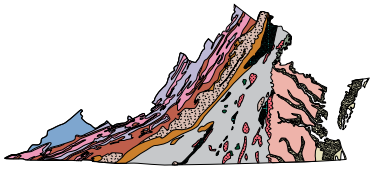


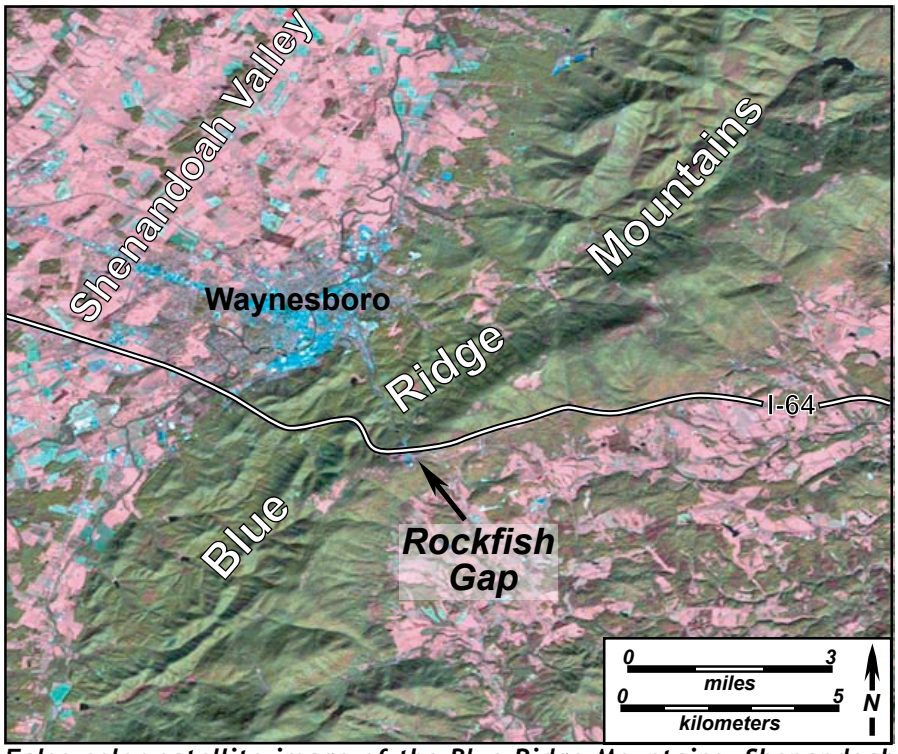
Worthy Field Locales

THE GEOLOGY of VIRGINIA

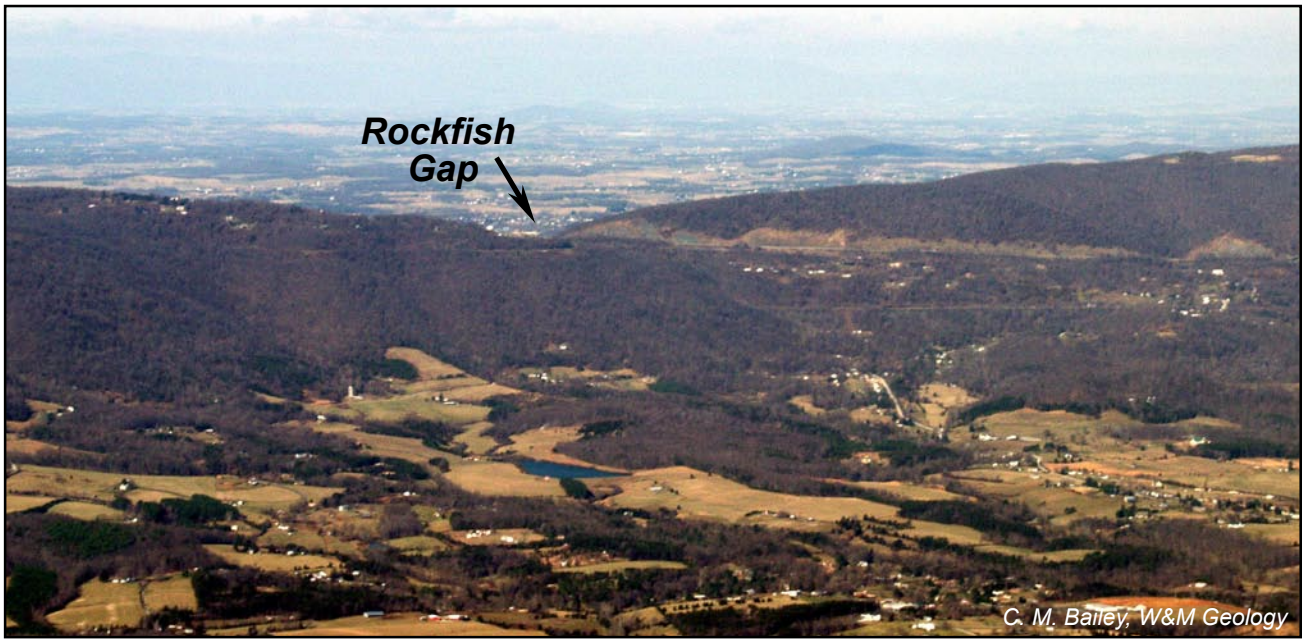
Mind the Gap! Where is Afton Mountain?

Christopher M. Bailey, College of William & Mary

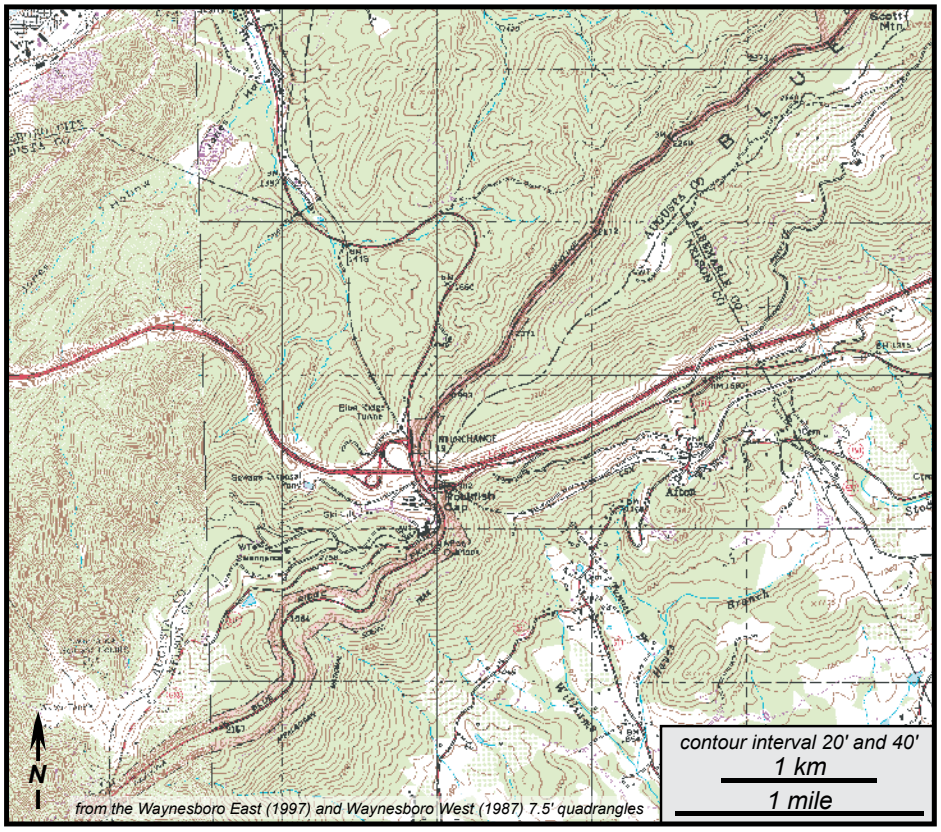
Ask Virginians where the top of Afton Mountain is located, and they will likely tell you "it's the place where Interstate 64 crosses the Blue Ridge Mountains between Charlottesville and Staunton". The trouble with that description is this: Interstate 64 crests the Blue Ridge Mountains at Rockfish Gap. So where exactly is Afton Mountain? Look on the U.S. Geological Survey's topographic map of the area and you'll not find an Afton Mountain. Afton is a small town located on the slopes of the Blue Ridge about a mile to the east of Rockfish Gap. Interstate 64 cuts a long gentle grade across the southern slope of the Blue Ridge topping out at 1900 ft (580 m) above sea level at Rockfish Gap before descending westward into the Shenandoah Valley. Rockfish Gap has long been an important nexus between the Piedmont and Shenandoah Valley, but as we shall see it is also a fascinating geological locale.



