National Park Service
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Natural Resource Stewardship and Science

Fort Donelson National Battlefield

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2020/2197

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ON THE COVER
Confederate batteries overlooking the Cumberland River (now impounded Lake Barkley) in northern Tennessee. Even with such a strong strategic position, the fort fell to siege tactics and Union gunboats in 1862. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.
THIS PAGE
Photograph of the sunset view from the Dover Hotel (surrender house). National Park Service photograph courtesy of Fort Donelson National Battlefield taken in February 2017.

Fort Donelson National Battlefield

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2020/2197

Trista L. Thornberry-Ehrlich
Colorado State University Research Associate

National Park Service Geologic Resources Inventory
Geologic Resources Division
PO Box 25287
Denver, CO 80225

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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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 2018 (see Appendix A). Chapters of this report discuss the geologic setting, distinctive geologic features and processes within Fort Donelson National Battlefield, highlight geologic issues facing resource managers, describe the geologic history leading to the present-day landscape, and provide information about the previously completed GRI map data. A poster illustrates these data.

The American Civil War began in 1861 with secessionist forces firing upon Fort Sumter. Upon the outbreak of war, Confederate strategists were forced to reinforce the northern border between Tennessee and Kentucky. They hastily constructed Forts Donelson, Heiman, and Henry along two major rivers—the Tennessee and Cumberland—to defend against enemy invasion (fig. 1). Union forces under the command of Ulysses S. Grant attacked these positions in February 1862. Fort Heiman was still under construction on the western bank of the Tennessee River. Fort Henry was flooded and muddy. Both positions were abandoned, and Confederate troops regrouped at Fort Donelson, whose position atop high bluffs offered a commanding view of the Cumberland River and more defensive infrastructure. The battle stretched over four days with both sides using local topography to gain the advantage. In the end, the Union forces prevailed and demanded unconditional surrender. This was the beginning of the end for the Confederate control of the Mississippi River corridor and ultimately the Confederacy itself.

The park's geology lays the groundwork for the historic battles that played out on its surface. The geology at Fort Donelson National Battlefield stretches back more than 300 million years. During the Mississippian Period (323.2 to 358.9 million years ago), the North American craton was at equatorial latitudes and largely underwater. Sediment from highlands to the east collected in the large Appalachian and Illinois basins. In the deeper water regions, mudstone, chert, dolomite, and limestone accumulated to become the Fort Payne Formation, Warsaw Limestone, and St. Louis Limestone (GRI GIS map units **Mfp**, **Mw**, and **Msl**). Continental collision driven by plate tectonics in the late Paleozoic pieced together a supercontinent and uplifted the Appalachian Mountains and the interior of North America. This began a prolonged period of weathering and erosion that largely continues today at Fort Donelson National Battlefield. In the Cretaceous period (more than 66 million years ago) and into the Cenozoic Era, precursors to today's rivers were incising channels and depositing reworked sediments on top of the weathered Mississippian rocks as the Tuscaloosa Gravel, McNairy Formation, Clayton Formation, high-level alluvial deposits, and continental deposits (**Kt**, **Km**, **TKcm**, **QTal**, and **QTc**). Modern Earth surface processes continue to sculpt the landscape. Following Pleistocene glaciation events, winds unimpeded by vegetation whipped loess (**Ql**) deposits across vast swaths of land. The youngest mapped unit is alluvium (**Qal**) transported, reworked, and deposited by local rivers.

This report is supported by the GRI-compiled map of the geology of Fort Donelson National Battlefield. The data show predominantly deeply weathered bedrock units (primarily limestone) mantled with loess, sand, gravel, and clay. The Kentucky Geological Survey and Tennessee Division of Geology prepared the source maps that cover all units of the park including Fort Donelson and Fort Heiman. Fort Henry was inundated upon the impoundment of the Tennessee River to create Kentucky Lake and is not within park boundaries.

Geologic features and processes discussed in this report, some with associated resource management issues, include the following:

- **Flooding**. Downstream dams on the Tennessee and Cumberland rivers greatly reduce the impact of seasonal floods on the park's landscape. Flooding still occurs on local streams (e.g., Indian Creek). The increased storm activity predicted by climate change models may force the system out of normal ranges of water height.
- **Fluvial processes and features**. Fluvial features are those which are formed by flowing water as it both constructs and erodes landforms. Fluvial features

occur on many scales in the park ranging from the large river valleys (e.g., Cumberland and Tennessee rivers) to small tributary valleys (e.g., Hickman and Indian creeks) to the smallest streams (e.g., unnamed rivulets and ephemeral gullies).

- **Windblown loess**. Windblown sediment is naturally sorted according to grain size as the wind's power can only transport lighter materials. Winnowed silt accumulated as loess deposits when stabilizing vegetation was denuded at the end of the last glaciation. Loess occurs on the highest elevations in the park within the Fort Heiman park unit, Kentucky.
- **Upland weathering**. Surficial deposits accumulating on and being reworked or removed from the landscape are testament to the ongoing processes of weathering and erosion as local bedrock is worn away by wind and water. These natural processes threaten the historic context of the landscape within Fort Donelson National Battlefield.
- **Historic resources**. Local topography, terrain, location, and rivers were important to the military story at Fort Donelson. Earthwork fortifications, waterfront artillery batteries, other archeological resources, and battle setting are among the park's fundamental resources and values. Given the park's mission, it is not surprising that historic preservation is a resource management concern and priority.
- **Faults**. Faults and folds accommodate stresses within Earth's crust. They form where the rock has compressed, stretched, sheared, or fractured and moved. Faults in the park (and included in the GRI GIS data) occur as normal faults and faults with unknown offset/displacement. Fort Donelson National Battlefield is near a seismic zone known for historically large earthquakes—the New Madrid seismic zone. The potential for strong seismicity exists. Earth shaking would have the potential to trigger slope movements and damage infrastructure.
- **Karst features**. Karst is a landscape that forms through the dissolution of soluble rock. The park's limestone and dolomite are soluble and prone to karst formation. A solution cave and karst spring occur within the park boundaries.
- **Slope movements, hazards, and risks**. Slope movements, or the downslope transfer of material is not common at the park. Most of the local slopes are vegetated and considered relatively stable. Slope movements may include rockfalls, thin planar slides, landslides, and slumps. Slope movement can be caused by frost weathering, root wedging, water-saturated soils, and human disturbance.
- **Abandoned mineral lands and disturbed lands**. Abandoned mineral lands are lands, waters, and surrounding watersheds that contain disturbances associated with past mineral exploration, extraction, processing, and transportation. Disturbed lands are those park lands where the natural conditions and processes have been directly impacted by development. Local mining features may include iron-ore pits.
- **Bedrock exposures**. Bedrock is deeply weathered at the park and not well exposed. The bedrock is all sedimentary and formed from fragments of other rocks or chemical precipitation. The Warsaw Limestone (**Mw**) crops out along a maintenance road within the Fort Donelson park unit and along the Cumberland River shoreline just beyond the park boundary near the lower river battery.
- **Paleontological resource inventory, monitoring, and protection**. Paleontological resources (fossils) are non-renewable evidence of life preserved in a geologic context. The park protects several examples of Mississippian fossils including crinoids, brachiopods, and bryozoans. Fossils are a protected resource in the National Park system.

Products and Acknowledgments

The NPS Geologic Resources Division partners with the Colorado State University Department of Geosciences to produce GRI products. The US Geological Survey, Kentucky Geological Survey, and Tennessee Division of Geology developed the source maps. The Kentucky Geological Survey and park staff 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 non-geoscientists.

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.

Acknowledgments

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Review

Drew Andrews (Kentucky Geological Survey)

Michael Barthelmes (Colorado State University)

Glynn Beck (Kentucky Geological Survey)

Matt Crawford (Kentucky Geological Survey)

David Hamby (Fort Donelson National Battlefield)

Brian McCutchen (Fort Donelson National Battlefield)

Editing

Michael Barthelmes (Colorado State University)

Report Formatting and Distribution

Michael Barthelmes (Colorado State University)

Source Maps

L. V. Blade (US Geological Survey)

M. V. Marcher, L. T. Larson, R. E. Hershey, and R. H. Barnes (Tennessee Division of Geology)

M. A. Tyra (Kentucky Geological Survey)

GRI GIS Data Production

John Gilbert (Colorado State University)

Stephanie O'Meara (Colorado State University)

Ethan Schaefer (Colorado State University)

Heather Stanton (Colorado State University)

GRI Map Poster Design

Georgia Hybels (Colorado State University)

Dalton Meyer (Colorado State University)

GRI Map Poster Editing

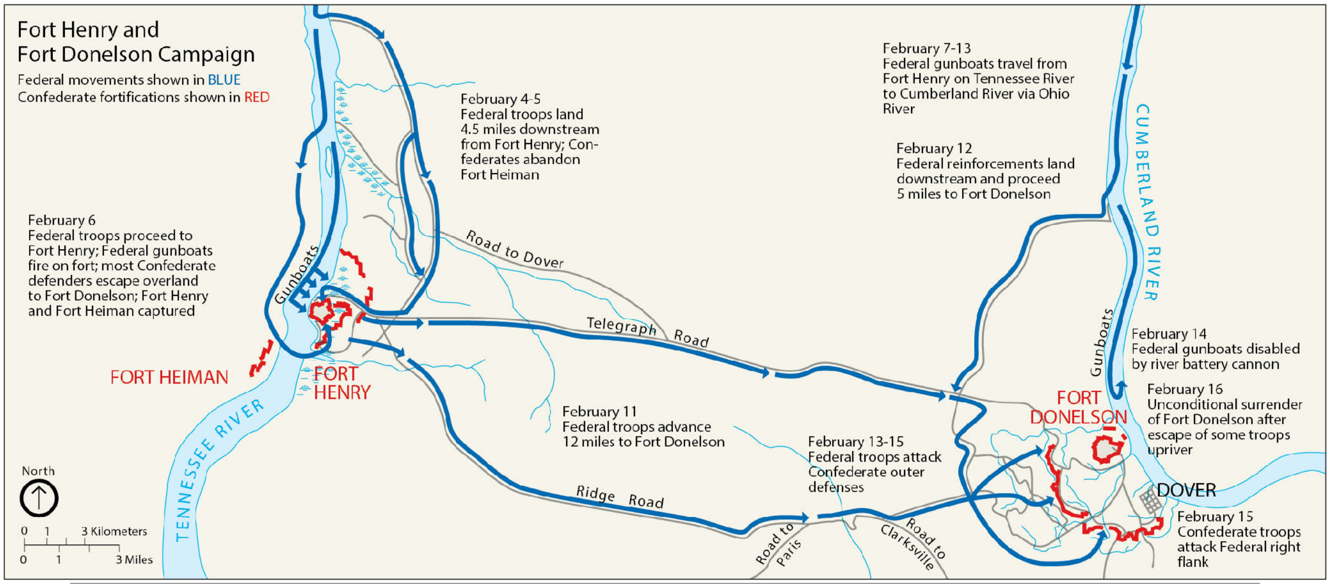
Georgia Hybels (Colorado State University)

