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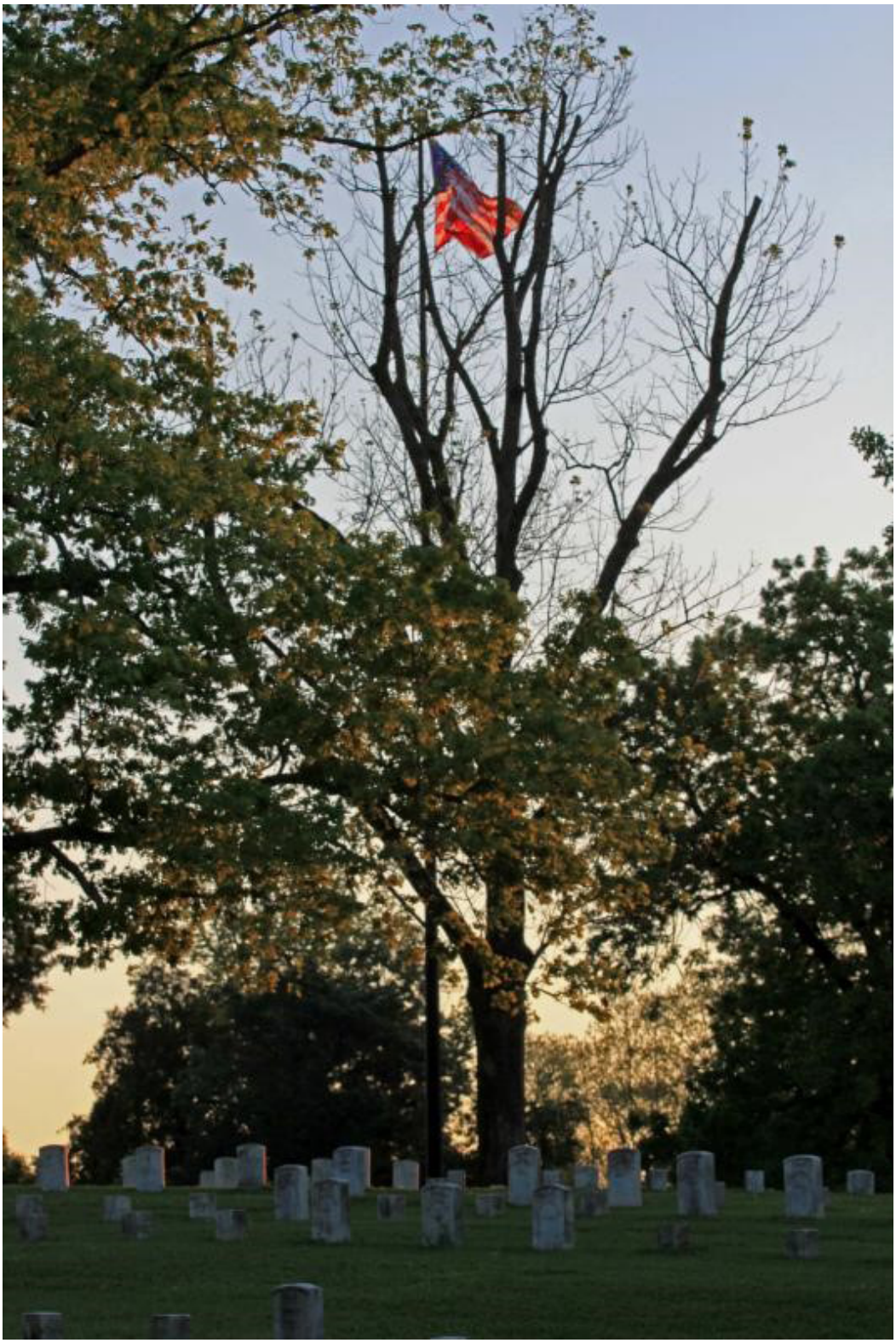
Natural Resource Stewardship and Science

Shiloh National Military Park

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2018/1778





ON THE COVER
Cannon and memorials overlooking Bloody Pond.
Photograph by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.
THIS PAGE
American flag at sunrise over Shiloh National Cemetery.
National Park Service photograph (Shiloh National Military Park).

Shiloh National Military Park

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2018/1778

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U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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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 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 report synthesizes discussions from a scoping meeting held in 2009 and a follow-up conference call in 2017 (see Appendix A). Chapters of this report discuss the geologic setting and history leading to the present-day landscape, distinctive geologic features and processes within Shiloh National Military Park, highlight geologic issues facing resource managers, and provide information about the previously completed GRI map data. A poster (in pocket) illustrates these data.

The steep bluffs overlooking the Tennessee River and fronting the rolling upland of "Shiloh Hill" set the stage for one of the bloodiest and most influential conflicts of the American Civil War. The battle of Shiloh was critical in deciding the eventual control of the Mississippi River valley during the war. Geologic features and processes created a landscape of battle-relevant sites such as the roads and railroads atop well-drained fluvial deposits, Pittsburg Landing on the Tennessee River, Dill Branch and many other strategic ravines, as well as Bloody Pond and other wetlands. The Tennessee River bluffs also supported prehistoric American Indian societies and are a well-preserved Mississippian archeological site. Shiloh National Military Park commemorates a great sacrifice on both sides of the Civil War conflict by preserving Shiloh's battle-era appearance with agricultural fields, forests, and road traces, as well as memorials put in place as early as 1893.

More than 66 million years of Earth's history is recorded in the geologic units underlying Shiloh Battlefield. The oldest are the marine sands and clays of the Cretaceous Eutaw Formation (geologic map unit **Ke**), deposited along the margin of the uplands present in western Tennessee during a time of rising global sea level. Following a period of erosion, sea level rose again and the fine-grained sands and clays of the Coffee Formation (**Kc**) were deposited in nearshore and lagoonal environments atop the Eutaw Formation. Sea level fluctuations continued into the Cenozoic Era. Precursors of modern rivers deposited coarse gravels, sands, and silts (**QTf**). Modern rivers and streams cut down through the sedimentary layers, depositing and constantly reworking the youngest geologic map unit, alluvium (**Qal**).

This report is supported by a GRI-compiled map of the geology of Shiloh National Military Park; the present map data cover only the battlefield unit (including Shiloh Battlefield, Shiloh National Cemetery, and Shiloh Indian Mounds), not the Davis Bridge site, or siege site in Corinth, Mississippi, or the Fallen Timbers area (a potential addition to the legislated park). The GRI map was compiled from a series of four geologic and mineral resources maps produced by E. E. Russell of the Tennessee Division of Geology in the 1960s at 1:24,000 scale. The spatial distributions and unit descriptions of the map units informed a table of geologic features, processes, and associated resource management issues in Shiloh National Military Park in the context of relevant geologic map units that occur within park boundaries.

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

- **Fluvial Features**. Fluvial features are those which are formed by flowing water constructing and eroding landforms. The Tennessee River follows the eastern boundary of the park and continues to carve the high bluffs that factor heavily in both the park's history and management. Many small streams flow through the battlefield eroding steep ravines and cutbanks along meandering channels. These streams rework and deposit modern alluvium (**Qal**) in point bars and gravel bars.
- **Slope Movements**. Slope movements are the downslope transfer of earth materials under the influence of gravity. Vegetation disturbances on slopes destabilize sediments entrained by roots. Slope movements are an issue along the steep bluffs fronting the Tennessee River. Further retreat of these bluffs will threaten archeological resources associated with the Shiloh Mound Complex, park infrastructure, and Civil War cultural resources.

- **Paleontological Resources, Inventory, Monitoring, and Protection**. Fossils are evidence of life preserved in a geologic context. Fossils have not yet been documented in situ within the park, but fossils associated with the Shiloh Mound Complex in an archeological context were originally preserved in the older Cretaceous units. Fossils elsewhere from these rock layers include plant remains, mollusks, insects, and trace fossils. These fossils are non-renewable and subject to science-informed inventory, monitoring, protection, and interpretation as outlined by the 2009 Paleontological Resources Preservation Act
- **Seeps, Springs, Ponds, and Wetlands**. Seeps and springs (e.g., Rhea Spring) occur where groundwater percolating downward encounters an impermeable layer and flows laterally along it to intersect the surface. Impermeable, clay-rich layers in the bedrock at Shiloh National Military Park are responsible for these features. Ponds (e.g., Bloody Pond) and wetlands factor into the battle-era landscape at the park. Wetlands are transitional areas between land and water where the soil is frequently saturated by flooding. Geologic controls of wetland locations include the drainage capacity of the substrate, local topography, and underlying bedrock. Nearly 6% of the park area are wetlands, including flanking areas of most streams, the largest of which occurs along Owl Creek. These wetlands provide several significant functions, including (1) wildlife habitat, (2) surface water detention, (3) nutrient transformation, and (4) retention of sediments.
- **Bedrock Exposures and Ancient Sedimentary Features**. Bedrock is the older rock that underlies the recent unconsolidated surficial deposits of the park. The bedrock is exposed in the walls of deep ravines and gullies in the park. Information about the deposition of the Cretaceous Eutaw (**Ke**) and Coffee (**Kc**) formations in shallow marine and fluvial environments is revealed in these outcrops.
- **Flooding and Climate Change**. Flooding occurs along the Tennessee River, and local streams in the park such as Shiloh Branch, Dill Branch, Glover Branch (Tilghman) and Owl Creek. Pickwick Dam, upstream of the park mitigates some of the flood risk from the Tennessee River. Flooding in the park area will likely be exacerbated by predicted changes in climate. Climate change models for southern Tennessee predict hotter conditions with more extreme storms and daily high temperatures. Increased storms may increase runoff, flooding, and upland erosion.
- **Erosion**. The park boundary follows the Tennessee River for 2.4 km (1.5 mi) and comparing modern conditions with an 1895 survey reveals that 38 to 43 m (125 to 140 ft) of landmass has eroded away since 1895. Erosion was exacerbated in 1944, when the shoreline was cleared between Pickwick and Kentucky dams to support navigation. The advancing river threatens the Shiloh Mounds complex as well as park infrastructure, and in 1973 approximately 30.5 m (100 ft) of the eastern edge of Mound A was lost in a slide. In the early 2000s, the park imported limestone blocks for armoring along Riverside Road. In upland areas, erosion is forming gullies on sloped areas which threatens cultural resources. Erosion is also undermining local trail beds.
- **Abandoned Mineral Lands and Disturbed Lands**. Since the earliest American Indian inhabitants more than 1,000 years ago, humans have altered the landscape of the Shiloh area via mound building, clearing, farming, fighting, and transportation development. Quarrying for clay, sand, gravel, and other mineral resources in the area has been ongoing. Some prehistoric quarries are considered cultural features. Shallow sand and gravel pits within the park provided materials for park road construction and may have unstable walls. Quarries that had been used as dumps or left abandoned are filled with organic waste (e.g. downed trees, branches, and clippings) by the park.
- **External Development**. Established in 1894, Shiloh National Military Park has been protected from much of the urban and agricultural development that has occurred outside of the park. However, newly renewed mining of a historical quarry just north of the park by the Santana Dredging and Coring Company potentially threatens archeological artifacts and has destroyed Union troop camps. The quarry is 9 to 12 m (30 to 40 ft) deep within the Cretaceous Eutaw Formation, and provides material for roadwork on US Highway 64 and Tennessee Highway 22. Traffic on these roads, along with nearby coal fired power plants, threaten the air quality; battlefield views are often obscured by pollution caused haze. There is potential for incompatible development near the park, including cellular towers that could impact historic viewsheds.
- **Seismicity**. The park is not located near a major seismic zone and is not considered to be at high risk of strong earthquakes; however, seismicity could impact park resources, particularly within unconsolidated alluvium (**Qal**) and fluvial deposits (**QTf**) and areas of steep slopes. There is a 2% to 3% probability of a moderate (magnitude-5.0 or greater) earthquake within 100 years.

Products and Acknowledgments

The NPS Geologic Resources Division partners with the Colorado State University Department of Geosciences to produce GRI products. The Tennessee Division of Geology 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), 2006 National Park Service Management Policies, and the Natural Resources Inventory and Monitoring Guideline (NPS-75). The "Additional References" 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. The current status and projected completion dates of products are available at http://go.nps.gov/gri_status.

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Additional thanks to: **Tammy Kirk** (librarian, US Army Corps of Engineers, Nashville District) for her assistance finding photographs and additional information regarding the Corps' restoration project along the Tennessee River. Park staff provided substantial information for this report: **Stacy Allen** (chief ranger/resource management), **Marcus Johnson** (resource management, inventory and monitoring), and **Randy Martin** (assistant facilities manager)

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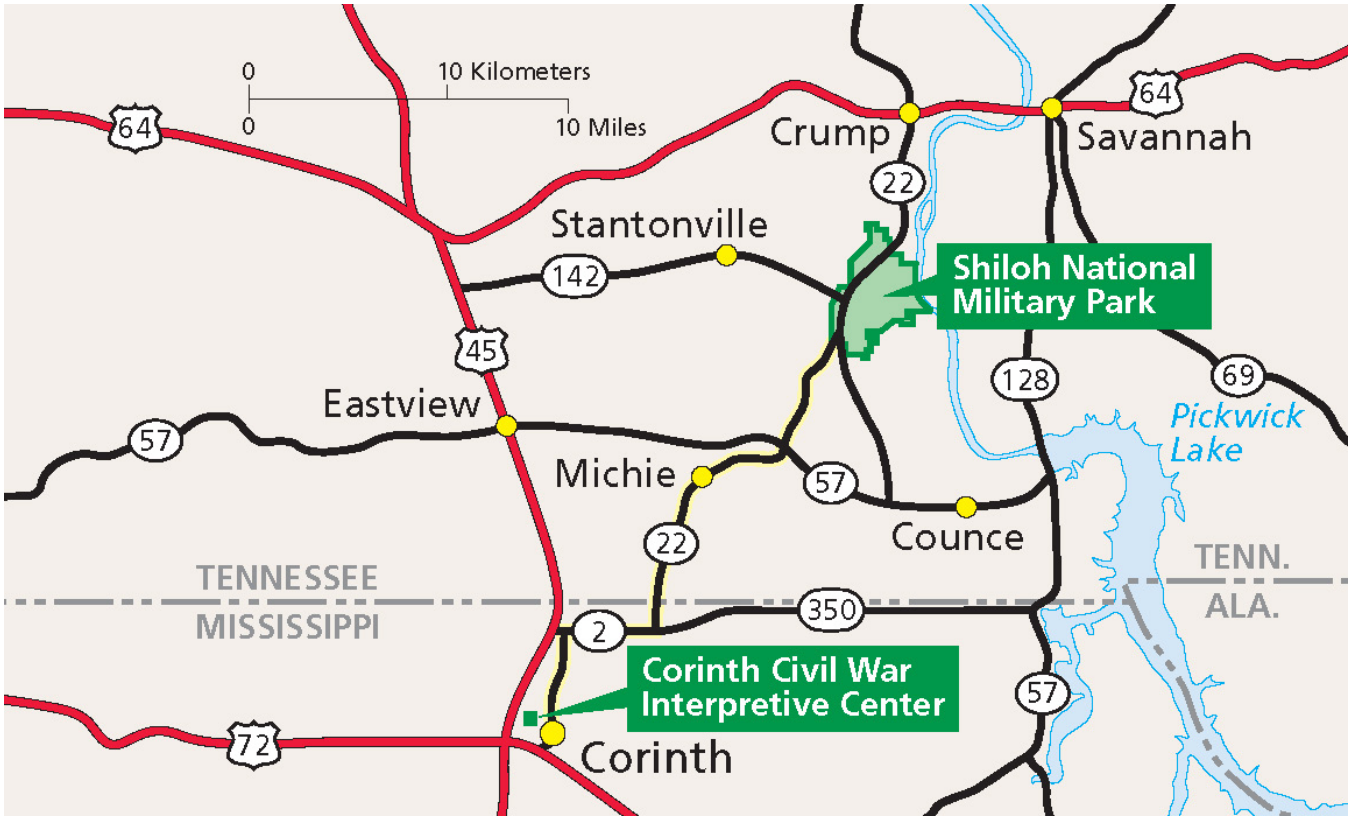


Figure 1. Regional map of Shiloh National Military Park and Corinth Civil War Interpretive Center. National Park Service map, available at https://home.nps.gov/carto/app/#!/parks.