False color satellite image of the Blue Ridge Mountains, Shenandoah Valley, and Rockfish Gap.



Oblique aerial photo of Rockfish Gap and the crest of the Blue Ridge Mountains as viewed from the south-southeast. Shenandoah Valley in the background.



Above- U.S. Geological Survey 7.5' topographic map of the Rockfish Gap area. Below- Annotated aerial photo of the Rockfish Gap area.

Rockfish Gap is the lowest point along the crest of the Blue Ridge Mountains from Front Royal to the James River, a distance of ~120 miles (~190 km), and as such the gap has long been utilized as a crossing point over the mountains. By the late 18th century a carriage road traversed the gap. In 1818, Thomas Jefferson and other luminaries selected Charlottesville as the site for the newly founded University of Virginia while at a Rockfish Gap tavern. The French-born Claudius Crozet engineered a railroad tunnel beneath the gap in the 1850s that was supplanted by a second railroad tunnel under the gap in the 20th century. U.S. Route 250 crosses the gap, and in 1973 Interstate 64 opened.

The town of Afton is located on the lower slopes of a northeast-trending ridge named Scott Mountain. In the early 20th century the Scott family of Richmond bought a mountain top orchard and built Scott's "Castle". The ridge to the southwest of Rockfish Gap, upon which the Swannanoa estate is located, has no formal name on U.S. Geological Survey maps. The oldest maps of the area, dating to the 1860's and 1880's, clearly delineate Rockfish Gap but not Afton Mountain. Claudius Crozet's letters concerning the location of the Blue Ridge railroad tunnel (1849-1858) refer only to Rockfish Gap. Afton Mountain is a modern creation.

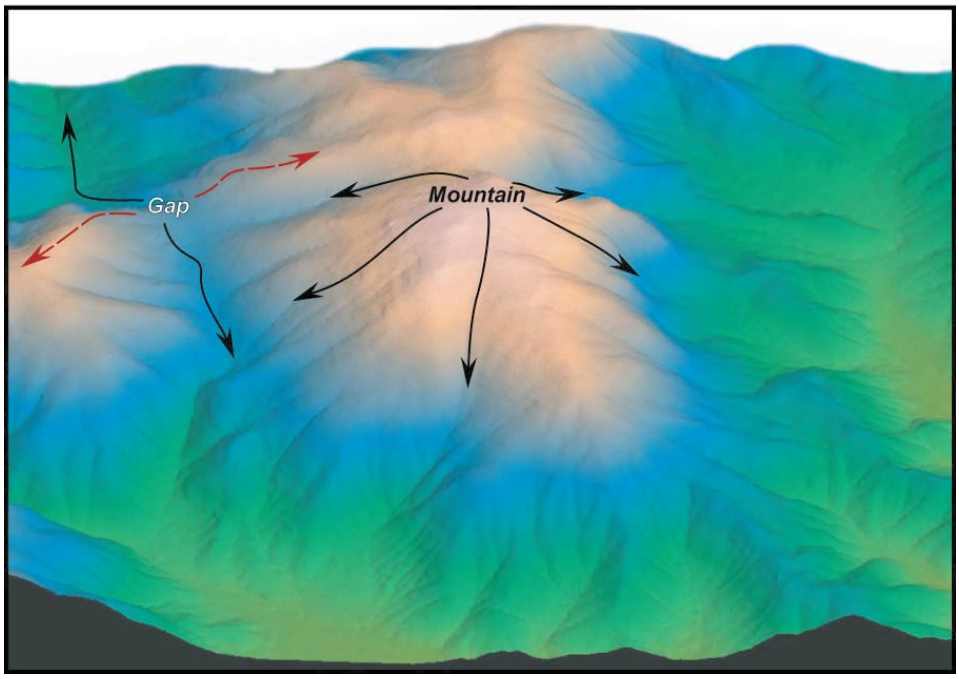
Yes, Virginia, there is now an Afton Mountain. But there shouldn't be! In 1997, the U.S. Board on Geographic Names was petitioned to name an "Afton Mountain". On September 10, 1998 the title Afton Mountain was officially applied to a summit located at 38˚ 01' 09" N and 78˚

53’ 02” W, approximately 1.5 miles to the southwest of Rockfish Gap and some 2.5 miles distant from Afton. The “Afton Mountain” high-point stands by the old water tank between the 13th and 16th holes on the Swannanoa Golf Course. If this highpoint must be named, a far better appellation would be Swannanoa Mountain, not Afton Mountain. Curiously, Interstate 64’s nearest approach to “Afton Mountain” is at Rockfish Gap and Virginia Route 6 (Afton Mountain Road) is never closer than 2 miles from the summit.

View of the summit of the recently named “Afton Mountain”.

