National Park Service
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Natural Resource Stewardship and Science

Horseshoe Bend National Military Park

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2020/2158

ON THE COVER
The Tallapoosa River forms the namesake bend of Horseshoe Bend National Military Park. NPS photograph (from National Park Service 2014).

THIS PAGE
A reenactment cannon firing drill at Horseshoe Bend National Military Park. NPS photograph.

Horseshoe Bend National Military Park

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2020/2158

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Executive Summary

The Geologic Resources Inventory (GRI) provides geologic map data and pertinent geologic information to support resource management and science-informed decision making in more than 270 natural resource parks throughout the National Park System. The GRI is one of 12 inventories—including geologic resources, vegetation mapping, natural resource bibliography, water resources, vertebrates and vascular plants, climate, base cartography, air quality, and soil resources (see https://www.nps.gov/im/inventories.htm)—funded by the National Park Service (NPS) Inventory and Monitoring Program. The Geologic Resources Division of the NPS Natural Resource Stewardship and Science Directorate administers the GRI.

This GRI report synthesizes discussions from a scoping meeting held in 2012 for Horseshoe Bend National Military Park (referred to as the "park" throughout this report) and a follow-up conference call in 2018 (see Appendix A). Chapters of this report discuss the park's geologic setting and significance and draw connections between geologic and cultural resources, outline the geologic history leading to the present-day landscape, describe geologic issues facing resource managers, suggest future geologic investigations pertinent to the park's resources, and provide information about the previously completed GRI map data. A poster (in pocket) illustrates these data.

The Battle of Horseshoe Bend in central eastern Alabama shaped United States history in the 19th century. More than 3,000 fighters under the command of Andrew Jackson defeated 1,000 Red Stick Creek warriors who had fortified themselves on the inside of a bend in the Tallapoosa River. The battle effectively ended the Red Stick resistance. Shortly after the battle on 27 March 1814, Jackson forced Creek leaders to cede 1.9 million acres (770,000 hectares) to the United States, including part of what is now Georgia and much of Alabama. Jackson's success in the battle led to his promotion to major general and set his military career on a path that would lead to eventually becoming the seventh president of the United States. In the same way that the Battle of Horseshoe Bend would set the political stage for the next 200 years of American history, a geologic history of more than 300 million years shaped the landscape, setting the physical stage for the battle itself.

Deposition of the Emuckfaw sediments in the Cambrian–Ordovician Periods (541 million–444 million years ago), and continental collision and mountain building in the Early Mississippian Period (359 million–323 million years ago) resulted in a landscape underlain by different types of metamorphic rocks. Some of these rocks are harder than others and this directly influences the path that the Tallapoosa River takes on its eventual course to the Gulf of Mexico. In the vicinity of the park, the river flows around the hardest rocks, the ridge-forming outcrops of Jacksons Gap Quartzite (map unit **PCPZjgq**); directly over other hard rock, the Jacksons Gap Group (**PCPZjg**); and takes a winding, meandering path through the softest rocks, the Kowaliga Gneiss (**PCPZkg**) and the Emuckfaw Group (**PCPZeg**). It is in one of these meander bends that the Creek peoples fortified their final defense against the advancing forces of Andrew Jackson, whose superior numbers were able to break through the barricade. The Tallapoosa River is incised into these bedrock units, cutting slowly deeper but not developing new meander bends or oxbow lakes, and preserving the Horseshoe Bend as a slice of US history.

This report is supported by a GRI-compiled map of the geology of Horseshoe Bend National Military Park that covers the park boundary and the surrounding area. The GRI map was compiled from a 2012 map at 1:24,000 scale completed by Kevin Jones, an M.S. student at Auburn University. The spatial distributions and unit descriptions of the map units informed a discussion of geologic features, processes, and associated resource management issues in Horseshoe Bend National Military Park. See Geologic Map Data chapter for more information about the map.

Geologic features, processes, and associated resources management issues identified during the GRI scoping meeting and follow-up conference call include the following:

- Fluvial Features and Processes. Fluvial features are formed by flowing water, either constructing or eroding landforms. The Tallapoosa River forms the defining feature of the park, the Horseshoe Bend. Other fluvial features in the park include perennial, ephemeral, and intermittent streams and stream terraces. Fluvial processes are ongoing and dynamic, and may also be management issues. At Horseshoe

Bend National Military Park, potential management issues related to fluvial processes include erosion, mass wasting (gravity-driven transport of material), and flooding. Flood-level events cause erosion that threatens cultural resources along the Tallapoosa River. The vast majority of flooding in the park is a result of the Tallapoosa River's artificial flow regime, which is controlled by an upstream hydroelectric dam.

- Climate Change. Climate change models for Alabama suggest hotter conditions with more extreme storms. Higher temperatures could impact the type and amount of vegetation that currently stabilizes the river banks and prevents erosion. Extreme storms may increase runoff and severity of floods.
- Brevard Zone. The Brevard zone is a regional geologic feature that borders the park to the southeast and is a key component of the geologic history of Horseshoe Bend. The Brevard zone represents regional-scale faulting associated with mountain building, and is characterized by two rock types within the Jacksons Gap Group, undifferentiated phyllites and schists (**PCPZjg**) and a prominent ridge-forming quartzite (**PCPZjgq**).
- Cave Features and Processes. Caves typically form as part of a karst landscape where soluble rock is removed by flowing water. The bedrock in Horseshoe Bend National Military Park is non-soluble and does not host caves in the traditional sense. However, Wilson's Rock, an overhang of unknown cultural significance does fit under the broader heading of a cave feature.
- Seismic Activity. The park has a history of felt earthquakes, although is not considered to be at high risk of strong earthquakes. Seismicity could impact park resources, particularly if movement along faults led to changes in groundwater flows, which in turn led to a loss of water in wells.
- Mining and Minerals. The Brevard zone has historically been the site of minor gold production, although within the park no current plans for commercial mining and minimal recreational interest exist. A gravel pit to supply road material is one of two Abandoned Mineral Lands (AML) features in the park, neither requiring mitigation.
- Paleontological Resources. Fossils are evidence of life preserved in a geologic context. Fossils have not been documented in the park, but may exist in an archeological context. Fossils are non-renewable and are subject to science-informed inventory, monitoring, protection, and interpretation as outlined by the 2009 Paleontological Resources Preservation Act.

Appendix A of this report provides a list of people who participated in the scoping meeting for the park in 2012, as well as those who participated in a follow-up conference call in 2018. The list serves as a legacy document and reflects participants' affiliations and positions at the time of scoping and the conference call.

Appendix B of this report lists laws, regulation, and NPS policies that specifically apply to geologic resources in the National Park System. The NPS Geologic Resources Division can provide policy assistance and technical expertise, regarding the park's geologic resources.

Products and Acknowledgments

The NPS Geologic Resources Division partners with the Colorado State University, Department of Geosciences, to produce GRI products. The US Geological Survey, state geological surveys, local museums, and/or universities developed the source maps and reviewed GRI content. This chapter describes GRI products and acknowledges contributors to this report.

GRI Products

The GRI team undertakes three tasks for each park in the Inventory and Monitoring program: (1) conduct a scoping meeting and provide a summary document, (2) provide digital geologic map data in a geographic information system (GIS) format, and (3) provide a GRI report (this document). These products are designed and written for nongeoscientists.

Scoping meetings bring together park staff and geologic experts to review and assess available geologic maps, develop a geologic mapping plan, and discuss geologic features, processes, and resource management issues that should be addressed in the GRI report. Following the scoping meeting, the GRI map team converts the geologic maps identified in the mapping plan to GIS data in accordance with the GRI data model. After the map is completed, the GRI report team uses these data, as well as the scoping summary and additional research, to prepare the GRI report. The GRI team conducts no new field work in association with their products.

The compilation and use of natural resource information by park managers is called for in the 1998 National Parks Omnibus Management Act (§ 204), National Park Service *Management Policies 2006*, and the Natural Resources Inventory and Monitoring Guideline (NPS-75). The "Additional Resources" chapter and Appendix B provide links to these and other resource management documents and information.

Additional information regarding the GRI, including contact information, is available at http://go.nps.gov/gri.

Acknowledgments

The GRI team thanks the participants of the 2012 scoping meeting and 2018 conference call (see Appendix A) for their assistance with this inventory. Thanks very much to Kevin Jones, who produced the source map (Jones 2012) for the GRI GIS data of the park. Thank you to the reviewers of this report, especially Jake McDonald of the University of North Georgia for his comments on fluvial features and processes; and to Mark Steltenpohl of Auburn University, and Dane S. VanDervoort and John P. Whitmore of the Geological Survey of Alabama for the helpful review of the local and regional geology. Thanks to Stacy Speas of Horseshoe Bend National Military Park for her comments on the cultural and historical information included in this report. And a big thank you to Trista Thornberry-Ehrlich (Colorado State University) for creating many of the graphics used in this report.

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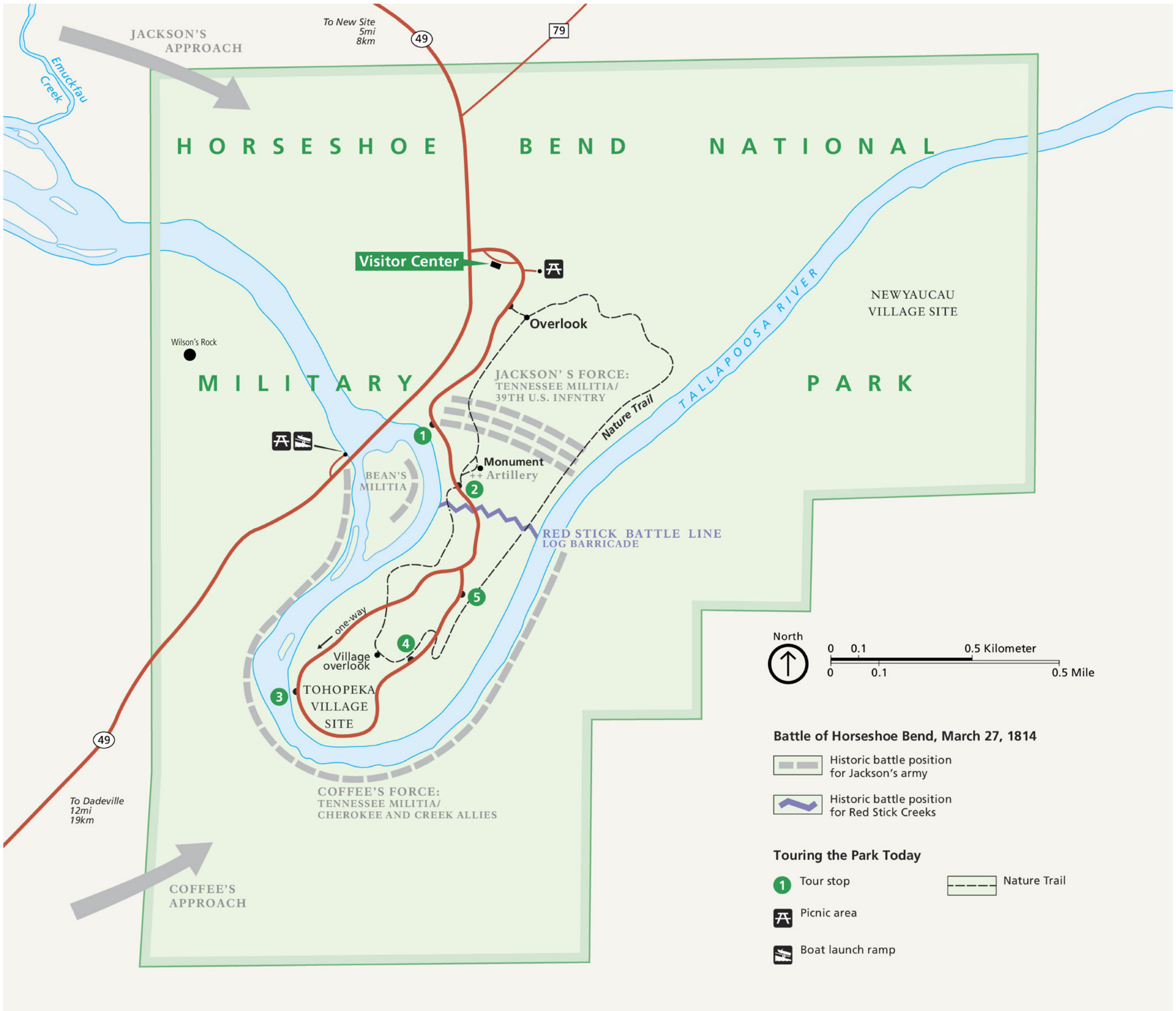

Figure 1. Map of Horseshoe Bend National Military Park.
The Tallapoosa River enters the park boundary on the northeast side and exists at the northwest. A walking tour of the park includes stops at sites important to the history of the park. National Park Service Map, available at https://www.nps.gov/carto/hfc/media/HOBEmap1.jpg.

Geologic Setting, History, and Significance

This chapter describes the regional geologic setting and history of Horseshoe Bend National Military Park and summarizes connections among geologic resources, other park resources, and park stories.

Park Establishment

Horseshoe Bend National Military Park (Figure 1) was established by presidential proclamation 3308 by Dwight D. Eisenhower on 11 August 1959. The park was established with the stated purpose to “preserve and protect the site of the last major engagement of the Creek War (1813-1814). The park interprets the events of the battle in the larger context of the War of 1812, as well as their impacts on the Creek people and the development of the United States.” The park gets its name from a bend in the Tallapoosa River where the battle took place on 27 March 1814, between US forces under the command of Andrew Jackson and Red Stick warriors, who had built fortifications on the inside bend of the river.

The park is distinctive in that it is the only National Park Service unit east of the Mississippi River to protect the site of a battle between an American Indian tribe and the US Military (National Park Service 2014). In addition to the site of the battle, the park also protects two Creek habitation sites, Nuyaka and Tohopeka. Nuyaka was burned by Georgia militia three months before the battle, and its inhabitants retreated to Tohopeka along with refugees from five other destroyed Creek towns where the Creek warriors and families prepared for the Battle of Horseshoe Bend.

