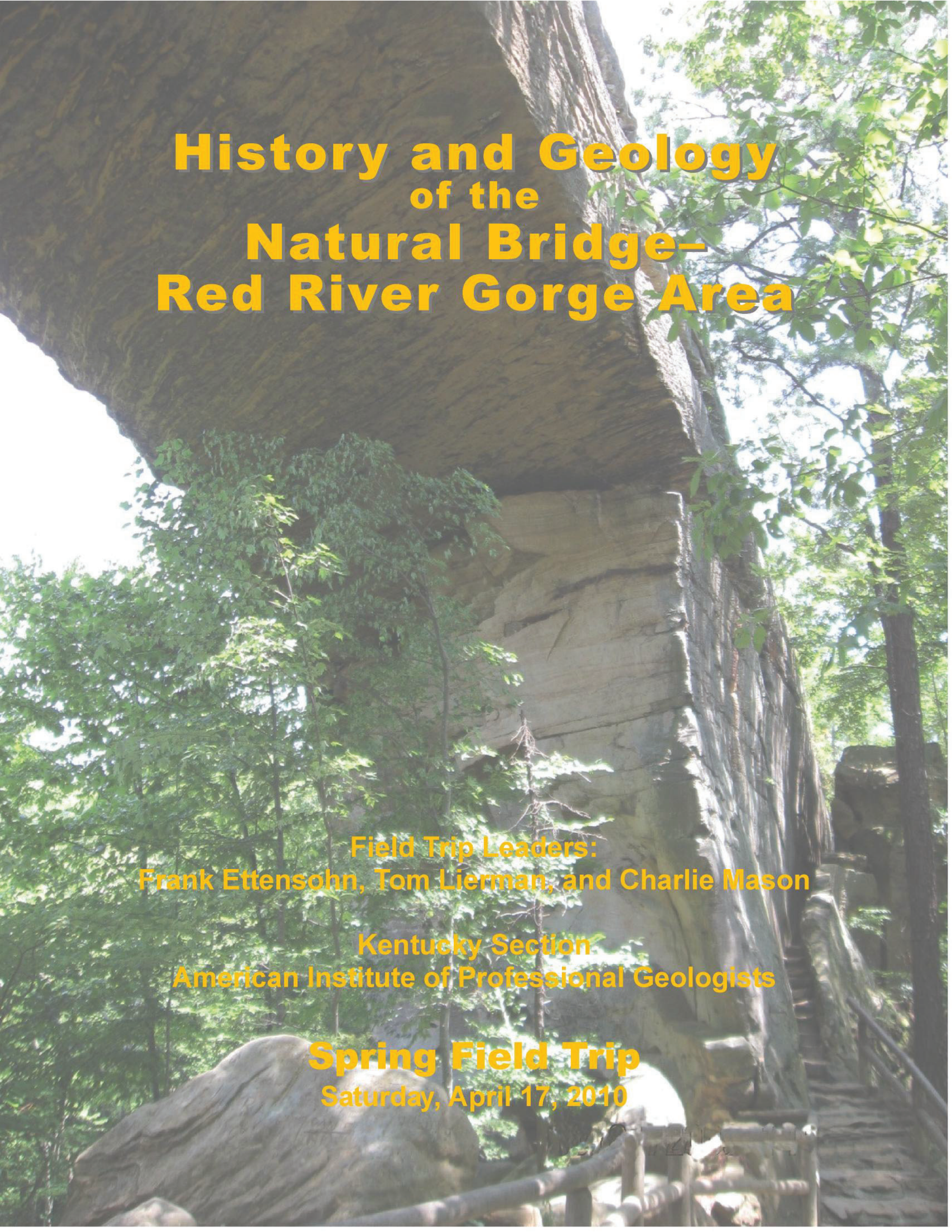

History and Geology of the Natural Bridge–Red River Gorge Area

Field Trip Leaders:
Frank Ettensohn, Tom Lierman, and Charlie Mason

Kentucky Section
American Institute of Professional Geologists

Spring Field Trip

Saturday, April 17, 2010

The Kentucky Section

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of the
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Kentucky Section
American Institute of Professional Geologists

Spring Field Trip

Saturday, April 17, 2010

Kentucky Section
American Institute of Professional Geologists
Lexington, KY

FIELD-TRIP ROUTE AND GUIDE

R.T. Lierman, F.R. Ettensohn, and C.E. Mason

Introduction

The State of Kentucky can boast of many historical and natural "wonders," and one of the best known is the Natural Bridge-Red River Gorge area. The geological community that forms the Kentucky Section of the American Institute of Professional Geologists (A.I.P.G.) thinks that it is not only important to enjoy these historical and natural areas, but also to understand something about the way they developed in Earth history. We believe that if more of our citizens understood just some of the basics about how the Earth functions, we would not be experiencing many of the current environmental problems that we hear about all too often. Realizing this, the Kentucky Section of A.I.P.G. continues to organize its annual spring field trip as a means of outreach to the local community and as a means of providing some understanding of the way the Earth functions by examining Kentucky's scenic, natural areas through the eyes of its geologists and historians. We believe that it is especially important to provide this information to our students and teachers so that they can disseminate it more widely.

The trip today involves examining features along the low valley of the Red River, or the Red River Gorge, as well as some of the high ridge-top arches, with a combined relief of more than 500 feet. This stark relief, for which the Gorge is famous, was probably incised by the Red River in as little as two million years and probably reflects the combination of resistant Pennsylvanian sandstones at the ridge tops with a drop in sea level during relatively recent glaciations. On the trip we will discuss additional manifestations of these processes, and at all times we encourage your questions and comments. Have a good time and let's enjoy learning from each other!

Natural Bridge State Resort Park

Natural Bridge State Resort Park is situated along the Middle Fork of the Red River in Powell and Wolfe Counties, along Kentucky State Highway 11. The park is surrounded by the Daniel Boone National Forest and is located just to the southeast of the Red River Gorge Geological Area. Natural Bridge State Resort Park derives its name from a large natural sandstone arch that is found within its boundaries. It was established as a State Park in 1926 and is one of 52 parks in the Kentucky State Park system. Natural Bridge State Park covers an area of 2,369 acres (approximately 3.7 square miles) and boasts over 20 miles of hiking trails. In 1981 the Kentucky Nature Preserves Commission set aside 1,188 acres within the park as a nature preserve. Kentucky's nature preserves system was designed to protect the ecological communities and rare species habitats.

History

In 1889 the Kentucky Union Railway established a rail line through the town of Slade to connect existing lines with the extensive timber resources in the area. Railroad executives recognized the natural beauty of the area and saw that the great sandstone arch had potential value as a commercial development that could attract visitors to the area. The railway acquired the land around Natural Bridge, and began to build trails and campgrounds. Eventually a private park was founded in 1896 as a tourist attraction. The Louisville Nashville Railroad later acquired the title to the property and in 1926 donated the lands around Natural Bridge to the newly formed state park system. In this way Natural Bridge became one of the four original state parks in Kentucky.

The main feature within the park, and the park's name sake, is a spectacular sandstone arch called Natural Bridge. This arch has an estimated weight of some 900 tons, spans a distance of 78 feet, is 65-feet high, 12-feet thick, and 20-feet wide. Many geologists have estimated this natural sandstone arch to be at least a million years old. There are other natural archways in the area, but none have gained the prominence of Natural Bridge.

In addition to Natural Bridge, there are a number of other unique geologic features within the park. One called "Balanced Rock' is a large pedestal rock — an isolated, rock body that has weathered in such a way that its upper portion is supported or balanced on a narrow pedestal. This is one of the biggest and most perfectly formed examples of a pedestal rock east of the Rocky Mountains. Other impressive feature includes the massive sandstone cliffs of Battleship Rock and Laurel Ridge, the Needles Eye, and Devils Gulch.

Natural Bridge State Resort Park
2135 Natural Bridge Road
Slade, KY 40376-9701
Phone: (606) 663-2214
Toll Free: (800) 325-1710
Web site: http://parks.ky.gov/findparks/resortparks/nb/

Red River Gorge Geological Area

The Red River Gorge is located in the Slade and Pomeroyton 7.5-minute quadrangles, in Powell, Menifee, and Wolf Counties (Weir, 1974; Weir and Richards, 1974) and is situated within the Daniel Boone National Forest in east-central Kentucky along State Highways 77 and 715 (Fig. 1). Physiographically, the Gorge is lies along the western margin of the Cumberland Plateau (a physiographic region that extends from Pennsylvania to Alabama). The eastern edge of the Cumberland Plateau is called the Pottsville Escarpment. The Red River Gorge is lies along this escarpment and was formed when the Red River cut through resistant Pennsylvanian-age (approximately 310 million years old) sandstones and conglomerates known as the Corbin Sandstone. It is the manner in which these sandstones weather and erode along the Pottsville Escarpment that results in sheer cliffs, the steep-walled gorges, rock shelters, waterfalls, natural bridges and arches that this area is so famous for. In fact, the Red River Gorge has the highest concentration of arches and rock shelters anywhere east of the Colorado Rockies (the U.S. Forest Service has been able to document nearly one-hundred fifty (150) natural bridges and arches in the area). The gorge also contains a number of sites of historic and archaeological importance. In addition, the area contains an estimated 500 miles of trails through rugged sandstone cliffs and exposed limestone rock faces. Popular activities in the region include hiking, camping, horseback riding, bicycling, rock climbing and rappelling, spelunking, kayaking and canoeing, bird watching, photography, nature studies, and much more. This area is noted for its magnificent scenery, unique geologic features, and diverse vegetation. So unique is this region that the U.S. Congress and other federal agencies have set aside certain areas within the gorge as worthy of special consideration. These include:

- **Red River Gorge Geological Area:** Containing over 29,000 acres and established in 1974.
- **National Natural Landmark**: Designated by the National Park Service in 1976.
- **Clifty Wilderness:** In 1985, U.S. Congress approved 12,646 acres as a National Wilderness Area. The area has been set aside for the preservation of wilderness values and experiences and overlaps with the eastern part of the Red River Gorge Geologic Area.
- **National Wild and Scenic River:** On December 2, 1993, the U.S. Congress designated a 9.1-mile stretch of the Red River as a National Wild and Scenic River, making it the first in Kentucky. Most of the designated portion flows through the Clifty Wilderness and the Red River Gorge Geological Area.
- **National Scenic Byway:** The Federal Highway Administration adopted 46 miles in and around the Red River Gorge as a National Scenic Byway in 2002.
- **National Archaeological District:** In 2003, the National Park Service named 37,000 acres in and around the Red River Gorge as a National Archaeological District and listed it on the National Register of Historic Places.

The Red River Gorge supports an unusual variety of plant and animal life. This diversity can be attributed to its geographic location, topography, and geologic history of the area. The unique conditions found in the gorge, conditions ranging from stream bottoms to the sides and tops of ridges, has allowed for the development of a number of different ecosystems. For this reason a wide variety of trees populate the area including: beeches, tulip poplars, birches, yellow buckeye, magnolias, sycamores, sugar maples, white pines, hemlock, various species of oak, and hickory, along with thickets of rhododendron and laurels. These trees provide the necessary habitat for an estimated 67 different species of reptiles and amphibians, 46 species of mammals, and over 100 species of birds. More than 23 of these species are listed as endangered, threatened, sensitive or rare species. The U.S Forest Service, along with other agencies and individuals, has been working to protect these unique species along with their habitats.

A rare opportunity also exists for the protection and scientific study of many cultural resources in the area. Archaeological studies are providing insight into the lives of the prehistoric people who lived in the gorge area. In the 1800's, the Red River Gorge area was also an important mining area for iron ore; saltpeter (potassium nitrate), used in the manufacture of gunpowder up through the Civil War; and timber. Nearly all of the virgin timber within the Gorge has been logged. This unfettered harvesting of timber was pushed even further by the introduction of the railroads in the mid and late 1800s. The railroads did eventually provide the area with the first truly permanent industry, "tourism." Starting around 1900 until 1939, excursion trains from Lexington, Cincinnati and Louisville brought tourists to what is now Natural Bridge State Resort Park.

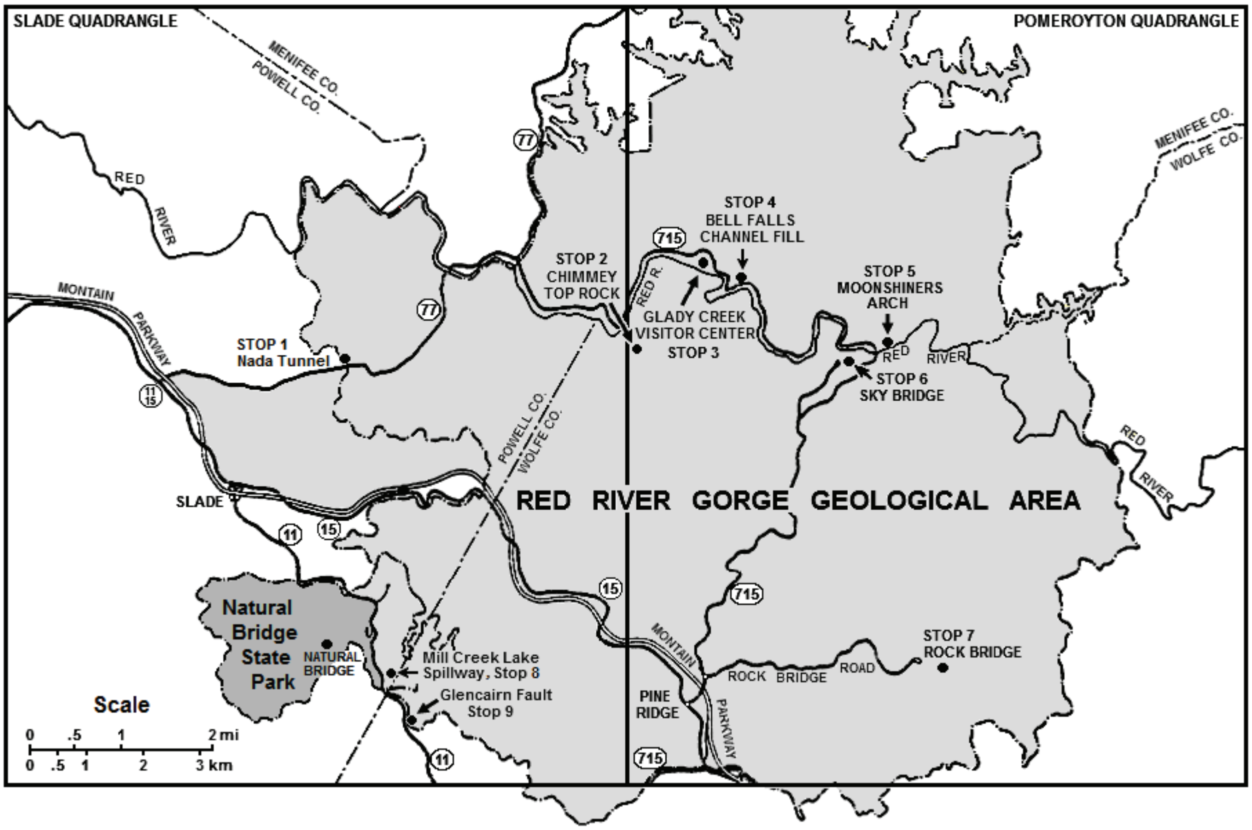

Fig. 1. Map of the Red River Gorge Geological Area and Natural Bridge State Park, showing field-trip stops and main roads.

Our trip will begin from the parking lot at Hemlock Lodge, Natural Bridge State Resort Park. We leave promptly at 8:30 a.m.

1. From the parking lot proceed down the Hemlock Lodge road to State Highway 11.
2. Turn left onto State Highway 11 and proceed north to Slade, Kentucky.
3. Continue north through Slade under the Bert T. Combs Mtn. Parkway to the intersection of Kentucky State Highways 11 and 15.
4. Turn left (west) onto State Highways 11/15 and continue approximately 1.5 miles to the junction of State Highways 11/15 and 77.
5. Turn right (north) onto State Highway 77, continue 2 miles to **Stop 1**, **The Nada Tunnel.**

Stop 1
The Nada Tunnel (Lat.: 37°49’01” N; Long.: 83°40’53”W)

One interesting way to enter the Red River Gorge is through the 900-foot Nada Tunnel, located along KY State Route 77 (Fig. 2). Open to one-lane traffic only, the Nada Tunnel takes us directly under the aptly named Tunnel Ridge. It was originally built by a local logging company so they could haul timber out of the Red River Gorge by rail and is listed on the National Register of Historic Places.

Many see the Nada Tunnel as the “entrance” or “gateway” to Red River Gorge. The tunnel which measures 12-ft wide, 12-ft high, and 900-ft long, was originally constructed to haul logs via a narrow gauge railroad from timber operations in the Gorge. Construction of the tunnel began in December of 1910 and was finally completed by September 1911. The tunnel was excavated using picks and shovels, steam drills and dynamite. Only one worker was killed during construction of the tunnel when he attempted to thaw some frozen dynamite next to an open fire, with predictable results.

The Nada Tunnel and the nearby community of Nada were named after the Dana Lumber Company *(just transpose the d and the N).* In the early 1900s, a logging company built the tunnel so they could haul timber out of the Red River Gorge by rail. The railroad carried logs some 15 miles to a mill at Clay City which at the time was the largest sawmill operating in the eastern U.S. Trains loaded with logs began moving through the tunnel in 1912. Typically they would use 25-ton or 35-ton Climax locomotives to haul logs through the tunnel. The first load of logs actually became wedged in the tunnel and had to be dynamited free. The tunnel was later enlarged to accommodate the large logs that were coming out of the area.

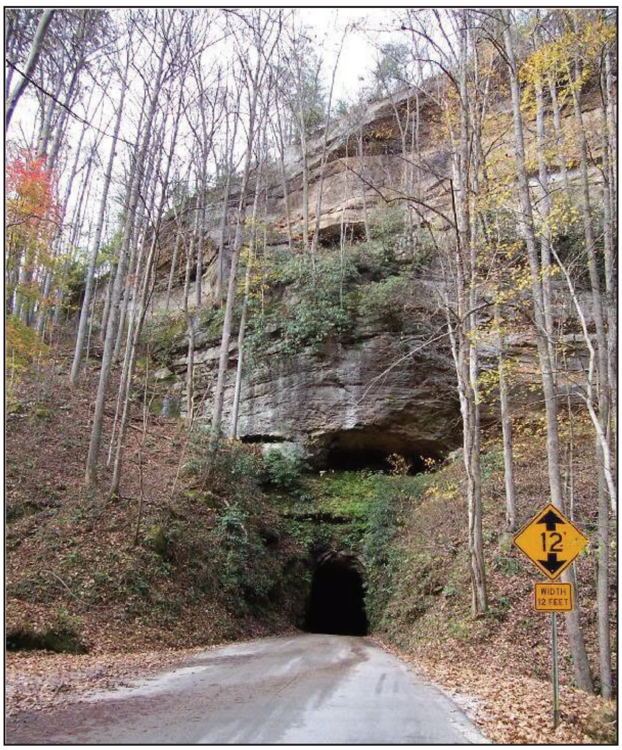

Fig. 2. East-facing view of the Nada Tunnel.