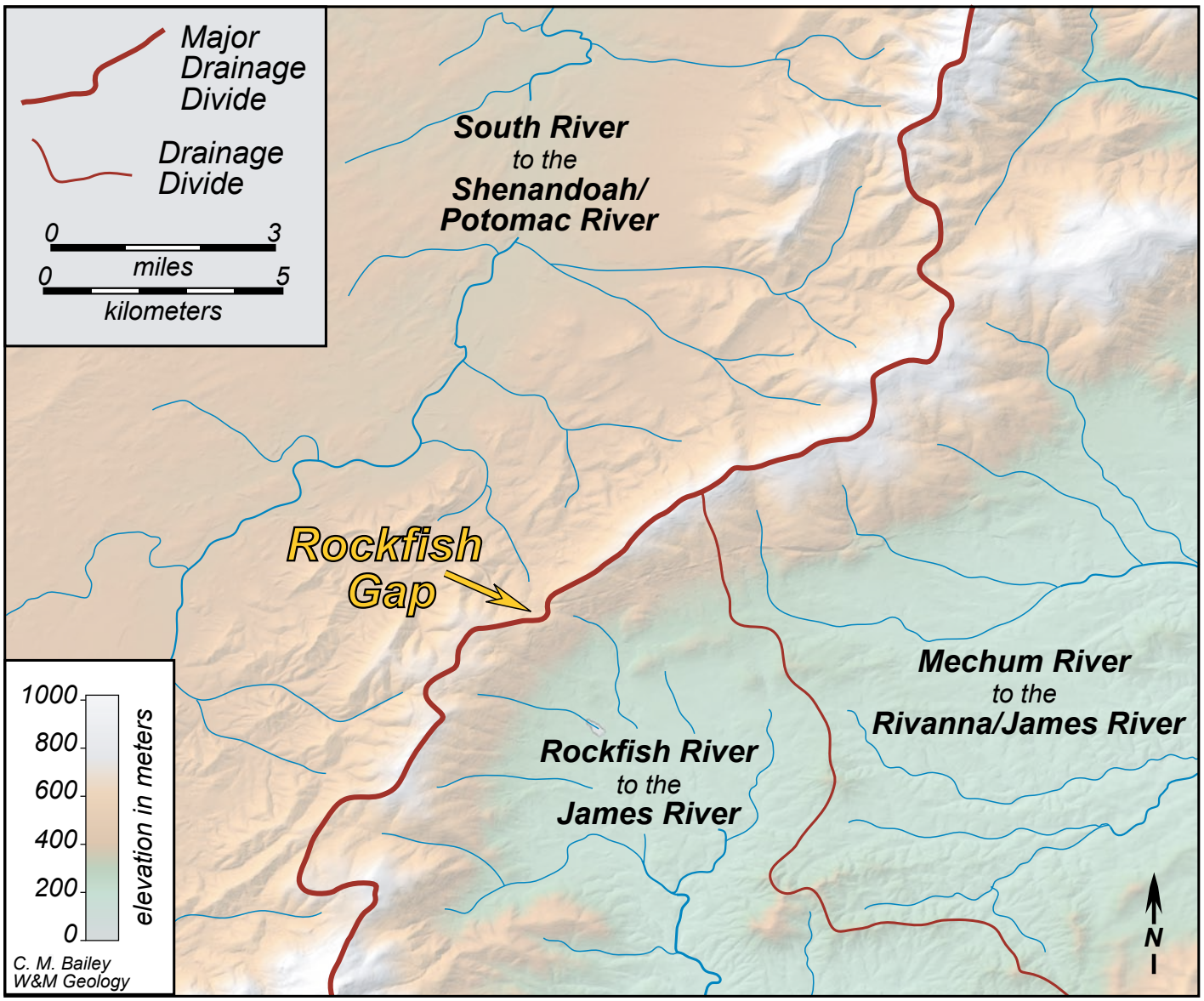
Mountains have a top (a summit), and from the top of a mountain, one descends in every direction. Gaps (also known as saddles, passes, notches, or cols in other parts of the world) are low points along the crests of mountain ranges. From a gap, one can descend in two directions and ascend (gain elevation) in two other directions. At Rockfish Gap the topography drops away to the east-southeast and the west-northwest, but rises to the southwest and northeast along the crest of the Blue Ridge. Our discussion about gaps versus mountains may seem like a point of trivia, best left to geographic savants and topologists, but to all things their proper name. And the proper name is **Rockfish Gap** not Afton Mountain.

Like it or not, the term “Afton Mountain” is promulgated in the official literature of the Virginia Commonwealth and even wineries and bed & breakfast’s are named for a non-existent mountain. That’s hard to beat! Will Afton Mountain be dropped from the popular lexicon? Unlikely, but it is worth a try. At the very least, let’s give Rockfish Gap its due status as a Virginia landmark of the first order.



A terrain model (view angle is above and oblique to the topography) illustrating that from a mountain top it is down in every direction, whereas from a gap there are two directions down and two directions up (red arrows).

From a geological perspective, Rockfish Gap is an interesting destination. It forms a notable point along the drainage divide between the Shenandoah-Potomac River system on the northwest and the Rockfish-James River system on the southeast. Consider a rainy day at Rockfish Gap. Rain that falls on the northwest side of the gap flows northwest into the South River, then to the South Fork of the Shenandoah, and eventually merges with the Potomac at Harpers Ferry where the river turns southeast finally emptying into the Chesapeake Bay off the Northern Neck. On the southeast side of the gap water flows into the Rockfish River and



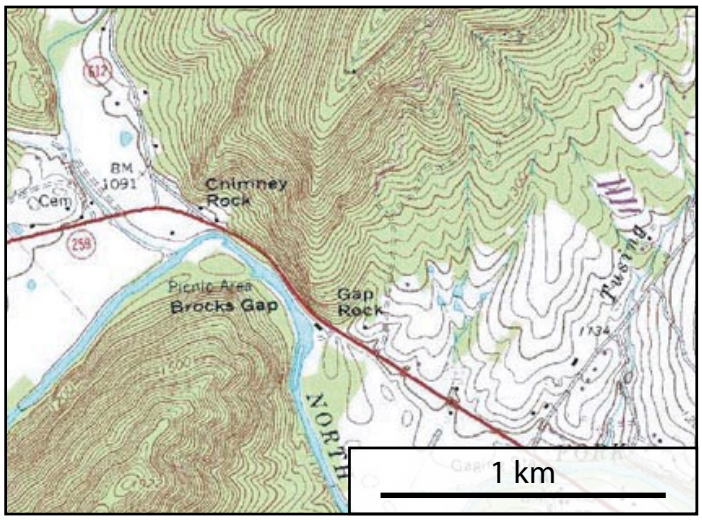
Shaded digital elevation model of the Rockfish Gap with drainage patterns and drainage divides.

then to the James where it reaches the Chesapeake Bay at Hampton Roads. From Rockfish Gap, water in the Shenandoah-Potomac drainage must journey over 300 miles (500 km) to reach the Atlantic, whereas water in the Rockfish-James system completes the journey in less than half that distance.

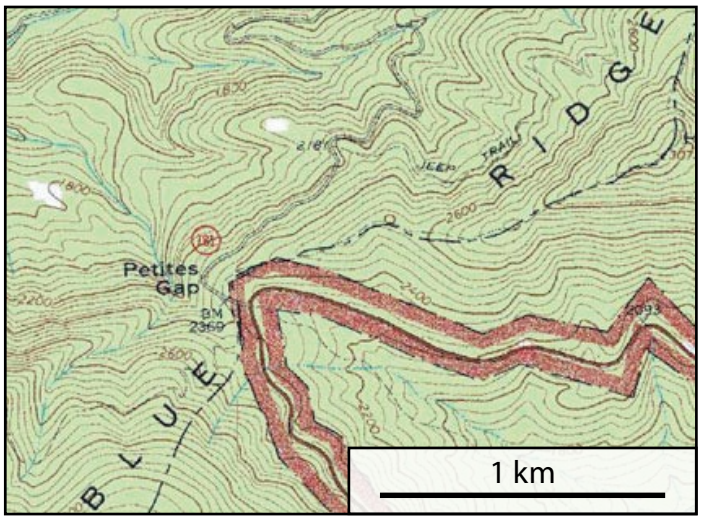
Gaps come in two flavors: water gaps and wind gaps. Rivers flow through water gaps (some Virginia examples include the James River Gap and Brocks Gap along the North Fork of the Shenandoah). Air, rather than water, flows (or blows) through wind gaps. Rockfish Gap is a classic wind gap. Wind gaps always occur astride a drainage divide. Delve into the geologic literature and you'll learn that wind gaps are thought to be former water gaps that have been abandoned due to stream piracy.

Is there any evidence that a river once flowed through Rockfish Gap? What river would have flowed through Rockfish Gap and how long ago would Rockfish Gap have been abandoned? The floor of the Shenandoah Valley is approximately 600 ft (180 m) lower than Rockfish Gap, and the Rockfish Valley is over a 1,000 ft (300 m) lower than the Gap; at the very least, 600 ft (180 m) of differential erosion would have occurred since abandonment.

Wind gaps can develop without stream piracy and the abandonment of a former water gap. Many Blue Ridge



Brocks Gap, a water gap, in the Valley & Ridge.

