apart and the ancient ocean basin grew in size, the troughs created during rifting eventually filled with sediment. Nevertheless, weathering and erosion continued to wear away land above sea level farther to the west.

In Cambrian time, about 550 million years ago, large rivers washed sediments down to the ocean and deposited them along the edge of the continent. Small crab-like creatures called "trilobites" and other strange and unique life forms, now long extinct, lived in the warm ocean waters near the coast. Later, massive limestone reefs grew. For nearly 80 million years, this part of the Appalachian Mountains was relatively "geologically" quiet.

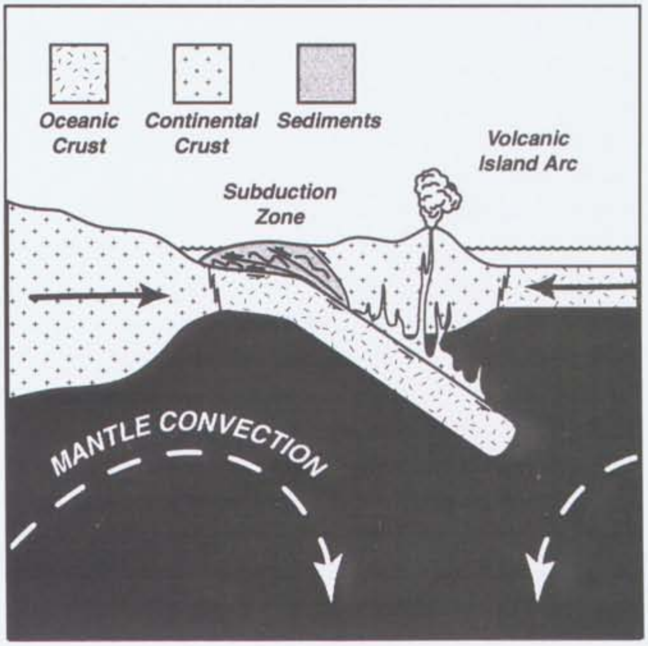
But further offshore in the ancient ocean, Earth forces were beginning to reverse the direction of plate movement. The ancient ancestor of the Atlantic Ocean which had been slowly opening for some 200 million years began to close. Magma worked its way up from deep within the Earth's crust into the ocean sediments and crystallized into plutonic igneous rocks.

THE AGE OF MOUNTAIN-BUILDING

Roughly 475 million years ago, the second major mountain-building event occurred in this part of the Appalachians. As the ancient ocean basin continued to close, the North American crustal plate collided with a chain of volcanic islands. This period of mountain-building is called the Taconic orogeny.

As compression from the collision mounted, the sedimentary rocks deposited during the earlier periods were thrust up and over the older basement rocks along huge faults, or cracks in the Earth's crust. These sedimentary rocks were then metamorphosed and folded, while the older Grenville basement rocks were metamorphosed and deformed for a second time. Deeper within the crust, heat generated by the collision melted rocks, and the magma rose toward the surface and crystallized.

In a relatively short period of geologic time, perhaps only about 5 to 10 million years, the oceanic sediments were pushed up above sea level to form a region of high mountains. Continued spasmodic uplift of the landscape during the Taconic orogeny probably lasted for another 50 million years.



A subduction zone. A subduction zone is formed when convection currents (shown by large white arrows) within the mantle drive two crustal plates together. Compression forces one of the plates down beneath the other. Heat generated by the process partially melts the descending slab of crust, generating igneous activity and sometimes producing a volcanic island arc. Sediments on the ocean floor and along the edge of continental land masses are folded and shoved forward along thrust faults by compression above the descending slab.

Following this significant pulse of mountain-building, this part of the Appalachians again experienced a period of relative geologic quiescence. Weathering and erosion outpaced orogenic uplift, and the highlands formed during the Taconic orogeny slowly weathered down.

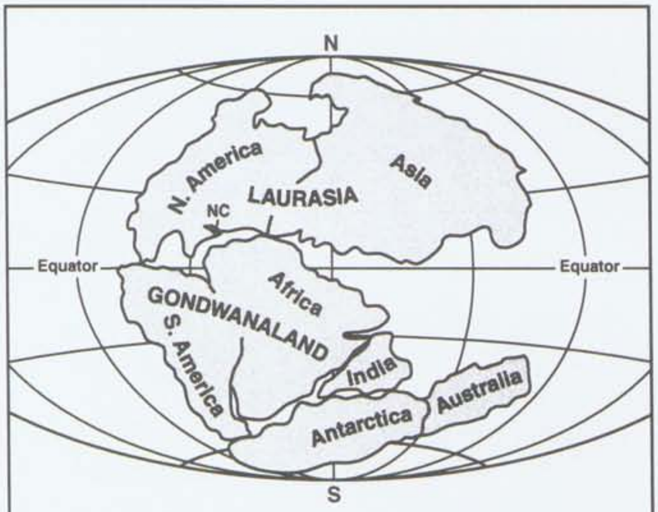
It was during this time that the first plants came into existence on the planet, and they covered the lowlands with dense, lush forests. Nevertheless, the ocean basin continued to close. To the east, volcanic islands collided and accrete to the edge of the continent. Magma generated within the crust rose toward the surface and crystallized.

Faulting, and possibly metamorphism, may have affected some of the rocks in this region. Some geologists refer to these events as belonging to a Devonian mountain-building episode known as the Acadian orogeny. Geologists have concluded that the large bodies of plutonic igneous rock around Spruce Pine, North Carolina, crystallized about this time, by determining the age of radioactive minerals within them. Today, humans utilize these plutons for their wealth of industrial minerals, including feldspar, mica, quartz, and gemstones.

Finally, during the Carboniferous time-period, about 300 million years ago, the culminating episode of mountain-building in the Appalachians took place. Geologists refer to this grand event as the Alleghanian orogeny. The ancient ancestor of the Atlantic Ocean completely closed and North America slammed against the supercontinent "Gondwanaland."

Gondwanaland was comprised of the modern continental landmasses of Africa, South America, Antarctica, India, and Australia. The results of the collision were truly spectacular. A chain of mountains, quite possibly as high as the modern Rocky Mountains, was pushed up from Canada to Alabama. In the process, the rocks that we now see along the Parkway in North Carolina were warped and shoved more than 200 miles to the west along major thrust faults in the Earth's crust. By the time collision ceased some 50 million years later, the largest of all landmasses ever to occur on the planet had been formed.

This "mega" supercontinent is called Pangea. Creatures ancestral to the dinosaurs lived then, and they could quite possibly walk from what is now North Carolina to Australia without ever getting their feet wet!



Reconstruction showing the arrangement of the continents to form the supercontinent Pangea in the Permian period about 250 million years ago.

The supercontinent Pangea lasted "only" 80 million years or so. By around 220 million years ago, during Triassic time, Earth forces were at work rifting the continent apart to form our modern Atlantic Ocean. South America and Africa split, creating their characteristic coastlines that seem to fit together like "pieces of a torn newspaper," as one famous geologist expressed early in this century. Africa and North America also split apart. In fact, what's now the state of Florida was actually at that time a piece of Africa, but during the breakup of Pangea, it remained attached to the North American plate. Large rift basins, not unlike those which formed in this region by continental rifting some 500 million years before, broke the landscape along the eastern side of the mountains from New England to Florida.

By the time that the largest dinosaurs lived on the Earth in the Cretaceous time-period, some 90 million years ago, weathering and erosion had already started to reduce the lofty mountains uplifted during the Alleghanian orogeny in North Carolina. Rivers transported the sediments derived from these former high mountains to the coast and deposited them in gently sloping layers that make up our present-day Coastal Plain.

THE MOUNTAINS TODAY

Since the Cretaceous, the Atlantic Ocean has continued to widen, and North America and Africa continue to move apart. In North Carolina, sporadic uplift has intermittently raised the landscape, but without major continental collisions. Erosion has been in continual competition with uplift to sculpture the present-day landscape.

Constant weathering and erosion could have reduced the mountains which were uplifted during the Alleghanian orogeny to a gently rolling plain by now, so how can the Blue Ridge Mountains, including Mount Mitchell, the highest peak east of the Black Hills in South Dakota, still persist in this region today? The answer lies, at least partially, with another on-going Earth process which can also raise the landscape.

ISOTASY

The Earth's outer layers are segregated into low-density and high-density materials. Less dense material in the crust and uppermost mantle essentially "floats" on higher density material deeper in the mantle, just like the way a layer of oil always floats above a layer of water. Like oil and water, these Earth layers are in "balance" with each other. When extra material is added to the Earth's uppermost layer, however, this balance, or equilibrium is disturbed, and the upper layer is depressed down into the higher density material, much like the way you depress a seat cushion when you sit down. When this extra material is removed, the layer springs back upward, or rebounds, in the same way that the cushion rises after you stand up. This crustal phenomenon is called "isostasy."

Unlike plate collisions, isostatic rebound does not generate much heat and pressure to form new metamorphic or igneous rocks, but it can considerably raise the elevation of the Earth's surface. For example, massive continental glaciers, like those now covering Greenland and Antarctica, can be up to several miles thick, and add significant weight to the Earth's outer layer. About 50,000 years ago, a huge continental ice sheet covered much of Canada and the northern United States. After this continental glacier began melting back about 10,000 years ago, the Earth's outer layer started to rebound, and continues to rise today. In fact, land around the Great Lakes in Michigan and Ontario has actually risen almost 1,000 feet since the ice sheet melted.

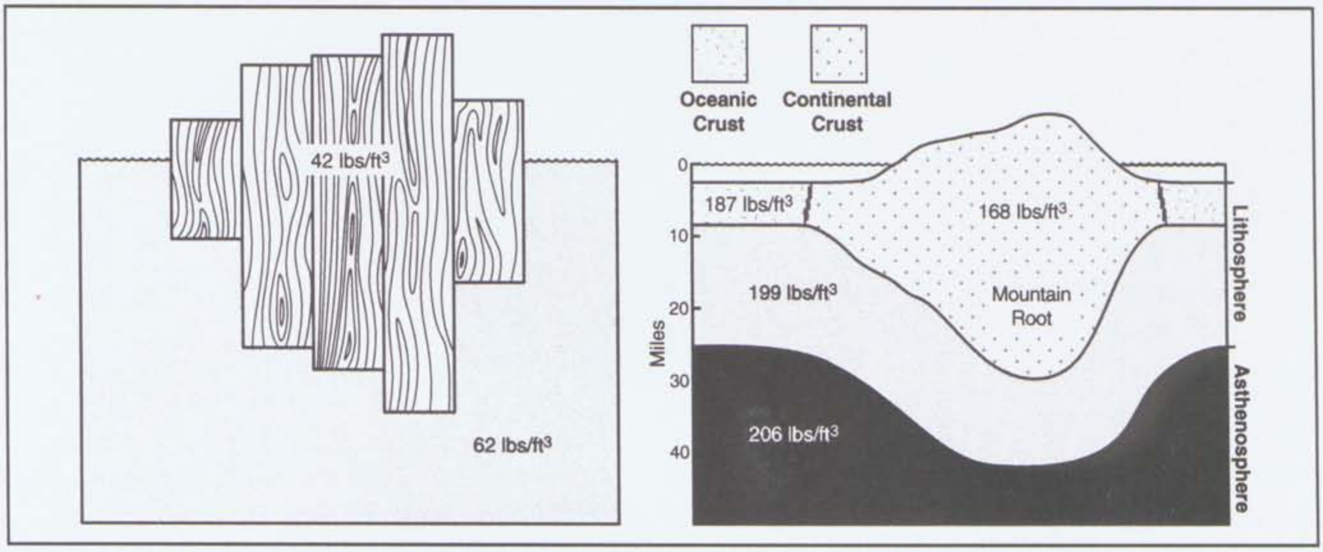
But glaciers typically leave behind very distinct and characteristic features on the landscape. Geologists have not recognized such features farther south than upstate Pennsylvania; thus, they know that the massive continental glacier that existed 50,000 years ago did not cover this region of the United States.

So if the mountains we see in North Carolina today are not the products of glaciers, why are they still here? The answer is that mountains, like glaciers, also affect the isostatic balance between the Earth's layers.

Rock is more than twice as dense as ice, but still less dense than the material lower in the mantle. During an episode of continental collision, lower density material is stacked up above the high-density layer within the mantle, causing the lower layer to depress. As more and more material is added to the stack during mountain-building, the underlying layer continues to be depressed, so that a "root" develops beneath the mountain chain. This root within the Earth helps to "buoy up" the less-dense mountains above the higher density layer, and maintains isostatic balance between the layers.

To help understand this concept, imagine blocks of wood floating upright in a bucket of water. Part of the blocks is buoyed above the water's surface, but a greater part is submerged. If you then cut off the tops of the blocks that stick out of the water, part of the bottom of the blocks is buoyed up to maintain equilibrium. Of course, the total length of the blocks is shortened, but part of it still floats above the surface, and a part stays submerged. In much the same way as our floating blocks of wood, mountain chains are continually uplifted as weathering and erosion act simultaneously to reduce their total height.

So the majestic mountain ranges and exquisite rocks that we see along the Blue Ridge Parkway in North Carolina tell the story of a complex interaction between the Earth's natural forces and processes throughout geologic time. These mountains and their rocks are, in part, the product of spectacular continental collisions which occurred here hundreds of millions of years ago, but they are also the result of a much more delicate "imbalance" between isostatic uplift, weathering, and erosion within the last few tens of millions of years of the Earth's history. All of these processes, working simultaneously, seem to explain the origin of our beautiful Appalachian Mountains.



The principle of isotasy. Blocks of wood, being less dense than water, float partially above the water's surface. In a similar manner, less dense material in the crust and upper part of the mantle (the lithosphere) float above more dense material lower in the mantle (called the asthenosphere) in a state of equilibrium.

Mile 216.9 to 286

Weathering and Erosion Sculpture the Landscape

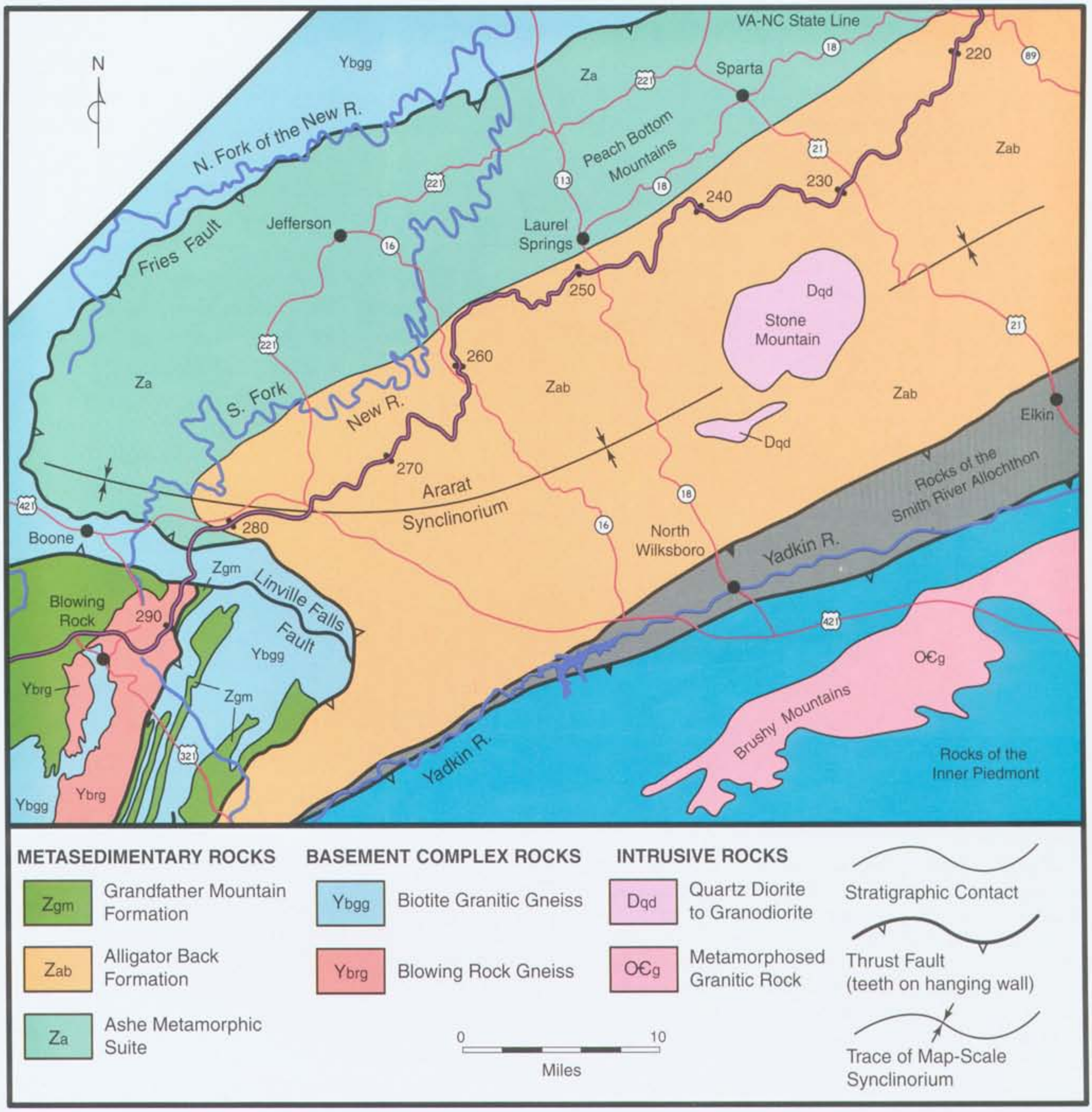
Weathering and erosion play an important role in sculpturing the present-day landscape throughout these beautiful Blue Ridge Mountains. Along this northernmost segment of the Parkway, several prominent topographic features serve as mute witnesses to the effects of millions of years of weathering and erosion of the bedrock. The Blue Ridge escarpment, a sharp topographic rise separating the gently rolling hills of the Piedmont from the mountains of the Blue Ridge, can be clearly seen at several overlooks. Also visible in the distance from several overlooks is a huge, distinctive mass of igneous rock that underlies Stone Mountain. This prominent rounded bare rock feature is known as an exfoliation dome. Stone Mountain State Park, a few miles south of the Parkway, is accessible from the Parkway via U.S. 21 (mile 229.6).

The dominant rock unit that you will encounter along this segment of the Parkway is the Alligator Back Formation. It is a Late Proterozoic metamorphosed sedimentary unit that is composed of various kinds of metamorphic rock, mainly schist and gneiss, as well as a rock type called amphibolite. Amphibolite consists of small black grains of hornblende and lighter colored grains of plagioclase feldspar.

Near the end of this segment, you will also encounter rocks of the Ashe Metamorphic Suite. It too is a Late Proterozoic metasedimentary unit similar to the Alligator Back Formation.

Before Taconic metamorphism, schist and gneiss of both units are thought to have been sediments which were deposited offshore in the ancient ancestor of the Atlantic Ocean during Late Proterozoic continental rifting. Interlayered amphibolite rocks were probably originally layers of lava (basalt) that spread out over the ocean floor along with the sediments. A rock unit composed of biotite granitic gneiss is a Middle Proterozoic basement rock that crops out at the end of this segment. It was highly deformed and metamorphosed during the Grenville orogeny more than 1 billion years ago.

Visitor facilities include: Cumberland Knob recreation area (visitor center with information and bookstore, hiking trails, picnic area, restrooms, water fountains); Little Glade Mill Pond (nature walks, picnic area, fishing); Brinegar Cabin (weaving demonstrations); Doughton Park (restrooms, water fountains, auto service, trailer and tent camping, Bluffs Lodge and coffee shop, picnic area, interpretive naturalist programs, nature walks); Northwest Trading Post (mountain handicrafts); E. B. Jeffress Park (nature trail, cascades, water fountains, restrooms, and picnic areas).

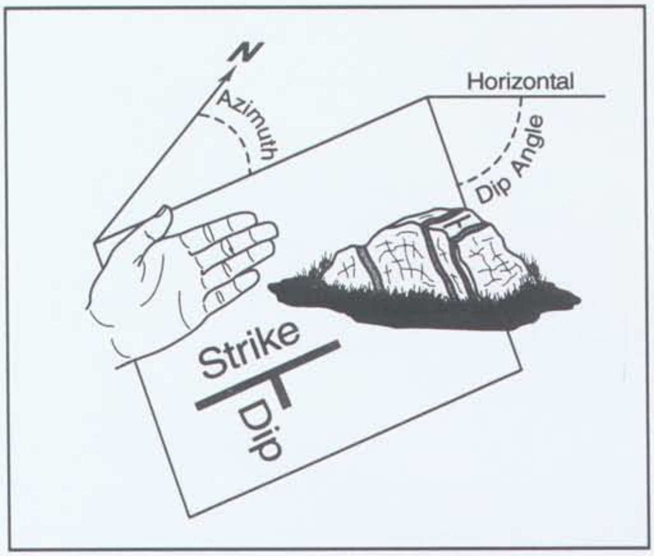


A geologic map of a portion of northwestern North Carolina showing the location of the Blue Ridge Parkway (in purple) from the Virginia-North Carolina state line to the vicinity of Blowing Rock near mile 295.0. Rocks of the Alligator Back Formation and the Ashe Metamorphic Suite are folded into a large U-shape syncline (the Ararat Synclinorium) north and west of the Smith River Allochthon.

217.3 Junction with N.C. 18, west to Sparta, 19 miles.

Northward to the Virginia-North Carolina state line at mile 216.9 are scattered outcrops of gneiss of the Alligator Back Formation containing red garnet crystals and small grains of the black mica mineral biotite.

Gneiss, a type of metamorphic rock, is recognized by its alternating bands of light and dark minerals. The banding, or foliation, in these rocks generally trends (strikes) to the northeast and is inclined (dips) to the southeast. Southward, the Parkway passes through outcrops of mica schist to mile 221.2.



Geologists use the concept of strike and dip to describe the geometry and orientation of "planar" features (such as foliation or layers of gravel) within a rock. Imagine an invisible plane (like a sheet of glass) that is oriented parallel with the planar feature in the rock. Use your hand to help visualize the plane. The "strike" or trend of the feature is parallel to the surface of the Earth (and parallel to your fingers) and is measured with a compass with respect to true north (the azimuth). The "dip" of the feature is perpendicular to the strike and describes which direction (north, south, east or west) the plane plunges down into the Earth from a horizontal plane that parallels the surface of the Earth. The dip angle, measured with a clinometer, is the value (or amount, measured in degrees) that the plane plunges into the Earth.

217.9 Cumberland Knob, elevation 2,885 feet.

At Cumberland Knob, picnic grounds and hiking trails are underlain by finely laminated schist of the Alligator Back Formation. The schist is a thinly foliated rock containing abundant muscovite and biotite mica, and garnet crystals.

Schist is distinguished from gneiss primarily by its thinner foliation. In schist, mica flakes tend to lie flat and make up all layers, whereas in gneiss, darker minerals tend to be separated from lighter ones, resulting in thicker, more distinct bands.

Hiking trails through outcrops of schist offer scenic views of the low, rolling topography of the Piedmont physiographic province to the south, which borders a prominent geomorphic feature of the Southern Appalachians known as the Blue Ridge Escarpment (see discussion at next mile marker).

218.6 Fox Hunters Paradise, elevation 2,805 feet.

A short walk from the upper parking area leads to the crest of High Piney Spur and a spectacular view of the rolling topography of the Piedmont to the southeast.

Western North Carolina is divided into two distinct physiographic provinces: the Piedmont and the Blue Ridge. The Piedmont is an area of generally low, rolling relief lying at the foot of the Blue Ridge Mountains.

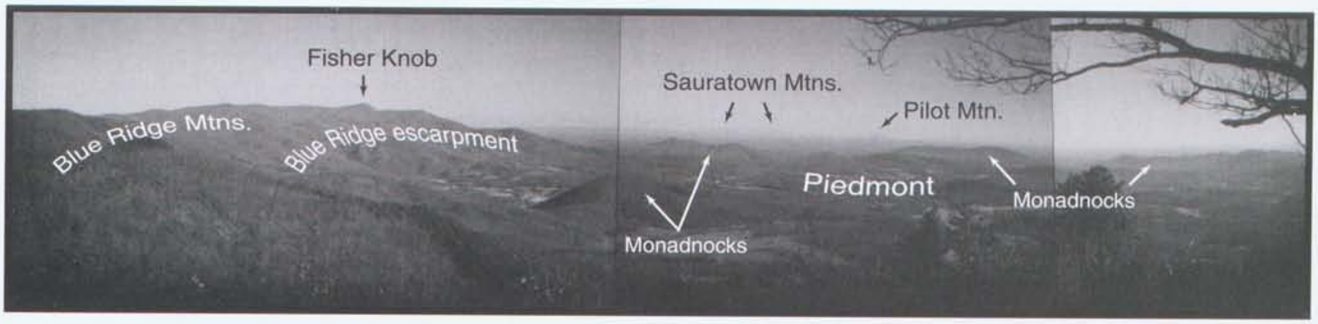
The steep slope between the Mountains and Piedmont is known as the Blue Ridge Escarpment. This rugged erosional feature is produced, in part, by headward erosion of the Blue Ridge Mountains by Atlantic-flowing streams, but its early origin is still subject to debate.