Rebecca Port (NPS Geologic Resources Division)

Michael Barthelmes (Colorado State University)

Chelsea Bitting (NPS Geologic Resources Division)

Jason Kenworthy (NPS Geologic Resources Division)



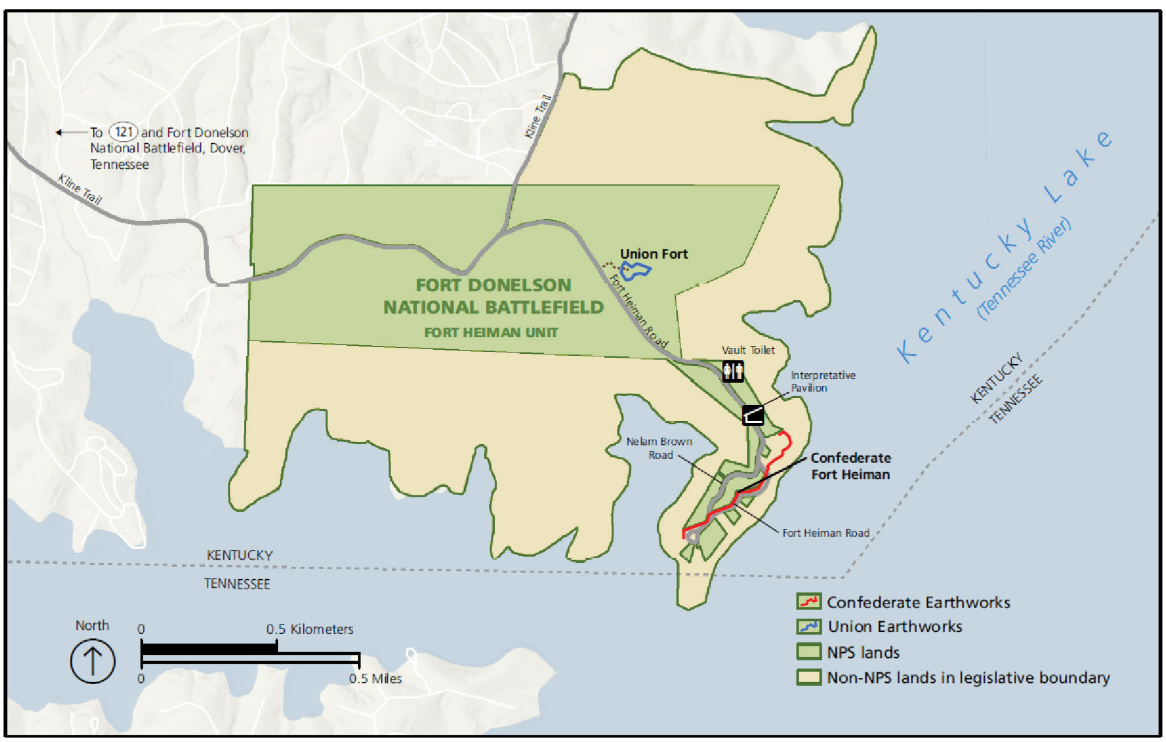


Figure 1. Maps of Fort Donelson National Battlefield.
The upper map shows the location of the main unit of Fort Donelson and the associated national cemetery in Dover, Tennessee, and Fort Heiman in Calloway County, Kentucky. The lower map shows a detailed view of the Fort Heiman unit. National Park Service maps.

Geologic Setting, History, and Significance

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

Park Establishment

Perched on high bluffs overlooking the Cumberland River (fig. 2) in northern Tennessee, Fort Donelson was a daunting Confederate stronghold, whose unconditional surrender following a four-day battle on 16 February 1862 shocked the Confederacy and reinvigorated the Union cause during the American Civil War. Union General Ulysses S. Grant and Admiral Andrew Hull Foote ultimately captured three forts (Donelson, Henry, and Heiman), and opened two major rivers—the Tennessee and Cumberland rivers—to force the Confederacy to give up southern Kentucky and much of central and western Tennessee. The rivers and railroads in the area supplied the Union forces for the next three years as the heartland of the Confederacy was made vulnerable. According to the park's foundation document (National Park Service 2019a), Fort Donelson National Battlefield protects the historic resources associated with the 1862 Civil War campaign for Forts Henry, Heiman, and Donelson and control of the Cumberland and Tennessee rivers, while providing a setting for contemplation for the nearly 200,000 annual visitors. The historic resources are closely aligned with the natural resources, including geology, that heavily influenced the history (table 1 and fig. 3).

On 26 March 1928, Fort Donelson National Battlefield was established under the management of the War Department before being transferred to the Department of the Interior on 10 August 1933. The battlefield was included on the National Register of Historic Places on 15 October 1966. The National Park Service manages 412 ha (1,017 ac) of the 530 ha (1,309 ac) within the legislative boundary, comprising the main unit of Fort Donelson and the associated national cemetery in Dover, Tennessee, and Fort Heiman in Calloway County, Kentucky (fig. 1).

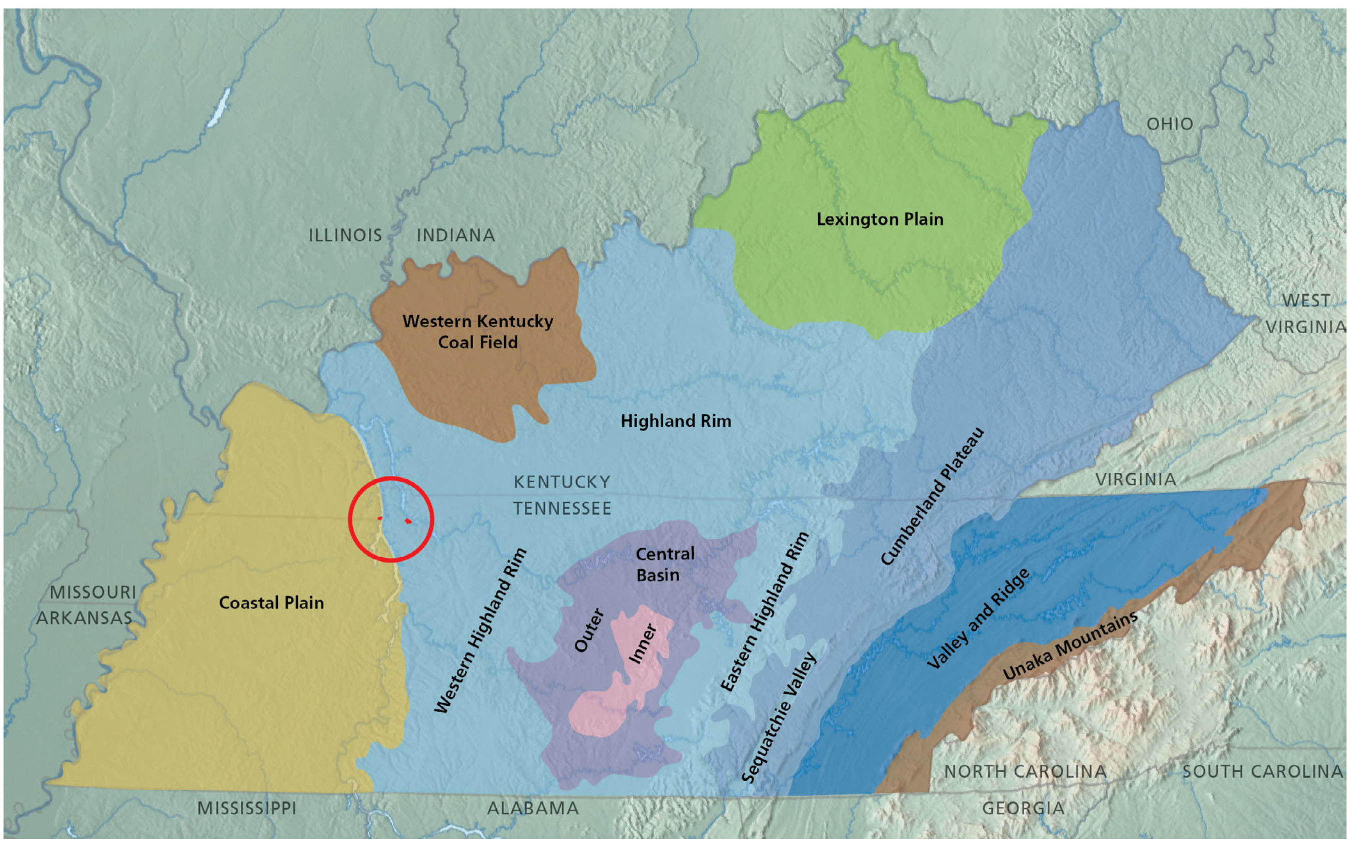


Figure 2. Map of physiographic provinces of Tennessee and Kentucky.
Fort Donelson National Battlefield (small, encircled red areas) is located on the western edge of the Highland Rim province near where deposits of the coastal plain cover the older bedrock. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) after Harris (2012). Shaded relief base map courtesy of Tom Patterson (National Park Service).

Table 1. 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. A mass extinction event is a widespread and rapid decrease in the biodiversity on Earth. Geologic units mapped within the park only are included. Age ranges are millions of years ago (MYA). The Quaternary and Tertiary periods are part of the Cenozoic Era. The Triassic, Jurassic, and Cretaceous periods are part of the Mesozoic Era. The periods from Cambrian through Permian are part of the Paleozoic Era. National Park Service graphic using dates from the International Commission on Stratigraphy (http://www.stratigraphy.org/index.php/ics-chart-timescale).