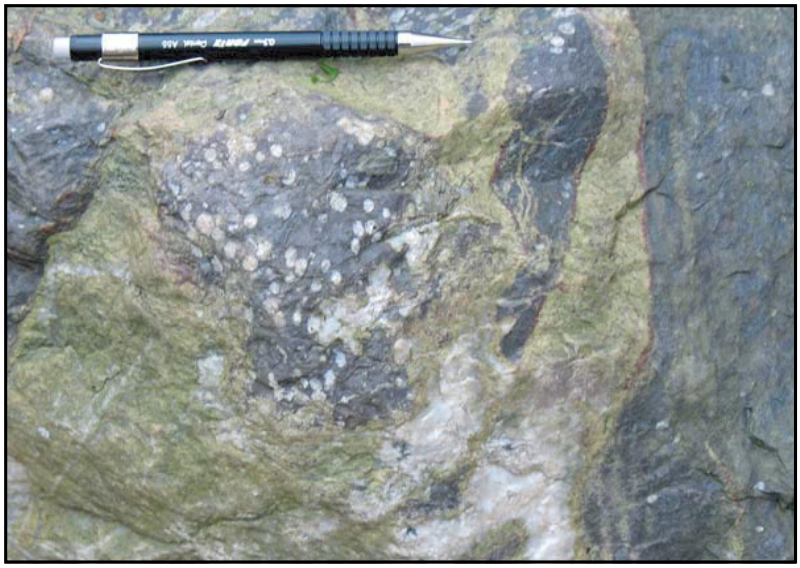


Petites Gap, a wind gap, in the Blue Ridge province.

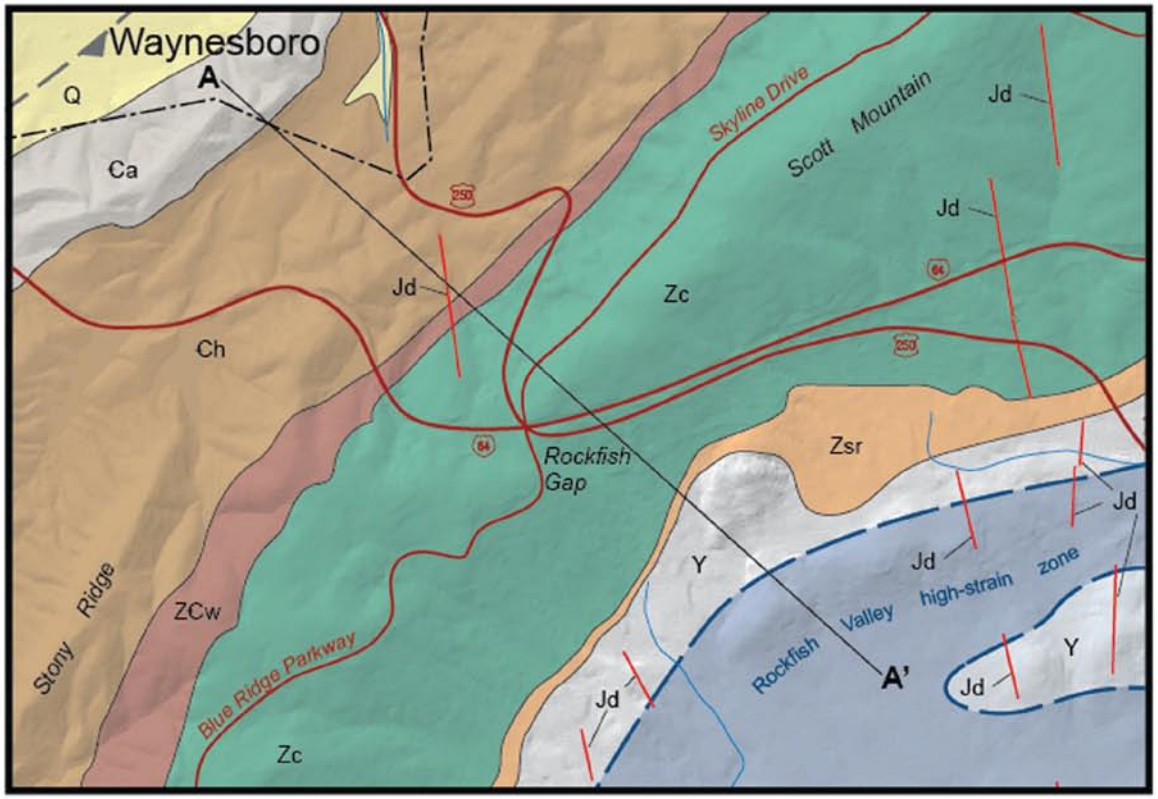
wind gaps are located along faults. Fractured and brecciated bedrock along fault zones is more erodable than less fractured bedrock away from fault zones. As erosional processes sculpt the Blue Ridge Mountains, the more easily eroded fault zones are lowered faster than their surroundings and develop into wind gaps. Although no major fault occurs at Rockfish Gap, it does lie astride a zone of localized north-northwest striking fractures.

Metamorphosed volcanic and sedimentary rocks of the Catoctin Formation underlie Rockfish Gap. Volcanic rocks in the Catoctin Formation were originally erupted as basaltic lava flows, and in the Rockfish Gap area, this unit is 1,500 to 3,000 feet thick (500 to 900 m). When was the Catoctin Formation erupted? In 1988, geologists determined the isotopic age of Catoctin samples collected from exposures along Interstate 64 approximately 2 miles (3 km) east of Rockfish Gap. They used the rubidium-strontium method and estimated that Catoctin lavas solidified 565 ± 30 million years ago. More recent isotopic studies of Catoctin samples from northern Virginia, Maryland, and southern Pennsylvania have refined the age of Catoctin volcanism to an interval between 560 and 575 million years ago.

During the late Paleozoic (~300 million years ago), eastern North America underwent an episode of tectonic collision and mountain building. During this interval, rocks in the



Top: Catoctin metabasalt/greenstone.
Bottom: Epidote and quartz vein in Catoctin greenstone.



GEOLOGIC UNITS

Mesoproterozoic | Neoproterozoic | Cambrian | Jurassic | Quat.

- **Q** — **Quaternary surficial deposits** - sand, gravel, and clay deposits associated with modern floodplains, ancient alluvial fans and terraces (0 to 100 m thick).
- **Jd** — **Jurassic dikes** - diabase.
- **Ca** — **Antietam Formation**- well-cemented quartz sandstone with *Skolithos* (~180 m thick).
- **Ch** — **Harpers Formation**- fine-grained sandstone, siltstone, sandy phyllite, ferruginous sandstone, and minor quartz sandstone (~700 m thick).
- **ZCw** — **Weverton Formation**- quartz sandstone, quartz pebble conglomerate, quartzose phyllite, and minor arkose (~200 m thick).