Geologic Setting, History, and Significance

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

Park Establishment and Significance

On April 6, 1862, nearly 110,000 Union and Confederate troops engaged in a major, two-day battle that played out on the landscape at Shiloh Meeting House (a church) and Pittsburg Landing, Tennessee. This battle ignited a six-month struggle for the key railroad junction at Corinth, Mississippi during the American Civil War. Following the battle at Shiloh, Union forces marched from Pittsburg Landing on the west bank of the Tennessee River to lay siege to Corinth in May and withstood a Confederate counter-attack in October 1862. Ultimately, the Union victory at Shiloh set the stage for the Union capture of Vicksburg, Mississippi on July 4, 1863. Shiloh National Military Park, established on December 27, 1894, commemorates this clash that resulted in 23,746 casualties—more casualties than in all of America's previous wars combined. The carnage of the fighting experienced on "Shiloh Hill" forecast an increasingly bloody and protracted war (National Park Service 2016b). In addition to the battlefield, the park includes Shiloh National Cemetery (founded in 1866), Shiloh Indian Mounds National Historic Landmark, and separate units at Davis Bridge Battlefield site in McNairy County, Tennessee, and Corinth, Mississippi (fig. 1). Russell House in Corinth, Fallen Timbers (the site of final combat on April 8, 1862), and more area at the Davis Bridge unit are currently in the process of being added to the park in new legislation. This report focuses on the geographical area covered by the GRI GIS data—Shiloh Battlefield, Shiloh National Cemetery, and Shiloh Indian Mounds.

The National Park Service manages 2,048.31 ha (5,061.48 ac) at Shiloh National Military Park, the nation's second oldest national military park, near Stantonville and Shiloh, Tennessee in Hardin County (fig 2). The park's eastern boundary is the Tennessee River, impounded just 14 km (9 mi) upstream by the Pickwick Dam (US ACOE 1984).

Geologic Setting and History

Shiloh National Military Park is within the west Tennessee River valley on coastal plain deposits at the edge of the Western Tennessee Uplands physiographic province (figs. 3 and 4). This is all part of the greater Mississippi Embayment—a large trough that extends southward to the Gulf of Mexico (fig. 5). Sediments within this trough are younger towards the center of the embayment. Geologic formations in western Tennessee all have a westerly regional dip towards the axis of the embayment (US ACOE 1984).

The geologic units mapped within the park reflect a long history of deposition and the evolution of the Tennessee River valley (figs. 5, 6, and 7). The units are broadly divisible into two categories: (1) Cretaceous sedimentary bedrock, and (2) unconsolidated Tertiary and Quaternary deposits. During the late Cretaceous, more than 66 million years ago, the Eutaw and Coffee Formations (geologic map units **Ke** and **Kc**, respectively; fig. 7B) were deposited upon ancient Silurian, Devonian, and Mississippian rocks (e.g., **Sw**, **Dr**, and **Mfp**; 485 to 323 million years old) along the margin of the uplands in western Tennessee. At this time global sea level was rising and an ancient precursor to the Tennessee River deposited the pebbles, sand, silt, and clay of the Eutaw Formation in nearshore environments. Sea level fluctuation continued and, following a period of nondeposition, the Coffee Formation was deposited in lagoonal, barrier bar, and shoreline environments on top of the Eutaw Formation. Streams then began to rework the Cretaceous deposits, cutting channels and leaving thick fluvial deposits (**QTf**) in their floodplains (fig. 7C). These fluvial deposits were left as perched, dissected river terraces (including "Shiloh Hill") as modern streams, such as the Tennessee River and its tributaries in the park, cut their present courses and transported, deposited, and reworked modern alluvium (**Qal**) along their channels and adjacent floodplains over at least the past 2.6 million years (fig. 7D) (Bossu et al. 2013).

Geologic Significance and Connections

Landforms and resources of the Shiloh area influenced human history and natural systems. More than 1,000 years of human history is recorded on the geologic foundation of Shiloh National Military Park. Brewer (1987) compiled an archeological overview of Shiloh National Military Park, which includes the status of sites from prehistoric uses up through the Civil War battle.

Shiloh Indian Mounds

The earliest record of human habitation in the Shiloh area dates back to about 1,100 years ago when seven earthen mounds and dozens of houses were enclosed by a wooden palisade atop the 30 m (100 ft) high Tennessee River bluff at the eastern edge of the Shiloh plateau (US ACOE 1984; National Park Service 2016a). The bluff was just one part of Woodland (1000 BCE–1000 CE) and Mississippian (about 950–1350 CE)

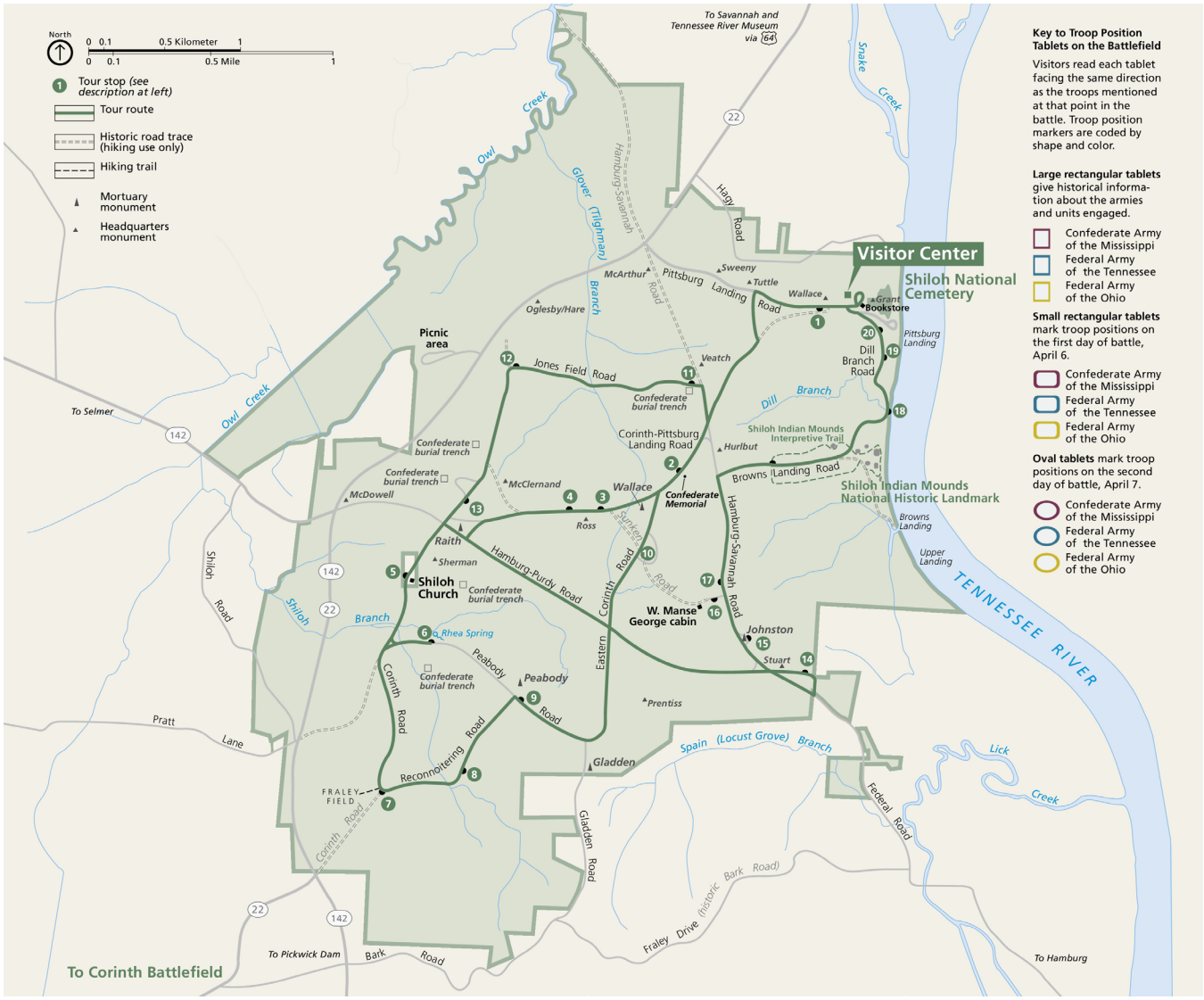


Figure 2. Map of Shiloh National Military Park.
The Tennessee River flows along the eastern edge of the park and small streams and tributaries traverse the park. National Park Service map, available at https://home.nps.gov/carto/app/#!/parks.

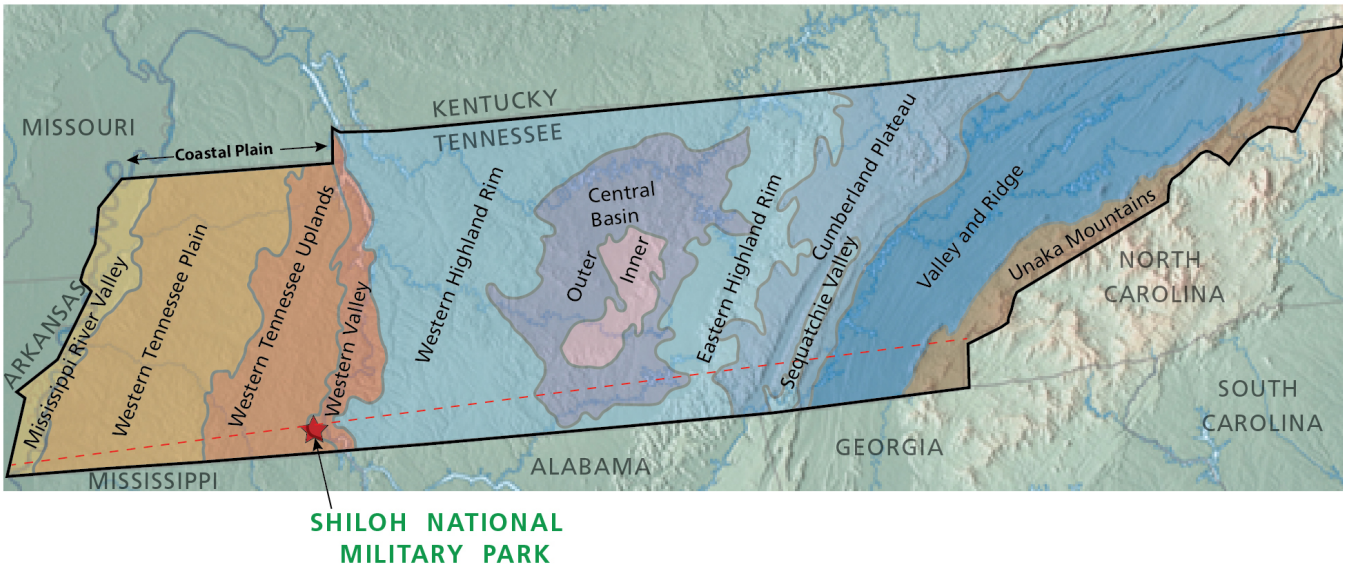


Figure 3. Map of physiographic provinces of Tennessee.
Differential erosion across a landscape shaped initially by mountain building and marine deposition have created the varying character of landforms in Tennessee. The dashed red line represents the trace of a cross-sectional view through the state presented in figure 4. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) after Harris (2012).

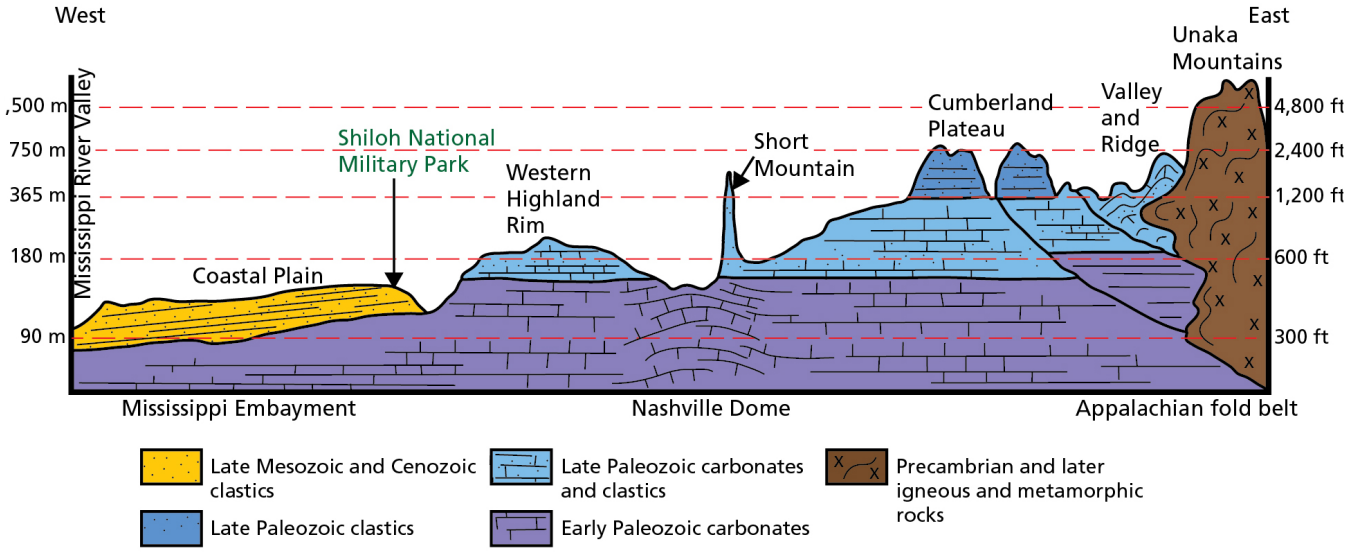


Figure 4. Cross section through Tennessee.
From west to east, the section crosses from the low-lying coastal plain, upwards across the highland rim and into the central basin before rising further east onto the Cumberland Plateau and ultimately into the Unaka Mountains of the Appalachian Mountains. The trace of the section is marked by a red dashed line on figure 3. Carbonates are chemical sediments such as limestone and dolomite. Clastics are rocks composed of smaller fragments of other rocks, such as sandstone or siltstone. Graphic shows the western dipping topography of the Mississippi Embayment, as described in the "Geologic History" section. The vertical scale is marked and nonlinear to emphasize the differences in each area's topographic expression. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) after Harris (2012).

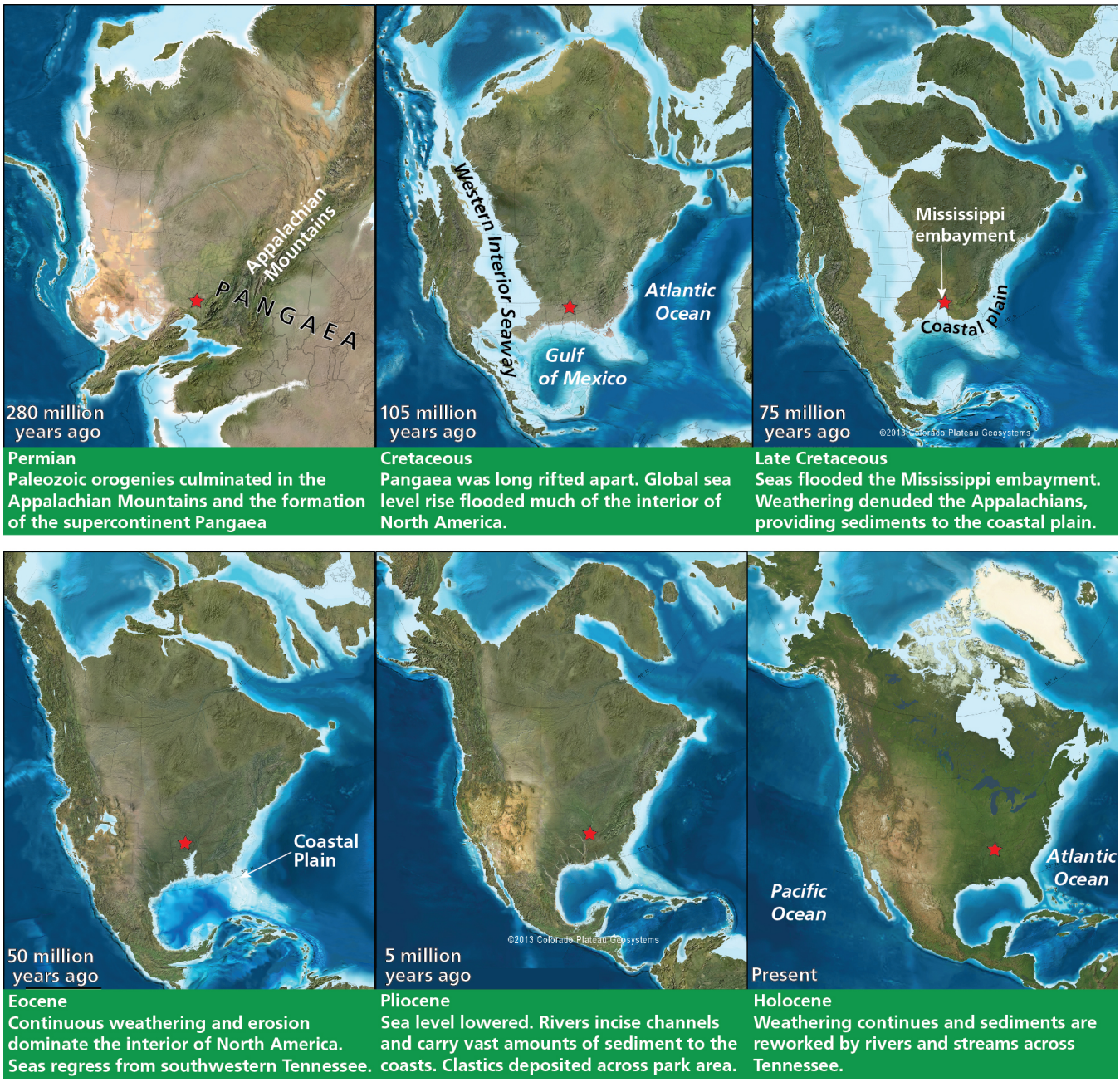


Figure 5. Paleogeographic maps of North America.
The red star indicates the approximate location of Shiloh National Military Park, which, after longstanding marine deposition in the Silurian, Devonian, and Mississippian (geologic map units Sw, Dr, and Mfp), was in the center of the supercontinent Pangaea at the end of the Paleozoic Era. After the supercontinent rifted apart, the park area was the scene of alternating deposition and erosion throughout the Mesozoic Era as the coastal plain extended out into the Gulf of Mexico and Atlantic Oceans. Graphic compiled by Trista L. Thornberry-Ehrlich (Colorado State University). Base paleogeographic maps created by Ron Blakey (Colorado Plateau Geosystems, Inc.), available at https://deeptimemaps.com/.

