

Geologic Resource Evaluation Scoping Summary Cumberland Gap National Historical Park

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The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park Service units with a geologic scoping meeting, a digital geologic map, and a geologic resource evaluation report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity for discussion of park-specific geologic management issues and, if possible, include a site visit with local geologic experts. The purpose of these meetings is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and potential monitoring and research needs. Outcomes of this scoping process are a scoping summary (this report), a digital geologic map, and a geologic resource evaluation report.

The National Park Service held a GRE scoping meeting for Cumberland Gap National Historical Park (CUGA) on June 6, 2007 at the park near Middlesboro, Kentucky followed by a park site visit on June 7, 2007. Tim Connors (NPS-GRD) facilitated the discussion of map coverage and Lisa Norby (NPS-GRD) led the discussion regarding geologic processes and features at the national historical park. Participants at the meeting included NPS staff from the park, Southeast Region, and Geologic Resources Division, geologists from the Tennessee Division of Geology, Virginia Division of Mineral Resources, and Kentucky Geological Survey as well as cooperators from Colorado State University and College of William and Mary (see table 1). This scoping summary highlights the GRE scoping meeting for Cumberland Gap including the geologic setting, the plan for providing a digital geologic map, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, lists of recommendations and action items, and a record of meeting participants.

Park and Geologic Setting

Cumberland Gap National Historical Park preserves a major thoroughfare through the Appalachian Mountains that was significant to the settlement of the nation's interior. Congress authorized this unit on June 11, 1940. This long narrow unit covers some 20,508 acres (with an additional 4,500 acres currently being acquired) of Cumberland Mountain along the borders of Kentucky, Virginia, and Tennessee. After the future boundary change, the park will extend southwestward from White Rocks overlook along Cumberland Mountain across the gap and into the Little Yellow Creek watershed beyond Fern Lake Reservoir. The national historical park sits within or just adjacent to 10 7.5-minute quadrangles of interest along the western edge of the Appalachian Mountains.

Regional dipping of stratigraphic units, geologic structures, and faulting in the area controlled the formation of Cumberland Gap. Cumberland Mountain sits between Pine Mountain and the Middlesboro syncline to the west and the Owen Valley anticline (Powell Valley anticline further north) to the east along a back thrust fault (Doublings fault zone) of the Pine Mountain thrust sheet. The Pine Mountain thrust sheet is a large mass of rock about 1,200 m (4,000 ft) thick that slid westwards along a detachment surface deep within the earth's crust during the formation of the Appalachian Mountains. Movement along local faults resulted in uplift and tilting of the originally horizontal rock layers. Internal stresses within the Pine Mountain thrust sheet caused the formation

of tear faults such as the Rocky Face Fault that runs through Cumberland Gap perpendicular to the Pine Mountain and Doublings faults. The deformation associated with the Rocky Face Fault created a local zone of weakness. This zone preferentially weathered in contrast to the rest of Cumberland Mountain. Wind and water carved the gap through this faulted zone.

Sharp cliffs, narrow ridges, notches, and steep v-shaped valleys characterize the landscape at Cumberland Gap National Historical Park. Exposed in the park and surrounding areas are geologic units primarily Devonian, Mississippian, and Pennsylvanian in age. Black Devonian shale is the oldest unit in the park and only outcrops in the lowermost elevations. Deposited atop this unit were the cherts and limestones of the Mississippian Period, the dissolution of which formed caves such as Gap, Skylight, and Big Salt caves. Pennsylvanian-age sandstones support the ridgetops and form steep cliffs. Streams originating within the park including Martin's Fork, Shillalah, Devil's Garden, Sugar Run, Davis Branch, Lewis Hollow, and Station Creek cut steep valleys into the sandstones with many cascading waterfalls. The town of Middlesboro, Kentucky, just west of the national historical park, sits within an ancient meteorite impact structure. A ring of faults surrounds the structure and the rocks within the ring are intensely brecciated, deformed, and susceptible to erosion. Today's exposure was once 300 m (1,000 ft) or more below the original crater.

Geologic Mapping for Cumberland Gap National Historical Park

During the scoping meeting Tim Connors (NPS-GRD) showed some of the main features of the GRE Programs digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of GIS compatibility. The NPS GRE Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation set for the GRE Program. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcMap software. Final digital geologic map products include data in geodatabase, shapefile, and coverage format, layer files, FGDC-compliant metadata, and a Windows HelpFile that captures ancillary map data. Completed digital maps are available from the NPS Data Store at <http://science.nps.gov/nrdata/>.

When possible, the GRE program provides large-scale (1:24,000) digital geologic map coverage for each park's area of interest, usually composed of the 7.5-minute quadrangles that contain park lands (figure 1). Maps of this scale (and larger) are useful to resource management because they capture most geologic features of interest and are positionally accurate within 40 feet. The process of selecting maps for park management begins with the identification of existing geologic maps and mapping needs in vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data to be derived by GRE staff as well as determine areas in need of further mapping or refinement. Table 2 (at the end of this document) lists the source maps chosen for Cumberland Gap National Historical Park as well as any further action required to make these maps appropriate for inclusion in the final geologic map for the park.

Cumberland Gap National Historical Park expressed interest in obtaining map coverage for significant portions of their viewshed for interpretive programs. There are 10 7.5' quadrangles of interest: Kayjay, Middlesboro North, Varilla, Ewing, KY, Rose Hill, VA, Fork Ridge, Middlesboro South, Wheeler, TN, Coleman Gap, and Back Valley. At present, there is adequate geologic map coverage, completed by the U.S. Geological Survey, the Kentucky Geological Survey, the

Tennessee Division of Geology, and the Virginia Division of Mineral Resources (VDMR) for some of the quadrangles of interest (figure 2).