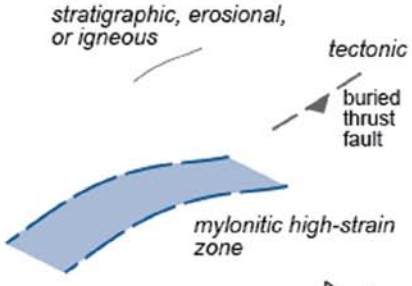
Chilhowee Group

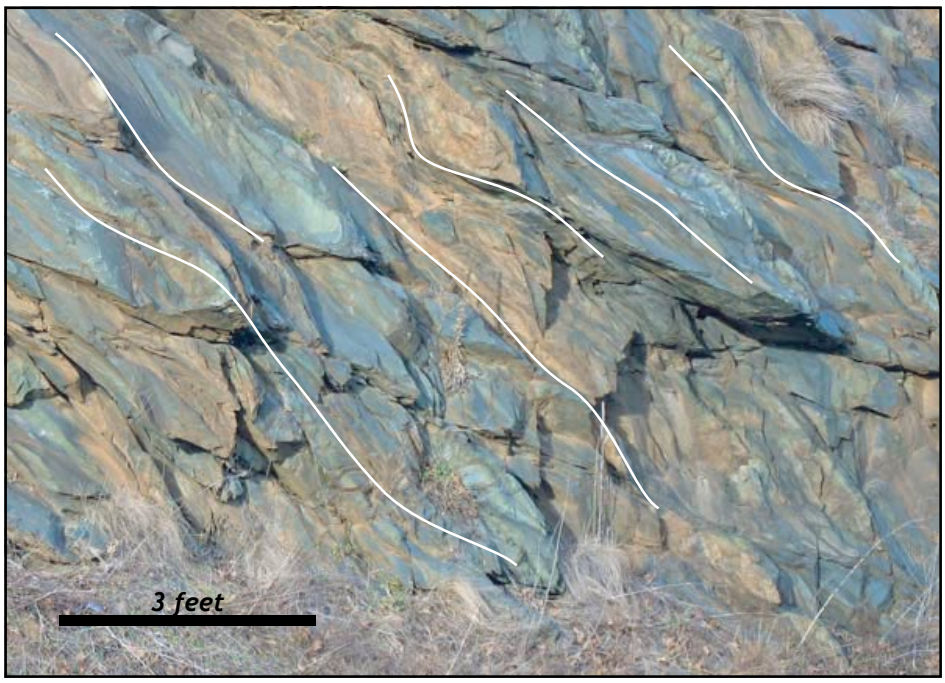
- **Zc** — **Catoctin Formation**- predominately metabasaltic greenstone with interlayers of meta-arkose and conglomerate, spotted phyllite, and epidote breccia (~1100 m thick). 570 - 550 Ma
- **Zsr** — **Swift Run Formation**- arkosic phyllite, phyllite, metasiltstone, meta-conglomerate, and minor metabasalt. Heterogeneous and discontinuous unit (0 - 40 m thick).
- **Y** — **Blue Ridge basement complex** *(undivided)*- granite, leucogranite, charnockite, granitoid gneiss and layered gneiss. 1180 - 1030 Ma

0 1 2 3 kilometers

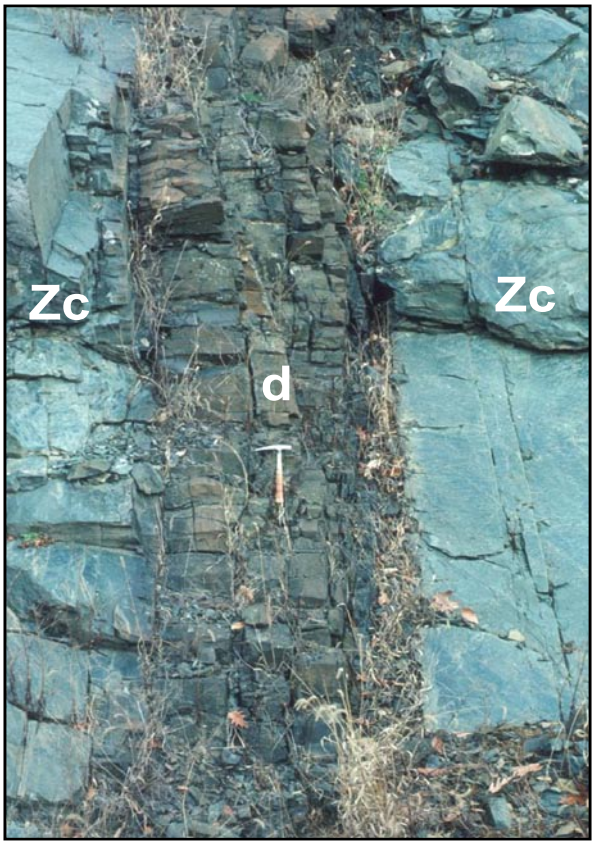
0 1 2 miles

GEOLOGIC CONTACTS & STRUCTURES





Foliated greenstone of the Catoctin Formation exposed on US 250 ~0.3 mi east of Rockfish Gap. White lines illustrate the trace of foliation, which dips to the southeast.



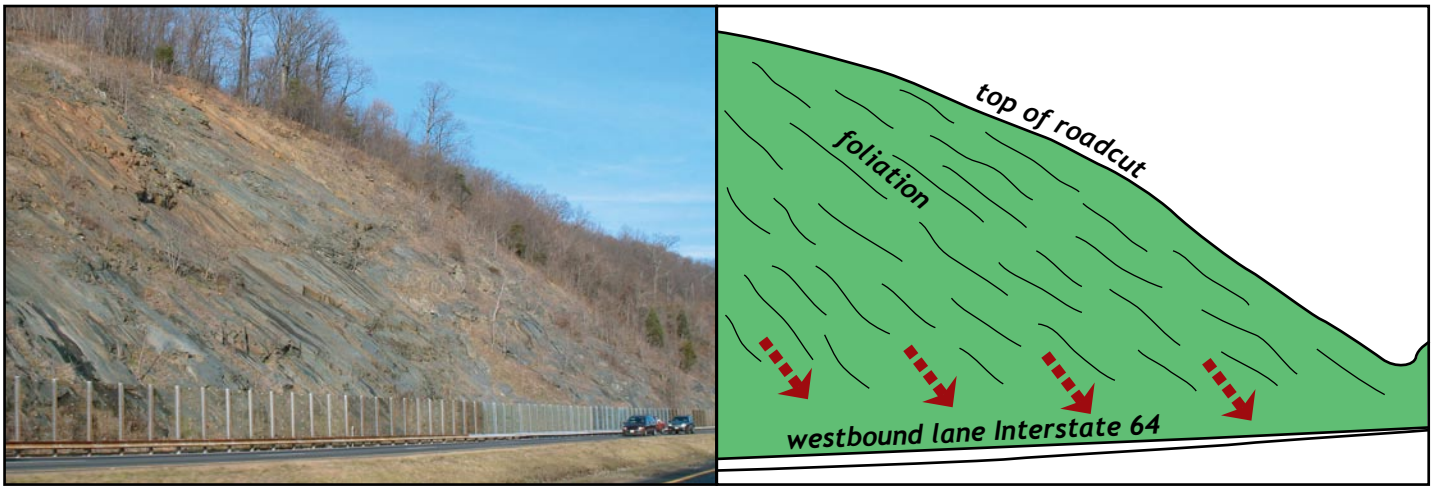
Diabase dike (d) cutting greenstone of the Catoctin Formation (Zc) in highway cut on the north side of I-64 ~1 mile east of Rockfish Gap. Hammer is ~1 foot in length.

Catoctin Formation were buried to depths of 6 to 10 miles (10 to 15 km), heated to temperatures of ~600˚ F (~300˚ C), and strongly deformed. These processes created new minerals such as epidote and chlorite and transformed the basalt into schistose greenstone. Greenstone is a fine-grained foliated metamorphic rock. Foliation is defined by the parallel arrangement of minerals within the rock. Whack a greenstone with a rock hammer and it will commonly break parallel to the foliation.