American Indian societies that occupied a 32 km (20 mi) stretch of the Tennessee River Valley (Brewer 1987; National Park Service 2016a). The bluff formed where the river incised fluvial terrace deposits (geologic map unit **QTf**) that accumulated more than 2.6 million years ago. Terrace settings are common settlement sites as their elevation protects from flooding while still providing access to water. The Tennessee River flows through the aboriginal homeland of the Chickasaw Nation. The river would have enabled

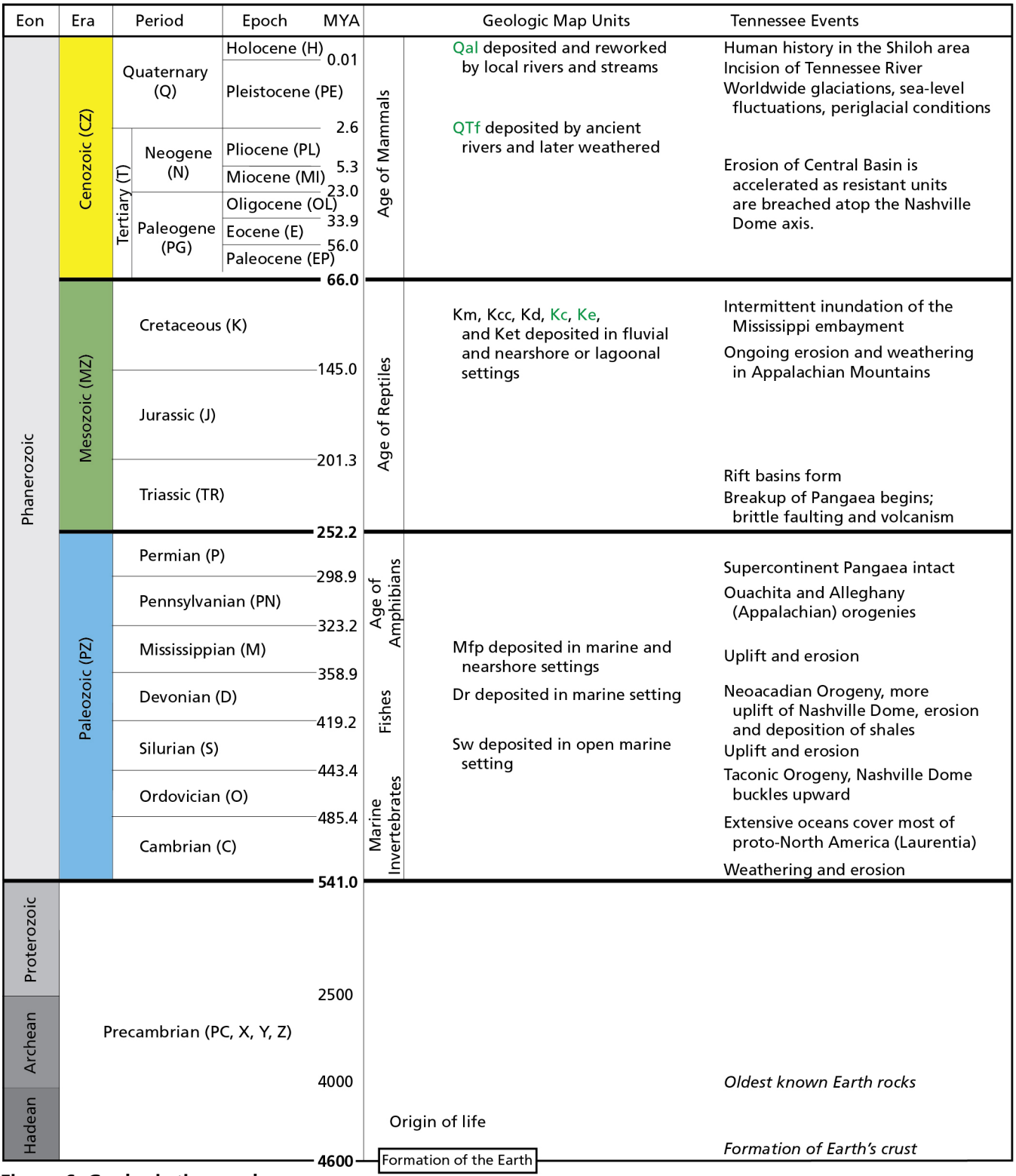


Figure 6. Geologic time scale.
The divisions of the geologic time scale are organized stratigraphically, with the oldest divisions at the bottom and the youngest at the top. GRI map abbreviations for each time division are in parentheses. Geologic units mapped within the park are in green text. Boundary ages are millions of years ago (MYA). National Park Service graphic using dates from the International Commission on Stratigraphy (http://www.stratigraphy.org/index.php/ics-chart-timescale).

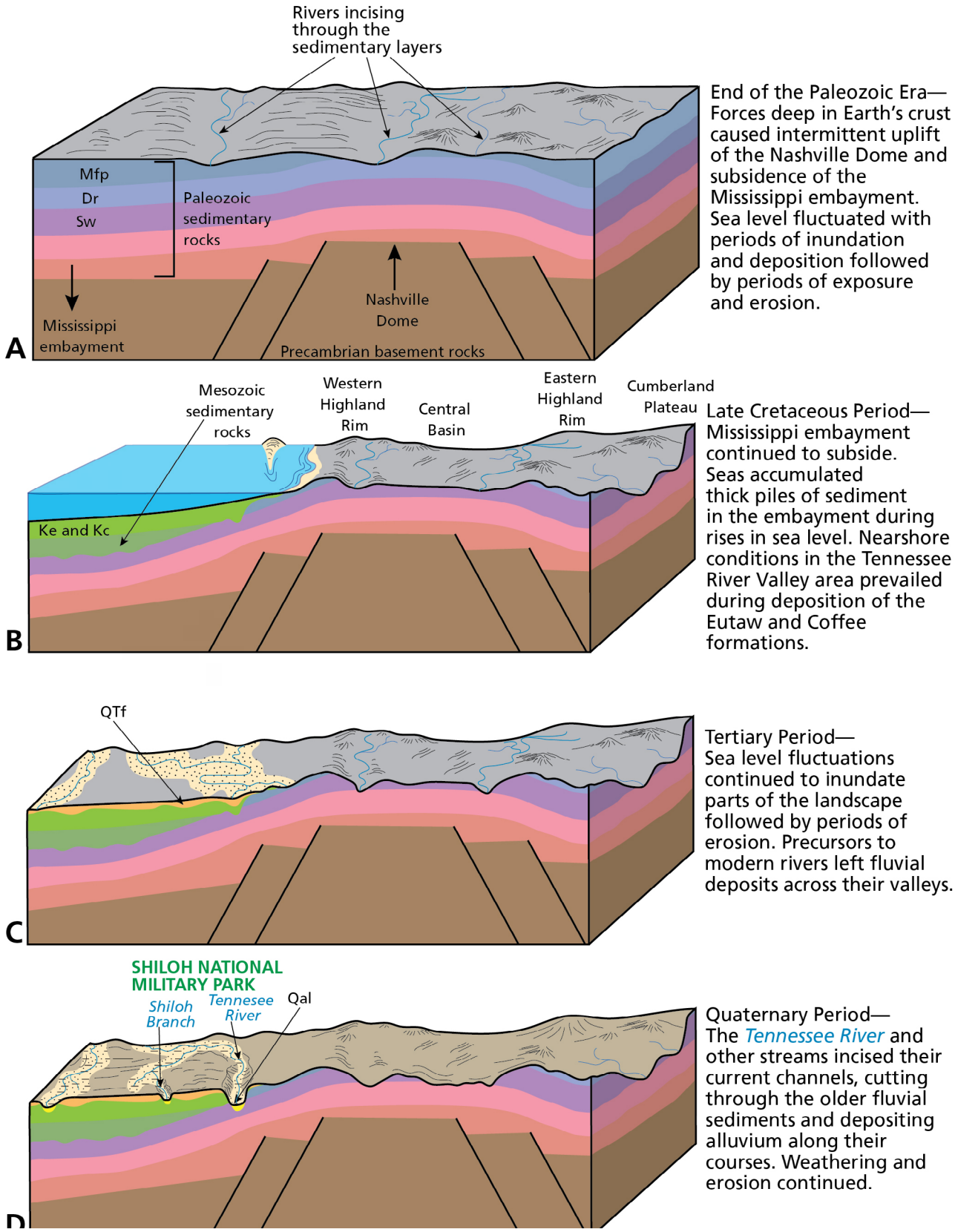


Figure 7. Illustration of the geologic evolution of the Shiloh landscape.
Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) with information from US ACOE (1984) and Russell (1964, 1967a, 1967b, and 1968).

travel and trade in these early societies, but later, it also was one of the routes (Trail of Tears) used by the US Government to forcibly move Indian populations from their southeastern homelands to reservations in the west (National Park Service 2009). Shiloh Indian Mounds is the best preserved Mississippian town site in the Tennessee River Valley and one of the "other important resources and values" identified by the park's foundation document as significant in the operation and management of the park and warrant special consideration in park planning (National Park Service 2016a).

Mineral Resource Extraction

Over 1,000 years ago, American Indians quarried clay, sand, and gravel to build the distinct mounds that exist within Shiloh Indian Mounds National Historic Landmark. They dug quarries within the park into the fluvial terrace deposits (**QTf**) that dominate the mapped area within park boundaries (Russell 1964; Thornberry-Ehrlich 2009). During the early development of the military park, beginning in the 1890s, shallow sand and gravel pits within the park provided materials for park road construction (no park quarries are mapped in the GRI GIS data; Thornberry-Ehrlich 2009). In the 1930s, the Civilian Conservation Corps (CCC) also mined rock material from local streams (**Qal**) for stabilization projects such as the Causeway culvert. Their work on the cemetery's stone wall, erosion control, and drainage systems are among the important resources and values identified in the park's foundation document (National Park Service 2016a). By the 1930s, mining activity within park boundaries ended. Local landowners continue to quarry the 15 m (50 ft) thick terrace deposits outside the park boundaries (Thornberry-Ehrlich 2009).

Prospecting for iron deposits occurred in the Shiloh area ca. 1800s; however, there is no record of actual mining (Thornberry-Ehrlich 2009). Iron content is elevated in park streams and iron staining is noticeable at seeps. Some gravel layers are cemented by iron minerals into a material called ferricrete. This distinctive, locally mined material forms the lower portion of the reconstructed Shiloh Church. After the economic crash of 1929 which halted the reconstruction of the church, builders used bricks to complete the reconstruction (Thornberry-Ehrlich 2009).

Civil War Battle Connections

The history of the battle at Shiloh is covered in a number of publications such as Shedd Jr. (1954) and Dillahunty (1955), as well as cultural resource websites such as www.civilwar.org (accessed 27 August 2016) and https://www.nps.gov/civilwar/index.htm (accessed 3 August 2017). An exhaustive review of this history is not presented here; this report highlights the direct connections between the park's geology and the resulting human history and landscape evolution.

The modern roads within Shiloh National Military Park reflect routes in place at the time of the Civil War battle. The battle focused here because of the strategic value of the confluence of rail, road, and river transit. Roads and railways followed local ridges or high ground (underlain by fluvial terrace deposits [**QTf**]) above marshy floodplain areas along the Tennessee River Valley (underlain in part by alluvium [**Qal**]). Pittsburg Landing, formed where a break in the high bluffs gives access to the river, was a hub of trade at the time of the battle. According to significance statements in the park's foundation document (National Park Service 2016a, page 5): "The intersection of two major railroad crossings at Corinth allowed Confederate armies to mass their forces in northern Mississippi, while Pittsburg Landing on the Tennessee River served as both a vital supply line and base of operation for Union forces deep in Confederate territory. Control of these transportation routes allowed the Union to remain on the offensive in the western theater, and illustrates the importance of logistics during the Civil War." The Tennessee River was part of the western defense line of the Confederacy, but this was breached with the Union capture of Fort Henry on the Tennessee River and Fort Donelson on the Cumberland River. In early March 1862, a Union fleet steamed upriver to establish a camp on the high bluffs above Pittsburg Landing in anticipation of an offensive towards Corinth, Mississippi (Shedd Jr. 1954). Confederate forces attacked these camps on April 6, 1862 in an attempt to gain the advantage before Union reinforcements could arrive from Nashville.

The battlefield terrain consists of rugged ravines lined with alluvium (**Qal**), rolling uplands atop fluvial (terrace) deposits (**QTf**), marshy creeks, natural springs, and small- to medium-sized agricultural fields, surrounded by eastern deciduous open forest (National Park Service 2016b). The Owl Creek wetlands (or bottomlands) in the northern park area, while a potentially strategic location, were not ultimately a deciding factor in the battle of Shiloh. However, Owl Creek remains significant as a unique and diverse ecosystem (National Park Service 2016b).

Among the key features of the historic battlefield incorporated into the park are

- the site of Shiloh Church (figs. 8 and 9).
- Fraley Field where fighting commenced on April 6, 1862.
- the site of the Union camps.



Figure 8. Photographs of historic features of the Shiloh National Military Park landscape. Historic structures and artifacts maintain a battle-era appearance on the landscape but are in turn subject to weathering and exposure to the elements. Photographs by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.

- the Hornets' Nest and Sunken Road where the largest artillery concentration till then seen on a North American battlefield (Ruggles' battery of 62 cannon) forced the Union troops from their defensive division.
- the Confederate Memorial commemorating capture of 2,100 Union troops in the Hornets' Nest.
- Duncan Field.
- the ravine where General Albert Sidney Johnston died.
- the site of Grant's last line near Pittsburg Landing.
- Bloody Pond.
- the site of the Union field hospital.
- Pittsburg Landing on the Tennessee River.
- Dill Branch Ravine, where Union gunboats (Tyler and Lexington) bombarded Confederate forces in defense of Grant's last line, which was anchored on the west side by a battery of siege guns around the crest of a hill about 400 m (0.25 mi) to the west of Pittsburg Landing.
- Water Oaks Pond, where Confederate forces attempted to blunt the Union counterattack of April 7 by wading through waist-deep water (Brewer 1987; National Park Service 2016b).