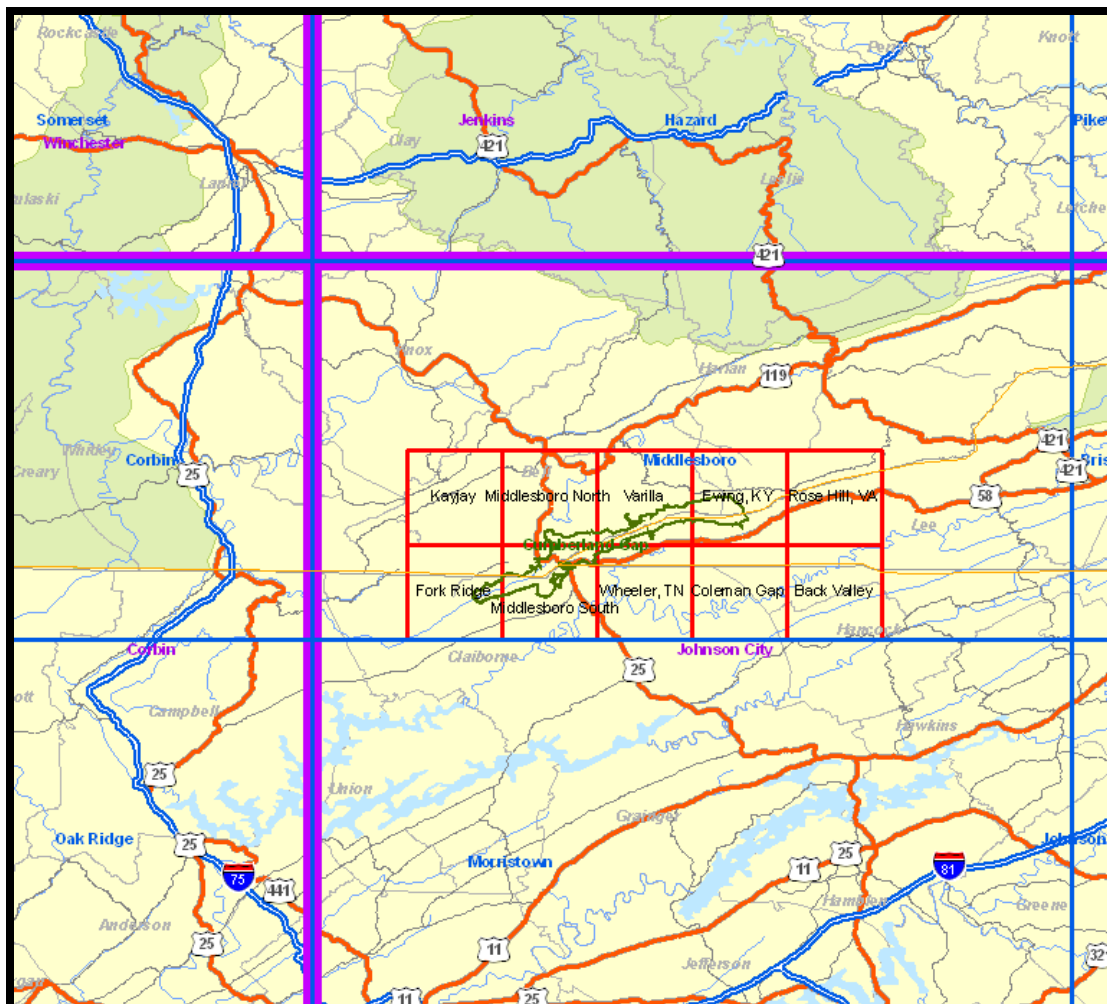


Figure 1. Quadrangles of interest for Cumberland Gap National Historical Park. The figure shows USGS 7.5' quadrangles (red outline), 30' × 60' sheet (blue outline, blue font labels), and 1° × 2° sheets (purple outline, purple font labels). The green outline is the CUGA boundary.

The following geologic maps were used to compile the CUGA digital geologic map:

- (GMAP 2477) Englund, K.J., 1964, Geology of the Middlesboro South quadrangle, Tennessee-Kentucky-Virginia, U.S. Geological Survey, GQ-301, 1:24000 scale
- (GMAP 2478) Englund, K.J., Landis, E.R., and Smith, H.L., 1963, Geology of the Varilla quadrangle, Kentucky-Virginia, U.S. Geological Survey, GQ-190, 1:24000 scale
- (GMAP 2479) Englund, K.J., Roen, J.B., and Delaney, A.O., 1964, Geology of the Middlesboro North quadrangle, Kentucky, U.S. Geological Survey, GQ-300, 1:24000 scale

- (GMAP 2480) Englund, K.J., Smith, H.L., Harris, L.D., and Stephens, J.G., 1963, Geology of the Ewing quadrangle, Kentucky and Virginia, U.S. Geological Survey, Bulletin 1142-B, 1:24000 scale
- (GMAP 2481) Harris, L.D., Stephens, J.G., and Miller, R.L., 1962, Geology of the Coleman Gap quadrangle, Tennessee and Virginia, U.S. Geological Survey, GQ-188, 1:24000 scale
- (GMAP 2482) Maughan, E.K. and Tazelaar, J.F., 1973, Geologic map of part of the Rose Hill quadrangle, Harlan County, Kentucky, U.S. Geological Survey, GQ-1121, 1:24000 scale
- (GMAP 2483) Rice, C.L. and Maughan, E.K., 1978, Geologic map of the Kayjay quadrangle and part of the Fork Ridge quadrangle, Bell and Knox Counties, Kentucky, U.S. Geological Survey, GQ-1505, 1:24000 scale
- (GMAP 8179) Harris, L.D., 1965, Geologic map of the Wheeler quadrangle, Claiborne County, Tennessee and Lee County, Virginia, U.S. Geological Survey, Geologic Quadrangle Map GQ-435, 1:24000 scale
- (GMAP 68208) Brent, W.B., 1988, Geologic Map and Mineral Resources Summary of the Back Valley Quadrangle, Tennessee Division of Geology, Geologic Quadrangle Map 161 SE, 1:24000 scale
- (GMAP 68311) Kohl, M.S.; Sykes, C.R., 1991, Geologic Map and Mineral Resources Summary of the Fork Ridge Quadrangle, Tennessee Division of Geology, Geologic Quadrangle Map 144 SE, 1:24000 scale
- (GMAP 69198) Crawford, M.M., 2003, Spatial database of the Rose Hill quadrangle, Harlan County, Kentucky, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_1121, 1:24000 scale
- (GMAP 69704) Conley, T.J., 2003, Spatial database of the Kayjay quadrangle and part of the Fork Ridge quadrangle, Bell and Knox Counties, Kentucky, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_1505, 1:24000 scale
- (GMAP 69705) Sparks, T.N.; Lambert, J.R., 2003, Spatial database of the Middlesboro North quadrangle, Kentucky, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_1663, 1:24000 scale
- (GMAP 69706) Mullins, J.E., 2003, Spatial database of the Ewing quadrangle, Kentucky-Virginia, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_172, 1:24000 scale
- (GMAP 69707) Johnson, T.L., 2003, Spatial database of the Varilla quadrangle, Kentucky-Virginia, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle

- (GMAP 69708) Thompson, M.F., 2003, Spatial database of the Middlesboro South quadrangle, Tennessee-Kentucky-Virginia, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_301, 1:24000 scale
- (GMAP 53392) Energy and Minerals Section, Kentucky Geological Survey, University of Kentucky, 10-May-2005, kyog83v10: Kentucky Oil and Gas Well Data, NAD 83 Version 10, Kentucky Geological Survey, Lexington, Kentucky

GRE staff compiled a digital geologic map in ESRI geodatabase format from these sources. It is available from

<http://science.nature.nps.gov/nrdata/quickoutput.cfm?type=ds&cat=geology&key=GRE&parkcode=CUGA> .

Units were correlated and reconciled across the multiple state boundaries (Kentucky, Virginia, and Tennessee) by examination of their geologic age and use of the USGS Geologic Lexicon of Stratigraphic Names database (http://ngmdb.usgs.gov/Geolex/geolex_home.html).

It has a Windows helpfile, FGDC-compliant metadata, ancillary information, and the following layers:

- Geologic attribute and observation localities
- Geologic point features
- Fossil localities
- Mine point features
- Map symbology
- Structure contours for Base Fire Clay coal bed
- Structure contours for Base Manchester coal bed
- Structure contours for Base Upper Elkhorn Number 2 (Jellico) coal bed
- Structure contours for Top Upper Elkhorn Number 2 (Jellico) coal bed
- Folds
- Faults
- Geologic contacts
- Linear geologic units
- Mine area feature boundaries
- Mine feature lines
- Geologic cross section lines
- Surficial contacts
- Geologic units
- Mine area features

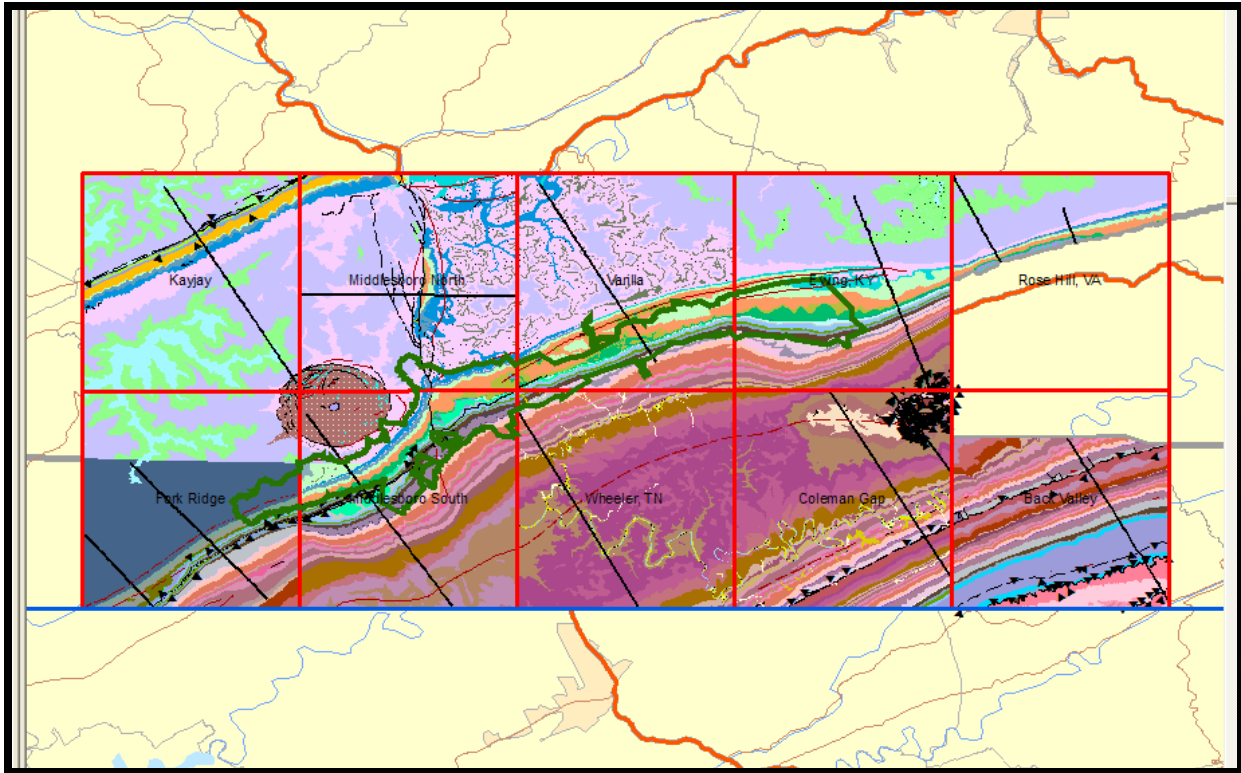


Figure 2. CUGA compiled digital geologic map

Table 2 lists the source maps chosen for Cumberland Gap National Historical Park and mapping needs in certain quadrangles, in addition to a unique “GMAP ID” number assigned to each map by GRE staff for data management purposes, map scale, and action items.