Remnants of mountains that once occupied this portion of the Piedmont rise to the south. More resistant to erosion than the rocks of the land around them, these isolated mountains are called monadnocks. They mark former positions of the Blue Ridge Mountains and the Escarpment at previous stages in the evolution of the landscape.

As erosion continues, mountains and ridges along the present Escarpment that are more resistant to weathering and erosion will form new monadnocks as the Escarpment continues migrating toward the northwest.

219.4 The rocks exposed from here to mile 221.2 are mostly mica schist with just a few interbeds of metagraywacke.

Geologists apply the name metagraywacke to a non-banded to faintly banded metamorphosed sedimentary rock. Originally, this rock was a muddy sandstone composed of coarse mineral and rock fragments embedded in a compact, finer-grained micaceous matrix.

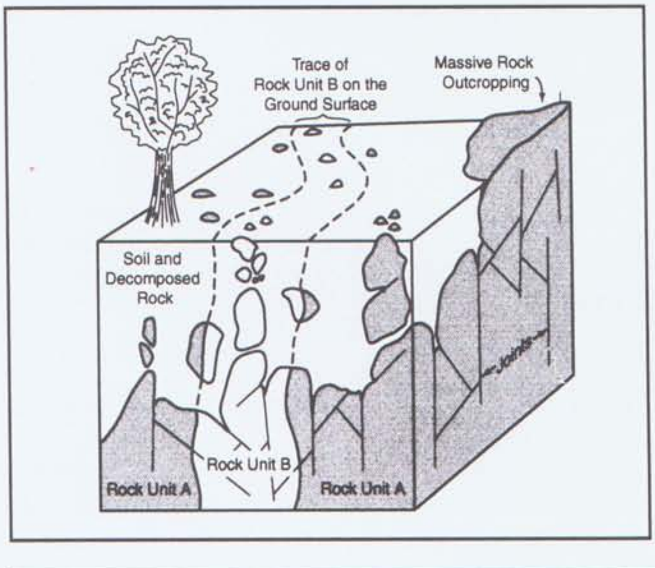


A photo mosaic of the spectacular view from the crest of High Piney Spur at Fox Hunters Paradise. From this vantage, you can see the Blue Ridge escarpment, the sharp topographic break that separates the gently rolling Piedmont province from the high mountains of the Blue Ridge. Resistant knobs and hills out in the Piedmont, including the Sauratown Mountains and Pilot Mountain, are called monadnocks. They mark the position of former high mountains that have now been almost completely eroded away.

Large red almandine garnet crystals that range from one-eighth to one-half inch in diameter are exposed in an outcrop of mica schist at mile 220.4, where State Road 1460 crosses the Parkway. When transparent and flawless, deep-red almandine garnets are prized as gemstones and faceted for use in jewelry.

Almandine garnets are also used by geologists to interpret progressive changes in temperature and pressure that occur during episodes of metamorphism (see discussion at mile 300.6). Collecting of these or any other rock or mineral is NOT PERMITTED on Parkway land.

220.5 On the southeast side of the Parkway, resistant residual white quartz boulders are exposed on the ground surface. They mark the position of a quartz vein that intruded mica schist. As the mica schist weathered and was eroded away, boulders of the more resistant quartz were left behind.



229.5 Junction of U.S. 21N - Sparta, 8 miles.

229.6 Junction of U.S. 21S - Roaring Gap, 5 miles; Elkin, 23 miles.

230.1 Little Glade Millpond Overlook, elevation 2,709 feet.

This picturesque mill pond is fed by waters of Little Glade Creek. The rock that crops out near the parking area across the Parkway is "pin-striped" gneiss of the Alligator Back Formation containing both muscovite and biotite mica. This "pin-striped" appearance is characteristic of the rocks of the Alligator Back Formation.

Before continuing your journey, you may wish to picnic, relax, or enjoy a leisurely walk along a short trail that loops around the pond. Because of the blind hill and curve, be very careful when crossing the Parkway to visit the outcrop on the opposite side.

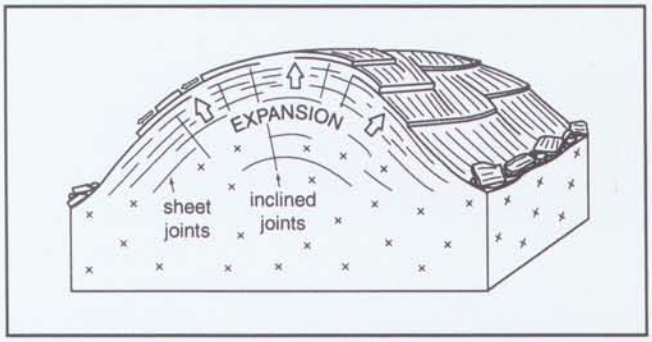
232.5 Stone Mountain Overlook, elevation 3,115 feet.

Stone Mountain, a bold, dome-shaped outcrop of granodiorite, is visible just southeast of the Parkway. At its highest point, elevation 2,305

Geologists construct maps that show the distribution and areal extent of rock units within an area. They construct maps by observing the rocks where they crop out at the surface. But in many places, rocks are not exposed at the surface. Other clues may be used to decipher what types of rocks are located beneath the ground. Rocks near the Earth's surface are weathered and decompose to form soil. Water seeps down along joints in the unweathered rocks, and weathering begins. Larger fragments of the underlying bedrock do not weather as rapidly or completely, and remain within the soil near the surface. Types of vegetation and topography may also indicate different rock types.

feet, the dome rises 700 feet above the surrounding terrain of the Piedmont province. Just west of Stone Mountain is Wolf Rock, another dome-shaped outcrop of granodiorite exposed by weathering and erosion. Plutonic igneous intrusive rock bodies of this size and shape are called stocks.

During the Devonian Period of the Paleozoic Era, about 390 million years ago, this intrusive igneous rock mass cooled and crystallized from a magma deep within the Earth's crust. During ensuing periods of mountain-building and erosion, the overlying rock mass was removed, exposing the granodiorite of Stone Mountain. Later, the rock was weathered to its present form. A weathering process known as exfoliation, which produces concentric, rounded surfaces where angular surfaces may have once existed, created the dome-shape of Stone Mountain.



A block diagram showing how exfoliation domes are formed. As weathering and erosion removes overlying rock, pressure on the underlying rock is relieved, and the rock mass expands. Joints, or cracks in the rock, form both parallel (sheet joints) and perpendicular (inclined joints) to the surface of the rock body, creating thin plates at the top of the mass. These plates then spall off during continued weathering and erosion, creating a rounded dome.

The Brushy Mountains are also visible in the Piedmont on the horizon. These monadnocks are underlain by metamorphosed granite rocks which are more resistant to erosion than the rocks surrounding them. They were left standing east of the escarpment as the Blue Ridge Escarpment migrated northwestward (see discussion at mile 218.6).

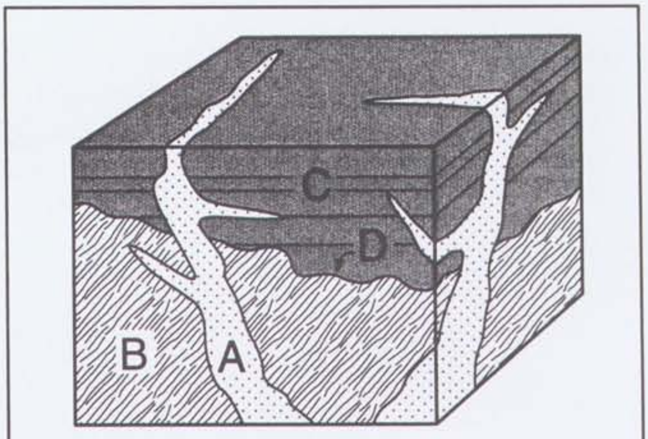
The rock outcrop here consists of light-to dark-gray migmatitic gneiss. Migmatites are "composite" igneous and metamorphic rocks that were heated and pressurized to a point that locally, feldspar and quartz within the rock melted and recrystallized into veins and pods. The highly folded light-colored veins of feldspar and quartz that in some places parallel, and in others cut across the banding of the rock, define the migmatitic character and appearance of the gneiss.

233.7 Bullhead Mountain Overlook, elevation 3,200 feet.

The rock at this overlook is garnet-bearing mica schist of the Alligator Back Formation. Crystals of garnet, known as porphyroblasts, grew in the rock mass as the rock was heated and pressurized during an episode of metamorphism. While the garnets were growing, intense pressure crinkled the schist into small tight folds known as crenulations.

In the road cut just across the Parkway, you can see quartz veins that cut across the foliation of the mica schist and must therefore be younger than the schist. They may be associated with the intrusive plutonic igneous activity that emplaced the younger igneous rocks within the area.

Native stone used in building the wall and curbing that arch around the contour of the overlook is one of the rock types of the gneiss unit of the Alligator Back Formation. The rock is a migmatitic gneiss containing biotite and muscovite mica.



The principle of crosscutting relationships. Igneous rock A intruded rock units B and C, indicating that it is younger than these older rock units. D is an old surface of weathering and erosion, called an unconformity, that separates rock unit B from rock unit C.

235.0 Mahogany Rock Overlook, elevation 3,420 feet.

This overlook offers views of a rolling upland "plateau" within the mountainous Blue Ridge physiographic province. Rocks of the Alligator

Back Formation underlie the valley below. These rocks, in the core of a huge fold called the Ararat River synclinorium, apparently are more susceptible to weathering and erosion than the surrounding rocks holding up the mountains and ridges to the northwest. Older rocks of the Ashe Metamorphic Suite underlie the higher ridges to the west, which form the gently east-dipping western limb of the synclinorium (see discussion of folds at mile 352.4 and 452.3).

Originally, rocks of the Alligator Back Formation were classified as part of the Ashe Metamorphic Suite. Both units consist largely of metasedimentary rocks — metagraywacke, mica gneiss, and mica schist, and metamorphosed volcanic rock (amphibolite). Geologists recognized, however, that rocks in the upper part of the sequence were finer grained, more thinly layered to laminated, and more micaceous, than rocks in the lower part. Hence, they separated these rocks from the rest of the Ashe Metamorphic Suite, thereby defining a new geologic unit that they named the Alligator Back Formation (see discussion at mile 242.3).

In the distance to the northwest are the Peach Bottom Mountains, also underlain by gneiss and schist of the Ashe Metamorphic Suite.

235.7 Devil's Garden Overlook, elevation 3,428 feet.

The Devil's Garden area is underlain by mica schist of the Alligator Back Formation. Excellent outcrops of this fine-grained garnetiferous rock are within a short walk east and west. Foliation in the schist on the northeast side of the parking area strikes, or trends to the northeast. The rock there contains elongated quartz masses, stretched by forces these rocks were subjected to during several episodes of mountain-building.

Native stone quarried during Parkway construction is visible in the wall that faces the edge of the overlook.

236.9 Air Bellows Gap Overlook, elevation 3,729 feet.

Here you can view the rocks just south of the overlook, where road cuts expose an interlayered sequence of rocks of the Alligator Back Formation, including mica schist, dark-gray to black amphibolite, and gneiss. The gneiss is especially interesting because it is cross-cut by highly folded veins of white quartz.

238.5 Brinegar Cabin, elevation 3,508 feet.

Situated high in the Blue Ridge is Brinegar Cabin, built by Martin Brinegar for his wife Caroline during a five-year period from 1885 to 1890. The original log exterior is now cedar-shingled and the cabin is used for demonstrating Appalachian handicrafts. It is an excellent example of how local stone was used in early mountain cabin construction.

Rock of various types, including gneiss, mica schist and amphibolite of the Alligator Back Formation, was used in the construction of the foundation, chimneys, and stepped walkways that lead to the cabin and the other structures on the Brinegar home site. Native stone was also used in building the water fountain and walks that enclose the Parkway area. Outcrops opposite the parking area are amphibolite of the Alligator Back Formation.

239.5 Entrances to campgrounds at Doughton Park.

These spacious campgrounds are underlain by gneiss of the Alligator Back Formation. Explore the nature trails of this 6,000-acre park that wind through outcrops of garnet-bearing mica gneiss. At Wildcat Rocks, once the site of a wildcat's den, are excellent examples of gneiss of the Alligator Back Formation. Similar rocks are also exposed along the trail that leads to Basin Cove.

241.1 Bluffs Lodge.

Bluffs Lodge is on the crest of Bluff Mountain, elevation 3,792 feet. A leisurely walk to the south side of the mountain brings you to Ice Rocks. The rock here is gneiss of the Alligator Back Formation. In winter, sheets of ice often cover these cliffs.

242.3 Alligator Back Overlook, elevation 3,385 feet.

The outcrops in this area represent the type locality of the Alligator Back Formation. To enhance the understanding of the geology of an area, geologists give a distinctive unit such as this a formal name. The name can be a combination of both geographic locality and rock type. The geographic part of the name tells others where they can find the best exposures of the rock (the type locality). The petrologic part of the name indicates the type of rock that characteristically composes the unit. The terms "Formation" or "Suite" are used in formal rock names when the geologic unit is distinctive and can be mapped, but consists of several different rock types.

Once the name of a map unit has been formalized by publishing it in a geologic report, other geologists can use the name to describe equivalent rocks in other areas. Geologic map units that have not been formalized because the rocks are difficult to characterize or recognize are usually referred to only by their dominant rock type.

Gneiss of the Alligator Back Formation crops out on the southeast side of the overlook. The rock is rich in biotite and muscovite mica. The upper half of the trail to Bluff Mountain winds its way across excellent exposures of "pin-striped" gneiss and schist. The "pin-striping," so evident here, is also a common characteristic of the rocks of the Alligator Back Formation elsewhere.

243.4 Bluff Mountain Overlook, elevation 3,334 feet.

From here, looking to the northeast, you can see Bluff Mountain. Massive ribs of gneiss radiate from its crest, resembling the ribs of an alligator. This is why the southwest face of the mountain is known as the Alligator Back.

To the southwest, just across the Parkway opposite the overlook, are small outcrops of "pin-striped" gneiss identical in composition and appearance to the gneiss on Bluff Mountain.

244.7 Basin Cove Overlook, elevation 3,312 feet.

From here you have a panoramic view of the dissected ridges of the Blue Ridge Escarpment and the low, rolling topography of the Piedmont physiographic province. The domed granodiorite outcrop of Stone Mountain is visible to the east. Beyond Stone Mountain, the quartzite-capped pinnacle of Pilot Mountain is visible in the Piedmont, over 40 miles away.

Pilot Mountain, part of the Sauratown Mountains, stands like a sentinel above the rolling plateau surrounding it. Pilot Mountain and Sauratown Mountains are monadnocks that were left behind as erosion caused the Blue Ridge Escarpment to retreat to the northwest (see discussion at mile 218.6).

247.9 Junction with N.C. 18N - Laurel Springs, 2 miles.

248.1 Junction with N.C. 18S - North Wilkesboro, 20 miles.

258.8 Northwest Trading Post.

Four miles north of here, on N.C. State Route 88, is the site of the Ore Knob copper mine, where a large deposit of gold-and silver-bearing copper ore was mined from the 1870s to 1883, and from 1957 to 1962. Most of the copper produced by North Carolina in the 20th century, as well as millions of dollars worth of gold and silver, came from this mine.

Take time from your geologic tour of the Blue Ridge Parkway to stop at the Northwest Trading Post, where you can view handicrafts made by the mountain folk of the Blue Ridge.

260.6 Jumpinoff Rocks Overlook, elevation 3,165 feet.

From the overlook at the end of the half-mile trail from the parking area, you can view the serrated ridges of the mountains and get a panoramic view of the Blue Ridge Escarpment, Stone Mountain, and the more distant Brushy Mountains to the southeast.

The Blue Ridge Escarpment is an erosional feature that marks the physiographic break between the Piedmont to the southeast and the higher, mountainous terrain of the Blue Ridge to the northwest. Through millions of years of continual erosion, the Piedmont has been reduced to a low-lying terrain of rolling hills where tall mountains may have previously existed. The Blue Ridge Escarpment continues to retreat northwestward as vigorous erosion by Atlantic-flowing streams attacks the existing mountains.

The more distant Brushy Mountains to the southeast belong to a class of features called monadnocks. They are isolated erosional remnants of the ancient, more extensive, Blue Ridge Mountains that once occupied today's Piedmont. As the Blue Ridge Escarpment retreated to the northwest (over millions of years) these mountains, held up by more resistant rock types, were left behind.

The Brushy Mountains are underlain by a resistant granitic rock that crystallized from magma between 400 and 500 million years ago (for further discussion, see mile 218.6).

261.3 Junction with N.C. 16 at Horse Creek Gap, elevation 3,103 feet; north to

West Jefferson, 13 miles; south to North Wilkesboro, 20 miles.

262.6 The extensive outcrops here show mica schist, amphibolite, and metagraywacke of the Alligator Back Formation. There are many pegmatites in outcrops from here to mile 270. The mica in some of these rocks was mined in the past. The Parkway passes an abandoned mica mine near mile 262.6.

264.4 The Lump Overlook, elevation 3,465 feet.

Rocks of the Alligator Back Formation underlie this panoramic view of the undulating terrain of the Blue Ridge Escarpment. (See discussion of the Blue Ridge Escarpment at mile 260.6.)

266.9 Mount Jefferson Overlook, elevation 3,699 feet.

The view at this stop on your geologic tour is of Mount Jefferson, elevation 4,515 feet. The summit and slopes of the mountain are in Mount Jefferson State Park. The plateau-like aspect of this area is very different from the rugged terrain further south along the Parkway. Amphibolite of the Ashe Metamorphic Suite is the rock that makes up this mountain.

267.8 Betsy's Rock Falls Overlook, elevation 3,400 feet.

Betsy's Rock Falls is visible to the northeast, through a narrow gap in the forest cover. Numerous Atlantic-flowing streams such as these cascade down the Blue Ridge front. The erosive effect of these streams causes the gradual retreat of the escarpment toward the northwest. Falls such as the one here are known as knickpoints—abrupt changes in the topograpic profile of a stream that develop as a result of headward erosion of a landmass.

270.2 Lewis Fork Overlook, elevation 3,290 feet.

In the valley below is the South Prong of Lewis Fork Creek, which flows into the Yadkin River. The headwaters of the creek cascade down the Blue Ridge Escarpment on their way to the Atlantic Ocean, facilitating erosion that causes the escarpment to migrate toward the northwest.

270.4 This large Parkway road cut displays interlayered metagraywacke and mica schist of the Alligator Back Formation, cut by quartz veins.

271.2 Small scattered outcrops of metagraywacke and mica schist of the Alligator Back Formation appear in road cuts from here to mile 271.5.

271.9 Cascades Overlook, elevation 3,570 feet.

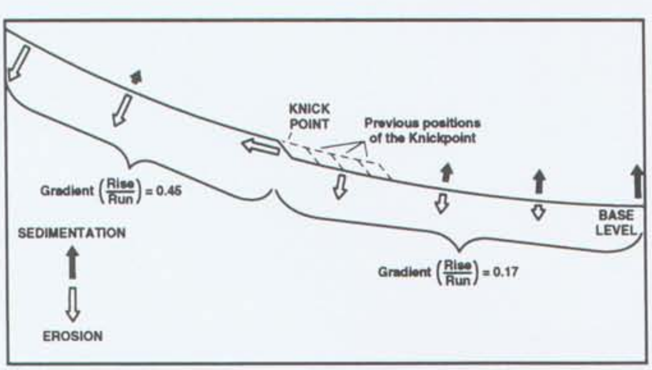
This area is part of E. B. Jeffress Park, a 600-acre section of mountain forest set aside in memory of a Chairman of the North Carolina Highway Commission who worked to secure the present location of the Blue Ridge Parkway.

The Cascades Trail meanders through outcrops of metagraywacke of the Alligator Back Formation. The coarse, granular layers attest to the original sedimentary protolith of these metamorphic rocks.

Notice the locally granular to gritty characteristic of some of the rocks along the trail.

At the falls, the metagraywacke layers are inclined into the mountainside. These layers are also intruded by light-colored granitic to pegmatitic rocks.

Like Betsy's Rock Falls (mile 267.8), the Cascades of Falls Creek dance their way down the Blue Ridge escarpment to the Yadkin River and the Atlantic Ocean beyond. The Cascades are a prime example of a knickpoint along the escarpment, marking the headward retreat of the escarpment by northwestward-directed erosion (see discussion at mile 267.8).



A cross section of a stream showing the configuration of a knickpoint. A knickpoint is an abrupt change in the slope, or gradient, of a stream or river. In the portions of the stream above the knickpoint, where the gradient is higher, the base of the stream undergoes active erosion at a far greater pace than below the knickpoint. Where the gradient of the stream is less, more sediment is deposited than is eroded away. Base level is that portion of the stream or river where the gradient is near zero. The ocean is the ultimate base level for all of the Earth's streams and rivers. Continued erosion causes the knickpoint to migrate upstream.

274.3 Elk Mountain Overlook, elevation 3,795 feet.

From here you can see Yadkin Valley, through which the Yadkin River flows on its way to Wilkesboro Reservoir and from there to the Atlantic Ocean. Visible on the skyline are a group of monadnocks known as the Brushy Mountains. These are eroded vestiges of the high mountains that once occupied the Piedmont (see discussion at mile 260.6).

276.4 Deep Gap, elevation 3,142 feet, junction with U.S. 421-east to North Wilkesboro, 26 miles; west to Boone, 12 miles.

This gap marks the location of the Eastern Continental Divide (see map at mile 393.8). Rivers and streams to the east flow directly to the Atlantic Ocean, whereas rivers and streams west of this divide flow into the Mississippi River and the Gulf of Mexico.

280.8 Access to U.S. 421 and U.S. 221-Boone, 7 miles west; North Wilkesboro, 29 miles east.

281.9 Here is the contact between rocks of the Alligator Back Formation and rocks of the Ashe Metamorphic Suite.

Although both of these Late Proterozoic units consist chiefly of metasedimentary rocks in which gneiss and schist are the main rock types, there are certain differences that allow one to be distinguished from the other. Two chief differences are: (1) overall, the rocks of the Alligator Back are more thinly layered than those of the Ashe, and (2) amphibolite is more common, and it occurs in thicker layers, in the Ashe Metamorphic Suite in this region.

Geologists believe that the Alligator Back Formation formed from sediments that were deposited on top of, and are therefore younger than, the rocks of the Ashe Metamorphic Suite.

283.1 Small outcrops of hornblende gneiss and metagraywacke of the Ashe Metamorphic Suite can be seen in Parkway road cuts here.

284.6 Here is the contact between the Ashe Metamorphic Suite and an older rock unit composed of biotite granitic gneiss.

Unlike the rocks of the Ashe Metamorphic Suite, which are some 700 million years old, this biotite granitic gneiss unit of the Middle Proterozoic basement complex is over 1 billion years old (see further discussion at mile 446.0). The contact is interpreted as a thrust fault, with rocks of the Ashe Metamorphic Suite thrust up and over the older basement rock.

Mile 286.1 to 350

A Window Through Time

Around 300 million years ago, tremendous masses of rock were shoved some 200 miles westward along major faults in the Earth's crust as the North American and African continents collided during the Alleghanian orogeny. These masses of rock were piled one on top of the other and arched upward as the thrust sheets were stacked.

Following this final episode of orogenic mountain-building, 250 million years of sporadic uplift and continual stream erosion carved a huge gap in the pile of thrust sheets in this part of the Blue Ridge, exposing rocks in the underlying sheets. This hole through the stack of thrust sheets is known as the Grandfather Mountain window. As the name implies, a window is a geologic structure where one can view younger rocks in the footwall of a thrust fault from older rocks that overlie them in the hanging wall.

Several geologic units of these underlying rocks within the Grandfather Mountain window can be seen along this stretch of Parkway. They include metasedimentary and metavolcanic rocks of the Late Proterozoic Grandfather Mountain Formation, and billion-year-old Grenville basement rocks of the Blowing Rock Gneiss and a unit composed of biotite granitic gneiss. Younger metasedimentary rocks of the Chilhowee Group of Cambrian age are also exposed in the window. Similar Chilhowee Group rocks are not seen elsewhere in western North Carolina except along the far western edge of the Blue Ridge province near the Tennessee state line.

The Linville Falls fault marks the edge of the Grandfather Mountain window. Having first crossed the fault and entered the window at mile 286.4, southbound visitors cross it again at mile 316.8, as they leave the window. The Upper Falls Overlook at Linville Falls features a close-up view of the fault. Here, erosion by the Linville River has exposed billion-year-old biotite granitic gneiss thrust over Paleozoic rocks of the Chilhowee Group. This is one of the few places along the Parkway where rocks as young as the Chilhowee (less than 570 million years old) are exposed.