Geologic Time Unit	MYA	Geologic Map Units	Local Geologic Events
Quaternary Period (Q): Holocene Epoch (H)	0.01–today	**Qal** deposited in river channels **Ql** deposited in wind-swept environment	Fluvial meandering, incision, and deposition; slope processes Sea level rose
Quaternary Period (Q): Pleistocene Epoch (PE)	2.6–0.01	**QTal** and **QTc** deposited, weathered, and reworked	Ice age glaciations; glacial outburst floods; river courses modified; weathering and incision accelerated
Tertiary (T): Neogene Period (N)	23.0–2.6	Any units deposited during this time were eroded away	Fluctuating sea levels; meandering rivers
Tertiary (T); Paleogene Period (PG)	66.0–23.0	**TKcm** deposited	Ongoing erosion and weathering
Cretaceous Period (K)	145.0–66.0	**Kt** and **Km** deposited in terrestrial environments	Global mass extinction at end of Cretaceous (dinosaurs extinct)
Jurassic Period (J)	201.3–145.0	Any units deposited during this time were eroded away	Ongoing erosion and weathering
Triassic Period (TR)	252.2–201.3	Any units deposited during this time were eroded away	Global mass extinction at end of Triassic Breakup of Pangaea begins; Atlantic Ocean opened; sediments began building out the coastal plain
Permian Period (P)	298.9–252.2	Any units deposited during this time were eroded away	Global mass extinction at end of Permian. Supercontinent Pangaea intact. Appalachians may have rivaled height of modern Himalayas.
Carboniferous; Pennsylvanian Period (PN)	323.2–298.9	Any units deposited during this time were eroded away	Alleghany (Appalachian) Orogeny; some terrestrial depositional settings
Carboniferous; Mississippian Period (M)	358.9–323.2	**Mfp**, **Mw**, and **Msl** deposited in Appalachian Basin	Open marine to fluctuating nearshore settings

Table 1, continued. Geologic time scale.

Geologic Time Unit	MYA	Geologic Map Units	Local Geologic Events
Devonian Period (D)	419.2–358.9	None mapped	Global mass extinction at end of Devonian; Appalachian Basin collected sediment and subsided
Silurian Period (S)	443.8–419.2	None mapped	Ongoing marine sedimentation Neoacadian Orogeny
Ordovician Period (O)	485.4–443.8	None mapped	Global mass extinction at end of Ordovician; deeper marine settings Sea level fluctuations; marine and nearshore settings Taconic Orogeny; open marine settings
Cambrian Period (C)	541.0–485.4	None mapped	Extensive oceans covered most of proto-North America (Laurentia)
Proterozoic Eon; Neoproterozoic (Z)	1,000–541	None mapped	Supercontinent Rodinia rifted apart
Proterozoic Eon; Mesoproterozoic (Y)	1,600–1,000	None mapped	Formation of early supercontinent; Grenville Orogeny
Proterozoic Eon; Paleoproterozoic (X)	2,500–1,600	None mapped	None reported
Archean Eon	~4,000–2,500	None mapped	Oldest known Earth rocks
Hadean Eon	4,600–4,000	None mapped	Formation of Earth approximately 4,600 million years ago

The Fort Donelson park unit in Steward County includes two river batteries along Lake Barkley (impounded Cumberland River), outer earthworks, the Surrender House (Dover Hotel), and the national cemetery (originally established in 1867; Sundin et al. 2013). About 20% of the original 1862 battlefield is within park boundaries (Jobe Date Unknown). About 160 ha (400 ac) were added to the Tennessee side of the park since 2009, mostly comprising the Confederate breakout areas (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call 16 April 2018). Across the Land Between the Lakes National Recreation Area, on the west bank of the Tennessee River is the Fort Heiman park unit, which was transferred to the National Park Service in 2006 (National Park Service 2019a). Nearby Fort Henry was inundated in 1944 when the river was dammed to create Kentucky Lake.

Fort Donelson Battlefield is situated atop high bluffs of a rolling upland that was poised above the Cumberland River in 1862. Tributary streams dissect the upland and two such streams, Hickman and Indian creeks (now flooded), incised steep edges around the fort to create an imposing vantage point. Indian Creek separates the fort area from the community of Dover and the surrender building, Dover Hotel. Fort Heiman to the west and Fort Henry to the east were composed of earthworks and fortifications that fell to Union forces prior to the battle at Fort Donelson. The forts were dug into dissected uplands underlain by unconsolidated loess (windblown silt) and continental deposits on opposite shores of the Tennessee River.

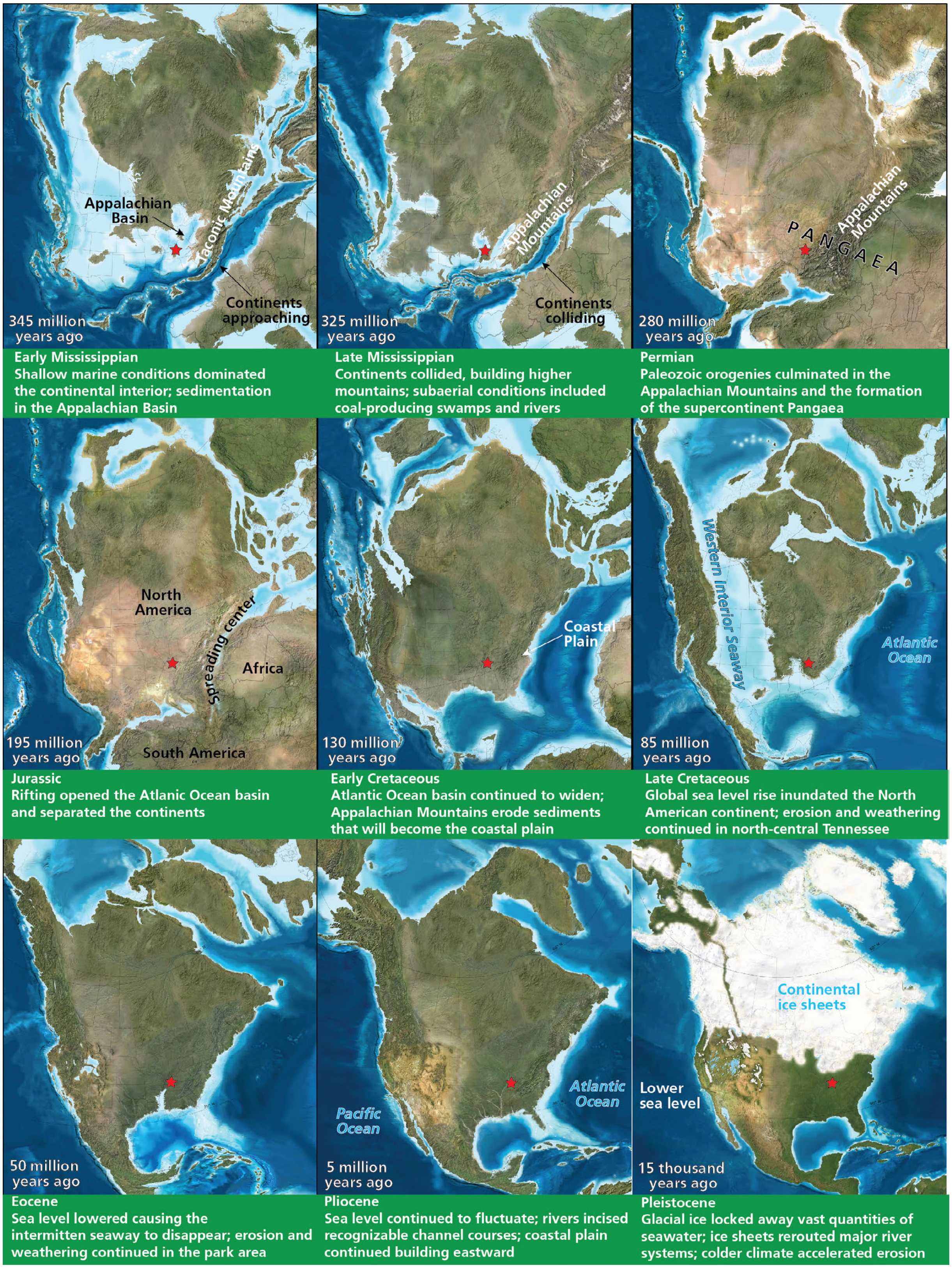


Figure 3. Paleogeographic maps of North America.
The red star indicates the approximate location of Fort Donelson National Battlefield. Base paleogeographic maps created by Ron Blakey (North American Key Time Slices © 2013 Colorado Plateau Geosystems Inc.), additional information is available at https://deeptimemaps.com/. Annotated by Trista L. Thornberry-Ehrlich (Colorado State University).

The Cumberland, Tennessee, and Ohio rivers played a vital role in the battle history of the area. Using gunboats and steamships, Union forces could fire upon the forts and move troops, supplies, and reinforcements to face the increasingly besieged and stranded Confederate troops. The 1,107 km (688 mi) long Cumberland River drains nearly 47,000 km^2 (18,000 mi^2) of southern Kentucky and north-central Tennessee and flows through Nashville and Clarksville, Tennessee. The Tennessee River is the largest tributary to the Ohio River, draining 105,868 km^2 (40,876 mi^2) of eastern Tennessee and northern Alabama. It is approximately 1,049 km (652 mi) long and flows through Knoxville and Chattanooga. Both rivers drain into the Ohio River near Paducah, Kentucky, just northwest of Fort Donelson National Battlefield.

Geologic Setting and History

Fort Donelson National Battlefield is part of the Highland Rim physiographic province of Tennessee, also referred to as the Mississippian Plateau or western Pennyroyal Plateau in Kentucky (fig. 2). The Highland Rim surrounds the Central Basin of Tennessee. It is a cuesta, or a hill or ridge with a gentle slope on one side and a steep slope on the other. Locally, the border between the rim and basin is a sharply pronounced escarpment. Where the Highland Rim is topographically higher than the Central Basin, it is rarely at an elevation above 340 m (1,100 ft). Ridges and valleys, with a few low hills dissected by perennial streams, characterize the Highland Rim in the park area. The bedrock of the Highland Rim was largely undeformed by the mountain building orogenies responsible for the Appalachian Mountains to the east. Erosion has exposed deeply weathered bedrock across the Highland Rim. Fort Donelson National Battlefield is near the boundary of the Coastal Plain province where Cretaceous and younger sediments shed from adjacent uplands mantle older bedrock. Locally, this includes the channel, floodplain, and terraces of the northward flowing Tennessee River. The dissected meandering river valley contains remnants of alluvial terraces and natural levees overlying sandy Cretaceous bedrock.

The geology at Fort Donelson National Battlefield records more than 300 million years of Earth's history (table 1 and fig. 3). The rock units in the park can be separated into three distinct groups by age and type. These are, from oldest to youngest: Mississippian carbonate (dolomite and limestone) bedrock; Cretaceous siliciclastic (non-carbonate, sandstone and conglomerate) bedrock; and unconsolidated surficial deposits from the Cenozoic Era (fig. 4). During the Mississippian Period (approximately 325 million years ago), North America was located near the equator and was partially covered by a shallow sea. The chert, dolomite, and limestone of the Fort Payne Formation (GRI GIS unit **Mfp**) were deposited in deep-water, open marine environments of the Illinois Basin—a longstanding center of deposition throughout the Paleozoic (fig. 5A). The Illinois Basin was intermittently separated from the greater Appalachian Basin by the Cincinnati arch. As conditions within the basin changed to shallower marine shelf, deposition of the Warsaw Limestone (**Mw**) and St. Louis Limestone (**Msl**) began. Today, the Fort Payne Formation (**Mfp**) crops out in the deepest stream valleys in the area and within the Fort Heiman park unit. The fossiliferous Warsaw Limestone is locally very weathered in both the Fort Donelson and Fort Heiman park units. The St. Louis Limestone is similarly deeply weathered and occurs in the highest reaches of the Fort Donelson park unit.