Corinth Unit

GRI GIS data do not cover the Corinth unit of Shiloh National Military Park; however, several geologically relevant connections exist there. In addition to the transportation crossings already mentioned, the Corinth, Mississippi unit has remnants of Union and Confederate siege lines, earthworks, and fortified battery positions (National Park Service 2016b). The siege was necessary due to the defensible location of Corinth atop a long ridge in the fork of two streams

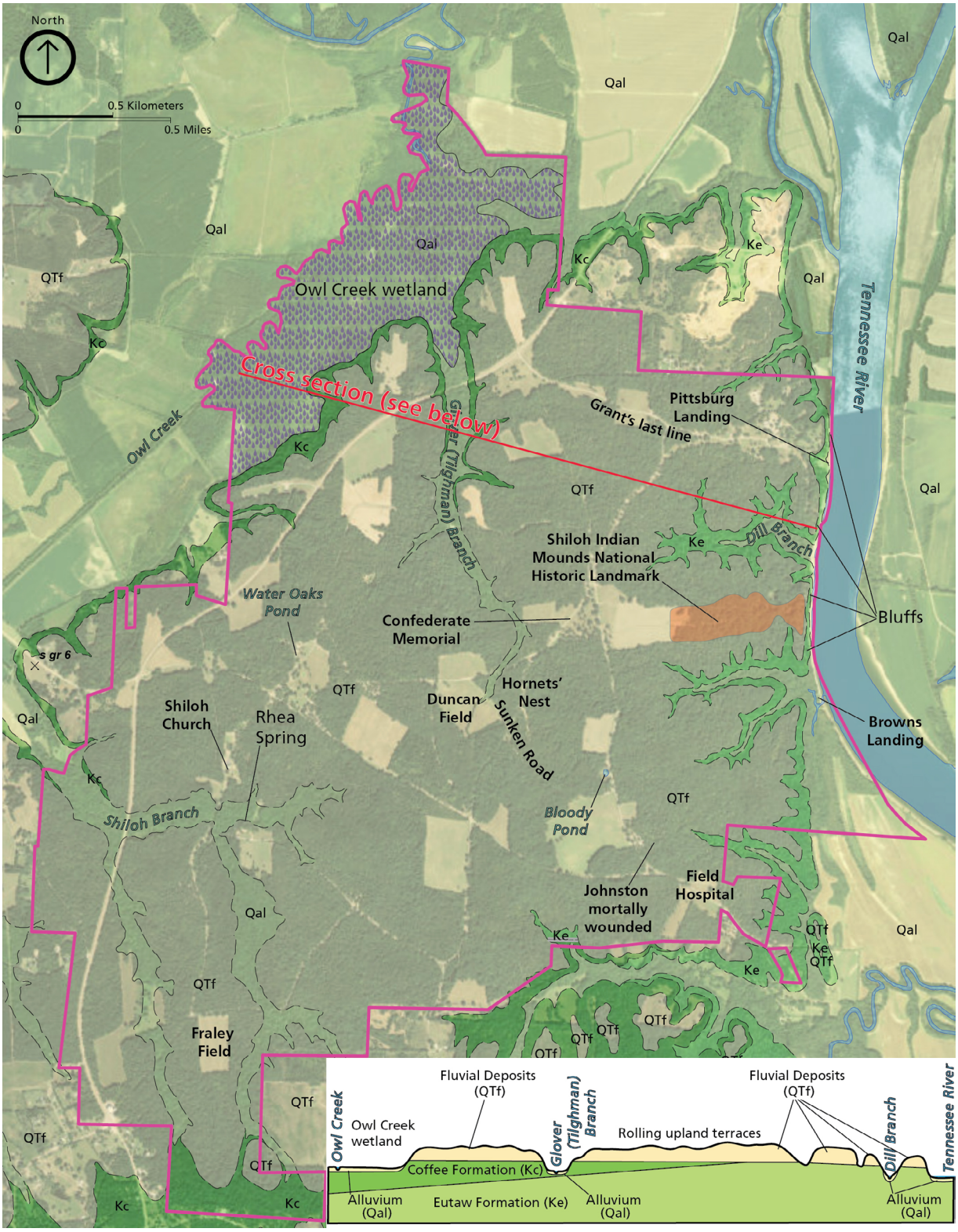


Figure 9. Map of battlefield features over geology.
Fluvial deposits (QTf) dominate the mapped geologic units on the battlefield. These deposits underlie rolling upland areas dissected by narrow ravines lined with younger alluvium (Qal). Where incision has progressed far enough, the underlying bedrock (Ke and Kc) is exposed below the fluvial deposits. Map legend, including units not exposed within the park, but in the surrounding region, is included with the GRI GIS map data poster. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) using GRI GIS data with a basemap by ESRI World Imagery (accessed 29 August 2016).

surrounded by low, swampy land broken up by impenetrable thickets (Yessin and Brent 1993). Per the significance statements in the park's foundation document (National Park Service 2016a, page 5), the park "preserves and protects the few surviving examples of early earthen fortifications that foreshadowed the complex trench warfare that would come to define the final desperate year of the Civil War." Weathering is constantly denuding these historic features (Thornberry-Ehrlich 2009).

Commemorative Landscape

Shiloh National Military Park is a commemorative landscape honoring the shared sacrifices and bravery of both Union and Confederate Civil War veterans (significance statement in National Park Service 2016a). The Shiloh Battlefield Landscape, Corinth Landscape (siege, battle, and occupation), Shiloh National Cemetery, and Davis Bridge site are among the fundamental resources in the park (National Park Service 2016a). Because the commemorative efforts began so early (1893), suburban development in the mid-20th century that altered the landscape at many other battlefield sites was largely avoided at Shiloh (Brewer 1987). At the time of the battle, 253 ha (625 ac) were cultivated. The National Park Service seeks to maintain the historic agricultural appearance of the park. Current agricultural leases in the park ensure good crop rotation and stabilizing vegetation to prevent excess erosion (Thornberry-Ehrlich 2009).

Commemorative resources/features are also identified as fundamental resources at Shiloh National Military Park (National Park Service 2016a), some of which date back to just after the Civil War battle. More than 150 commemorative markers dot the landscape within the main battlefield unit alone. Park resource managers are concerned as to the effects of climate change on the preservation of these monuments, some of which are made of bronze and marble and are susceptible to weathering (fig. 10; Thornberry-Ehrlich 2009; GRI conference call participants, 9 March 2017). Buried archeological resources spread over nine known sites include a potentially vast trove of artifacts from the extended Union encampment on "Shiloh Hill" in the spring of 1862, unmarked graves, and five mass Confederate burial trenches (see fig. 10). Park managers consider relic poaching to be an ongoing issue for these fundamental resources (National Park Service 2016a, 2016b). Shiloh National Cemetery (established 1866) includes a stone wall that is in poor condition; it is in need of repointing and capstone replacement (National Park Service 2016a).

Geologic Connections with the Ecosystem

In addition to its influence on history, the geology at Shiloh National Military Park provides the foundation for flora and fauna. Despite its small size, Shiloh National Military Park preserves a diverse ecosystem. The park contains Owl Creek, the largest wetland complex within the Cumberland Piedmont Network. Formation of wetlands is a direct result of the permeability of the sediments and underlying bedrock. In some cases, water will permeate the unconsolidated sediment and encounter an impermeable layer in the bedrock; the water flows laterally along the impermeable layer until it reaches the surface as a seep or spring. As summarized in National Park Service (2016b), some 30 species of amphibians, 50 species of fish, 204 species of birds, and 41 mammal species were observed within park boundaries.

Lichens are composite organisms that stem from algae or cyanobacteria living symbiotically among filaments of a fungus. Lichens can grow on almost anything from bare rocks, to trees, and other lichens. A lichen species at Shiloh National Military Park only occurs at 11 other known locations in the world (Thornberry-Ehrlich 2009). This species grows on bedrock (**Ke** and **Kc**) and is sensitive to changing climate (see "Geologic Features, Processes, and Resource Management Issues").

Geology and geologic processes in part give rise to soils, which are covered in another inventory (NPS 2007). Soils form where geology and biology combine to produce a mixture of minerals, organic material, gases, liquids, and countless organisms. Nearly two-thirds of the park is covered in a forest of mixed deciduous hardwoods in a transitional zone between the mixed oak-poplar forest of the Appalachian Plateau and the oak-hickory forests to the west and south of the Tennessee River (US ACOE 1984). There are 3 basic forest types within the park: upland oak forests (e.g., Indian Mounds area), ravine mixed hardwoods (e.g., Dill Branch ravine), and bottomland oak-sweetgum forests (e.g., Owl Creek wetland; US ACOE 1984). More than 700 species of vascular plants and 27 distinct vegetation communities have also been identified in the park (National Park Service 2016b). Climate change may also affect park vegetation, and in turn, erosion and slope stability. A vegetation map for the park is e available at https://irma.nps.gov/DataStore/Reference/Profile/2192583.



Figure 10. Photographs of commemorative features and cultural resources of the Shiloh National Military Park landscape.
Park resource managers are concerned as to the effects of climate change on the park's monuments, particularly those that contain bronze and marble or limestone, some of which date back to just after the Civil War. Photographs by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.

Geologic Features, Processes, and Resource Management Issues

These geologic features and processes are significant to the landscape and history of Shiloh National Military Park. 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 provides technical and policy assistance for these issues.

During the 2009 scoping meeting (see Thornberry-Ehrlich 2009) and 2016 conference call, participants (see Appendix A) identified the following features, processes, and resource management issues. Each is discussed on table 1 in the context of relevant geologic map units that occur within Shiloh National Military Park (Battlefield unit) boundaries. Additional information about resource management issues is presented after the table.

- **Fluvial features**. The Tennessee River is the dominant process and management issue in Shiloh National Military Park (fig 11). Comparing modern conditions with mapped surveys in 1895 by the War Department reveals that parkward erosion along the shoreline has removed 38 to 43 m (125 to 140 ft) of landmass since 1895, threatening cultural resources and park infrastructure. River and flood dynamics changed significantly in the 1930s, when the US Army Corps of Engineers constructed Pickwick Dam, impounding the Tennessee River upstream of Shiloh National Military Park. Riprap currently armors 2 km (1 mi) of riverfront up to the 100–500-year floodlines (123 m [402 ft] elevation) to prevent massive blowouts. Streams gradients are constantly adjusting due to upstream erosion and this headward erosion has resulted in steep gullies throughout the park (fig. 12). Waterways meander across their floodplains leaving point bars, cut banks, and meander bends (fig. 13).
- **Erosion**. Erosion threatens infrastructure and cultural resources in some areas. Erosion has been a historical problem at the park since 19th century agricultural clearing increased following the 1862 battle. CCC work in the 1930s attempted to stabilize streams and restore battle-era fields and forests. An enormous episode of erosion followed the 1944 clearing of the shoreline between the Pickwick and Kentucky dams along the Tennessee River. This created a massive pulse of siltation into the river and local streams, shallowing channels. At Sunken Road, foot traffic caused erosion and required stabilization and infilling in 2002 (fig. 14). At the Indian Mounds site, a slope is eroding back towards a large mound on the river bluff (fig. 15). Prior to 1999, Gabions were installed and backfill emplaced to attempt to stabilize the bluff. The upper slope was left to naturally repose or evolve into a stable setting normal slope. In the 2000s, the park imported limestone blocks for armoring along Riverside Road (figs. 15, 16, and 17). Erosion is also incising gullies in the park.
- **Slope movements**. The downslope transfer of material (e.g., soil, regolith, and/or rock) (fig. 18) can occur very rapidly (e.g., rockfall) or over long periods of time (e.g., slope creep). Frost weathering, plant-root wedging, streambank erosion, and differential erosion cause slope instability.
- **Paleontological resources, inventory, monitoring, and protection**. Fossils have not yet been documented in situ within the park, but fossils associated with the Shiloh Mound Complex in an archeological context were probably originally preserved in park bedrock **Ke** and **Kc** units. All paleontological resources are nonrenewable and subject to science-informed inventory, monitoring, protection, and interpretation as outlined by the 2009 Paleontological Resources Preservation Act.
- **Seeps, springs, ponds, and wetlands**. Groundwater percolates downward through the unconsolidated Quaternary deposits until it reaches 1–2-m (3–6-ft) thick, clay-rich layers in the Cretaceous bedrock where it flows laterally, eventually intersecting the surface to emerge as a seep or spring (e.g., Rhea Springs and Shiloh Spring; figs. 19 and 20). These clay-rich aquitard layers may also underlie natural ponds and wetlands within the park such as Bloody Pond and Water Oaks Pond. There are 81 documented wetlands in the park totaling about 150 ha (370 ac). Many streams originate within the park and serve as examples of intact watersheds.
- **Bedrock exposures and ancient sedimentary features**. There are two Cretaceous bedrock units exposed in the park. **Kc** is separated from the underlying **Ke** by an unconformity (or period of erosion or nondeposition—a gap in the geologic record).
- **Flooding and climate change**. Climate change models for southern Tennessee predict hotter conditions with more extreme severity of storms and daily high temperatures. Increased storm severity and/or frequency may increase runoff (contaminant flushing), turbidity, flooding, and upland erosion.

Table 1. Geologic features, processes, and associated resource management issues in Shiloh National Military Park.

Age	Map Unit (symbol)	Features and Processes	Potential Resource Management Issues
QUATERNARY	Alluvium (Qal)	**Fluvial Features** The thick deposits of silt, sand, and gravel in the Tennessee River and thinner deposits in tributaries such as Owl Creek, Glover (Tilghman) Branch, Old Creek, Dill Branch, Snake Creek, and Shiloh Branch, make up 17% of the area of mapped geologic units within the park. **Qal** continues to be transported, reworked, and deposited in channels (figs. 11 and 13). Seasonal flooding deposits finer grained silt and clay in the floodplain. **Slope Movements** **Qal** is an unconsolidated unit and is prone to failure when exposed on steep slopes. Steep slopes flank the Tennessee River and smaller park streams including Shiloh Branch, Old Creek, Glover (Tilghman) Branch, and Dill Branch. Erosion occurs along the Tennessee River shoreline, particularly in areas where the river has washed away the base of the slope. Slope failures removed 24 m (80 ft) of bluff line at the Indian Mounds site. In 1954, the old Pittsburg Landing site washed away overnight after losing approximately 60 m (200 ft) of the base of the slope at the US National Cemetery (US ACOE 1984). **Seeps, springs, ponds, and wetlands** **Qal** deposits underlie four riverine wetlands in the park, including the vast, 127 ha (315 ac) Owl Creek wetland (fig. 19). There are 81 documented wetlands in the park totaling about 150 ha (370 ac) (Roberts and Morgan 2008).	**Flooding and Climate Change** During seasonal floods, backwater flows from the Tennessee River up into Owl and Snake creeks reworking Qal deposits. Local flood control projects (e.g., canals) intended to protect agricultural areas from inundation were largely unsuccessful in the park. Heavy precipitation can reach 25–30 cm (10–12 in) in 24 hours. **Erosion** About 2.4 km (1.5 mi) of erosion along the Tennessee River's shoreline has removed 38–43 m (125–140 ft) of earth (**Qal** and **QTf**) since 1895 evidenced by comparing War Department mapping with current topography. **Earthquakes** Hazards associated with earthquakes include slumping (fig. 18) along the streams and rivers, and liquefaction within water saturated, unconsolidated floodplain deposits (**Qal**) along the Tennessee River and its tributaries.
QUATERNARY AND TERTIARY?	Fluvial deposits (QTf)	**Fluvial Features** Ancient rivers deposited the coarse gravel (chert, quartz, and sandstone), sand, and scant silty clay of **QTf**. These deposits were once part of a wide floodplain that is now dissected and perched above the level of the modern floodplains. Mapped deposits of **QTf** dominate the area within park boundaries making up over 77% of the total area. **Slope Movements** As much as 70 m (230 ft) of topographic relief occur within park boundaries. Steep slopes (40–70%) flank the Tennessee River and smaller park streams including Shiloh Branch, Old Creek, Glover (Tilghman) Branch, and Dill Branch. **QTf** is mapped in upslope areas of the park. Unconsolidated units such as **QTf** are prone to failure when exposed on slopes. **Seeps, springs, ponds, and wetlands** Groundwater percolates downward through the **QTf** deposits until it reaches 1–2-m (3–6-ft) thick, clay-rich layers in **Ke** and **Kc**.	**Erosion** In addition to the erosion of **Qal** and **Qtf** along the Tennessee River shoreline, gullies are forming on sloped areas of **QTf** in upper reaches of the park (fig. 12). Erosion is also undermining local trail beds in **QTf** despite installation of some hardened asphalt surfaces (fig. 14) before 2009. Most trails are now covered with wood chips. **Abandoned mineral lands and disturbed lands** Terrace deposits (**QTf**) up to 15 m (50 ft) thick are locally quarried by landowners. Shallow sand and gravel pits (in **QTf**) within the park provided materials for initial park road construction by the War Department in the 1890s. The walls of these quarries, some of which are several stories high may be unstable. Presently, the park is reclaiming several historic quarries by filling them with organic material such as downed trees and clippings. A nonhistoric pond is also being filled with organic debris to return to a battle-era appearance.