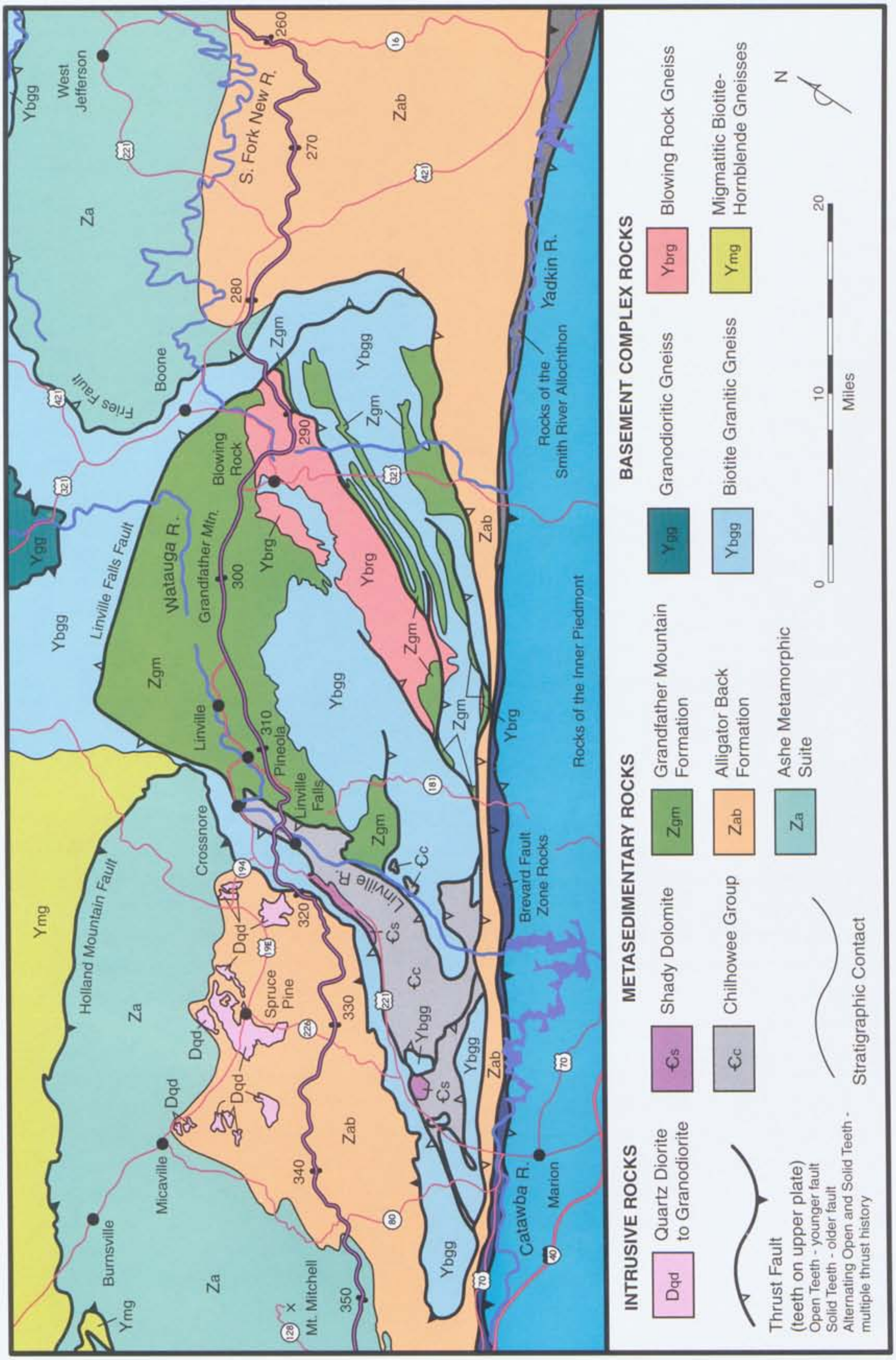
Almost the first half of this 64-mile segment is within the Grandfather Mountain window. The Chestoa Overlook, at mile 320.8, offers an opportunity to learn more about the structure.

The overlook at mile 318.4 offers a glimpse of the tallest range in eastern North America—the Black Mountains. Further south, at mile 330.9, is the Museum of North Carolina Minerals, near Spruce Pine. The museum displays specimens of many of the more than 300 minerals found in North Carolina, as well as information about the mines of the Spruce Pine area, a mining district with the longest record of continuous activity in the state.

South of the Grandfather Mountain window, the rocks along this segment of the Parkway belong to two Late Proterozoic geologic units: the Alligator Back Formation, familiar from the 69-mile stretch south of the Virginia-North Carolina state line, and the Ashe Metamorphic Suite.

The Ashe Metamorphic Suite is a composite of varieties of gneiss and schist, metagraywacke, and amphibolite, and is the most widespread Late Proterozoic formation in western North Carolina. It underlies more than a thousand square miles, including the Black Mountains. From mile 344.8 southward for the next 95 miles, all the rocks along the Parkway belong to this extensive geologic unit.

Visitor facilities include: Moses H. Cone Memorial Park (visitor center with information and bookstore, naturalist interpretive programs, craft center, fishing, horseback and carriage rides, hiking, restrooms); Julian Price Memorial Park (picnic areas, hiking and nature walks, campground, fishing, boat rental, naturalist programs, restrooms); Linn Cove Visitor Center (information and bookstore, trails, exhibit, restrooms); access to Grandfather Mountain (entrance fee); Linville Falls Recreation Area (visitor center with information and bookstore, camping, picnicking, fishing, and naturalist programs, nature walks and self-guiding trails, and restrooms; Museum of North Carolina Minerals (exhibits of minerals, rocks and gemstones, information, books, gifts, restrooms); Crabtree Meadows (picnicking, camping, hiking, coffee and gift shop, naturalist program, restrooms).



Geologic map of the Grandfather Mountain window in western North Carolina showing the location of the Blue Ridge Parkway (in purple) from mile 255.0 to mile 354.0. Rocks within the Grandfather Mountain window are exposed in a lower thrust sheet than the rocks surrounding the window.

286.4 Here is the contact between rocks of the biotite granitic gneiss unit and the Blowing Rock Gneiss in Goshen Branch.

The Blowing Rock Gneiss is a distinctive Middle Proterozoic geologic map unit that has always been mapped separately from the typical, layered biotite granitic gneiss and other Middle Proterozoic basement rocks of the Blue Ridge Mountains. It is characterized and distinguished by abundant megacrysts of light potassium feldspar in a finely banded biotite schist. This rock type underlies the outcrops and exposures for which the town of Blowing Rock is named.

The contact between the biotite granitic gneiss and the Blowing Rock Gneiss is interpreted as the Linville Falls fault. The Linville Falls fault is the geologic structure that outlines the Grandfather Mountain window, a large area in which erosion has stripped away overlying rocks in the hanging wall, exposing the rocks beneath the sheet.

In the Blue Ridge Mountains, thrust faulting has rearranged the original sequence of rock layers by inverting them, so that younger, more recently formed rocks are buried by the older rocks of the thrust sheet — a reversal of the normal order. Rocks above the fault, such as the biotite granitic gneiss, have been thrust many miles northwestward from where they originally resided.

The fault on which this movement occurred is named for its excellent exposure at the Upper Falls of the Linville River (see mile 316.4, Linville Falls Visitor Center). It is also described at mile 316.8 and 320.8, along with additional discussions of the Grandfather Mountain window.

289.6 Raven Rocks Overlook, elevation 3,810 feet.

A 30-foot overhang in the Blowing Rock Gneiss offers a spectacular example of differential weathering of rocks and minerals. Here, cream-colored augen of potassium feldspar stand out in relief against the dark, biotite-rich matrix of the gneiss. Where prominent joints intersect foliation planes in the gneiss, the erosional process of mass wasting causes rock to fall and cliffs like these to form.

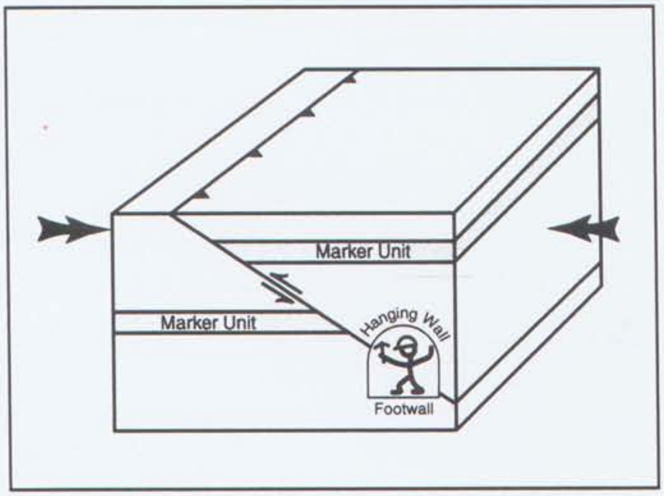
289.9 Yadkin Valley Overlook, elevation 3,840 feet.

This stop offers an excellent view of the headwaters of the Yadkin River, where it begins its seaward journey to the Atlantic. At the foot of the mountains, the flow of the river changes direction from southeasterly to northeasterly. From there the river flows nearly 60 miles, following the northeasterly structural trend of the Brevard Fault zone (see discussion at mile 413.2). This direction of flow is unusual for Southern rivers.

An abrupt change in the direction of flow of a river may signal control by a fault, as it does here for the Yadkin, or by contact boundaries between rocks of different compositions.

290.4 Thunder Hill Overlook, elevation, 3,795 feet.

The low outcrop across the Parkway to the north is the Blowing Rock Gneiss. This rock type is called an "augen" gneiss because of its large white feldspar crystals, some more than 2.5 inches long, that are surrounded by a dark-colored, fine-grained mineral matrix. Augen is the German word for



Elements of a thrust fault. A thrust fault occurs where older rocks deeper within the Earth are shoved up and over younger rocks by compressional forces. Geologists refer to the overlying mass of rock as the hanging wall of the thrust fault (they also refer to this body of rock as a "thrust sheet"). The rock mass beneath the thrust fault is called the footwall. The terms hanging wall and footwall came from old-time miners. If a tunnel is drilled along the fault, the rocks at your feet are in the footwall, and the rocks hanging above your head are in the hanging wall. On geologic maps, geologists use triangular "teeth" to indicate which body of rock is in the hanging wall (the thrust teeth point to the hanging wall). In cross section, arrows are used to indicate movement.

"eyes," which these feldspar crystals resemble. The matrix consists mostly of biotite mica and green epidote.

At the west end of the outcrop, the feldspar crystals stand out from the matrix because of differences in resistance to erosion of the various mineral components of the rock.

A surveyor's benchmark, a brass disk over three inches in diameter, is cemented into the bedrock on top of the outcrop. The positions of benchmarks are very accurately determined. It is illegal to tamper with them because they are reference points for precise location. The latitude and longitude of this one is 36°8'11.18851" North Latitude; 81°38' 35.69237" West Longitude; and its elevation is 3,799 feet.

291.8 Junction with U.S. 321 and U.S. 221; north to Boone, 8 miles; south to Blowing Rock, 1 mile.

292.7 Moses H. Cone Memorial Park.

A turn-of-the-century country manor, Moses H. Cone Memorial park now houses a visitor and craft center, and gift shop, set in a 3,500-acre forested highland which is criss-crossed by 25 miles of carriage roads for riding or hiking.

292.8 Here is the contact between the Blowing Rock Gneiss and the Grandfather Mountain Formation (not exposed).

The Grandfather Mountain Formation is a thick sequence of metasedimentary rocks in which strata of metamorphosed arkose, graywacke, conglomerate, siltstone, and shale alternate with each other and with meta-volcanic rock. It lies nonconformably on biotite granitic gneiss and on the Blowing Rock Gneiss.

Despite metamorphism, many of the primary sedimentary and volcanic characteristics can still be recognized in outcrops of this formation. Features such as graded bedding and cross-bedding can be seen in some of the rocks.

293.5 Moses Cone Overlook, elevation 3,888 feet.

Here is an exposure of fine-grained metamorphosed siltstone and shale of the Grandfather Mountain Formation. Rocks of the Grandfather Mountain Formation were originally volcanic and sedimentary rock deposited during Late Proterozoic continental rifting into a deep rift trough along the edge of the continent, but heat and pressure during the Ordovician Taconic orogeny later metamorphosed them.

294.6 Sandy Flat Gap, access to U.S. 221; east to Blowing Rock, 2 miles.

295.8 Julian Price Memorial Park.

This 3,900-acre forested highland, dissected by trout streams, is inviting to naturalists, fishermen and campers.

295.9 Sims Pond Overlook, elevation 3,447 feet.

Natural lakes are rare in the mature mountain landscape of the Blue Ridge. This small pond exists here because a dam was built across the stream valley. Without upkeep, the impoundment will be destroyed, either by deterioration and failure of the dam, or by filling of the pond with silt and organic material.

296.1 The green boulders under the clump of oak trees next to the barn are rocks of the Linville Metadiabase, a geologic formation described at mile 302.1.

296.5 Price Park Picnic Area.

This beautiful picnic area, located in the floodplain of the meandering tributaries of Boone Fork, is a pleasant place to rest and enjoy the natural beauty of the site.

296.6 Bridge and dam over Boone Fork.

Boone Fork has been dammed here to form 47-acre Price Lake, stocked with trout for the fisherman and bordered by winding lakeside trails for the hiker.

296.7 Price Lake Overlook, elevation 3,380 feet.

Outcrops to the northwest are metagraywacke of the Grandfather Mountain Formation.

298.6 Access to U.S. 221 via Holloway Mountain Road.

299.7 Calloway Peak Overlook, elevation, 3,798 feet.

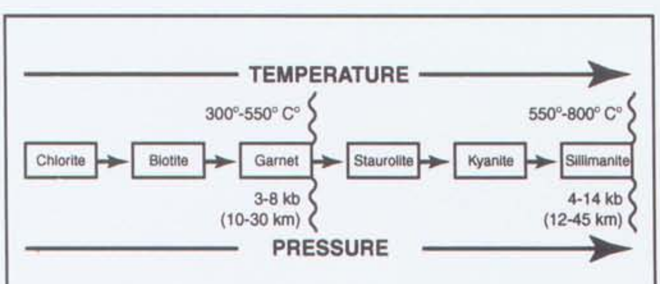
Conglomerate of the Grandfather Mountain Formation is exposed here. The rock is made up of different size fragments of pre-existing rock, including rounded cobbles up to six inches long. Most of the larger cobbles and pebbles are composed of quartz or metavolcanic rock.

300.6 Green Mountain Overlook, elevation 4,134 feet.

The outcrop of metagraywacke across the Parkway to the west has a greenish color caused by the minerals chlorite and sericite within the rock. These minerals formed when the rocks of the area underwent metamorphism.

Chlorite is one of several minerals that geologists use to interpret metamorphic conditions that rocks were subjected to during orogenic mountain-building. As temperature and pressure in the rock increase during metamorphism, certain minerals start to form. This phenomenon was first recognized, described, and mapped by George Barrow, a Scottish geologist, in 1893.

In the Highlands of Scotland, he recognized that certain sedimentary rocks subjected to progressive changes in temperature and pressure during metamorphism display certain "index" minerals. Chlorite is an indicator of low temperatures and pressures, followed by biotite as temperatures and pressures increase. Biotite, in turn, is followed by garnet, staurolite, and kyanite at higher temperatures and pressures, and finally by sillimanite at the highest temperatures and pressures. Geologists refer to this index mineral zonation as "regional Barrovian-type metamorphism."



Sequence of index metamorphic minerals that appear during progressive regional Barrovian-type metamorphism in certain sedimentary rocks. At low temperatures and pressures, chlorite is the only index metamorphic mineral that appears in the rock. With increasing temperature and pressure, biotite is formed at the expense of chlorite. Garnet appears in the rock at temperatures of 300° to 500° C and 3 to 8 kilobars of pressure (equivalent to burial at depths of 10 to 30 kilometers below the surface). Sillimanite forms at the highest temperature and pressure.

302.1 Wilson Creek Valley Overlook, elevation 4,356 feet.

The rock outcrops at the headwaters of Anthony Creek are composed of Linville Metadiabase. They formed from a magma that intruded the sediments of the Grandfather Mountain Formation. They owe their green color to minerals such as actinolite and chlorite, which formed when the rocks were subjected to low-grade regional metamorphism.

304.0 thru 304.3 Linn Cove Viaduct.

Five years in construction, the $10-million Linn Cove Viaduct received the President's Design Award in 1984 for its innovative engineering design and harmony with the environment. Each of its seven pre-cast supporting piers is bolted to the rock on which it stands. Pre-cast roadway sections are held together by epoxy and interlocking cables strung through the interior of the concrete deck. The 1,243-foot structure hugs the contours of Grandfather Mountain in a giant S-curve, designed so that none of the 153 sections of the roadway are in contact with the steeply sloping boulder field that the viaduct traverses. This protects the environment by maintaining the existing terrain and allowing unrestricted passage of wildlife.

304.4 Linn Cove Visitor Center, elevation 4,350 feet.

From the parking area, you can walk under and around the viaduct. The trail winds between huge metagraywacke boulders of the Grandfather Mountain Formation. Here and there, the boulders overhang each other to form shallow "caves" (for further information on caves, see mile 422.4).

In places, the rock is distinctly conglomeratic, with rounded and flattened quartz pebbles of different sizes.

305.1 Junction with U.S. 221; south to Grandfather Mountain entrance, 1 mile; south to Linville, 3 miles; north to Blowing Rock, 15 miles.

The road cuts along the access road between the Parkway and U.S. 221 exhibit excellent exposures of the metagraywacke of the Grandfather Mountain Formation, as does the trail from the Beacon Heights Overlook, at mile 305.2.

306.6 Grandfather Mountain Overlook, elevation 4,154 feet.

The weathered outcrops across the Parkway are fine-grained metasiltstone of the Grandfather Mountain Formation. Soil-forming processes of weathering and erosion are breaking down the rock to make a thin, stony, relatively infertile acidic soil.

To the northeast, you have a good view of the rugged majestic peaks of Grandfather Mountain, rising to a height of 5,964 feet at Calloway Peak.

307.4 Grandmother Mountain parking area, elevation 4,160 feet.

Resistant layers of metagraywacke underlie Grandmother Mountain, the hill to the northeast.

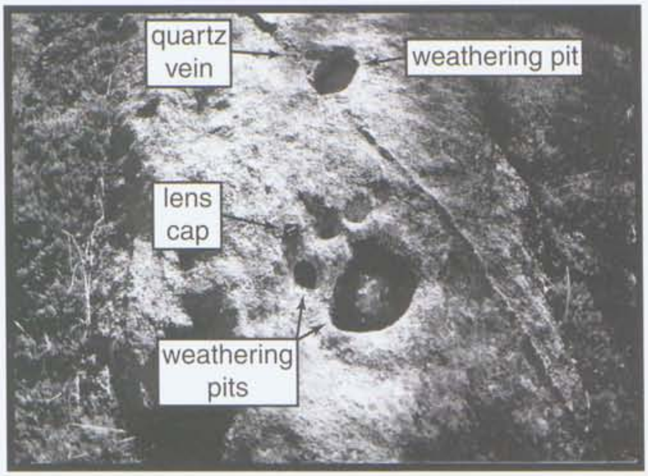
307.9 Intersection with SR 1511, northwest to Linville, 1.5 miles.

308.3 Parking area for Flat Rock Trail, elevation 3,987 feet.

Interesting geological features are exposed and can easily be observed at various places along this trail, a short self-guiding trail that can be walked in about 30 minutes.

The principal rock type is metagraywacke of the Grandfather Mountain Formation. It occurs as individual boulders and as pavement-like exposures that form Flat Rock. An abundance of rounded quartz pebbles and other resistant rock types demonstrate the original sedimentary, conglomeratic nature of the rock.

The circular depressions on Flat Rock are weathering pits, which form because erosion is focused by the arrangement of cracks or fractures within the rock. Continued erosion by solution, frost action, and abrasion has enlarged these depressions to their present size.



Photograph of weathering pits along Flat Rock trail, mile 308.3. The lens cap is for scale.

There is also an impressive view of Grandfather Mountain to the northeast.

310.0 Lost Cove Cliffs Overlook, elevation 3,812 feet.

The rock cliffs visible from here are about 1.5 miles away. They are composed of biotite granitic gneiss, one of the oldest units of the basement complex in the region, formed in Middle Proterozoic time, about 1 billion years ago.

A display at this overlook tells about a mysterious phenomenon known as the Brown Mountain Lights. Scientists have speculated for many years about what causes the eerie night-time glow that can sometimes be seen from here, off in the distance. They have concluded that what people see on certain summer nights are the beams of headlights from trains and cars, refracted by atmospheric disturbances.

312.2 Access to N.C. 181, south to Morganton, 28 miles; north to Pineola, 2 miles; north to Linville, 5 miles.

315.0 Here is the contact between rocks of the Grandfather Mountain Formation and the Chilhowee Group.

The boulders in the field to the north, at mile 314.8, are of Grandfather Mountain Formation meta-arkose, typical of the bedrock beneath the field. About 250 feet south are outcrops of white, fine-grained feldspathic quartzite typical of the Chilhowee Group.

The boundary between these two formations of vastly different age is a fault contact (see discussion at mile 284.6). The fault that has brought these formations together has been identified and mapped for several miles in the area. It is named the Table Rock fault because of good exposures on the sides of Table Rock Mountain.

315.6 Camp Creek parking area, elevation 3,443 feet.

Outcrops on the south side of the parkway are of the Chilhowee Group. Individual beds of quartzite at this outcrop are mostly less than one foot thick.

316.4 Linville Falls Visitor Center.

Turn south onto the Linville Falls access road for an interesting side trip. A scenic riverside camping area lies 0.5 miles south of the entrance, and the Linville Falls Visitor Center parking area is a mile beyond that. Allow at least an hour or two for a pleasant and interesting walk to several scenic overlooks where you can see the Falls and the Upper Gorge of the Linville River. The Gorge, a Wilderness Area within the Pisgah National Forest, is protected from development and preserved in its natural state.

0.3 River Bend Parking Area.

Across the Linville River, on the outside curve of a bend in the river, is a cliff of distinctly bedded metasedimentary rocks of the Chilhowee Group. The beds, originally deposited horizontally, are now tilted and folded. In their deformed state, the strata are evidence of the effects of mountain-building forces that helped create the Southern Appalachians during the Paleozoic Era.

Today, sediment is being deposited along the inside curve of the river bend. Sand and cobbles of resistant quartzite make up much of the material. Deposition occurs here along the inside curve of the river bend because the water flows less swiftly there than on the outside bend.

The velocity of the water is the force that suspends and carries sediment. Where it slackens, as on the river's inside bend, heavier particles of sediment lose buoyancy and drop to the bottom, forming a sedimentary deposit.

Certain geologic principles, such as those that govern transportation and deposition of sediment into horizontal layers by water, are inviolate laws of nature that have not changed throughout the course of time. The idea that our understanding of processes which occur in the present can be applied to events in the past is collectively known as the Principle of Uniformitarianism.

0.5 Entrance to camping area to west.

0.9 Parking area.

The prominent double-peaked ridge, about 2.5 miles to the southwest, is Humpback Mountain, elevation 4,260 feet.

Across from the parking area is an extensive road cut exposing uniformly layered or bedded rocks of the Chilhowee Group. Many of the surfaces are stained various shades of red and brown by the iron-oxide minerals limonite and hematite. However, the rock itself is much lighter in color.

At the south end of this exposure, medium- and coarse-grained metasandstone is relatively abundant. At the north end, the rock is more thinly layered, and consists mainly of phyllite.

The Chilhowee rocks decompose to a silty, gritty non-fertile soil, as seen in this road cut. Mountain laurels and other plants establish themselves in joints or fractures in the rock. Little else grows except mosses and ferns in the wet spots.

During rainy weather, some of the rock fractures act as conduits for groundwater and form small springs.

1.4 Linville Falls Visitor Center, elevation 3,185 feet.

Several scenic walking trails begin here. Geologically, the most interesting is the easy half-mile walk on the Erwin's View Trail to the Upper Falls. Cross the bridge over the Linville River, behind the visitor center, and observe the rocks exposed along the path to the Upper Falls. They are granitic in composition, composed mostly of the minerals feldspar and quartz, with lesser amounts of biotite mica. Abundant lichens and an iron-oxide stain cover most of the rock surfaces, making it difficult to identify many of the local rock features. The biotite granitic gneiss here is about a billion (a thousand million) years old.

As you descend the steps to the Upper Falls Overlook, you pass downward from the very old biotite granitic gneiss and cross a nearly horizontal fault contact into well-bedded metasedimentary rocks of the much younger Chilhowee Group. These rocks have parallel folds that are spaced a few feet apart.