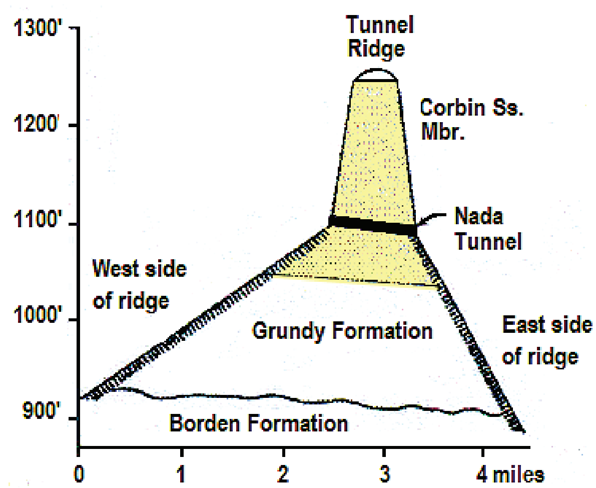

Fig. 3. East-West cross-section across Tunnel Ridge (adapted from Chesnut, 2001).

The tunnel itself is cut into the lower half of the Corbin Sandstone Member of the Grundy Formation (Chestnut, 2001) (Fig. 3). The sandstone cliffs on either side of the tunnel stand between 60- and 80-ft high. Several features are quite noticeable in these cliffs and include such things as **cross-bedding**, conglomeratic lenses and lags, and **liesegang banding**. Cross-beds are one of the more noticeable features in the cliff faces. Paleocurrent measurements on these cross-beds indicate a general flow direction to the west and northwest for the streams responsible for depositing these sandstones and conglomerates (Rice, 1984).

On the north side of the tunnel one can see a **rock shelter** or **reentran**t (overhang exposed along the road). These shelters served as resting and camping sites for early American Indians (hunter/gatherers) who where passing through the area. Many of these overhangs and rock shelters help keep rainwater off the soils which form along the base of cliffs and in the rock shelters. These dry, nitrate-rich soils allow for excellent preservation of normally perishable artifacts. Archeologists have uncovered numerous artifacts, including seeds, which indicate that Native Americans were cultivating wild plants in the gorge as long ago as 3000 years. Unfortunately this rich archeological heritage is one of the reasons why many of the shelters have been pillaged and vandalized over the years. In an effort to protect these areas from further destruction, the National Park Service designated 37,000 acres in and around the Red River Gorge as a National Archaeological District and listed it on the National Register of Historic Places.

6. Get back into the vehicles and continue through the tunnel. Make sure to turn your lights on and watch for any oncoming traffic.

7. Take State Highway 77 north from the tunnel. Just after Highway 77 crosses the Red River, turn right onto State Highway 715 (Sky Bridge Road). Continue on Highway 715 and follow the signs to Gladie Learning Center.

8.

Stop 2

Chimney Top Rock (Lat.: 37°49'21"N; Long.: 83°37'20"W; Peak Elevation: 1,155 feet [352.04 m])

Approximately 1.8-1.9-miles east of the junction of Kentucky State Highways 77 and 715 (before reaching the Gladie Learning Center), turn your attention to the right and look across the Red River. Along the ridgeline you will see one of the most visited features in the Gorge, a spectacular structure called **Chimney Top Rock**. Chimney Top is a sandstone rock formation which resembles a large chimney (Fig. 4). It raises some 500-feet above the valley floor so the view from its summit is truly spectacular. Chimney Top occurs along a cliff that developed within the Corbin Sandstone Member of the Grundy Formation. The cliff itself is between 150- and 200-ft high. Chimney Top Rock is isolated by a deep **joint** or **fracture** that separates the rock mass from the main ridge to the east, forming a "chimney-like" feature (Fig. 4). This joint has apparently been enlarged and expanded by the freezing and thawing water in the joint and by water running down and along the joint surface.

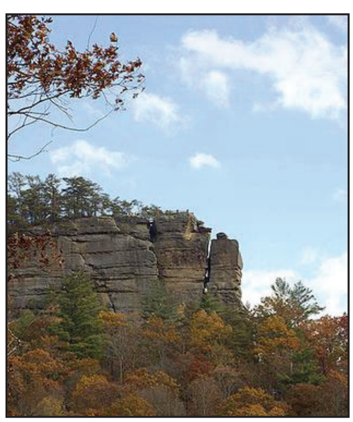

Fig. 4. Southeast-facing view of Chimney Top Rock from Kentucky State Highway 715.

9. Continue traveling east along State Highway 715 until you reach the parking area for (about 3.6-miles away from the Nada Tunnel) the **Gladie Learning Center, Stop 3**.

Stop 3
Gladie Cultural - Environmental Learning Center (Lat.: 37°50'07"N; Long.: 83°36'32"W)

The center contains an informative combination of exhibits and displays on the geology, geography, archeology, and cultural heritage of the Red River Gorge area. Visitors may purchase maps, passes, books, and souvenirs at the center. It is open from spring through the fall.

Gladie Learning Center
Hours: 7 days/week 9:00 a.m. - 5:30 p.m.
Address: 3451 Sky Bridge Road
Stanton, KY 40380
Phone: 606-663-8100
Website: http://www.fs.fed.us/r8/boone/districts/cumberland/gladie.shtml

10. Get back into your vehicles and turn right onto State Highway 715.
11. Travel about ¾ of a mile and pull off to either side of the road as best you can. There is a small roadcut and stream valley (Bell Branch) on the left hand side of the road, **Stop 4**, **Bell Falls Channel Fill.**

Stop 4
Bell Falls Channel Fill, Mississippian-Pennsylvanian Unconformity (Lat.: 37°49'52" N; Long.: 83°36'08" W)

The roadcut along the highway and back toward Bell Falls consists of a **conglomerate** containing abundant chert clasts (derived from the Slade Formation), rock clasts (from the Borden Formation) quartz pebbles, sand, along with scattered casts or impressions of logs. The conglomerate is part of a Pennsylvanian sandstone body, more that 100 ft (30 m) thick in the lower portion of the Grundy Formation (Weir and Richards, 1974). It fills a **channel** cut deep into the siltstones of the Cowbell Member of the Borden Formation (middle Mississippian) which is exposed along the highway and along the base of the falls. The Paragon Formation, the Slade Formation and the Nada Member of the Borden Formation have all been removed by erosion prior to deposition of Pennsylvanian sediments. So the surface separating the Pennsylvanian conglomerate and sandstone from underlying Mississippian Cowbell siltstones is an **unconformity**, which represents about 40 million years of missing time reflected in the missing rock units. Remnants of these missing units can be found as clasts within this conglomerate. A radioactivity profile of the lower rock section in the branch shows that the bases of the respective channels are very radioactive (Fig. 5). The radioactivity probably reflects the concentration of uranium salts from ground water by organic matter in the channel bottoms as water percolated through the sandstone. This deeply incised channel was part of a southeast-draining **paleovalley** that has been postulated by Rice (1984, pg. G 41-G49). This paleovalley was part of a large, meandering, Ganges-type river system that drained the western margin of the rising Alleghany Mountains approximately 300 million years ago. These ancient mountains (the remains are reflected in the current Appalachian Mountains) resulted from the collision of the African parts of Gondwana with North America.

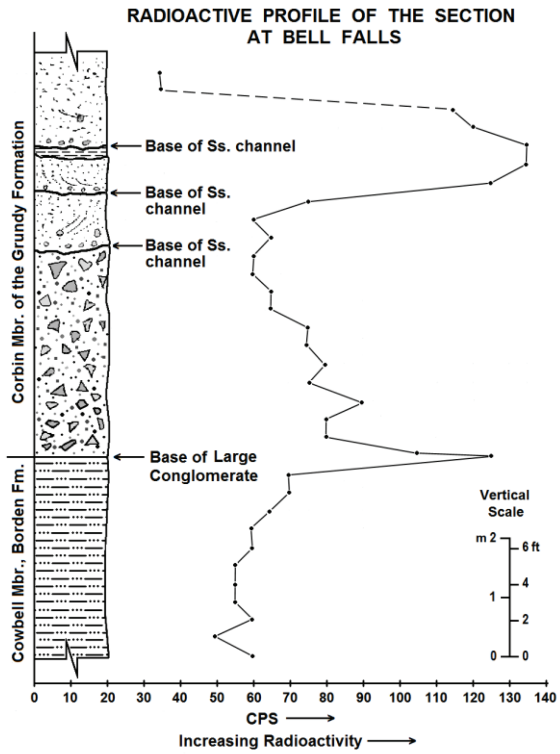

Fig. 5. Radioactivity profile from the Mississippian-Pennsylvanian section at Bell Falls. The Pennsylvanian Corbin Member sits unconformably on the Mississippian Cowbell member. About 40 million years of time and stratigraphic units are missing along the surface at the base of the large conglomerate.

12. Get back into your vehicles and turn onto State Highway 715 and continue traveling east.
13. Take Highway 715 for approximately 2.2 miles, and pull off on your left into a small parking area at the north side of the bridge. The stream to the right side is the Red River. Climb down the banks to the trail you see leading upstream. Follow this trail for about ½ mile. The left side of the trail will open up to a grassy, marshy area with a trail leading off through it. Follow this train and almost immediately, you come to **Stop 5**, **Moonshiners Arch.**

Stop 5
Moonshiners Arch (Lat.: 37°49’15” N; Long.: 83°34’30” W)

Moonshiner's gets name from moonshiners who used the arch to distill their "White Lightning." There is a hole in the top of the arch, which acted as a flue for the wood fires. Moonshiners Arch is a limestone arch that has developed in the Upper Mississippian Slade Formation. It was formed by collapse of the roof in a cave passage that was exposed by erosion. The cave has its floor in the Mill Knob Member and is in turn covered by the Tygarts Creek Member of the Slade Formation. The arch was formerly part of a **karstic** underground drainage system that flowed southward toward the Red River. The underground drainage system is still active but now drains into the river through the underlying Renfro Member (a dolostone). Talus-covered springs can be seen flowing from dolostones in the Renfro a short distance upstream from Moonshiners Arch. These springs are exposed along the footpath at the mouth of an actively draining cave.

Fig. 6. Stop 6, Moonshiners Arch.

14. Get back into your vehicles and turn onto State Highway 715 and continue.
15. We cross the Red River at the concrete bridge, take a wide turn to the right and proceed uphill along State Highway 715, Sky Bridge Road. At the top of the ridge (approximately 1.2 miles) turn right onto Forest Service Road 214 this will take you to Sky Bridge. Proceed another three quarters of mile to the parking area for **Sky Bridge, Stop 6** and lunch. Sky Bridge is approximately 400 feet from the end of the parking lot. The trail around Sky Bridge is about 1-mile long and goes over and below the arch. The trail leads directly out across the top of the bridge, which is bounded on both sides by sheer drop-offs of over 30 feet or more, it is unprotected by railings. EXERCISE CAUTION WHEN CROSSTNG; PLEASE DO NOT APPROACH THE EDGE TOO CLOSELY!

Stop 6
Sky Bridge (Lat.: 37°49'07" N; Long.: 83°34’48” W)

One of the most frequently visited sites in Red River Gorge is Sky Bridge. Sky Bridge is a ridge-top arch developed in the upper parts of the Corbin Member of the Grundy Formation. It is impressive in both its size and the distance of its span. It has two connected openings: the first is 9-ft long by 6-ft high; a second larger opening is 73-ft by 23-ft high. Sky Bridge is developed in the Middle Pennsylvanian, Corbin Sandstone Member of the Grundy Formation (Chesnut, 1992; Dever and Barron, 1986). Here the Corbin Member is a quartz-rich sandstone that is fine to medium grained and which typically weathers to a grayish-orange color. It contains easily recognized cross-beds which dip to the southwest. The Corbin also contains numerous conglomeratic layers and lags that contain quartz pebbles up to a half-inch diameter. Features present at this outcrop include: **cross-bedding**, **liesegang banding**, both **honeycomb and boxwork structures**, joints, and the casts or impressions of ancient logs. There is also a rock shelter or reentrant present on the trail leading back to the parking area.

The orientation and shape of Sky Bridge appears to be controlled by the presence of a set of vertical fractures called joints that are visible from the base and top of the arch (Fig. 7a). If you look at either side of Sky Bridge, you can see that the cliff line is exceptionally straight. This is because the arch occurs between these parallel sets joints. The overall trend of the arch, as well as the joint set is around N 75° E.

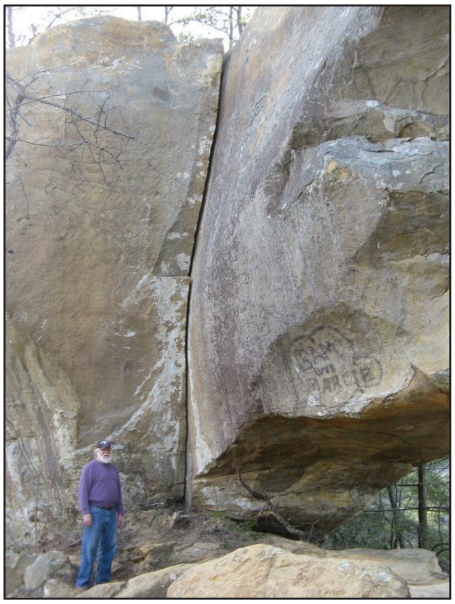

Fig. 7a. Large joint bounding the side of Sky Bridge.

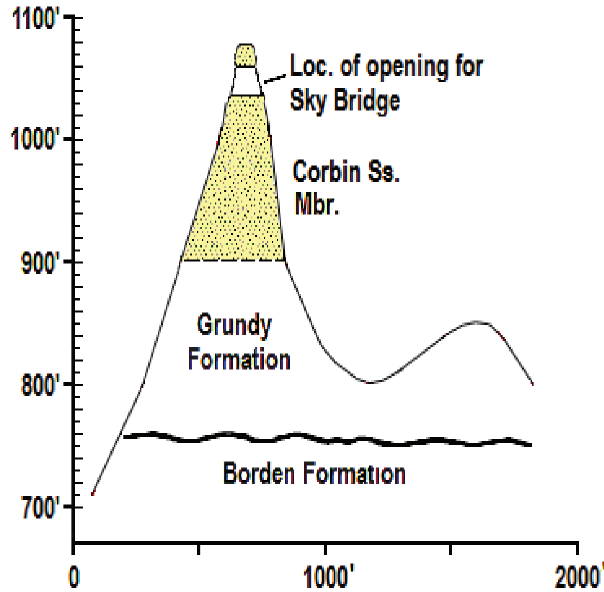

Fig. 7b. North-South cross-section across Sky Bridge ridge.

A natural arch or bridge, like Sky Bridge, is a rock exposure that has a passageway or hole passing completely through it (Fig. 7b) and is formed by selective removal of rock in such a way that is leaves behind a relatively intact frame or arch. The choice of the terms "bridge" or "arch" may seem a bit arbitrary at first. Some would argue that "Sky Bridge," as well as "Natural Bridge," are not truly bridges, but instead, **natural arches**. The Natural Arch and Bridge Society (www.naturalarches.org) identifies a **natural bridge** as a type of arch that is primarily formed by running water and has a stream flowing beneath it. An arch can be considered a natural bridge if it is being used by man as a bridge to support a portion of a road, providing it has a flat, level top over an arched opening.

According to The Natural Arch and Bridge Society several conditions must be met for a feature to be considered an arch.

1. A natural arch must be made of rock. A feature made of compacted soil, ice, or some other material is not a natural arch.
2. The rock must be sufficiently exposed that one can observe that it exhibits the other attributes of the definition.

3. The hole through the rock must conform to the topological, definition of a hole. In simple terms it means that caves, alcoves, and other recesses or concavities in a rock do not qualify as arches, even if they are arch shaped. This simply means that the hole or passageway must go completely through the rock.
4. The passageway must have formed from the natural, selective removal of rock. Features constructed by man do not qualify.
5. The frame of rock that remains to surround the hole must be intact. Fractures and joints may be present. Even some slippage along these may have occurred, as long as it is clear that this has happened after the hole formed. Also no gaps can exist in the framework of the arch.

With these definitions in mind, both “Sky Bridge” and “Natural Bridge” would technically be considered arches.

Arch Formation: Arches in the Red River Gorge area are known to form in several ways, and Sky Bridge is an example of a ridge-top arch.

Ridge-Top Arch – occurs on top of a narrow ridge, neck, or promontory of land. Most natural arches in the Red River Gorge area form along a narrow ridge that is walled by cliffs to either side. Several steps are necessary in the formation and development of a **ridge-top arch**. This is explained below and shown in the following illustration (Fig. 8).

1. The formation of Sky Bridge, as well as other arches in the Red River Gorge area is in part related to the presence of deep fractures or joints that penetrate the sandstone making up the arch (Fig. 7a).

2. As water from rain or melting snow flows down either side of the ridge, it slowly erodes away the sides of the ridge. Erosion also wears away and enlarges the joints that are present on either side of the ridge. In addition freeze-thaw weathering and root-wedging on the forested slopes also helps to widen these fractures. Gradually large sandstone blocks detach from the sides of the ridge or cliff. Over time these blocks of sandstone slip away down slope to either side of the ridge, until only the center portion of the ridge is left. You can see evidence of this by simply looking up and down the hillsides and along the stream valleys. Here, you will notice the large slabs and blocks of Corbin Sandstone that are scattered about the hillsides and up and down the river valley.

3. As the ridge steadily becomes narrower, the softer rock that lies beneath the arch-forming layer is gradually undercut by erosion until an overhang or natural rock shelter forms on either side of the ridge-top. Subsequent erosion will gradually deepen these cavities and undermine the rock shelter. Eventually the backs of these shelters break through from either side of the ridge and a natural arch will formed.

   The shape of this type of opening is usually one with a flat floor and a convex upward ceiling (called an inverted catenary). Compressional strengthening of the arch itself then acts to resist subsequent erosion. As a result, these types of natural arches tend to be long-lived and very common.