Additional items of interest pertaining to geologic mapping from the scoping

The national historical park has some interest in groundwater flow maps, additional fault mapping, cave and karst feature mapping, landscape evolution maps, mapping landslide areas, and detailed mine feature and oil and gas maps (especially in the Fern Lake Reservoir area).

If desired, map coverage needs persist in the Virginia portion of the Rose Hill 7.5 quadrangle. The VDMR has a draft version of the geologic map for the Middlesboro 30x60 sheet that also covers the Hubbard Springs quadrangle. This area is of interest to biologists and ecologists at the national historical park. Maps of landslide features in the quadrangles of interest exist for the national historical park, although it would be beneficial to park resource management if these were updated to reflect more recent slide events in the area. The Middlesboro 30x60 sheet contains coverage of recent landslide events in Virginia.

Geologic Resource Management Issues

The scoping session for Cumberland Gap National Historical Park provided the opportunity to develop a list of geologic features and processes, which will be further explained in the final GRE report. During the meeting, participants prioritized the most significant geologic issues as follows:

- (1) Fluvial issues and pH changes in surface waters
- (2) Cave and karst issues
- (3) Mass wasting
- (4) Disturbed lands and adjacent land use
- (5) Acquisition of Fern Lake and dam
- (6) Seismicity
- (7) Paleontological resources

Fluvial Issues and pH Changes in Surface Waters

Cumberland Gap National Historical Park contains the headwaters of several large streams. These high elevation streams are an important natural resource for the national historical park. Fluvial issues include riverbank and head-cutting erosion as well as unknown decreases in pH resulting in streams devoid of fish and other aquatic life. The pH of certain streams in the park including Martin's Fork and Shillalah Creek is 4.0. This is too low to sustain healthy aquatic communities. Acid rain may be a factor, but this alone cannot explain the high acidity. The local geologic setting may contribute to the low pH of certain streams. If sulfidic shales and coal beds are exposed to water, reactions between iron sulfide and water may release sulfuric acid into the stream water. If the cause for the acidity were due to the local geology, the streams should have always had low pH; however, these streams supported fish populations in the past. The park has at least a 15-year record of water quality for these streams. This issue requires further research at the national historical park.

The inherent steepness of the stream courses leads to high-energy instability along their corridors. During high flow events, the energy of the water may dislodge large boulders and slabs of rock. Streams such as Shillalah Creek contain blocks of cliff-forming sandstone as large as passenger busses that tumbled down the slopes after being undercut by erosion and dislodged by processes such as frost heave and root wedging (figure 3).



Figure 3. Large blockfall area along Shillalah Creek. Photograph is by Lisa Norby (NPS-GRD).

Caves and Karst Issues

Karst processes are active on the landscape at Cumberland Gap National Historical Park. Karstification involves the processes of chemical erosion and weathering of limestone or dolomite (carbonate rocks) (Palmer, 1981). Dissolution occurs when acidic water reacts with carbonate rock surfaces along cracks and fractures. At Cumberland Gap, karst dissolution occurs in the tilted Mississippian-age units that contain carbonate or carbonate cemented sandstone. Karst features include caves, conduits, sinking springs, gaps, pits, sinkholes, and springs. The high relief and tilted rock units in the area promotes the development of extensive cave networks. The significant cave resources at the national historical park are underutilized and understudied. Formerly called Cudjo's Cavern, Gap Cave became part of the park approximately 10 years ago and is gated and used for interpretive tours throughout the year. The cave includes beautiful cave formations also called speleothems (figure 4). Other caves include Salt Peter Cave, Skylight Cave (with a natural skylight a short distance from the entrance), and Big Salt Cave. Gap and Big Salt caves are connected into a cave network that is surveyed to be more than 22 km (14 miles) long (Jenny Beeler, professional communication, 2008).

The national historical park is aware of most, if not all, cave locations and is planning a formal cave inventory. There are at least 24 named caves located in Cumberland Gap National Historical Park. Gates block the larger openings to prevent visitor access and potential negative impacts on resources. Caves are at risk of vandalism, archaeological looting, and speleothem theft. Past vandalism is evident in most of the larger caves. Cave locations and maps are considered sensitive data by the NPS.

Caves provide habitat for unique species at Cumberland Gap including the threatened and endangered Indiana bat, amphibians, and beetles. There is no artificial lighting in the caves at the national historical park. This helps protect cave resources and maintain habitats for the cave-dwelling fauna. During the cooling periods of the Pleistocene Epoch, caves provided important habitat for animals and fossil remains may be present. The Cave Research Foundation found a black bear skeleton in one of the park caves in Virginia. Caves may also contain significant archaeological artifacts and cultural resources. Remnants such as torch fragments, flint chips, pottery shards, and basket remains are present in caves at the national historical park. In Soldiers Cave, American Civil War soldiers carved 19th century graffiti on the cave walls. A baseline inventory of all cave resources would be a useful data set for resource management.

Nearly a decade ago, the National Park Service and an advisory group of resource experts developed a cave management plan for Cudjo Cavern (Gap Cave). The Cave Research Foundation is starting to do GIS-based cave mapping, and is remapping Gap Cave. Detailed mapping of the smaller caves may reveal isolated biological communities with specialized species.

Sand Cave is a large rock shelter not related to karstification. Instead, this feature is in quartz arenite sandstone. The sandstone forms a steep cliff in the area. Erosion by seeping water and frost wedging removed the less resistant rock underlying the sandstone. This in conjunction with the regional dip of the geologic unit created the large rock overhang. It is the largest rock shelter in Kentucky.