Age	Map Unit (symbol)	Features and Processes	Potential Resource Management Issues
CRETACEOUS	Coffee Formation (Kc)	**Bedrock Exposures and Ancient Sedimentary Features** **Kc** is the most common bedrock within park boundaries making up over 3% of the mapped area. **Kc** occurs along deeper stream valleys such as Shiloh Branch and Glover (Tilghman) Branch, and near W. Manse George cabin and Fraley Field in Shiloh National Military Park. The fine-grained sand and clay-shale layers of **Kc** were deposited over 66 million years ago in lagoonal, barrier bar, and shoreline environments similar to those off North Carolina coast today. **Seeps, springs, ponds, and wetlands** The thick, clay-rich aquitard layers in **Kc** intercept percolating groundwater, directing its flow laterally until it eventually intersects the surface to emerge as a seep or spring (e.g., Rhea Springs and Shiloh Spring; fig. 20).	**Paleontological resources, inventory, monitoring, and protection** Fossils are not documented in situ in **Kc** within the park; elsewhere fossils include plant remains, mollusks, insects, and trace fossils.
CRETACEOUS	Eutaw Formation (Ke)	**Bedrock Exposures and Ancient Sedimentary Features** **Ke** makes up more than 2% of the the mapped geologic units within park boundaries. **Ke** is present in the park along the eastern riverfront area, in the vicinity of the National Cemetery, Shiloh Indian Mounds National Historic Landmark, and Browns Landing. The well-sorted quartz sands, thinly-laminated clays, and pebbly layers of **Ke** were deposited in a nearshore, fluvial environment over 66 million years ago. **Seeps, springs, ponds, and wetlands** The clay-rich aquitard layers in **Ke** intercept percolating groundwater, directing its flow laterally until it eventually intersects the surface to emerge as a seep or spring (e.g., Rhea Springs and Shiloh Spring; fig. 20).	**Paleontological resources, inventory, monitoring, and protection** Fossils are not documented in situ in **Ke** within the park; elsewhere fossils include silicified logs, plant material, mollusks, and trace fossils. **External Development** Immediately north of the park boundary to the mouth of Snake Creek, the Santana Dredging and Coring Company acquired and renewed mining within a historic quarry 9 to 12 m (30 to 40 ft) deep into layers of **Ke**.

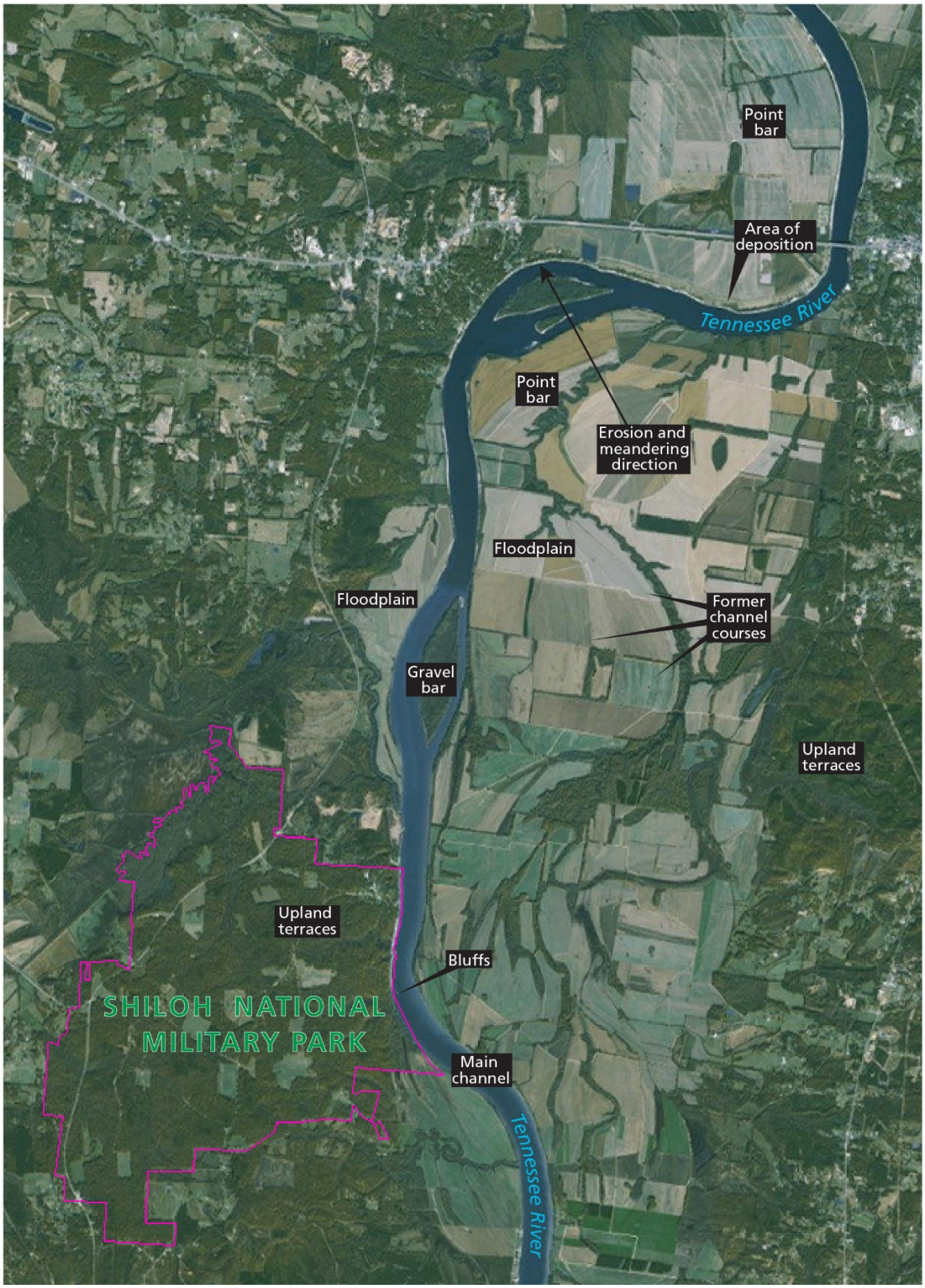


Figure 11. Aerial image of fluvial features along the Tennessee River.
Related to the schematic diagram of fluvial features presented in figure 13, the Tennessee River displays classic fluvial features along its length in the park area. Upstream dams have muted the force of flooding on the system, but the river continues to meander, eroding banks in some places and depositing alluvium in others. Graphic by Trista Thornberry-Ehrlich (Colorado State University) using GRI GIS data with a basemap by ESRI World Imagery basemap (accessed 7 February 2017).



Figure 12. Photographs of fluvial channels, ravines, and gullies.
Water flowing across the landscape at Shiloh National Military Park is a major contributor to landscape change. Large channels, ravines, and smaller gullies crisscross the landscape. These would have provided cover during the battles there, but may also have hindered troop movements in some cases, acting as natural barriers. Deeper cuts are where the older, consolidated bedrock exposures are found. Photographs taken in spring 2009 by Trista L. Thornberry-Ehrlich (Colorado State University).

- **Abandoned mineral lands and disturbed lands**. Quarrying for clay, sand, gravel, and other mineral resources in the area has been ongoing for the past several centuries (see Geologic Significance and Connections section). Prehistoric quarrying to build the distinct mounds at the Shiloh Indian Mounds National Historic Landmark is evident in the park—these are considered cultural features. Some artificial ponds are within park boundaries, it is unclear if these will be restored.
- **External development**. Quarrying to the north of the park creates noise and, along with cellular towers, viewshed issues. Cultural resources such as Union troop camps, old homesites, and potentially, American Indian archeological sites, have been destroyed as a result of this quarrying.
- **Seismicity**. The risk of earthquakes at Shiloh National Military Park is relatively low (fig. 21). According to the US Geological Survey's Earthquake Hazards Program, there are frequently earthquakes in the area strong enough to be felt by humans. In 2006, a magnitude 2–3 earthquake occurred with an epicenter near Savannah, TN, 16 km (10 mi) northwest of the park. Strong seismic shaking could damage park infrastructure including buildings, roads, trails, monuments, and bridges.

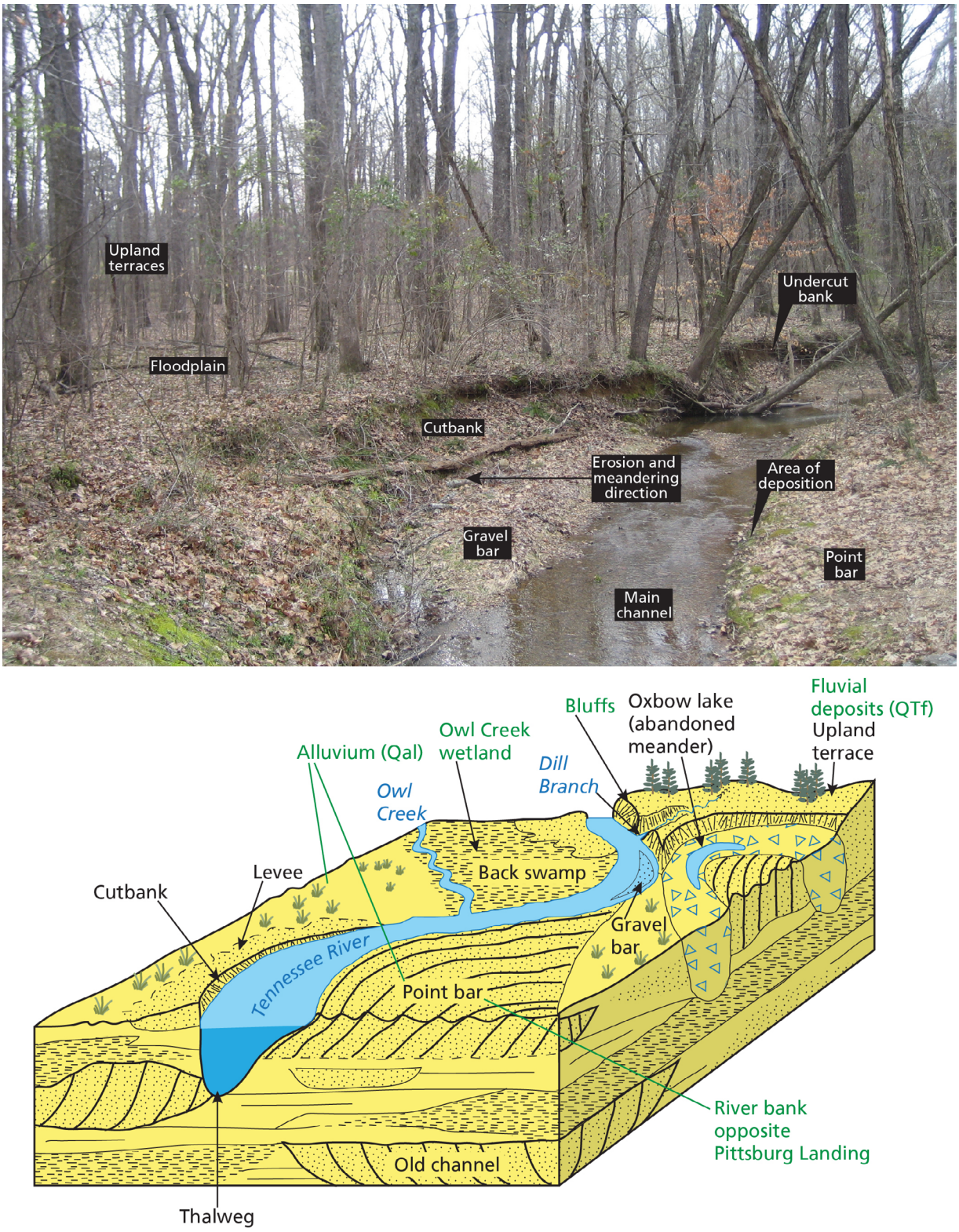


Figure 13. Schematic illustration of small-scale alluvial deposits and depositional settings. Several of the park's streams are flanked by swamps and wetlands. The rivers and streams incise an upland area. Green text refers to local examples and relevant geologic map units present at Shiloh National Military Park. Figure 11 shows the larger Tennessee River system's fluvial features. Graphic and photograph (taken in spring 2009) by Trista Thornberry-Ehrlich (Colorado State University).



Figure 14. Photographs of erosional features. Runoff and vegetation disturbances exacerbate erosion on the landscape at Shiloh National Military Park. Even on the park's moderate slopes (e.g., Indian mounds), social trail use causes localized erosion. Exposed roots along unpaved trails indicate areas where erosion has removed stabilizing soil. Photographs taken in spring 2009 by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.

Geologic Resource Management

The park's foundation document (National Park Service 2016a) and State of the Park Report (National Park Service 2016b) are primary sources of information for resource management. Miller (2014) provides a summary of the geologic setting, history, and features of central Tennessee. Cultural landscape restoration and management are also addressed in a number of publications, including Bearss et al. (1973), National Park Service (1973) and some documentation for Civil War landscapes dating back to the Civil War itself; however, no formal, specifically themed cultural landscape inventories exist for Shiloh or Corinth. This remains a crucial resource management need at the park (National Park Service 2016b).

The Geologic Resources Division provides technical and policy support for geologic resource management issues in three emphasis areas, all of which are present in Shiloh National Military Park:

- geologic heritage
- active processes and hazards
- energy and minerals management

Contact the division (http://go.nps.gov/geology) for assistance with resource inventories, assessments and monitoring; impact mitigation, restoration, and adaptation; hazards risk management; law, policy, and guidance; resource management planning; data and information management; and outreach and youth programs (Geoscientists-in-the-Parks and Mosaics in Science). Park staff can formally request assistance via https://irma.nps.gov/Star/.

Resource managers may find Geological Monitoring (Young and Norby 2009; https://go.nps.gov/geomonitoring) useful for addressing geologic resource management issues. The manual provides guidance for monitoring vital signs—measurable parameters of the overall condition of natural resources. Each chapter covers a different geologic resource and includes detailed recommendations for resource managers, suggested methods of monitoring, and case studies.

The Geoscientists-in-the-Park (GIP) and Mosaics in Science are internship programs to place scientists (typically undergraduate students) in parks to complete geoscience-related projects that may address resource management issues. No GIP projects have occurred yet at Shiloh National Military Park. Projects and ideas are listed on the GIP website: http://go.nps.gov/gip_products. Products created by the program participants may be available on that website or by contacting the Geologic Resources Division. Refer to the programs' websites at http://go.nps.gov/gip and http://go.nps.gov/mosaics.htm for more information.



Figure 15. Photographs of eroding shorelines along the Tennessee River.
Prior to stabilization efforts by the US ACOE, bluffs along the Tennessee River were eroding despite earlier efforts to direct flow and minimize erosion. Undercut areas were causing large blocks to fall into the river, threatening park roads and the Indian mounds site. Photographs by Don Getty (US ACOE) taken in 1999 (top two and lower right image) and 2003 (lower left image); annotation by Trista L. Thornberry-Ehrlich (Colorado State University).

Erosion, Fluvial Features, Flooding, and Slope Movement

The dominant resource management issue in the park is erosion along the Tennessee River shoreline, aided and exacerbated by fluvial processes, flooding, and slope movements (see figs. 15, 16, 17, and 18). High river velocities occur during flood flows from the Pickwick Dam upstream and erode the vulnerable soils at the toe of the bluffs. The undermining of the bluff eventually triggers a landslide, and the retreat of the bluffs. Dramatic erosion of Mound A at Shiloh Indian Mounds (see fig. 2) has required mitigation, and Pittsburg Landing and Shiloh National Cemetery are considered at risk. The US ACOE (1984) Streambank Protection Project included a comprehensive review of these processes and hazards, and National Park Service (2016a) recommended working with the US ACOE to focus future erosion and flooding control efforts on the Tennessee River.