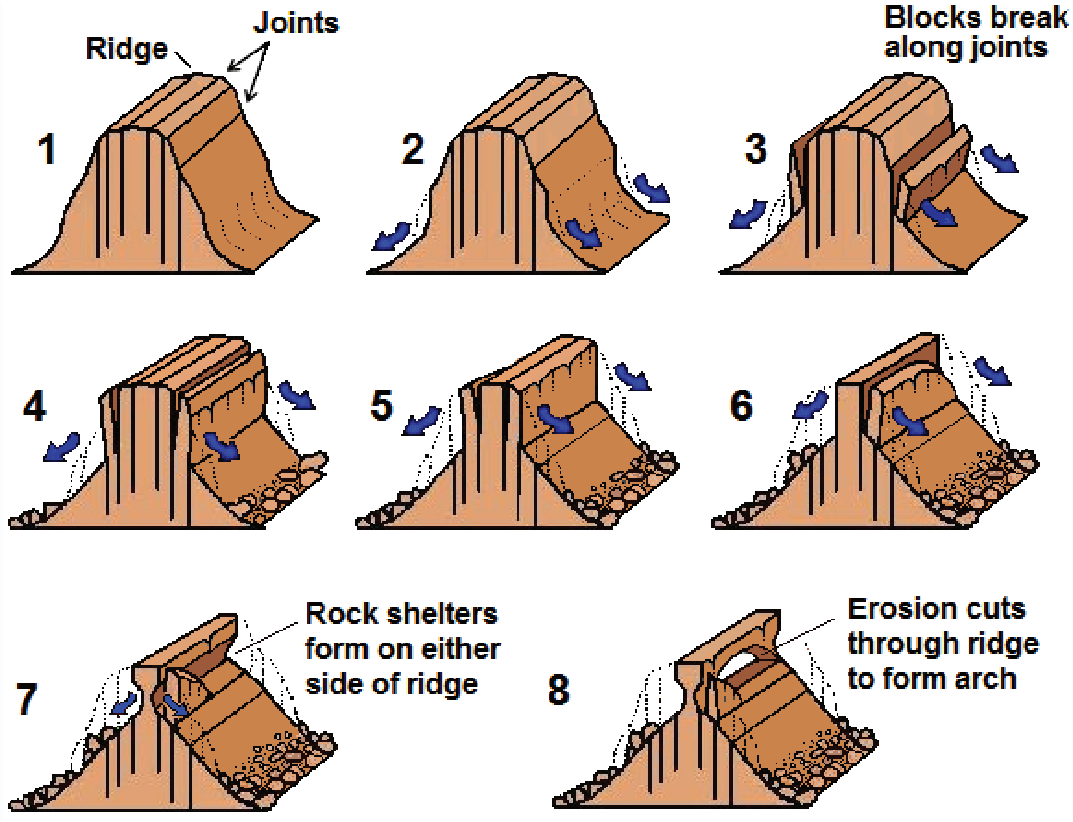

Fig. 8. Illustration showing formation of a ridge-top arch (modified from KGS, http://www.uky.edu/KGS/geoky/fieldtrip/naturalbridge/naturalbridgeguide.htm).

Other types of arches include the Waterfall Arch or Bridge. This type of natural arch occurs when a subterranean stream undercuts and isolates a portion of the streambed, leaving a lintel or bridge that is supported by the two banks of the stream. This can happen at the lip of a waterfall when cracks and joints allow the water to shorten its course through the rock under the lip. It can also happen for long stretches of rock streambed where no waterfall is apparent. The presence of a waterfall either at, or upstream from the natural arch is also a good indicator of a waterfall natural bridge. The waterfall gradually retreats upstream from the natural arch as time passes. Rock Bridge at Stop 7 is an example of a waterfall bridge.

Natural bridges can also form from natural **limestone caves**, where paired sinkholes collapse and a ridge of stone is left standing in between (Fig. 6), with the cave passageway connecting sinkhole to sinkhole. "Moonshiners Arch" at Stop 5 is just such a case. This arch formed when the roof of rock that was overlying a subterranean passage or cave became so thin that it could no longer support its own weight. This resulted in the structural failure and collapse of the roof. If two sinkholes form close together and the section of cave roof remaining between them has an open passage beneath it, a natural arch is formed. This is an important arch type in regions with well-developed cave systems.

Except for the handful of natural arches whose actual formation has been observed, there is no way to determine the age of any specific arch. It is also clear that arches are, generally speaking, short-lived geologic features. Most of them tend to form in areas that have been subjected to rapid uplift and erosion since the last ice age. It is safe to say that no natural arch is older than about 30,000 years and that most are probably between 5,000 and 15,000 years old (www.naturalarches.org).

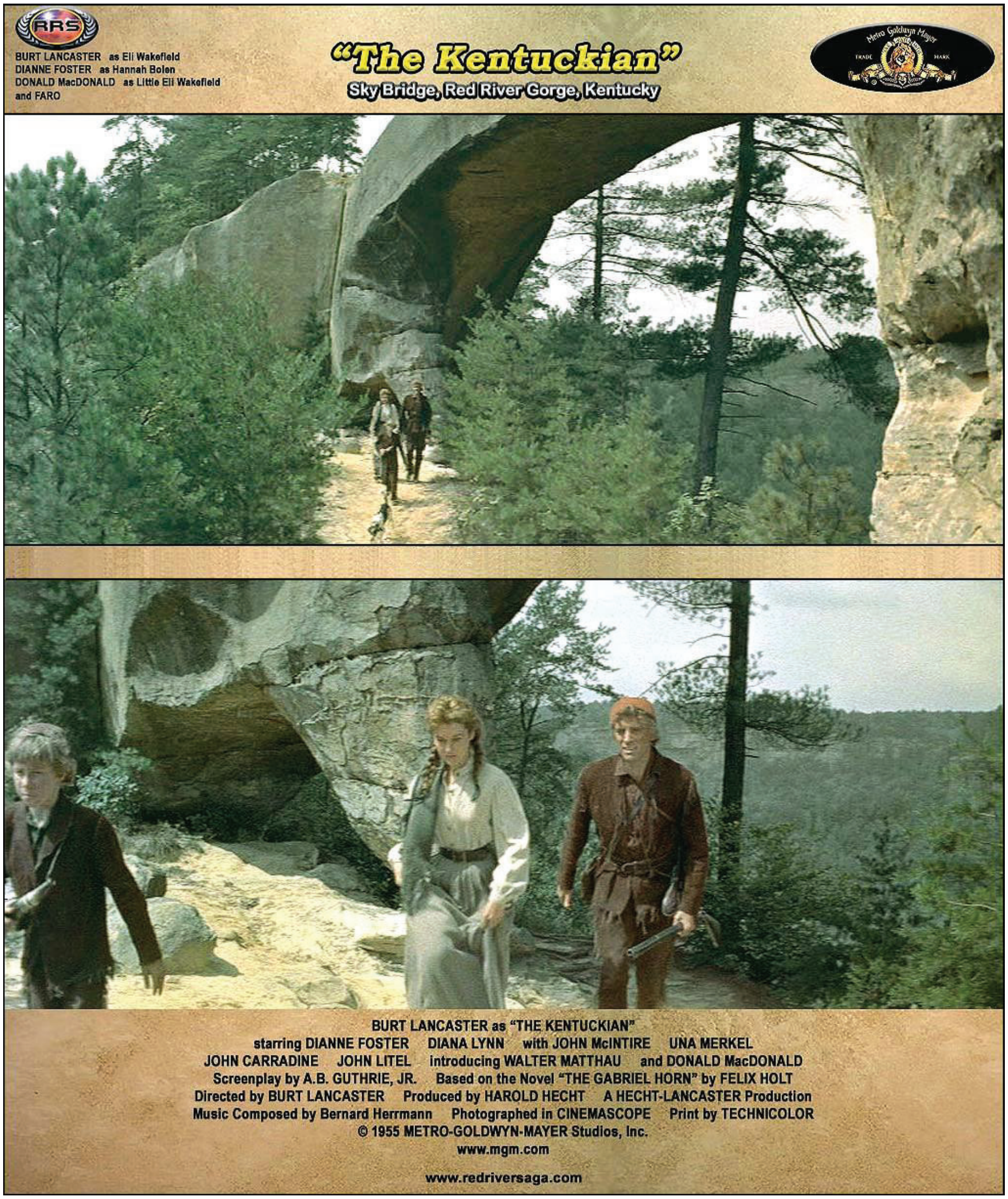

Fig. 9. Advertisement for the MGM movie, The Kentuckian, filmed at Sky Bridge.

One last point that should be noted is that "Sky Bridge" was the location for the first major motion picture to be filmed in the State of Kentucky. The picture, a frontier adventure, entitled

"The Kentuckian" (1955) was stared in and directed by Golden Globe and **Academy Award Winner Burt Lancaster** (Fig. 9). **See:** http://www.redriversaga.com/KENTUCKIAN.html

16. Get back into your vehicles and continue back along Forest Service Road 214.
17. Continue onto State Highway 715 travel southward for approximately 4.5 miles to the junction of Highway 715 and Rock Bridge Road.
18. Turn left onto Rock Bridge Road (Forest Service Road 24) and proceed straight ahead to the parking area, approximately 2.9-miles away. Park in and around the picnic area for **Stop 7, Rock Bridge**.
19. Trail 207starts at the picnic area at the end of the road. It loops back around and ends at the same picnic ground.

Stop 7
Rock Bridge (Lat.: 37°46'07" N; Long.: 083°33'30" W)

Rock Bridge gets its name because the arch spans across and over Swift Camp creek. It is the only true natural bridge in the area that was formed by water running over, under and through it. Rock Bridge across Swift Camp Creek is a waterfall arch developed in the lower part of the Corbin Sandstone Member of the Grundy Formation. The arch is in a local tongue of sandstone, split off the base of the main body of the Corbin Sandstone and inter-tongues with the lower portion of the Grundy Formation (Weir and Richards, 1974). The main body of the Corbin crops out along the upper part of Trail 207. The origin of Rock Bridge was originally outlined by McFarlan (1954). Water from Swift Camp Creek penetrated a vertical joint that was running along the stream bed upstream from a waterfall. Water moved laterally through the sandstone, and initially issued from the face of the waterfall. Leaching of sandstone cement and water erosion enlarged the pathway through the joint and sandstone, progressively diverting the stream flow to beneath the top of the falls. With complete diversion, the upper part of the former waterfall was left as sandstone span (Rock Bridge) across Swift Camp Creek. The position of the waterfall gradually migrated upstream and is now short distance upstream from the mouth of Rock Bridge Fork.

Features one can see in at this outcrop include: cross-bedding, liesegang banding, both honeycomb and boxwork structures, joints, and the casts or impressions of ancient logs.

Creation Falls is also along the trail leading the Rock Bridge. It is a beautiful waterfall right before reaching the Bridge. You can cross the bridge but you have to climb up a couple of rock faces 4- to 5-feet high. The trail continues up and crosses Swift Camp Creek trail and Bear's Den trail. The grade back to the picnic area is not as steep as the one down.

20. Back at the parking lot, please return to your vehicles and proceed back along Rock Bridge Road towards State Highway 715.
21. At the junction of Rock Bride Road and State Highway 715 turn left onto Highway 715 and proceed south crossing over the Mountain Parkway to the junction of Highway 715 with Kentucky State Highway 15 (approximately 0.4 miles).
22. Turn right onto Highway15. Continue on Highway 15, paralleling the Bert T. Combs Mountain Parkway to the junction of State Highways 15 and 11 at Slade (a distance of approximately 7.3 miles).
23. Turn left onto State Highway 11 and continue for approximately 3.4 miles to the access road leading to the parking area for Mill Creek Lake on the left (north side of the road).

24. Park in any of the available spaces for **Stop 8**, **Mill Creek Lake Spillway Section**.

Stop 8
Mill Creek Lake Spillway Section (Lat.: 37°45’58”N; Long.: 83°40’27”W)

Mill Creek Lake is a small, man-made lake located at the far end of the parking area, just east of State Highway 11. The purpose of this stop is to give provide the participants with an excellent view of the Middle and Upper Mississippian Rocks exposed in this region. On either side of the parking area one can see exposures of the upper Borden Formation and lower portions of the Slade Formation. This includes in ascending order the Cowbell and Nada Members of the Borden Formation, along with the Renfro, St. Louis, Mill Knob, Cave Branch Bed, and the Tygarts Creek Members of the Slade Formation. Descriptions for each of these units are provided in the appendix of this guide.

At the base of the section, exposed at road level on either side of the parking lot, lies the Cowbell Member of the Borden Formation. This part of the section is readily accessible to fieldtrip participants. At this locality the Cowbell is a purple-gray, thick to medium bedded siltstone and shale. Sedimentary structure visible within these beds include: parallel laminae, wavy laminae, and small-scale scour-and-fill structures. The lower contacts of individual siltstone beds tend to be quite sharp or abrupt with the upper contacts grading into the intervening shale layers. The upper surfaces of some of the siltstone beds can also exhibit low amplitude ripples marks and can include both asymmetrical and symmetrical ripples. Some of these siltstone beds contain iron stained clasts of shale, as well as fossils. A wide variety of body fossils have in seen in this unit at other localities including: crinoid debris, brachiopods, fenestrate bryozoans, rugose corals, gastropods, pelecypods, goniatite and nautiloid cephalopods, trilobites, and others.

Carefully search through these rocks and see what sort of fossils you can find. In addition to the body fossils, the Cowbell is also noted for its splendid assemblage of trace fossils. Trace fossils are sedimentary structures formed by the biologic activities of plants and animals. This may include something as simple as crawling across the sediment surface, to more complex activities like burrowing through the sediment in search of food or excavating a burrow for the purposes of living in the burrow. The most common trace fossils you can see at this locality are *Zoophycos* and *Lophoctenium*. *Zoophycus* is a spirally-shaped feeding trace that formed as deposit-feeding organisms tunneled through the soft sediment in search for food. Opinions differ as to which organism was actually responsible for creating this trace fossil. Some researchers have laid the blame on a burrowing marine worm; others have suggested that some sort of burrowing shrimp may be responsible for forming these structures.

The position of the Cowbell Member between prodelta deposits of the Nancy Member and the overlying shallower delta platform of the Nada Member suggest that the Cowbell was deposited along a delta-front. A **delta front** is the sloping frontal portion of a delta just seaward of the delta platform. In this case the siltstone beds seen here probably represent storm deposits (tempestites) that formed along the top edge of a delta system. The Lower to Middle Mississippian Borden Formation represents subaqueous parts of a westwardly advancing delta complex that is slowly prograding across this area.

25. Once we have finished looking over this section, please return to your vehicles and proceed out of the parking area and turn left onto State Highway 11.

26. Continue south on State Highway 11 for approximately 0.7 mile. Pull off the right side of the road, there should be plenty of parking. Get out of your vehicles and turn your attention to the opposite side of the road. Across the road you will see a spectacular view of **Stop 9**, the **Glencairn Fault**.

Stop 9
The Glencairn Fault (Lat.: 37°45'58" N; Long.: 83°40'27" W)

The Glencairn Fault of part of a much larger fault system call the Irvin-Paint Creek Fault System. The Irvin-Paint Creek system a east-west oriented set of normal faults in which the down thrown block is to the south. The Irvin-Paint Creek Fault System is thought to be a surface expression of a much larger structure deep beneath the surface called the Rome Trough. The Rome Trough, a huge northeast-trending graben that involves a large part of the basement rock which underlies the Appalachian Plateau. Basement rocks in the Rome trough may be buried beneath as much as 20,000 feet of Paleozoic strata. Movement along the Rome Trough is thought to have affected sedimentation in the area as long ago as Early Cambrian time (approximately 530 million years) and clearly has extened up through Pennsylvanian time (approximately 310 million years).

At this stop we are looking at the lower part of the Slade Formation and upper part of the Borden Formation (Fig. 10). The left hand side of the fault (known to geologists as the **foot wall**) lies within the Borden Formation. The right hand side of the **fault** (called the **hanging wall**) is within the uppermost Borden Formation and the lower portion of the Slade Formation. It is evident that that the left side (the north side) of the fault, relatively speaking, has moved up and that the right hand side (the south side) has moved down. A fault in which the hanging wall has move down relative to the footwall is called a **normal fault**.

In the base of the limestone on the right-hand side of the fault is an elliptical body of dolostone that seems to have been injected in a more fluid stage (Fig. 10). This body and others in the area have been interpreted to represent **seismites**, or unconsolidated sediments that were deformed by ancient earthquake activity (Zeng and Ettensohn, 2009). In this case, the earthquake activity occurred about 340 million years ago and was responsible for injecting the unconsolidated carbonate in the elliptical, ball-like body.

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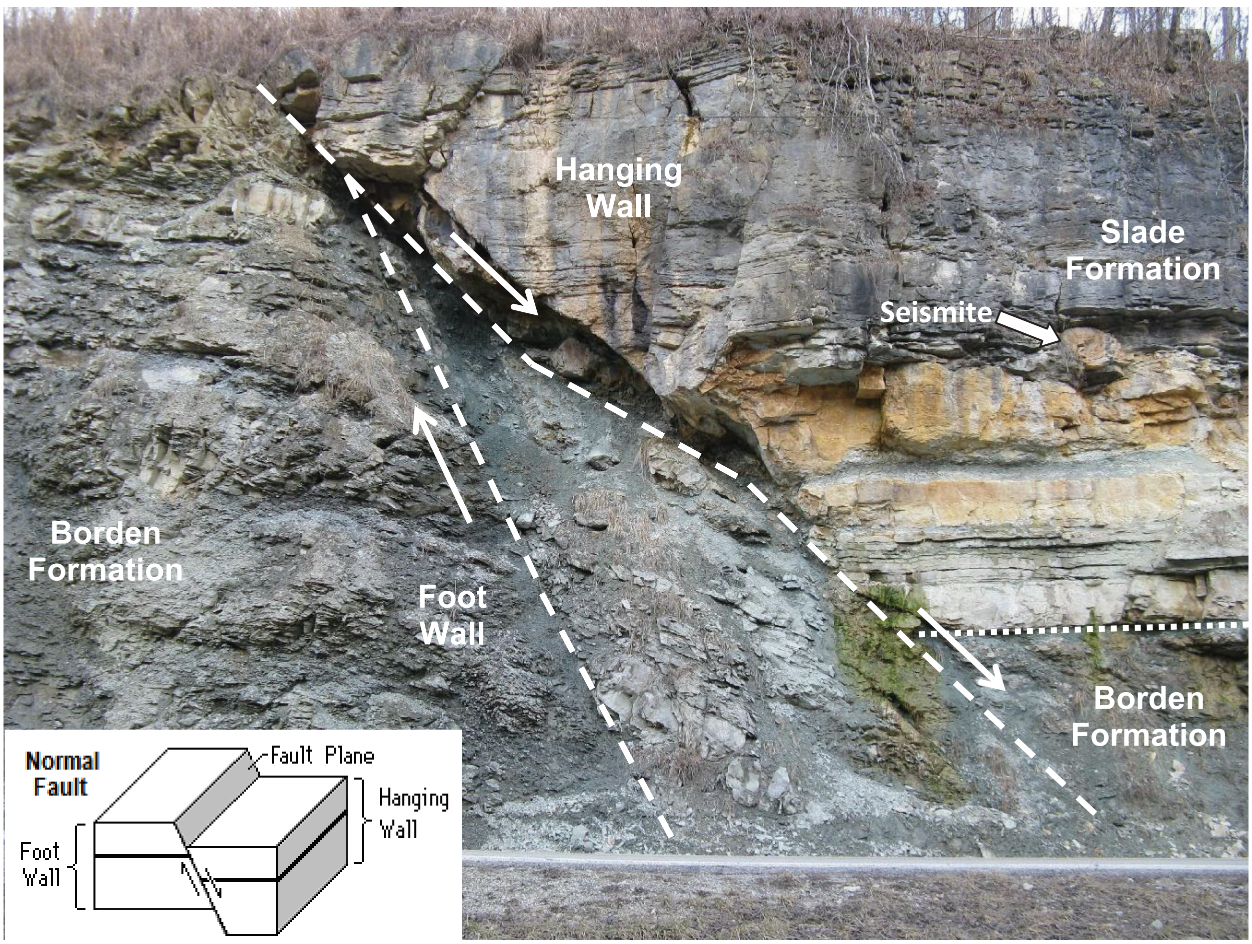


Fig. 10. Photograph of the Glencairn Fault on the east side of Kentucky State Highway 11, just south of Natural Bridge State Park.