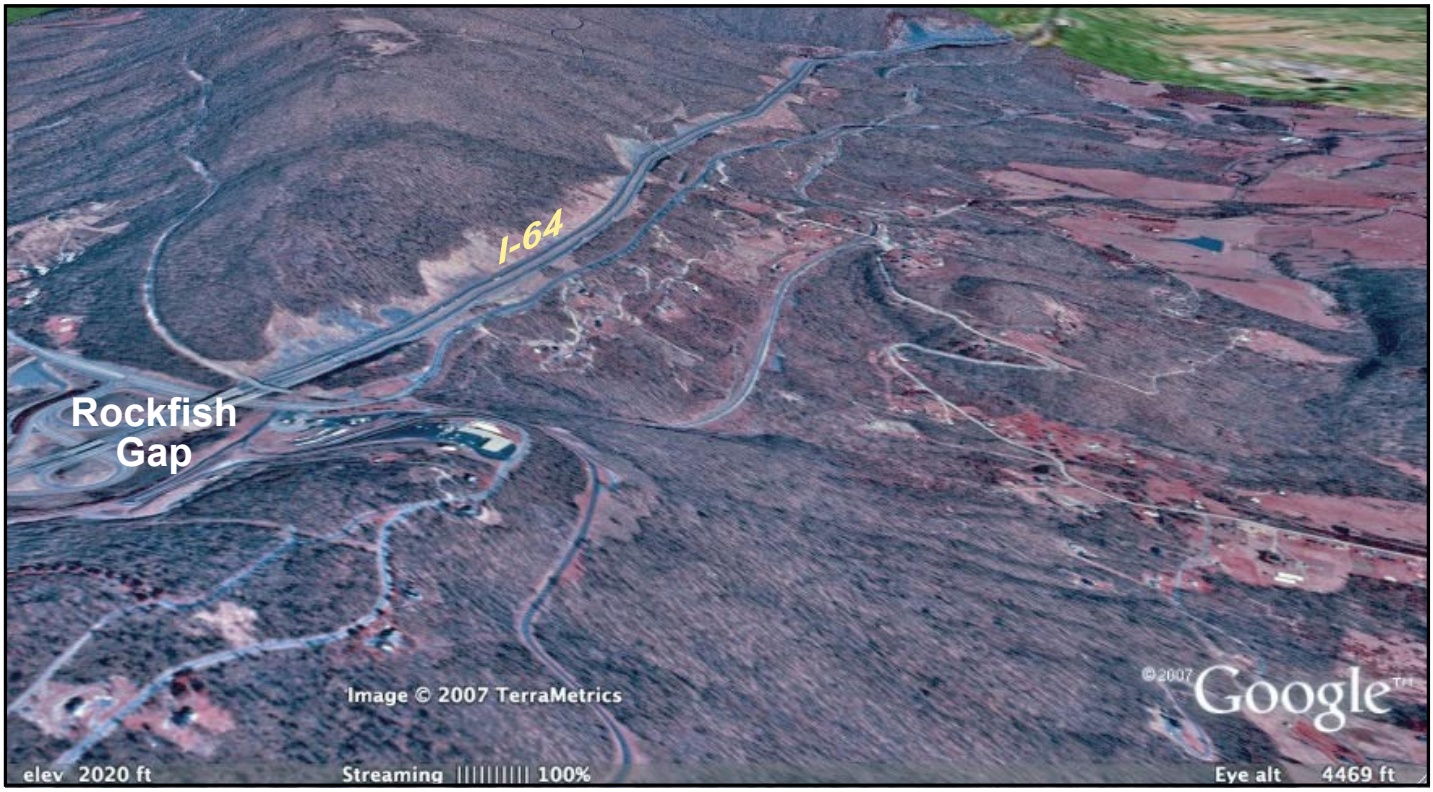
The western slopes of the Blue Ridge are underlain by a sequence of metamorphosed sedimentary rocks known as the Chilhowee Group. These rocks were originally deposited as gravel, sand, and mud during the early Cambrian period (525 to 545 million years ago). As with the Catoctin Formation these rocks were buried, metamorphosed, and folded during Appalachian mountain building in the late Paleozoic. Rusty-brown colored metamorphosed siltstone and sandstone of the Chilhowee Group is well exposed along Interstate 64 in the large looping road cut approximately 1 mile (2 km) west of Rockfish Gap.

A set of nearly vertical north-northwest striking diabase dikes intrude the older rocks in the Rockfish Gap area. A 6-foot (2 m) thick, fine-grained dike is well exposed along Interstate 64 approximately 2 miles (3 km) east of Rockfish Gap. Diabase is a medium- to fine-grained igneous rock with a chemical composition identical to basalt. Regionally, these diabase dikes show no evidence of metamorphism or ductile deformation and thus are interpreted to have formed after the late Paleozoic tectonic activity in the region. Although the diabase dikes have not been directly dated in the Rockfish Gap area, they are similar to a suite of intrusions in north-central Virginia that solidified between 195 and 200 million years ago during an episode of rifting that produced sets of north-northwest striking fractures and extended the crust in a east-west direction.

Road cuts along Interstate 64 near Rockfish Gap are



Southeast facing roadcut along Interstate 64, ~2 miles east of Rockfish Gap exposing foliated greenstone of the Catoctin Formation (Left). Foliation dips towards the road. Line drawing, red arrows indicate the dip direction of the foliation (Right). Google Earth virtual view to the east of Rockfish Gap and Interstate 64 (Below).



of monumental size. These are among the best exposures of the Catoctin Formation anywhere in Virginia. Roadcuts to the east of Rockfish Gap are prone to mass wasting and Interstate 64 has been closed multiple times over the years. Recall that from the east, Interstate 64 traverses the southern slopes of Scott Mountain (*no it's not Afton Mountain!*) on its climb to Rockfish Gap; the natural slope of the mountain is inclined between 10 to 20 degrees towards the south. To achieve the desired grade for the interstate, the highway cuts are inclined more steeply than the natural slope (~25 to 40 degrees to the south). Unfortunately, the foliation in the greenstone also dips to the south-southeast at angles between 20 and 50 degrees, such that along the steeper highway cuts, the foliation planes are generally angled towards the road. The orientation of the rock structures with relation to the highway cuts produces an unstable geometry and mass wasting is an inevitable consequence.

As rain percolates into the subsurface it preferential-

ly flows parallel to the foliation and through fractures in the greenstones, and as the water freezes and thaws, it may pry the rock apart causing slabs to move down slope towards the highway. This loose rock and the overlying soil may creep downward at velocities of an inch or two (2-5 cm) per day or vigorously slide down at rates of a few miles (5 km) per hour. VDOT has attempted to mediate the problem by constructing retaining walls and inserting drains into the slopes. In spite of these efforts, mass wasting along Interstate 64 is likely to be a persistent problem east of Rockfish Gap. The geology of the Blue Ridge has a direct bearing on human activities in the Rockfish Gap area.