The late Paleozoic Alleghany Orogeny, which was the last major Appalachian building event (figs. 5B and C), was focused further east of the park. Any Pennsylvanian, Permian, Triassic, or Jurassic age units that may have been deposited in the park area have since eroded away (fig. 6D). Following this period of erosion or nondeposition, the gravel, sand, and clay of the Cretaceous Tuscaloosa Gravel (**Kt**) and McNairy Formation (**Km** and **TKcm**) were deposited in terrestrial, fluvial (river) channel settings (fig. 6E; Olive and McDowell 1986). The entire park area has been slowly uplifted, weathered, and eroded after deposition of the Cretaceous and Tertiary coastal plain sediments of the McNairy Formation (William Andrews, Kentucky Geological Survey, geologist, written communication, 2 April 2020).

Since the end of Paleozoic mountain building, the Appalachian Mountains and adjacent uplands have been eroding. Regional rivers transport the eroded sediments along their channels and ultimately, they become part of the coastal plain building seaward in the Atlantic Ocean and Gulf of Mexico. The story at Fort Donelson National Battlefield has largely been one of weathering, erosion, and reworking of sediments for at least the last 60 million years (fig. 6F). During the colder climates of the Pleistocene, continental glaciers scoured the northern reaches of North America and left vast tracts devoid of vegetation when they melted and retreated. The finest grained of the now-unstable sediment was swept away by the wind and deposited as winnowed silt, also called loess (**Ql**) in layers throughout the park area and surrounding regions. Loess occurs in the highest reaches of the Fort Heiman park unit. The youngest geologic unit in the park is modern alluvium (**Qal**), unconsolidated deposits of gravel, sand, silt, and clay reworked by streams and rivers such as Lake Barkley at Fort Donelson and several unnamed drainages in the Fort Heiman park unit.

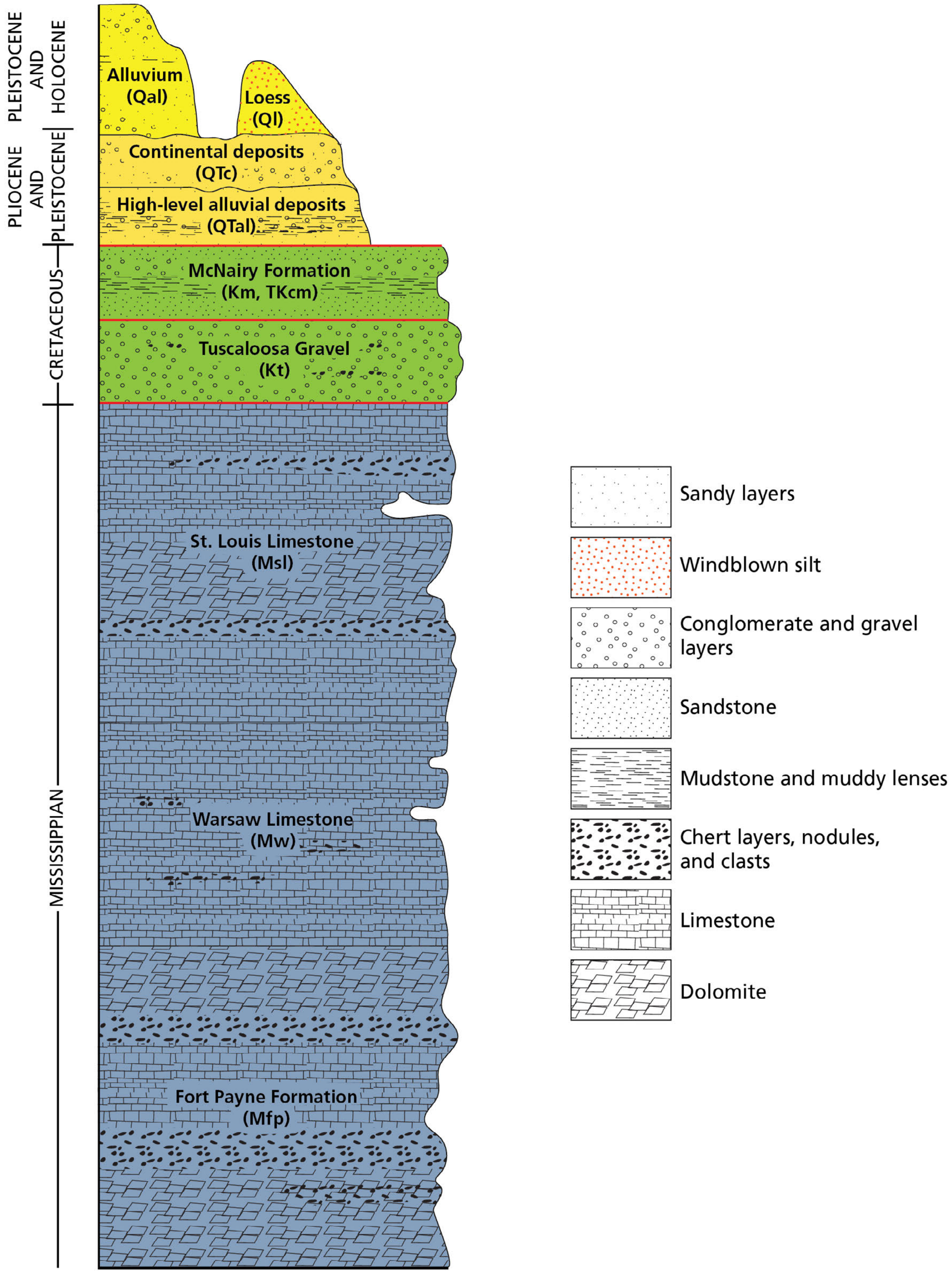
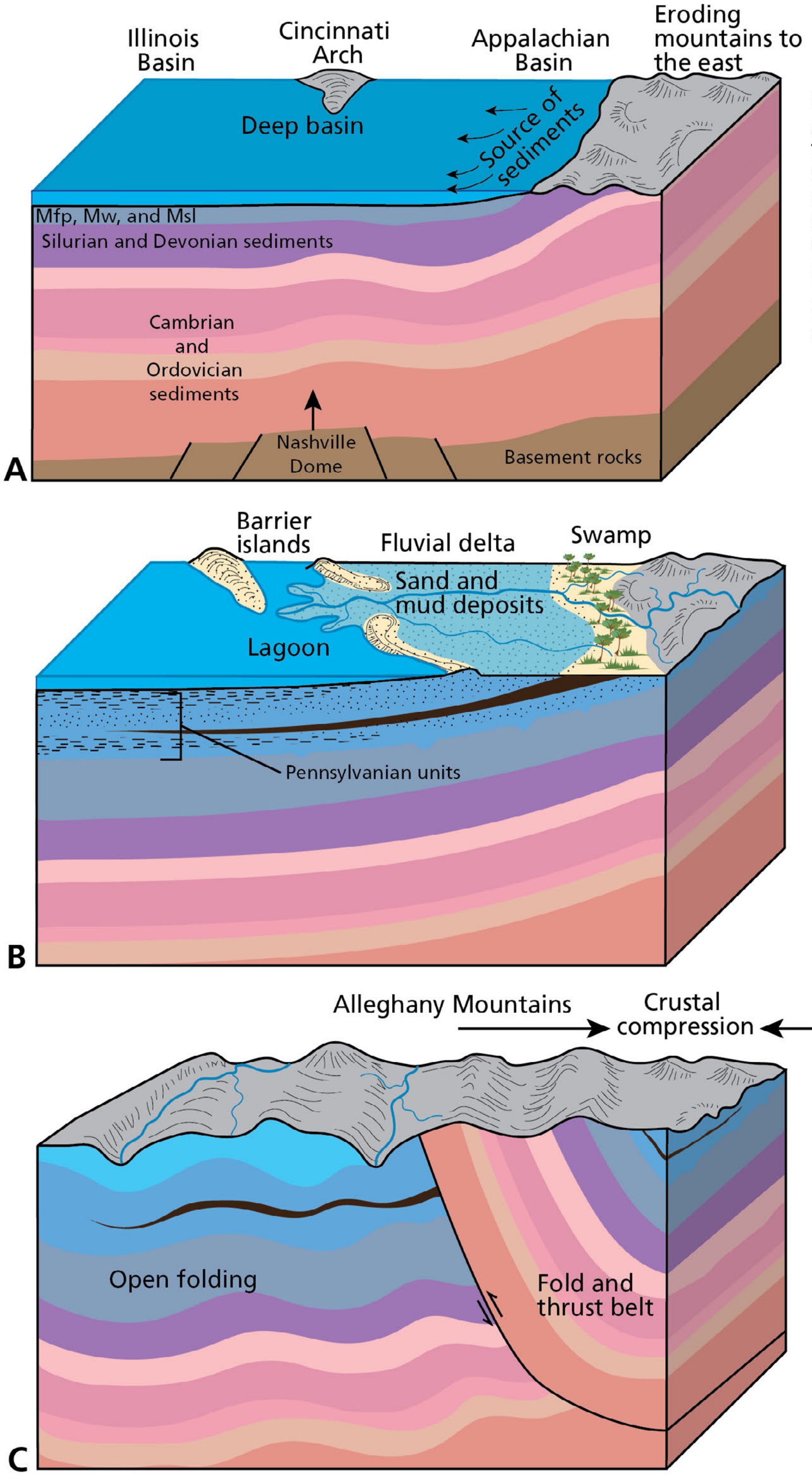


Figure 4. Stratigraphic section.
Mississippian sedimentary bedrock underlies more recent Cretaceous, Tertiary and Quaternary bedrock and surficial deposits. Periods of erosion or nondeposition (unconformities) appear as bold red lines. Vertical placement is representative of age only and not necessarily spatial proximity. Only units that are mapped within the preserve in the GRI GIS data are included. Unit colors are according to US Geological Survey standards for geologic time periods. Section is not to scale. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) with information from Marcher and Larson (1965), Marcher et al. (1965a), Marcher et al. (1965b), Blade (1966), Marcher et al. (1967), and Tyra (2002).