Glossary of Field-Trip Terms and Images

Archaeology and Culture in the Gorge

For nearly 12,000 years, the beautiful landscape of the Red River Gorge has provided food, shelter and inspiration for many different kinds of people. The Red River Gorge's unusual geological features, like the sandstone cliffs and rockshelters, as well as its difficult terrain and extreme elevation changes, have played a role in preserving materials that normally decay completely in other settings. These preserved materials include seeds, nutshells, cordage, wood, leather, and textiles.

Native Americans lived here first as hunters and gatherers and later as gardeners and farmers. Since they had no written languages they left no history books about their time. Archaeology helps to tell that history by studying the places Native people lived and the things they left behind.

People of European and African descent were the next to arrive: farmers, and moonshine makers; wage workers digging out saltpeter or cutting down trees; businessmen and teachers. They did write some things down, but the day-to-day lives of common people often do not appear in recorded history. Archaeology helps us learn about them, too.

Unfortunately these resources are very fragile and as a result are easily lost through intentional and unintentional actions of modern visitors. Decades of looting, vandalism, and recreational use, such as rock climbing or camping, have destroyed or damaged many of the rockshelter sites, prehistoric rock art, and historic logging camps and homestead sites. Archaeologists estimate that at least 90 percent of the archaeological sites in the Gorge have been disturbed. Campers often unknowingly burn wood from rockshelters that may be hundreds of years old. When archaeological sites are damaged, their ability to tell us about the past is hindered; it is as if a page in a history book was erased.

The following is a brief outline of Red River Gorge history based on what we've learned from its archaeological resources. The history is divided into nine different periods: four pre-contact and five historic.

Paleoindian (about 12,000 to 10,000 years ago)

The first people arrived in the Red River Gorge as the last glaciers were retreating. Because the climate was cooler and wetter than today, an evergreen forest covered the area. Different types of plants and animals, including mastodons, mammoths, and giant bison lived in the region at this time.

Paleoindian people were successful hunters and foragers who lived in small groups. They used spears tipped with long, narrow stone points and gathered wild plants. Because they moved their camps often, their belongings were portable. Archaeologists have not identified many Paleoindian campsites in the Red River Gorge but it is possible that more Paleoindian sites could be identified in the future.

Archaic (10,000 to 3,000 years ago)

By about 10,000 years ago, the climate had begun to grow warmer. A deciduous forest eventually replaced the evergreen forest, and the plants and animals we see today appeared. Like their ancestors, Archaic peoples were hunters and gatherers. They developed a new weapon, the spearthrower or atlatl (at-uhl-at-uhl), and gathered wild plants for food, medicines, and dyes. They prepared nuts with heavy, smoothed stone tools like mortars and pestles, or in stone-drilled depressions called bedrock mortars or hominy holes. Undisturbed hominy holes can contain residue from the foods processed within them.

Archaic people established their camps in rockshelters, at the base of slopes, and along floodplains. They may have used the mature fruits of gourds and another kind of squash as water bottles or storage containers. Painstaking archaeological investigation of an Archaic campsite in a rockshelter in the Gorge found fragments of a 3,700-year-old squash rind. Along with it, archaeologists found chipped and ground stone tools and pollen grains. The pollen was important because it showed how the climate had changed over time.

As the centuries passed, Archaic peoples came to rely more on plants for food. They ate plants called "weedy annuals" like sunflower and goosefoot, along with "fleshy" plants like squash. Archaic people returned to the same plant patches to collect the seeds and fruits from the largest and most productive plants. Over time, their choices changed the plants physically. This was the beginning of plant domestication.

Woodland (3,000 to 1,000 years ago)

Around 3,000 years ago, the prehistoric gardeners of the Red River Gorge began to make jars from local clays. We call these pottery-making groups the Woodland peoples. Ceramics joined wooden and gourd bowls and cane baskets as containers used for cooking and storage.

Hunting and gathering continued to play a major role in the economy of the Woodland people. They hunted with the atlatl until about 1300 years ago, when they replaced it with the bow and arrow. Like their ancestors, they planted seeds in gardens near their camps. These seeds included those of squash and weedy annuals, such as goosefoot, marshelder, sunflower, amaranth, and knotweed. With this predictable source of food, the Woodland gardeners began to live in certain spots for longer periods. They still made short trips to other places for the raw materials they needed.

Hundreds of rockshelters along the many clifflines in the Gorge provided more than adequate shelter. Archaeologists have identified many important Woodland camps in the Gorge. At these sites, they have found the remains of Woodland peoples' storage pits and the fires they built for heat, lighting, and cooking. They also have found pottery, spear points, cordage, textiles, leather items, grass beds, and a wooden cradleboard (used in caring for babies). Dried plant and fecal remains show a dramatic increase in the role garden plants played in people's diet.

In addition to its dry rockshelters, the Gorge also is known for its rock art or petroglphys. Archaeologists think Woodland peoples were the ones who carved or chiseled images into boulders and cliff walls. These petroglyphs are mainly geometric designs, like circles and spirals or animal related, such as turkey, deer or bear tracks but human footprints and figures do appear, though more rarely.

Late Prehistoric (1,000 to 300 years ago)
Outside the Gorge around 1,000 years ago, people began living in villages. Called Fort Ancient, they turned to a more settled way of life that farming provided. Like their ancestors, they still grew squash and sunflower, but they replaced most of the old crops with new ones, such as corn and beans. Tobacco became an important crop, too. They continued to hunt with bows and arrows and gather wild plants.

Within the Gorge, Fort Ancient people lived in rockshelters. The prehistoric farmers of central Kentucky also may have come to the Gorge to hunt at this time. Temporary Fort Ancient hunting camps include a variety of materials including triangular arrowheads, a grinding slab, and a few ceramic jars, like the one shown here, as well as cornhusks, corn kernels, cut cane, and cordage.

By around 400 years ago, Native Americans were trading with Europeans indirectly. Evidence of this contact comes in the form of European glass beads and metal kettle fragments. European diseases, like smallpox, influenza, and measles, appeared in the late 1600s. Thousands of people died because they had never been exposed to these kinds of diseases before. The people that survived did the best they could to cope and sometimes coalesced into new groups, sometimes moving to new areas to live.

Early European Settlement & the Frontier (300 to 180 years ago)
After the first epidemics had passed, some native groups may have continued to live full-time in the area. They may have hunted in the Gorge as their ancestors had done. They could have traded deerskins and furs at early colonial trading posts such as Shawnee Town at the mouth of the Scioto River. During the first years of European expansion into the area, conflicts also arose between the new settlers and the Native people. However, eventually most of Kentucky was ceded to the Europeans by the Cherokee and Shawnee tribal leaders via treaties.

European pioneers arrived in Kentucky via the Ohio River and the Cumberland Gap. The Europeans who settled in the Gorge area also made their living farming, much like the Native people before them. Historic crops included corn, tobacco, hemp, flax, and wheat. Early settlers also raised livestock such as cattle, horses, and hogs. Rockshelters in the Gorge often show evidence of use as animal pens and as drying areas for tobacco.

Not long after they arrived, European people started to make use of the natural resources in the area. Saltpeter, also called niter, forms naturally in caves and rockshelters and is used to make gunpowder. The miners processed the niter in wooden vats and sold it for income or used it themselves in hunting, curing meat, and treating ailments. Pine tar was made by slowly burning pine wood in kilns, with the tar collected in drainage grooves around outer edge of the kilns. The resulting tar could be used for sealing wooden buckets or boats and in roofing construction and maintenance. Pine tar production in the Gorge is interpreted near a former kiln site along Tunnel Ridge Road.

The Civil War & Before (180 to 140 years ago)

The population of the Gorge before the Civil War was likely very small. Farm sites from this era are not numerous and may be partly because the narrow bottomlands and ridgelines do not provide much tillable land. The three counties within which the Gorge is found, Menifee, Powell, and Wolfe, were created in the latter years of this period.

Pine tar production continued during this era, but it is not clear whether systematic niter mining persisted, since neither the Confederates nor the Union would have wanted a gunpowder source to fall into the enemies' hands. It is possible that guerillas or local people produced saltpeter and gunpowder for their own consumption, but no one has yet found proof of that. It has been difficult to identify Civil War-related sites in the Gorge with any certainty.

After the Civil War (140 to 94 years ago)
Kentucky's population increased dramatically in the decades following the Civil War. In the Gorge, farming became a money-losing activity, and many farmers were forced to search for wage-earning jobs elsewhere. However, the Gorge's isolated inhabitants had to travel far to get to a marketplace or a city.

The major industry in the Gorge at this time was logging. Initially, logging did not advance deeply into the Gorge because of its difficult terrain. The railroad came in thru the Nada Tunnel, constructed by the Dana Lumber Company in 1911. After that time, it was much easier to get people and goods in and out of the Gorge. Evidence of past logging activities takes the form of splash dams, and logging-related residences and communities. Logging trails and roads are still visible throughout the Gorge.

In the mid-1870s, a small community, known as Gladie or Gladie Creek, developed at the confluence of Gladie Creek and the Red River. The Ledford family and their friends established a community here as the logging industry moved deeper into the Gorge. At one time, Gladie consisted of a post office, a school, and a cemetery along with the houses and farms of its occupants.

Today at Gladie, you can see the "Gladie Cabin." Assembled in the late 1900s, it consists of portions of an original cabin, once used as the post office, and sections of other buildings from the community. Gladie became part of the Daniel Boone National Forest in 1987.

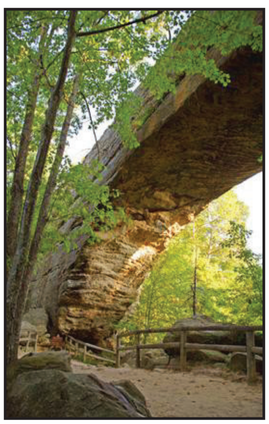
Industrial & Commercial Consolidation (93 to 63 years ago)
As urbanization increased throughout Kentucky, more people in the Gorge worked wage jobs in nearby towns and cities. Access to stores and consumer goods became easier. Farming became more mechanized, but overall as an occupation, it continued to decline in importance.

One way farmers could supplement their decreasing agricultural income was by distilling alcohol from their grain crops (corn, wheat, and rye). Usually referred to as 'moonshine,' it could be stored longer than fresh corn and took up less room. Making moonshine was a one way to turn surplus grain in to profit. The Gorge was a good place for alcohol production. The rockshelters were preferred locations because they were isolated and water and firewood were easily available. The remains of old moonshine stills are present today in some of the rockshelters in the Gorge.

By the 1920s, the industrial era of the Gorge was ending. The Gorge area had never had much iron ore, but it did have oil and gas deposits. But by this time, even those were generally depleted. During the Depression, the Federal government established programs to provide jobs to large numbers of people. The Civilian Conservation Corps (CCC) built two bridges, Tunnel Ridge Road, two powder houses, and a quarry in the Gorge. They also built the Pine Ridge CCC Camp, the archaeological remains of which are still visible today.

In the 1930s, people considered the logged areas of Menifee County a wasteland. So, the U.S. Forest Service began buying up land to establish the Cumberland National Forest. They also started a program of reforestation. In 1966, the Forest Service was renamed it the "Daniel Boone National Forest." Although most land within the Gorge is under federal control, there still are land parcels that are privately owned.

The National Forest, Tourism, and Recreation (63 years ago to today)
The United States established the National Forest system to create a perpetual logging industry for the United States. But in the latter part of the twentieth century, people began to visit National Forests for recreational purposes. The Red River Gorge was no different.



The Gorge has a long history as a tourist destination, with people visiting Natural Bridge, shown here, as early as the late 1800s. A state park was established there in 1926. By the early 1920s and 1930s, new highways meant people could travel more easily to places for recreation. Archaeological research began in the Gorge Area at this time, partly due to the access these roads provided. A small log cabin alongside the road near Sky Bridge, known as "Sleepy Hollow Lodge," is said to have been built at this time as a get-away spot for landowners from Cincinnati.

The construction of the Slade Interchange on Mountain Parkway in the 1960s also helped open the Gorge to more weekend visitors. Campgrounds, recreation spots, and private homes reflect these activities. Estimates of the number of visitors to the Gorge each year range from 250,000 to 750,000.

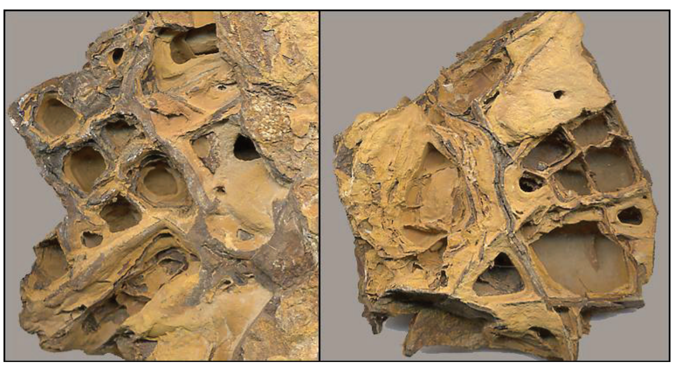
One of the Gorge's major attractions is its clifflines and the rock climbing opportunities they provide. Some people consider the Red River Gorge to be among the top five climbing locales in the world. From the time climbers established the first climbing routes in the Gorge in the 1950s/1960s, people have traveled from all over the world to try their skills here. Other tourists visit the area for its hiking trails, camping spots, and for the Gorge's scenic beauty.

In 1966, the U.S. Army Corps of Engineers considered building a dam across the Red River. The resulting lake would have flooded the Gorge. Archaeological investigations revealed that a wealth of unique and nationally significant prehistoric sites were concentrated in the Gorge area, particularly in its rockshelters. Eventually, citizen protests and the growing controversy over the proposed dam put the project on hold indefinitely. This safeguarded the Gorge's cultural and natural resources, such as the river itself, shown here. Due to the unique concentration and preservation of archaeological sites, the Red River Gorge District was listed in the National Register of Historic Places in 2003.

Protecting Cultural Resources
Today the Daniel Boone National Forest works to protect the unique and significant cultural resources of the Red River Gorge in many different ways. Due to the fact that they often contain important resources, camping is no longer allowed in rockshelters. Forest heritage staff, backcountry rangers, college students, and volunteers monitor the condition of sites, checking to see if illegal activities are occurring. If problems are discovered during monitoring, law enforcement will be involved. People caught digging are prosecuted, and may pay hefty fines or serve prison sentences. However, the most important tool for protecting sites in the Gorge is educating people about how modern human impacts can destroy the cultural heritage contained in these sites.

Everyone can help stop site destruction and vandalism. Don't dig in sites or collect artifacts. Don't buy artifacts from people who dig and destroy sites. Report people who are digging and collecting on the Forest to law enforcement officials; write to: Forest Supervisor's Office, Daniel Boone National Forest, 1700 Bypass Road, Winchester, Kentucky, 40391; phone (859) 745-3112; or go to the web: **http://www.fs.fed.us/r8/boone/contact/**
Image Credits: Late Prehistoric Pottery Vessel: *www.as.uky.edu/Anthropology/museum.html;* Natural Bridge: *parks.ky.gov;* Red River Rapids: *www.visitusa.com —Living Arch Weekend Steering Committee and Wayna L. Adams*

Boxwork Structures



These are box-shaped or triangular patterns of iron oxide or siderite in many rocks. At some point in geologic history of the rock water fills the pore spaces in a rock formation. This groundwater can have a variety of different minerals dissolved in it. Under the right set of conditions these minerals precipitate out along joints, fractures or bedding planes in the rock formation. This commonly happens with various iron-rich minerals such as hematite (Fe_2O_3), limonite (FeOOH), or siderite ($FeCO_3$). As the rock is exposed to the elements and slowly weathers, these more chemically resistant areas stand out from the surface of the rock. With time it develops a surface that resembles a set of intersecting lines or planes. —*R. Thomas Lierman*

Caves and Karst

Caves are natural, underground, open spaces, generally with an opening to the surface. Most caves form through the natural dissolution of calcium carbonate, the major constituent in limestone, in limestone-rich areas. The term **karst** is used to describe limestone-rich areas that exhibit a distinctive assemblage solution-related landforms like caves, sinkholes, underground drainage and disappearing springs. The name is derived from a limestone-rich region in the

Fig. 1. A cave in the Slade Limestone from Natural Bridge State Park.

former Yugoslavia , dominated by such landforms. In parts of the Red River Gorge-Natural Bridge area, the presence of the Middle-Upper Mississippian Slade Limestone makes this area a karst area. Moonshiners Arch at Stop 5 is a collapsed cave, whereas caves, sinkholes, and disappearing springs characterize parts of Natural Bridge State Park (Fig. 1).—*Frank R. Ettensohn and Charles E. Mason*

Climbing the Red

In recent years the Corbin Sandstone cliffs of the Red River Gorge have become a world famous climbing destination attracting rock climbers from all around the globe. On any given weekend in the peak climbing season, you can meet climbers from Spain, France, and Germany… or any, if not all, of the fifty states. The Red, as it is known in the climbing community, offers climbers some of the most diverse types of climbing around, such as overhangs, vertical faces, less than vertical slabs, and many types of cracks. The Red as far as climbing goes is not limited to the area within the Red River Gorge. Climbers consider the Red to include an area many miles south of Natural Bridge State Park to an area just north of the Reds established boundary. Also, east and west a few miles outside it's established boundaries. The Red offers climbers breath-taking vistas that only they can enjoy, because many of the summits of towers and pinnacles are only accessible by climbing. The summit registries in the Red read like a who's who of the climbing community. These registries feature notes and signatures from the pioneers of climbing in North America to today's rising stars, but most of the cliffs within the Red River Gorge area are accessible by hiking to their summits, allowing anyone access to their memorable panoramas.