Physiographic Setting

The park is situated in the southernmost extent of the Piedmont physiographic province (Figure 2), which spans roughly parallel to the Appalachian Mountains from Alabama to New York. The province consists of weathered metamorphosed sedimentary and igneous rocks; in the park, the igneous rocks have also been metamorphosed to gneiss (**PCPZkg**). The topography of the area is a result of the resistance to weathering of the different types of rocks. Softer rocks are eroded away and harder rocks remain to form ridges, including Cherokee Ridge along the southeast border of the park (see poster, in pocket). The paths of rivers are also controlled by the bedrock, with rivers more likely to take a meandering path through softer rock and to follow a more direct route over harder rock. This can be observed in the bend that gives the park its name.

There are two distinct lithologies in the park: the Emuckfaw Group (**PCPZeg**), a metasedimentary schist unit with metamorphosed igneous intrusions (the Kowaliga Gneiss, map unit **PCPZkg**); and the Jacksons Gap Group, a gradational tangle of metasedimentary schist and phyllite (**PCPZjg**) with ridge forming quartzites (**PCPZjgq**). The Emuckfaw Group is separated from the Waresville Schist (**PCPZws**) by the Brevard fault zone, which is characterized by sheared and faulted rocks of the Jacksons Gap Group. The fault zone is bounded on the north, and structurally lower, side by the Abanda fault; and on the south, and structurally highest, side by the Katy Creek fault. See Table 1 for detailed descriptions of the GRI GIS map units.

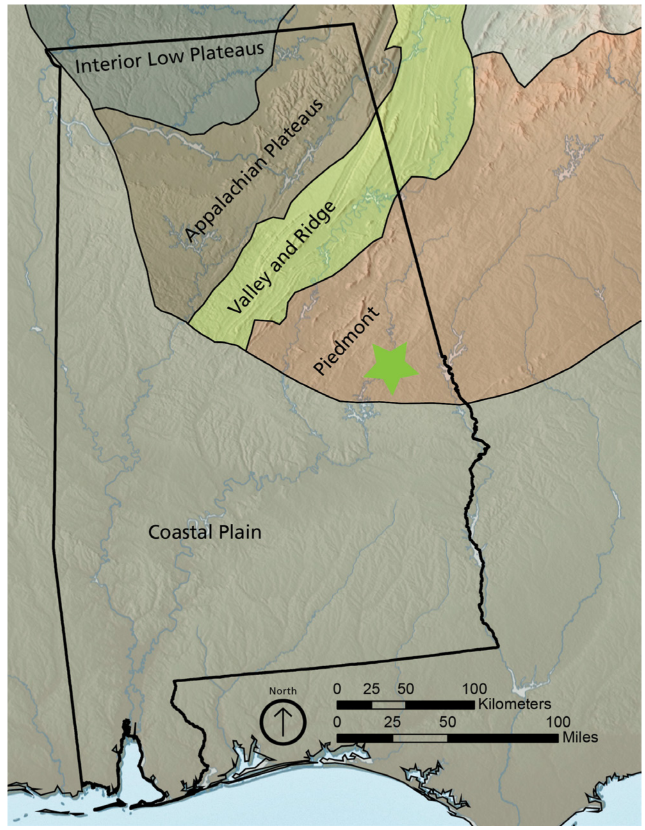

Figure 2. Physiographic provinces of Alabama. Horseshoe Bend National Military Park (marked on map with a green star) is within the Piedmont physiographic province. Graphic by author, aerial imagery from ArcMap (accessed 4 April 2020).

Table 1. Stratigraphic table of GRI GIS (hobe_geology.mxd) bedrock map units.

amphibolite. A coarse-grained metamorphic rock made up primarily of amphibole (silicate) minerals and plagioclase feldspar. Amphibolite facies is a high temperature, high pressure metamorphic facies under which amphibolite is produced.

biotite. A dark-colored, shiny silicate mineral (silicon + oxygen) of the mica group composed of magnesium and/or iron, $K(Mg,Fe)Si_3O_{10}(OH)_2$; characterized by perfect cleavage, readily splitting into thin sheets.

chlorite. A phyllosilicate mineral often formed in the early stages of metamorphism. Commonly greenish, although can appear as yellow, red, or white.

epidote. A common metamorphic minerals with the chemical formula $Ca_2(Al,Fe)_2(SiO_4)_3(OH)$

euhedral. A grain bounded by perfect crystal faces; well-formed.

felsic. Derived from feldspar + silica to describe an igneous rock having abundant light-colored minerals such as quartz, feldspars, or muscovite; also, describes those minerals.

foliation. A metamorphic texture of repeated layering caused by shearing or differential stress.

garnet. Refers to a group of silicate minerals sharing general physical characteristics but differing in chemical composition.

greenschist facies. A low-temperature, moderate pressure (typically 300-450°C, 2-10 kilobars) set of metamorphic conditions. Minerals produced include chlorite, actinolite, and albite. Chlorite is often a green mineral, which gives the facies and rock type its name.

K-feldspar (k-spar) or potassium feldspar. A feldspar mineral rich in potassium such as orthoclase, microcline, and sanidine.

lineation. A metamorphic texture of linear features. The one-dimensional counterpart of foliation.

mafic. Derived from magnesium + ferric (Fe is the chemical symbol for iron) to describe an igneous rock having abundant dark-colored, magnesium- or iron-rich minerals such as biotite, pyroxene, or olivine; also, describes those minerals.

metamorphic rock. Any rock derived from preexisting rocks that was altered in response to marked changes in temperature, pressure, shearing stress, and chemical environment. One of the three main classes of rock—igneous, metamorphic, and sedimentary.

micaceous. Consisting of, containing, or pertaining to mica; also, resembling mica, for example, a "micaceous mineral" capable of being easily split into thin sheets.

microcline. A potassium-rich alkali feldspar occurring in igneous rocks ($KAlSi_3O_8$).

monzonite. An igneous intrusive rock of approximately equal parts plagioclase and alkali feldspar. If a monzonite contains more than 5% quartz it is called "quartz monzonite."

muscovite. A light-colored silicate (silicon + oxygen) mineral of the mica group, $KAl_3Si_3O_{10}(OH)_2$, characterized by perfect cleavage in one direction and the ability to split into thin, clear sheets.

oxidize. The process of combining with oxygen.

phenocryst. A coarse-grained crystal in a porphyritic igneous rock.

plagioclase. A silicate (silicon + oxygen) mineral of the feldspar group that contains both sodium and calcium ions that freely substitute for one another; characterized by striations (parallel lines) in hand specimens.

porphyroblast. A large grain occurring in smaller groundmass in a metamorphic rock.

quartz. Silicon dioxide, SiO_2. The only silicate (silicon + oxygen) mineral consisting entirely of silicon and oxygen. Synonymous with "crystalline silica."

saprolite. A chemically weathered rock occurring in humid or temperate climates.

schist. A medium- to coarse-grained, strongly foliated, metamorphic rock with eminently visible mineral grains, particularly mica, which are arranged parallel, imparting a distinctive sheen or "schistosity" to the rock.

sericite. A fine-grained and fibrous variety of muscovite. Common in schist or hydrothermally altered rocks.

subhedral. A grain partly bounded by crystal faces; intermediate between euhedral and anhedral.

Geologic Map Unit	Map Unit Description
Waresville Schist (**PCPZws**)	Felsic schist with quartz, biotite, k-spar, and sericite in saprolitized light-tan-to-white outcrops with <1 cm (<0.3 in) k-spar porphyroblasts.

Table 1, continued. Stratigraphic table of GRI GIS (hobe_geology.mxd) bedrock map units.

Geologic Map Unit	Map Unit Description
Katy Creek fault	Katy Creek fault
Jacksons Gap Group quartzite (**PCPZjgq**)	Ridge-forming erosion-resistant micaceous quartzite within the Jacksons Gap Group. Accessory minerals include epidote, biotite, graphite, and local garnets. Forms Cherokee Ridge in the park.
Jacksons Gap Group (**PCPZjg**)	Up to four mappable unites have been observed in the Jacksons Gap Group but they are a complex tangle of gradational contacts that can singularly be best described as a graphitic quartz schist. A prograde mineral assemblage includes muscovite, biotite, garnet, and quartz; minerals indicative of greenschist facies metamorphism. At the structural top of the Jacksons Gap Group, lower amphibolite conditions are documented, suggesting an inverted thermal gradient likely caused by "down heating" from the Waresville Schist/Dadeville Complex. The Jacksons Gap Group is dominated by a retrograde overprint where biotite and muscovite are replaced by chlorite and sericite, respectively.
Abanda fault	Abanda fault
Kowaliga Gneiss (**PCPZkg**)	Quartz monzonite with well-foliated and lineated quartz, k-spar, plagioclase, and biotite. Schistosity is defined by biotite, muscovite, and quartz draped around subhedral microcline (Figure 8). Exists as a sapprolite in outcrop. Bedrock unit beneath the Horseshoe Bend.
Emuckfaw Group (**PCPZeg**)	Amphibolite facies, coarse-grained muscovite schist with euhedral garnets up to 1 cm (0.3 in) in diameter where composition allows. Exposures weather to a deep red-maroon, garnets oxidized to dark brown.

Much of the geology and topography of the park reflects a series of orogenies, or mountain building events, that took place more than 300 million years ago. Before this upheaval, about 500 million years ago (Figure 3a), the area was an environment much like today's Gulf of Mexico seaboard with sediment being deposited along a passive continental margin (Barineau et al. 2015). Around 350 million years ago (Figure 3b), pieces of continental crust and island arc called terranes were colliding with and accreting to what is now the eastern United States. In the park, this produced deformation (in the form of thrust faults) and metamorphism as the southern Appalachian Mountains formed.

Connections between Geologic and Cultural Resources

The namesake bend in the Tallapoosa River is an obvious geologic connection to the park's cultural resources. The park's resource stewardship strategy (RSS) identifies the battlefield, the Tallapoosa River, and the Tohopeka and Nuyaka Village sites as priority resources "necessary to maintain the park's purpose and significance." The path of the Tallapoosa River in the park is a direct result of the underlying geology, see the "Geologic History" chapter for further discussion.

The Nuyaka Village was established in 1777 and offers archeological evidence of Creek life before the onset of the Creek War. The Tohopeka Village was established as a refuge for Creeks fleeing the Creek War in 1813 and was destroyed by US troops in 1814 during the Battle of Horseshoe Bend. Both village sites are important locations for archeologic and ethnographic study of the Creek people (National Park Service 2017). The battlefield itself is the principal resource of the park and includes the site of the wood barricade built to protect the Tohopeka Village. This log barricade was constructed across the narrowest part of the neck of the meander bend (Figure 1).

Rivers, and meander bends in particular, have been important strategic features in many historic battles (Henderson 2000). In the case of the Battle of Horseshoe Bend, the river, combined with the log barricade, initially protected the Red Sticks because Jackson's artillery fire had little effect on the barricade. Cherokee warriors allied with Jackson seized an opportunity to swim across the Tallapoosa, steal Creek canoes, ferry additional Cherokee to the village and set it on fire. This diversion allowed the 39th Infantry under General Andrew Jackson to charge over the barricade. During the battle, more than 800 Red Sticks died; 72 Americans and Indian allies were also killed. The course of the Tallapoosa River as influenced by geological factors that created the horseshoe bend in the river (see "Tallapoosa River"), is undeniably critical to the cultural history of the Creek War and the Battle of Horseshoe Bend.

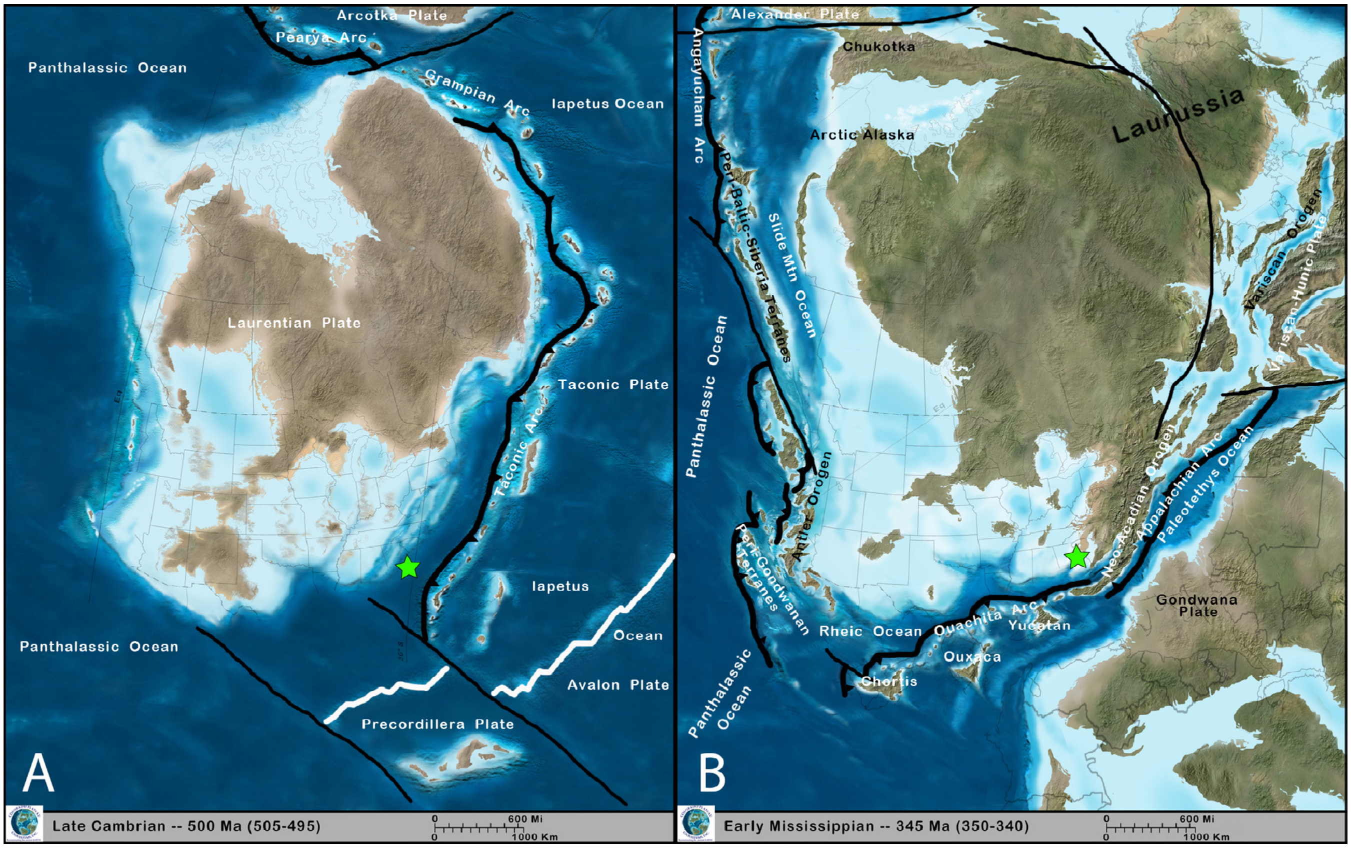

Figure 3. Paleogeographic maps of North America.
The green star indicates the approximate position of Horseshoe Bed National Military Park. In A, the sedimentary material of the Emuckfaw Group (PCPZeg) is being deposited in the Iapetus Sea. In B, continents are colliding and causing metamorphism and deformation. Basemaps are "North American Key Time Slices" © 2013 Colorado Plateau Geosystems, Inc; used under license. Refer to http://deeptimemaps.com/ for additional information.