Erosion

Erosion has been a problem for the park for more than 100 years in their efforts to restore and maintain an 1862 appearance (see fig. 14). According to the park's foundation document (National Park Service 2016a), erosion and drainage mitigation structures put in place by the US ACOE and CCC, such as the revetment on the recreated double branch on Shiloh Branch, are aging and deteriorating. Additionally, issues with sloping and drainage need to be considered for historical field (agricultural) restoration. Some unauthorized use of all-terrain vehicles and off-road driving has also caused local erosion and damaged park resources (including the earthworks at the Corinth unit and along the sandy banks of the Hatchie River at the Davis Bridge site).



Figure 16. Photographs of efforts to stem bluff erosion along the Tennessee River. Limestone blocks (rip rap) were installed along portions of the newly graded Riverside Road to attempt to stabilize the erosion threatening the Indian mounds atop the adjacent bluff. Shoreline armoring was also installed near Pittsburg Landing to protect the historic site from the meandering of the Tennessee River. Photographs taken in spring 2009 by Trista L. Thornberry-Ehrlich (Colorado State University).

Planning needs identified in National Park Service (2016a) include

- Developing trail, earthworks, cemetery management, and land protection plans.
- Mapping at Davis Bridge site (including elevation study for Hatchie River) and Corinth unit.
- GIS data of monuments and Confederate mass grave sites.

Fluvial Features and Flooding

If the park desires quantitative information regarding rates of change and channel morphology, repeat photography could be performed at designated photo points to monitor changes. Refer to http://go.nps.gov/grd_photogrammetry for information about using photogrammetry for resource management. Consult NPS planning documents including Director's Orders 77-1 (Wetland Protection) and 77-2 (Floodplain Management), as well as the other laws, regulations, and policies listed in Appendix B and available at https://www.nps.gov/applications/npspolicy/index.cfm. The following resources may provide further guidance for flooding and fluvial processes:

- Technical assistance NPS Water Resources Division: http://nature.nps.gov/water/.
- Water quality data briefs (monitoring at Lower Dill Branch, Owl Creek, Pittsburg Landing, Rhea Spring, Shiloh Branch, Glover (Tilghman) Branch, and upper Dill Branch): https://www.nps.gov/im/ncpn/monitoring-briefs.htm.
- Monitoring Fluvial Geomorphology: Lord et al. (2009).
- History of Tennessee River flooding: Harden and O'Connor (2017) https://pubs.usgs.gov/sir/2017/5052/sir20175052.pdf.
- FEMA flood hazard mapping: http://www.fema.gov/national-flood-insurance-program-flood-hazard-mapping.
- History of the Tennessee River: Miller (2014).
- The US ACOE has a record of shoreline engineering and monitors the river's shorelines regularly.

Slope Movements

The following resources provide further guidance for slope movement (see fig. 18) management:

- Wieczorek and Snyder (2009) for slope movement monitoring.
- Highland and Bobrowsky (2008) presented a landslides guide.

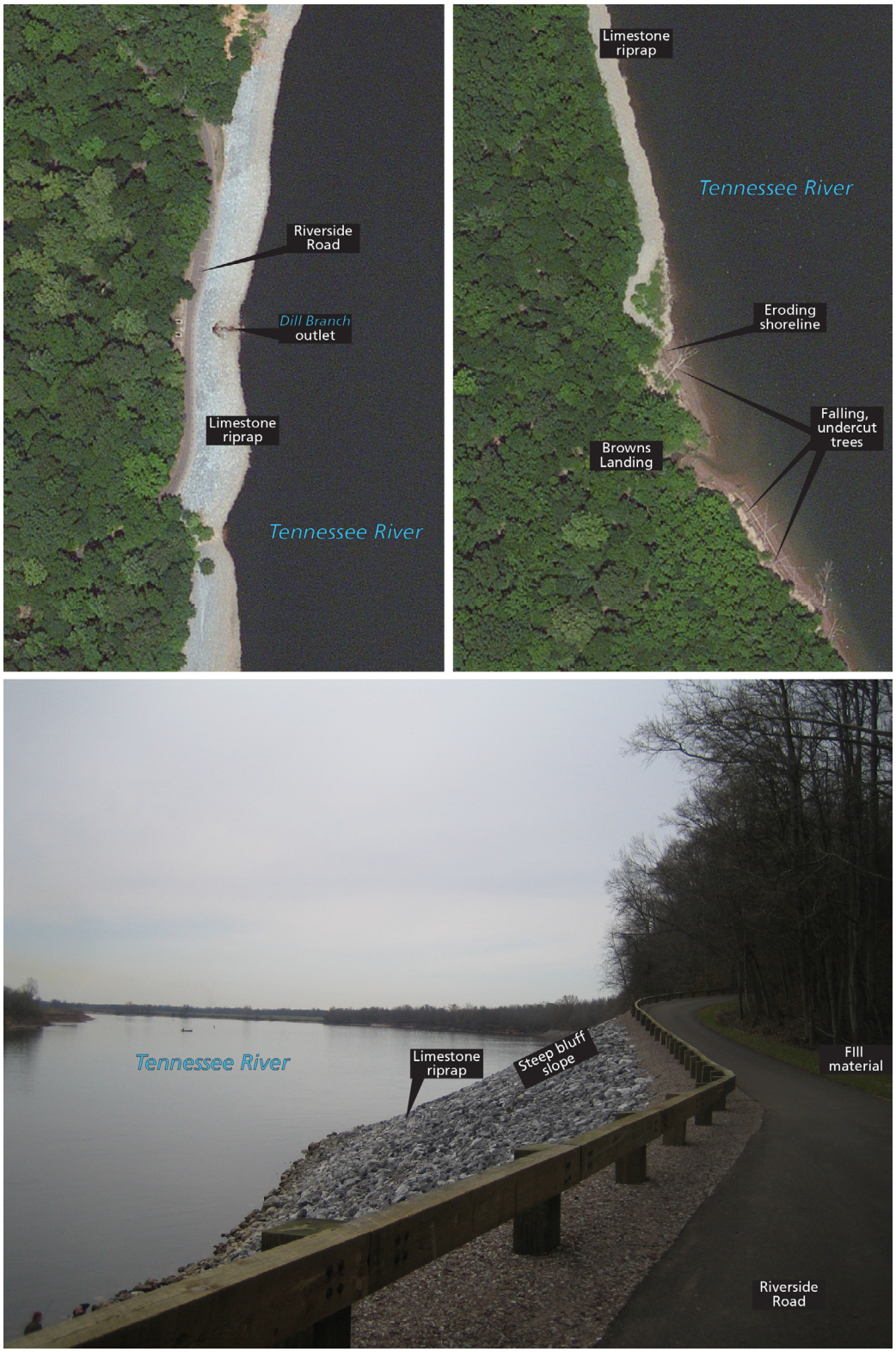


Figure 17. Photographs of bluff erosion along the Tennessee River.
Aerial images show the limestone riprap fronting the Tennessee River shoreline along Riverside Road. Further south, the riprap ends and erosion is evident from receding shorelines and falling trees. Bottom photograph by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009; top images are ESRI World Imagery basemaps (accessed 7 February 2017).

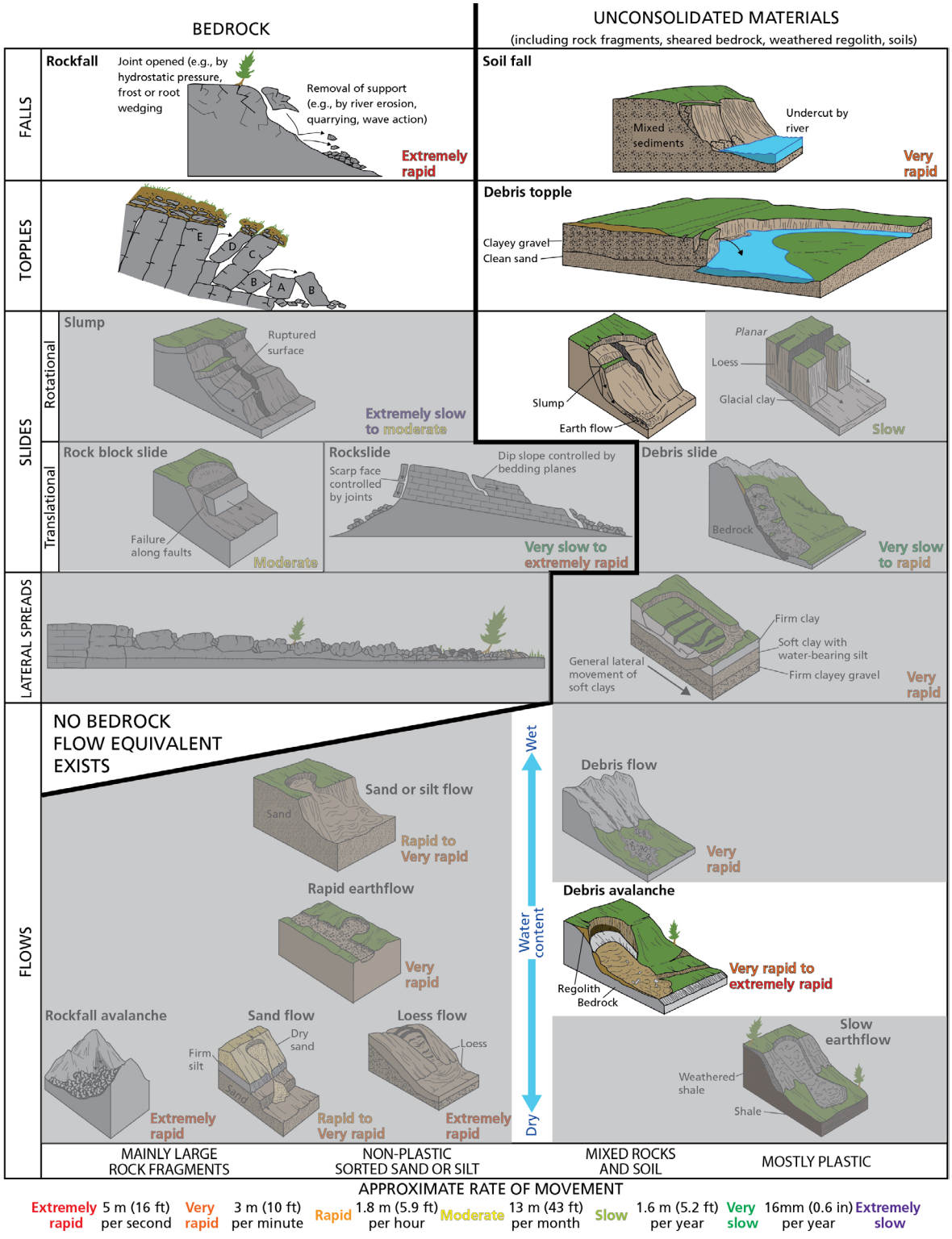


Figure 18. Schematic illustrations of slope movements.
Different categories of slope movement are defined by material type, nature of the movement, rate of movement, and moisture content. Grayed areas depict conditions unlikely to exist at Shiloh National Military Park. The abundant vegetation in the park stabilizes most slopes, but potential exists and slope issues could be exacerbated by natural or anthropogenic removal of vegetation. Graphic by Trista Thornberry-Ehrlich (Colorado State University) redrafted after a graphic and information in Varnes (1978) and Cruden and Varnes (1996).



Figure 19. Photographs of wetlands. Perennial wetlands maintain water-saturated conditions all year long whereas ephemeral wetlands retain water only seasonally. Wetlands at Shiloh National Military Park tend to occur in low-lying areas where the underlying material is clay-rich preventing the downward percolation of groundwater. Such clay-rich layers occur in the otherwise well-drained fluvial (terrace) deposits (geologic map unit QTf) that dominate the mapped geology in the park, as well as clay-rich layers in the Cretaceous bedrock (Ke or Kc). Photographs taken in spring 2009 by Trista L. Thornberry-Ehrlich (Colorado State University).

- Natural hazards science by Holmes et al. (2013).
- The US Geological Survey landslides website: http://landslides.usgs.gov/.
- GRD Slope Movement Monitoring http://www.nature.nps.gov/geology/monitoring/slopes.cfm.

Climate Change

Climate change predictions for southern Tennessee include higher daily temperatures and more extreme storms. These conditions could amplify the shoreline erosion, as well as threaten ecological niches and habitat within the park. The following resources may provide further guidance for climate change:

- NPS climate change response program strategy: https://www.nps.gov/orgs/ccrp/upload/NPS_CCRS.pdf.
- NPS ecosystem response to climate change predictions: http://science.nature.nps.gov/climatechange.
- Tennessee's state wildlife action plan for climate change: Tennessee Wildlife Resources Agency (2009).
- Vulnerability of the southeastern US to climate change: Treasure et al. (2008).
- Climate change projections, impacts, and NPS policy considerations: Fisichelli et al. (2014), Melillo et al. (2014), Melnick et al. (2015), Jarvis (2014), see Appendix B.

Paleontological Resources, Inventory, Monitoring, and Protection

Paleontological resources (fossils) are any evidence of life preserved in a geologic context (Santucci et al. 2009). 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. As of March 2018, 268 parks had documented paleontological resources in at least one of these contexts—Shiloh National Military Park has documented fossils in archeological contexts (e.g., crinoids, bivalves, and coral) with the potential for fossils in rocks or unconsolidated deposits, as well as commemorative monument stones or shoreline riprap.

Hunt-Foster et al. (2009) prepared a paleontological resource summary for the parks of the Cumberland Piedmont Network, including Shiloh National Military Park. The summary was compiled through extensive literature reviews and interviews with park staff and professional geologists and paleontologists,

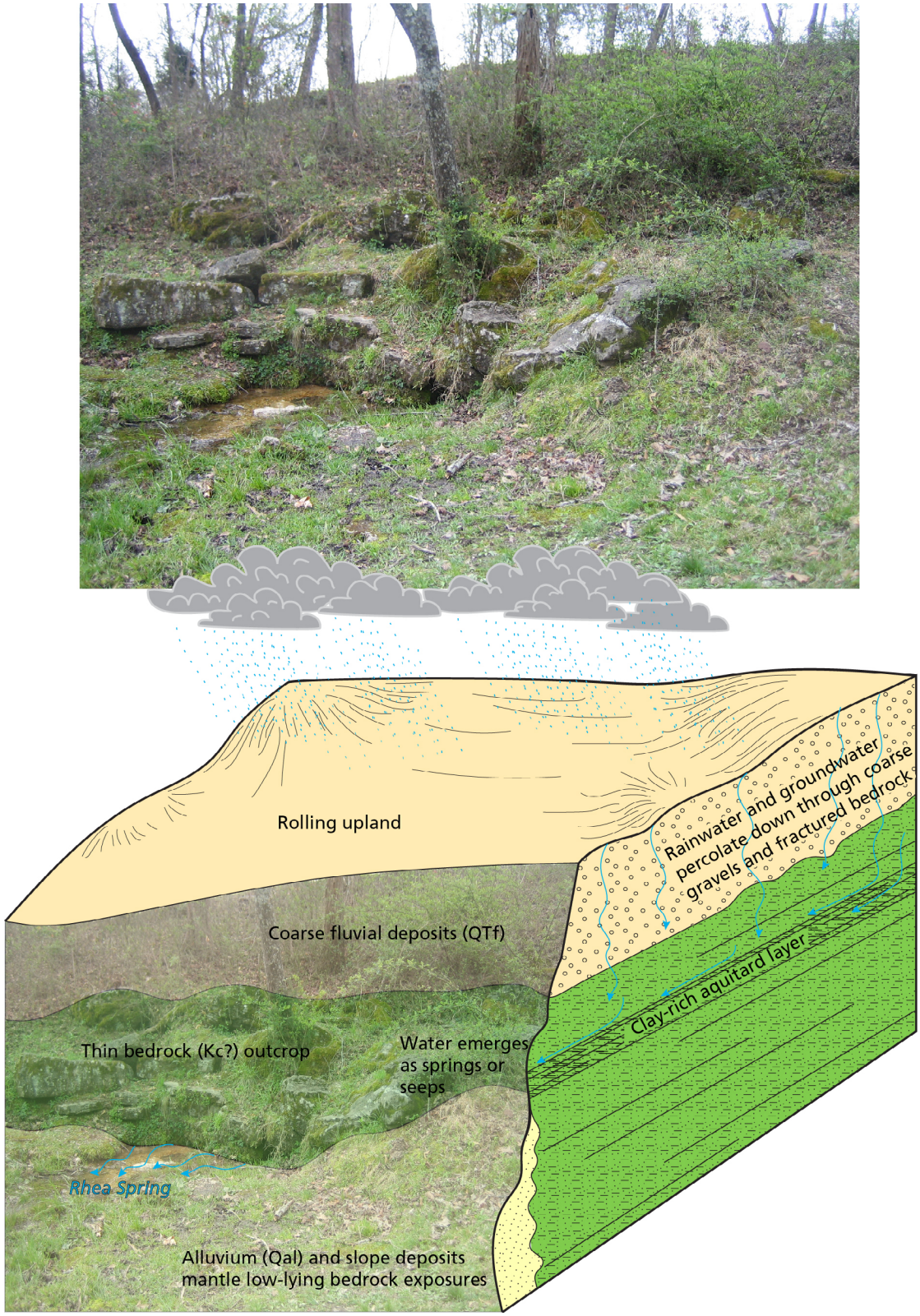


Figure 20. Three-dimensional schematic of Rhea Spring.
Rainfall and groundwater percolate downward through the fluvial (terrace) deposits that underlie much of the landscape in the park. When this water intersects a relatively impermeable layer (such as a clay-rich layer in the Coffee Formation [Kc]), it flows laterally towards the surface to emerge as a spring. Photograph (taken in spring 2009) and annotations by Trista L. Thornberry-Ehrlich (Colorado State University).

but no field-based investigations. Resource-management recommendations from Hunt-Foster et al. (2009) for the park included

- Park staff should be encouraged to observe exposed gullies, other erosional bedrock, and streams for fossil material, while conducting their usual duties. Given the fossiliferous nature of many of these rock units any exposures might yield paleontological resources.
- Staff should monitor and photodocument any occurrences of paleontological resources that may be observed in situ. Fossils and their associated geologic context (surrounding rock) should be documented but left in place unless they are subject to imminent degradation by artificially accelerated natural processes or direct human impacts.
- A field-based inventory of paleontological resources may yield more information regarding the scope and significance of fossils within Shiloh National Military Park. Significant localities should be documented using National Park Service fossil locality and condition assessment forms.