Corbin Sandstone is the singular reason for the quality of climbing in this area. The way this type of stone formed created a hardness and texture that lends itself to climbing remarkably well. Iron oxide bands make crisp foot and hand holds of various sizes. *Lepidodendron* molds in the walls form remarkable holds. Ripple marks are incredibly diverse and often razor sharp and tough, if not impossible, to break with a bare hand. Knobs and especially pockets line many of the walls at popular climbing areas. Geologists have explanations for many of the pocket features but some "honeycomb" like pockets defy explanation. Erosion has played a major role in climbing at the Red creating overhangs and rock shelters that Native Americans once lived in and climbers today play in. No climbing at all here would be possible if this area was still buried under many layers of sediment. But wind and rain continue to carve plates, fissures, and giant pockets into the Red's sandstone. Many of the climbs in the Red get a few millimeters taller every year due to wind, rain, and the pitter-patter of hiking boots along the base of the walls. Cracks that formed due to precipitants flowing through the weakness in compacted sands form perfect splitter cracks that men, women and children today cling to today. However, stone is an ever changing medium, plates pull off walls, iron oxide bands break, and freeze thaw cycles crack bullet hard rock every winter. Caution is always warranted when climbing or hiking in the Red. Rotten sandstone or poorly consolidated rock is mostly avoided by climbers but can be found throughout the Red. BE CAREFUL.

The way that the rock was formed and then eroded created a plethora of climbing areas, as well as types of climbing. Currently there are more than 1900 climbing routes, established on 146 cliffs, or walls, in and around the Red. The Red has something to offer all levels of climbing experience, from the complete novice to the seasoned professional, which is why the Red River Gorge has become such a wildly popular cragging destination. Difficulty ratings for routes in the Red run the full range of the Yosemite Decimal System. The Yosemite Decimal System is the scale that climbers use to rate climbing difficulty (5.0-5.14). The 5 represents the class while the number behind the decimal represents a difficulty rating. For example:

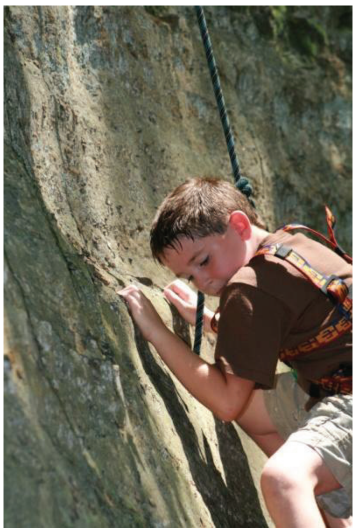
1st class: flat easy walking

2nd class: uneven terrain but not difficult
3rd class: more uneven, difficult to negotiate; care must be taken to keep from falling.
4th class: very strenuous walking, a fall could result in a serious injury, one might need to use ones hands to balance, but possible to make progress without using ones hands
5th class: the realm of the climber, 5.0 could be thought of as a ladder set at 85 degrees and as the scale goes up, 5.1, 5.2, 5.3, and so on, the ladder gets steeper to past vertical and the rungs get smaller. The rating of 5.14 is something that is beyond words, and I will not try to describe it. I will only say there are very few people in the world the can climb at this level.

Access to the cliff tops is one of the major reasons for the explosion of routes in The Red. Early in its history, climbers established routes from the ground up, placing removable protection points such as pins, cams, nuts, and chocks, as they went gunning for the top. This style of climbing, known as traditional climbing, limited climbers to areas with cracks or fissures that would accept their protection points. The earliest ascentionist used pins or pitons that were hammered into cracks like nails and clipped to the rope with carabiners for protection. As a result of the generally weak nature of pins in sandstone, climbers avoided falling at all cost. Recently climbers have begun to bolt routes on seemingly blank faces by rappelling from the top, drilling small holes in the rock, and inserting masonry anchor bolts with hangers to clip carabiners and their ropes to, creating permanent protection points. This type of climbing, known as sport climbing, has become the means to deliver climbing to the general public because of the great strength of this type of protection a fall can be arrested in a very safe and some consider fun way. Sport climbing offers access to the overhangs and rock houses that fill the Red River area. Sport climbing requires less equipment and the permanency of the bolts makes it safer for beginners to master. It is not possible to discuss all styles, types, or areas to climb in the Red in this limited publication. However, as we all know there are books written about every conceivable subject, including climbing. Two of the best are *Red River Gorge Rock Climbs* by

Ray Ellington, 2nd Edition, and *Moutaineering the Freedom of the Hills* edited by Steven M. Cox & Kris Fulsaas, 7th Edition.

As you are traveling through the Red, if you pay close attention, you can see climbers in action. Many of the walls near the road are developed for climbing. One particularly good area is Route 11 south of Natural Bridge State Park. Beginners can find on Route 11 one of the best introductory opportunities to climbing available in the Red area. The Via Ferrata, or iron path, which is a privately owned horseshoe shaped cliff in the Torrent Falls area. This area is especially equipped to allow nearly anyone to take a short course and get a real taste of climbing in a very safe environment. Also, there are many quality guide services in the area that can offer the adventurous soul a day out they will never forget.

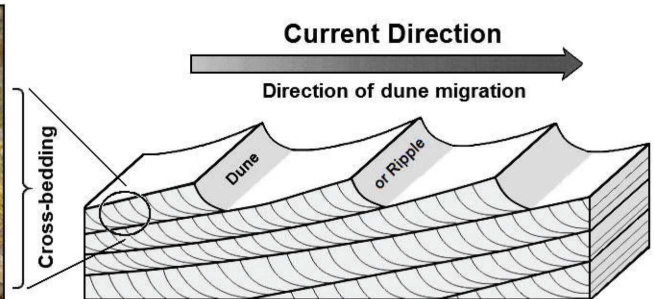


Climbing is dangerous; no one should attempt to climb in The Red or any other area without expert supervision or training. Some factors that make the Red River Gorge a particularly great place to climb also make it particularly deadly. The same erosion influence that created the routes here continually tears them down. What was solid last summer could be loose and friable after a winter of freezing and thawing. This point cannot be stressed enough. CLIMBING IS INHERENTLY DANGEROUS. Hence, many seasoned climbers in this area have developed nuances for moving along a route. Such as pulling down only, not out, on flakes and not fully weighting questionable holds. Intentionally, most of the developed areas offer bullet hard sandstone, and loose rock is removed as areas are developed.

The Red has also seen another movement involving climbers that is spreading to the rest of the country. Climbers as individuals and in large groups are purchasing large tracts of land around the Red and preserving them for climbing and wildlife habitat. The Red River Gorge Climbers Coalition (RRGCC) is one major group in this area that has purchased over 700 acres south of Natural Bridge State Park. This area known as Pendergrass Murray Recreational Preserve has been set aside for outdoor recreation activities that are not given top priority in other areas, such as climbing and mountain biking. Other privately owned areas that are set up similarly to this area are Muir Valley Nature Preserve and Climbing Arena LLC, Graining Fork Nature Preserve LLC, Torrent Falls Bed and Breakfast, and other unpublished properties. This insures that rock climbers will have a place to practice their skills because in the past government owned areas (public property) within the Red have been closed to climbers without notice or reason. This includes Pocket Wall the gem of The Red, an area that had been established on private land that was later purchased by Natural Bridge State Park. The loss of this beloved area prompted the purchase of these other areas.

Purchasing land is not the only goal of the RRGCC because many of these areas are being loved to death; the RRGCC is working to maintain sustainability by trying to control factors such as human created erosion problems by sponsoring trail work days, trash pickup, and maintence of areas at the base of the cliffs. The RRGCC also tries to work with both private and government land owners to insure future climbing access. In short, climbing in The Red has evolved from a few crazy people living in the woods, climbing with shoe strings a hammer and nails to today's climbers who are well trained, well equipped, and very organized. Climbers recognize that they impact the Red both positively via the revenue they bring to the area and negatively by loving it to death. The Red is a wild and beautiful place that will climb to a higher level of stewardship in the future because of climbers' efforts. —*John Ed Aragon*

Cross-bedding consists of inclined layers of sediment (generally sand) that are deposited by water currents or wind. This sedimentary structure is produced by the migration of sand dunes or ripples. Cross-bedding can form in any environment in which either water or wind flows over a bed of sand. It is most common in stream deposits (generally consisting of sand and gravel), in



tidal areas, or as wind blow dunes. The direction of inclination of the cross-beds reflects the direction of the current responsible for depositing these inclined layers; this can show us the direction that ancient streams flowed or the direction that ancient wind blew (we call these ancient directions paleocurrents). Geologists believe the paleocurrents responsible for the deposition of the cross-bedding seen in the sandstones of the Corbin Member were the result of ancient streams that flowed west and northwest from the rising Appalachian Mountains to our east (Rice, 1984).—*R. Thomas Lierman*

Depositional Environment

The depositional environment describes the combination of physical, chemical and biological processes associated with the deposition of a particular type of sediment and, therefore, the rock types that will be formed after the sediment lithifies (turns to rock). In most cases, the environments associated with particular rock types and be easily related to similar modern environmental analogs. Hence, geologists commonly study modern environmental settings to understand those represented in the geologic rock record, using the principle of uniformitarianism (the present is the key to the past). Common types of sedimentary environments are shown below in Figure 1.

The three formations in the Red River Gorge-Natural Bridge each represent distinct sedimentary depositional environments. The lowermost Borden Formation represents the submarine parts of an ancient delta complex and deep-water marine parts of a basin into which the delta built out (Fig. 1). In contrast, the Slade Formation limestones and dolostones represent deposition in warm, shallow-marine environments. The sandstones and conglomerates of the Lee Formation, however, represent fluvial deposits in a large, meandering river system. Although the diagram above make it seem like these three environments were present together, in reality they were each present in the area at a different time.—*Frank R. Ettensohn*

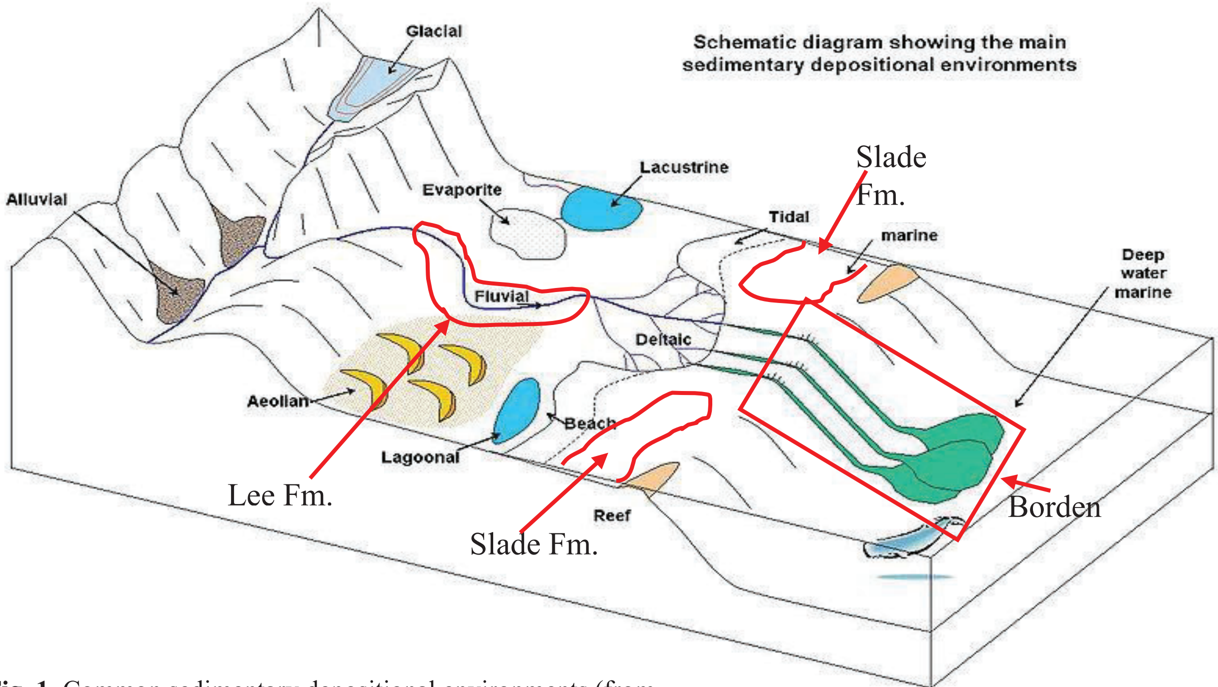


Fig. 1. Common sedimentary depositional environments (from http://en.wikipedia.org/wiki/Sedimentary_depositional_environment).

Escarpment

Fig. 1. Pottsville Escarpment and concordant ridgetops of the Cumberland Plateau from Natural Bridge.

A long continuous cliff or steep slope facing in one direction that separates two level or gently sloping surfaces; the cliff may be produced by erosion or faulting. In the Red River Gorge-Natural Bridge area, the escarpment has been produced by the erosion of the resistant Corbin Sandstone. In this area, one surface is at the level of the Red River and is continuous with the Lexington Plain to the west. The upper surface is the Cumberland Plateau and is represented by the concordant ridge tops in Figure 1. The escarpment in this area is called the Pottsville Escarpment, and it forms a nearly continuous cliff along the western margin of the Appalachian highlands.—*Frank R. Ettensohn and Charles E. Mason*

Fossils

A fossil is defined as the remains and/or evidence of past life preserved in the rock record. The actual remains of past life such as bones, teeth, plants, and shells are referred to as body fossils. Figures 1 and 2 show examples of shell and plant body fossils respectively. Fossil shells are very commonly found in both the Borden and Slade formations of Mississippian age, whereas plant fossils are most commonly found in the overlying beds of Pennsylvanian age.

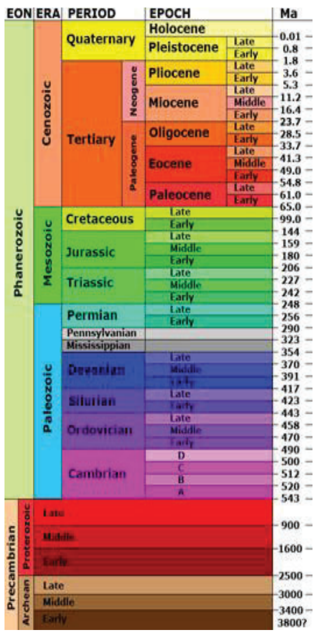
Fig.1. Brachiopod fossil from Slade Formation.

Fig. 2. Plant fossil impression from the Corbin Sandstone.

Fig. 3. *Zoophycus* trace fossils.

Fossils that show the evidence of past life such as foot- prints, worm burrows and fecal material (called coprolites) are called trace fossils. These are important fossils, as well, because they tell a lot about the trace maker such as what they ate and how they moved which body fossils alone cannot provide. Figure 3 is a picture of the trace fossil called *Zoophycus* which is a grazing or feeding trace of a worm-like organism which is commonly found in the Borden Formation. Fossils are commonly found in the rock layers exposed in both the Red River Gorge and Natural State Resort Park. However, it should be pointed here that collecting fossils in both state parks and national forests without a permit is prohibited. —*Charles E. Mason and Frank R. Ettensohn*

Geologic Age

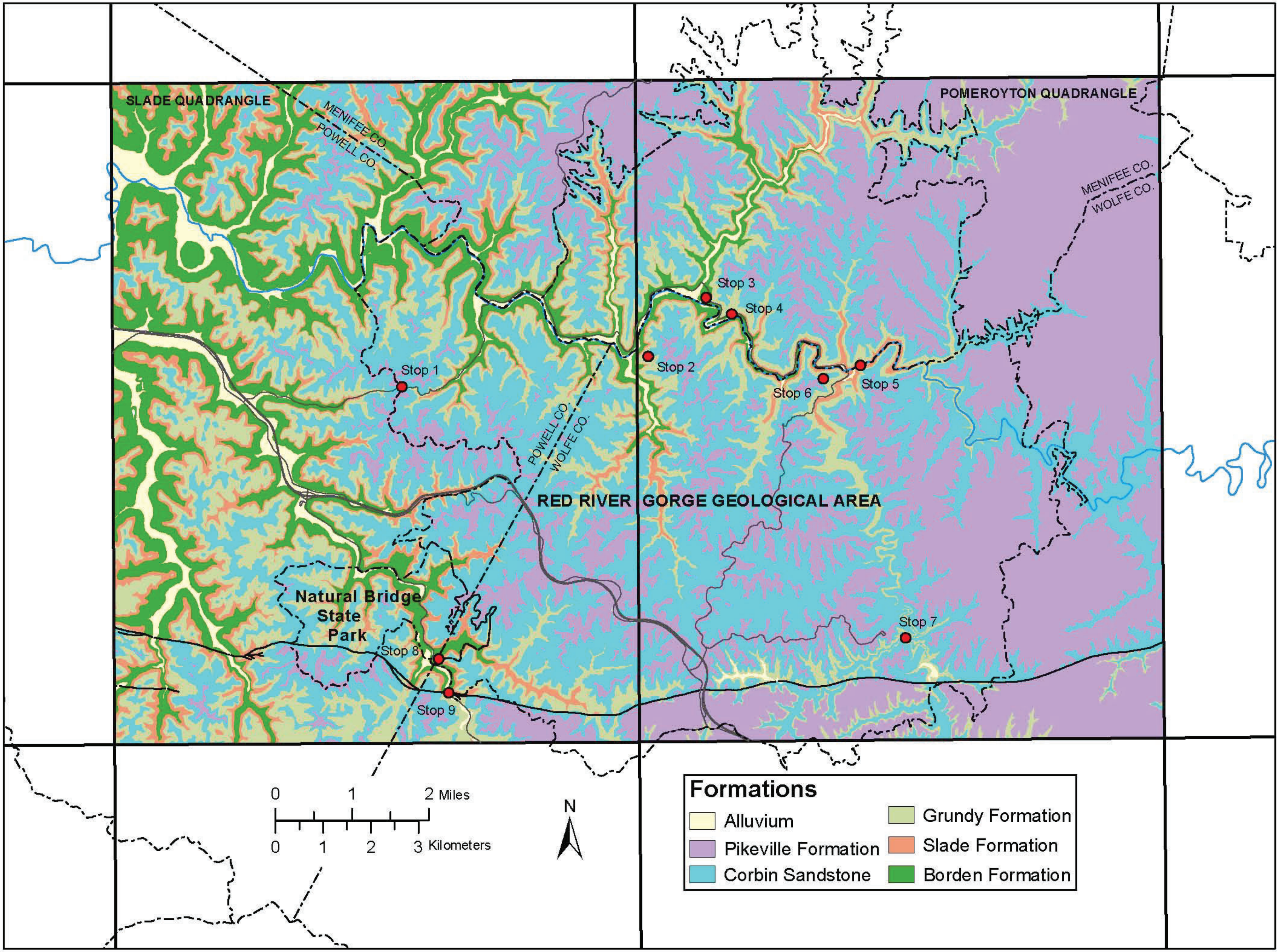


The geologic age of rocks is discriminated using twelve time periods and the Precambrian from the geologic time scale (Fig. 1). Originally, the periods were established through relative means and their ages were only very approximately known, but because of radiometric dating the ages of the period are known much more precisely as shown below in Figure 1. All the rocks in the Gorge are either Mississippian (354–323 million years) or Pennsylvanian (323–290 million years. In particular, the Mississippian rocks at the base of the Gorge belong to the upper part of the Borden Formation (siltstones and shales) and are about 340 million years old. The overlying limestones and dolostones of the Slade Formation range in age from about 340–330 million years old. In contrast, the overlying Pennsylvanian sandstones and conglomerates of the Lee Formation are about 311 million years old. The nearly 19-million-year time gap between the Slade and Lee formations is the result of a period of deep Early Pennsylvanian erosion that destroyed most of the intervening sedimentary deposits.—*Frank R. Ettensohn*