The folds formed perpendicular to the direction of fault movement during thrusting. Movement along the Linville Falls fault carried the overlying biotite granitic gneiss many miles northwestward, away from the present falls. The Linville Falls fault is the same thrust fault that the Parkway crosses when it enters the Grandfather Mountain window, 30 miles to the north, at mile 286.4.

The beautiful Linville River cascades over biotite granitic gneiss, which forms the prominent rock ledge of the Upper Falls. Immediately beneath this rock is metasandstone of the Chilhowee Group. A rock type called mylonite marks the fault boundary here. Heat and pressure caused by movement along the Linville Falls fault changed the character of the original rock to a soft, very fine-grained, banded mylonite (a type of fault rock) less than two feet wide.

Explore the other trails that branch from the path to the Upper Falls, winding their way through a forested terrain highlighted by native rhododendrons. At the Chimney View Overlook, well-bedded Chilhowee rocks are exposed. Here you can view the Upper and Lower Falls as they cascade over the bedded and complexly folded Chilhowee rocks.

Erwin's View Overlook is an excellent place to view the falls and Upper Gorge of the Linville River. The combined drop from the top of the Upper Falls to the base of the Lower Falls is about 125 feet.

Retrace Your Route Back To The Blue Ridge Parkway.

316.5 Entrance to Linville River Picnic Area.

316.8 The Parkway crosses the Linville Falls fault again (see discussion of the fault at mile 286.4). The actual fault surface is not well exposed, as it is at the Upper Falls Overlook. However, fragments of mylonite occur at the west end of the stone-retaining wall on the south side of the Parkway.

The small outcrops to the west are of old biotite granitic gneiss. The outcrops to the east are younger metasedimentary rocks of the Chilhowee Group. This outcrop data is sufficient to map the path of the fault with confidence.

The Linville Falls fault is the great thrust fault that encircles the Grandfather Mountain window (see discussion at mile 286.9). Thus, traveling south on the Parkway, you leave the Grandfather Mountain window at this point, some 30 miles south of where you first entered it.

317.4 Junction with U.S. 221, south to Linville Falls community, 1 mile, and to Marion, 23 miles; north to Crossnore, 5 miles.

318.4 North Toe River Valley Overlook, elevation 3,540 feet.

The main valley in the foreground is Brushy Creek, a tributary of the North Toe River which lies several miles to the west.

Visible from here are mine excavations from many years of kaolin mining. Most of the kaolin output from these mines was used to produce ceramic ware and fine china. The kaolin formed through weathering of an unusual igneous rock called alaskite, characterized by abundant feldspar, quartz, and mica, and an extremely low iron content. High-purity quartz is now the most significant mineral recovered from this mining operation.

Chalk Mountain, in the middle background, is composed almost entirely of alaskite (not chalk as the name implies). Unweathered rock from Chalk Mountain is mined for feldspar, quartz, and mica.

In the far distance, about 20 miles to the southwest, are the peaks of the Black Mountains. The tallest of these is Mount Mitchell. At 6,684 feet above sea level it is the highest mountain east of the Mississippi. From this distance, the Black Mountains are easiest to see on clear days, during the cooler months of the year.

Small weathered outcrops across the Parkway are biotite granitic gneiss, parts of which have changed to mylonite through faulting during the Alleghanian orogeny.

319.8 Here is the fault contact between the billion-year-old biotite granitic gneiss and the overlying metasedimentary and metavolcanic rocks of the Alligator Back Formation. Biotite-muscovite gneiss and schist containing small pegmatites and feldspathic veins overlie the layered biotite granitic gneiss here, but there are no outcrops at this point on the Parkway in which to see the contact.

320.8 Chestoa View parking area, elevation 4,090 feet.

From the parking area, walk down the path 200 feet to the observation area. The rock type at this overhanging cliff is thin-layered gneiss of the Alligator Back Formation. The gneiss formed from sedimentary rocks originally deposited as clay, silt, and sand on an ancient sea floor, over 700 million years ago.

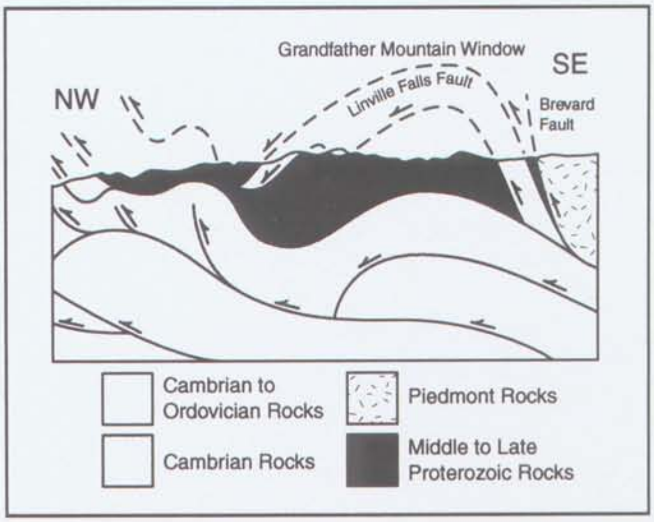
During the Taconic episode of mountain-building in the Ordovician time-period, rising temperatures metamorphosed the rocks. During the Alleghanian orogeny, in the Carboniferous time-period, they were thrust on top of a younger sequence of rocks and domed upward.

Subsequent erosion exposed the underlying younger sequence of rocks, producing what geologists call a window, a geologic structure where one can view younger rocks through the older rocks that overlie them. The window before you is the Grandfather Mountain window. Rocks within the window can be observed along the Parkway from mile 286.4 to mile 316.8 (see discussion of the Grandfather Mountain window at mile 286.4).

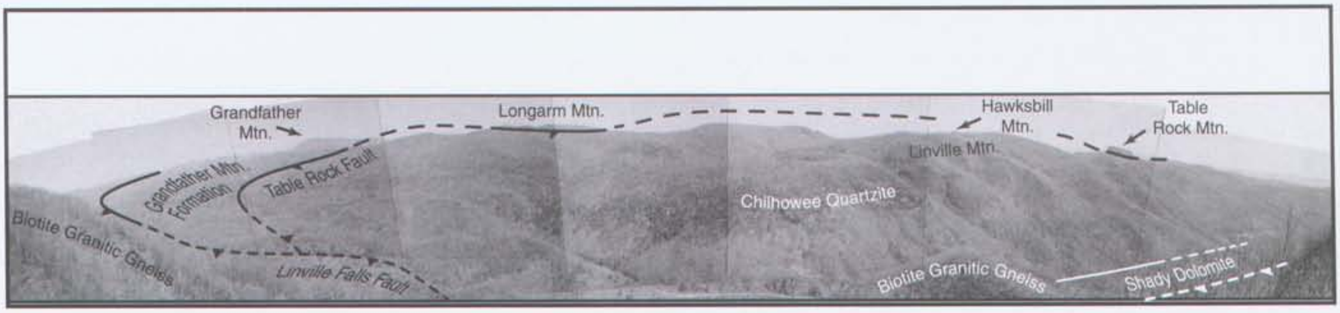
The surfaces along which older rocks (such as the Alligator Back Formation) were thrust up upon younger rocks can be identified by the abrupt changes in rock type and the change in the age of the rocks that occur in the valley walls below Chestoa View. For example, on the valley floor, at an elevation 1,500 feet below the overlook, the Shady Dolomite, a Lower Cambrian-age rock unit, crops out. This rock unit is common to the Valley and Ridge province of eastern Tennessee and southwestern Virginia and provides evidence that faulting moved the rocks of the Blue Ridge.

The Cambrian-age rocks of the Grandfather Mountain window differ greatly in their susceptibility to erosion. Linville Caverns has developed in the Shady Dolomite, a unit of soluble carbonate rocks composed of the calcium-magnesium carbonate mineral dolomite. Linville Mountain lies east of the North Fork of the Catawba River. It is underlain by a resistant rock called quartzite. The quartzite of the mountain is part of the Chilhowee Group and is the reason for the mountain's prominence.

Linville Gorge is out of view on the eastern side of Linville Mountain. The quartzite summit visible on the far side of the gorge is Table Rock Mountain. The peak visible to the northeast is the jagged, rocky spine of Grandfather Mountain. Grandfather Mountain is underlain by a much older rock sequence, the Late Proterozoic geologic unit known as the Grandfather Mountain Formation.



A simplified cross section through the Grandfather Mountain window. Notice how rocks in the window are the same age as rocks that crop out to the northwest.



Photomosaic of the view looking east from the Chestoa View Overlook, mile 320.8, at the southwestern end of the Grandfather Mountain window. The Linville Falls fault, the boundary fault surrounding the window, lies in the valley floor at the bottom of the slope (the fault is shown as a short-dashed line where it is not exposed to view from this vantage point). The small knoll in the foreground just below the overlook is underlain by biotite granitic gneiss outside of the window. Rocks of the Grandfather Mountain Formation underlie the northern part of the window in the vicinity of Grandfather Mountain, and Hawksbill Mountain, behind Linville Mountain. Quartzite rock of the Chilhowee Group underlies the ridges and peaks just across the valley. These rocks, and rocks of the Shady Dolomite, lie within the Table Rock thrust sheet, another fault-bounded body of rocks within the Grandfather Mountain window. On the horizon to the southeast is Table Rock Mountain. It is also underlain by rocks of the Chilhowee Group in the Table Rock thrust sheet (the fault plane is long-dashed where weathering and erosion have already removed the rock units that comprise the thrust sheet). Biotite granitic gneiss inside the Grandfather Mountain window lies beneath Chilhowee quartzite on Table Rock Mountain.

323.0 Bear Den Overlook, elevation 3,359 feet.

Gneiss of the Alligator Back Formation in the Parkway road cut opposite this overlook contains large flakes of muscovite mica as well as a zone of light-colored quartz and feldspar. During regional metamorphism during the Ordovician, high temperatures and pressures made this rock material very ductile, perhaps even partly molten. Rocks like these are described as migmatitic.

The peaks of Honeycutt Mountain in the eastern foreground are composed of old Grenville basement rocks. The ridge farther east is within the Grandfather Mountain window and is underlain by resistant quartzite of the Chilhowee Group. The high peaks to the west are the Black Mountains. Mount Mitchell, the highest, is near the southern end.

The view to the southeast is of the highly dissected and typically irregular Blue Ridge Escarpment (see discussion at mile 218.6 and 260.6). The uneven headward erosion of the tributaries of the Catawba River causes this sculptured erosional pattern. The different rock types vary in resistance to erosion, some are far more susceptible than others.

325.9 Heffner Gap Overlook, elevation 3,067 feet.

Approximately 1,200 feet north of this overlook, a Parkway road cut exposes gneiss of the Alligator Back Formation. From here you can view the long ridgeline of Linville Mountain. Running along the summit is Kistler Memorial Highway, an unpaved road providing access to the many hiking trails that descend the mountain into the Linville Gorge Wilderness Area.

327.3 North Cove Overlook, elevation 2,815 feet.

From here you can view Dobson Knob, the southern terminus of Linville Mountain, and North Cove. The less resistant Early Cambrian-age Shady Dolomite in the cove is easily eroded, forming a broad valley along the North Fork of the Catawba River.

329.8 Table Rock Overlook, elevation 2,870 feet.

A highlight of the drive is this dramatic view of Table Rock Mountain, elevation 3,509 feet, an erosional remnant of resistant quartzite of the Chilhowee Group within the Grandfather Mountain window (see discussion at mile 320.8). The quartzite was thrust faulted over the less resistant biotite granitic gneiss during Alleghanian mountain-building.

330.9 Gillespie Gap, elevation 2,819 feet; exit to Museum of North Carolina Minerals and N.C. 226; south to Marion, 14 miles; north to Spruce Pine, 6 miles.

The Museum of North Carolina Minerals showcases specimens of the large variety of minerals, rocks, and gemstones found in North Carolina. Also featured is the history of mining in the state, especially in the neighboring Spruce Pine District, with displays of most of North Carolina's important economic minerals.

The museum building and the nearby monument are faced with greenish-gray metagraywacke quarried from the Grandfather Mountain Formation. The drinking fountain and the main walkway are constructed of gneiss quarried from road cuts in the Alligator Back Formation when the Parkway was being built.

On the lawn next to the walkway are large blocks of ore from the Cranberry Iron Mine, which is located on U.S. 19E in Avery County. The large dark block consists almost entirely of the iron-oxide mineral magnetite and is magnetic enough to attract a magnet. The other blocks are mixtures of magnetite and other minerals, including the pistachio-green mineral epidote.

In the Spruce Pine Mining District, three companies mine alaskite, a medium-to coarse-grained, light colored rock that contains the minerals feldspar, quartz, and muscovite mica. The rock is abundant throughout the District. The Spruce Pine Mining District is the nation's chief supplier of feldspar, ultra-high pure quartz, and mica.

In the past, these minerals were produced from exceptionally coarse-grained igneous rock called pegmatite that is also found throughout the District. Pegmatite, a rock of granitic composition, intruded into the gneiss, schist, and alaskite that now surround it in the Devonian time-period. Technological developments in the late 1940s enabled great increases in mineral production. Consequently, attention shifted from the small, highly variable bodies of pegmatite as sources of ore to the much larger, more uniform bodies of alaskite.

More than 50 rocks and minerals have been mined in North Carolina in the 19th and 20th centuries. Dimension stone, crushed stone, sand, and gravel are used for construction. Olivine is used in the steel industry. Mica has a variety of uses, including fillers for paint, wallboard, rubber, and plastic. High-purity quartz is used in the electronics and computer industries. Spodumene, a source of lithium, is used in aerospace alloys, batteries, and medicine. Talc is used in paints, insecticides, paper, and cosmetics. Pyrophyllite is used in soap and bleaching powder. Feldspar is used for making glass, ceramic tiles, and bathroom fixtures.

In 1995, North Carolina led the nation in the production of feldspar, scrap mica, olivine, and lithium. It ranked fifth in the production of talc and clay, and seventh in production of sand and gravel. The state also leads the nation in the production of brick clay and is second in phosphate production. "If it can't be grown, it has to be mined," is a saying often quoted by geologists in the minerals industry.

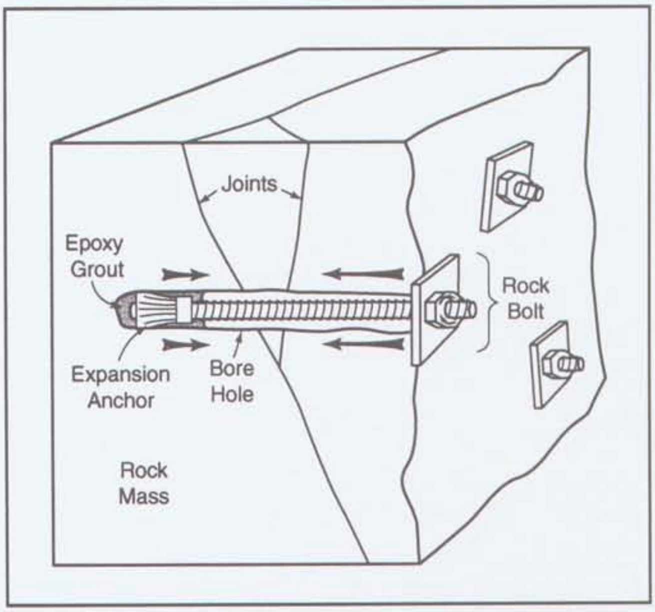


Diagram showing how rock bolts hold masses of rock in place. A hole is drilled into the rock and a long, threaded bolt is inserted, held in place by epoxy and an expansion anchor. A metal plate acts as a washer on the face of the rock, and a nut is tightened around the bolt. As the nut is tightened, force (indicated by arrows) is exerted to tightly press together loose rock along joints and cracks, holding the fractured rock in place and stabilizing the mass.

333.4 Little Switzerland Tunnel, elevation 3,190 feet.

The Blue Ridge Parkway passes through 25 tunnels in North Carolina. Excavating tunnels through solid rock can be difficult. Many of the Parkway's tunnels are reinforced to insure safe passage.

As you pass through this 547-foot-tunnel, notice the large steel rock bolts and steel nets used to hold the rocks of the ceiling in place. The bolts are installed in holes drilled into the rock and are anchored by epoxy and an expansion nut. A square steel plate and bolt are fastened to the end of the rod and tightened to hold the rock in place.

Notice too that the north portal is constructed of hand-hewn blocks of metagraywacke from the Grandfather Mountain Formation. The south portal is bare gneissic bedrock of the Alligator Back Formation.

333.9 McCall Gap, elevation 3,490 feet; junction with N.C. 226A; exit to Little Switzerland.

The bridge here is constructed with local stone probably taken from some of the road cuts during construction of the Parkway.

336.8 Wildacres Tunnel.

Until the late 1980s, Wildacres Tunnel had no internal reinforcement. Since it was built in the 1930s, however, the gneiss of the Alligator Back Formation that provided the tunnel with structural stability has weathered and weakened. This has forced engineers to coat the tunnel walls with concrete, a different solution to the problem of reinforcement than what was used in the Little Switzerland tunnel (mile 333.4).

The rocks at the south portal display effects of the chemical weathering that weakened the tunnel's internal support. The folded gneiss is covered with red, orange, and yellow secondary oxides, hydroxides, and sulfate minerals created during weathering of iron-sulfide minerals scattered in the rock mass. These colorful secondary minerals usually indicate that the unweathered rock contains pyrrhotite and pyrite. Pyrite is also known as "fool's gold."

The chemical weathering of these minerals produces very weak sulfuric acid. As the acid seeps through the cement binding the hand-hewn blocks of rock facing the south portal together, it dissolves some of the cement and precipitates a white coating on the rockwork. Small stalactites are also precipitated and hang from the undersides of the blocks.

The presence of sulfide minerals in the bedrock of the tunnel requires engineers to periodically reinforce the tunnel walls to offset the effects of chemical decomposition. (See further discussion of environmental problems associated with sulfides at mile 452.3.)

- $$\underset{\text{Pyrite}}{2FeS_2} + \underset{\text{Oxygen}}{7O_2} + \underset{\text{Water}}{2H_2O} = \underset{\text{Ferrous Iron}}{2Fe^{2+}} + \left[\underset{\text{Sulfate Anion}}{4SO_4^{2-}} + \underset{\text{Acidic Cation}}{4H^+}\right] \text{(Sulfuric Acid)}$$
- $$\underset{\text{Ferrous Iron}}{Fe^{2+}} + \underset{\text{Sulfate Anion}}{SO_4^{2-}} + \underset{\text{Water}}{2H_2O} = \underset{\text{Melanterite (Iron Sulfate)}}{FeSO_4 \cdot 7H_2O}$$
- $$\underset{\text{Ferrous Iron}}{Fe^{2+}} + \underset{\text{Oxygen}}{O_2} + \underset{\text{Acidic Cation}}{4H^+} = \underset{\text{Ferric Iron}}{4Fe^{3+}} + \underset{\text{Water}}{2H_2O}$$
- $$\underset{\text{Ferric Iron}}{4Fe^{3+}} + \underset{\text{Oxygen}}{3O_2} = \underset{\text{Hematite (Iron Oxide)}}{2Fe_2O_3}$$
- $$\underset{\text{Potassium Cation (from feldspar, muscovite, etc)}}{K^{1+}} + \underset{\text{Ferric Iron}}{3Fe^{3+}} + \underset{\text{Sulfate Anion}}{2SO_4^{2-}} + \underset{\text{Water}}{2H_2O} + \underset{\text{Oxygen}}{\tfrac{3}{2}O_2} = \underset{\text{Jarosite (Iron Sulfate)}}{KFe_3(SO_4)_2(OH)_6}$$

Chemical formulas showing the natural breakdown of the iron sulfide mineral pyrite to form iron oxide and iron sulfide minerals, and acid.

338.1 The road cut here exposes gneiss of the Alligator Back Formation, interlayered with amphibolite and schist.

338.8 Three Knobs Overlook, elevation 3,875 feet.

Here the rocks of the Alligator Back Formation consist of thin-layered, fine-grained muscovite-biotite gneiss interlayered with amphibolite and schist. The outcrop is just opposite the overlook across the Parkway. Because they split into thin layers, similar rocks in the region outside of the Parkway boundaries are in demand by the decorative stone industry of the Spruce Pine and Marion areas. The stone is quarried, hand-split, and trucked to Florida, Louisiana, and Texas, where it is used as a decorative, ornamental exterior facing.

From here you have an outstanding panoramic view of the Black Mountains and Seven Mile Ridge. Also visible is Crabtree Creek Valley, the South Toe River Valley, and Roan Mountain, elevation 6,285 feet, on the northern horizon.

The magnificent Black Mountains are scarred from recent debris avalanches. In the southern Blue Ridge, torrential rainstorms trigger debris avalanches. As avalanches move downslope, they remove everything in their path down to bedrock and deposit large quantities of debris at the base of slopes. For this reason, such slope failures are a potential geologic hazard in the high and steep mountains.

The largest and most obvious debris avalanche scar visible from this overlook is on the east side of Gibbs Mountain. It occurred in November 1977, covering 98 acres of U.S. Forest Service land with 400,000 tons of debris.

339.2 Large outcrops of gneiss of the Alligator Back Formation, interlayered with metagraywacke and mica schist, form cliffs along the northwest side of the Parkway. The layering in these rocks is inclined eastward toward the Parkway. The dip of the rocks is different from that in outcrops to the north, reflecting changes with distance from the influence of the Linville Falls thrust fault and associated warping.

The view from the Parkway opposite this outcrop is of the steep, rough and irregular, highly dissected Blue Ridge Escarpment, the frontal escarpment that bounds the Blue Ridge Mountains on the east and separates them from the lower terrain of the rolling Piedmont (see discussion at mile 260.6 and 218.6).

339.5 Crabtree Meadows, elevation 3,720 feet.

Enjoy the Crabtree Meadows picnic grounds and the 0.9-mile walk to the Falls. As you hike along the trail, it will become evident that this area and the southern half of Seven Mile Ridge is relatively flat. This area is a remnant of an older landscape. Crabtree Creek and its tributaries are now sculpturing the terrain. These streams flow westward toward the continent's great Mississippi Basin, draining eventually into the Gulf of Mexico.

Across the Parkway, however, Armstrong Creek and its tributaries, whose courses are shorter, steeper, and straighter than Crabtree Creek, flow in the opposite direction, toward the Atlantic Ocean. In the distant future, Armstrong Creek will capture portions of Crabtree Creek and re-sculpture most of Crabtree Meadows. This process, called stream piracy, is occurring all along the Eastern Continental Divide (the upper edge of the Blue Ridge Escarpment) and is causing the divide and the Escarpment to migrate northwestward.

The trail to Crabtree Falls begins at a parking lot just east of the northernmost camping area. The face of the falls is composed of a thick sequence of thin-layered amphibolite. At the top of the falls, the amphibolite is covered by a ledge of gneiss containing muscovite and biotite. The gneiss serves as a resistant cap, protecting the amphibolite from erosion by the Falls.

The building stones used as facing for the restaurant and store are grayish-to greenish-white metagraywacke of the Grandfather Mountain Formation, quarried on the slopes of Grandfather Mountain.

342.2 Black Mountains Overlook, elevation 3,892 feet.

Road cuts opposite the overlook are in gneiss of the Alligator Back Formation, a massive rock interlayered with garnet-mica schist. Small veins and pods of quartz are also present in these rocks.

Across the valley are the Black Mountains, the highest mountain range east of the Black Hills in South Dakota. The Black Mountains are underlain by metagraywacke of the Ashe Metamorphic Suite. They owe their lofty height to the resistance of the metagraywacke to weathering.

344.1 Buck Creek Gap, elevation 3,355; junction with N.C. 80; south to Marion, 12 miles; north to U.S. 19E, 13 miles.

The overpass here is constructed in part of the greenish to grayish-white metagraywacke of the Grandfather Mountain Formation.

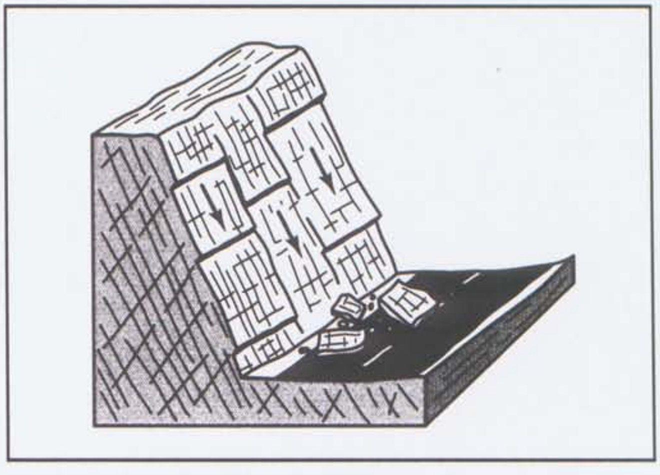
344.8 Here is the contact between the Alligator Back Formation and the Ashe Metamorphic Suite. Soil and vegetation here cover the contact.