In the Cumberland Gap area, the groundwater aquifer does not always correspond with the surficial drainage basin divides because of preferential flow through karst conduits and networks. Groundwater flows through dissolved conduits, emerging as springs such as the Cumberland Gap Spring located in Gap Cave in the park. The national historical park does not own the water rights to this spring. Lincoln Memorial University bottles this water for sale. Dye tracing studies can delineate the recharge area for a particular spring. The national historical park has interest in more dye trace work for the karst conduit networks throughout the area (contact: Joe Meiman).

Other hazards related with karst features include sinkhole development. The Lewis Hollow area has several sinkholes and sinking streams. Southeast-directed drainage in this area sinks below the ground.



Figure 4. Stalagmite in Gap Cave. Photograph is by Lisa Norby (NPS-GRD).

Mass Wasting

The steep landscape characteristic of Cumberland Gap National Historical Park is prone to mass wasting events such as landslides, block falls, slumps, and debris flows. Gravity, frost heave, root wedging, erosion, and karst dissolution are primary causes of natural slope instability. Features such as dipping geologic units, undercut sandstones, thick, weak shale units, and natural groundwater seeps create unstable settings on steep slopes. Human activities such as landscaping, road construction, and facilities development may lead to new mass wasting and reactivation of old landslide features. Developers may cut into the toe of a slope or load the top of a slope. Diverting water into certain areas may lubricate slopes. Recent mass wasting in the national historical park occurred at the entrance to the Wilderness Road campground, along the trail to Gap Cave, and near the Cumberland Gap tunnel as well as near the Thomas Walker parking lot and along a campground road in Lee County, Virginia. A slide prone area in Claiborne County required shotcrete and bolts to stabilize the slope. Spalling rocks (fractured limestone) near the exit of Gap Cave threaten visitor safety. A large rockfall event in 1999 prompted the construction of an engineered support structure. Two pillars support a rock slab that is already detached, poorly supported, and may fail. Loose boulders are also above the exit to the cave. These often fall onto the trail below the cave exit especially during heavy rainfall.

The Geologic Resources Division completed an evaluation of geohazards at Cumberland Gap National Historical Park. Following completion of the Cumberland Gap tunnel (see following section and references), restoration of the Wilderness Road across Cumberland Gap within the national historical park began in October 2001. The goal was to restore historical contours (ca. 1788) of the original routes through the gap (figure 5). Historic accounts and early photographs aided the restoration. This project involved removal of all traces of the previous highway including 9 m (28 ft) of fill material along 6.3 km (3.9 miles) and restoration of what is believed to be the historical trace of the road. The restoration did not completely remove old drainage structures from the highway. Now, these structures concentrate runoff and trigger mass wasting events. Slumping in this area disrupts the Wilderness Road trail requiring repeated maintenance of a section of slope approximately 45 m (150 ft) below the trail (figure 6). Visitors should be made aware of rockfall potential and warned about active slide and rockfall areas.



Figure 5. Restored Cumberland Gap along the Wilderness Road Trail. Note natural revegetation and steep slopes. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).



Figure 6. Area prone to slumping along Wilderness Road with rip rap installed in an effort to stabilize the slope. Photograph is by Lisa Norby (NPS-GRD).

Disturbed Lands and Adjacent Land Use

The Cumberland Gap tunnel opened in 1996, completing a rerouting project for Highway 58 and Highway 25E. The national historical park owns the tunnel, which crosses a large karst area. The states of Tennessee and Kentucky in addition to the Federal Highway Administration maintain the roadway. The tunnel sits on a suspended floor to allow it to accommodate any significant earthquake shaking. An impermeable layer lines the upper surface of the tunnel. The floor of the tunnel contains drainage tubes to channel subsurface water flow. The tunnel was built through heavily fractured rocks. During high precipitation events, water percolating down through the rocks can overwhelm the drainage system of the tunnel. This is causing local undercutting and may threaten the integrity of the road surface. The volume changes within the shrink-and-swell clays in the coal and shale geologic units around the tunnel also undermine its structural integrity. Ground penetrating radar and dye tracing indicate voids are developing beneath the roadway in addition to a naturally occurring cavern.

The outflow area for drainage from the tunnel is on privately owned land in Cumberland Gap, Tennessee. The area covers 24 acres. This land was previously the site of a construction debris

dump. The national historical park is concerned that the debris in this area may clog the drainage system for the tunnel.

Other disturbed lands include coal mines (described below), historic iron mines, nitre mines, old haul access roads, and perhaps a few sand and gravel quarries. Geologic units locally contain oolitic hematite deposits. These iron-rich deposits fueled early iron ore mining in the area. Pre-1900 iron furnaces in Middlesboro rivaled early Pittsburgh, but the local source of iron ore was insufficient to maintain production. Today, historic mine features related to early mining are along the Greenleaf trail, Chadwell Gap, and Honey Tree spur loop. Local miners also extracted potassium nitrate (saltpetre or “nitre”) from sediments in small caves and shelters in the area. Saltpetre is an oxidizing component that is combined with charcoal and brimstone (sulfur) to make black powder. Mining for saltpetre from cliff mines at Cumberland Gap peaked before the American Civil War. Remnants from this activity include the traces of a large haul system. Access roads cross through the rugged mountainous area and along the northwestern side of the Little Yellow Creek drainage. Some access roads are used by ATVs. These roads are prone to erosion resulting in increased sediment loads in park streams. The impact of these access roads is relatively limited.

The Chattanooga Shale contains organic deposits, which act as source rocks for oil and gas reservoirs in the Appalachian Basin. In the Cumberland Gap area, the shale is exposed, thus there is no potential for hydrocarbon extraction. It may serve as a useful model analog for other, buried shale beds. Surrounding areas may be of some interest to oil and gas development in the future. The only hydrocarbons commercially produced in Virginia came from Lee County in the Rose Hill and Jonesville area. There are oil and gas wells in Kentucky and Tennessee west of Cumberland Gap National Historical Park. Several oil and gas wells have been drilled in the Fern Lake area which is being acquired by the park. The location of private mineral rights in this area need to be confirmed by the NPS.