Fig. 1. Geologic time scale (http://3dparks.wr.usgs.gov/haywardfault/images/timescale_small.jpg)

Geologic Map

A geologic map is a map which shows geologic information at the surface. Most importantly, such maps show the distribution, nature and age of rock units, typically formations, at the surface. In the Red River Gorge-Natural Bridge area, five major rock units are present, the Mississippian Borden and Slade formations and the Pennsylvanian Grundy, Corbin Sandstone, and Pikeville formations (see attached map). In all of the valley bottoms, recent sediments deposited by streams are mapped as Alluvium (see attached map).—*Tom Sparks and Frank R. Ettensohn*



SLADE QUADRANGLE
POMEROYTON QUADRANGLE
MENIFEE CO.
POWELL CO.
MENIFEE CO.
WOLFE CO.
POWELL CO.
WOLFE CO.
Stop 1
Stop 2
Stop 3
Stop 4
Stop 5
Stop 6
Stop 7
Stop 8
Stop 9
RED RIVER GORGE GEOLOGICAL AREA
Natural Bridge State Park
0 1 2 Miles
0 1 2 3 Kilometers
N
Formations
Alluvium
Pikeville Formation
Corbin Sandstone
Grundy Formation
Slade Formation
Borden Formation

Honeycomb or Cavernous Weathering

Weathering of the sandstones may liberate silica (SiO_2), calcium carbonate ($CaCO_3$), or various iron compounds in solution that tend to form a crust on the surface of the rock once the dissolving water evaporates from the surface. This crust or case-hardened outer shell on the surface of the rock can help to protect the rock form additional weathering. However, once weathering agents break through this outer shell, the softer inner core of the rock is exposed and sand grains are loosened and carried away. As a result, hollows and recesses (Fig. 1) continue to enlarge as individual grains are carried away by water and wind. The result is a series of hollow depressions called honeycomb weathering, cavernous weathering, talfoni, or alveolar weathering (Fig. 1). In some situations, mineral-filled bedding planes or joints may create linear or angular margins for some of the cavities. Cavernous weathering is a common feature in the ridge-top sandstones in the Red River Gorge-Natural Bridge area.—*Frank R. Ettensohn, R. Thomas Lierman and Charles E. Mason*

Fig. 1. Honeycomb or cavernous weathering at Natural Bridge. The size of the weathering cavities in this exposure is controlled by crossbeds and bedding planes.

Joints

A major component of the formation of natural arches in the area is the distribution, spacing, and orientation of joints or fractures in the rock. Joints are natural breaks in the rocks that form conduits through which water can flow, and subsequently freeze and thaw (see Fig. 7a in the field guide). Joints in the area form as a result of stress-relief exfoliation and tectonic forces. Jointing parallel to the ridge weathers to create "fins" or rock walls that define the sides or boundaries of the arches (see Fig. 8 in the field guide). Vertical joints also form perpendicular to the ridges or rock wall, and may expand preferentially near the middle or bottom, resulting in the formation of a natural arch (Wilber, 2007). At least one well-defined perpendicular joint usually bounds the arches in the Natural Bridge State Park/Red River Gorge/Clifty Wilderness areas.

Strike and dip measurements taken on joint surfaces can be plotted on a Rose diagram to show the orientation of fractures or joints (Fig. 1). A Rose diagram is used, as opposed to a stereo net, because most of the joints are vertical, and it is a convenient way to represent the joint orientations. These joint orientations also provide clues as to the regional fracture trends in the area. If you compare the joint orientations (Rose diagrams) with topography, you will also notice a correlation with the orientations of streams and ridges and the orientation of the joints. Although there is a wide range of joint orientations, the most dominant orientation of the joints in this area is northeast and northwest. —*Steve L. Martin*

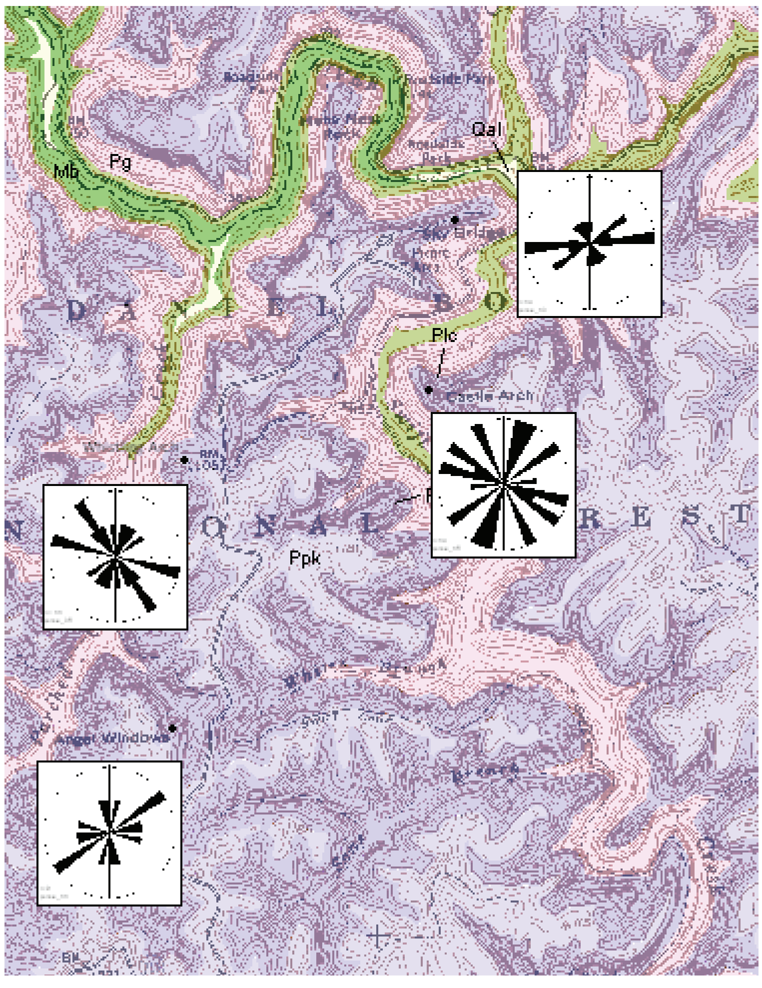


Fig. 1. Geologic map of part of the Pomeroyton quadrangle showing joint orientations (Rose diagrams) for Sky Bridge, Castle Arch, Whistling Arch, and Angel Windows. The map units Qal refers to alluvium, Mb refers to the Borden Formation, Pg refers to the Grundy Formation, Plc refers to the Corbin Sandstone Member of the Grundy Formation, and Ppk refers to the Pikeville.

Liesegang Banding

Fig. 1. Liesegang banding at Natural Bridge.

Colored or compositional rings or bands (Fig. 1) formed in a fluid-saturated rock lacking convection due to rhythmic precipitation. They were formed deep underground by the rhythmic deposition of various iron and manganese compounds from mineral-rich solutions. For this phenomenon to occur, a fluid containing a salt must be introduced into a colloidal suspension within a porous medium (such as this coarse sandstone). Most of the iron and manganese salts were derived from the dissolution of older iron- and manganese-bearing minerals originally …fluid and the colloid causes the precipitation of …dissolved salt reaches a supersaturated level. The precipitation at regular intervals, or rhythmic banding, depends upon the rate of diffusion of the entering mineral-rich solutions versus precipitation of the oxide precipitates. The banded patterns commonly appear polygonal or take on geometric designs that reflect nearby joint patters along which the salt-containing fluid entered. Such Liesegang patterns are very common in the thick jointed sandstones on the ridgetops. The phenomenon was named after the German chemist Raphael E. Liesegang who discovered it in 1896. Banded rocks that have particularly pleasing color patterns are sometimes collected, cut, polished, and sold in local rock shops and gift stores as "picture rocks." These can resemble surreal looking seascapes or landscapes.—*Frank R. Ettensohn, R. Thomas Lierman and Charles E. Mason*

Mineral

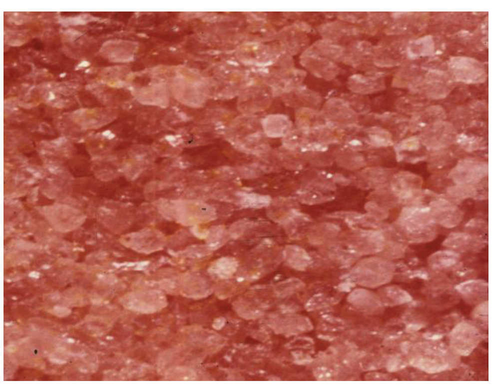


Fig. 1. Grains of the mineral quartz cemented together to form the rock sandstone.

A mineral is a naturally occurring, inorganic, crystalline element or chemical compound with a characteristic chemical composition and a set of distinctive physical and chemical properties. Minerals form as a result of natural geologic processes, but similar substances formed as a result of artificial or human-made processes are not considered to be minerals. Minerals are the basic building blocks of rocks, so that rocks consist of natural combinations of one or more minerals. Commonly, the rocks are formed of small grains of minerals that are inter-grown or cemented together; the grains are commonly so small that they may not be visible. The most common minerals in the Red River Gorge-Natural Bridge area are quartz (SiO_2) (Fig. 1), calcite ($CaCO_3$), and dolomite [$CaMg(CO_3)_2$]. Small quartz grains are the major constituents of the siltstone and sandstones in the area (Fig. 1); small calcite grains are major constituents of limestones; and dolomite is the major constituent of the yellowish-orange dolostones in the area. Dark reddish-brown nodules that occur in some of the sandstones and siltstones in the area are sometimes called ironstone and are composed of the mineral siderite ($FeCO_3$); whereas many of the pale yellowish-orange and brown encrustations on the local sandstones are composed of the minerals limonite [$FeO(OH) \cdot nH_2O$] and hematite (Fe_2O_3), respectively, due to weathering. —*Frank R. Ettensohn*

Natural Arches and Bridges

The state of Kentucky has the second or third most natural arches in the country, with Utah being the first, and probably Arizona containing the next most abundant natural arches (Wilber, 2007). Natural Bridge State Park, Red River Gorge Geological Area, and Clifty Wilderness Area in eastern Powell, western Wolfe, and southern Menifee Counties contain well over 200 natural arches (Patrick, 2002, 2004, 2005).

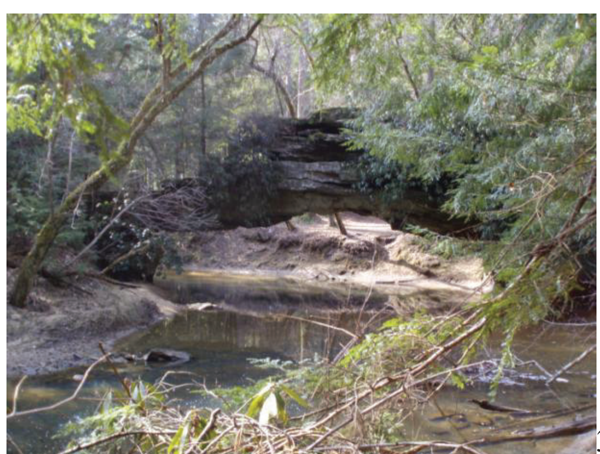
A natural arch is a rock exposure in which a hole has completely formed through it by the natural, selective removal of rock, leaving a relatively intact frame. A natural bridge is a type of natural arch that has been formed by water or spans a stream or ravine. Water, gravity, temperature fluctuation, or tectonic pressures are the principal forces involved in the carving of natural arches out of rock. Wind is not a significant factor in their formation, but has a polishing effect after a natural arch has formed (Wilbur, 2007). Most of the arches in eastern Kentucky form in the Corbin Sandstone, with a few forming in the Grundy Formation. The Corbin Sandstone is a pebble conglomerate that is cemented with limonite (Weir, 1974; Weir and Richards, 1974). Limonite is an iron oxide that is very resistant to weathering. Because of the fluvial nature of this deposit, some beds contain a higher concentration of limonite than others. Natural arches are abundant in this region because of the limonite concentrations in the Corbin Sandstone, which affect the differential weathering of this unit. Just as important to the formation of arches in the Corbin Sandstone is the orientation and distribution of joints, which act as a conduit for water to flow.

Different types of classification schemes have been used to describe the arches in the Natural Bridge/Red River Gorge/Clifty Wilderness areas. The arches in the area have been informally classified as lighthouse arches, ridgetop arches, buttress arches, waterfall step arches, and waterfall arches (McFarlan, 1954; Ruchhoft, 2009). The Natural Arch and Bridge Society have set forth guidelines to classify natural arches based on observable attributes. The observable attributes fall into five categories: contextual, morphologic, metric, geologic, genetic, and maturity. Based on NABS taxonomy, some of the types of natural arches and bridges that occur in the Natural Bridge State Park/Red River Gorge/Clifty Wilderness areas are shelter natural arch, pillar natural arch, buttress natural arch, cave natural arch, and waterfall natural bridge.

Shelter natural arches are the most common and most mature in the area. This type of arch occurs on ridgetops and is usually the result of a cavity merger or wall collapse (Fig. 1). Cavities (rockhouses) form on opposite sides of a narrow ridge that is bounded by joints. Differential erosion deepens these cavities. These cavities eventually join to create an opening (lighthouse). Compressive strengthening then acts to resist subsequent erosion. Shelter natural arches typically have a semicircular aperture. The span of an arch is the minimum/maximum of the lengths of the horizontal projections of the chords of all opening orbits. In other words, from a set of maximum measured chord lengths, the span is the minimum value. Examples of shelter natural arches in the area are Double Arch, Natural Bridge, Sky Bridge, and Star Gap Arch.

Pillar natural arches are also the result of a cavity merger, and the lintel is always vertical. Examples of pillar natural arches are Hidden Arch and the smaller arch at Sky Bridge (Fig. 1). Buttress natural arches form at the end of a wall or vertical slab of rock. Examples of buttress natural arches in the area are the larger arch at Angel Windows, Gray's Arch, and Indian Arch (Fig. 2). Henson's Arch, near Natural Bridge State Park, and Moonshiner's Arch are examples of a cave natural arch. Cave natural arches result when the roof collapse occurs over a cave. Natural bridges also occur in the area, with Rock Bridge, Silvermine Arch, and Whittleton Arch being examples of waterfall natural bridges (Fig. 3). Remember, it's called a natural bridge if it was formed by water or the arch spans a ravine or stream.—*Steve L.Martin*

Fig. 1. Shelter natural arch and smaller pillar arch at Sky Bridge. The span of the smaller pillar arch is approximately 19 feet, and the span of the larger shelter arch is approximately 97 feet.



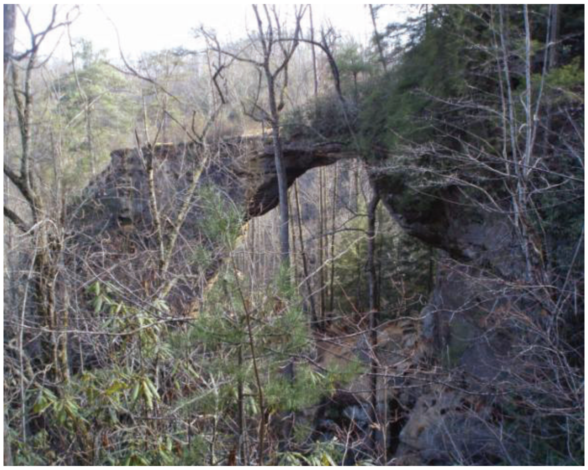


Fig. 2. Gray's Arch is an example of a buttress natural arch. Gray's Arch has a span of approximately 76 feet.

Fig. 3. Rock Bridge is one of the few natural bridges in the area. Rock Bridge has a span of 60 feet.

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Railroads

Fig. 1. Red River and Beattyville Southern No.2.

Considering how remote the Natural Bridge and Red River Gorge areas were in the late 19th and early 20th centuries, Powell, Menifee, Wolfe, Lee, and Breathitt Counties have a rich railroad history. No less than 28 railroads are known to have existed in these five counties, but this report will discuss only those railroads closest to the Natural Bridge State Park and the Red

River Gorge Geological Area. In a time when the first state road did not reach the Natural Bridge area until 1924 and a trip from Whitesburg to Jackson could take 7 days, these railroads were important to the people of the region. They provided jobs and transportation in a region where roads were still thought to be primitive to nonexistent. These included several logging railroads near the Natural Bridge area that were built solely to move forest products and one that was built to transport cannel coal. All but one of the roads in the area connected with the dominant railroad in the region, the Kentucky Union Railway. Without a known exception, these logging railroads used climax or shay locomotives, which were designed to conquer the steep grades, sharp curves, and less-than-optimum track common to such railroads. For those who are interested, pictures of these types of locomotives are plentiful on the Web. Even now, the ghosts of these railroads are still with us. Several of the State and county roads in this area are built on parts of the rights-of-way that belonged to these railroads. Information for this discussion is from Herr (1964), Sulzer (1967), and Klein (1972).