Geologic History

Much of the “action” of the geologic history of the park is related to events that took place between 500 million and 300 million years ago during the early- to mid-Paleozoic Era (Figure 4) and is associated with the formation of the Appalachian Mountains. As with the Appalachians, the area has been largely tectonically inactive for the past 300 million years; the mountain formations have slowly but thoroughly weathered to produce a surface of minimal relief.

570 million to 444 million years ago (Precambrian to Paleozoic [Cambrian/Ordovician Periods]) Continental Rifting and Back-Arc Sedimentation

Around 570 million years ago, the supercontinent Rodinia was rifting apart to form continental landmasses, including the precursor to North America: Laurentia (Thomas 2006; Barineau et al. 2015). Rifting also created the Iapetus Ocean, a precursor to today’s Atlantic Ocean. During the Early Cambrian Period, about 540 million years ago, the Ouachita rift opened, separating a block of land from Laurentia (Figure 5a). As this “microcontinent” drifted across the Iapetus Ocean (to eventually collide with the supercontinent Gondwana), it left behind an area of thin, stretched crust characteristic of continental rift zones. Geologists theorize that an extensional fault associated with this crustal thinning initiated a minor, westward-dipping subduction zone as the cold, dense oceanic crust of the Iapetus Ocean plunged into the mantle (McClellan et al. 2007; Tull et al. 2007, 2012; Hawkins 2013) (Figure 5b).

Subduction zones, whatever their size, create a distinct set of depositional environments where rocks are created. As a “downgoing slab” of oceanic crust is subducted into the hot mantle it begins to melt and the hot magma rises to the surface where some is erupted as lava. This creates a line of volcanic islands between the subduction trench and the continental mainland; the space between this “volcanic arc” and the mainland is known as a “back-arc basin,” and is characterized by deposition of sediments with both continental and volcanic origins. Additionally, some of the magma rising

Eon	Era	Period	Epoch	MYA		Life Forms	North American Events
Phanerozoic	Cenozoic (CZ)	Quaternary (Q)	Holocene (H)	0.01	Age of Mammals	Extinction of large mammals and birds Modern humans	Ice age glaciations; glacial outburst floods
			Pleistocene (PE)	2.6			
		Tertiary (T) Neogene (N)	Pliocene (PL)	5.3		Spread of grassy ecosystems	Cascade volcanoes (W) Linking of North and South America (Isthmus of Panama) Columbia River Basalt eruptions (NW) Basin and Range extension (W)
			Miocene (MI)	23.0			
		Tertiary (T) Paleogene (PG)	Oligocene (OL)	33.9			
			Eocene (E)	56.0			Laramide Orogeny ends (W)
			Paleocene (EP)	66.0		Early primates	
						Mass extinction	
	Mesozoic (MZ)	Cretaceous (K)		145.0	Age of Reptiles	Placental mammals Early flowering plants	Laramide Orogeny (W) Western Interior Seaway (W) Sevier Orogeny (W)
		Jurassic (J)		201.3		Dinosaurs diverse and abundant	Nevadan Orogeny (W) Elko Orogeny (W)
		Triassic (TR)		251.9		Mass extinction First dinosaurs; first mammals Flying reptiles	Breakup of Pangaea begins Sonoma Orogeny (W)
						Mass extinction	
	Paleozoic (PZ)	Permian (P)		298.9	Age of Amphibians		Supercontinent Pangaea intact Ouachita Orogeny (S)
		Pennsylvanian (PN)		323.2		Coal-forming swamps Sharks abundant First reptiles	Alleghany (Appalachian) Orogeny (E) Ancestral Rocky Mountains (W)
		Mississippian (M)		358.9		Mass extinction	Antler Orogeny (W)
		Devonian (D)		419.2	Fishes	First amphibians First forests (evergreens)	Acadian Orogeny (E-NE)
		Silurian (S)		443.8		First land plants Mass extinction	
		Ordovician (O)		485.4	Marine Invertebrates	Primitive fish Trilobite maximum Rise of corals	Taconic Orogeny (E-NE)
		Cambrian (C)		541.0		Early shelled organisms	Extensive oceans cover most of proto-North America (Laurentia)
Proterozoic	Precambrian (PC, W, X, Y, Z)			2500		Complex multicelled organisms Simple multicelled organisms	Supercontinent rifted apart Formation of early supercontinent Grenville Orogeny (E) First iron deposits Abundant carbonate rocks
Archean				4000		Early bacteria and algae (stromatolites)	Oldest known Earth rocks
Hadean				4600		Origin of life Formation of the Earth	Formation of Earth's crust

Figure 4. Geologic time scale.
The divisions of the geologic time scale are organized stratigraphically, with the oldest divisions at the bottom and the youngest at the top. GRI map abbreviations for each time division are in parentheses. Rocks and deposits of interest for the park are from the Precambrian (X and Y), Cretaceous Period (K), Tertiary (T), and Quaternary Period (Q) (see table 1). Compass directions in parentheses indicate the regional locations of events. Boundary ages are millions of years ago (mya). NPS graphic using dates from the International Commission on Stratigraphy (http://www.stratigraphy.org/index.php/ics-chart-timescale; accessed 15 August 2018).

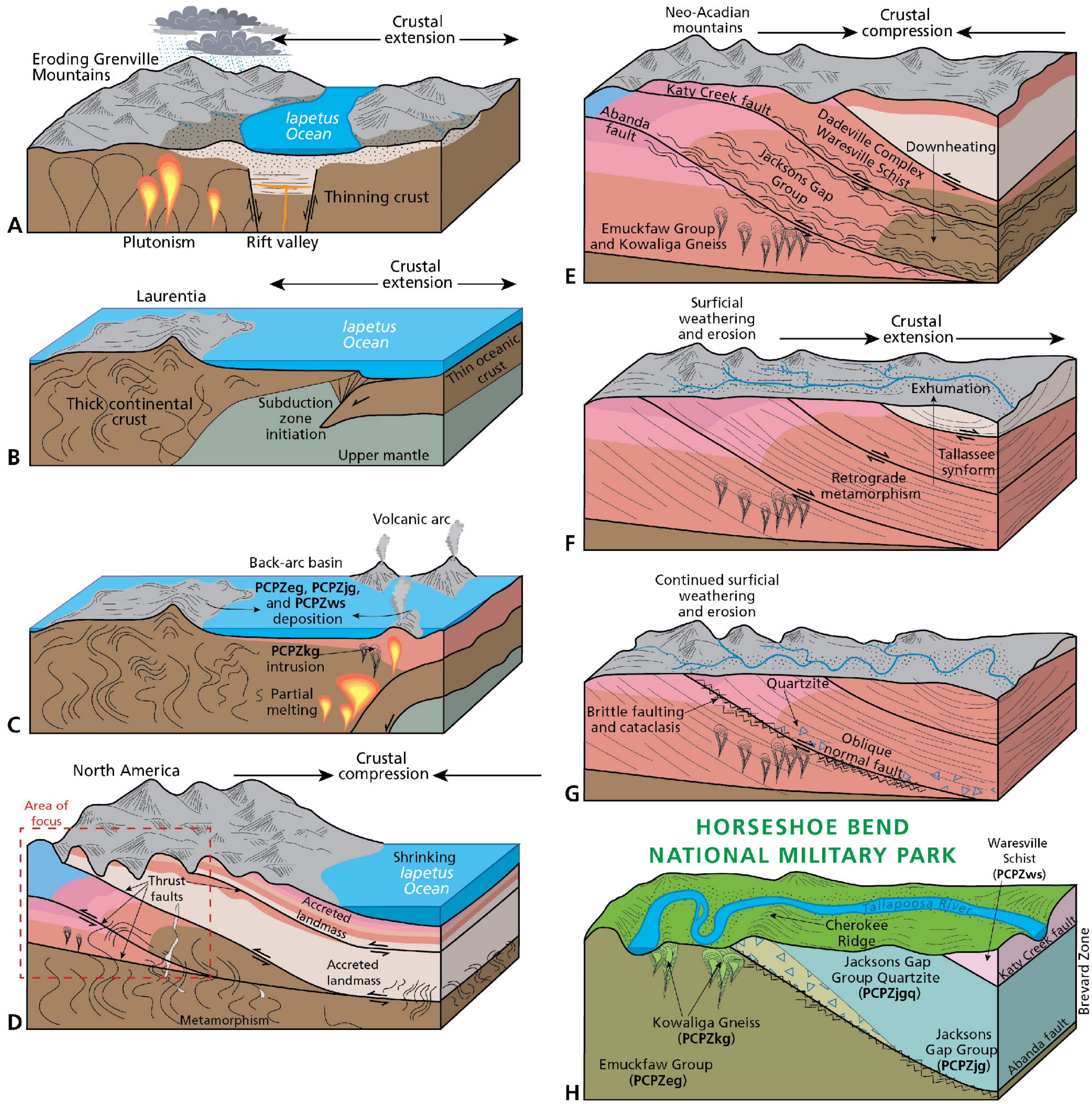

Figure 5. Block diagrams of the geologic evolution of Horseshoe Bend National Military Park.
Block diagram show stages in the geologic evolution of Horseshoe Bend over the past 570 million years, including crustal extension (A, B); subduction initiation (C); thrust faulting and prograde metamorphism (D, E); normal faulting and retrograde metamorphism (F, G); and the present-day park with the path of the Tallapoosa River shaped by the underlying rocks (H). Graphic by Trista Thornberry-Ehrlich (Colorado State University).

to the surface does not erupt but becomes emplaced in these sedimentary rocks as plutons.

In the case of the geology of the park, the sedimentary rocks that were later metamorphosed into the Emuckfaw Group and the Jacksons Gap Group may have been deposited in this back-arc environment (Figure 5c) (Tull et al. 2012, 2014). The igneous (plutonic) rocks of the park and the surrounding area were likely emplaced this way. These include the Kowaliga Gneiss (included in GRI GIS data, **PCPZkg**) and the Zana Granite (not included in GRI GIS data). Crystallization ages (the time that has passed since a melt solidified into rock) for the Kowaliga Gneiss give a value of 441 million ± 6 million years ago (Hawkins 2013; Tull et al. 2014). Because the magma could not have intruded into the sedimentary rocks before they existed, the Emuckfaw Group must be older than this. This principle is known in geology as the law of cross-cutting relationships.

350 million years ago (Devonian Period): Neo Acadian Orogeny, including Thrust Faulting and Metamorphism

Beginning in the Cambrian Period and continuing into the Devonian Period, large westward-dipping subduction began closing the Iapetus Ocean, and islands and microcontinents were pulled in to collide with the eastern margin of Laurentia. On the continental margin, these collisions pushed the crust up to form the towering Appalachian Mountains reaching heights that may have rivaled today's Himalayas. Farther inland, in the area that would become the park, the compression of the crust deformed the sedimentary rock layers that had been deposited in the back-arc basin. A series of thrust faults (Figure 5d) developed as rocks were pushed on top of one another. In the GRI GIS data, the Waresville Schist (of the Dadeville Complex) was thrust on top of the Emuckfaw Group. Separating these two units is the Brevard fault zone, characterized by rocks of the Jacksons Gap Group (Figure 5e).

Thrust faulting placed rock units deep beneath other rocks, subjecting them to intense temperatures and pressures. These conditions caused the mineral assemblages in the rocks to metamorphose into new minerals. Because different pressure and temperature conditions cause different minerals to grow, geologists name different types of metamorphic rocks according to the mineral assemblages that form (see Figure 7). The Emuckfaw Group was metamorphosed at lower/middle amphibolite facies. The Jacksons Gap Group experienced an inverted thermal gradient, as the thrusted Dadeville Complex heated it from above (Steltenpohl and Singleton 2014). Accordingly, the Jacksons Gap Group shows a range of metamorphic mineral assemblages, from lower greenschist to lower/middle amphibolite facies (amphibolite facies occurs at higher temperatures and pressures, or a higher metamorphic grade, than greenschist facies).