Acquisition of Fern Lake and Dam

Cumberland Gap National Historical Park is in the process of acquiring approximately 4,500 acres that includes the Fern Lake Reservoir and a large portion (~2,000 acres or nearly half) of the Little Yellow Creek watershed (figure 7). The dam is made of concrete and earth and includes a pump station. Water from Fern Lake Reservoir is a major water supply for Middlesboro. According to Public Law 108-199, if the park acquires Fern Lake, the rights to the water, along with the dam and all appurtenances associated with the withdrawal and delivery of water from the lake will be given to the city of Middlesboro, KY.

Past coal mining activity in this area may create resource management issues for the national historical park including acid mine drainage, shaft subsidence or collapse, and associated geologic hazards. The park did not obtain the mineral rights to this new addition and privately owned mineral resources may be a future target for mineral development (coal, oil and gas). The Surface Mining Control and Reclamation Act of 1977 controls surface coal mining and reclamation activities on both federal and non-federal lands. Surface coal mining includes activities conducted on the land surface in connection with a surface coal mine or surface operations and impacts associated with an underground mine. Section 522(e) of this Act contains provisions that protect “publicly owned parks” from adverse impacts of surface coal mining on lands within the boundaries of parks, unless there are “valid existing rights.” As recently as 1998, the National Park Service opposed local

surface coal mining within a prominent park viewshed. The national historical park has interest in knowing of any permit application activity in the Fern Lake area (within 8 km, 5 miles of the new park boundary). Gas wells are also be present in the acquisition area. The Geologic Resources Division is providing policy and technical support to parks involved with minerals development both inside and outside the parks.



Figure 7. View from Pinnacle Overlook to the southwest towards Fern Lake Reservoir. Note scars from surface coal mining on the neighboring slopes. Photograph is by Lisa Norby (NPS-GRD).

Seismicity

Earthquakes are not widely associated with the Cumberland Gap area, but small earthquake events are occurring along local faults. The Eastern Tennessee seismic zone has earthquake events that are detectable on the surface at the national historical park. Earthquakes take up tectonic stresses on basement structures deep beneath the earth's surface. The largest recent event was close to a magnitude 4 (on the Richter scale). The U.S. Geological Survey maintains an earthquake monitoring website: <http://earthquake.usgs.gov/eqcenter/recenteqsus/>. The KGS has a record of historic seismic locations for the state of Kentucky at the following website: <http://www.uky.edu/KGS/geologic hazards/index.htm>.

Paleontological Resources

The fossil resources at Cumberland Gap National Historical Park have yet to be comprehensively studied or inventoried. The Mississippian and Pennsylvanian units throughout the park contain abundant marine fossils including colonial corals, in addition to lepidodendron trunks and other plant remains. Fossils are often well-exposed on cave walls. Pleistocene fossil remains including a black bear skeleton were found in a Virginia cave within the national historical park. Other geologic structures such as karst traps (collapsed sinkhole), notches, and alcoves may contain vertebrate fossil remains. The National Park Service is compiling a paleontological inventory for the Cumberland Piedmont Network, based on literature research. A field inventory would be a helpful data set for resource management.

Features and Processes

Cumberland Gap and History

Cumberland Gap was a major transportation thoroughfare for explorers, Native Americans, settlers, traders, and soldiers. Migrating animals were the first to take advantage of the natural break or gap in the steep ridge of the Appalachian Mountains. Native Americans followed the game and later used the gap for trade and as a path to warfare. In 1750, Dr. Thomas Walker first explored the gap. Later, Daniel Boone marked out the first Wilderness Trail through Cumberland Gap opening Kentucky to settlers. Indian Rock, an isolated boulder down inside the gap, contains old scratches and graffiti from passersby. At the height of westward travel through the gap, there were likely dozens of different routes carved into the landscape. Today there are no known original intact segments of these routes.

The unique geology of the Cumberland Gap area promoted its historical development. The underlying geologic structures support different natural resources on either side of the gap. Access across the gap promoted trade of these resources and the development of industry in Middlesboro, Kentucky, and Cumberland Gap, Tennessee. The gap then allowed for the transportation of manufactured products towards the east and west thereby promoting the local economy.

During the American Civil War, the strategic importance of Cumberland Gap was obvious to both the Confederate forces and Union troops. It changed hands several times. Pinnacle Overlook sits near a natural chimney carved by frost wedging. This was another landmark for travelers approaching the gap and was a strategic high ground during the American Civil War. Troops used the Pinnacle area as a vantage point to guard the gap. The ridges were entirely cleared of trees to provide better strategic views. These slopes have since naturally revegetated. Along the trail to Tri-State Peak, a crater formed during a Union retreat is a visible scar on the landscape (figure 8). Union troops wished to leave behind no resources for Confederate troops so they chose instead to detonate their powder kegs here.



Figure 8. Small crater along the trail to Tri-State Peak formed by exploding munitions during the Union retreat from Cumberland Gap during the American Civil War. Photograph is by Trista L. Thornberry-Ehrlich (Colorado State University).

Middlesboro Meteorite Impact Structure

Although not located within national historical park boundaries, the circular impact structure in which sits the town of Middlesboro, Kentucky, is part of the park viewshed as well as an interesting interpretive geologic feature. Morning fog often settles into the circular structure visible from Pinnacle Overlook and other vantage points within the national historical park. The circular structure is clearly visible on geologic map and air photos. Geologists do not agree as to when this meteorite impact took place. Some surmise the impact structure was in place prior to the uplift of the Appalachian Mountains, whereas others define the possible age brackets as late Paleozoic to pre-Quaternary – a span of more than 250 million years.

Circular faults and fractures form outer and inner rings, defining the structure's extent. The center of the structure features a small uplift area that formed as a pop-up during the impact. Today, homes cover this small hill. Within the structure itself, the original rock units are deformed pervasively (figure 9). Textures include shocked quartz grains, chaotic breccias, and cone-in-cone structures (thin shale layers that resemble a set of nested cones). Due to this extensive deformation, the rocks within the structure are nearly unconsolidated, especially friable, and susceptible to erosion. The rocks exposed at the surface today were originally 300 m (1,000 ft) below the original crater.