The Kentucky Union Railway

The Kentucky Union Railway was chartered by the Kentucky Legislature on March 10, 1854. This was an ambitious project, with plans to build from a junction with the Elizabethtown, Lexington, and Big Sandy Railroad at Hedges station, 7 miles east of Winchester through Powell, Wolfe, Breathitt, Perry, and Letcher Counties to Cumberland Gap, thence through Virginia to Big Stone Gap and Abingdon. The company was content to buy up tracts of coal and timber land and survey possible routes for the railroad until the railroad was finally incorporated in 1872. Construction of the railroad began in 1886, when 14.7 miles of railroad were built from Hedges to Clay City. By July of 1891, the Kentucky Union had built a Lexington to Jackson mainline that was 92 miles long. A trip for passenger trains between the two cities was scheduled to take about 3 or 4 hours. The line required the construction of six tunnels. It is the second, a 750-foot tunnel at Natural Bridge in Powell County, and the third, an 1,110-foot tunnel at Torrent in Wolfe County that are of interest to us. The station for Natural Bridge and a picnic shelter were built just south of the second tunnel. The land that was to become Natural Bridge State Park was a part of the lands purchased by the company. The Kentucky Union maintained the station and a large picnic area there and ran profitable Sunday excursion trains to the area from Cincinnati every summer. These trips were to continue on the Lexington and Eastern Railway and the Louisville and Nashville Railroad until 1926, when the L&N sold the land to the Commonwealth of Kentucky so that a park could be established there.

The economic realities of railroad construction had become obvious some 5 months before the track had entered Jackson when the Kentucky Union had been forced into receivership. A foreclosure sale was held in March of 1884 and the railroad was reorganized as the Lexington and Eastern Railway on October 16, 1884. The L&E successfully operated the line until November, 1910, when 100 percent of its capital stock was purchased by the Louisville and Nashville Railroad. The Lexington and Eastern carried 173,000 passengers and moved 254,000 tons of freight in its last full fiscal year, which included 8,105 tons of bituminous coal and 57,780 tons of cannel coal, and earned a profit of $73,136.36.

This stock transaction placed the L&E under the control of a strong, profitable and well-capitalized railroad. Even though the property was not officially conveyed to the L&N until October 15, 1915, the L&N immediately launched its plan to expand into the eastern Kentucky coal fields by extending the L&E's main line southeast from Jackson. The line reached Hazard on June 17, 1912; Whitesburg on October 20, 1912; and farther into Letcher County to the end of the line at McRoberts on November 23, 1912. By then, the L&N had determined that most of the L&E trackage west of Jackson was unsuitable for the efficient movement of heavy coal trains and had begun to build a new low-grade line from Winchester to Jackson. The opening of the new line for business on May 14, 1916, sealed the doom of the L&E trackage. With mainline traffic following the new route, the local traffic left to support the line declined steadily from 1916 through the Great Depression years. The L&N finally applied to the Interstate Commerce Commission for permission to abandon the L&E, now called the Maloney Branch, between Winchester and Fincastle. Permission was granted in 1942, and the U.S. government's War Production Board promptly requisitioned all the steel on the line in July 1942 for the war effort. The rails had been pulled up and the bridges demolished and cut up into small pieces suitable for shipment on the L&N by December of 1942. Approximately 8,840 tons of high-grade railroad steel and iron were thus obtained for the war effort by scrapping 46.6 miles of the Maloney Branch. The remaining 6 miles to the junction with the new mainline at Maloney was abandoned in 1947. Between Winchester and Maloney, only the tunnels remain.

The Mountain Central Railway

The Mountain Central Railway was a narrow-gauge (36-inch versus 56½-inch standard gauge) logging railroad that ran for 12 miles from Campton Junction, 0.3 mile west of Natural Bridge station to Campton. It was built by the Swan-Day Lumber Company, which owned a large sawmill in Clay City. The railroad originally ascended a series of switchbacks up Whittleton Ridge to Mountain Top and then back down to the Red River. When the timber in that part of the Red River Gorge was exhausted, the railroad built a new line from Mountaintop to Campton, reaching the latter in the fall of 1907. The line featured rickety bridges, steep hills, and sharp curves, but it also featured great scenic beauty, including a view allowing passengers to look straight through the space below Natural Bridge. The railroad's fortunes waned after the first State road reached Campton in 1924, despite a small oil boom in the area during the 1920's. The Mountain Central ceased operation in 1928 and was scrapped in 1930. Part of the old right-of-way is now the Whittleton trail at Natural Bridge State Park.

The Big Woods, Red River & Lombard

The Big Woods, Red River & Lombard Railroad was a narrow-gauge (36-inch-wide track) railroad that was in operation from 1902 to 1909. The railroad originally built from a junction on the L&E at Lombard, approximately 5 miles north of Natural Bridge, and ran 15 miles into the Red River Valley to Big Woods in Menifee County. Big Woods Lumber Company owned the BW, RR & L and a saw mill at Lombard that was supplied by the logs hauled by the railroad. This may have been an extension of the Big Woods Railway, which was apparently owned by a company named Lombard and Clay. That railroad also started at Lombard, was 10.5 miles long, used the same 36-inch gauge, and was in operation from 1900 to 1902. Sometime later, a new line was built by the BW, RR & L to relieve the severe grades of the original line to Lombard. This line bored through Tunnel Ridge and made junction with the L&E at Nada, 0.5 mile east of Lombard. The passage of the first train to use the tunnel proved to be an embarrassment to the railroad when a load of logs got stuck in the tunnel and had to be dynamited to free the train. This was the origin of the Nada tunnel, which is still used as an access point to Red River Gorge.

The Dana Lumber Company

Another logging operation in Nada was the Dana Lumber Co., which operated a standard-gauge railroad of undetermined length from 1906 to 1914, after which the company was sold to the Brodhead-Garret Lumber Company. Brodhead-Garrett operated the road from 1914 to 1917. Little else seems to be known about these companies.

D.H. Eastin & Co. Railroad

D.H. Eastin & Co. was a partnership between four of the Eastin brothers: Dudley, Charlie, Sim, and Gus. The Eastins were associates of Floyd Day, owner of the Mountain Central Railway, and had been involved in the lumber business for some years when Gus Eastin acquired the timber rights to 123 acres located on the Smokey Fork and Middle Fork of Lower Devil's Creek in southwestern Wolfe County, about 3 miles from the nearest rail line. A side track was laid on the L&E at a point 1 mile south of the Torrent tunnel and named Walker's Switch. A saw mill and lumber storage yard was established at this point. Three miles of railroad were built from Walker's Switch across Big Andy Ridge to Eastintown, where another saw mill was placed. Wooden tram roads built for horse and mule-drawn cars radiated out from the railroad to assure a steady flow of timber to the saw mills. Most eastern logging railroad construction techniques were primitive, but this railroad gave new meaning to the phrase "rough and ready." Almost no grading was done, the railroad mostly being supported by trestles measuring from a few inches high to tens of feet high, and even the rails were made of wood. To reach the top of Big Andy Ridge from Walker's Switch required two switchbacks, after which the railroad went through a deep cut across the top of Big Andy Ridge and descended down the Eastintown side of Big Andy Ridge to the Lower Devil's Creek area with the assistance of six switchbacks. What a ride it must have been! Operations began in 1893. Additional tracts of timber were acquired as the original lease was cleared. When that timber had been cleared, an additional 800 acres were logged for Floyd Day under contract. By May of 1902, this stand of timber was exhausted and the railroad was shut down.

The Red River & Beattyville Southern

The Red River & Beattyville Southern was a narrow-gauge railroad owned by the Ridgewood Lumber Co. and after 1902 by the Eastern Kentucky Stave Co. It made junction with the L&E Railway at Ridgewood Junction, 5 miles south of Natural Bridge, and ran for 7 miles to Ridgewood in Estill County. This is another logging road that apparently used rails produced from wood. The RR&BS operated from 1898 to 1909. Its locomotive eventually ended up on the Mountain Central Railway.

The Ohio & Kentucky Railway

The Ohio & Kentucky Railway was built by the Kentucky Block Cannel Coal Co., which had leased 5,400 acres of coal reserves in the area of Caney. Construction commenced in October 1889 at O&K Junction, about 1.4 miles west of Jackson on the L&E Railway. The line worked its way along the Wolfe-Breathitt and Morgan-Magoffin County lines and the 26 miles to Cannel City was finished on June 10, 1901. The railroad's sharp curves, two tunnels, and the use of switchbacks on the steepest grades presented severe operating problems and caused several wrecks. These drawbacks did not prevent the O&K from becoming the preeminent cannel coal carrier in the United States for several years. The company eventually decided to expand their railroad and formed the Caney Valley Railroad Railway to construct the extension in 1910.

Construction began immediately and the line was quickly extended a further 12.8 miles to the Licking River before the end of 1911. The O&K was abandoned after the coal and timber reserves were exhausted in 1938. The last train ran on November 1, 1938.

The Red River Valley Railroad

Only one railroad approached the field trip area from the north. The Red River Valley Railroad was incorporated in Menifee County in 1898. It had originated as a 2½-mile-long narrow-gauge railroad that was built from Rothwell to the top of the unnamed ridge south of the town by an unknown lumber company circa 1893. This venture was not successful and the assets of that company were acquired by the Union City Lumber Co., which had large timber reserves in the area around Big Amos Creek. The existing part of the railroad, which included four switchbacks, was retained and new trackage was built 6½ miles along the ridge to a point south of Frenchburg that was christened McCausey. Two miles west of McCausey, at Amos, a branch was built 5 miles south to a point just north of the Powell County line called Apperson. Logs and lumber hauled by the Red River Valley reached the outside world through a junction with the Chesapeake & Ohio's Kentucky & South Atlantic branch, which ran from Rothwell to Mount Sterling to a junction with the C&O's Ashland-Lexington line. It was necessary to transload the cargo of each narrow-gauge RRVR car onto a standard-gauge C&O car before the loads could be shipped out of Rothwell. The Red River Valley Railroad was scrapped in 1911 after the timber had been removed.—*Robert R. Daniel*

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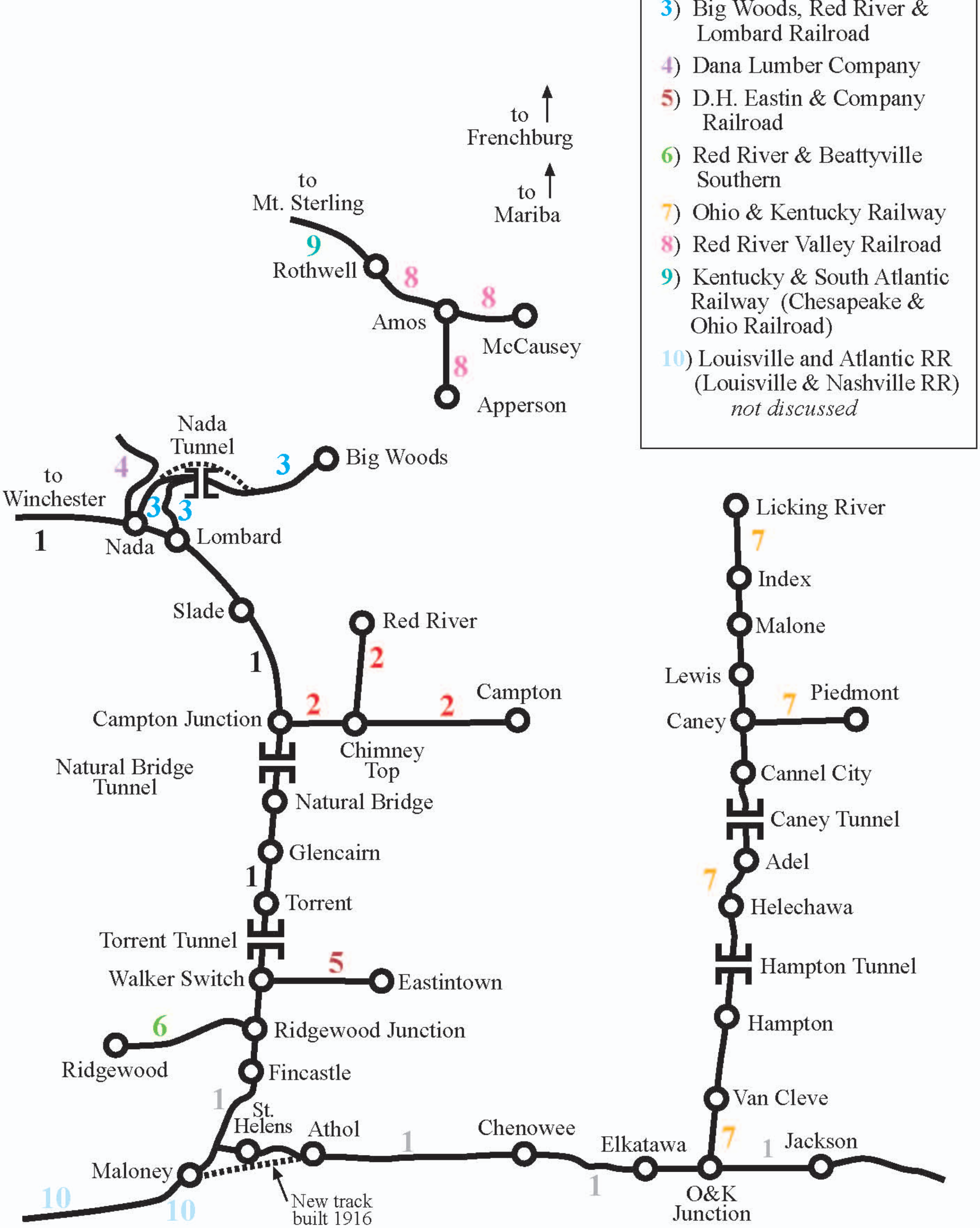
Railroads
of the Natural Bridge and Red River Gorge Area



Rocks

Sandstone is a sedimentary rock composed of grains 0.0625–2 mm in diameter. Like sand, sandstone may be any color, but the most common colors are tan, brown, yellow, red, gray and white. The spaces between grains may be empty or filled with either a chemical cement of silica or calcium carbonate or a fine-grained matrix of silt and clay particles. The principal mineral constituents of the grain framework are quartz, feldspar, and rock fragments. Sandstones allow percolation of water and other fluids and are porous enough to store large quantities, making them valuable aquifers and petroleum reservoirs. Most sandstones in the Red River Gorge area are yellowish orange in color.

Siltstone is a sedimentary rock composed of grains 0.0039–0.0625 mm in diameter. Siltstone is typically found as shades of gray to brown in color. It is primarily composed (greater than 2/3) of silt-size particles. Siltstones differ significantly from sandstones due to their smaller pores and for containing a significant clay fraction. Although often mistaken for shale, siltstone lacks the laminae which are typical of shale. Siltstone tends to weather at oblique angles unrelated to bedding. Most siltstones in the Red River Gorge are bluish gray in color.

Shale is a sedimentary rock composed of a majority of grains less than 0.0039 mm in diameter. Typically, shales in the Red River Gorge area are gray to black in color. Shales are primarily composed of a fine-grained mix of clay particles and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. The ratio of clay to other minerals is variable. Shale is characterized by a parallel layering (laminae) or bedding less than one centimeter in thickness, called fissility.

Conglomerate is a sedimentary rock that formed by the cementation of rounded cobble- and pebble- size rock fragments which are 4–256 mm in diameter. Calcite, silica, and iron oxides typically fill the spaces between fragments to form the solid rock. In the Red River Gorge area, conglomerates are typically associated with sandstones and are a similar yellowish-orange color. The formation of conglomerates is commonly related to transportation by rivers and ocean waves.

Limestone is a sedimentary rock that is composed of the mineral calcite, which is calcium carbonate ($CaCO_3$). In the Red River Gorge, they are white to gray in color. 80–90% of limestone grains are skeletal fragments of marine organisms such as coral or foraminifera. Other common grains include ooids or peloids. Some limestones do not consist of grains at all and are formed completely by the chemical precipitation of calcite or aragonite (i.e., travertine, which is found in caves). Limestone may contain variable amounts of silica in the form of chert (flint), which often occurs as nodules. Limestone can easily be dissolved by acids, and if you drop vinegar or a weak acid on limestone it will fizz.

Dolostone is a sedimentary carbonate (related to limestone) rock that contains a high percentage of the mineral dolomite. Most dolostone formed as a magnesium replacement of limestone or lime mud prior to lithification (becoming a rock). It is resistant to erosion and can either contain bedded layers or be unbedded. Dolostones often have a sugary texture and commonly weather to a buff, orange, or brown color caused by iron carbonate in the rock. Dolostone fizzes very slowly in dilute hydrochloric acid and is slightly heavier and harder than limestone. Dolostones in the Red River Gorge area are typically a yellowish-orange color.

Chert, often called flint, is a very hard sedimentary rock that is usually found in nodules in limestone. Chert is light gray to dark gray and/or pink to red in color and is composed of silica (SiO_2). The silica was probably derived from the skeletal remains of ancient sea sponges or other ocean animals; it was secondarily dissolved from these remains and moved in solution to replace parts of the calcite skeletal remains of other organisms. All of the chert in the Red River Gorge occurs as bands and nodules in the limestones. In the Gorge, these bands are typically black to red in color. Chert breaks to form sharp, conchoidal fractures, making it widely used by ancient people to fashion arrowheads, spear heads, and knives.—*Sam K. Williams*

Rockfall

Rockfall is an erosional process involving the rapid downslope movement or freefall of blocks of rock, largely independent of each other. The surface of rupture is typically a nearly vertical joint plane on a steep cliff face, and the rock movement may be straight down or in a series of leaps and bounds down a slope. Rockfall may be facilitated by pressure release, freeze and thaw or root activity along joints; undercutting of a steep cliff by a stream or human activity may also enhance the process. The large blocks of sandstone along the side of the road (Fig. 1) and in the stream valley (Fig. 2) in the Gorge are the product of earlier period of rockfall. Rockfall was a major erosional process in shaping Red River Gorge.—*Frank R. Ettensohn*

Fig. 1. Rockfall blocks of sandstone along the roadside in Red River Gorge.