330 million years ago (Carboniferous Period): Early Alleghenian Orogeny, including Reactivation of Faults and Retrograde Metamorphism

During a break in continental accretion, the compressed crust relaxed and extended (Figure 6). This coincided with the formation of the Tallassee Synform, a massive, landscape-scale feature. The Emuckfaw Group and Brevard fault zone form the western limb of this structure; the Dadeville Complex forms the core.

As the rocks relaxed from their compressed conditions and erosion removed some of the overlying units, retrograde metamorphism took place (Bobyarchick et al 1988; Steltenpohl and Singleton 2014) (Figure 5f). This occurs when rocks move from the highest temperature/pressure conditions of their metamorphic path and some of the minerals become unstable, metamorphosing into lower grade minerals (Figure 7). This is often an incomplete metamorphism, so the rocks show minerals formed in both the original metamorphic event (prograde) and minerals formed in subsequent metamorphism (retrograde). Because retrograde metamorphism is often a result of rock units being exhumed, the retrograde overprint is almost always at a lower metamorphic grade than the prograde assemblage.

In the park, the Emuckfaw Group experienced a middle/upper greenschist overprint, causing the mineral hornblende to be replaced by actinolite and chlorite (Steltenpohl and Singleton 2014). In the Jacksons Gap Group, which is dominated by the retrograde overprint, biotite and muscovite were replaced by chlorite and

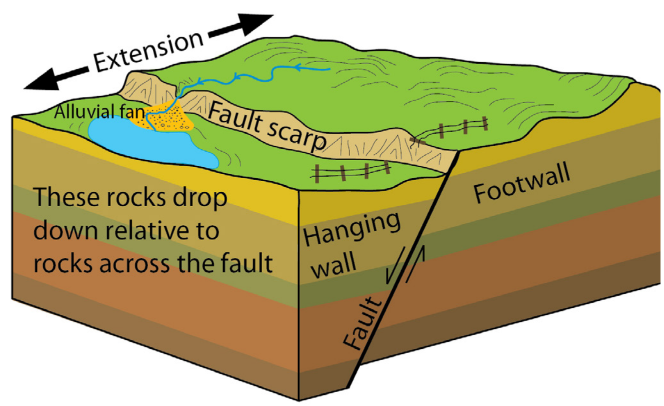

Figure 6. Normal faulting.
Block diagram showing a normal fault. During crustal extension, rocks will slide along existing fault lines or fractures. Blocks will drop down along normal faults as a result of extension. Diagram by Trista Thornberry-Ehrlich (Colorado State University).

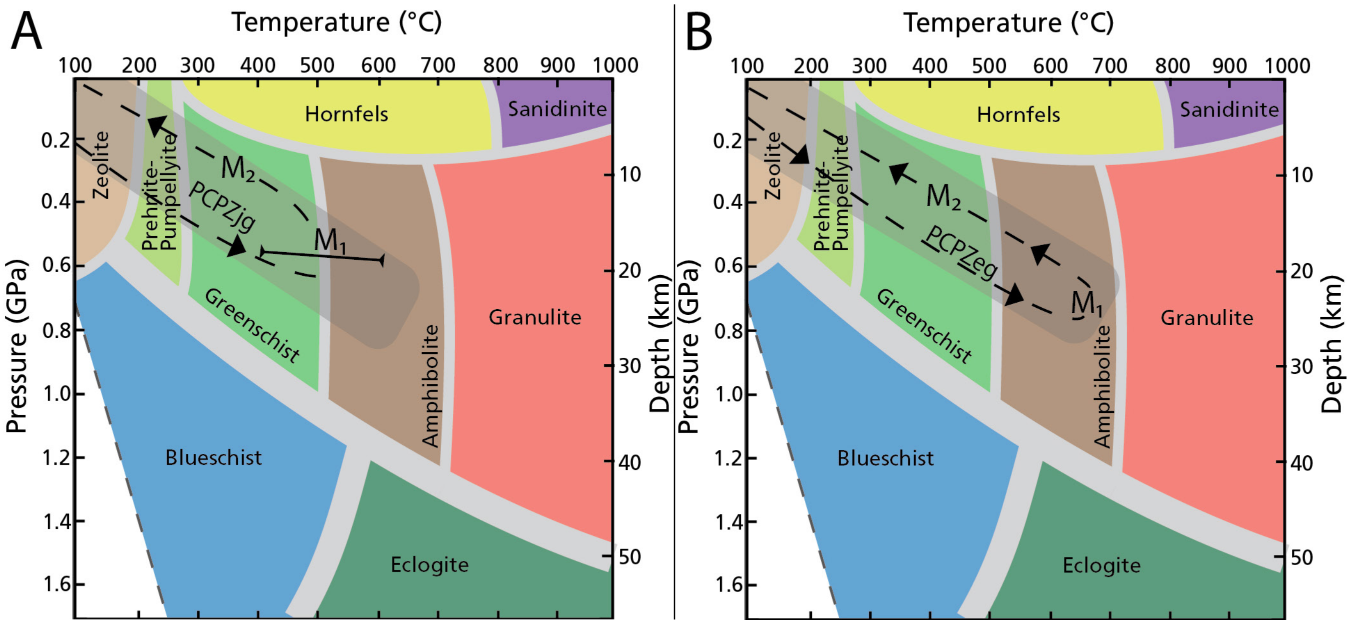

Figure 7. Diagram showing the metamorphic pressure and temperature path of the Jacksons Gap and the Emuckfaw Groups (PCPZeg).
The diagram shows the different rock types (based on mineral assemblages) that are created at different temperatures and pressures at depth. The dashed line shows the path of the rock unit as it reached prograde metamorphic conditions (M1) and retrograde metamorphic conditions (M2). In panel A, the Jacksons Gap Group (PCPZjg) has a bar indicating a range of temperature at M1 as part of the unit was heated from above by the Waresville Schist. Both units experienced greenschist facies retrograde overprinting at M2. NPS graphic by Amanda Lanik after Winter (2001), with P-T paths by the author.

sericite respectively. Another thing geologists look at to determine the metamorphic history of a rock is the orientation of the minerals within the rock. The metamorphism related to thrust faulting physically stresses, or strains, the mineral grains, causing them to align. This texture in a rock, where platy minerals align, is known as schistosity, and can be visible in hand sample and/or microscopically (Figure 8). In the case of the retrograde overprint, the chloritoid minerals of the Jacksons Gap Group are not aligned, but are randomly oriented, suggesting that the conditions under which they formed did not include physical stress (Figure 9).

Similar to the rocks within the park, the Waresville Schist (**PCPZws** in the GRI GIS map data, but not mapped within the boundaries of the park) was also subjected to a retrograde overprint at upper greenschist to lower amphibolite facies conditions.

Although there were no additional metamorphic events, the rocks underwent two further deformations (Steltenpohl and Singleton 2014). In the first, the Abanda fault (the structurally lowermost boundary of the Brevard fault zone) was reactivated as an oblique normal fault (Figure 5g). In this movement, the overlying rock unit moved in a top-down-to-the-east direction. This juxtaposed rock units of different metamorphic grade, whose contacts had previously been gradational. Finally, as the rocks had cooled, brittle faults developed along the Abanda fault. These faults are characterized by cataclasite, or a rock type that develops along faults as brittle rocks are fragmented as they slide along faults. Much of the cataclasite along the Abanda fault is related to the Kowaliga Gneiss, which is harder than the Emuckfaw Group. This brittle movement may have been related to the breakup of Pangea in the Mesozoic Era (175 million–140 million years ago).

The Last 66 million years (Cenozoic Era): Development of the Tallapoosa River

In the time since the Paleozoic Era and the formation of the Appalachian Mountains, the area has been largely tectonically inactive. Today, the eastern margin of North America is a passive margin with no subduction or collision occurring. The last large-scale tectonic event to affect the Appalachians was the post-orogenic collapse of the mountain chain following the Mesozoic rifting of Pangea (approximately 170 million years ago). Since then, the most significant forces acting upon the landscape have been erosional, slowly weathering and transporting away the relief features of the landscape. Over millions of years this has transformed

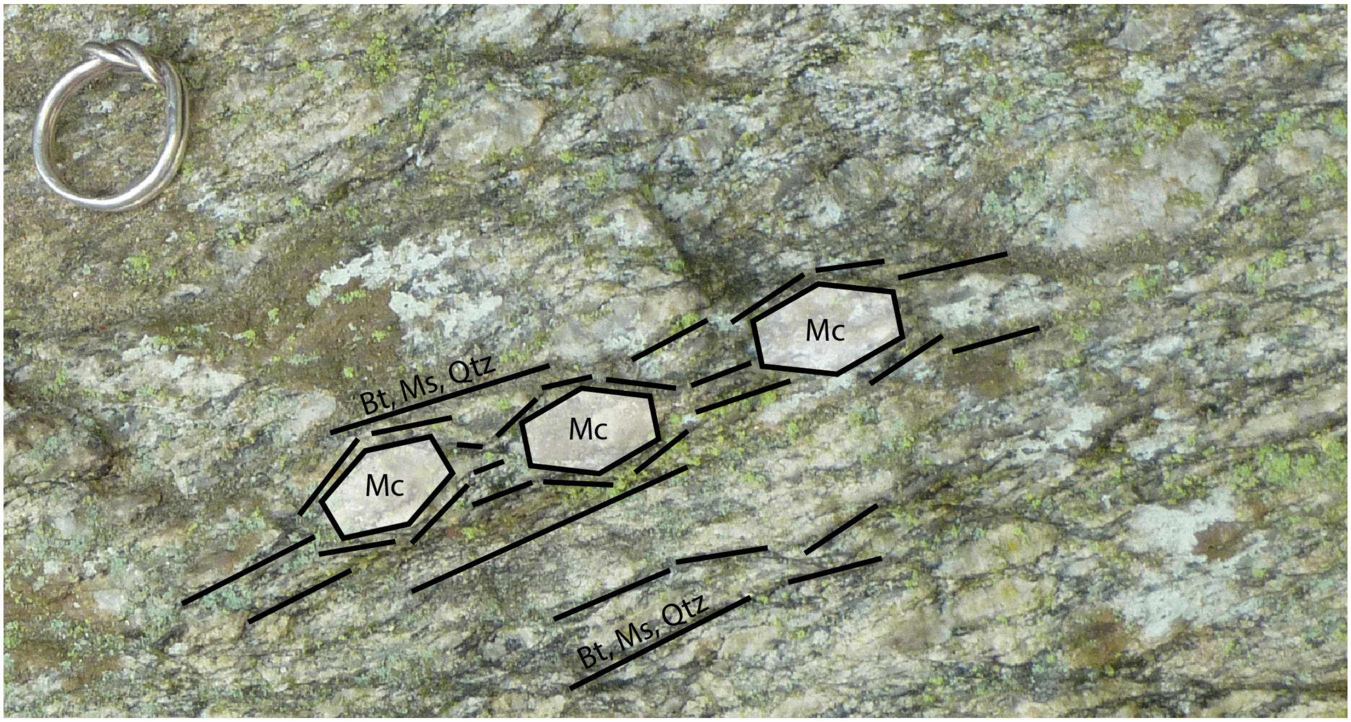

Figure 8. Photograph of Kowaliga Gneiss from Horseshoe Bend National Military Park.
Notations show direction of foliation (black lines) of biotite (Bt), muscovite (Ms), and quartz (Qtz) draped around microcline (Mc) crystals. Finger ring for scale. NPS photograph by Rebecca Port, notations by author.

Figure 9. Photograph of a piece of the Jacksons Gap Group.
Notice the minerals of the Jacksons Gap Group (PCPZjg), with a quartzite inclusion (PCPZjgq, in box), visible in the picture are not foliated (compare to figure 8). Much of the prograde mineral assemblage was replaced during retrograde metamorphism, which was not accompanied by physical strain to produce foliation. Pen for scale. Photograph by Katie KellerLynn (Colorado State University).

the Appalachian Mountains from a range to rival the Himalayas to their present, gently rolling form.

Like the rocks of the Appalachian Mountains, the rocks of the park have been similarly eroded. The different types of metamorphic rock in the park have different hardnesses, or resistance to erosion. Therefore, softer rocks such as the Emuckfaw Group (**PCPZeg**) and the Kowaliga Gneiss (**PCPZkg**) are preferentially eroded while the harder rocks like the Jacksons Gap Group quartzite (**PCPZjgq**) remain to form surface relief such as Cherokee Ridge, on the southeastern boundary of the park.

The rocks' resistance to erosion has also affected the flow path of the Tallapoosa River (Figure 5h). The Tallapoosa is a meandering river, meaning that it winds back and forth across its relatively level floodplain (Figure 10), following the path of least resistance as it makes its way from near Atlanta, Georgia, to its confluence with the Coosa River near Montgomery, Alabama, to form the Alabama River. The path of least resistance is heavily influenced by the rock type over which the river flows. In the park, the Tallapoosa River takes a more direct route over the harder rocks of the Jacksons Gap Group (see poster, in pocket). Conversely, over the softer Kowaliga Gneiss, the river takes a meandering path. This includes the meander that forms the horseshoe shaped bend for which the park is named. This feature is what is known as an entrenched meander, meaning that the river has cut through the sediment of the floodplain and into the bedrock, and is unlikely to change its morphology. In contrast, the meander just upstream of the bridge (Figure 1) is actively being cut off and may eventually become an oxbow lake (Figure 10).