Erosion removed the overburden. Mass wasting, slope creep, slumps, and landslides present serious geohazard issues for urban development within the impact structure, especially in areas near the edges of the structure where developers dig into steep slopes.



Figure 9. Exposure of intensely fractured rocks within the Middlesboro meteorite impact structure. Photograph is by Lisa Norby (NPS-GRD).

White Rocks

White Rocks towers 1,100 m (3,500 ft) above Powell Valley to the east forming a prominent historical landmark. During the early historical migrations through Cumberland Gap, the site of the white cliffs provided westward travelers the indication that they were only a day's journey away from the gap. Resistant Pennsylvanian-age sandstones comprise White Rocks.

The rock climbing interest in White Rocks prompts requests to the national historical park to permit climbing there. The long pitches and scenic value of the area is very attractive to these kinds of visitor uses. A well-organized climbing group from North Carolina notes that the rock is highly fractured and friable. Despite not being the best climbing medium, presumably, rock-climbing activity occurs sporadically without the consent of park management. Popular climbing areas can be overused and if climbing were allowed there would be the potential for degradation of the rock face from drilling anchors and for local vegetation to be trampled at the top and bottom of the routes

(Jenny Beeler, professional communication, 2008). Climbing would disturb delicate habitat along cliff faces and small alcoves. Through inventory projects including one by Appalachian State University, it is known that there are at least 14 different vascular plants associated with the cliffs, one of which is endangered (Jenny Beeler, professional communication, 2008). Forty-nine species of lichen thrive on the White Rocks; one species in particular is unique to the area.

Type Sections and Unique Features

Type sections refer to the originally described sequence of strata that constitute a geologic unit. It serves as an objective standard for comparison with spatially separated parts of that same unit. Preferably, a type section describes an exposure in an area of maximum unit thickness and completeness. Though not formal type sections, there are excellent quality exposures of Mississippian and Pennsylvanian geologic units in the national historical park. The Devonian-Mississippian Chattanooga Shale outcrops at the lowest elevations in the area. This black shale unit contains shrink-and-swell clays, uranium-rich minerals, and sulfides, in addition to being a source for radon. It is also a source rock for natural gas in the Appalachian Basin. It tends to be more petroliferous in Kentucky. It is structurally weak and is a regional slip surface prone to faulting and landsliding. Some local geologic units contain carbonate intergranular cements. These may be useful to buffer low pH surface water. Thin coal beds exist in shale-rich units and contain high iron and manganese contents. Other notable rock exposures include the Pennington Sandstone (contains expanding clays), the Lee Formation named for Lee County, and subunits including the Crab Orchard Sandstone, Middlesboro Member, Pinnacle Overlook Member. The names and definitions of units differ locally across state boundaries. The U.S. Geological Survey maintains a website pertaining to the descriptions and locations of type sections across the United States: <http://ngmdb.usgs.gov/Geolex/>.

Other unique features in the national historic park or surrounding areas subject to enabling legislation include many waterfalls, proto-arches (isolated small-scale arches may be present), Devil's Garden, Pinnacle Overlook, and peat bogs. Devil's Garden is a large boulder field formed by frost-wedging of Pennsylvanian conglomeratic rocks along oriented fracture sets. Melt water from snow and rain trickles through cracks in the rock and freezes at night during the colder months. The expansion of the ice in the cracks works in concert with tree and plant roots to wedge the rocks apart. Often slope creep then separates the rock masses into interesting configurations. Along the Martins Fork drainage on either side of the creek is the largest peat bog in the state of Kentucky. The underlying geology influenced the location of this bog. Peat bogs may contain paleoclimate information including pollen and plant remains. Decaying plant remains may also contribute to a lower pH in the Martins Fork drainage.

Recommendations

- (1) Perform further groundwater dye trace studies to understand the flow of groundwater in the national historical park and delineate the subterranean aquifers.
- (2) Use the KGS Geoportal online to access a variety of geologic information including local maps, GIS layers, aerial photographs, historic seismic locations, well sites, etc. as well as links to other Kentucky publications, records, and maps. Website is: kgsweb.uky.edu/main.asp
- (3) Perform a comprehensive paleontological inventory of the national historical park. Establish a plan to deal with potential illegal fossil collecting in the park.

- (4) Research the low pH streams occurring in the national historical park. High acidity may be due to myriad of factors including underlying geology, pine soils, highland wetlands, and acid rain.
- (5) Cooperate with the Cave Research Foundation and other agencies to perform comprehensive cave mapping at Cumberland Gap. Incorporate cave maps and locations into GIS.
- (6) Locate all vertebrate paleontological resources in caves.
- (7) Obtain University of Georgia vegetation maps for the park; these include recent aerial photographs, which may aid restoration efforts.
- (8) Consider reconstructing and reinforcing rock buttresses beneath the Wilderness Road trailbed to increase stability there.
- (9) Inventory all cliff areas within the national historical park focusing on rock quality, past recreational use, plant and lichen communities, and unique habitat.
- (10) Monitor all rockfall incidents to determine patterns and potential triggers. Focus on areas of high visitation such as Gap Cave.

Action Items

- (1) GRE staff will discuss promoting cave inventory with NPS-GRD.
- (2) GRE will produce digital geologic map for the national historical park (see above geologic mapping section).
- (3) GRE report author will consult the Cumberland Gap tunnel website:
<http://www.efl.fhwa.dot.gov/projects/cumgap/cumbgap.htm>
- (4) GRE report author needs to obtain the 1964 Englund map and a reference by Mitra in 1988 regarding the geologic setting and history at the national historical park.
- (5) GRD will consider a possible paleontological inventory for the national historical park.
- (6) GRE report author will attempt to obtain a copy of the cave management plan for the national historical park.
- (7) GRE report author will obtain Bulletin 52 by Butts (VDMR) regarding paleontological resources of Lee County.
- (8) GRE report author will obtain a copy of Zena Orndorf's VA Tech. PhD dissertation regarding acid-forming rocks that includes whole rock analyses for the area.
- (9) GRD will research mineral rights and mineral development in the Fern Lake expansion area.