Other resources for guidance on paleontological issues include

- The NPS Fossils and Paleontology website, http://go.nps.gov/paleo.
- Kenworthy and Santucci (2006) presented a summary of National Park Service fossils in a cultural resource context.
- Santucci et al. (2009) details paleontological resource monitoring strategies.
- The Southeast Archeology Center (https://www.nps.gov/seac/index.htm) has a record of the fossils found in archeological excavations at the mounds site that were completed in 2005.

Seeps, Springs, Ponds, and Wetlands

The presence of these features in the Shiloh park area is a result of layers of clay in the cretaceous units **Ke** and **Kc** (see figs. 9, 19, and 20). Surface water may percolate through **QTf** or **Qal** until it reaches the impermeable layers in the bedrock, at which point it moves laterally until it reaches the surface as a seep or a spring (see fig. 20). In natural basins, water will saturate the soil and pool on the surface, forming ponds or wetlands (see fig. 19). Wetlands are transitional areas between land and water bodies, where water periodically floods the land or saturates the soil. The term wetlands include environments such as marshes, swamps, and bogs. They may be covered perennially, most of the year, or be wet only seasonally. The largest wetland in the park by far is Owl Creek on the northwest corner; it floods seasonally (see figs. 9 and 13). Owl Creek wetland supports great biodiversity in the park, including acting as breeding habitat for amphibians. Roberts and Morgan (2008) suggested the large bottomland hardwood wetland complex of Owl Creek could provide a useful study area for a variety of wetland research topics.

Other resources for guidance on wetland related issues include

- Inventory and classification of wetlands: Roberts and Morgan (2008)
- NPS Water Resources Division: http://nature.nps.gov/water/

Abandoned Mineral Lands and Disturbed 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 operations, for which the NPS takes action under various authorities to mitigate, reclaim, or restore in order to reduce hazards and impacts to resources. Disturbed lands are where natural conditions and processes have been directly impacted by development, including facilities, roads, dams, and abandoned campgrounds; agricultural activities such as farming, grazing, timber harvest, and abandoned irrigation ditches; overuse; or inappropriate use. The National Park Service considers abandoned quarries or borrow pits to be Abandoned Mineral Lands (AML) features. Although no resource impacts or hazards are currently documented at the quarries within the park (not included in the GRI GIS data), park staff should consider documenting the features in the NPS AML database. Currently there are no AML sites or features recorded for Shiloh National Military Park. Refer to Burghardt et al. (2014) and http://go.nps.gov/grd_aml for information about AML in the National Park System, as well as a comprehensive inventory of sites, features, and remediation needs.

External Development

Lands adjacent to the park are typically suburban to agricultural, and in some areas urban development and quarrying are threatening the areas surrounding the park. Just north of the park, the Santana Dredging and Coring Company acquired and renewed mining within a historic quarry. The quarry extends from the northern boundary of the park to the mouth of Snake Creek, and reaches 9 to 12 m (30 to 40 ft) deep into the Cretaceous Eutaw Formation (**Ke**) (see fig. 9). Materials from the quarry are used in roadwork projects on US Highway 64 and Tennessee Highway 22. According to GRI scoping

meeting participants (Thornberry-Ehrlich 2009), quarrying has destroyed cultural resources outside of the park such as Union troop camps and old home sites, and has likely impacted American Indian archaeological sites. In addition to destruction of cultural resources, mining activity creates noise and viewshed issues. The construction of cellular towers outside of the park also impacts the viewshed, including of historical battlefield sites. The view from Pittsburg Landing and other battlefields are often obscured by haze caused by pollution, warranting significant concern based on NPS Air Resources Division benchmarks (National Park Service 2016a).

Potential Land Acquisition

Over the past 20 years, the park's scope has increased to include sites at Davis Bridge, Corinth, and additional lands adjacent to the main battlefield unit and land acquisition is considered a key issue (National Park Service 2016a). Potential additional historic sites that could be added to the park include areas around Corinth, Davis Bridge, Russell House, Fallen Timbers Battlefield, and Parkers Crossroads (National Park Service 2016a). These are currently under legislation review (GRI conference call participants, 9 March 2017). Adjacent lands are typically suburban to agricultural. Adjacent land cover and use was one of the natural resources inventoried in National Park Service (2016b). According to that source, all future lands acquired by the park will be allowed to succeed back to natural conditions and based on the National Land Cover Dataset (2011), the 30-km (18-mi) area surrounding Shiloh National Military Park contains 73% natural cover and is therefore considered "good". The smaller, 3-km (2-mi) area centered around Shiloh National Military Park (Battlefield unit) contains 64% natural cover and so is also "good", whereas the area within the park boundary is 86% natural, which verges on the 90% requirement to be considered "intact" (With and Crist 1995, McIntyre and Hobbs 1999, Wade et al. 2003). A land protection plan to guide future acquisitions is considered a high priority planning need (National Park Service 2016a). GRI GIS data extend at least 6 km (4 mi) from the park boundary. Geologic mapping data needs exist in the newly acquired areas, as well as the Corinth, MS, and Davis Bridge sites. The Tennessee Division of Geology has published maps available (Corinth NW quadrangle) that may cover the area, these data would need to evaluated and incorporated into the GRI GIS data.

Seismicity

Although the park is not considered to be at high risk of strong earthquakes, seismicity could impact park resources (fig. 21). In particular, liquefaction (destabilization of unconsolidated, water-saturated sediments during earthquakes) of **Qal** and **QTf**, and areas of steep slope could threaten infrastructure and cultural resources. 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 website: https://earthquake.usgs.gov/learn/topics/nmsz/
- Seismic hazard maps: Petersen et al. (2008).
- Monitoring seismicity: Braile (2009).

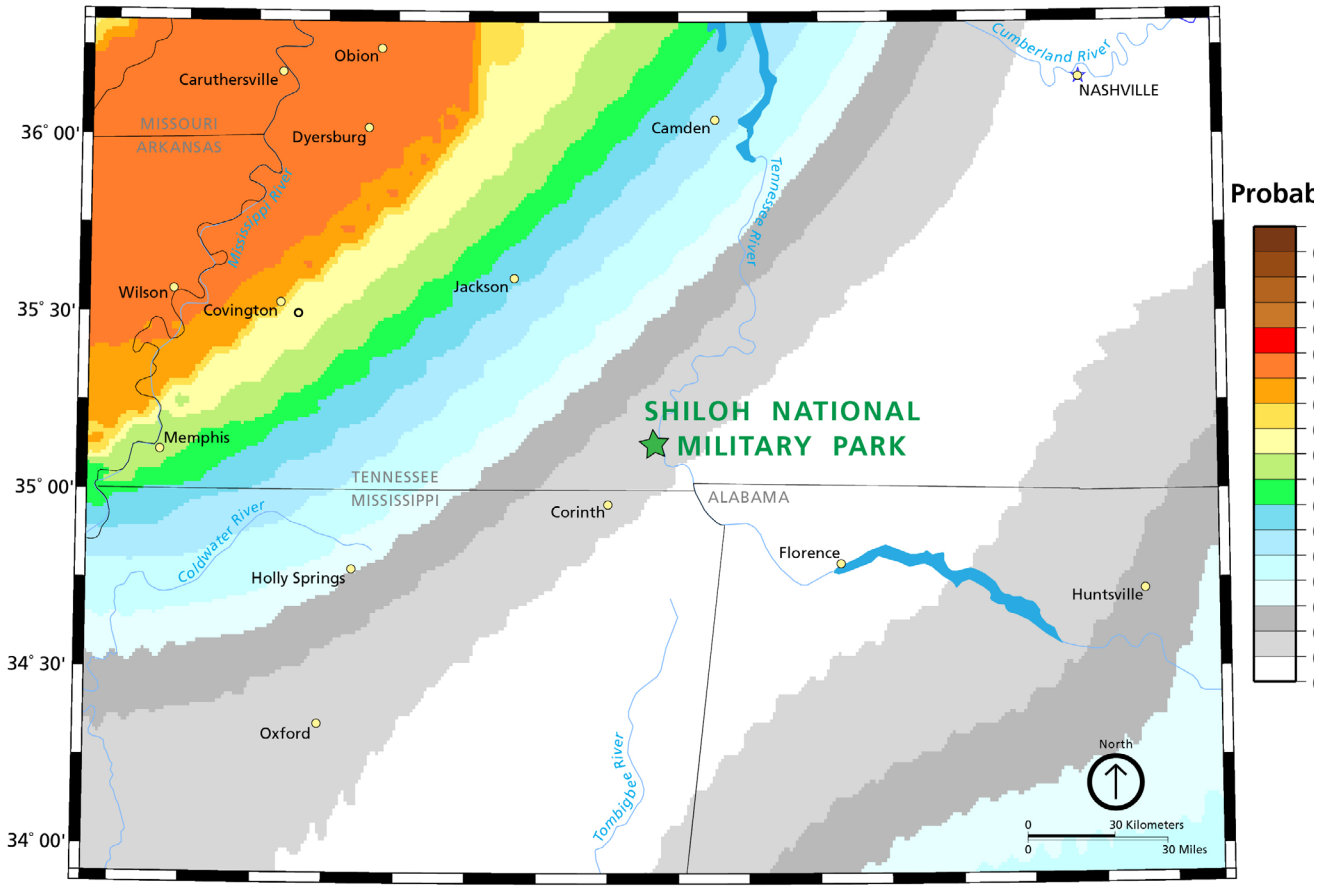


Figure 21. Map of probability of earthquakes with magnitude greater than 5.0 (moderate earthquake). This probability assumes a 100-year timespan and a 50-km (30-mi) radius around Shiloh, Tennessee (green star). The higher probability area to the northwest is the New Madrid Seismic Zone (https://earthquake.usgs.gov/learn/topics/nmsz/). Graphic was generated by the US Geological Survey earthquake probability mapping program (no longer available online).

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 over imagery of the park and surrounding area. Complete GIS data are available at the GRI publications website: http://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). Colors and symbols on geologic maps correspond to geologic map units. The unit symbols consist of an uppercase letter indicating the age (see fig. 6) and lowercase letters indicating the formation's name. Other symbols depict structures such as faults or folds, locations of past geologic hazards that may be susceptible to future activity, and other geologic features. Anthropogenic features such as mines or quarries, as well as observation or collection locations, may be indicated on geologic maps. The American Geosciences Institute website, http://www.americangeosciences.org/environment/publications/mapping, provides more information about geologic maps and their uses.

Geologic maps are typically 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 (the Quaternary Period). Surficial map units are differentiated by geologic process or depositional environment. 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. GRI produced a bedrock map for Shiloh National Military Park.

Source Maps

The GRI team does not conduct original geologic mapping. The team digitizes paper maps and compiles and converts digital data to conform to the GRI GIS data model. The GRI GIS data set includes essential elements of the 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 the shil_geology.pdf. The GRI team used the following sources to produce the GRI GIS data set for Shiloh National Military Park. These sources also provided information for this report.

- Bedrock Map and Mineral Resources: Russell (1964, 1967a, 1967b, and 1968)

GRI GIS Data

The GRI team standardizes map deliverables by using a data model. The GRI GIS data for Shiloh National Military Park was compiled using data model version 2.1, which is available at http://go.nps.gov/gridatamodel. This data model dictates GIS data structure, including layer architecture, feature attribution, and relationships within ESRI ArcGIS software. The GRI Geologic Maps website, https://go.nps.gov/geomaps, provides more information about the program's map products.

GRI GIS data are available on the GRI publications website http://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 following components are part of the data set:

- A GIS readme file (shil_gis_readme.pdf) that describes the GRI data formats, naming conventions, extraction instructions, use constraints, and contact information.
- Data in ESRI geodatabase GIS format;
- Layer files with feature symbology (table 2);
- Federal Geographic Data Committee (FGDC)–compliant metadata;
- An ancillary map information document (shil_geology.pdf) that contains information captured from source maps such as map unit descriptions, geologic unit correlation tables, legends, cross-sections, and figures; and
- An ESRI map document (shil_geology.mxd) that displays the GRI GIS data.

GRI Map Poster

A poster of the GRI GIS draped over a shaded relief of the park and surrounding area is included with this report. Not all GIS feature classes are included on the poster (table 4). 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. Contact GRI for assistance locating these data.

Table 2. GRI GIS data layers for Shiloh National Military Park.

Data Layer	On Poster?
Mine Point Features	No
Mine Area Features	No
Mine Area Feature Boundaries	No
Geologic Contacts	Yes
Geologic Units	Yes

Use Constraints

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

Minor inaccuracies may exist regarding the locations of geologic features relative to other geologic or geographic features on the poster. Based on the source map scale (1:24,000) and US National Map Accuracy Standards, geologic features represented in the geologic map data 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 References

These references, resources, and websites may be of use to resource managers. Refer to Appendix B for laws, regulations, and policies that apply to NPS geologic resources.

Geology of National Park Service Areas

- NPS Geologic Resources Division (Lakewood, Colorado) Energy and Minerals; Active Processes and Hazards; Geologic Heritage: http://go.nps.gov/geology
- NPS Geologic Resources Division Education Website: http://go.nps.gov/geoeducation
- NPS Geologic Resources Inventory: http://go.nps.gov/gri
- NPS Geoscientist-In-the-Parks (GIP) internship and guest scientist program: http://go.nps.gov/gip
- NPS Views program (geology-themed modules are available for Geologic Time, Paleontology, Glaciers, Caves and Karst, Coastal Geology, Volcanoes, and a variety of geologic parks): http://go.nps.gov/views

NPS Resource Management Guidance and Documents

- Management Policies 2006 (Chapter 4: Natural resource management): http://www.nps.gov/policy/mp/policies.html
- 1998 National parks omnibus management act: http://www.gpo.gov/fdsys/pkg/PLAW-105publ391/pdf/PLAW-105publ391.pdf
- NPS-75: Natural resource inventory and monitoring guideline: http://www.nature.nps.gov/nps75/nps75.pdf
- NPS Natural resource management reference manual #77: http://www.nature.nps.gov/Rm77/
- Geologic monitoring manual (Young, R., and L. Norby, editors. 2009. Geological monitoring. Geological Society of America, Boulder, Colorado): http://go.nps.gov/geomonitoring
- NPS Technical Information Center (TIC) (Denver, Colorado; repository for technical documents): https://www.nps.gov/dsc/technicalinfocenter.htm

Climate Change Resources

- NPS Climate Change Response Program Resources: http://www.nps.gov/subjects/climatechange/resources.htm
- US Global Change Research Program: http://www.globalchange.gov/home
- Intergovernmental Panel on Climate Change: http://www.ipcc.ch/

Geological Surveys and Societies

- Tennessee Division of Geology GIS data: http://www.tngis.org/geology.htm
- Tennessee Geological Survey: https://www.tn.gov/environment/section/geo-geology
- US Geological Survey: http://www.usgs.gov/
- Geological Society of America: http://www.geosociety.org/
- American Geophysical Union: http://sites.agu.org/
- American Geosciences Institute: http://www.americangeosciences.org/
- Association of American State Geologists: http://www.stategeologists.org/

US Geological Survey Reference Tools

- National geologic map database (NGMDB): http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
- Geologic names lexicon (GEOLEX; geologic unit nomenclature and summary): http://ngmdb.usgs.gov/Geolex/search
- Geographic names information system (GNIS; official listing of place names and geographic features): http://gnis.usgs.gov/
- GeoPDFs (download PDFs of any topographic map in the United States): http://store.usgs.gov (click on "Map Locator")
- Publications warehouse (many publications available online): http://pubs.er.usgs.gov
- Tapestry of time and terrain (descriptions of physiographic provinces): http://pubs.usgs.gov/imap/i2720/

Appendix A: Scoping Participants

The following people attended the GRI scoping meeting, held on 23 March 2009, or the follow-up report writing conference call, held on 9 March 2017. Discussions during these meetings supplied a foundation for this GRI report. The scoping summary document is available on the GRI publications website: https://go.nps.gov/gripubs.