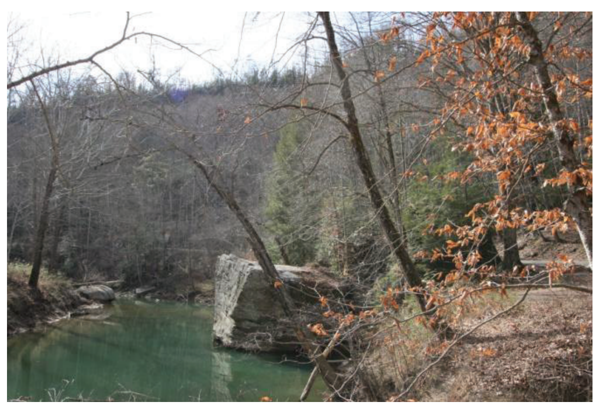


Fig. 2. Rockfall blocks of sandstone along the stream in Red River Gorge.

Seismite is a geologic word derived from the Greek word *seismos*, meaning shaking, shock or earthquake, and the Latin suffix *–ite*, meaning mineral, rock or rock-like. The term was coined by Seilacher (1969, 1984) for any features preserved in the rock record that are interpreted to have had an earthquake origin. Most commonly these features were produced in sediments that were not fully lithified (turned into rock) prior to an ancient earthquake event. High pressures generated by the passage of earthquake waves caused these still soft sediments to severely deform, producing contortions called soft-sediment deformation (Fig. 1). Although ancient earthquakes (paleoseismicity) caused much of the soft-sediment deformation seen in the geologic record, other causes are possible. At places where we believe that ancient earthquakes were the most likely cause of this deformation, we may call these rocks *seismites*. In the Red River Gorge-Natural Bridge area, seismites are commonly present in the lowermost limestones of the Slade Formation. They occur as round, elongate, or elliptical bodies of structureless, yellowish-orange dolomite [$CaMg(CO_3)_2$] that appear to randomly interrupt the limestone beds. These bodies are interpreted to have come from water-saturated beds of carbonate mud ($CaCO_3$) that were moved from the original site of deposition and forcefully injected at other locations by ancient earthquake waves; they were later altered to dolomite during the lithification (rock-making) process. Seismites like this are present in the limestones at Stop 9, and this particular type of seismite has been called an injection roll (see Fig. 10 in the field guide).

Fig.1 Soft-sediment deformation from the Lexington Limestone, Paris, KY. The folded, contorted beds are parts of a seismite from the Cane Run Bed.

Stratigraphy

One of the most fundamental properties of sedimentary rocks is their tendency to occur in distinct layers or in beds. There exists an entire branch of geology called **stratigraphy** that is dedicated to the study of stratified rocks. It not only examines the succession and age relations of various rock layers but also examines their overall shape, geographic distribution, lithology *(what kind of rock it is?)*, fossil content, along with their geophysical or geochemical properties, and tries to interpretation these in terms of its environment of deposition and geologic history.

In order to communicate with fellow scientists and to aid in the mapping and study of these rock units, geologists give names to the various layers. The most important of these is a rock unit is called a **formation**. This is the fundamental formal unit of lithostratigraphic classification and is used worldwide. A formation is defined solely on the lithologic characteristics of the rock without regard to its age or fossil content. The only other criteria a formation must have is that it must be mappable at the earth's surface (at whatever scale it is being used) or traceable in the subsurface. Formations may be combined into larger subdivisions called **Groups** or they may be subdivided into smaller units called **Members**. A hierarchical arrangement of these lithostratigraphic units is as follows.

Group -
Formation -
Member -
Bed –

Lithostratigraphy of the Red River Gorge Geologic Area

Below you can see the general stratigraphy of Mississippian and Pennsylvanian age rocks in the area of the Red River Gorge and Natural Bridge Resort State Park.

Pennsylvanian *(318 to 299 million years ago)*
Breathitt Group

Grundy Formation

Corbin Sandstone (100 and 280 feet)

The cliff forming rocks that cap most of the ridges in the Red River Gorge area are known as the Corbin Sandstone. The Corbin was previously considered a member of the Lee Formation but is now classified as a part of the Grundy Formation (Chesnut, 1992). The Corbin in this area is a very fine to medium-grained, cross-bedded sandstone that is locally conglomeratic. The conglomeratic lenses and layers found in the Corbin are composed of quartz pebbles that are dominantly between ⅛ to ½ inches in diameter. The unit generally weathers a reddish brown to grayish orange color. This is the featured unit in Stops 1, 6, and 7.

Grundy Formation (30 to 220 feet)

The Corbin Sandstone is underlain by shales, siltstones, and thin coals belonging to the Grundy Formation (Weir, 1974; Weir and Richards, 1974). This unit was previously mapped as the lower tongue of the Breathitt Formation. Chesnut (1992), however, placed this interval in with the Grundy Formation and elevated the Breathitt to the status of a group (see figure below). This portion of the Grundy Formation is not very well exposed and generally forms vegetated slopes beneath the Corbin. The base of the Grundy in this area is an unconformity that rests on top of the Mississippian. The extreme variability in the thickness of the Grundy is thought to be the result of past erosion/incision by the overlying Corbin, as well as erosion into underlying Mississippian strata by the Grundy.

Mississippian *(359 to 318 million years ago)*

Paragon Formation (0 to 35 feet)

The Paragon Formation is the uppermost Mississippian (upper Chesterian) strata preserved in the field trip area. The Paragon was previously called the Pennington Formation but was renamed by Ettensohn and others in 1984. The Paragon mostly consists of variegated red, green, and gray shales, sandstones, siltstones, and thin limestones. West of the gorge the Paragon is up to 35 feet thick (Weir, 1974), but in the area of the gorge the unit has been erosionally removed by overlying Pennsylvanian strata (this is why it is shown in figure below).

Slade Formation (0 to 120 feet)

The Slade Formation was named by Ettensohn and others (1984) for units previously called the Newman Limestone and the Renfro Member of the Borden Formation. The Slade is dominated by carbonate rocks (limestones and dolostones) with only minor amounts of shale. We'll be able to see several members of the Slade Formation at Stops 6, 8, and 9. This includes the Tygarts Creek, Mill Knob, St. Louis, and Renfro Members. The Tygarts Creek Member is a white, medium to coarse grained, oölitic limestone that it may occasionally exhibit cross-bedding. The Mill Knob Member is a series of interbedded limestones and dolostones that can contain lenses of reddish chert. The limestones tend to be fine-grained and light gray in colored whereas the dolostones are more silty and weather to a grayish orange color. The St. Louis Member is a light-colored, micritic, limestone that contains laminated micritic (caliche) crusts along its upper surface. It may also contain reddish colored chert and silicified fossils including colonial rugose corals. The Renfro Member is an orange-weathering, silty, dolostones to dolomitic limestone.

Borden Formation.

Nada Member (20 to 50 ft)

Below the Slade Formation lies the Nada Member of the Borden Formation. The Nada consists of shales and siltstones. The shales tend to be a greenish-gray to a purplish gray. Siltstones are more calcitic or dolomitic and are commonly bioturbated. Fossils can locally be very abundant. The unit is very nicely exposed the along Mill Creek Lake spillway, at Stops 8 and 9.

Cowbell Member (70 to 180 ft)

The Cowbell consists of interbedded siltstones and shales. Siltstones are green to brown-gray or even purple-gray. They are also highly bioturbated and fossils can be locally very abundant. This unit is poorly exposed in the area of the gorge and tends to form vegetated slopes. The unit is also well exposed the along Mill Creek Lake spillway, at Stops 4, 8 and 9. —*R. Thomas Lierman*

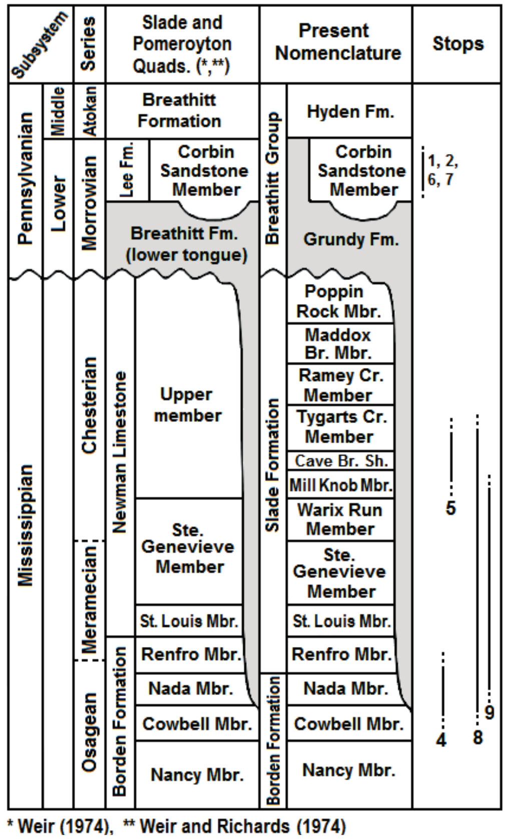


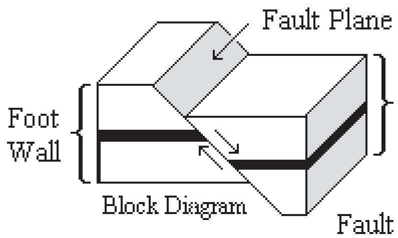
Fig. 1. Rock units (stratigraphy) in the Red-River Gorge-Natural Bridge area.

Structures

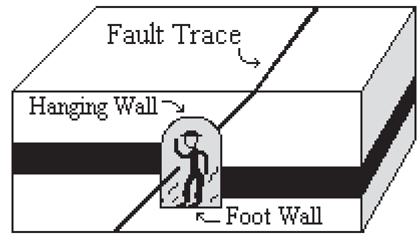
Structural geology is the study of the form, arrangement and internal structure of rocks; in particular it deals with the way rocks are deformed. **Crustal deformation** is a general term use to describe the process of folding, faulting, or shearing of rocks as the result of forces acting on the Earth's crust. The forces responsible for bending and breaking rocks are call **stress**. The Earth is continually being subjected to various types of stress. We define stress as the set of forces that act on rocks and in the process changes the rock's shape or volume. When rock is subjected to stress that is greater than the strength of the rock itself, it will begin to deform by either folding or by breaking. Three types of directed stress can be recognized:

1. **Tensional stress** (⇐ ⇒) acts to extent the Earth's crust or to pull it apart, these forces are directed towards one another.
2. **Compressional stress** (⇒ ⇐) acts to shorten the Earth's crust, these stresses are directed towards one another.
3. **Shear stress** (⥢) causes two adjacent parts of the Earth's crust to slide past one another.

Faults are a fractures in the earth's crust in which there has been differential movement of the rock on either side of the fault. Movement along a fault is the primary cause of earthquakes. In order to understand the various types of faults we encounter in nature, we need to review some of the fundamental terminology associated with faulted structures.



Fault Terminology

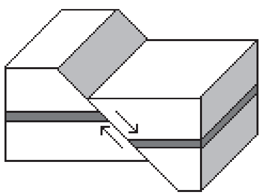


Faulted Area
(with Mine Shaft)

* **Hanging Wall**: the section or rock or block that lies immediately above an inclined fault plane.
* **Foot Wall**: the section or rock or block that lies beneath an inclined fault plane.
* **Fault Plane**: the surface of breakage along which movement has occurred of a fault.
* **Fault Trace**: the intersection of the fault plane with the surface of the earth.

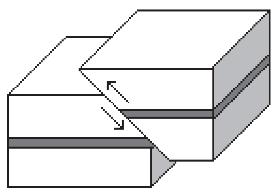
Types of Faults:

Normal Fault



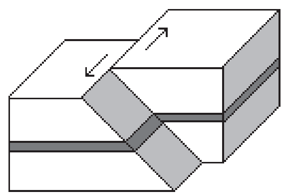
Tensional stress
(⇐ ⇒)

Reverse Fault



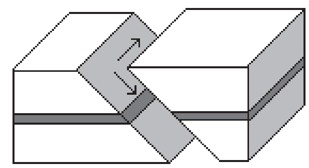
Compressional stress
(⇒ ⇐)

Strike-Slip Fault



Sheer stress
(⇋)

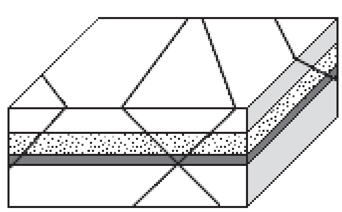
Oblique Slip Fault



Combination of Stresses

1. **Dip-Slip Faults**: a fault in which the movement is parallel to the dip of the fault, movement is mainly vertical. This includes both Normal and Reverse Faults
   a. **Normal Faults** (**Gravity Fault**): a fault in which the hanging wall above the fault plane has moved down relative to the foot wall. **Tensional stress** (⇐ ⇒) is primarily responsible for the formation of normal faults, ex. the Kentucky River Fault System or Lexington Fault System in central Kentucky.
   b. **Reverse Faults**: a fault in which the hanging wall above the fault plane moved up in relation to the footwall. A **Thrust Fault** is simply a low angle reverse fault. **Compressional stress** (⇒ ⇐) is primarily responsible for the formation of most reverse faults, ex. Pine Mountain Thrust Fault in southeast Kentucky.
2. **Strike-Slip Faults**: a fault in which movement is horizontal. **Sheer stress** (⇋) is primarily responsible for the formation of strike-slip faults, ex. San Andreas Fault, southern California.
3. **Oblique-Slip Faults**: a fault showing both horizontal and vertical movement.

C. **Joints** are fractures in a rock along which there has been no movement. —*R. Thomas Lierman*



Joints

Unconformities

Unconformities are major breaks or gaps in the geologic record, in which one geologic rock unit is overlain by one that is not next in the normal stratigraphic succession. The surface separating these two units is said to be an **unconformity**, and the surface represents an interval of missing time and missing units. At Stop 4, Bell Falls, the Pennsylvanian Corbin Member unconformably overlies the Mississippian Cowbell Member. More than 200 ft of rock units, representing approximately 40 million years, are missing along this unconformity surface. The overlying Pennsylvanian Corbin Member represents a large river channel, and most of the missing section was probably eroded away at the base of the channel.—*Frank R. Ettensohn*

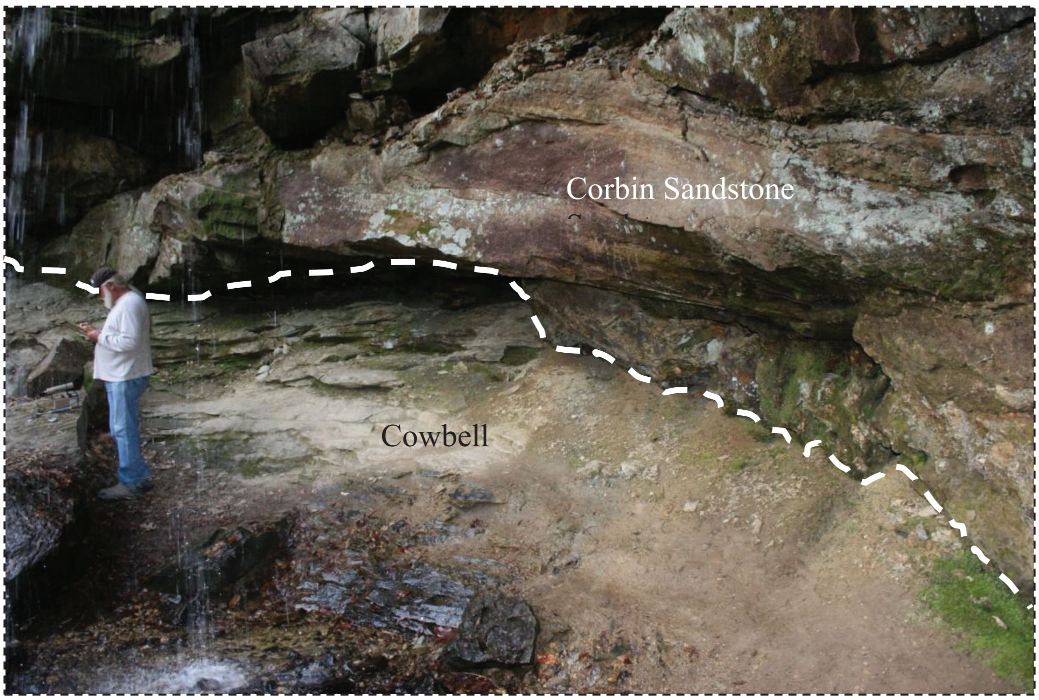


Fig. 1. Unconformity (dashed white line) at Bell Falls between the Cowbell Member and the Corbin sandstone.

Weathering and Erosion

Weathering is the physical breakdown (disintegration) and chemical alteration (decomposition) of rock at or near the Earth's surface. Mechanical weathering is responsible for breaking the rock down into smaller and smaller pieces without altering or changing its chemical composition. There are four important physical processes that lead to the fragmentation or breakup of rock: frost wedging, unloading, thermal expansion, and biological activity. All four are important in the Red River Gorge and Natural Bridge State Resort Park area; however frost wedging and biological activity are the dominant two processes that can be observed here. An example of root wedging can be seen in Figure 1 which is a very common example of biological activity. Chemical weathering differs from mechanical

Fig. 1. Mechanical weathering of a sandstone boulder by root wedging at Natural Bridge State Park.

weathering in that it does change the chemical composition of the rock. A good example of mechanical weathering would be to tear a sheet of paper into pieces; the end result would be that you still have paper only many small pieces of it. However an example of chemical weathering using the sheet of paper would be to set it on fire; the end result here would be that you no longer have a piece of paper but only a thin sheet of ash. There are three important chemical processes that lead to the chemical breakdown of rock: dissolution, oxidation, and hydrolysis. All three are very important processes in the Red River Gorge and Natural Bridge State Resort Park. Dissolution is like salt disappearing in a pan of water on the stove and it is the chief process contributing to the formation of limestone caves (like "Moonshiners Arch"). Oxidation is the process that causes iron to rust and silverware to tarnish. This process contributes to the formation of such features found in the sandstone rocks as "liesegang bands" and "box work". Hydrolysis is best known as the chemical process that alters previously existing minerals to clays. It should here be pointed out that chemical and mechanical weathering work together to break down the rocks in the area and to form the physical part of the soils found in the region.

Erosion is the process that incorporates and transports weathered material from one area to another. The transporting or erosional agents are wind, water, ice, and gravity. All of these erosional agents have been active in this area however water and gravity have been the most dominant. It should here be pointed out that the material (such as rock and soils) which has been transported downhill by gravity is called **mass wasting**. There are many types of mass wasting such as rock avalanches, slides, and slumps to name a few. The clearest example that be observed in the gorge is “rock fall.”

Collectively the above processes are referred to as **external processes** as they occur at or near the Earth’s surface and are powered by energy from the Sun. It is these processes that are most responsible for what you see at present in the Red River Gorge and Natural Bridge State Resort Park, and they will continue to alter the scenery as days and years go by.—*Charles E. Mason*