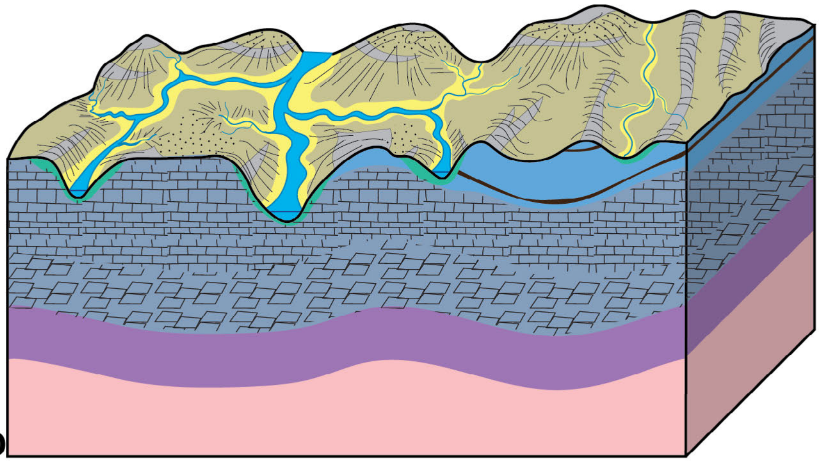
340 million years ago–the Acadian-Neoacadian Orogeny to the northeast provided source of sediment to the Appalachian and Illinois basins, which continued to subside and deepen. Quiet marine conditions dominated deposition of mixed sand, silt, mud, and carbonate Mississippian sediments in the park area.

*geologic map unit symbols included for units present in the park

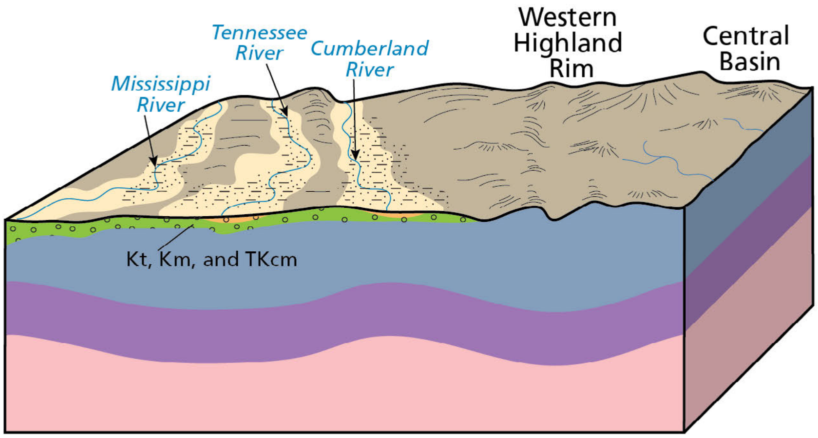
310 million years ago–the Alleghany Orogeny was beginning to uplift the Appalachian Mountains to the east causing folding and faulting in the Valley and Ridge province. Mixed fluvial and swamp depositional environments accumulated Pennsylvanian sands, silts, muds, and thick coal beds in the Appalachian Basin. Sea level was relatively low.

265 million years ago–the Alleghany Orogeny resulted in formation of **Pangaea and** extensive thrust faulting shoved older rocks atop younger rocks to the east. Faulting and folding formed long, linear ridges separated by narrow valleys to the east of the park. In the Appalachian and Illinois basins, deformation was limited to broad, open folds and very minor faulting. Rivers continued to cut through any Permian and Pennsylvanian sediments.

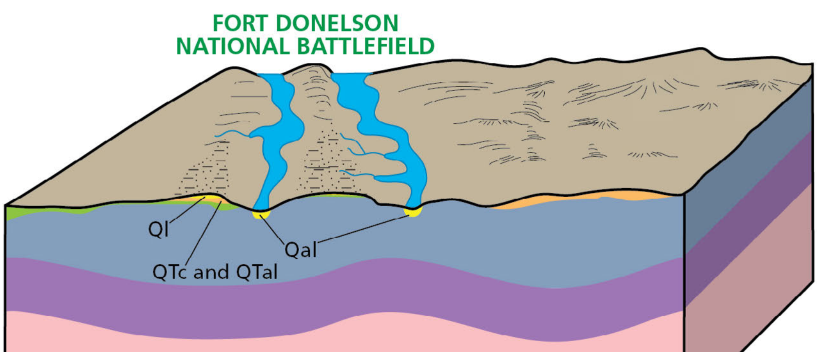
Figure 5A–C. Illustration of the evolution of the landscape and geologic foundation of Fort Donelson National Battlefield.
Continued on next page. Graphics are not to scale. Colors are standard colors approved by the US Geological Survey to indicate different time periods on geologic maps and correspond to the colors on the figures in this report. Map symbols are included for the geologic units mapped within the park. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University).

D


150 million years ago–
Pangaea rifted apart and the *Atlantic Ocean* opened. Erosion and weathering continued to wear away the Appalachian highlands. Residuum formed via deep weathering and slope deposits accumulated. Rivers and streams deposited terraces and reworked alluvium mixed with colluvium.

E


66 million years ago–
Deep weathering of all local bedrock continued into the Mississippian rocks. Fluvial conditions prevailed transporting sediments to the Mississippi embayment and depositing Cretaceous sedimentary rocks along the *Cumberland* and *Tennessee* river valleys.



Quaternary Period to present day–
The *Cumberland* and *Tennessee* rivers incised their current channels, cutting through older fluvial sediments and depositing alluvium along their courses. Windblow silt accumulated during post-glacial conditions. Weathering and erosion continued.

Figure 6D–F. Illustration of the evolution of the landscape and geologic foundation of Fort Donelson National Battlefield.
Continued from previous page. Graphics are not to scale. Colors are standard colors approved by the US Geological Survey to indicate different time periods on geologic maps and correspond to the colors on the figures in this report. Map symbols are included for the geologic units mapped within the park. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University).

Geologic Significance and Connections

The unusually well-preserved archeological, cultural, and *natural* resources offer an outstanding opportunity to research, protect, and interpret Fort Donelson as an example of a 19th century Civil War fortification. Additionally, the iron industry, railroads, rivers, and the Tennessee Valley's agricultural resources were vital aspects of the Civil War history that unfolded at Fort Donelson in 1862. The park's significance statements presented in National Park Service (2019a) capture the essence of the national battlefield's importance to the country's natural and cultural heritage:

- The well-preserved archeological, cultural, and natural resources offer outstanding opportunities to study, preserve, and interpret Forts Henry, Heiman, and Donelson as examples of early Civil War river fortifications.
- The first use of inland ironclad gunboats and the first joint Army/Navy operation in the Civil War occurred in the Campaign for Forts Henry, Heiman, and Donelson. These events provide insight into the evolution of naval technology and riverine tactics in the western theater of the Civil War.
- The Campaign for Forts Henry, Heiman, and Donelson resulted in the first major strategic Union victory in the Civil War under the leadership of General Ulysses S. Grant, via "unconditional surrender." The National Battlefield provides excellent opportunities for studying the successes and failures of tactics and leadership.
- The Union victories at Forts Henry, Heiman, and Donelson affected the outcome of the Civil War by thwarting a key Confederate strategy for the defense of the western theater. This resulted in the Federal Army gaining control of important resources such as the iron industry, railroads, rivers, and the Tennessee Valley's agricultural wealth.
- The presence of the Union Army at Forts Henry, Heiman, and Donelson encouraged enslaved African Americans to seek freedom through Union Army protection, leading to the establishment of Free State, one of the first freedmen's communities in Tennessee, and perhaps the nation.
- The Fort Donelson National Cemetery was one of the first national cemeteries and was established in 1867 as a burial ground for Union soldiers and sailors initially buried in the Fort Donelson area. The cemetery was established on a tract that included the majority of the old Union fort. The fort was leveled to accommodate the cemetery. Today, the Fort Donelson National Cemetery contains Civil War veterans as well as veterans who have served the United States since that time. Many spouses and dependent children are also buried there.

American Indians (Shawnee tribe) first used the rivers and trails in the Fort Donelson area. White-spotted "Dover chert" from the Fort Payne Formation (**Mfp**) was locally prized for making arrowheads and other implements. No known quarries for this material exist within park boundaries (Thornberry-Ehrlich 2009). Mapped exposures of **Mfp** occur just downstream from the Fort Donelson park unit and at the river's edge within the Fort Heiman park unit. Today, this chert is used locally as aggregate for road building.

European settlers scoured the area for natural resources. Iron-rich deposits occur throughout the area near the contact between the St. Louis Limestone (**Msl**) and the Warsaw Limestone (**Mw**). Limonite iron ore crops out within the Fort Donelson park unit. Around the time of the war of 1812, the Highland Rim area of Tennessee (see fig. 2), including Dover, had a great number of iron furnace operations contributing to the war effort—among the largest in the southern states (Thornberry-Ehrlich 2009). Regionally, remnants of these operations include mines, pits, and furnace sites.

Civil War Battle Connections

The history of the battle at Fort Donelson is covered by the 1950s and 1960s battle and resource history studies of Edwin C. Bearss, and in a number of publications such as Cooling (1987), Jobe (2012), Knight (2011), and Smith (2016), as well as cultural resource websites such as www.civilwar.org (accessed 11 September 2017) 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. Fort Donelson National Battlefield staff contributed to this historical narrative (written communication 13 April 2020).

The Tennessee and Cumberland rivers were major factors in the Civil War. Kentucky never joined the Confederacy and had issued a status of neutrality, and southern military leaders were forced to construct defensive positions along the border. The longitudinal Kentucky-Tennessee border is crossed by three major rivers—the Mississippi, Tennessee, and Cumberland (fig. 7). By late 1861, Confederates occupied Fort Donelson, perched on bluffs high above the Cumberland River, Fort Henry on the eastern shore of the Tennessee River, and were completing Fort Heiman on the western shore of the Tennessee River. Deeply weathered Mississippian bedrock capped by terrace gravels supported the uplifted, strategic topography at Fort Donelson. The steep, dissected terrain afforded commanding views over the adjacent floodplains and should have been a strategic location that was easily

Figure 7. Map of major rivers of Tennessee and Kentucky.
Fort Donelson National Battlefield (small, encircled red areas) is located in the narrow strip of land between the Cumberland and Tennessee rivers (highlighted blue). Confederate fortifications along the river borders between Tennessee and Kentucky were constructed to maintain control of the rivers and protect the heart of Tennessee. Fort Heiman was still under construction during the 1862 battle and abandoned prior to the Battle of Fort Henry. Union victory of the two rivers in addition to existing railroad lines gave direct access to points further south and ultimately cost the Confederacy the Mississippi River corridor. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University). Shaded relief base map courtesy of Tom Patterson (National Park Service).

defendable. Fort Henry meanwhile had earthen walls that were 6 m (20 ft) high and 6 m (20 ft) thick at the base. The local regolith and unconsolidated geologic units made for easy excavation and construction of earthworks, trenches, and batteries. Despite the significant Confederate fortifications and armament, and the commanding topography of Forts Donelson and Heiman, the Union command began planning to take the three forts and open a strategic water route into the heart of the Confederacy.