345.3 Singecat Ridge Overlook, elevation 3,406 feet.

The view from here shows the contrast between the deeply incised Blue Ridge Escarpment and the lower, more subdued topography of the Piedmont (see discussion at mile 218.6 and 260.6).

347.0 This outcrop of schist creates a maintenance problem for the National Park Service. Foliation in the schist slopes steeply into the road surface. This situation creates the potential for rockfalls, rockslides, or landslides. Usually, the steeper the dip of the planar features in the rocks, the greater the hazard. Other planar features that may allow rock to slide include bedding, foliation, cleavage, and jointing.

Although roads cannot always be designed to prevent this situation, road cuts can be constructed so that the angle at which they slope is less than the angle of dip of the foliation. Rock bolts can be installed to stabilize the mass, or wide road shoulders (called "catch zones") can be constructed to reduce rockfall in the roadway. The highly deformed rocks of the Blue Ridge Mountains are a challenge to road builders.



Dip slope failure. Blocks of rock break along intersecting foliation planes, joints, and cracks in the rock mass, and slide or fall down the slope into roadway. Alternating freezing and thawing of water along these planes can loosen the blocks of rock making them more susceptible to movement.

348.8 Curtis Valley Overlook, elevation 4,460 feet.

Curtis Creek cascades down the front of the Blue Ridge Escarpment to join the Catawba River near the historic town of Old Fort. An unpaved U.S. Forest Service road intersecting the Parkway at mile 347.6 follows a zigzag route south, down the Escarpment to campgrounds and hiking trails on Curtis Creek.

The rocks at this overlook are metagraywacke interlayered with mica schist. Small crinkles (crenulations) in the schist form subtle linear structures that can be seen in the rock faces.

349.9 Mount Mitchell Overlook, elevation 4,825 feet.

The low outcrops on the Parkway just below the overlook are rocks of the metagraywacke unit of the Ashe Metamorphic Suite, consisting of mica schist interlayered with metagraywacke. The resistant metagraywacke unit of the Ashe Metamorphic Suite, interlayered with mica schist and muscovite-biotite gneiss underlies Mount Mitchell, elevation 6,684 feet.

Roan Mountain is visible on the northern horizon. This huge mass of Middle Proterozoic gneiss rises to an elevation of 6,285 feet on the North Carolina-Tennessee state line.

The white scars on the lower hills in the middle distance are the mines of the Spruce Pine District, where minerals such as feldspar and quartz are produced from the igneous rock called alaskite.

Mile 350.1 to 410

Continents Pulled Asunder

In the Late Proterozoic, about 700 million years ago, Earth forces tore the North American Continent apart. Huge blocks of crust were rifted from the mainland as an ancient ocean basin, the precursor of our modern Atlantic Ocean, opened between the continental masses.

Sediments from these crustal blocks washed into deep troughs that developed along the jagged edge of the continent. Underwater avalanches carried sediment far out into the ocean, where they were interlayered with basalt and other volcanic rocks on the ocean floor. These sediments, composed of layers of gravel, sand, and silt, later hardened into rock and were metamorphosed to produce the rock unit geologists now call the Ashe Metamorphic Suite.

All of the rocks that you will encounter along this segment of the Parkway belong to this unit. The south end of the segment offers a nearly mile-long continuous exposure of the Ashe, along a stretch of the Parkway particularly inviting for a sunset stroll.

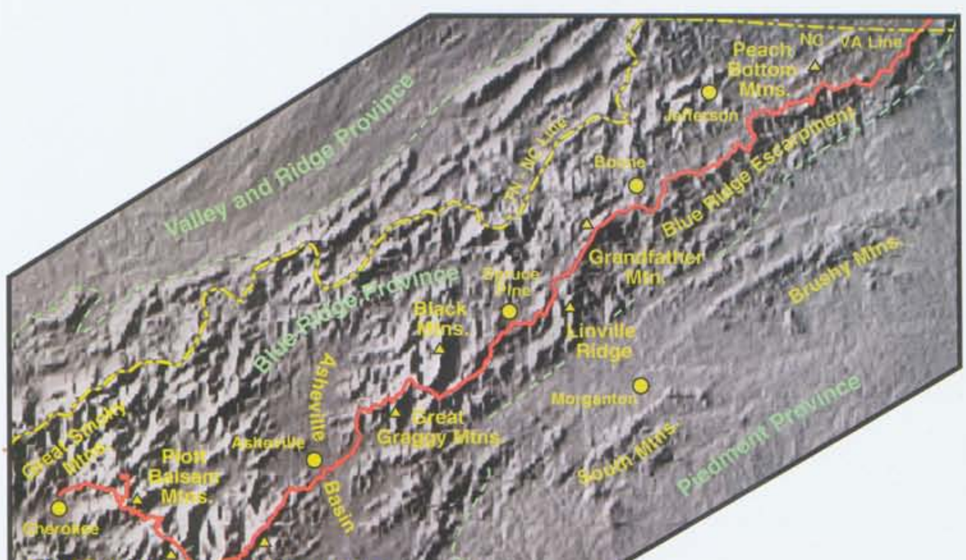
Rocks of the Ashe Metamorphic Suite in this region have been sculptured by millions of years of erosion into two prominent mountain ranges: the Black Mountains and the Great Craggies. Consisting primarily of hard, resistant metagraywacke, the Blacks are the tallest mountains east of the Mississippi, with six peaks rising to elevations of over 6,500 feet.

The mountains here are so high that they exhibit characteristics of cooler, more northerly climatic zones. These elevations are covered with trees typical of Canadian forests—red spruce and Fraser (balsam) fir. The summits of the Great Craggies are almost bare of trees, covered instead with shrubs of the heath family—mountain laurel, blueberry, rhododendron, azalea—from which they get the name "heath balds."

The Parkway skirts the south end of the Black Mountains and begins heading in a more westerly direction, moving further and further from the Blue Ridge Escarpment.

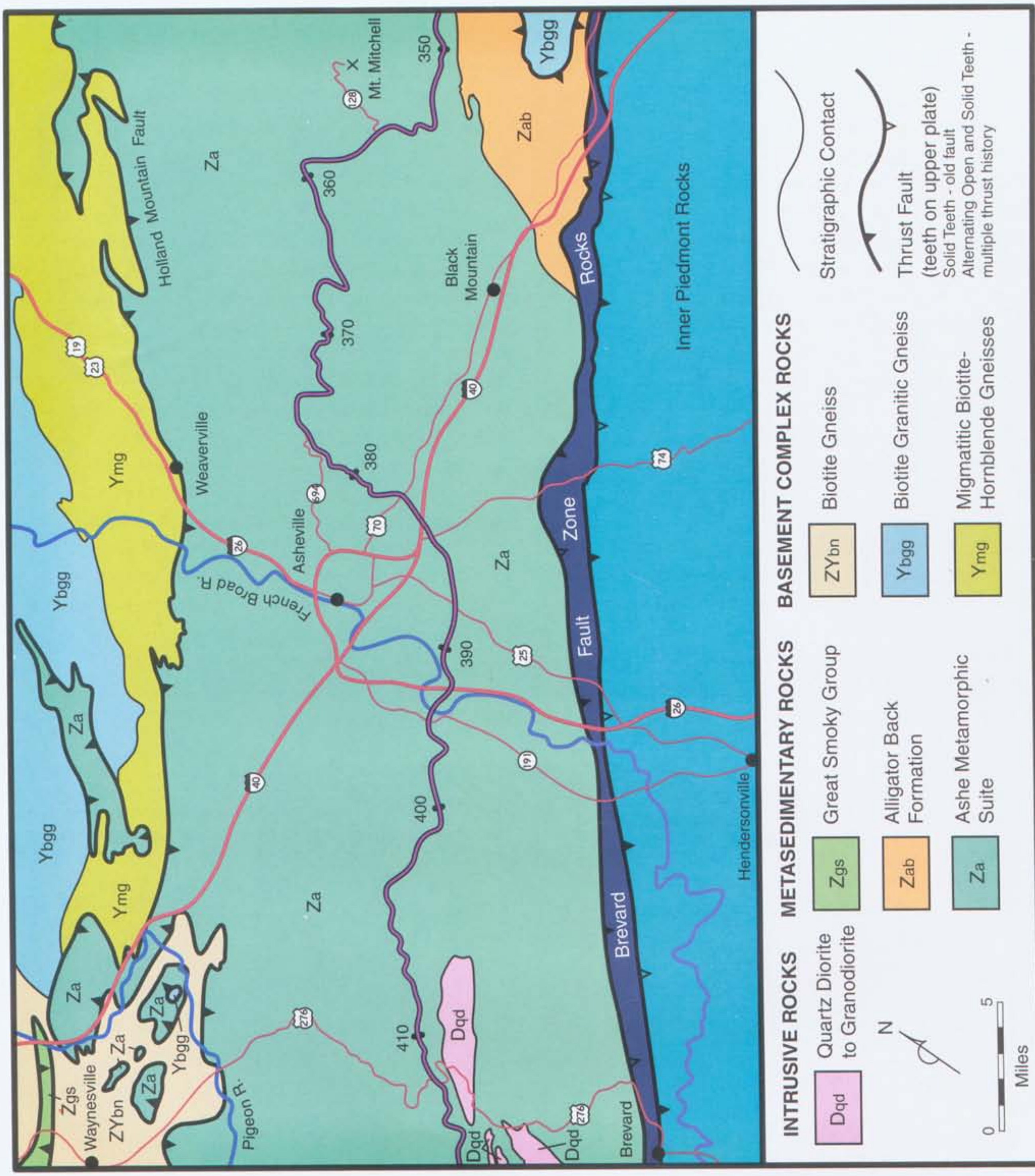
The Asheville Basin, a low-lying geographic feature drained by the French Broad River, occupies much of the southern half of this segment. To the south, not until the Parkway crosses the river and begins climbing Pisgah Ridge, do outcrops again become numerous.

In ascending the ridge, the Parkway bores through the mountains in a series of nine tunnels.



A satellite image showing major topographic features and physiographic provinces of western North Carolina and eastern Tennessee. The Blue Ridge Parkway is shown in red.

Visitor facilities include: Mount Mitchell State Park (picnicking, camping, restaurant, souvenir shop, nature museum, observation tower, restrooms); Craggy Gardens Visitor Center (information and bookstore, water fountains, nearby picnicking, hiking, restrooms); Folk Art Center (visitor center with information and bookstore, craft sales and art exhibits, craft demonstrations, lectures, films, music, and dance exhibitions), Mount Pisgah Inn and Campground (lodging and camping, restaurant, gift shop, picnicking, interpretive programs and trails).



Geologic map of a portion of western North Carolina in the vicinity of Asheville showing the Blue Ridge Parkway (in purple) from mile 345.0 to mile 417.0. The predominant rock unit along this segment of the Parkway is the Ashe Metamorphic Suite, an interlayered sequence of gneiss, schist, and amphibolite that formed on an ancient ocean floor over 600 million years ago.

350.4 Green Knob Overlook, elevation 4,761 feet.

From here the view south is into the valley of Curtis Creek, one of the headwaters of the Catawba River.

The Catawba River Basin is one of the major drainage systems in North Carolina. From its headwaters, the river flows approximately 150 miles to the South Carolina state line. The river then joins the Wateree River and becomes part of the Santee River Basin. The Catawba River Basin within this area drains approximately 5,300 square miles (for more about Curtis Creek, see the description at mile 348.8).

Just opposite the overlook on the west side of the Parkway is a high road cut of layered metagraywacke, one of the many rock types of the Ashe Metamorphic Suite. Metamorphism by heat and pressure changed the original sedimentary rock, a type of sandstone, to form a harder, denser rock. This outcrop also contains layers of fine-grained mica schist.

The reddish-brown to black colors are iron and manganese oxide stains formed by the decomposition of iron-rich minerals such as pyrrhotite and manganese-bearing garnet.

351.5 At this location, the Parkway cuts through Ashe Suite metagraywacke and mica schist, with good exposures of both rock types on either side of the road.

351.9 Deep Gap, elevation 4,284 feet.

An unpaved U.S. Forest Service road leads to Black Mountain Campground, 5 miles to the north, in Pisgah National Forest.

352.1 For the next 0.2 miles, the Parkway passes through a continuous exposure of Ashe metagraywacke and mica schist.

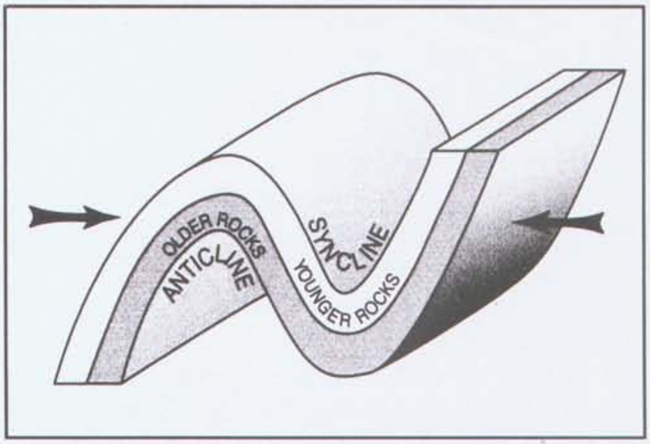
Water seeps out of joints and fractures at many places in the rock. Alternating freezing and thawing of water in these joints and fractures can loosen blocks of rock, making them susceptible to failure.

352.4 Bald Knob Ridge Overlook, elevation 4,500 feet.

Opposite the overlook is a good exposure of Ashe metagraywacke and mica schist. The rock has a banded, layered appearance because of the alternating layers of schist and metagraywacke.

A white, milky quartz vein lies parallel to the layering. Several pegmatite dikes are also visible, both cutting across, and nearly parallel, to the layering.

The layering here is folded into large anticlines and synclines, as well as much smaller crinkles, or crenulations. The folds were created by intense compressional stress acting on the rock during an episode of Paleozoic mountain-building.



How rocks are folded. Intense compression (shown by arrows) caused by an episode of mountain-building arches layers of rocks into A-shaped anticlines and U-shaped synclines.

353.4 This small exposure glistens when sunlight reflects off sheets of muscovite mica in a pegmatite dike that intruded into Ashe metagraywacke.

355.3 Black Mountain Gap, elevation 5,160 feet.

At this point in your geologic tour of the Blue Ridge Parkway, you enter the Black Mountains.

Looking east on clear days, especially in spring and fall, you can see the distinctive shape of Table Rock Mountain, elevation 3,908 feet, on the east rim of Linville Gorge. Also visible, off in the distance are Hawksbill Mountain, elevation 4,017 feet (immediately to the north of Table Rock), and the much-visited Grandfather Mountain, elevation 5,964 feet.

Here you are on the northeastern border of the Asheville Watershed, the 20,000-acre drainage basin of Burnett Reservoir, from which the City of Asheville draws its water supply. Besides supplying the city with water, the Watershed preserves one of the few remaining spruce and fir forests in the region. For the next 15 miles, from here to mile 370.3, you cannot stop along the Parkway except at designated points (overlooks, Craggy Gardens Visitor Center and picnic grounds). There is no public access to the Watershed—no trails or roads—and no powerlines.

355.4 Junction with N.C. 128, access to Mount Mitchell State Park.

N.C. 128 leads north to Mount Mitchell State Park, where you can camp, picnic, hike, or enjoy a meal at the mountain-top restaurant. The road leads to the summit of the mountain, 4.8 miles from the Parkway.

Established in 1915 as North Carolina's first State Park, the park covers 1,677 acres of the crest of the Black Mountains.

Mount Mitchell is named for Dr. Elisha Mitchell, a geologist who may have been the first person to measure the elevation of the peak. Dr. Mitchell made a second trip to the mountain in 1857, to make additional measurements but fell to his death on the way back to his base camp. Thomas L. Clingman, the Senator and Civil War General, also claimed the distinction of having been the first to measure the height of the mountain. The controversy has never been settled. Dr. Mitchell lies buried at the foot of the observation tower.

Midway along the short path from the parking lot to the observation tower is a small museum, with natural history exhibits describing the geology, plants, and wildlife.

At the crest, if you look toward the east, the horizon seems far off—you can see 70 miles on clear days. To the south, the sculptured, dissected ridge of the Blue Ridge Escarpment plunges away from the Parkway, losing half of its mile-high altitude as it drops toward the intersection with Interstate 40, just east of the town of Black Mountain. The Catawba River drainage basin is clearly visible in the foreground. The Linville and Catawba Rivers empty into Lake James. From Lake James the Catawba flows in an east-southeasterly direction into Lake Norman.

On windy days, orographic clouds, distinguished by their streamlined shapes, often form above the mountains. Their shapes reflect the way that the mountains influence air currents flowing over them.

In early spring and late fall, the red spruce and Fraser fir trees are sometimes covered with rime (or hoar frost), a sparkling coating of ice crystals left by clouds drifting over the cold summit of Mount Mitchell and depositing their moisture. Because of its altitude, the mountain is measurably colder than lower elevations just a short distance away. (Temperatures drop an average of 3.6°F with every 1,000-foot rise in elevation.)

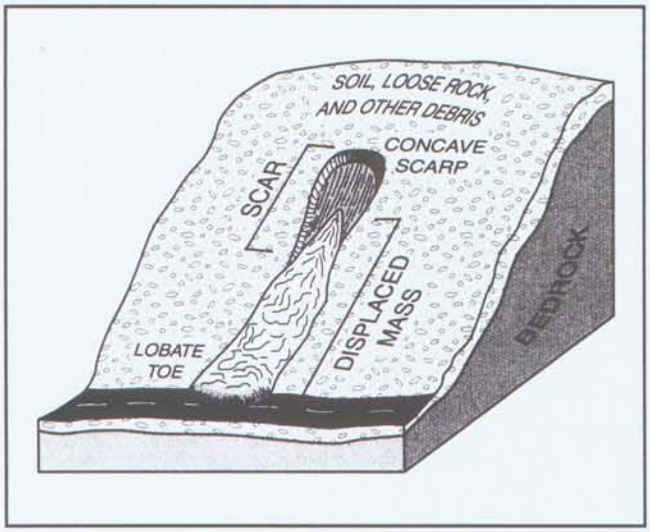
The fir trees and spruce here and at other places above 5,000 feet are dying from a combination of adverse environmental factors, including acid precipitation and invasive insect pests.

357.7 The Parkway passes the scar of a large debris flow on the north side of the road (to maintain the integrity of the municipal water supply, stopping is not permitted here or at any other place within the Watershed of the City of Asheville not designated as a parking area). The flow occurred as a result of heavy rains from Hurricane Opal in September 1995, forcing the closure of a large section of the Parkway for two weeks.

Debris flows occur when loose rock and soil on steep slopes become saturated with water. Infiltrating water saturates the soil mantle, leading to a buildup of water pressure within the soil mass, and at the contact between the soil and underlying rock. This water pressure actually pushes apart the mineral grains and decreases the strength of the soil by reducing the friction or interlocking effect between the individual soil grains.

Groundwater moving downslope through the soil and along the contact of the soil and rock also has a destabilizing effect, producing a slurry of mud, trees, rocks, and debris that rushes downhill at tremendous speed, pushing aside everything in its path. Debris flows, slides, avalanches, and other slope-related failures are the number one hazard in mountainous regions of the world.

358.5 You have now reached the highest point on the Parkway north of Asheville, 5,676 feet above sea level.



Elements of a debris flow. Moisture along the interface between impermeable bedrock and saturated material above causes the slope to fail. The concave scar is the location where debris of a flow originated. The material slides down the slope and piles up at the bottom into a lobate toe (compare this form of mass-wasting with the mass-wasting processes discussed at mile 347.0 and mile 413.2).

359.8 Balsam Gap Overlook, elevation 5,317 feet.

This gap marks the junction between the Black Mountains and the Great Craggy Mountains. The North Carolina Division of Parks and Recreation Mountains-to-Sea Trail passes through the gap as it skirts the south end of the Black Mountains.

361.2 Glassmine Falls Overlook, elevation 5,197 feet.

Glassmine Falls is only visible in wet weather, when there is enough water to flow and cascade down the bare rock surface. It is named Glassmine because of an old mica mine at the base of the rock. Mica was once known as isinglass.

Sheet mica was mined here before World War I and during World War II from the many pegmatites that occur in this area. It was used for many electrical purposes, as insulators in electrical appliances, and as transparent heat-resistant mineral material for furnace and oven door windows.

There were many mica mines in this area. This is reflected in names such as Glass Rock Knob and Glassmine Branch that appear on topographic maps throughout the region.

363.4 Graybeard Mountain Overlook, elevation 5,592 feet.

The overlook provides a good view of Graybeard Mountain, elevation 5,365 feet, and the Asheville Watershed. The mountain is underlain by resistant rock belonging to the metagraywacke unit of the Ashe Metamorphic Suite.

364.1 Craggy Dome Overlook, elevation 5,640 feet.

A 0.7-mile hike up Craggy Pinnacle, elevation 5,892 feet, crosses good outcrops of mica schist and gneiss belonging to the Ashe Metamorphic Suite. The rock here is full of small red garnet crystals and gray blades of kyanite.

Kyanite and garnet are two minerals that geologists use to interpret metamorphic conditions of heat and pressure that rock was subjected to during episodes of metamorphism and mountain-building (see discussion at mile 300.6).

Please leave the rocks and minerals for others to enjoy—remember, edible berries and mushrooms are the only things you are permitted to collect along the Parkway (and blueberry bushes are common here).

Craggy Dome, elevation 6,085 feet, is immediately to the northeast. On the northern horizon, almost 8 miles away, you can make out the Mount Mitchell observation tower when the sky is clear.

Craggy Dome and Craggy Pinnacle, what botanists describe as "heath balds," are two of the landmark peaks of the Great Craggies. High, treeless summits such as these are unique to the Southern Appalachians. Heath balds are covered by shrubs of the heath family, including rhododendron, blueberries, mountain laurel, and flame azalea. The balds on this section of the Parkway harbor many nationally endangered and threatened plants. The few trees you see as you climb Craggy Pinnacle—yellow birch, buckeye, and mountain ash—have all been stunted by the severe weather conditions of this cool, wet, windswept location. The Pinnacle is also a good spot to see migrating birds in spring and fall.

364.5 Craggy Gardens Visitor Center, Pinnacle Gap, elevation 5,497 feet.

Notice the windswept appearance of the trees and shrubs on the north slope of the mountain.

They lean to the southeast and appear quite stunted. You may feel a stiff wind blowing from the northwest. This low area in the ridgeline is commonly referred to as a wind gap. Prevailing winds here are from the west-northwest. Entering the Southern Appalachians, they are funneled through gaps like this one. These forceful, year-round air currents have shaped the trees and shrubs into the forms you see here.

Good exposures of Ashe Metamorphic Suite mica gneiss crop out at the north side of the parking lot, near Craggy Pinnacle Tunnel. Layers in the gneiss contain clusters of pinkish-red garnets.

The wall at the Visitor Center is constructed largely of metagraywacke and mica gneiss. At the west end of the wall is a self-guiding nature trail. It leads to a picturesque shelter, built by the Civilian Conservation Corps, and to the Craggy Gardens Picnic Area, 0.8 mile northwest.

Looking southeast, standing on the road shoulder across from the Visitor Center, you have a good view of Burnett Reservoir and the North Fork of the Swannanoa River, in the Asheville Watershed (described at mile 355.3).

364.9 The road cut here exposes metagraywacke and mica gneiss intruded by a nearly vertical pegmatite dike. The dike is a tabular intrusive rock that cuts across the foliation and layering of the gneiss and therefore must be younger than the gneiss and its foliation (see diagram at mile 233.7).

367.6 Bee Tree Gap, elevation 4,900 feet.

The turnoff to the north leads to Craggy Gardens Picnic Area, an excellent opportunity for a break in your Parkway adventure. Enjoy a picnic lunch or leisurely walk along one of the picturesque hiking trails. Outcrops of metagraywacke and mica gneiss visible along the trails here contain small garnet crystals. These rocks are members of the Ashe Metamorphic Suite.

370.3 Boundary of the Asheville Watershed.

Traveling south along the Parkway you leave the Asheville Watershed at this point, having entered it at mile 355.3. If you are traveling north, no stopping is permitted for the next 15 miles, except at designated places (overlooks, picnic areas, Craggy Gardens Visitor Center).

372.1 Lane's Pinnacle Overlook, elevation 3,890 feet.

Lane's Pinnacle, elevation 5,230 feet, is named for Charles Lane, who mined a small vein of iron ore here in the 1790s and processed the ore at his forge on nearby Reems Creek.

Opposite the overlook is an outcrop of the muscovite-biotite gneiss unit of the Ashe Metamorphic Suite, in which metagraywacke is interlayered with mica gneiss, and biotite is the chief mica mineral.

373.8 Bull Creek Valley Overlook, elevation 3,483 feet.

Bull Creek is a small tributary to the Swannanoa River and is named for the bull buffalo that was shot by Joseph Rice in 1799. A small farm community with meadows and pastures occupies this valley.