References

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Table 2. GRE Mapping Plan for Cumberland Gap National Historical Park

GMAP ID	REFERENCE	scale	appraisal
2477	Englund, K.J., 1964, Geology of the Middlesboro South quadrangle, Tennessee-Kentucky-Virginia, U.S. Geological Survey, GQ-301, 1:24000 scale	24000	2007-0516: superceded by GMAP 69708
2478	Englund, K.J., Landis, E.R., and Smith, H.L., 1963, Geology of the Varilla quadrangle, Kentucky-Virginia, U.S. Geological Survey, GQ-190, 1:24000 scale	24000	2007-0516: should be superceded by GMAP 69707 (KYGS digital version)
2479	Englund, K.J., Roen, J.B., and Delaney, A.O., 1964, Geology of the Middlesboro North quadrangle, Kentucky, U.S. Geological Survey, GQ-300, 1:24000 scale	24000	2007-0516: superceded by GMAP 2484 and 69705
2480	Englund, K.J., Smith, H.L., Harris, L.D., and Stephens, J.G., 1963, Geology of the Ewing quadrangle, Kentucky and Virginia, U.S. Geological Survey, Bulletin 1142-B, 1:24000 scale	24000	2007-0516: should be superceded by GMAP 69706 (primarily; KYGS digital version) and should superce GMAP 7337
2481	Harris, L.D., Stephens, J.G., and Miller, R.L., 1962, Geology of the Coleman Gap quadrangle, Tennessee and Virginia, U.S. Geological Survey, GQ-188, 1:24000 scale	24000	2006-0111 : Heather Stanton working to acquire digital map versions from KYGS Matt Crawford for GRE conversion
2482	Maughan, E.K. and Tazelaar, J.F, 1973, Geologic map of part of the Rose Hill quadrangle, Harlan County, Kentucky, U.S. Geological Survey, GQ-1121, 1:24000 scale	24000	2007-0516: should be superceded by GMAP 69198 (KY digital version); make sure all attributes captured though
2483	Rice, C.L. and Maughan, E.K, 1978, Geologic map of the Kayjay quadrangle and part of the Fork Ridge quadrangle, Bell and Knox Counties, Kentucky, U.S. Geological Survey, GQ-1505, 1:24000 scale	24000	2007-0516: should be superceded by GMAP 69704 (KY digital version)
8179	Harris, L.D., 1965, Geologic map of the Wheeler quadrangle, Claiborne County, Tennessee and Lee County, Virginia, U.S. Geological Survey, Geologic Quadrangle Map GQ-435, 1:24000 scale	24000	2007-0516: not sure if it's digital
53392	Carey, D.I.;Nuttall, B.C., 1995, Distribution of oil and gas wells in Kentucky, Kentucky Geological Survey, Map and Chart Series MCS-11_009, 1:1000000 scale	1000000	2006-0628: KYGS supplied GRE staff with digital version (filename: kyog83)
68208	Brent, W.B., 1988, Geologic Map and Mineral Resources Summary of the Back Valley Quadrangle, Tennessee Division of Geology, Geologic Quadrangle Map 161 SE, 1:24000 scale	24000	2006-0111 : Heather Stanton working to acquire digital map versions from KYGS Matt Crawford for GRE conversion
68311	Kohl, M.S.;Sykes, C.R., 1991, Geologic Map and Mineral Resources Summary of the Fork Ridge Quadrangle, Tennessee Division of Geology, Geologic Quadrangle Map 144 SE, 1:24000 scale	24000	2006-0111 : Heather Stanton working to acquire digital map versions from KYGS Matt Crawford for GRE conversion
69198	Crawford, M.M., 2003, Spatial database of the Rose Hill quadrangle, Harlan County, Kentucky [The original, paper version of this product, and online images, are available], 137, Digitally Vectorized Geological Quadrangle DVGQ-12_1121, 1:24000 scale; http://kgsweb.uky.edu/PubsSearching/MoreInfo.asp?titleInput=5153&map=0	24000	2006-0111 : Heather Stanton working to acquire digital map versions from KYGS Matt Crawford for GRE conversion
69704	Conley, T.J., 2003, Spatial database of the Kayjay quadrangle and part of the Fork Ridge quadrangle, Bell and Knox Counties, Kentucky, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_1505, 1:24000 scale	24000	
69705	Sparks, T.N.;Lambert, J.R., 2003, Spatial database of the Middlesboro North quadrangle, Kentucky, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_1663, 1:24000 scale	24000	2006-0111 : Heather Stanton working to acquire digital map versions from KYGS Matt Crawford for GRE conversion
69706	Mullins, J.E., 2003, Spatial database of the Ewing quadrangle, Kentucky-Virginia, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_172, 1:24000 scale	24000	2007-0516: should supercede both GMAPs 2480 & 7337; 2006-0111 : Heather Stanton working to acquire digital map versions from KYGS Matt Crawford for GRE conversion
69707	Johnson, T.L., 2003, Spatial database of the Varilla quadrangle, Kentucky-Virginia, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_190, 1:24000 scale	24000	2007-0516: should supercede GMAP 2478; need digital files from Heather; 2006-0111 : Heather Stanton working to acquire digital map versions from KYGS Matt Crawford for GRE conversion
69708	Thompson, M.F., 2003, Spatial database of the Middlesboro South quadrangle, Tennessee-Kentucky-Virginia, Kentucky Geological Survey, Digitally Vectorized Geological Quadrangle DVGQ-12_301, 1:24000 scale	24000	2007-0516: should supercede GMAP 2477; need digital file

¹GMAP numbers are unique identification codes used in the GRE database.