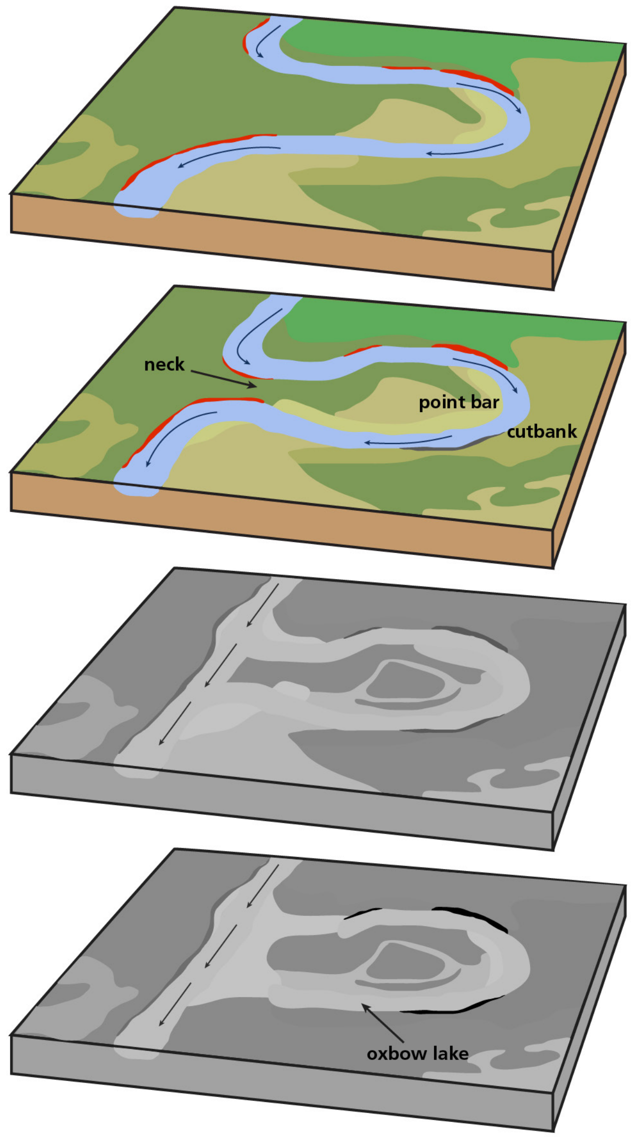

Figure 10. Diagram of a meandering river. Series of four block diagrams showing the evolution of a meandering stream. The "neck" of the meander bend becomes narrower until a flood causes the river to close off the neck. Sediment slowly plugs the up- and down-stream sides of the cutoff meander, creating an oxbow lake to the side of the new flow path. Because the Tallapoosa River is incised into the bedrock, the Horseshoe Bend is stuck at the second stage and is unlikely to "close off" the neck of the bend and form an oxbow lake (in grey). NPS graphic by Phil Reiker.

Geologic Features and Processes, and Resource Management Issues

Some geologic features, processes, or human activities may require management for human safety, protection of infrastructure, and preservation of natural and cultural resources.

The NPS Geologic Resources Division (GRD) (see http://go.nps.gov/grd) can provide technical and policy support for geologic resource management issues or direct park managers to other resources, such as for climate change, monitoring, interpretation, and resource education relating to the park's geologic resources (discussed below). GRD programs and staff focus on three areas of emphasis: (1) geologic heritage, which would address the Brevard fault zone and paleontological resources; (2) active processes and hazards, which would address fluvial features and processes, mass wasting, cave features and processes, and seismic hazards; and (3) energy and minerals management, which would address mining operations (discussed below).

Resource managers may find *Geological Monitoring* (Young and Norby 2009) useful for addressing geologic resource management issues. The manual, which is available online at http://go.nps.gov/geomonitoring, provides guidance for monitoring vital signs (measurable parameters of the overall condition of natural resources). Each chapter of Geological Monitoring covers a different geologic resource and includes detailed recommendations for resource managers, suggested methods of monitoring, and case studies. Where applicable, those chapters are highlighted in the following discussion. Notably, the Southeast Coast Network is currently monitoring wadeable streams, a vital sign related to the geologic resources in the park (see https://www.nps.gov/im/secn/wadeable-streams.htm).

Since scoping in 2012, the National Park Service completed a foundation document for the park (National Park Service 2014) and a resource stewardship strategy (National Park Service 2017). Because these documents are a primary source of information for resource management within the park, they were used in preparation of this report to draw connections between geologic features and "core components" such as "fundamental resources and values" and "other important resources and values."

In 2018, a follow-up conference call with park and network staff, an Alabama Geological Survey (AGS) geologist, and GRI team members (see Appendix A) verified the present-day pertinence of the issues identified in 2012. In addition, the call helped to update the list of geologic resource management issues and guide research of this report.

The following updated list of geologic features and processes, and resource management issues is based on the 2012 scoping summary, 2014 foundation document, 2017 resource stewardship strategy, 2018 conference call discussion, and reviewers' comments. The issues are ordered based on management priority.

- Fluvial Features and Processes
- Erosion and Mass Wasting
- Climate change
- Seismic Activity
- Cave Features and Processes
- Brevard Zone
- Mining and Minerals
- Paleontological Resources

Fluvial Features and Processes

Fluvial features and processes are related to flowing water, such as rivers and streams. Fluvial features in Horseshoe Bend National Military Park include ephemeral and intermittent streams, gullies, stream terraces and the namesake bend, an entrenched meander. Fluvial processes in the park include flooding and erosion, which can lead to mass wasting. The Tallapoosa River is the defining feature of the park, but included in the park boundary are at least three unnamed perennial streams, one of which is being monitored for vital signs by the Southeastern Coastal Region (McDonald 2019). For a thorough description of perennial and ephemeral streams in the park, see *Wadeable Stream Suitability Assessment for Long-Term Monitoring: Horseshoe Bend National Military Park* (McDonald 2019).

Tallapoosa River

The Tallapoosa River flows 426 km (265 mi) from the Appalachian Mountains in Georgia southwest into Alabama where it joins the Coosa River to form the Alabama River. Along its course, the Tallapoosa River is dammed in four locations; Horseshoe Bend National Military Park is located between the Harris Dam (68 km [42 mi] upstream of the park) and the Martin Dam (53 km [33 mi] downstream of the park) (Figure 11).

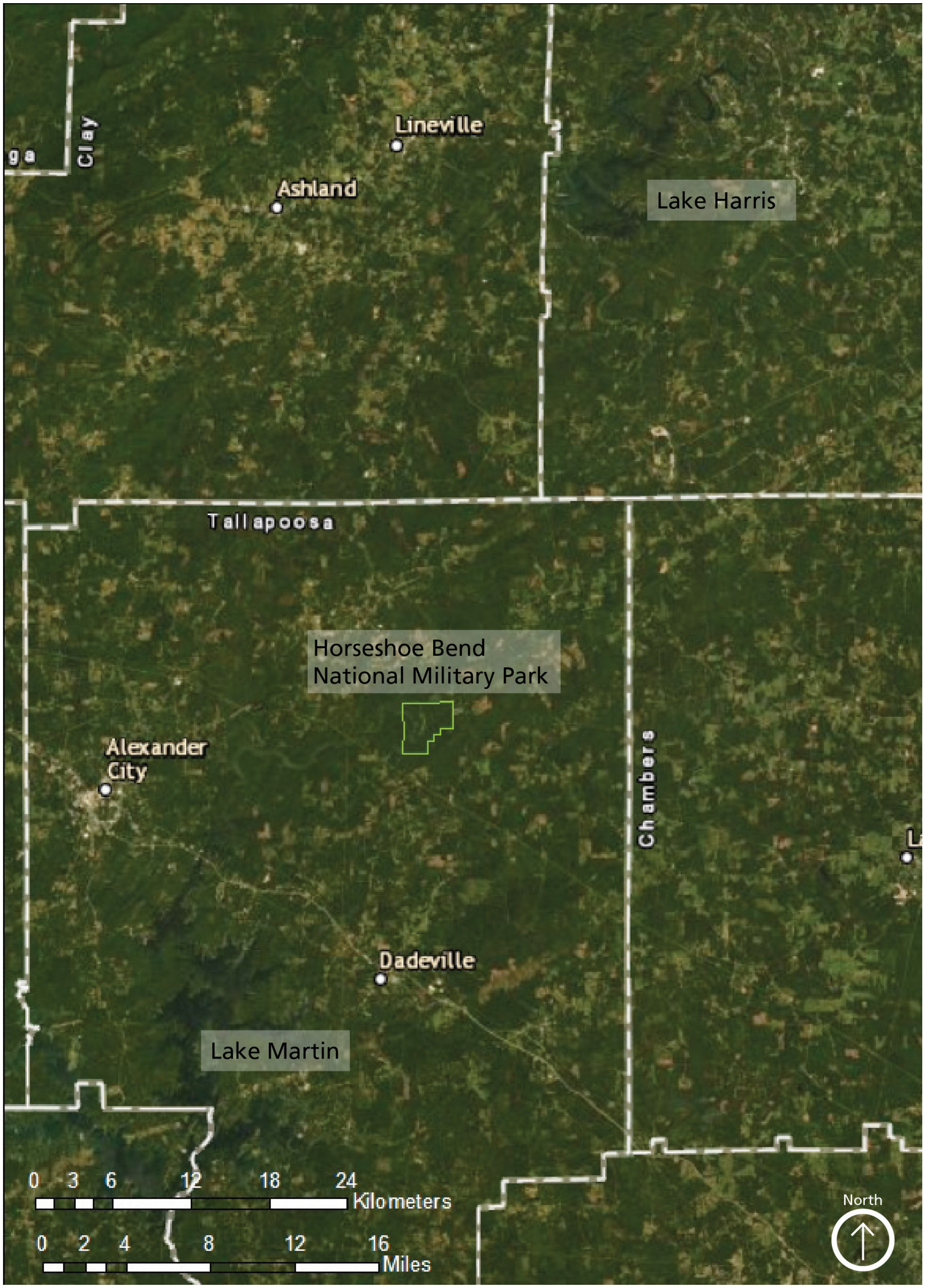

Figure 11. Aerial photograph of the Tallapoosa River between Lake Harris and Lake Martin. The Tallapoosa River is dammed upstream (Lake Harris) and downstream (Lake Martin) of Horseshoe Bend National Military Park (park boundary in green). The upstream Harris Dam is the primary factor in regulating the flow regime of the Tallapoosa River in Horseshoe Bend. Aerial imagery from ArcMap (accessed 23 April 2020).

The Harris Dam is the main driver of flow regime (via impoundment of water behind the dam or release from the reservoir) for the Tallapoosa River in the park. Park staff have a working relationship with the hydroelectric company that manages the dam (Alabama Power), and provided input to the ongoing relicensing process for the Harris Dam (Stacy Speas, Horseshoe Bend National Military Park, lead ranger, GRI conference call, 27 November 2018). For a timeline of human activities affecting streams monitored by the Southeastern Coastal Network (SECN), see *Monitoring Wadeable Stream Habitat Conditions in Southeast Coast Network Parks Protocol Narrative* (McDonald et al. 2018). The segment of the Tallapoosa River that meanders through the park is approximately 6 km (3.7 mi).

Horseshoe Bend

The namesake bend in the river is perhaps the park's most significant feature, fluvial or otherwise. The Tallapoosa River is a meandering stream, meaning that the river is composed of a single channel that winds its way snakelike across the landscape, so that the channel length (distance the stream flows) is substantially greater than valley length ("as the crow flies"). As water flows through a river channel, its velocity is greater at the outside of its curves. This increased velocity leads to erosion at the outer edge of a bend and the formation of a "cutbank." Low velocities on the inside curve of a river commonly leads to deposition at the inner edge or the formation of a "point bar" (Figure 10). Erosion also occurs at the downstream side of the stream channel so that in addition to moving laterally, bends will migrate downstream over time. A time-lapsed video of a meandering stream would look like a large snake moving downstream.

Another feature of meandering streams is the formation of oxbow lakes (Figure 10). The bends of a meander will migrate, via flooding and erosion, closer and closer, until only a narrow neck of land separates them. During floods, or other high-flow events, the river may breach the neck of land and the flow will bypass the meander entirely, leaving a bend-shaped body of water known as an oxbow lake. These oxbow lakes may subsequently be filled in with sediments that wash or blow in over land. The formation and filling in of oxbow lakes occur when the river is flowing over and through a floodplain, and the recently deposited sediments are easily reworked by the fluvial processes.

Horseshoe Bend is an entrenched meander, that is, the river has cut through the surficial deposits and into bedrock. Because bedrock is harder and more erosion resistant than the loose, surficial sediments of a floodplain, once a river becomes entrenched it is unlikely to develop new meanders or oxbow lakes. For a dramatic example, a truly catastrophic flood would be required to cause the Colorado River to jump its banks and turn the Horseshoe Bend of the Grand Canyon into the Grand Oxbow Lake. In the same way, the Tallapoosa River is incised into the metamorphic bedrock and is similarly unlikely to form a "Horseshoe Lake" at the park.

The underlying geology also has had an effect on the morphology of the Tallapoosa River in the park. Most notable in the GRI GIS data is the presence of the Jacksons Gap Group quartzite (**PCPZjgq**), the erosion-resistant bedrock that forms the Cherokee Ridge along the southeastern border of the park. Before the Tallapoosa River enters the park on the eastern boundary, it clearly flows around the extent of an outcrop of Jackson Gap Group (**PCPZjgq**). This phenomenon is also observed shortly after the river leaves the park boundary on the western side: the river flows around a mapped outcrop of the Jacksons Gap Group quartzite (see poster, in pocket).

Also of note is the course that the river takes when it does flow over the different bedrock units. As the Tallapoosa River approaches the park from the south, it takes a direct path across the hard rocks of the Jacksons Gap Group (**PCPZjg**). Once the river enters the park, it flows over the softer Kowaliga Gneiss (**PCPZkg**), and it is into this erodible rock that the characteristic horseshoe bend meander was carved.

Erosion and Mass Wasting

During the 2018 conference call, participants identified erosion as the primary resource management concern of the park. The erosion in the park is primarily caused by fluvial processes associated with the Tallapoosa River. As discussed elsewhere in this report, the flow regime of the Tallapoosa River is controlled by the Martin Dam upstream (Figure 11). Other drivers of flow include storms and seasonal variation, with higher flow rates occurring during spring and peaking in March. If park staff members desire quantitative information regarding rates of change and channel morphology, repeat photography could potentially be used, although vegetation cover has prevented high-resolution studies from being carried out. Refer to http://go.nps.gov/grd_photogrammetry for information about using photogrammetry for resource management. Also see the chapter about fluvial geomorphology (Lord et al. 2009) in *Geological Monitoring* (Young and Norby 2009).