2009 Scoping Meeting Participants

Name	Affiliation	Position
Stacy Allen	NPS Shiloh National Military Park	Chief of interpretation & resource management
Vince Antonacci	Tennessee Division of Geology	Geologist
Gib Backlund	NPS Stones River National Battlefield	Chief of operations
Ron Clendening	Tennessee Division of Geology	Geologist
Tim Connors	NPS Geologic Resources Division	Geologist
Elaine Foust	Tennessee Division of Geology	Geologist
Albert Horton	Tennessee Division of Geology	Geologist
Mike Hoyal	Tennessee Division of Geology	Geologist
Mike Manning	NPS Fort Donelson National Battlefield	Chief ranger
Joe Meiman	NPS Gulf Coast & Cumberland-Piedmont networks	Hydrologist
Lisa Norby	NPS Geologic Resources Division	Geologist
Trista L. Thornberry-Ehrlich	Colorado State University	Geologist, graphic designer, report writer
Ron Zurawski	Tennessee Division of Geology	State geologist

2017 Conference Call Participants

Name	Affiliation	Position
Stacy Allen	Shiloh National Military Park	Chief ranger/resource management
Vince Antonacci	Tennessee Division of Geology	Geologist
Michael Barthelmes	NPS Geologic Resources Division	Writer/editor
Robert Horton	Tennessee Division of Geology	Geologist
Marcus Johnson	Shiloh National Military Park	Resource manager/inventory & monitoring
Jason Kenworthy	NPS Geologic Resources Division	Geologist, GRI reports coordinator
Randy Martin	Shiloh National Military Park	Assistant facilities manager
Trista L. Thornberry-Ehrlich	Colorado State University	Geologist, graphic designer, report writer
Ron Zurawksi	Tennessee Division of Geology	State geologist

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
Caves and Karst Systems	**Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309** requires Interior/Agriculture to identify "significant caves" on Federal lands, regulate/restrict use of those caves as appropriate, and include significant caves in land management planning efforts. Imposes civil and criminal penalties for harming a cave or cave resources. Authorizes Secretaries to withhold information about specific location of a significant cave from a Freedom of Information Act (FOIA) requester. **National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of cave and karst resources. **Lechuguilla Cave Protection Act of 1993, Public Law 103-169** created a cave protection zone (CPZ) around Lechuguilla Cave in Carlsbad Caverns National Park. Within the CPZ, access and the removal of cave resources may be limited or prohibited; existing leases may be cancelled with appropriate compensation; and lands are withdrawn from mineral entry.	**36 CFR § 2.1** prohibits possessing/destroying/disturbing…cave resources…in park units. **43 CFR Part 37** states that all NPS caves are "significant" and sets forth procedures for determining/releasing confidential information about specific cave locations to a FOIA requester.	**Section 4.8.1.2** requires NPS to maintain karst integrity, minimize impacts. **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity. **Section 4.8.2.2** requires NPS to protect caves, allow new development in or on caves if it will not impact cave environment, and to remove existing developments if they impair caves. **Section 6.3.11.2** explains how to manage caves in/adjacent to wilderness.
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.	**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 Monument 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.
Geothermal	**Geothermal Steam Act of 1970, 30 USC. § 1001 et seq. as amended in 1988**, states ● No geothermal leasing is allowed in parks. ● "Significant" thermal features exist in 16 park units (the features listed by the NPS at **52 Fed. Reg. 28793-28800** (August 3, 1987), plus the thermal features in Crater Lake, Big Bend, and Lake Mead). ● NPS is required to monitor those features. ● Based on scientific evidence, Secretary of Interior must protect significant NPS thermal features from leasing effects. **Geothermal Steam Act Amendments of 1988, Public Law 100--443** prohibits geothermal leasing in the Island Park known geothermal resource area near Yellowstone and outside 16 designated NPS units if subsequent geothermal development would significantly adversely affect identified thermal features.		**Section 4.8.2.3** requires NPS to ● Preserve/maintain integrity of all thermal resources in parks. ● Work closely with outside agencies. ● Monitor significant thermal features.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
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.
Nonfederal Oil and Gas	**NPS Organic Act, 54 USC § 100751 et seq.** authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights). Individual Park Enabling Statutes: • **16 USC § 230a** (Jean Lafitte NHP & Pres.) • **16 USC §450kk** (Fort Union NM), • **16 USC § 459d-3** (Padre Island NS), • **16 USC § 459h-3** (Gulf Islands NS), • **16 USC § 460ee** (Big South Fork NRRA), • **16 USC § 460cc-2(i)** (Gateway NRA), • **16 USC § 460m** (Ozark NSR), • **16 USC§698c** (Big Thicket N Pres.), • **16 USC §698f** (Big Cypress N Pres.)	**36 CFR Part 6** regulates solid waste disposal sites in park units. **36 CFR Part 9, Subpart B** requires the owners/operators of nonfederally owned oil and gas rights outside of Alaska to • demonstrate bona fide title to mineral rights; • submit an Operations Permit Application to NPS describing where, when, how they intend to conduct operations; • prepare/submit a reclamation plan; and • submit a bond to cover reclamation and potential liability. **43 CFR Part 36** governs access to nonfederal oil and gas rights located in, or adjacent to, National Park System units in Alaska.	**Section 8.7.3** requires operators to comply with 9B regulations.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Federal Mineral Leasing (Oil, Gas, and Solid Minerals)	**The Mineral Leasing Act, 30 USC § 181 et seq., and the Mineral Leasing Act for Acquired Lands, 30 USC § 351 et seq.** do not authorize the BLM to lease federally owned minerals in NPS units. **Combined Hydrocarbon Leasing Act, 30 USC §181**, allowed owners of oil and gas leases or placer oil claims in Special Tar Sand Areas (STSA) to convert those leases or claims to combined hydrocarbon leases, and allowed for competitive tar sands leasing. This act did not modify the general prohibition on leasing in park units but did allow for lease conversion in GLCA, which is the only park unit that contains a STSA. **Exceptions: Glen Canyon NRA (16 USC § 460dd et seq.), Lake Mead NRA (16 USC § 460n et seq.), and Whiskeytown-Shasta-Trinity NRA (16 USC § 460q et seq.)** authorizes the BLM to issue federal mineral leases in these units provided that the BLM obtains NPS consent. Such consent must be predicated on an NPS finding of no significant adverse effect on park resources and/or administration. American Indian Lands Within NPS Boundaries Under the **Indian Allottee Leasing Act of 1909, 25 USC §396, and the Indian Leasing Act of 1938, 25 USC §396a, §398 and §399, and Indian Mineral Development Act of 1982, 25 USCS §§2101-2108**, all minerals on American Indian trust lands within NPS units are subject to leasing. **Federal Coal Leasing Amendments Act of 1975, 30 USC § 201** prohibits coal leasing in National Park System units.	**36 CFR § 5.14** states prospecting, mining, and…leasing under the mineral leasing laws [is] prohibited in park areas except as authorized by law. **BLM regulations at 43 CFR Parts 3100, 3400, and 3500** govern Federal mineral leasing. **43 CFR Part 3160** governs onshore oil and gas operations, which are overseen by the BLM. Regulations re: Native American Lands within NPS Units: • **25 CFR Part 211** governs leasing of tribal lands for mineral development. • **25 CFR Part 212** governs leasing of allotted lands for mineral development. • **25 CFR Part 216** governs surface exploration, mining, and reclamation of lands during mineral development. • **25 CFR Part 224** governs tribal energy resource agreements. • **25 CFR Part 225** governs mineral agreements for the development of Indian-owned minerals entered into pursuant to the **Indian Mineral Development Act of 1982, Pub. L. No. 97-382, 96 Stat. 1938** (codified at **25 USC §§ 2101-2108**). • **30 CFR §§ 1202.100-1202.101** governs royalties on oil produced from Indian leases. • **30 CFR §§ 1202.550-1202.558** governs royalties on gas production from Indian leases. • **30 CFR §§ 1206.50-1206.62 and §§ 1206.170-1206.176** governs product valuation for mineral resources produced from Indian oil and gas leases. • **30 CFR § 1206.450** governs the valuation coal from Indian Tribal and Allotted leases. • **43 CFR Part 3160** governs onshore oil and gas operations, which are overseen by the BLM.	**Section 8.7.2** states that all NPS units are closed to new federal mineral leasing except Glen Canyon, Lake Mead and Whiskeytown-Shasta-Trinity NRAs.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Nonfederal minerals other than oil and gas	**NPS Organic Act, 54 USC §§ 100101 and 100751**	NPS regulations at **36 CFR Parts 1, 5, and 6** require the owners/ operators of other types of mineral rights to obtain a special use permit from the NPS as a **§ 5.3** business operation, and **§ 5.7 – Construction of buildings or other facilities**, and to comply with the solid waste regulations at **Part 6**.	**Section 8.7.3** states that operators exercising rights in a park unit must comply with **36 CFR Parts 1 and 5**.
Coal	**Surface Mining Control and Reclamation Act of 1977, 30 USC § 1201 et. seq.** prohibits surface coal mining operations on any lands within the boundaries of a NPS unit, subject to valid existing rights.	**SMCRA Regulations at 30 CFR Chapter VII** govern surface mining operations on Federal lands and Indian lands by requiring permits, bonding, insurance, reclamation, and employee protection. **Part 7** of the regulations states that National Park System lands are unsuitable for surface mining.	None applicable.
Uranium	**Atomic Energy Act of 1954** Allows Secretary of Energy to issue leases or permits for uranium on BLM lands; may issue leases or permits in NPS areas only if president declares a national emergency.	None applicable.	None applicable.
Common Variety Mineral Materials (Sand, Gravel, Pumice, etc.)	**Materials Act of 1947, 30 USC § 601** does not authorize the NPS to dispose of mineral materials outside of park units. **Reclamation Act of 1939, 43 USC §387**, authorizes removal of common variety mineral materials from federal lands in federal reclamation projects. This act is cited in the enabling statutes for Glen Canyon and Whiskeytown National Recreation Areas, which provide that the Secretary of the Interior may permit the removal of federally owned nonleasable minerals such as sand, gravel, and building materials from the NRAs under appropriate regulations. Because regulations have not yet been promulgated, the National Park Service may not permit removal of these materials from these National Recreation Areas. **16 USC §90c-1(b)** authorizes sand, rock and gravel to be available for sale to the residents of Stehekin from the non-wilderness portion of Lake Chelan National Recreation Area, for local use as long as the sale and disposal does not have significant adverse effects on the administration of the national recreation area.	None applicable.	**Section 9.1.3.3** clarifies that only the NPS or its agent can extract park-owned common variety minerals (e.g., sand and gravel), and: ● only for park administrative uses; ● after compliance with NEPA and other federal, state, and local laws, and a finding of non-impairment; ● after finding the use is park's most reasonable alternative based on environment and economics; ● parks should use existing pits and create new pits only in accordance with park-wide borrow management plan; ● spoil areas must comply with Part 6 standards; and ● NPS must evaluate use of external quarries. Any deviation from this policy requires a written waiver from the Secretary, Assistant Secretary, or Director.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Coastal Features and Processes	**NPS Organic Act, 54 USC § 100751 et. seq.** authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights). **Coastal Zone Management Act, 16 USC § 1451 et. seq**. requires Federal agencies to prepare a consistency determination for every Federal agency activity in or outside of the coastal zone that affects land or water use of the coastal zone. **Clean Water Act, 33 USC § 1342/ Rivers and Harbors Act, 33 USC 403** require that dredge and fill actions comply with a Corps of Engineers Section 404 permit. **Executive Order 13089** (coral reefs) (1998) calls for reduction of impacts to coral reefs. **Executive Order 13158** (marine protected areas) (2000) requires every federal agency, to the extent permitted by law and the maximum extent practicable, to avoid harming marine protected areas. *See also "Climate Change"*	**36 CFR § 1.2(a)(3)** applies NPS regulations to activities occurring within waters subject to the jurisdiction of the US located within the boundaries of a unit, including navigable water and areas within their ordinary reach, below the mean high water mark (or OHW line) without regard to ownership of submerged lands, tidelands, or lowlands. **36 CFR § 5.7** requires NPS authorization prior to constructing a building or other structure (including boat docks) upon, across, over, through, or under any park area. *See also "Climate Change"*	**Section 4.1.5** directs the NPS to re-establish natural functions and processes in human-disturbed components of natural systems in parks unless directed otherwise by Congress. **Section 4.4.2.4** directs the NPS to allow natural recovery of landscapes disturbed by natural phenomena, unless manipulation of the landscape is necessary to protect park development or human safety. **Section 4.8.1** requires NPS to allow natural geologic processes to proceed unimpeded. NPS can intervene in these processes only when required by Congress, when necessary for saving human lives, or when there is no other feasible way to protect other natural resources/ park facilities/ historic properties. **Section 4.8.1.1** requires NPS to: • Allow natural processes to continue without interference, • Investigate alternatives for mitigating the effects of human alterations of natural processes and restoring natural conditions, • Study impacts of cultural resource protection proposals on natural resources, • Use the most effective and natural-looking erosion control methods available, and avoid new developments in areas subject to natural shoreline processes unless certain factors are present. *See also "Climate Change"*

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.	*No applicable regulations, although the following NPS guidance should be considered:* **Coastal Adaptation Strategies Handbook (Beavers et al. 2016)** provides strategies and decision-making frameworks to support adaptation of natural and cultural resources to climate change. **Climate Change Facility Adaptation Planning and Implementation Framework**: The NPS Sustainable Operations and Climate Change Branch is developing a plan to incorporate vulnerability to climate change (Beavers et al. 2016b). **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. *continued in 2006 Management Policies column*	**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. (2016). *NPS guidance, continued:* **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
Upland and Fluvial Processes	**Rivers and Harbors Appropriation Act of 1899, 33 USC § 403** prohibits the construction of any obstruction on the waters of the United States not authorized by congress or approved by the USACE. **Clean Water Act 33 USC § 1342** requires a permit from the USACE prior to any discharge of dredged or fill material into navigable waters (waters of the US [including streams]). **Executive Order 11988** requires federal agencies to avoid adverse impacts to floodplains. (see also **D.O. 77-2**) **Executive Order 11990** requires plans for potentially affected wetlands (including riparian wetlands). (see also **D.O. 77-1**)	None applicable. *2006 Management Policies, continued:* **Section 4.6.6** directs the NPS to manage watersheds as complete hydrologic systems and minimize human-caused disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams. **Section 4.8.1** directs the NPS to allow natural geologic processes to proceed unimpeded. Geologic processes…include…erosion and sedimentation…processes. **Section 4.8.2** directs the NPS to protect geologic features from the unacceptable impacts of human activity while allowing natural processes to continue.	**Section 4.1** requires NPS to manage natural resources to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities; maintain all components and processes of naturally evolving park ecosystems. **Section 4.1.5** directs the NPS to re-establish natural functions and processes in human-disturbed components of natural systems in parks, unless directed otherwise by Congress. **Section 4.4.2.4** directs the NPS to allow natural recovery of landscapes disturbed by natural phenomena, unless manipulation of the landscape is necessary to protect park development or human safety. **Section 4.6.4** directs the NPS to (1) manage for the preservation of floodplain values; [and] (2) minimize potentially hazardous conditions associated with flooding. *continued in Regulations column*

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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National Park Service
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https://www.nps.gov/nature/index.htm