When troops under General Grant and Admiral Foote set out for the forts in early February 1862, winter rains had swollen the rivers. The rain made for soggy conditions for the Confederate forces under General Lloyd Tilghman at Forts Henry and Heiman, underlain by unconsolidated sediments and Cretaceous sandy layers. Where Fort Heiman was constructed atop a high bluff (137 m [450 ft] above sea level) across the river from and looking down on Fort Henry and the floodplain on which it set (<110 m [360 ft] above sea level), it remained unfinished and unarmed. Its small garrison was evacuated prior to the Union flotilla attack against Fort Henry. Fort Henry had been constructed on lower ground and was frequently flooded. The parade ground was submerged beneath less than one meter (2 ft) of water and gunpowder was damp. Troops were withdrawn from the incomplete walls of Fort Heiman, on slightly higher ground.

On 6 February 1862, the thick walls and defensive heavy guns of Fort Henry could not stand up to a barrage of Union gunboat shots from point-blank range of less than 300 m (330 yds). When Union command entered the surrendered fort by rowboat, they found the cannons mired in mud, much of the fort submerged (soon to be completely flooded by the Tennessee River), and the majority of the Confederate garrison already en route to reinforce Fort Donelson. With the Tennessee River now open to passage, in short order a raid by the Union flotilla proceeded as far upriver (south) as Muscle Shoals, Alabama, destroying infrastructure, and seizing supplies and weapons.

In the days that followed, General Grant's Union forces arranged themselves on the landward side of Fort Donelson, fronted by Confederate earthworks on ridges. This blocked a landward exit for the troops at the fort, isolating the fort on its ridge. The vast majority of Confederate troops were positioned along the 5 km (3 mi) outer defensive line of earthworks. Their army was between Hickman Creek to its right, and the Cumberland River on the left. Trapped, the Confederate troops were going to have to fight their way to freedom. The heavy guns looking over the Cumberland River overwhelmed the Union gunboats on 13 and 14 February, during significant bombardment. The higher position of the fort on the bluffs allowed the heavy guns to fire downward on the gunboats, causing serious damage to the unarmored upper decks of the vessels. The gunboats had to fire upwards and nearly always overshot the fort and river batteries. Confederate celebration was short lived, however.

On 15 February, the Confederates identified the need to abandon Fort Donelson. They initiated an early morning surprise break-out attack in order to push the Union line back counterclockwise for an escape. The attack was successful, crossing Dudley Hill and opening the intended line of escape. The charge pushed the federal line back almost 3 km (2 mi) before halting. However, instead of diverting the forces toward the road for escape, command was given to return to the outer defenses from where they had originated. General Grant, seeing the enemy slowly falling back, issued a counterattack to chase the recently exuberant Confederates back toward their lines. The Confederate retreat descended steep slopes and into eroded areas such as Erin Hollow, where the valley's topography channeled troop movements as avenues to return to the safety of their line.

At the same time on the opposite end of the battle, Union forces breeched the Confederate defenses, bringing a close to the fourth day of the battle and signaling that surrender was the only option. On 16 February 1862 an "unconditional and immediate surrender" of the Confederate force to General Ulysses S. Grant occurred, bringing an end to the Fort Henry, Heiman and Donelson Campaign. Confederate leaders agreed to unconditional surrender at Dover Hotel of more than 13,000 soldiers. The Union army now had control of the Tennessee and Cumberland rivers, and soon occupied Nashville, thereby providing them with a base and a river and rail network to support a huge influx of men and supplies necessary to defeat the Confederacy and preserve the Union.

In 1867 the Fort Donelson National Cemetery was established on the ridge between east of Indian Creek, on the site of the Union Fort Donelson. The brick "Meigs style" national cemetery lodge was completed in 1878. The lodge contains bricks (likely sourced from clays on the western shore of the Tennessee River), and limestone blocks, the exact source of which is unknown, but likely local. (Thornberry-Ehrlich 2009). The park administration building was constructed five years later of the same materials (Thornberry-Ehrlich 2009). River clay (part of **Qal**) supplied material to the Dover Brick Company as late as the 1930s (Thornberry-Ehrlich 2009). Fort Donelson National Military Park (later renamed National Battlefield) was established in 1928. In its development, limestone blocks were used for building material of the block walls at the river battery loop road, the Confederate Monument, and at the national cemetery. Not surprisingly, battle-era remnants and features factor heavily in the park's fundamental resources and values that warrant primary or special consideration in park planning efforts.

Geologic Connections with the Ecosystem

In addition to its influence on history, the geology at Fort Donelson provides the foundation for flora and fauna. Despite its small size, Fort Donelson National Battlefield preserves a diverse ecosystem.

Geology and geologic processes in part give rise to soils, which are covered in the soil resources inventory (https://irma.nps.gov/DataStore/Reference/Profile/1049322, accessed 26 September 2017). Soils form where geology and biology combine to produce a mixture of minerals, organic material, gases, liquids, and organisms. Soils support plants and animals. Species lists for Fort Donelson National Battlefield include 175 birds, 30 mammals, 11 fish, and 37 types of reptiles and amphibians (Sundin et al. 2013). At least 665 plant species occur within the park (White 2005); 1,275 distinct taxonomic classes are included on the park's vascular plants list (Sundin et al. 2013). Most of the park is covered in a forest of mixed deciduous hardwoods and some evergreens with at least 30 identified vegetation classes of which the mesic alkaline forest is most prevalent (White 2005; Jordan and Madden 2010). Climate change may also affect park vegetation by changing the kinds of plants that thrive there, and in turn affecting erosion and slope stability (Coe 2016). NPS digital vegetation maps for the Cumberland Piedmont Network are available from Jordan and Madden (2010) and at https://irma.nps.gov/Datastore/Reference/Profile/2166394.

Geology often also controls the location of wetlands. Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, fens, and similar areas (US Army Corps of Engineers 1987). Wetlands function to store surface water, discharge groundwater to streams, trap sediments, filter contaminants from water, provide wildlife habitat, and support wetland plants.

The National Wetland Inventory has no record of any wetlands within park boundaries (as of writing this report). The rugged terrain and karstic nature of the site preclude the presence of large wetlands. However, Roberts and Morgan (2006) located and characterized two wetlands at Fort Donelson totaling 0.01 ha (0.02 ac). One wetland is a palustrine, scrub-shrub wetland that is seasonally flooded. The other wetland is a palustrine, emergent wetland that is temporarily flooded. Both wetlands occupy depressions most likely man made (e.g., excavated or blocked drainage area). Both mapped wetland areas are underlain by weathered St. Louis Limestone (geologic map unit **Msl**) whose clay-rich residuum would act as an aquitard to precipitation percolating downwards. One wetland provides a notable breeding habitat for amphibians (Roberts and Morgan 2006).

Geologic Features, Processes, and Resource Management Issues

These geologic features and processes are significant to the park's landscape and history. 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.

Fundamental resources and values are those features, systems, processes, experiences, scenes, etc., determined to warrant primary consideration during planning and management because they are essential to achieving the purpose of the park and maintaining its significance. According to National Park Service (2019a), fortification systems, archeological sites, battlefield landscape and setting, historic roads and traces, core combat areas and troop positions within the park are among Fort Donelson National Battlefield's fundamental resources and values. These all have connections with the geologic features, processes, and issues at the battlefield. During the 2009 scoping meeting (see Thornberry-Ehrlich 2009), 2018 conference call, and follow-up with Fort Donelson National Battlefield staff, participants (see Appendix A) identified the following features, processes, and resource management issues. Each is discussed on table 2 in the context of relevant geologic map units. Background information, resources, and recommendations follow the table.

- Flooding
- Fluvial processes and features
- Windblown loess
- Upland weathering
- Historic resources
- Faults and seismicity
- Karst features
- Slope movements, hazards, and risks
- Abandoned mineral lands and disturbed lands
- Bedrock exposures
- Paleontological resource inventory, monitoring, and protection

Table 2. Geologic features, processes, and associated resource management issues in Fort Donelson National Battlefield.

Map Unit (symbol)	Features and Processes	Potential Resource Management Issues
Alluvium (**Qal**)	**Fluvial Features and Processes** **Qal** occurs in the Fort Donelson and Fort Heiman park units Faults **Qal** conceals two, down-to-the northwest normal faults in the Fort Heiman park unit.	**Flooding** **Qal** is greatly reworked during flood events. Deposits of **Qal** also may mark high-water lines in the geologic record.
Loess (**Ql**)	**Windblown Loess** **Ql** occurs in the Fort Heiman park unit. **Ql** underlies the uppermost elevations in the park. Loess is windblown silt derived from glacial erosion of sediment and bedrock.	**Slope movements, hazards, and risks** Unconsolidated units may be unstable on slopes, particularly in water-saturated conditions.
Continental deposits (**QTc**)	**Upland Weathering** **QTc** occurs in the Fort Heiman park unit.	**Slope movements, hazards, and risks** Unconsolidated units may be unstable on slopes, particularly in water-saturated conditions.
High-level alluvial deposits (**QTal**)	**Qtal** is not mapped within any park unit boundaries.	None reported.
Clayton and McNairy Formations, undivided (**TKcm**)	**TKcm** is not mapped within any park unit boundaries.	None reported.

Table 2, continued. Geologic features, processes, and associated resource management issues in Fort Donelson National Battlefield.

Map Unit (symbol)	Features and Processes	Potential Resource Management Issues
McNairy Formation (**Km**)	**Bedrock Exposures** **Km** crops out within the Fort Heiman park unit.	**Paleontological resource inventory, monitoring, and protection** Potential remains (found within **Km** elsewhere) include trace fossils (*Halyenites major* burrows) and microfossils.
Tuscaloosa Gravel (**Kt**)	**Bedrock Exposures** **Kt** crops out within the Fort Heiman park unit. **Faults** Two, down-to-the-northwest normal faults cut through **Mfp**, **Kt**, and **Mw** in the Fort Heiman park unit. **Kt** locally conceals the fault trace.	**Paleontological resource inventory, monitoring, and protection** Potential remains (found within **Kt** elsewhere) include clasts with fossil brachiopods derived from underlying Mississippian units and plant microfossils.
St. Louis Limestone (**Msl**)	**Karst Features** Carbonate units such as **Msl** are prone to dissolution producing features such as caves, sinkholes, and sinking streams (underground drainage). **Abandoned mineral lands and disturbed lands** The contact between **Msl** and **Mw** contains valuable iron ore that may have supplied an iron furnace operation in Dover around 1812. **Bedrock Exposures** **Msl** crops out within Fort Donelson park unit. **Paleontological resource inventory, monitoring, and protection** Within park boundaries are fossil remains of crinoids, echinoids, bryozoans, brachiopods, and algae. Potential remains (found within **Msl** elsewhere) include colonial coral *Lithostrotion canadense* and gastropods. A few crinoids are in the museum collection at the park, collected by park staff.	**Disturbed Lands and Abandoned Mineral Lands** An iron prospect occurs along the contact between **Msl** and **Mw** within the Fort Donelson park unit. Two other prospects are just east of the park boundary. **Paleontological resource inventory, monitoring, and protection** Fossils may be subject to theft or in situ collecting.