As a result of flooding, the bank on the inside curve of the namesake bend collapsed (National Park Service 2014). This may have been caused by clearing of vegetation in the area, because established vegetation stabilizes sediment whereas the loss of vegetation can destabilize slopes. Vegetation removal occurs in

Horseshoe Bend for three reasons: (1) to clear space for visitor use/access, (2) to control invasive plant species, and to a lesser extent, (3) as part of an active fire management program.

Perennial Streams

One small, unnamed perennial stream flows along the south side of the Tallapoosa River (McDonald et al. 2018). The Southeastern Coastal Network is monitoring this stream for traits including bank height and channel width. The baseline report for this stream describes these traits in detail (McDonald 2020). Investigation (McDonald 2019) has also identified the potential for at least two more perennial streams in the park. This is part of a larger effort of the Southeastern Coastal Network to monitor wadeable streams in all network parks (https://www.nps.gov/im/secn/index.htm).

Flooding

Since construction of the Martin Dam in 1980, the flow regime of the Tallapoosa River within the park has been highly regulated. While this means that unpredictable storm-induced flooding is almost nonexistent, the river is still subject to a sometimes-extreme artificial flow regime (Burkholder and Rothenberger 2010). Power generation at the dam results in two high-water events per day, which causes the river levels to fluctuate as much as 1.5 m (5-6 ft). The dam also affects in stream flow and water temperature patterns (Burkholder and Rothenberger 2010).

Stream Terraces

Participants at the 2012 GRI scoping meeting identified a stream terrace (see GRI scoping summary by KellerLynn 2013) (Figure 12). Stream terraces are flat surfaces that flank an active floodplain, and represent a former (now inactive) floodplain from a time when the river was at a higher level. Conversation with Jake McDonald of the Southeastern Coastal Network during the 2018 conference call revealed that many streams in the southeastern United States have a historical stream terrace bounding any floodplains that may be present. These historical stream terraces were formed when an increased understanding and implementation of soil conservation practices in the early 20th century caused streams to incise into historic alluvium as the streams tried to re-equilibrate to a system with much less free sediment (Trimble 1969).

Climate Change

Because of the potential impacts that climate change may have to park resources, including geologic resources, a brief discussion of climate change is merited in this report. However, climate change planning is beyond the scope of the GRI program, and park managers are directed to the NPS Climate Change Response Program (CCRP) to address issues related to climate change (https://www.nps.gov/orgs/ccrp/index.htm).

Primary effects that climate change may have on natural resources in the park are, perhaps unsurprisingly, related to fluvial erosion. Directly, any change in storm frequency and intensity has the potential to impact the occurrence and intensity of flooding. More intense floods are more likely to cause significant undercutting of banks, which can lead to large-scale mass wasting events, such as bank collapse at the inside of the bend.

Many climate models suggest that in addition to increasing storm intensity, the intervals between storms may also increase as a result of changing climate (Kunkel et al. 2013). This could change the type and amount of vegetation in riparian areas, making river banks more susceptible to erosion.

Climate change may also impact the park's ephemeral streams. Dry periods in the past have led to the disappearance of ephemeral streams throughout the park, by definition. Ephemeral streams are important habitat. "Salamander Creek," for example, is an unnamed, unmonitored ephemeral stream that is home to crayfish and at least one salamander (McDonald 2019). The stream was dry during a 2008 drought, and climate change could exacerbate drought and further threaten biologically important habitat.

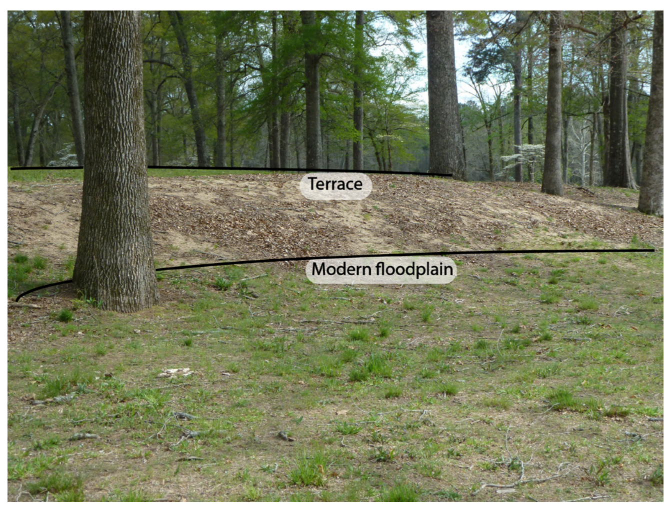

Figure 12. Photograph of stream terrace. The terrace represents an abandoned floodplain of the Tallapoosa River and the lower surface is the modern floodplain. As the river cuts deeper into the floodplain (or the bedrock), the old floodplain is abandoned and becomes a terrace. NPS photograph by Rebecca Port, annotations by the author.

Brevard Zone

The Brevard zone in Alabama is a 2–3-km- (1–2-mi-) wide zone of metamorphosed and deformed rocks that separates the Northern and the Inner Piedmont sections of the Piedmont physiographic province (Guthrie 2009). The Brevard fault zone is a massive structural feature that runs 600 km (370 mi) along the southern Appalachian Mountains and, along with the Emuckfaw Group, forms the western limb of the Tallassee Synform (see "Geologic History").

The Brevard fault zone is defined by the metamorphic rocks of the Jacksons Gap Group (**PCPZjg**) including micaceous quartzites (**PCPZjgq**) (Figure 5h). For a thorough discussion of the lithology and geologic evolution of the Brevard fault zone as relevant to Horseshoe Bend National Military Park, see the "Geologic History" section of this report.

Cave Features and Processes

The National Park Service defines a cave as any opening in the ground that a human can fit in. Commonly, caves exist as part of a karst landscape (a landscape where dissolution of the bedrock by flowing water has created features such as sinkholes, springs, and caves). These landscapes require a soluble bedrock, such as limestone or gypsum, which is not present in the park. Marble, which is metamorphosed limestone and is soluble, exists within the Brevard fault zone but not within the park. Therefore, there are no karst features associated with the park. See Weary and Doctor (2014) for more information about cave and karst features in the United States.

There is an erosional feature within the park that fits under the broader heading of cave features and processes: Wilson's Rock (Figure 13). A rock overhang of unknown cultural significance (KellerLynn 2013, 2018 GRI conference call), Wilson's Rock is known to park staff and is featured in walking tours of the park. The location of Wilson's Rock is marked on figure 1.

Seismic Activity

Strong seismic activity in the park is mostly historic, although earthquakes are occasionally felt within the park (KellerLynn 2013). The greatest risk from seismic activity to the park (Figure 14) is any impact to groundwater flow, which can lead to the loss of water in wells. Scoping and conference call participants, 2012 and 2018, respectively, both mentioned Sandy Ebersole (Geological Survey of Alabama) as a source of earthquake information for park managers. See Braile (2009) for more information about seismic activity in parks.

Figure 13. Wilson's Rock.
Wilson's Rock is an erosional feature large enough for a human to enter. NPS photograph by Brian Robinson.

Scoping participants mentioned the Fort Payne (210 km [130 mi] north of Horseshoe Bend) earthquake of 29 April 2003 as significant to the park. The magnitude 4.9 quake was felt in 13 states but did not cause significant damage.

The largest historic earthquake in Alabama occurred more than a century ago. The magnitude 5.9 Irondale quake damaged more than 20 chimneys in the town of Irondale, 145 km (90 mi) northwest of the park (Stover and Coffman 1993; KellerLynn 2013).

The New Madrid earthquake of 1811–1812 has cultural connections to the park's history and was likely felt in the Horseshoe Bend area (KellerLynn 2013). The New Madrid seismic zone (Figure 14) lies within the central Mississippi Valley and has historically been the site of some of the largest earthquakes in North America. Three main shocks occurred between December 1811 and February 1812; shaking from the last shock was felt across 5 million km^2 (2 million mi^2) and caused the Mississippi River to run backwards. Cultural legend holds that the American Indian leader Tecumseh predicted the New Madrid earthquake and said it would occur when he stomped his foot.

The following are useful resources for park awareness of earthquake hazards:

- GRD Seismic Monitoring website: http://go.nps.gov/geomonitoring.
- US Geological Survey Earthquakes Hazards website: https://earthquake.usgs.gov/.
- US Geological Survey New Madrid Seismic Zone webpage: https://earthquake.usgs.gov/learn/topics/nmsz/.

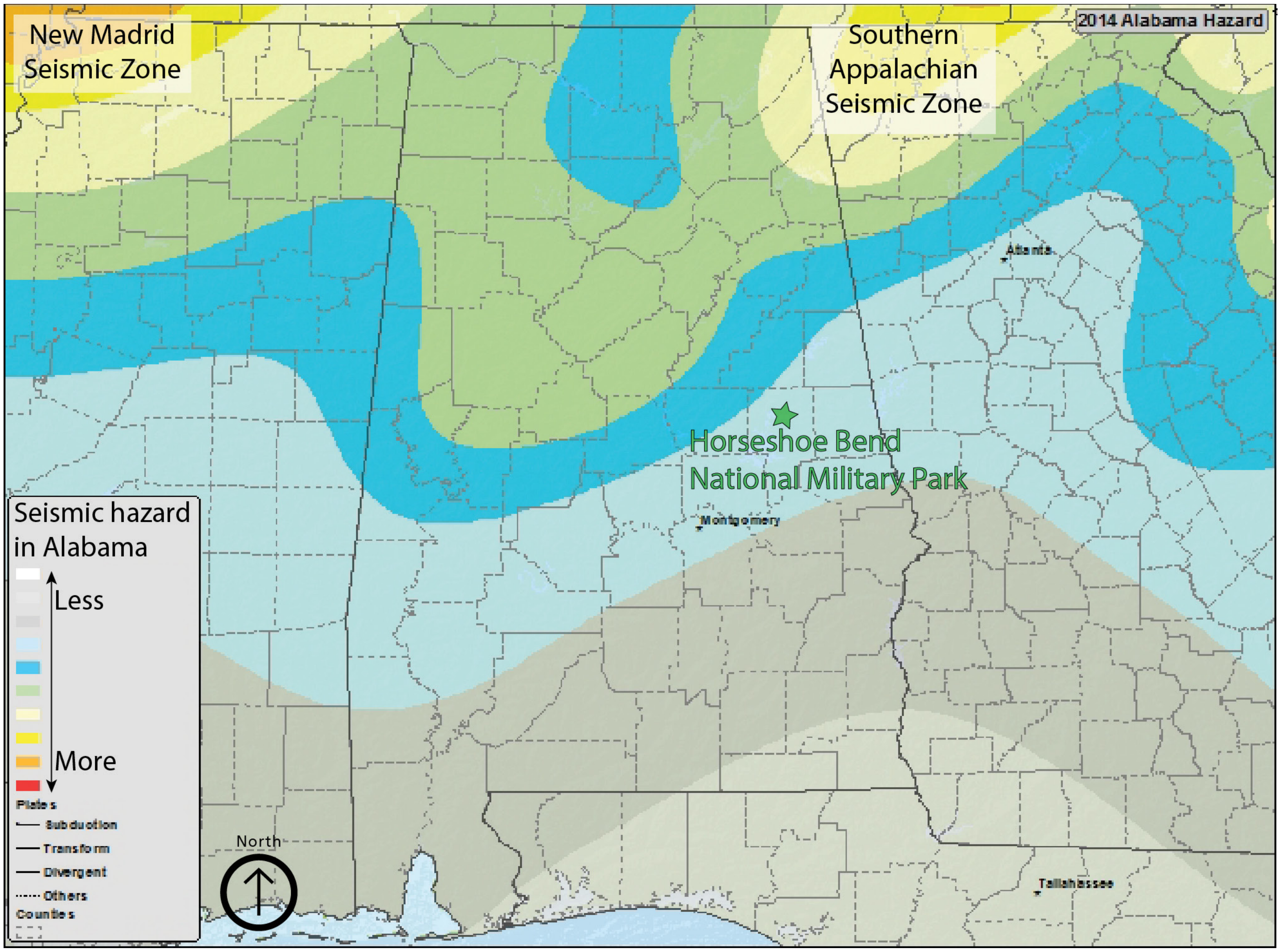

Figure 14. Map of seismic hazard potential around Horseshoe Bend National Military Park. Location of park marked with green star. Graphic adapted from the US Geological Survey Earthquakes Hazard Program (https://earthquake.usgs.gov/earthquakes/).

- Geological Survey of Alabama Geologic Hazards website: https://www.gsa.al.us/gsa/geologic/hazards/earthquakes/alquakes.

Mining and Minerals

The Brevard fault zone has historically been the site of minor gold production, and Tallapoosa County was home to gold mining operations from 1842 to 1936 (Guthrie 2009). There are no current plans for commercial mining, and minimal recreational interest (KellerLynn 2013). Dane VanDervoort is the current economic geologist at the Geological Survey of Alabama and oversees tracking the occurrence of mineral operations and interest throughout the state; he is a contact for information about potential activity near the park.

Abandoned Mineral Lands

Abandoned Mineral Lands (AML) are lands, waters, and surrounding watersheds that contain facilities, structures, improvements, and disturbances associated with past mineral exploration, extraction, processing, and transportation, including oil and gas features and operation, for which the National Park Service takes action under various authorities to mitigate, reclaim, or restore in order to reduce hazards and impacts to resources. *Abandoned Mineral Lands in the National Park System: Comprehensive Inventory and Assessment* (Burghardt et al. 2014) identified two AML features in the park; neither requires mitigation.

The 2013 GRI scoping summary identified one of these sites: a pit that was mined for gravel to supply road materials within the boundaries of park. The pit is long abandoned and mature trees now grow upon it.