375.6 Bull Gap, elevation 3,107 feet; access to N.C. 694, Weaverville, 8 miles.

376.8 Tanbark Ridge Overlook, elevation 3,175 feet.

Outcrops opposite the overlook are well-layered metasedimentary rocks of the Ashe Metamorphic Suite. At this location, layers of metagraywacke alternate with muscovite-biotite schist.

These rocks contain iron-sulfide minerals such as pyrite and pyrrhotite, so they are quickly decomposed by chemical weathering. This results in formation of new iron minerals, such as hematite and limonite, which impart stains of red, orange, and brown to the rock surface. Iron-sulfate minerals also form and impart cream-colored to yellowish stains (see additional discussion of chemical weathering at mile 336.8).

377.4 Craven Gap, elevation 3,132 feet; access to N.C. 694 (Town Mountain Road), Asheville, 7 miles.

377.8 Road cuts here expose outcrops of contorted gneiss and amphibolite cut by pegmatites. The amphibolite may have been a basaltic lava flow before metamorphism by heat and pressure changed its appearance.

379.4 This outcrop shows an anticlinal fold (see discussion at mile 352.4) produced in metagraywacke of the Ashe Metamorphic Suite by the forces of mountain-building.

380.0 Haw Creek Valley Overlook, elevation 2,720 feet.

The Asheville Basin, an area of roughly 400 square miles, forms the largest intermontane basin in the Blue Ridge province. It is drained by the French Broad River and its many tributaries. Although well-defined by elevations between 2,300 and 2,400 feet, the border of the basin is extremely irregular (see topographic map on page 31). The floor of the basin protrudes deep into many tributary valleys and interfingers with ridges from the adjacent highlands that extend down into the basin.

Downstream from Asheville, the French Broad has become entrenched and is dissecting the old basin floor. Where they leave the basin northwest of Marshall, the river and its tributaries are 400 to 500 feet lower than remnants of the former basin floor. A better understanding of the geomorphic history of the basin will require much additional research.

Immediately below the overlook is the Haw Creek Valley, formed by a tributary of the Swannanoa River, which flows in a nearly east-west trending fingerlike extension of the Asheville Basin.

Opposite the overlook is a 500-foot-long outcrop of well-layered metagraywacke and biotite gneiss of the Ashe Metamorphic Suite.

Drill marks—the long, smooth, vertical, concave features visible on the rock faces—were made during construction, when holes were drilled and filled with explosives to excavate the rock along the route of the Parkway.

382.0 Folk Art Center.

Offering sales and exhibits of traditional and contemporary crafts, plus handicraft demonstrations and illustrated programs, the Folk Art Center, completed in 1980, features a second-floor gallery and a large modern auditorium. The Center is open 362 days of the year, from 9:00 AM to 5:00 PM. Maps and post cards can be purchased at the information desk, as well as nature guides, tapes, and books conveying the rich cultural heritage of this region of the Southern Appalachians.

382.6 Access to U.S. 70; west to Asheville, 5 miles; east to Black Mountain, 9 miles.

384.7 Junction with U.S. 74; west to Asheville; east to Fairview, 7 miles; access to Interstate 40.

388.7 Junction with U.S. 25; north to Asheville, 5 miles; Biltmore, 4 miles; south to Hendersonville, 17 miles.

393.6 Junction with N.C. 191; access to Interstate 26; north to Asheville, 9 miles (access to The North Carolina Arboretum); south to Hendersonville, 18 miles.

393.8 French Broad Overlook, elevation 2,100 feet.

A panoramic view of the French Broad River is visible below. The "French" part of the name refers to the way that early settlers distinguished this river, flowing north into French territory during Colonial times, from the Broad River that rises near Lake Lure and flows south toward the Atlantic.

The river is a tributary of the Mississippi. From its headwaters near the South Carolina state line, it flows north to Hot Springs, North Carolina, where it turns sharply west, cutting through the Bald Mountains to enter the Tennessee Valley. There it joins the southwest-flowing Holston River just north of Knoxville to form the Tennessee River, which joins the Ohio River at Paducah, Kentucky, and the Mississippi River beyond.

Because of the long, circuitous trip they must make to enter the Gulf of Mexico, the waters of the French Broad flow at smaller gradients than the gradients of streams and rivers whose headwaters have been carving the Blue Ridge Escarpment further north along the Parkway. Still, the French Broad is entrenching itself into the landscape of western North Carolina.

"Entrenchment" refers to the gradual incision or down-cutting by erosion of a stream or river into the land surface over which it flows. The Grand Canyon of the Colorado River is a prime example of an entrenched river system. Millions of years from now, as the French Broad continues to entrench, it may one day flow through a deep gorge similar to the Grand Canyon.

An extensive outcrop of an interlayered sequence of rocks of the Ashe Metamorphic Suite, consisting of mica-rich gneiss and schist, is exposed opposite this overlook. Here and there, these rocks contain crystals of red garnet. The rocks have alternating light and dark bands, and are cut by joints. Quartz occurs throughout the outcrop as veins, lenses, and pods.

The faint, nearly horizontal lines visible on rock faces are the traces of crinkles, called crenulations, which deform the rock. These small, tight folds, along with larger folds and thrust faults, formed in response to intense compression produced during an episode of Paleozoic mountain-building. Weathering has made them easier to see; they protrude slightly above the bare rock surfaces.

396.4 Walnut Cove Overlook, elevation 2,920 feet.

Muscovite-biotite gneiss of the Ashe Metamorphic Suite occurs in outcrops across from the overlook. A few hundred feet to the east, the gneiss is folded and intruded by veins, lenses, and pods of quartz. Large deformed quartz veins are clearly visible at this outcrop.

397.1 Grassy Knob Tunnel.

In the 10-mile stretch from here to mile 407.3, the Parkway passes through a series of nine tunnels, climbing almost 2,000 feet in elevation along the sloping ridge known as Pisgah Ridge. Pine Mountain Tunnel (mile 399.3), the longest of the nine, is 1,320 feet long.

These tunnels are not illuminated. For your safety and that of other motorists, please turn your headlights on each time you enter one of these long, dark passages through the mountain.

Map showing the major rivers in the Southeastern United States. The Eastern Continental Divide (shown by a bold dashed line) separates the rivers, whose waters ultimately flow into the Gulf of Mexico, from rivers which flow directly into the Atlantic Ocean.

407.6 Mount Pisgah Parking Area, elevation 4,990 feet.

Visible a little to the northwest of the parking area is Mount Pisgah, elevation 5,721 feet, highest point on Pisgah Ridge and easily distinguished from its neighbors by its distinctly symmetrical shape.

407.7 Buck Springs Gap Overlook, elevation 4,980 feet.

Several trails originate from this parking area. The Mount Pisgah Trail, 1.6 miles long, climbs 712 feet in elevation to the summit of Mount Pisgah. The trail makes its way among iron-stained, lichen-covered boulders of muscovite-biotite gneiss, a unit of the Ashe Metamorphic Suite.

About 800 feet up the trail, the largest outcrop of the gneiss is exposed. Passing the outcrop, you will notice that the rock is interlayered with mica schist (see discussion at mile 217.9 for differences between schist and gneiss).

At the summit is a barren outcrop of thinly banded, highly deformed gneiss and schist. Here, you are rewarded with panoramic views of the surrounding mountains and valleys.

The coarsely crystalline mineral assemblage of the gneiss and schist includes crystals of red garnet. The laminated structure known as foliation, visible here and in outcrops along the trail, is steeply inclined, almost vertical. (See discussion at mile 217.3 to learn more about how geologists describe the orientation of foliation.)

408.5 Mount Pisgah Inn, elevation 4,925 feet.

408.6 Mount Pisgah Campground, elevation 4,850 feet.

The Inn and Campground, located on opposite sides of the Parkway, offer excellent views of Mount Pisgah, as well as places to stop, rest, and begin hiking the area's network of trails — an enjoyable way of becoming acquainted with this especially scenic section of the Parkway.

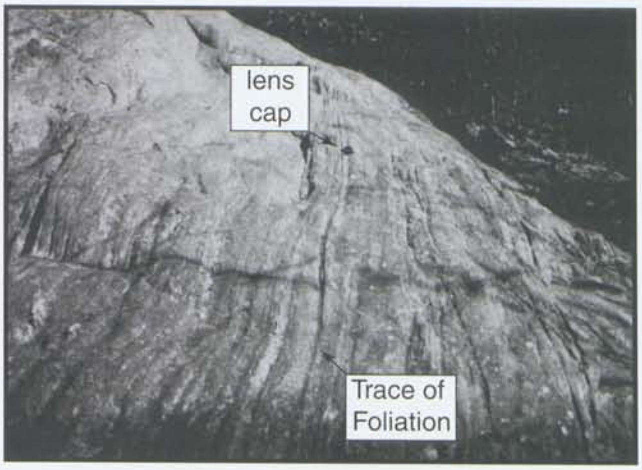
408.7 For the next 0.8 miles, from here to mile 409.5, nearly continuous road cuts expose a wall of rocks of the Ashe Metamorphic Suite along the northwest shoulder of the Parkway. In places, the muscovite-biotite gneiss displays the most intense deformation seen along this segment of the Parkway. Veins, lenses, and pods of quartz cut the massive to thin-banded rocks. The overlook at mile 409.3 is a good place to park, walk back, and view this section on foot.

409.3 Funnel Top Overlook, elevation 4,925 feet.

The broad flat valley below is known as the Pink Beds, probably for the profusion of rhododendron, mountain laurel, and azalea that bloom in late spring.

Southwest of the Pink Beds, jutting up above the valley, are the bare rock domes of Looking Glass Rock and John Rock.

The entire area below is underlain by intrusive, granite-like bodies of Devonian age, although the topographic expression of bedrock underlying the Pink Beds is markedly different from that at Looking Glass Rock and John Rock. Slight differences in the mineral assemblages of the granitic rock beneath these features may account for the topographic contrast. The granite under the Pink Beds contains more potassium feldspar than the rocks of Looking Glass Rock and John Rock and is thus more susceptible to weathering and erosion.



The alternating layers of gneiss and schist at this outcrop along the Pisgah Mountain trail define planes of foliations in these metamorphic rocks. The lens cap is for scale.

Mile 410.1 to 469.1

Ancient Mountains Rise

After the North American continent was rifted apart at the close of the Late Proterozoic, this region of the Appalachian Mountains experienced a period of relative "geologic" quiescence for nearly 400 million years. Sediments slowly filled the rift troughs along the edge of the continent, and spilled out into the newly formed ocean basin beyond.

Sometime in that 400-million-year span, however, the ancient ocean basin that was born during continental rifting began to close. By 475 million years ago, the ocean had closed so much that the North American continent started to collide with a chain of volcanic islands along the edge of another continental mass, signaling the start of the Taconic orogeny. Late Proterozoic sedimentary rocks, deposited during continental rifting, as well as the older Middle Proterozoic basement rocks, were metamorphosed.

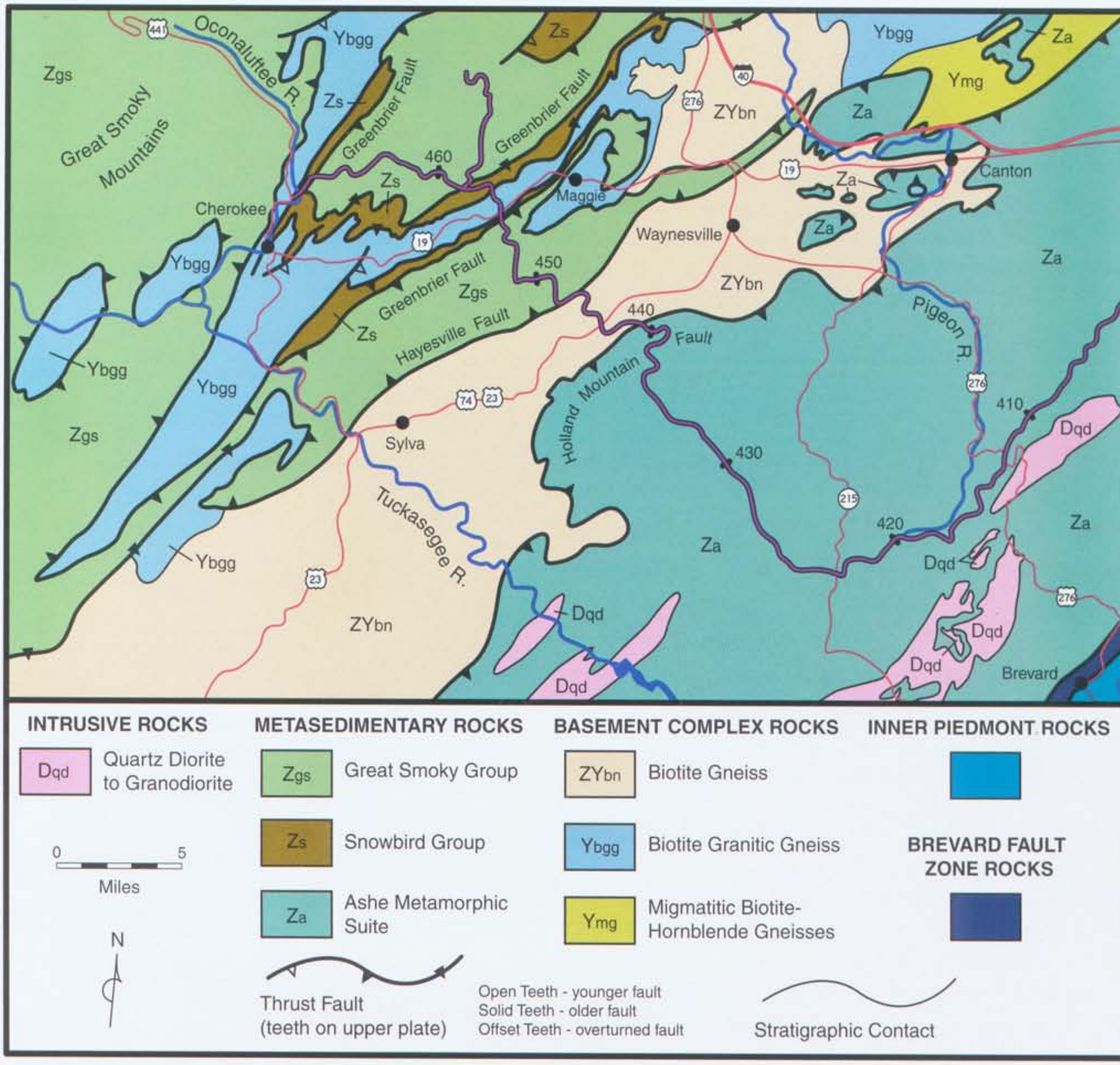
During metamorphism, the sedimentary "cover" rocks were shoved westward over the basement rocks along several huge thrust faults in the Earth's crust. Vestiges of these faults, including the Holland Mountain, the Hayesville, and Greenbrier faults, are observed in the rocks of this region and along the Parkway today. By the close of the Taconic orogeny in the Silurian, a chain of mountains had been pushed up throughout the Appalachians from Alabama to at least as far north as New York.

Rocks along this segment belong to several Proterozoic units. Traveling south from Asheville, Parkway visitors will first encounter various rock types of the Ashe Metamorphic Suite. Next are exposures of older, Middle Proterozoic biotite gneiss. Last are exposures of metagraywacke, schist, and quartzite of the Great Smoky and Snowbird Groups.

Rocks of these two units are interpreted to be former sediments that were deposited into rift basins along the edge, or margin of the Continent in the Late Proterozoic. Movement along several Taconic thrust faults has repeatedly placed rocks of the Great Smoky Group side by side with rocks of the Snowbird Group. The two units now appear in alternating succession along the last few miles of the Parkway.

A prominent landmark off to the east is Looking Glass Rock, composed of a mass of igneous quartz diorite, intruded into the metamorphic rocks of the Ashe Metamorphic Suite almost 400 million years ago. At Yellowstone Falls near Graveyard Fields (mile 418.8), running water has scoured outcrops of migmatite of the Ashe, throwing into bold contrast the contorted veins of quartz and feldspar that characterize this hybrid rock. The Parkway reaches its highest elevation, 6,047 feet, at Richland Balsam, the summit of the Great Balsam Range.

Visitor facilities include: Waterrock Knob (visitor center with information and bookstore, trails, exhibits, restrooms), Heintooga Overlook (picnic facilities, campsites).



Geologic map of a portion of western North Carolina showing the Blue Ridge Parkway (in purple) from mile 402 to its terminus near Cherokee. Thrust faults that formed some 400 million years ago broke the rock sequence in this part of the Blue Ridge into thin thrust sheets, and "telescoped" or piled them one on top of another, when North America collided with a chain of volcanic islands during the Taconic orogeny.

410.3 Pink Beds Overlook, elevation 4,822 feet.

The open pit of the Fletcher South Mine, operated by Boren Clay Products, is visible off in the far distance, to the northeast. Clay is made into bricks, paving, drains, and floor tiles. In terms of income generated, mining clay for the manufacture of bricks is the third largest mineral industry in North Carolina (for more about the state's mining industry, see the discussion at mile 330.9).

The rocks opposite the overlook belong to the Ashe Metamorphic Suite. They consist of layered mica gneiss with migmatitic zones of quartz and feldspar.

411.0 Cradle of Forestry Overlook, elevation 4,710 feet.

Layered mica gneiss of the Ashe Metamorphic Suite crops out across the road. Joints in the rock strike west-northwest, parallel to the trend of Pisgah Ridge. Jointing controls the topography here.

Geology controls the topography of the Southern Appalachians in various ways. The trend of many streams and ridgelines is controlled by joints or rock layers. Rocks particularly resistant to weathering and erosion hold up many of the mountains.

411.8 Cold Mountain Overlook, elevation 4,542 feet.

Here is a view of Cold Mountain, elevation 6,030 feet, to the northwest and Shining Rock to the west. A large white quartz vein on Shining Rock reflects sunlight, and can be seen from far away, hence the name.

411.9 Wagon Road Gap, elevation 4,535 feet; junction with U.S. 276; north to Waynesville, 22 miles; south to Cradle of Forestry, 3 miles, and to Brevard, 18 miles.

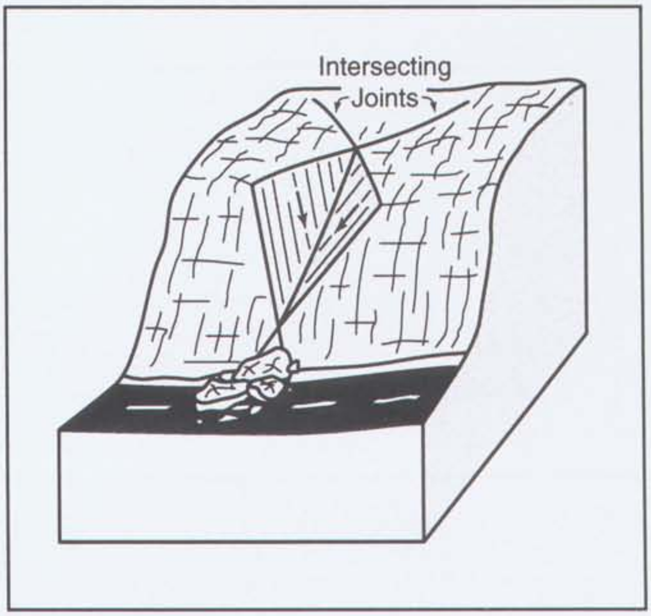
The small parking area south of the Gap is the trailhead for many hiking and bike trails in this area.

413.2 Pounding Mill Overlook, elevation 4,700 feet.

The rocks opposite the overlook are typical of the Ashe Metamorphic Suite in this area, consisting of layered mica gneiss and migmatitic zones of quartz and feldspar that give the rock a "marble cake" appearance.

At the northern end of the road cut, two joints intersect at an oblique angle, creating a common rock slide problem that engineering geologists refer to as a "wedge failure." The intersection weakens the overlying rock, which fails when destabilized by infiltrating rainfall and slides down, blocking the roadway.

Off to the southwest is a broad valley in which mountain farms and small communities are visible. Underlying the valley is the Brevard Fault Zone, a major geologic structure that trends northeast-southwest through much of the Blue Ridge Mountains in western North Carolina. The fault shows evidence of movement during several Paleozoic mountain-building events. It separates rocks of two geologic provinces: the Inner Piedmont south of the fault and the Blue Ridge province north of the fault.



Formation of a wedge failure, a type of mass-wasting process. Wedge failures occur when a body of rock between two intersecting joints gives way and slides down the joint planes into the road.

416.3 Log Hollow Overlook, elevation 4,445 feet.

The overlook here offers a spectacular view of Looking Glass Rock (described at mile 417.0) and a portion of the Brevard Fault Zone (see mile 413.2).

The folded rocks opposite the overlook are typical of the Ashe Metamorphic Suite in this area, consisting of layered mica gneiss and migmatitic zones of quartz and feldspar.

417.0 Looking Glass Rock Overlook, elevation 4,492 feet.

Looking Glass Rock, elevation 3,969 feet, is visible to the east of the Parkway. This massive dome-shaped outcrop is composed of varieties of granite ranging from quartz diorite to granodiorite which cooled and crystallized from a magma deep in the Earth's crust 390 million years ago.

Within the past 90 million years, it has been uplifted and exposed by weathering and erosion. The present dome, as a physical feature, is only a few million years old. During the past few million years, the overlying rock material was stripped away by erosion, thereby releasing internal pressures and causing concentric fractures to develop within the rock mass. The rounded, dome-shaped appearance of the mountain resulted from weathering and cracking of the rock along these fractures, a process called exfoliation (for more information on exfoliation, see discussion at mile 232.5).

418.3 East Fork Overlook, elevation 4,995 feet.

Looking north from here, into the steep-walled canyon of the East Fork of Pigeon River, you can see Yellowstone Falls, named for the yellowish stain of the rocks that the water flows over. The color that stains these rocks may be caused by chemical weathering of iron-bearing minerals, by deposition of iron-rich clay minerals in cracks and crevices, and by the oxidation of iron-bearing minerals by lichen growing on the rocks. A trail from the Graveyard Fields Overlook (mile 418.8) provides access to the Falls.

Yellowstone Falls are what geologists call a knickpoint, caused by uplift and erosion of the land surface. Uplift causes streams to erode their base at a faster rate in an attempt to maintain equilibrium with the rate at which the land surface is rising. The lowest elevation to which a stream can erode its base is called base level. The ultimate base level of all streams is sea level. Knickpoints mark the spot where erosion is most intense. Downstream, where the stream has already reached its local base level, an incised valley forms. As the stream continues to erode down to its local base level, the knickpoint will migrate upstream, leaving an incised valley downstream in its wake (also see discussion of knickpoints at mile 267.8).

On the south side of the Parkway, a rock type known as migmatite is exposed in a large road cut. This migmatite is biotite gneiss cut by stringers of quartz and feldspar. Looking at this outcrop, it is easy to imagine the tremendous heat and pressure that formed many of these rock types.

418.8 Overlook at Graveyard Fields, elevation 5,120 feet.

This overlook looks down on a gentle-sided perched valley that contrasts with the deep, incised canyon seen at East Fork Overlook. A perched valley is a valley that is higher than the general level of the adjacent valleys. We are on the same tributary of the Pigeon River here as seen at East Fork Overlook, above the knickpoint at Yellowstone Falls. As the knickpoint at the Falls continues to erode and migrate upstream, this area will eventually also become an incised valley.

The trail down to Yellowstone Falls from here is steep in places but short. At 0.2 miles, a footbridge crosses Yellowstone Prong, a tributary of the East Fork. The creek here has scoured and polished the complexly folded migmatitic gneiss of the Ashe Metamorphic Suite, making stringers of quartz and feldspar stand out in vivid contrast (causes of the yellow stain on these rocks are discussed at mile 418.3).

The name Graveyard Fields originated at a time when the mossy trunks and stumps of spruce, destroyed by fire, were a common feature of the landscape, giving the area a somber, funeral look. A huge fire in November 1925, that burned 25,000 acres, consumed deadwood as well as living timber. On the horizon to the west, Graveyard Ridge rises to an elevation of 5,600 feet.

419.4 John Rock Overlook, elevation 5,330 feet.

Like Looking Glass Rock (mile 417.0) and Stone Mountain (mile 232.5), John Rock is an exfoliation dome resulting from millions of years of weathering and erosion. The rock is the same 390-million-year-old granitic rock that forms Looking Glass Rock. Although it cooled and crystallized from magma several miles below the surface of the earth, uplift, weathering, and erosion have had enough time (about 90 million years) to remove the overlying rocks and carve John Rock into the shape you see now.

420.2 Balsam Spring Gap, elevation 5,550 feet; access to Shining Rock Wilderness via Forest Service Road 816.

The mile-long access road leads to a parking area used by hikers who come to explore the trails of Pisgah National Forest's 18,500-acre Shining Rock Wilderness.

The open, relatively treeless area is a reminder of the fire of 1925. Forest fires are devastating, and recovery from fire is very slow in the Blue Ridge. After this fire, erosion washed away much of the topsoil. The spruce-fir forest that was destroyed here may not recover for a century or more.