Table 2, continued. Geologic features, processes, and associated resource management issues in Fort Donelson National Battlefield.

Map Unit (symbol)	Features and Processes	Potential Resource Management Issues
Warsaw Limestone (**Mw**)	**Karst Features** Carbonate units such as **Mw** are prone to dissolution producing features such as caves, sinkholes, and sinking streams (underground drainage). **Abandoned mineral lands and disturbed lands** The contact between **Msl** and **Mw** contains valuable iron ore that may have supplied an iron furnace operation in Dover around 1812. **Bedrock Exposures** **Mw** crops out within the Fort Donelson and Fort Heiman park units. **Mw** crops out along a maintenance road within the Fort Donelson park unit and along the Cumberland River shoreline just beyond the park boundary near the lower river battery. **Faults** Two, down-to-the-northwest normal faults cut through **Mfp**, **Kt**, and **Mw** in the Fort Heiman park unit. Locally, the faults are geologic map unit contacts, separating **Mfp** and **Mw**. **Paleontological resource inventory, monitoring, and protection** Within park boundaries are crinoid fragments, horn corals, bryozoans, brachiopod shells, echinoid spines and plates, and "shell hash". Potential remains (found within **Mw** elsewhere) include trilobites. Quick field surveys by the Tennessee Division of Geology staff revealed the presence of crinoid segments, and "shell hash" (a mélange of broken chunks of brachiopods and bryozoans). Some coral fossils were exposed in a gully wash near the Confederate Monument within clasts of clayey, weathered chert.	**Disturbed Lands and Abandoned Mineral Lands** An iron prospect occurs along the contact between **Msl** and **Mw** within the Fort Donelson park unit. Two other prospects are just east of the park boundary. **Paleontological resource inventory, monitoring, and protection** Fossils may be subject to theft or in situ collecting.
Fort Payne Formation (**Mfp**)	**Karst Features** Carbonate units such as **Mfp** are prone to dissolution producing features such as caves, sinkholes, and sinking streams (underground drainage). **Mfp** is not as soluble as **Mw** or **Msl**. **Bedrock Exposures** **Mfp** crops out within the Fort Heiman park unit. **Faults** Two, down-to-the-northwest normal faults cut through **Mfp**, **Kt**, and **Mw** in the Fort Heiman park unit. Locally, the faults are geologic map unit contacts, separating **Mfp** and **Mw**. **Paleontological resource inventory, monitoring, and protection** Potential remains (found within **Mfp** elsewhere) include crinoids, bryozoans, corals, brachiopods, and trilobites.	**Disturbed Lands and Abandoned Mineral Lands** "Dover chert" from **Mfp** was quarried in the area; however known quarries are not within park boundaries. **Paleontological resource inventory, monitoring, and protection** Fossils may be subject to theft or in situ collecting.

Flooding

Floods are the primary geomorphological agents shaping the fluvial environment and have an important role in controlling the pattern of riparian vegetation along channels and floodplains. During high flows or floods, a river deposits natural levees of sand and silt along its banks. These deposits represent the relatively coarse-grained component of a river's suspended sediment load and form a high area on an alluvial region's land surface.

The Tennessee Valley Authority (TVA) initiated flood control activities in the region in the late 1930s, with the construction of a dam turning the historic Tennessee River into the impounded Kentucky Lake. A quarter of a century later the US Army Corps of Engineers (ACOE) completed construction of a dam on the lower Cumberland River, forming Lake Barkley. The completion of the dams led to a dramatic change to the flood cycle of both rivers (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, written communication, 13 April 2020). Flooding on the two big rivers was greatly reduced by the dams. The ACOE installed riprap along the Cumberland shoreline to stabilize the banks (fig. 8). Indian Creek periodically floods low-lying areas below Graves Battery (Thornberry-Ehrlich 2009).

Flooding and climate change

Large-scale flooding along the Cumberland and Tennessee rivers is mostly controlled by the dams impounding Lake Barkley and Kentucky Lake. The ACOE controls the water level and communicates their intentions with the park staff. A small levy built in the 1980s around the Dover Hotel was nearly breached in 2010–11 flooding. Within the main unit, batteries along the waterfront are regularly inundated, but do not seem to need stabilization. Extreme precipitation may still cause flooding and upland streams may overflow their banks.

Climate change predictions for northern 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, such as wetlands. According to Monahan and Fisichelli (2014), climatic conditions at Fort Donelson are already shifting beyond the historical variability range. Temperatures (mean temperature of the wettest quarter) are trending extreme warm. An increase in mean annual temperature (+1.8°C to 2.7°C [+3.2°F to 4.9°F] by 2050) and precipitation (+6% by 2050), increases in storm frequency and intensity, and increases in extreme heat events (>35°C [95°F]) projected for the region due to climate change could impact hydrology (Melillo et al. 2014). The following resources may provide further guidance and information for flooding and climate change:

- FEMA flood hazard mapping: http://www.fema.gov/national-flood-insurance-program-flood-hazard-mapping.
- NPS climate change response program strategy: https://www.nps.gov/orgs/ccrp/upload/NPS_CCRS.pdf.
- NPS ecosystem response to climate change predictions and climate change response program: go.nps.gov/climatechange.
- Tennessee's state wildlife action plan for climate change: Tennessee Wildlife Resources Agency (2009).
- Guidance from Monahan and Fisichelli (2014): (1) characterize park exposure to recent climate change in a vulnerability assessment, (2) develop plausible and divergent futures for use in a climate-change scenario planning workshop, (3) synthesize desired future conditions (i.e., reference conditions) for use in a Resource Stewardship Strategy or other National Park Service management plan, and (4) create interpretive materials for communicating with local communities and park visitors.
- 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.
- National Wetlands Inventory: https://www.fws.gov/wetlands/.
- NPS Water Resources Division: https://www.nps.gov/orgs/1439/index.htm.
- Water quality: Meiman (2005; 2009).

Fluvial Processes and Features

The Tennessee and Cumberland rivers and tributaries form the fluvial features at Fort Donelson National Battlefield. Fluvial features are those which are formed by flowing water. Fluvial processes both construct and erode landforms. Fluvial features occur on many scales in the park ranging from the large river valleys to small tributary valleys to the smallest streams. Examples of park's fluvial features include meandering river channels, point bars, floodplains, and terraces (see fig. 8). River channels are the perennial course of the flowing water. As a river flows around curves the flow velocity (and thus erosive energy) is greatest on the outside of the bend. The river erodes into its bank on the outside of a curve and leaves point bar deposits on the inside of the bend. Point bars are crescent-shaped ridges of sand, silt, and clay deposited on the inside of meander loops where the water's velocity is slowest. As the process continues, the outside bend retreats farther, while the inside bend migrates laterally, thus creating migrating meanders.

Fluvial issues

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 fluvial processes:

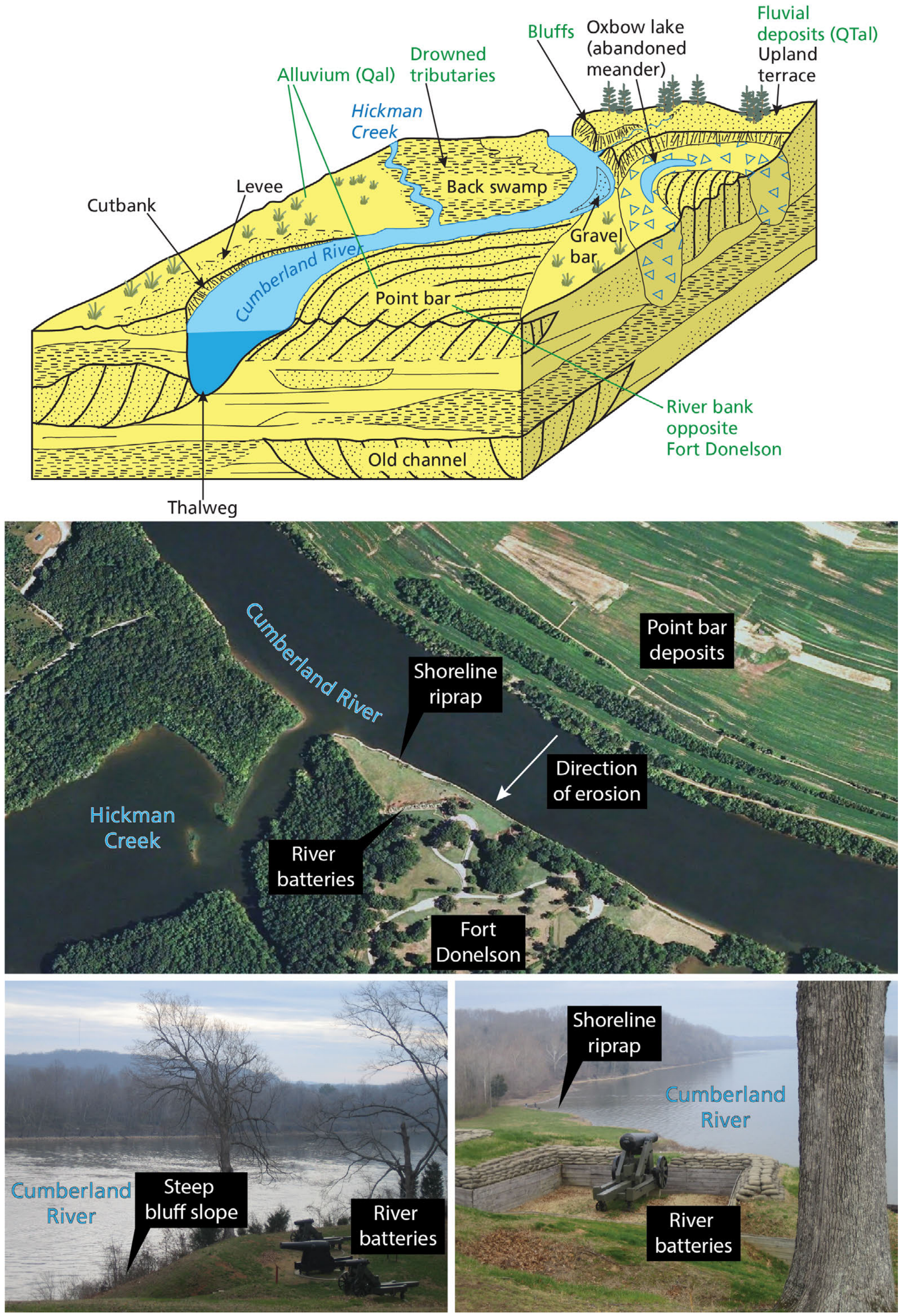


Figure 8. Block diagram and photographs of fluvial features along the Cumberland River. Many of the features presented on the schematic diagram occur along the lengths of the Tennessee and Cumberland rivers. Upstream dams have muted the force of flooding on the system, but the rivers continue to meander, eroding banks in some places and depositing alluvium in others. Riprap installed below Fort Donelson helps protect the shoreline and cultural resources from natural erosion. Graphic by Trista Thornberry-Ehrlich (Colorado State University) using GRI GIS data with a basemap by ESRI World Imagery basemap (accessed 7 February 2017). Photographs by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.