Refer to Burghardt et al. (2014) and https://go.nps.gov/grd_aml for information about AML in the National Park System. These resources provide a comprehensive inventory of sites, features, and remediation needs.

Paleontological Resources

Paleontological resources, or fossils, are any remains of past life preserved in a geologic context. All fossils are nonrenewable. Body fossils are any remains of the actual organism such as bones, teeth, shells, or leaves. Trace fossils are evidence of biological activity; examples include burrows, tracks, or coprolites (fossil dung). Fossils in NPS areas occur in rocks or unconsolidated deposits, museum collections, and cultural contexts such as building stones or archeological resources. With a few rare exceptions, fossils occur exclusively in sedimentary rocks, as organisms (or their traces) are buried by sediment and preserved in lithified layers. A paleontological resource summary of the Southeastern Coast Network including Horseshoe Bend National Military Park reported no known fossils associated with the park (Tweet et al. 2009). The 2018 conference call confirmed this status.

As the bedrock of Horseshoe Bend is metamorphic and unlikely to yield any fossils, the most likely chance of paleontological resources occurring in the park is in an archeological context. Paleontological resources have been used in tools and jewelry by American Indian tribes who may have traded them into possession by the Creek peoples who lived in the villages at Horseshoe Bend. Therefore, any cultural artifacts discovered in an archeological context in the park has the potential to contain fossils. Tweet et al. (2009) made the following resource-management recommendations for the park:

- Park staff should be encouraged to observe the surface deposits for fossil material while conducting their usual duties. Staff should document any observations with photographs using a common item (e.g., pocketknife) for scale. Fossils and their associated geologic context (rock matrix) should be documented but left in place unless they are subject to imminent degradation by artificially accelerated natural processes or direct human impacts.
- Fossils found in a cultural context should be documented as other fossils but will also require the input of an archeologist. Any fossil within a cultural context may be culturally sensitive as well (e.g., subject to the Native American Graves Protection and Repatriation Act [NAGPRA]) and should be regarded as such until otherwise established. The Southeast Archeology Center (https://www.nps.gov/seac/index.htm) and the NPS Geologic Resources Division can coordinate additional documentation/research of such material.
- Contact the NPS Geologic Resources Division for any additional assistance regarding paleontological resource management or interpretation at the park.

Other resources for guidance on paleontological issues include:

- The NPS Fossils and Paleontology website: https://go.nps.gov/paleo.
- Kenworthy and Santucci (2006) presented a summary of National Park Service fossil in a cultural resource context.
- Santucci et al. (2009) details paleontological resource monitoring strategies.

Future Geologic Investigations

This section provides some suggestions for future geologic studies. This list is primarily derived from various needs identified in the park foundation document; these needs are interpreted as having a geologic component. It is not an exhaustive list of research, nor is it a list of the highest priority research to support park management. Some of the suggested studies have clear ties to park management issues; other studies have broader interests and applications.

The park's 2014 foundation document (National Park Service 2014) identified several fundamental resources and values (FRVs), as well as other important resources and values (OIRVs), that have data and/or GIS needs with geologic components. Fundamental resources and values are those features, processes, experiences, stories, scenes, sounds, smells, or other attributes determined to warrant primary consideration during planning and management processes because they are essential to achieving the purpose of the park and maintaining its significance. Other important resources and values are not fundamental to the purpose of the park and may be unrelated to its significance but are important to consider in planning processes.

Fundamental resources and values identified at the park include the following:

- The battlefield (encompassing the barricade site, Tohopeka village site, Lemuel Montgomery gravesite, Bean's Island, the Tallapoosa River, and areas on the other side of the river)
- Battle-related artifacts in the museum collection
- Battle-related archeological resources
- Nonbattle-related archeological resources associated with the Creek culture
- Tohopeka Village site
- Nuyaka Village site
- Congressional Monument and Jackson Trace marker

Other important resources and values identified at the park include the following:

- Miller's Bridge Piers
- Archeological resources unrelated to the battle or to Creek culture
- Artifacts in the collection unrelated to the battle or to Creek culture
- Archival materials
- Mission 66 Visitor Center
- The historically prevalent natural and cultural landscape (during the period of the significance/ period of the battle)
- Opportunities for recreation, wildlife viewing, and water-based recreation

Investigation of erosional change to archeological resources is a need for both battle- and non-battle-related archeological resources associated with Creek culture. These resources include known and yet-to-be-discovered artifacts in the battlefield as well as the village sites of Tohopeka and Nuyaka, all of which could be threatened by increased erosion related to climate change. Photogrammetry is an effective method of monitoring active processes, including erosional change. GRD has acquired equipment and software to develop a photogrammetric data program to support parks and regions. For more information, contact GRD or visit https://www.nps.gov/subjects/geohazards/photogrammetry.htm.

The GRI GIS data for the park does not include surficial deposits. If monument managers are interested in acquiring this updated information as part of their GRI GIS data, they can contact the NPS Geologic Resources Division and/or Inventory and Monitoring Division. The next generation of NPS inventories, termed "inventories 2.0," may support such expanded map coverages. The estimated starting date for inventories 2.0 is 2020. Notably, culturally sensitive information would not be included in the publicly available GRI GIS data.

The foundation document also cites a need for remote sensing of archeological resources (opposed to invasive archeology). This may be a project that could be completed by a Geoscientist-in-the-Parks (GIP; https://go.nps.gov/gip) or Mosaics in Science (MIS; https://go.nps.gov/mosaics) intern under the supervision of a NPS or state archeologist. This could also be an opportunity to investigate archeological resources for any paleontological components.

Geologic Map Data

A geologic map in GIS format is the principal deliverable of the GRI program. GRI GIS data produced for the park follows the source maps listed here and includes components described in this chapter. A poster (in pocket) displays the data draped over imagery of the park and surrounding area. Complete GIS data are available at the GRI publications website: https://go.nps.gov/gripubs.

Geologic Maps

A geologic map is the fundamental tool for depicting the geology of an area. Geologic maps are two-dimensional representations of the three-dimensional geometry of rock and sediment at or beneath the land surface (Evans 2016). The colors on a geologic map indicate the rock types or deposits and ages present in an area. In addition to color, rocks and deposits are delineated as map units, and each map unit is labeled by a symbol. Usually, the map unit symbol consists of uppercase letters indicating the age (e.g., **PC** for Precambrian or **PZ** for Paleozoic) and lowercase letters indicating the rock formation's name or the type of deposit (see table 1). Other symbols on geologic maps depict the contacts between map units, and structures such as faults or folds, The American Geosciences Institute website, https://www.americangeosciences.org/environment/publications/mapping, provides more information about geologic maps and their uses.

Geologic maps are generally one of two types: surficial or bedrock. Surficial geologic maps typically encompass deposits that are unconsolidated and formed during the past 2.6 million years (Quaternary Period). Surficial map units are differentiated by geologic process or depositional environment. The GRI GIS data for Horseshoe Bend National Military Park does not include surficial mapping.

Bedrock geologic maps encompass older, typically more consolidated sedimentary, metamorphic, and/or igneous rocks. Bedrock map units are differentiated based on age and/or rock type. The 5 bedrock map units in the GRI GIS data for the park consist of Precambrian to Paleozoic ("**PCPZ**" units). These map unit descriptions are from Jones (2012).

Source Maps

The GRI team does not conduct original geologic mapping. Scoping participants (see Appendix A) and the GRI team identify the best available geologic maps for a park unit. Determinations are made based on coverage (extent or area mapped), map scale, date of mapping, and compatibility of the mapping to the current geologic interpretation of an area. The GRI team then digitizes paper maps and/or converts existing digital data to the GRI GIS data model. The GRI team may compile multiple source maps to cover a park boundary or provide a greater extent as needed for resource management.

The GRI team used the following source map to produce the GRI GIS data for the park and surrounding area. The data cover the Jacksons Gap and Buttston quadrangles (Figure 15). Information provided in this report is based on the following source map:

- *Preliminary Geologic Map of the Horseshoe Bend National Military Park, Alabama* (scale 1:24,000) (Jones 2012).

GRI GIS data include essential elements of source maps such as map unit descriptions, a correlation chart of units, a map legend, map notes, cross sections, figures, and references. These items are included in a GRI ancillary map information document, which for the park is hobe_geology.pdf.

GRI GIS Data

The GRI team standardizes map deliverables by implementing a data model that is based on an ESRI geodatabase to ensure data quality, product consistency, and that a digital map is user friendly and well communicated. The GRI GIS data model is the architectural blueprint or schema for the GIS data; it includes defining data layers based on spatial representation (i.e., polygon, line, or point) and geologic theme (e.g., faults, folds, and contacts). Feature attribution (how feature information is stored) and geodatabase topology (spatial relationship rules that ensure spatial integrity) are also components of the data model. The GRI GIS data for the park was compiled using data model version 2.0, which is available at https://go.nps.gov/gridatamodel.

GRI GIS data are available on the GRI publications website https://go.nps.gov/gripubs and through the NPS Integrated Resource Management Applications (IRMA) portal https://irma.nps.gov/App/Portal/Home; enter "GRI" as the search text and select a park from the unit list. The GRI Geologic Maps website, https://go.nps.gov/geomaps, provides more information about the program's map products.

The following components are part of the data for the park:

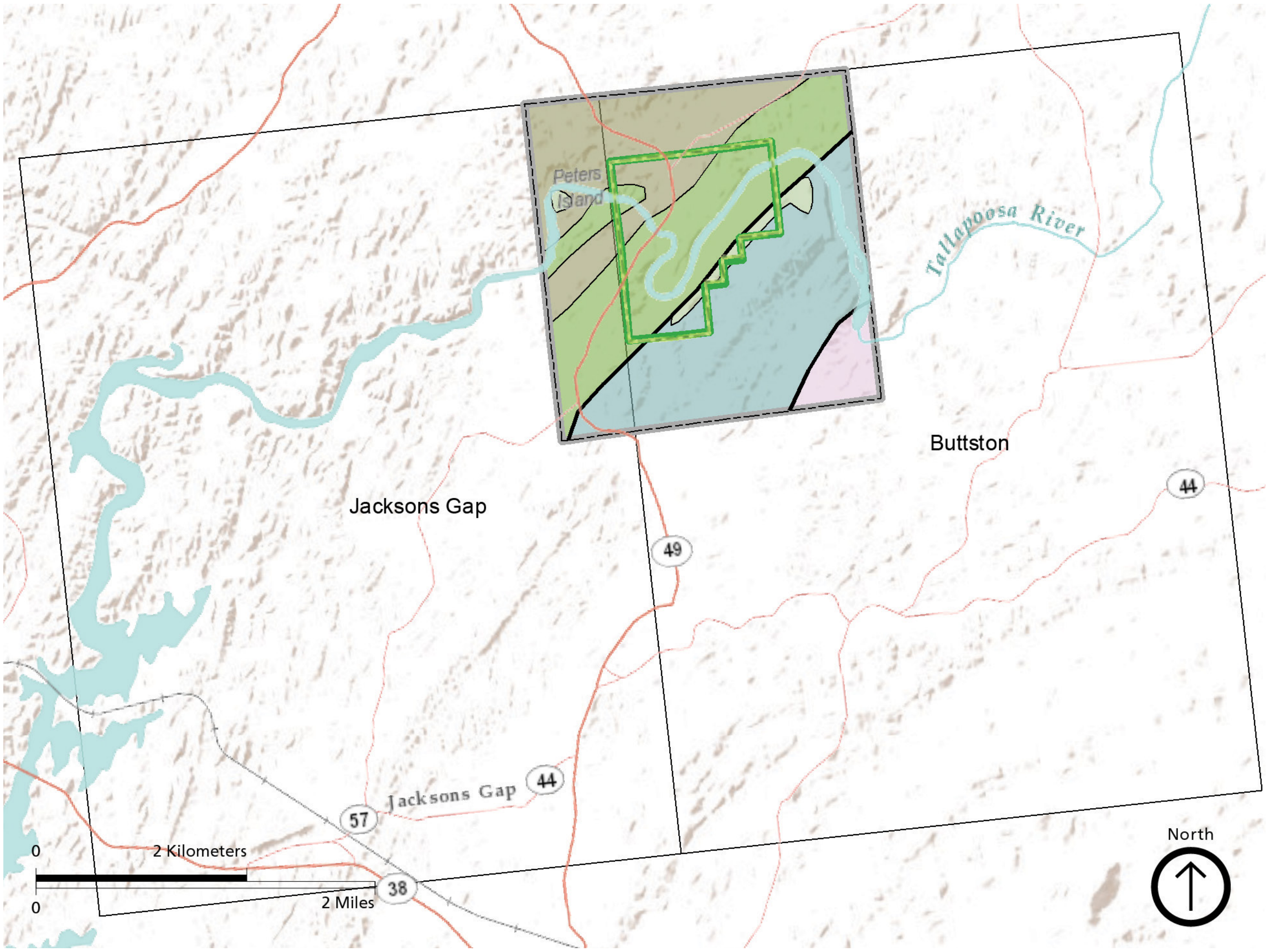

Figure 15. Index map for the GRI GIS data of the park.
Graphic shows the GRI GIS data and the two 7.5 minute quadrangles (Jacksons Gap and Buttston) surrounding the park. The NPS boundary of Horseshoe Bend National Military Park (green outline) ends at the border of the Buttston quadrangle, but the GRI GIS data continue west into the Jacksons Gap quadrangle. Graphic compiled by the author.

Table 2. GRI GIS data layers for Horseshoe Bend National Military Park.