Map of Field Stops at Rockfish Gap

Field Stops at Rockfish Gap:

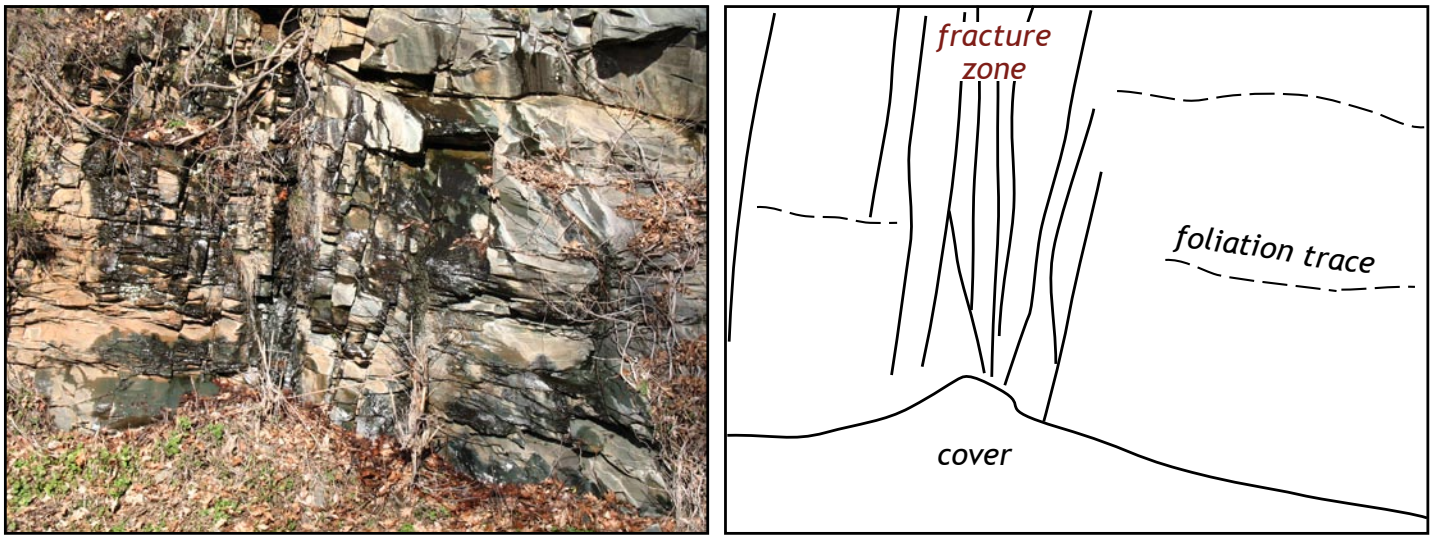
Find your way to Rockfish Gap at the junction of U.S. Rt. 250 and the southern entrance to the Skyline Drive/ northern terminus of the Blue Ridge Parkway

Proceed south along the Blue Ridge Parkway for ~0.2 mi to the first overlook (note- collecting, molesting, or hammering on rocks is not permitted along the Blue Ridge Parkway)

1. Afton Overlook on the Blue Ridge Parkway
38.0280˚N, 78.8576˚W

Our first stop offers us a wide view to the east and southeast. On the eastern horizon some 20 miles distant (32 km) is a low linear ridge, this is Southwestern Mountain in eastern Albemarle County and is underlain by a thick greenstone sequence of the Catoctin Formation. Catoctin greenstones also underlie the ground beneath us. The lower-relief hilly terrain between the Afton Overlook and Southwestern Mountain is underlain by granitic gneiss that formed over one billion years ago. We are standing on the western limb of the Blue Ridge anticlinorium and Southwestern Mountain forms the eastern limb of the structure. The Blue Ridge anticlinorium is a large regional-scale structure that extends from southern Pennsylvania southwest to nearly Roanoke. To the northeast, Interstate 64 is visible as it climbs obliquely up the south side of Scott Mountain towards Rockfish Gap. The town of Afton is approximately a mile to our east and 600 feet below us.

Walk to the southwest along the Blue Ridge Parkway for ~200 yards to the first roadcut on the northwest side of the road (38.0272˚N, 78.8597˚W). Greenstones are exposed in this roadcut, be careful during the summer months as this outcrop wears a thick arbor of poison ivy and Virginia creeper. The greenstone is foliated, but also contains fractures. The foliation, defined by the parallel arrangement of fine-grained minerals such as chlorite, actinolite, and epidote, dips approximately 35 degrees towards the road. There are at least two sets of fractures cutting these rocks. A prominent set of fractures strikes north-northwest and dips steeply, as you walk along the outcrop, notice that in some locations fractures are abundant whereas at other locations the fractures are widely spaced. Determining the age of fracturing is difficult; in the Rockfish Gap area there are



Outcrop photo and line tracing of exposure on northwest side of Blue Ridge Parkway, ~200 yards southwest of Afton Overlook. Note the unequal distribution of fractures, water commonly seeps from the fractures and foliation surfaces.

a set of north-northwest striking diabase dikes, these dikes formed ~200 million years old. In essence, we are using the orientation of the fractures as an indicator of when fracturing occurred. The logic is reasonable, but be mindful that we have not directly dated the age of fracturing. Regardless of when the fractures formed it is obvious that water drips from the fractures and the weathered spaces parallel to the foliation.

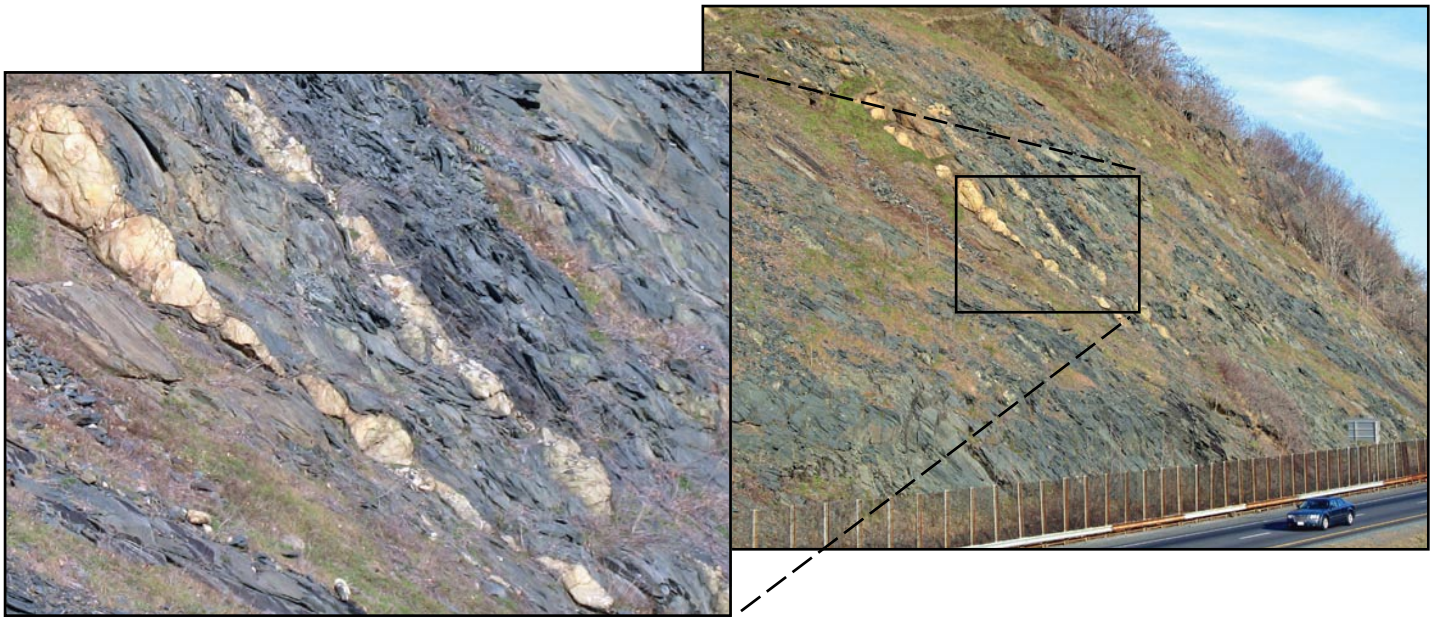
Turn around and proceed north along the Blue Ridge Parkway for ~0.1 mi, pull into the parking area on the right just before crossing over Interstate 64