422.4 Devil's Courthouse Overlook, elevation 5,462 feet.

Climb the half-mile trail to the top of Devil's Courthouse, elevation 5,720 feet, for a spectacular view of the Southern Appalachians. To the southeast is the Piedmont province.

The rock at the overlook and at the top of Devil's Courthouse is a migmatitic mica gneiss and schist of the Ashe Metamorphic Suite.

The so-called cave here is not a true solution cavity like Linville Caverns to the north, in the Grandfather Mountain window. Solution caves form in rocks easily dissolved by water, such as limestone, dolostone, and marble. The cavity here is a fissure cave, an opening along a joint or fissure in insoluble rock, large enough for people to enter.

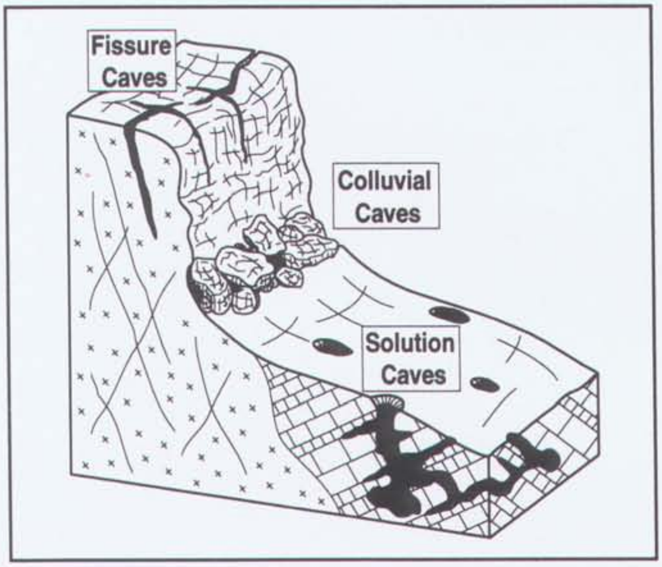


Illustration showing the three types of caves found in North Carolina. Solution caves, like Linville Caverns, are found when water dissolves a soluable rock like limestone or dolostone. Fissure caves are joints or cracks in the rock that are large enough for a person to enter. Colluvial caves form when loose rocks are piled up to produce a network of passageways between the rocks.

Cave-like cavities can also form where large blocks of rock have fallen from an outcrop and piled up at the base, creating a network of small passageways (see discussion at mile 304.4).

423.2 Beech Gap, elevation 5,340 feet; junction with N.C. 215, south to Rosman, 17 miles; north to Canton and Interstate 40, 24 miles.

423.5 Courthouse Valley Overlook, elevation 5,362 feet.

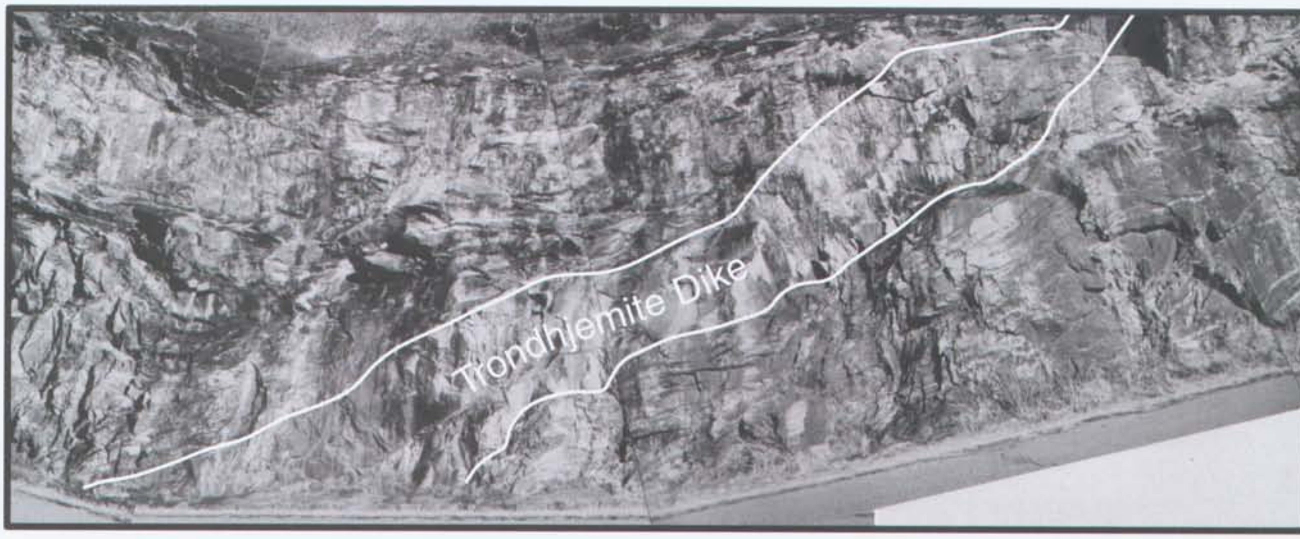
The outcrop here is a migmatitic muscovite-biotite gneiss that contains small red garnet crystals. Also interlayered are irregular bands and lenses of feldspar and quartz with some muscovite. The bands are folded in places. Geologists believe that the original rock was sedimentary in origin because of the layering it now displays. About 475 million years ago, this sedimentary rock was metamorphosed during the Taconic episode of mountain-building. Metamorphism transformed the mineral content and texture, producing the gneiss now exposed.

424.4 Herrin Knob Overlook, elevation 5,510 feet.

The migmatitic mica gneiss of the Ashe Metamorphic Suite in the road cut opposite here is cross-cut by a thick dike of a light-gray, medium-grained igneous rock called trondhjemite. The dike strikes east-northeast and dips to the northwest. It must be younger than the gneiss around it because it cuts across the foliation in the gneiss, thus illustrating the fundamental geologic principle known as the law of cross-cutting relationships. A rock mass that intrudes or cuts across another must be the younger of the two (also see discussion at mile 233.7).

425.4 Rough Butt Bald Overlook, elevation 5,300 feet.

The view to the southeast toward Lake Toxaway and the Highlands-Cashiers area, one of North Carolina's many scenic resort regions, is



Photomosaic of the trondhjemite dike intruding migmatitic mica gneiss at Herrin Knob Overlook, at mile 424.4. Notice how the dike cuts across foliation in the gneiss here, indicating that it must be younger than the rocks which it intrudes.

spectacular on a clear day. On the northwest horizon stands Rough Butt Bald. The small lake in the foreground is on Wolf Creek.

428.0 Caney Fork Overlook, elevation 5,650 feet.

The large outcrop across the Parkway is migmatitic muscovite-biotite gneiss cut by pegmatites that are composed mainly of feldspar and quartz with small amounts of muscovite.

The pegmatites were formed by intrusion of molten rock material along fractures in the gneiss. The molten material was probably derived from partial melting of nearby rock during Taconic metamorphism. The abrupt termination at the top end of the largest pegmatite may be the result of faulting, the displacement or movement of one rock in relation to another.

Over the next few miles, you will see several outcrops of highly contorted gneiss cut by pegmatites (the pegmatites here are best observed from the safety of the overlook).

430.7 Cowee Mountains Overlook, elevation 5,950 feet.

This is an excellent view of the rugged terrain of the Southern Appalachians. Here, one can gain a vivid visual impression of how erosion can carve an uplifted landmass to form a mountainous terrain.

Unlike rocks at previous exposures, the rock exposed here is of a type called calc-silicate granofels. It consists of minerals rich in calcium and/or silica, including hornblende, diopside, hedenbergite, epidote, garnet, and quartz. These rocks are so badly weathered, however, that individual minerals are hard to identify. Pod-shaped masses of quartz can be seen here as well.

431.4 Richland Balsam Overlook, elevation 6,053 feet.

This is the highest point on the Blue Ridge Parkway. Richland Balsam, elevation 6,410 feet, is the summit of the Great Balsam Range.

436.8 Grassy Ridge Mine Overlook, elevation 5,250 feet.

The Big Flint mica mine is located on the slopes of Grassy Ridge, opposite the overlook, to the southwest. Between 1932 and 1944, more than 5 tons of sheet and scrap mica were produced from open cuts and pits excavated into muscovite-rich pegmatites that intrude mica gneiss. Sheet mica was used in vacuum tubes for radios and other electronic equipment, while scrap mica was ground into powder and used as filler in paint and rubber.

439.4 Cove Field Ridge Overlook, elevation 4,620 feet.

A crushed-stone quarry is visible on the opposite side of the valley. The rock quarried is crushed for use in local construction projects.

North Carolina quarries produce over 44 million tons of crushed rock each year, valued at over $229 million. Tens of millions of tons of crushed stone were used in building the Blue Ridge Parkway.

Across the road from the overlook, a large outcrop consisting mainly of metagraywacke is cut by numerous intrusions. The composition of the intrusions is primarily quartz and sodium-rich plagioclase feldspar, with minor biotite and muscovite. Geologists call this rock type trondhjemite (trondhjemites are also described at mile 424.4.)

440.0 Saunook Overlook, elevation 4,375 feet.

The outcrop in the road cut across the Parkway from the overlook is a garnetiferous sericite-biotite gneiss that is cross cut by quartz veins. The outcrop is stained by a coating of secondary iron-oxide and iron-sulfate minerals (for more information on sulfate minerals, refer to mile 336.8).

440.8 Here is the fault contact between muscovite-biotite gneiss of the Ashe Metamorphic Suite and Middle Proterozoic biotite gneiss of the Grenville basement complex. This fault is named the Holland Mountain fault.

During the Taconic orogeny, rocks formed in the ancient ancestor of the Atlantic Ocean were shoved westward along this fault onto the edge of the continent over the older Grenville basement rocks. Soon after thrusting, Taconic metamorphism and deformation altered the rocks in both the hanging wall and footwall (see discussion of fault terminology at mile 284.6) of the Holland Mountain fault, and complexly folded the fault surface.

441.4 Standing Rock Overlook, elevation 3,915 feet.

Your geologic tour brings you to Standing Rock Overlook, where a fallen rock about 13 feet tall is perched on the side of the mountain. The rock is a thin-to medium-layered, complexly folded biotite gneiss and biotite-hornblende gneiss of the basement complex with abundant quartz- and feldspar-rich layers showing curved banding. Red iron-oxide stain, visible in places, results from the weathering of biotite mica and other iron-bearing minerals.

443.1 Balsam Gap, elevation 3,370 feet; junction with U.S. 23/74 - east to Waynesville, 8 miles; west to Sylva, 12 miles.

The gap marks the boundary between two mountain ranges: the Plott Balsams to the north and the Great Balsams to the south.

445.2 Mount Lynn Lowry Overlook, elevation 4,000 feet.

A short hike back to mile 445.0 offers a view of the Balsam Gap olivine deposit, across the valley to the south, and a look at a large road cut in Middle Proterozoic biotite gneiss of the Grenville basement complex.

The first commercial production of olivine in the United States was from a quarry in this deposit, which has operated on and off since the 1930s.

Olivine is heat-resistant, with a high melting temperature. Olivine bricks have been used for lining furnaces and the kilns in which clay bricks are baked. Before World War II, more than half of the olivine marketed from North Carolina came from this deposit. North Carolina olivine is now quarried at two other localities—one in Yancey County and one in Avery County.

The rocks in the road cut on the north side of the Parkway consist of migmatitic biotite gneiss and amphibolite, part of the Middle Proterozoic basement complex. Several younger trondhjemite dikes and biotite-bearing pegmatites intrude these old basement rocks.

446.0 Woodfin Valley Overlook, elevation 4,325 feet.

The road cut across the Parkway exposes banded, highly folded biotite gneiss of the Middle Proterozoic basement complex. These rocks are among the oldest in North Carolina, over 1 billion (a thousand million) years old. They have been metamorphosed and deformed many times in their long history.

Younger metasedimentary rocks such as those of the Ashe Metamorphic Suite appear to have been metamorphosed and deformed at least twice (once about 450 million years ago and, again, less intensely, 250 million years ago) since deposition of the original sediments some 700 million years ago.

In contrast, Middle Proterozoic basement rocks have been subjected to the stresses of mountain-building at least three times. The first, about 1 billion years ago, was during an event called the Grenville orogeny. At least two subsequent episodes of mountain-building have left their marks on these rocks. Observing their complex folds, it is not hard to imagine their long history.

446.2 Here is the fault contact between the Middle Proterozoic biotite gneiss and metagraywacke of the Great Smoky Group. This fault is named the Hayesville fault. Like the Holland Mountain fault (mile 440.8), the Hayesville fault is an old structure. Thrusting along it occurred during the Taconic orogeny. It was complexly folded, and rocks in its hanging wall and footwall were metamorphosed at that time.

The Great Smoky Group is a major rock unit in this region (for a discussion about how geologists name rock units, see mile 242.3). It consists of several formations which are composed of many rock types, including metagraywacke, schist, and slate.

Unlike the Ashe Metamorphic Suite, the Great Smoky Group contains no amphibolite (metamorphosed basalt). Although rocks of both units were deposited about the same time during Late Proterozoic continental rifting, rocks of the Great Smoky Group were deposited much closer to the edge of the continent into one or more large rift troughs.

446.7 Woodfin Cascades Overlook, elevation 4,535 feet.

The outcrop across from the overlook and around the curve is a folded, massive to thinly bedded quartz-rich garnetiferous metagraywacke. The overlook provides an excellent view of the cascading flow of Woodfin Falls.

448.3 Scott Creek Overlook, elevation 5,050 feet.

The outcrop opposite this overlook is of light- and dark-banded metagraywacke. The quartz veins and pegmatites that are also exposed here cut across the foliation of the metagraywacke and must therefore be of more recent geologic age (for more information on cross-cutting relationships, see mile 233.7 and 424.4).

449.0 Fork Ridge Overlook, elevation 5,280 feet.

The road cut opposite here exposes garnetiferous metagraywacke cut by several prominent pegmatites.

450.2 Yellow Face Overlook, elevation 5,610 feet.

Take time to view the erosion-sculptured ridge lines of the distant Plott Balsam mountains. They appear as narrow serrated crests from here.

Opposite the overlook is a massive to thin-bedded, fine-to coarse-grained metagraywacke. Note the rusty brown and greenish-yellow stains on many rock fractures and surfaces. This is a common feature in rocks of the Great Smoky Group. It comes from decomposition of iron-sulfide minerals, commonly pyrrhotite (the effects of decomposition of these minerals are also discussed at mile 336.8).

451.2 Entrance to Waterrock Knob Overlook, elevation 5,718 feet.

Along the road leading to the overlook are exposures of garnetiferous metagraywacke interbedded with mica schist. Note the prominent quartz vein and the muscovite-bearing pegmatites exposed opposite the Browning Knob Overlook.

At the Waterrock Knob Overlook, elevation 5,820 feet, an excellent outcrop of metagraywacke is exposed. The rock is massive to thinly bedded, and feldspathic. It is also cut by a narrow quartz vein. A massive vein of quartz can be seen to the southwest, on the flank of Yellow Face Mountain.

Along the trail to Waterrock Knob, elevation 6,292 feet, are many exposures of Great Smoky Group rocks. In the first bend above the parking area, a coarse-grained metagraywacke is interbedded with muscovite schist. Also present are thin pegmatite dikes that contain quartz, feldspar, and well-formed mica crystals.

Continuing your hike, the outcrop at the first bench is a mica-rich metagraywacke. At the second bench, view the two boulders with small quartz and pegmatite veins. Other poorly exposed outcrops occur along the trail.

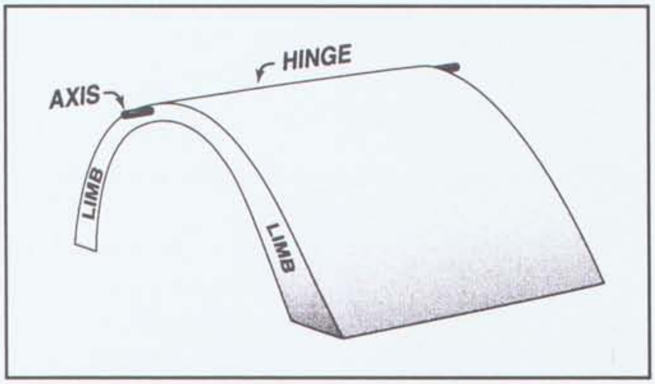
Panoramic views from Waterrock Knob include: Roan Mountain, Mount Mitchell and the Black Mountains to the northeast; the Great Smoky Range to the northwest; and Whiteside Mountain and Yellow Face Mountain to the south.

452.1 Cranberry Ridge Overlook, elevation 5,475 feet.

A massive outcrop of metagraywacke is exposed in the road cut opposite the overlook. The rock is interlayered with schist that contains the black mineral biotite mica. Cranberry Ridge is visible 500 feet below.

452.3 Woolyback Overlook, elevation 5,420 feet.

The metagraywacke exposed here is deformed into large folds, which the orientation of the road cut exposes to good effect. By standing at the southwest end of the exposure, you can look down the northeast-trending axes of these folds.



Elements of a fold. The limbs of a fold are the straighter segments of rocks that flank the fold hinge. The hinge of the fold represents the locus of maximum curvature or bending. The fold axis is an imaginary line that, when moved parallel to itself, generates the form of the fold.

As discussed at mile 336.8, the yellowish-brown stain on the rocks is from chemical decomposition of iron-sulfide minerals. Throughout western North Carolina, rocks rich in iron sulfides pose serious environmental concerns. Landslides and human-made disturbances expose fresh rock to the atmosphere. Weathering of the newly exposed iron sulfides produces sulfuric acid, which enters the streams and renders the water more acidic, endangering aquatic life.

453.4 Hornbuckle Valley Overlook, elevation 5,105 feet.

In the road cut just opposite here is a steeply dipping, well-layered outcrop of feldspathic biotite metagraywacke and muscovite biotite schist. The schist contains garnets, an important index mineral used by geologists to interpret progressive changes in temperature and pressure conditions that occur during episodes of metamorphism (for further information, see mile 300.6), and thin lenses and veins of quartz.

455.3 Here is the fault contact (not exposed) between rocks of the Great Smoky Group and rocks of the Snowbird Group. Like rocks of the Great Smoky Group (mile 446.2), rocks of the Snowbird Group were deposited into rift basins along the edge of the continent in the Late Proterozoic. Rocks of the Snowbird Group lie beneath rocks of the Great Smoky Group, and therefore must be older.

Here, rocks of the older Snowbird Group are faulted over younger Great Smoky Group rocks, indicating that the contact between the two units is a thrust fault (for more information on thrust faults, see mile 284.6).

455.4 Here is the fault contact (not exposed) between rocks of the Snowbird Group and biotite granitic gneiss basement rocks.

455.7 Soco Gap, elevation 4,340 feet; junction with U.S. 19, east to Maggie Valley, 4 miles, and Asheville, 38 miles; west to Cherokee, 12 miles.

456.9 Here is the fault contact (not exposed) between biotite granitic gneiss basement rocks and rocks of the Snowbird Group.

458.2 Wolf Laurel Gap, elevation 5,100 feet; junction with the Heintooga Spur Road to Heintooga Overlook and Balsam Mountain Campground.

Take a few moments to travel this 8.9-mile extension of the Parkway to Heintooga Overlook, which offers spectacular views of the Great Smoky Mountains National Park.

0.0 Here is the contact (not exposed) between rocks of the Snowbird Group and the Great Smoky Group.

1.3 View of Maggie Valley at Mile High Overlook, elevation approximately 5,220 feet.

Sparse outcrops in this area expose garnetiferous muscovite schist and very fine-grained metagraywacke of the Great Smoky Group. Both rock types contain biotite mica.

2.3 Lake Junaluska Overlook, elevation 5,034 feet.

Lake Junaluska was named for the Cherokee Chief Junaluska, a special friend of the seventh President of the United States, Andrew Jackson.

This 200-acre lake covers the site of a small Cherokee town named Tuscola.

Just opposite the Parkway from here is an outcrop of very fine-grained, micaceous metagraywacke interbedded with more quartz-rich muscovite schist that contains a few garnet crystals. These rocks belong to the Great Smoky Group.

3.6 The monument here, of special interest to geologists and rockhounds, is built of nearly 700 rocks and minerals from throughout the nation and the world.

4.0 For the next 0.7 miles, the road cut exposes fine-to coarse-grained metagraywacke interbedded with garnetiferous mica schist. These rocks were folded and deformed during at least one episode of Paleozoic mountain-building. Notable is a large anticlinal fold located in the vicinity of mile 4.3. Good examples of crenulations (small V-shaped crinkles) are exhibited on the limb of the fold.

8.9 Heintooga Overlook and picnic area, elevation 5,335 feet. End of Blue Ridge Parkway Extension.

Exposures of micaceous metagraywacke of the Great Smoky Group occur along the trail to the overlook and picnic area.

Retrace Your Route Back To The Blue Ridge Parkway.

458.9 Lickstone Ridge Overlook, elevation 5,150 feet.

Very little rock is exposed in the road cuts opposite this overlook, but at the tunnel entrance, 100 feet to the south, there is an outcrop of metagraywacke of the Great Smoky Group containing the minerals mica and quartz.

459.5 Bunches Bald Overlook, elevation 4,925 feet.

The outcrop along the road cut opposite this overlook is a steeply dipping, thin-to medium-bedded, fine-grained metagraywacke interlayered with muscovite-biotite schist.

467.4 Ballhoot Scar Overlook, elevation 2,550 feet.

In an outcrop at the northern end of this overlook, very fine-to coarse-grained gray metagraywacke is interbedded with fine-grained biotite-muscovite schist of the Great Smoky Group. Bedding is mostly massive and the inclination or dip of the beds is nearly vertical.

At the south end of the overlook, a massive, buff-colored, cross-bedded feldspathic quartzite crops out. This rock is part of the Snowbird Group and is named the Longarm Quartzite. Like rocks of the Great Smoky Group, it is over 700 million years old.

Both quartzite and metagraywacke are metamorphosed clastic sedimentary rocks. The quartzite was originally very clean quartz-rich sandstone, while the metagraywacke was originally sandstone that contained impurities such as feldspar, clay and mica minerals, and rock fragments, in addition to quartz.

The contact here between the Longarm Quartzite and metagraywacke of the Great Smoky Group is a thrust fault called the Greenbrier fault. Like the Holland Mountain fault (mile 440.8) and the Hayesville fault (mile 446.2), the Greenbrier fault is a major Taconic fault in this part of the Blue Ridge. The exposure at the south end of the overlook reveals that younger rocks of the Great Smoky Group have been thrust over older rocks of the Longarm Quartzite.

In most situations, thrust faults shove older rocks over younger rocks (see discussions at mile 455.3 and 284.6), but many geologists believe that the Greenbrier fault developed along an unconformity between the Great Smoky and Snowbird Groups. Thus, rocks of the younger Great Smoky Group in this region were shoved along the unconformity over rocks of the Snowbird Group during the Taconic orogeny.

467.9 Raven Fork Overlook, elevation 2,400 feet.

The outcrop here is Longarm Quartzite, a distinctly layered, buff-colored, very fine-to coarse-grained, cross-bedded feldspathic quartzite. Part of this outcrop consists of white, poorly indurated or crumbly weathered quartzite.

468.7 Here is the fault contact between rocks of the Snowbird Group and biotite granitic gneiss of the basement complex. The biotite granitic gneiss displays a mylonitic texture (see discussion of mylonites at Linville Falls, mile 316.4), which indicates that the rock was subjected to intense stress during faulting.

469.1 Terminus of the Blue Ridge Parkway; north into Great Smoky Mountains National Park, south to Cherokee, 0.5 miles; Oconaluftee Visitor Center, 0.5 miles; Newfound Gap, 16 miles; Gatlinburg, Tennessee, 30 miles.

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GLOSSARY

Note: *Some of the terms defined here have multiple meanings. The definitions here are focused on the terms' usage in geology.*

A

actinolite — A green mineral of the amphibole group, a hydrous calcium-iron-magnesium silicate.

alaskite — A type of light-colored plutonic igneous rock consisting mostly of feldspar and quartz, with muscovite mica as the chief accessory mineral.

allochthon — A mass of rock that has been moved from its place of origin by tectonic processes, as in a thrust sheet.

almandine — The iron-aluminum end member of the garnet group, characterized by a deep red to purplish color.

amphibole — A group of generally dark hydrous silicate minerals including common rock-forming varieties such as hornblende and actinolite.

amphibolite — A type of dark metamorphic rock consisting mainly of amphibole and plagioclase feldspar with little or no quartz.

anion — A negatively charged ion.

anticline — A fold in which, in map view, the oldest layers of rock are in the core. Usually, the layers are bent convex upward to form an arch, in contrast to a syncline.

argillite — A compact, fine-grained, clastic sedimentary rock.

arkose — A type of feldspar-rich sandstone commonly derived from rapid disintegration of granitic rocks.

asthenosphere — The layer of the Earth below the lithosphere, which is weak and in which isostatic adjustments take place and magmas may be generated.

augen — German word meaning "eyes." See porphyroblast.