Data Layer	On Poster?	On Google Earth Layer?
Geologic Attitude and Observation Localities	No	Yes
Faults	Yes	Yes
Geologic Contacts	Yes	Yes
Geologic Units	Yes	Yes

- A GIS readme file (readme.txt) that describes the GRI data formats, naming conventions, extraction instructions, use constraints, and contact information;
- Data in ESRI geodatabase GIS format;
- An ESRI map document (hobe_geology.mxd) that displays the GRI GIS data and allows for user interaction and analysis;
- Layer files that contain symbology for each data layer (see table 2);
- Federal Geographic Data Committee (FGDC)–compliant metadata, which are organized in a user-friendly, frequently asked questions (FAQ) format; and
- An ancillary map information document (hobe_geology.pdf) that contains information captured from source maps such as map unit descriptions, geologic

unit correlation tables, legends, cross sections, and figures.

GRI Map Poster

A poster of the GRI GIS data draped over a shaded relief image of the park and surrounding area is included with this report. Not all GIS feature classes are included on the poster (see table 2). Geographic information and selected park features have been added to the poster. Digital elevation data and added geographic information are not included in the GRI GIS data but are available online from a variety of sources. Park managers may contact the GRI team for assistance locating these data.

Use Constraints

Graphic and written information provided in this report and in the accompanying GRI GIS data is not a substitute for site-specific investigations. Ground-disturbing activities should neither be permitted nor denied based upon the information provided here. Park managers may contact the GRI team with any questions.

Minor inaccuracies may exist regarding the locations of geologic features relative to other geologic or geographic features in the GRI GIS data and on the poster. Based on the source map scale (1:24,000) and US National Map Accuracy Standards, geologic features represented are expected to be horizontally within 12 m (40 ft) of their true locations.

Literature Cited

These references are cited in this report. Contact the Geologic Resources Division for assistance in obtaining them.

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Additional Resources

These websites, online information, and books may be of use for geologic resources management and interpretation at Horseshoe Bend National Military Park.

Climate Change

- Intergovernmental Panel on Climate Change: https://www.ipcc.ch/
- NPS Climate Change Response Program Resources: https://www.nps.gov/subjects/climatechange/resources.htm
- The Climate Analyzer (an interactive website that allows users to create custom graphs and tables from historical and current weather-station data: https://www.climateanalyzer.org/
- US Global Change Research Program: https://www.globalchange.gov/home

Geological Surveys and Societies

- Geological Survey of Alabama: https://www.gsa.state.al.us
- American Geophysical Union: https://sites.agu.org/
- American Geosciences Institute: https://www.americangeosciences.org/
- Association of American State Geologists: https://www.stategeologists.org/
- Geological Society of America: https://www.geosociety.org/
- US Geological Survey (USGS): https://www.usgs.gov/

NPS Geology Interpretation and Education

- America's Geologic Heritage: An Invitation to Leadership by the NPS Geologic Resources Division and American Geosciences Institute (AGI). Published in 2015 by AGI: https://go.nps.gov/AmericasGeoheritage
- NPS Geologic Resources Division Education website: https://go.nps.gov/geoeducation
- NPS Geoscientist-In-the-Parks (GIP) internship and guest scientist program: https://go.nps.gov/gip
- NPS Mosaics-In-Science (MIS) internship program: https://go.nps.gov/mis
- Parks and Plates: The Geology of Our National Parks, Parks, and Seashores by Robert J. Lillie (Oregon State University). Published in 2005 by W. W. Norton and Company, New York.

NPS Resource Management Guidance and Documents

- 1998 National parks omnibus management act: https://www.gpo.gov/fdsys/pkg/PLAW-105publ391/pdf/PLAW-105publ391.pdf
- Appendix B of the GRI report.
- Geological Monitoring by Rob Young and Lisa Norby. Published in 2009 by the Geological Society of America. Available online at https://go.nps.gov/geomonitoring
- Management Policies 2006 (Chapter 4: Natural resource management): https://www.nps.gov/policy/mp/policies.html
- NPS-75: Natural resource inventory and monitoring guideline: https://www.nature.nps.gov/nps75/nps75.pdf
- NPS Natural resource management reference manual #77: https://www.nature.nps.gov/Rm77/
- NPS Technical Information Center (TIC) (Denver, Colorado; repository for technical documents): https://www.nps.gov/dsc/technicalinfocenter.htm

US Geological Survey (USGS) Reference Tools

- National Geologic Map Database (NGMDB): https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
- US Geologic Names Lexicon (Geolex; geologic unit nomenclature and summary): https://ngmdb.usgs.gov/Geolex/search
- Geographic Names Information System (GNIS; official listing of place names and geographic features): https://gnis.usgs.gov/
- GeoPDFs (download PDFs of any topographic map in the United States): https://store.usgs.gov (click on "Map Locator")
- Publications warehouse (USGS publications available online): https://pubs.er.usgs.gov
- Tapestry of Time and Terrain (descriptions of physiographic provinces): https://pubs.usgs.gov/imap/i2720/

Appendix A: Scoping Participants

The following people attended the GRI scoping meeting, held on 8 May 2006, or the follow-up report writing conference call, held on 21 February 2018. Discussions during these meetings supplied a foundation for this GRI report. The scoping summary document is available on the GRI publications website: http://go.nps.gov/gripubs.

2012 Scoping Meeting Participants

Name	Affiliation	Position
Joel Abrahams	Auburn University	Graduate Student
Jim Cahill	Horseshoe Bend National Military Park	Chief Ranger
Kelly Gregg	Jacksonville State University	Geologist
John Hawkins	Auburn University	Graduate Student
Bruce Heise	NPS Geologic Resources Division	Geologist/GRI Program Coordinator
Georgia Hybels	NPS Geologic Resources Division	Geologist/GIS Specialist
Kevin Jones	Auburn University	Undergraduate Student
Katie KellerLynn	Colorado State University	Geologist/Research Associate/Report Writer
Ed Osborne	Geological Survey of Alabama	Geologist/Program Director
Josh Poole	University of West Georgia	Undergraduate Student
Rebecca Port	Colorado State University	Research Associate
Doyle Sapp	Horseshoe Bend National Military Park	Superintendent
Mark Steltenpohl	Auburn University	Department of Geography and Geology, Professor and Chair

2018 Conference Call Participants

Name	Affiliation	Position
Michael Barthelmes	Colorado State University	Geologist/Research Associate/Report Writer
Don Irvin	Alabama Geological Survey	Geologic Map Coordinator
Jason Kenworthy	NPS Geologic Resources Division	Geologic Resources Inventory Coordinator
Jake McDonald	NPS Southeast Coast Network	Geomorphologist
Brian Robinson	Horseshoe Bend National Military Park	Maintenance Mechanic
Stacy Speas	Horseshoe Bend National Military Park	Lead Park Ranger

Appendix B: Geologic Resource Laws, Regulations, and Policies

The NPS Geologic Resources Division developed this table to summarize laws, regulations, and policies that specifically apply to NPS minerals and geologic resources. The table does not include laws of general application (e.g., Endangered Species Act, Clean Water Act, Wilderness Act, National Environmental Policy Act, or National Historic Preservation Act). The table does include the NPS Organic Act when it serves as the main authority for protection of a particular resource or when other, more specific laws are not available. Information is current as of December 2017. Contact the NPS Geologic Resources Division for detailed guidance.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Paleontology	**National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of paleontological resources and objects. **Paleontological Resources Preservation Act of 2009, 16 USC § 470aaa et seq.** provides for the management and protection of paleontological resources on federal lands. **Archaeological Resources Protection Act of 1979, 16 USC §§ 470aa – mm Section 3 (1) Archaeological Resource**—nonfossilized and fossilized paleontological specimens, or any portion or piece thereof, shall not be considered archaeological resources, under the regulations of this paragraph, unless found in an archaeological context. Therefore, fossils in an archaeological context are covered under this law. **Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309 Section 3 (5) Cave Resource**—the term "cave resource" includes any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems. Therefore, every reference to cave resource in the law applies to paleontological resources.	**36 CFR § 2.1(a)(1)(iii)** prohibits destroying, injuring, defacing, removing, digging or disturbing paleontological specimens or parts thereof. **Prohibition in 36 CFR § 13.35** applies even in Alaska parks, where the surface collection of other geologic resources is permitted. **43 CFR Part 49** (in development) will contain the DOI regulations implementing the Paleontological Resources Preservation Act.	**Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity. **Section 4.8.2.1** emphasizes Inventory and Monitoring, encourages scientific research, directs parks to maintain confidentiality of paleontological information, and allows parks to buy fossils only in accordance with certain criteria.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Recreational Collection of Rocks Minerals	**NPS Organic Act, 54 USC. § 100101 et seq.** directs the NPS to conserve all resources in parks (which includes rock and mineral resources) unless otherwise authorized by law. **Exception: 16 USC. § 445c (c) – Pipestone National Park enabling statute**. Authorizes American Indian collection of catlinite (red pipestone).	**36 C.F.R. § 2.1** prohibits possessing, destroying, disturbing mineral resources…in park units. **Exception: 36 C.F.R. § 7.91** allows limited gold panning in Whiskeytown. **Exception: 36 C.F.R. § 13.35** allows some surface collection of rocks and minerals in some Alaska parks (not Klondike Gold Rush, Sitka, Denali, Glacier Bay, and Katmai) by non-disturbing methods (e.g., no pickaxes), which can be stopped by superintendent if collection causes significant adverse effects on park resources and visitor enjoyment.	**Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.
Mining Claims (Locatable Minerals)	**Mining in the Parks Act of 1976, 54 USC § 100731 et seq.** authorizes NPS to regulate all activities resulting from exercise of mineral rights, on patented and unpatented mining claims in all areas of the System, in order to preserve and manage those areas. **General Mining Law of 1872, 30 USC § 21 et seq.** allows US citizens to locate mining claims on Federal lands. Imposes administrative and economic validity requirements for "unpatented" claims (the right to extract Federally-owned locatable minerals). Imposes additional requirements for the processing of "patenting" claims (claimant owns surface and subsurface). Use of patented mining claims may be limited in Wild and Scenic Rivers and OLYM, GLBA, CORO, ORPI, and DEVA. **Surface Uses Resources Act of 1955, 30 USC § 612** restricts surface use of unpatented mining claims to mineral activities.	**36 CFR § 5.14** prohibits prospecting, mining, and the location of mining claims under the general mining laws in park areas except as authorized by law. **36 CFR Part 6** regulates solid waste disposal sites in park units. **36 CFR Part 9, Subpart A** requires the owners/ operators of mining claims to demonstrate bona fide title to mining claim; submit a plan of operations to NPS describing where, when, and how; prepare/submit a reclamation plan; and submit a bond to cover reclamation and potential liability. **43 CFR Part 36** governs access to mining claims located in, or adjacent to, National Park System units in Alaska.	**Section 6.4.9** requires NPS to seek to remove or extinguish valid mining claims in wilderness through authorized processes, including purchasing valid rights. Where rights are left outstanding, NPS policy is to manage mineral-related activities in NPS wilderness in accordance with the regulations at **36 CFR Parts 6** and **9A**. **Section 8.7.1** prohibits location of new mining claims in parks; requires validity examination prior to operations on unpatented claims; and confines operations to claim boundaries.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Climate Change	**Secretarial Order 3289** (Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources) (2009) requires DOI bureaus and offices to incorporate climate change impacts into long-range planning; and establishes DOI regional climate change response centers and Landscape Conservation Cooperatives to better integrate science and management to address climate change and other landscape scale issues. **Executive Order 13693** (Planning for Federal Sustainability in the Next Decade) (2015) established to maintain Federal leadership in sustainability and greenhouse gas emission reductions.	None Applicable.	**Section 4.1** requires NPS to investigate the possibility to restore natural ecosystem functioning that has been disrupted by past or ongoing human activities. This would include climate change, as put forth by Beavers et al. (in review). **NPS Climate Change Response Strategy** (2010) describes goals and objectives to guide NPS actions under four integrated components: science, adaptation, mitigation, and communication. **Policy Memo 12-02** (Applying National Park Service Management Policies in the Context of Climate Change) (2012) applies considerations of climate change to the impairment prohibition and to maintaining "natural conditions". **Policy Memo 14-02** (Climate Change and Stewardship of Cultural Resources) (2014) provides guidance and direction regarding the stewardship of cultural resources in relation to climate change. **Policy Memo 15-01** (Climate Change and Natural Hazards for Facilities) (2015) provides guidance on the design of facilities to incorporate impacts of climate change adaptation and natural hazards when making decisions in national parks. **DOI Manual Part 523, Chapter 1** establishes policy and provides guidance for addressing climate change impacts upon the Department's mission, programs, operations, and personnel. **Revisiting Leopold: Resource Stewardship in the National Parks** (2012) will guide US National Park natural and cultural resource management into a second century of continuous change, including climate change. **Climate Change Action Plan** (2012) articulates a set of high-priority no-regrets actions the NPS will undertake over the next few years **Green Parks Plan** (2013) is a long-term strategic plan for sustainable management of NPS operations.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Soils	**Soil and Water Resources Conservation Act, 16 USC §§ 2011–2009** provides for the collection and analysis of soil and related resource data and the appraisal of the status, condition, and trends for these resources. **Farmland Protection Policy Act, 7 USC § 4201 et. seq.** requires NPS to identify and take into account the adverse effects of Federal programs on the preservation of farmland; consider alternative actions, and assure that such Federal programs are compatible with State, unit of local government, and private programs and policies to protect farmland. NPS actions are subject to the FPPA if they may irreversibly convert farmland (directly or indirectly) to nonagricultural use and are completed by a Federal agency or with assistance from a Federal agency. Applicable projects require coordination with the Department of Agriculture's Natural Resources Conservation Service (NRCS).	**7 CFR Parts 610 and 611** are the US Department of Agriculture regulations for the Natural Resources Conservation Service. **Part 610** governs the NRCS technical assistance program, soil erosion predictions, and the conservation of private grazing land. **Part 611** governs soil surveys and cartographic operations. The NRCS works with the NPS through cooperative arrangements.	**Section 4.8.2.4** requires NPS to -prevent unnatural erosion, removal, and contamination; -conduct soil surveys; -minimize unavoidable excavation; and -develop/follow written prescriptions (instructions).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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