2. Skyline Drive overpass above Interstate 64
38.0323˚N, 78.8587˚W

The sidewalk on the eastern side of the bridge is the best (and certainly the safest) place to view the highway cuts on the north side of Interstate 64. A cursory glance at the large roadcut reveals that the foliation in the Catoctin greenstone dips moderately downward towards the highway. High on the cut and in a somewhat lighter shade of green are lenses of epidote-rich metasandstone, originally these were layers of sediment deposited between the Catoctin lava flows. During deformation and metamorphism these layers of sandstone were somewhat stronger than the surrounding basaltic rocks and were stretched into boudins. Boudin, is the French word for blood sausage, but in the geologic lexicon it refers to tablet-shaped lenses (sausage-link shaped in two dimensions) of a relatively rigid rock that form as layers are stretched. Some sandstone lenses are completely isolated whereas others were never completely isolated. Rocks in the Catoctin Formation were tilted, folded, and elongated parallel to foliation during the tectonic event that formed the Appalachians in the late Paleozoic. Speculate on the time required for the boudins to form? A 100 years, a 1000 years, a million years, or more perhaps?

Given the geometry of the bedrock structures (a southeast dipping foliation that is angled towards the road) it is not difficult to understand why mass wasting is a persistent problem on Interstate 64 at Rockfish Gap and along the southeastern slopes of the Blue Ridge.

Recall Rockfish Gap is a wind gap, although from our vantage point you'll likely only hear the whistle of traffic hurtling through the gap at 70+ miles per hour. Was Rockfish Gap ever a water gap? Look around, is there any evidence that a stream once flowed through Rockfish Gap?



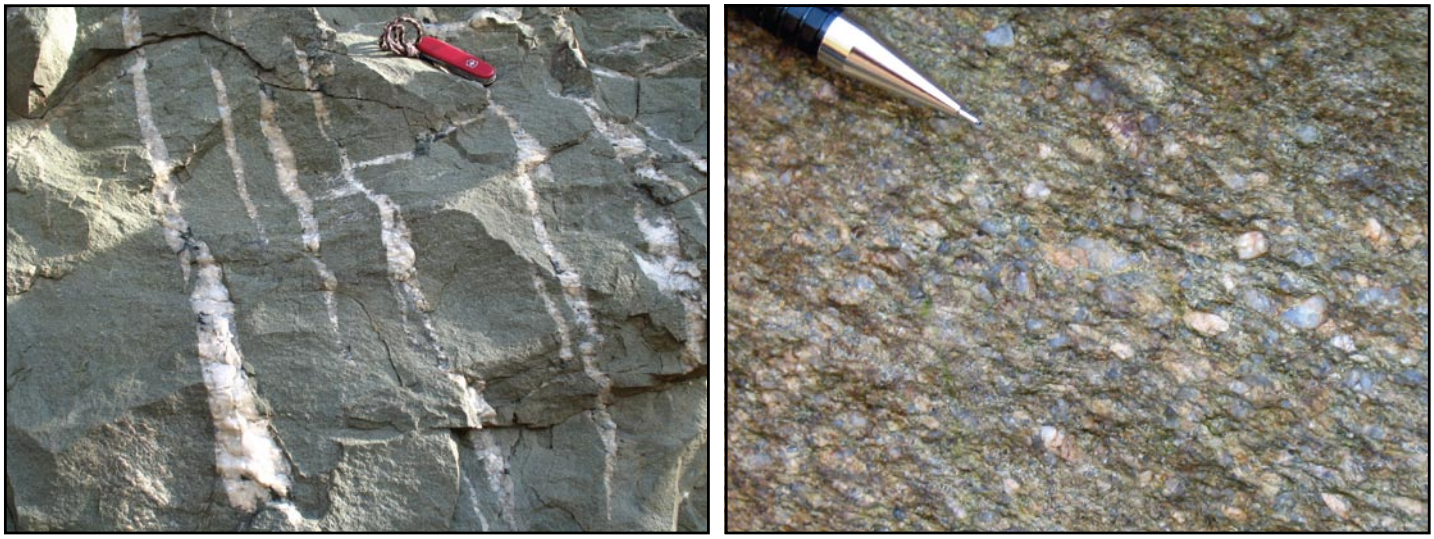
Outcrop photos of the highway cut immediately east of the Skyline Drive overpass. The westbound lane of Interstate 64 is visible. Note the foliation is angled towards the road and the lighter colored layers of boudinaged epidote-rich metasandstone.

Either walk to Stop 3 by walking down the slope to the west of the parking pullin and then proceed north along U.S. Rt. 250 under I-64 to exposures to the north Turn around and proceed north along the Blue Ridge Parkway for ~0.1 mi, pull into the parking area on the right just before crossing over Interstate 64 or drive by back tracking and turning West onto U.S. Rt. 250, pass under I-64 and park on the right shoulder prior to the traffic light.

3. Outcrops to the east of U.S. Rt. 250 and 50 to 100 yards north of the Interstate 64 bridge/overpass
38.0338˚N, 78.8596˚W

The northernmost outcrops expose foliated greenstone with pods of epidote, quartz, and jasper. Although too small to be discerned with a hand lens, there is enough magnetite in the greenstone to weakly attract a magnetic or deflect a compass needle. The foliation dips towards the east-southeast. Here on the northwest side of Rockfish Gap, the foliation is inclined back into the hillside (in contrast to the southern slope of the Blue Ridge). Walk south towards the Interstate 64 bridge and note the change in rock type. Although the Catoctin Formation is predominantly metamorphosed basalt, sedimentary layers do occur and at this locale metaconglomerate and metasandstone occur. The metasandstone is cross cut by an array of quartz filled veins. During deformation the metasandstone was fractured (while the greenstone deformed in a ductile fashion) and minerals such as quartz, chlorite, and epidote were precipitated into the opening cracks.

Closely examine the clasts in these metamorphosed sedimentary rocks. What materials were eroded, then transported, and finally deposited to form this rock? Could this material be derived from erosion of the Catoctin basalts or was there a different source for this sediment? The coarse clasts in the metaconglomerate are up to a quarter of an inch (6 mm) in diameter and include blue-gray quartz and white to pinkish feldspar. Catoctin basalts are almost completely lacking in primary quartz and feldspar, but the underlying granitic basement complex (today exposed at the base of the Blue Ridge to the east of Rockfish Gap) is rich in quartz and feldspar. Although these meta-sedimentary rocks are interlayered with metabasalts, during deposition of the original sediments, the granitic rocks must have still been exposed (not yet completely buried by lava flows) to have served as a source for the sediments.



Outcrop photos of quartz-filled fracture (veins) in metasandstone (left) and close up of quartz and feldspar clasts in the rock (right).

A basic geologic tenet is that older sedimentary layers occur at the bottom and are progressively overlain by younger layers above. Is that the case in these exposures? Look for evidence indicating the geological facing-direction; the direction in which the layers become younger. At this location the layering (bedding) dips towards the southeast; if these layers are "right-way up" then the layers would become older to the northwest. However, from the geologic map and cross section it is evident that younger rocks crop out to the northwest. These layers are "overturned", thus the structurally lower layers are actually younger than the structurally overlying layers. The tectonic forces at work to fold and ultimately overturn rock layers were immense.

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For a video concerning the geology of Rockfish Gap, check out:
http://web.wm.edu/geology/virginia/google_earth/video/rfgap.mov