B

basalt — A mafic extrusive rock consisting of iron and magnesium silicate minerals and plagioclase feldspar.

basement — The oldest rocks that underlie all other rocks in an area.

basin (sedimentary) — A low area of the Earth's crust in which sediments may accumulate.

batholith — A large, generally cross-cutting plutonic igneous rock mass that has more than 40 square miles of surface exposure, commonly composed of granitic rock.

bedding — The arrangement of sedimentary rock in layers; also referred to as stratification.

biotite — A black, dark-brown or dark-green iron- and magnesium-bearing mineral of the mica group.

C

calc-silicate — A mineral containing calcium and silica.

calc-silicate granofels — A metamorphic rock consisting mainly of calcium-bearing silicate minerals.

calcareous — A rock or sediment that is rich in calcium carbonate.

calcic — A mineral or rock containing a relatively high proportion of calcium.

calcite — A common white or colorless rock-forming mineral, calcium carbonate.

Cambrian — The oldest period of the Paleozoic Era, lasting from about 570 to 500 million years ago.

carbonaceous — A rock or sediment that is rich in carbon or organic matter.

chlorite — A green, platy, hydrous iron-magnesium silicate mineral, resembling and often associated with mica.

cation — A positively charged ion.

clastic — A rock or sediment composed of fragments derived from pre-existing rocks or minerals and transported by wind, water, or ice.

cleavage — In rocks, the property or tendency to split along aligned fractures, minerals, or other closely spaced planar structures or textures, produced by deformation or metamorphism; in minerals, the tendency to break along planes of inherent weakness in the crystal structure.

conglomerate — A sedimentary rock consisting of gravel-sized, rounded waterworn fragments of rock cemented together by another mineral substance.

contact zone — A zone surrounding an igneous intrusion in which the surrounding country rock shows the effects of increased heat during metamorphism.

contact — A surface forming the boundary between rocks of different types and/or ages.

crenulations — Small-scale folds or crinkles with wavelengths generally less than one inch; crenulations may occur along the cleavage planes of a rock that has undergone structural deformation; adj.: crenulated.

cross-bedding — In a sedimentary deposit, an arrange- of inclined layers between the main bedding planes.

crust — The outermost layer or shell of the Earth.

crystal — A chemical element or compound having a regularly repeating atomic arrangement. Under certain conditions, crystals may exhibit planar faces, such as those shown by many minerals exhibited in museums. Most rocks are composed of mineral crystals with few perfectly formed planar faces.

crystalline — An interlocking arrangement of mineral crystals in igneous or metamorphic rocks.

D

debris slide — The rapid to slow downward movement of a coherent mass of soil and rock fragments.

debris flow — The very rapid downward movement of a slurry of soil, rock, water, and other debris.

debris avalanche — The extremely rapid downward movement of an incoherent mass of soil and rock fragments.

deformation — A general term for the process of folding, faulting, shearing, compression or extension of the rocks as a result of various Earth forces; adj.: deformed.

dendritic — A mineral that has crystallized in a branching pattern; also, a drainage pattern in which the streams branch randomly in all directions.

deposition — The process by which material such as sediment is laid down by natural agents such as water, air, and ice; adj.: deposited.

Devonian — A period of the Paleozoic Era lasting from about 410 to 360 million years ago.

diabase — A dark, medium-grained plutonic igneous rock consisting mostly of calcium-rich feldspar and mafic minerals.

differential weathering — Weathering that occurs at different rates, as a result of variations in composition and resistance of a rock or differences in intensity of weathering, and usually results in an uneven surface where more resistant material stands higher or protrudes above softer or less resistant parts.

dike — A tabular igneous intrusion that cuts across the bedding or foliation of the rock surrounding it.

diorite — A type of plutonic igneous rock composed of plagioclase feldspar and one or more dark minerals, including biotite mica, hornblende, or pyroxene. Feldspar is more abundant than the dark minerals, giving the rock a characteristic "salt and pepper" appearance.

dip — The angle that a stratum or any planar feature (e.g., bedding, fault plane or foliation) makes with the horizontal, measured perpendicular to the strike of the feature and within a vertical plane.

dolomite — A common white or colorless rock-forming mineral, calcium magnesium carbonate; also a rock composed of this mineral; adj.: dolomitic.

dolostone — A rock composed of the mineral dolomite.

E

emplacement — A term used in describing the process of intrusion of a plutonic igneous rock; adj.: emplaced.

eon — The longest geologic time unit, consisting of eras and their subordinate time units, i.e., periods and epochs. Another use of the term is to denote one billion years.

epidote — A green silicate mineral, hydrous calcium-aluminum-iron silicate, common in certain metamorphic rocks.

epoch — The unit of geologic time into which a period is divided.

era — The unit of geologic time intermediate between an eon and a period; e.g., the Paleozoic Era.

erosion — The general process or group of processes that act upon the materials of the Earth's crust by loosening, dissolving or wearing them away, then moving them from one place to another by natural agencies such as wind, gravity, or water; adj.: eroded.

escarpment — A long, more or less continuous cliff or relatively steep slope facing in one general direction, breaking the continuity of the land by separating two levels or gently sloping surfaces, and produced by erosion or faulting.

exfoliation — The process of mechanical weathering of igneous and metamorphic rocks by which concentric scales, plates, or shells of variable thickness are successively spalled or stripped from the bare surface of a rock mass; adj.: exfoliated.

extrusive — A volcanic igneous rock that has been erupted onto the surface of the Earth; e.g., a lava flow; adj.: extruded.

F

fault — A fracture or a zone of fractures along which the rock on one side has been displaced relative to the rock on the other side; adj.: faulted.

feldspar — A group of widespread aluminum-silicate minerals containing oxides of sodium, calcium, or potassium, which constitute 60 percent of the rocks of the Earth's crust. Feldspar minerals occur as components of most rock types, especially igneous and metamorphic rocks.

feldspathic — A rock or other mineral aggregate containing feldspar.

felsic — An igneous or metamorphic rock in which light-colored minerals are abundant, most commonly feldspar and quartz.

ferric iron — A trivalent cation of iron.

ferrous iron — A bivalent cation of iron.

float — A general term for isolated, displaced fragments of rock, especially on a hillside below an outcropping ledge or vein.

fold — A product of deformation resulting in a curve or bend of a planar structure such as rock strata, bedding planes, foliation, or cleavage.

foliation — In metamorphic rocks, the layered texture that results from parallel arrangement of flat or elongated mineral grains such as mica; adj.: foliated.

formation — A lithologically distinct body of rock recognized as a stratigraphic unit for purposes of geologic mapping.

fracture — A break in a rock, usually a planar joint or fault surface.

G

garnet — A family of colorful silicate minerals, having a glassy luster and no cleavage, found in a wide range of igneous and metamorphic rocks. Many are various shades of red and occur as well-formed crystals.

garnetiferous — Containing garnet.

geologic map — A two-dimensional representation of the Earth's surface on which is recorded geologic information such as the distribution, nature, and age relationships of rock units and the occurrence of structural features, mineral deposits, and fossil localities.

geologic cross section — A diagram or drawing that shows features on a geologic map as they would appear at depth in a vertical section through the Earth.

geomorphic — Pertaining to the landforms that develop on the surface of the Earth.

geomorphology—The study of the classification, description, nature, origin, and development of landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features; adj.: geomorphic.

gneiss — A foliated rock, usually formed by regional metamorphism, in which bands or layers of granular minerals alternate with bands or layers in which minerals having flaky or elongate prismatic habits predominate.

graded bedding — A type of layering in sedimentary deposits in which each layer displays a gradual change in particle size, usually from coarse at the base to fine at the top.

granite — a common light-colored, coarse-grained plutonic igneous rock consisting of variable amounts of quartz, feldspar, and accessory minerals; adj.: granitic.

granodiorite — A type of plutonic igneous rock in which two or more varieties of feldspar are accompanied by quartz and smaller amounts of dark minerals such as biotite mica and hornblende; adj.: granodioritic.

granofels — A metamorphic rock with a texture that is neither foliated nor lineated.

graywacke — A type of dark, poorly sorted sandstone in which coarser fragments of rocks and minerals are cemented together by fine-grained material, much of which consists of clay minerals.

H

hematite — A common iron mineral occurring in metallic-looking, steel-gray or iron-black rhombohedral crystals, in reniform masses or fibrous aggregates, or in deep-red or red-brown earthy forms. It is the principal ore of iron, and a primary source of the red color of many soils.

hornblende — The most common mineral of the amphibole group, a complex hydrous aluminum silicate in which calcium, sodium, iron, and magnesium are present in varying amounts; commonly black, dark-green or brown and occurring in distinct long, slender crystals or in columnar, fibrous or granular forms. It is a primary constituent of many felsic and intermediate igneous rocks and less commonly of mafic igneous rocks, and it is a common metamorphic mineral in amphibolitic gneisses.

hydrous — A mineral compound containing water.

I

igneous — A rock formed by solidification from a molten or partially molten silicate material, i.e., from a magma.

interlayer — A layer situated between others of a different nature; adj.: interlayered.

intermontane — Situated between or surrounded by mountains, mountain ranges, or mountainous regions.

intrusive — Pertaining to intrusion, the process of emplacement (injection) of magma in pre-existing rock; also the igneous rock mass so formed within the surrounding rock mass; adj.: intruded.

isostasy — The condition of equilibrium, comparable to floating, of the lithosphere above the asthenosphere.

J

jarosite — An ochre-yellow or brown group of minerals consisting of hydrous iron sulfates.

joint — A planar break or crack in a rock, without displacement.

K

kaolin — The name given to a group of clay minerals that share a particular crystal structure, all of them derived from alteration of feldspar and mica.

knickpoint — An interruption or break in slope where the longitudinal profile of a stream or valley changes abruptly.

L

lamination — A rock fabric that consists of very thin layering in metamorphic and sedimentary rocks; adj.: laminated.

lava flow — Molten volcanic material poured out onto the surface of the Earth; also a solidified extrusive igneous rock.

lens — A mineral deposit or body of rock that is thick in the middle and thins out towards the edges, like a convex lens.

limestone — A sedimentary rock consisting predominantly of calcium carbonate.

limonite — The name given to a group of brown noncrystalline hydrous iron oxides formed by weathering of iron minerals.

lineation — A linear structure in a rock formed by aligned minerals or intersecting planes; adj.: lineated.

lithification — To change to stone, or to petrify; especially to consolidate from a loose sediment to a solid rock; adj.: lithified.

lithology — The description of rocks on the basis of such characteristics as color, mineralogic composition, and grain size.

lithosphere — A layer of the Earth characterized by strength relative to the underlying asthenosphere. It includes the crust and upper part of the mantle, and is in the order of 60 miles in thickness.

M

mafic — An igneous rock composed chiefly of dark minerals, such as hornblende and iron-and magnesium-rich biotite mica.

magma — Molten matter within the Earth's crust, from which igneous rocks form by cooling.

mantle — The zone, layer, or shell of the Earth below the crust and above the core.

marble — A metamorphic rock consisting predominantly of fine-to coarse-grained recrystallized calcite and/or dolomite.

mass wasting — Downward movement of rock fragments under the influence of gravity, without transport by or in another medium such as water or ice.

matrix — The fine-grained material surrounding the larger crystals or grains of an igneous, metamorphic, or sedimentary rock.

megacryst — See porphyroblast.

melanterite — A green or greenish blue mineral resulting from the decomposition of iron sulfides.

meta — A prefix that indicates that a rock has been metamorphosed, used with the name of a sedimentary or igneous rock, e.g., metabasalt, metaquartzite, metagraywacke, metaconglomerate, metadiabase.

metamorphism — Recrystallization of solid rock at variable temperatures and/or pressures below the Earth's surface, producing changes in the rock's texture or composition; adj.: metamorphosed.

mica — A group of hydrous aluminum-rich silicate minerals, all of which have perfect basal cleavage that allows them to be peeled apart in thin layers.

micaceous — A term describing a mica-rich rock.

migmatite — A metamorphic rock showing localized melting of light-colored materials; adj.: migmatitic.

mineral — A naturally occurring inorganic chemical element or compound having an orderly internal atomic structure and characteristic chemical composition. Most minerals have a definite crystal form, and physical properties.

monadnock — A hill or mountain above the general level of the land representing an isolated remnant in an area that has been largely beveled flat by erosion.

mud — A mixture of fine silt-and clay-sized particles.

mudstone — A sedimentary rock composed of consolidated fine silt-and clay-sized particles.

muscovite — A transparent to silvery colored potassium-bearing mineral of the mica group.

mylonite — A foliated fault rock characterized by a decrease of grain size from the original rock formed by grinding during intense faulting.

N

nonconformity — An unconformity between stratified rocks above and older igneous or metamorphic rocks below; adv.: nonconformably.

Normal fault — A fault in which the hanging wall has moved downward relative to the footwall.

O

olivine — An olive-green to brown iron-and magnesium-rich silicate mineral, common in mafic and very mafic igneous rocks.

Ordovician — The second oldest period of the Paleozoic Era, lasting from about 500 to 435 million years ago.

outcrop — Rock that is exposed at the surface of the Earth.

Oxide — A compound of oxygen with an element.

P

Paleozoic — The first of three eras of the Phanerozoic Eon, lasting from about 570 to 240 million years ago.

pebble — A small, partly rounded, generally waterworn rock fragment.

pegmatite — An exceptionally coarse-grained, light-colored intrusive igneous rock, with interlocking crystals of quartz, feldspar, and mica, usually found as irregular dikes, lenses or veins, especially at the margins of large bodies of plutonic igneous rock.

period — A geologic time unit intermediate in rank between an era and an epoch.

petrology — The branch of geology that deals with the origin, occurrence, structure, and history of rocks; adj.: petrologic.

Phanerozoic — That eon of geologic time represented by rocks in which there is abundant evidence of life (fossils) and comprising three eras — Paleozoic, Mesozoic, and Cenozoic — from about 570 million years ago to the present.

phyllite — A metamorphic rock, intermediate in degree of metamorphism between slate and mica schist; adj.: phyllitic.

phyllitic sheen — A silky luster on the surface of cleavage or schistosity of mildly or moderately metamorphosed rock, imparted by tiny mica crystals.

physiography — The description and origin of landforms of the Earth; adj.: physiographic.

plate tectonics — A theory that divides the Earth's crust into a number of rigid plates that move over the Earth's surface by internal Earth forces and interact with each other where they come in contact, producing volcanic eruptions, earthquakes, and mountain ranges.

pluton — An igneous rock that has crystallized from magma at great depth; adj.: plutonic.

pod — A metamorphic rock that is long in one dimension and short in two dimensions with its long axis most commonly parallel to layering.

porphyroblast — A large crystal developed in a metamorphic rock by recrystallization.

Proterozoic — That eon of geologic time represented by rocks in which there is little evidence of life (fossils), comprising three eras — Early, Middle, Late — from about 2,500 million to 570 million years ago.

protolith — The parent rock of a metamorphic rock.

pyrite — A common, pale-bronze or brass yellow, cubic-shaped mineral composed of iron and sulfur.

Q

quartz — A very common rock-forming mineral consisting of silicon dioxide.

quartzite — A granular metamorphic rock derived from sandstone and consisting of interlocking grains of quartz.

R

recrystallization — The formation of new crystalline mineral grains in the solid state by metamorphism.

rift — A long narrow continental trough that is bounded by normal faults. It marks a zone along which the entire thickness of the lithosphere has ruptured under extension.

rock — An aggregate of one or more minerals.

rock sequence — A succession of rocks arranged in their relative position and age.

S

sandstone — A sedimentary rock composed chiefly of sand-sized grains cemented by calcium carbonate, silica, or other materials.

schist — A finely foliated metamorphic rock that splits easily into thin layers or slabs because of the well developed parallelism of abundant flat or elongate minerals such as mica and hornblende.

sediment — Unconsolidated fragments of gravel-, sand-, and mud-sized particles that have been transported and deposited by water, wind, ice, or gravity induced flows.

sedimentation — The process of deposition of sediment.

sequence — A succession of geologic events, processes, or rocks, arranged in chronologic order to show their relative position and age with respect to geologic history as a whole.

sericite — Very fine-grained muscovite.

shale — A sedimentary rock composed chiefly of clay and very fine-grained particles of quartz.

silicate — A mineral whose crystal structure is characterized by a particular arrangement of silicon and oxygen atoms, in which one silicon atom is set in the middle of a cluster of four oxygen atoms.

siltstone — A sedimentary rock composed of silt-sized rock or mineral particles.

slate — A compact fine-grained metamorphic rock, typically metamorphosed from shale, that possesses a unique cleavage that allows it to be split into fine slabs and thin plates.

sodic — A mineral containing a relatively high percentage of sodium.

spheroidal weathering — A form of chemical weathering in which concentric or spherical shells of decayed rock are successively loosened and separated from a block of rock by water penetrating the bounding joints or fractures and attacking the rock from all sides; similar in effect to exfoliation.

stock — A pluton less than 40 square miles in surface area.

stratification — see bedding.

stratigraphy — A branch of geology concerned with the definition and description of natural divisions of rock strata, including their history and interrelationships with other rocks, adj.: stratigraphic.

strike — Direction of line formed by the intersection of a rock surface with a horizontal plane. Strike is always perpendicular to the direction of dip.

stringer — A thin rock or mineral vein occurring in a discontinuous pattern in the host rock.

structure — The general disposition, attitude, arrangement, or relative positions of the rock masses of a region or area, as expressed in features produced by deformation, such as folds and faults.

subduction — The process of one lithospheric plate descending beneath another along a long narrow zone or belt on the Earth's surface.

subsidence — The sinking or gradual downward settling of the Earth's surface, with little or no horizontal motion.

substrata — Rocks in the zone below the surface, whose geologic features, principally stratigraphic and structural, are interpreted on the basis of drill records and various kinds of geophysical evidence rather than by direct observation.

sulfate — A mineral compound characterized by the presence of SO_4.

sulfide — A mineral compound characterized by joining sulfur with a metal, commonly iron; adj.: sulfidic.

syncline — a fold in which, in map view, the youngest layers of rock are in the core. Generally, the layers are bent concave upward.

synclinorium — A synclinal structure of regional extent composed of smaller folds.

T

tectonic plate — Blocks of oceanic and continental crust and upper mantle, supported by a viscous underlayer of the lower mantle.

tectonics — A branch of geology dealing with the regional assemblage of structural and deformational features of the Earth's crust, and a study of their origins and histories.

thrust fault — A fault produced by forces acting to compress the rocks of the Earth's crust, squeezing them together and pushing one mass on top of another.

thrust sheet — A body of rock that has arrived at its present position by movement along an underlying thrust fault.

tourmaline — A group of varicolored silicate minerals with complex chemical formulas that always include boron and sometimes a little fluorine, commonly in granites and gneisses.

trondhjemite — An igneous rock composed chiefly of plagioclase feldspar and quartz, characteristically very low in potassium.

type locality — The place where the rocks of a geologic unit are described as being representative of the whole unit in a region.

U

unconformity — A surface of erosion or nondeposition in the rock record.

uplift — A structurally high area in the crust, produced by upward movements that raise or upthrust the rocks, as in a dome or arch.

V

vein — A thin sheet-like mass of rock or mineral intruded into a fracture.

volcano — A vent in the surface of the Earth through which magma and associated gases and ash erupt. Also, the often conical structure built by the products of such eruptions; adj.: volcanic.

W

weathering — The physical disintegration and chemical decomposition of rock at the Earth's surface.

window — An area in a thrust sheet where the rocks have been eroded down to the underlying thrust fault, thereby exposing rocks beneath the thrust sheet.

APPENDIX

CORRELATION OF A GEOLOGIC ADVENTURE ALONG THE BLUE RIDGE PARKWAY IN NORTH CAROLINA TO THE NORTH CAROLINA SCIENCE STANDARD COURSE OF STUDY, 1999 REVISION

Below we have interpreted the applicability of this bulletin to the competency goals and objectives presented in the North Carolina Science Standard Course of Study and Grade Level Competencies, for Earth/Environmental Science, Grades 9-12. Use this correlation to learn how this booklet supplements the new earth/environmental science curriculum. This course will be required for graduation from high school starting in the 2000-01 academic year. Our correlation has been reviewed and approved by the science staff of the North Carolina Department of Public Instruction.

Earth/Environmental Science - Grades 9-12

The earth/environmental science curriculum focuses on the function of the earth's systems. Emphasis is placed on matter, energy, crustal dynamics, environmental awareness, materials availability, and the cycles that circulate energy, and material through the earth system. The areas of inquiry include:

- Energy in the earth system.
- Geochemical cycles.
- Origin and evolution of the earth system.
- Origin and evolution of the universe.
- Predictability of a dynamic earth.
- Human interactions with the earth's geologic and environmental systems.

Strands: The Strands are: Nature of Science, Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives. They provide the context for teaching of the content Goals and Objectives.

COMPETENCY GOAL 1: ***The learner will build an understanding of lithospheric materials, processes, changes, and uses with concerns for good stewardship.***

Objectives

1.01 Analyze the dependence of the physical properties of minerals on the arrangement and bonding of their atoms.

1.02 Classify the three major groups of rocks according to their origin, based on texture, mineral composition, and the processes responsible for their formation.

1.03 Assess the importance of the economic development of earth's finite rock, mineral, fossil fuel, and other natural resources to society and our daily lives:
- Availability.
- Geographic distribution.
- Wise use.
- Conservation.
- Recycling.
- Challenge of rehabilitation of previously disturbed lands.

1.04 Analyze the importance of soils:
- Soil use and conservation.

1.05 Evaluate geologic hazards and their relationship to geologic processes and materials:
- Mass wasting.
- Flooding.

1.06 Interpret topographic, soil and other maps and images for:
- The location and identification of soils and rock types.
- The identification of erosional and depositional landforms.
- The evaluation of landforms resulting from tectonic activity.

COMPETENCY GOAL 2: ***The learner will develop an understanding of tectonic processes and their human impacts.***

Objectives

2.01 Analyze the evidence for the development of the Theory of Plate Tectonics:
- Propelling forces.
- Plate boundary interactions.
- Features of the sea floor.

2.02 Evaluate the forces that propel tectonic plates.

2.03 Analyze the model of the earth's interior resulting from the study of earthquake waves.

2.04 Analyze the nature, location of epicenters, and magnitude of earthquakes:
- Folds.
- Faults.

COMPETENCY GOAL 3: ***The learner will build an understanding of the origin and evolution of the earth system.***

Objectives

3.01 Interpret the order and impact of events in the geologic past:
- Relative and absolute dating techniques.
- Statistical models of radioactive decay.
- Fossils evidence of past life.

3.02 Assess evidence for and the influence on the divisions of geologic time of the major geologic events and paleoclimatic changes in global geologic history:
- Uniformitarianism.
- Unconformities.
- Stratigraphic principles.

3.03 Evaluate the geologic history of North Carolina and the Appalachian orogen.

COMPETENCY GOAL 4: ***The learner will build an understanding of the hydrosphere, and its interactions, and influences on the lithosphere, the atmosphere, and environmental quality.***

Objectives

4.01 Evaluate the stream erosion, and depositional processes:
- Land forms resulting from natural erosion, deposition, and mass wasting.
- Formation of stream channels with respect to the work being done by the stream (i.e. down cutting, lateral erosion, and transportation).
- Nature, and characteristics of sediments.
- Ability of running water to sort sediments.

4.02 Evaluate water beneath the earth's surface:
- Storage and movement.

COMPETENCY GOAL 7: ***The learner will build an understanding of alternative choices facing human societies in their stewardship of the earth.***

Objectives

7.01 Analyze the relationship between the potential of technology to improve the quality of life and the possible causes of stress on the environment.

7.02 Analyze the interdependence of Earth's natural resources and systems, including land, air, and water, with the need to support human activity and reduce environmental impacts.

7.03 Assess how society weighs the choices of economic progress, population growth, and environmental stewardship, and selects a balanced responsible course of action.

From: SCIENCE, Standard Course of Study and Grade Level Competencies, K-12, Public Schools of North Carolina, Department of Public Instruction, Revised 1999, p. 87-97.

The North Carolina Geological Survey (NCGS) examines, describes and maps the geology and mineral resources of the State, publishes reports and maps, and encourages the wise conservation and use of geologic resources by industry, commerce, agriculture, and government agencies for the general welfare of the citizens of North Carolina. Our mission, since our founding in 1823, is to provide unbiased and technically accurate applied earth science research and information to address societal needs, including geologic maps, mineral resource and geochemical information, topographic maps and digital products, earth science education initiatives, nuclear and other waste disposal issues, geologic hazards (landslides, etc.), engineering geology, and coastal management. The NCGS also administers cooperative geologic and topographic map agreements with the U.S. Geological Survey, the U.S. Minerals Management Service, the U.S. Forest Service, and other state and local government agencies.

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