- Technical assistance NPS Water Resources Division: https://www.nps.gov/orgs/1439/index.htm.
- Water quality data briefs (monitoring at Indian Creek near Graves Battery, Indian Creek embayment, Hickman Creek embayment, Hickman Spring, and the Cumberland River; Sundin et al. 2013): https://www.nps.gov/im/cupn/reports-publications.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 .
- History of the Tennessee River: Miller (2014).
- GRI GIS data: https://irma.nps.gov/DataStore/Reference/Profile/1049322.

Windblown Loess.

Loess is a fine-grained sediment formed by the accumulation of wind-blown, winnowed silt (fig. 9). Loess tends to be very homogenous with 20% or less clay and some sand grains that are loosely cemented by calcium carbonate. Map unit descriptions from Kentucky indicate that dark brown iron oxide nodules are present in local loess (Matt Crawford, Kentucky Geological Survey, geologist, written communication, 10 March 2020). Where loess is somewhat cemented, exposures may fracture and form steep bluffs. Loess covers about 10% of Earth's surface (Vasiljevic et al. 2011). At Fort Donelson National Battlefield, loess caps the highest hills in the Fort Heiman park unit overlying continental deposits. Loess deposition was widespread after Pleistocene glaciations when there was no vegetation to impede sweeping winds and available glacial deposits were abundant.

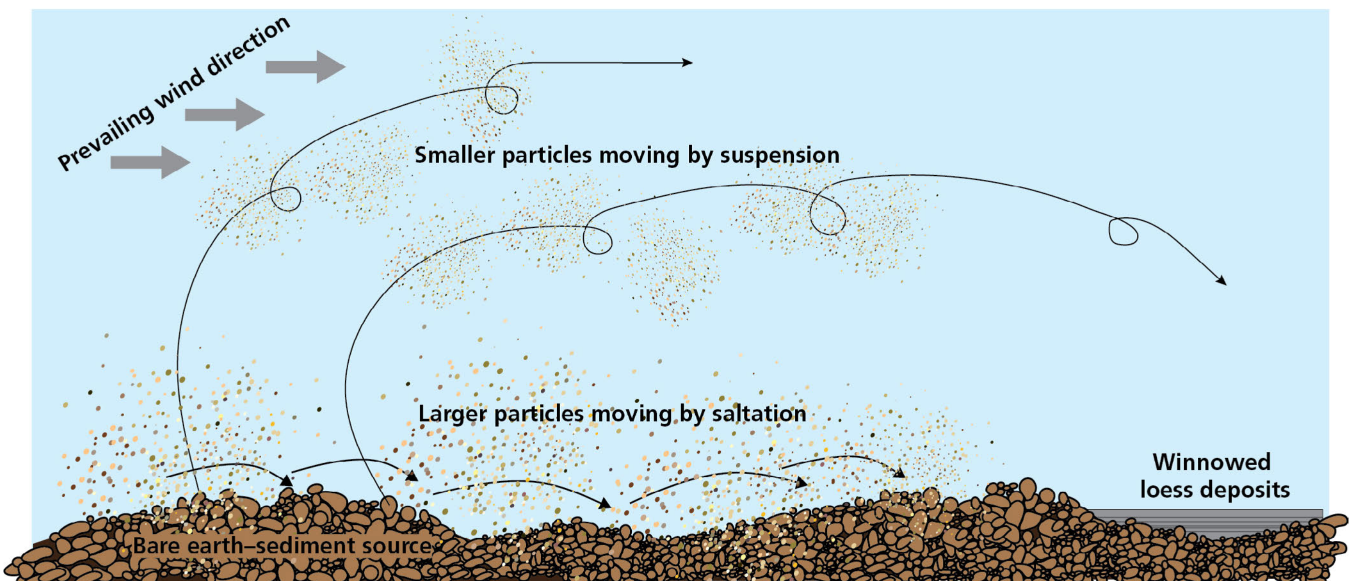


Figure 9. Diagram showing loess formation.
Windblown loess accumulated at the end of land-clearing events (e.g., glaciations) before land plants reestablished. Wind swept across barren landscapes, picking up the smallest particles, transporting them, and dumping them in deposits that blanketed entire landforms. Loess (geologic map unit Ql) occurs on the highest reaches of the Fort Heiman park unit at Fort Donelson National Battlefield. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University).

Upland Weathering

Weathering and erosion are longstanding processes at work on the Fort Donelson National Battlefield landscape. Bedrock is deeply weathered. Some outcrops are so "rotten" a person can plunge their hand into the rock (Ron Zurawski, Tennessee Division of Geology, geologist, conference call, 16 April 2018). Bedrock in the park is locally mantled by surficial deposits including terrace gravel veneers deposited by the Cumberland and Tennessee rivers. Unconsolidated surficial deposits are testament to this ongoing process as the bedrock breaks down to form regolith and eventually combine with organic elements to make soils. At Fort Donelson, cultural resources such as earthworks are at risk of diminishment by weathering and erosion.

Figure 10. Photographs of eroding earthworks.
The earthworks are among the most historically significant resources at Fort Donelson National Battlefield. Natural erosion, and human-induced erosion (e.g., climbing and social trail use) are denuding the earthworks. The depressions shown are historic "trenches" behind the earthwork. The trenches are filling up with sediment. On hills, such as the central line of the outer works, the steep slopes serve like a fast moving, down-hill rain gutter, eroding the earthwork, as well as eroding the historic trench or filling it with sediment. Restoration attempts (e.g., replacing sod) have been of mixed success. In 2018–2019 Youth Conservation Corps youth reconstructed check-dams to slow the water flow (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, written communication, 13 April 2020). Photographs by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.

Historic Resources

Fortification systems, including Fort Donelson and the waterfront artillery batteries, archeological sites, battlefield landscape and setting, and historic roads and traces are among the park's fundamental resources and values (National Park Service 2019a). Three km (two mi) of outer defense earthworks and 460 m (1,500 ft) of fort walls surrounding 6 ha (15 ac) at Fort Donelson, in addition to existing earthworks at uncompleted Fort Heiman, are primary cultural features at the park (fig. 10). Restored and maintained lower and upper riverfront batteries allow visitors to visualize the land-water battle. Archeological sites included within park boundaries are ammunition/powder magazines, communication trenches, tent pads, cabin sites, and gravesites. Local topography, terrain, location, and rivers were important to the military story at Fort Donelson.

Preserving the Historic Context

Historic context is at risk of degradation and/or loss by Earth surface processes such as erosion, sediment accumulation in trenches, animals burrowing, and tree blow downs, as well as anthropogenic use, including foot traffic. Resource managers have attempted to stem earthwork erosion by installing sod on earthworks. This has had limited success (see fig. 10; Thornberry-Ehrlich 2009). The park's management goal is to continue improving the earthworks' condition and stabilize eroding features (see fig. 10). Historic roads and road traces need to be identified, maintained, and interpreted. External disturbed lands and potential development needs to be monitored. Among the National Park Service's (2019a) recommendations for historic preservation were the following actions:

- Complete an earthworks preservation and treatment plan (listed as a high priority need),
- Use LiDAR surveys to analyze landscape for potential archeological resources (listed as a low priority need),
- Prepare a cultural landscape inventory and report for entire park, except Fort Heiman (listed as a high priority need),
- Area-specific hydrology and erosion studies (listed as a low priority need),
- Photo-point monitoring (listed as a medium priority need), and
- Climate change vulnerability assessment (listed as a medium priority need).

Faults

A fault is a fracture in rock along which movement has occurred and are indicative of stress and tectonic forces. Faults occur where rocks have been compressed, stretched, sheared, or fractured; movement along faults is sometimes accompanied by an earthquake. Faults are defined by the direction of movement along the fracture as normal faults, reverse faults, and strike-slip faults (fig. 11). Fault traces are in the GRI GIS data as a layer (see table 4 in the Geologic Map Data chapter). These faults are likely not active (Matt Crawford, Kentucky Geological Survey, geologist, written communication, 10 March 2020), but may have formed as Earth's crust was deforming during the construction of the Appalachian Mountains to the east and in response to the heavy pile of sediments accumulating in the Appalachian Basin.

Seismicity

The risk of earthquakes at Fort Donelson is moderate due to its proximity to the New Madrid seismic zone in western Tennessee (fig. 12). This region experienced major earthquakes during 1811–1812 and earlier due to tectonic stress along deeply buried faults in Earth's crust. The zone is a source of continuing small and moderate earthquakes indicating that the processes that produced the largest earthquakes are still active. Eyewitnesses on the Cumberland River during the New Madrid events reported strong waves on the river, overturning boats (Ron Zurawski, Tennessee Division of Geology, geologist, conference call, 16 April 2018). A repeat event could produce lateral spreading, ground subsidence, and liquefaction in areas as far away as northeastern Arkansas, southeastern Missouri, western Tennessee and Kentucky, and southern Illinois (Frankel et al. 2009; Ron Zurawski, Tennessee Division of Geology, geologist, conference call, 16 April 2018). 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 the past century, many magnitude >2.5 earthquakes have occurred near Fort Donelson National Battlefield (fig. 12). Strong seismic shaking could damage park infrastructure including buildings, roads, trails, monuments, and bridges.

Although the park is not considered to be at high risk of strong earthquakes, seismicity could impact park resources. In particular, liquefaction (destabilization of unconsolidated, water-saturated sediments during earthquakes) of **Qal**, **Ql**, and **QTc**, and areas of steep slope could threaten infrastructure and cultural resources. The following are useful resources for park awareness of earthquake hazards:

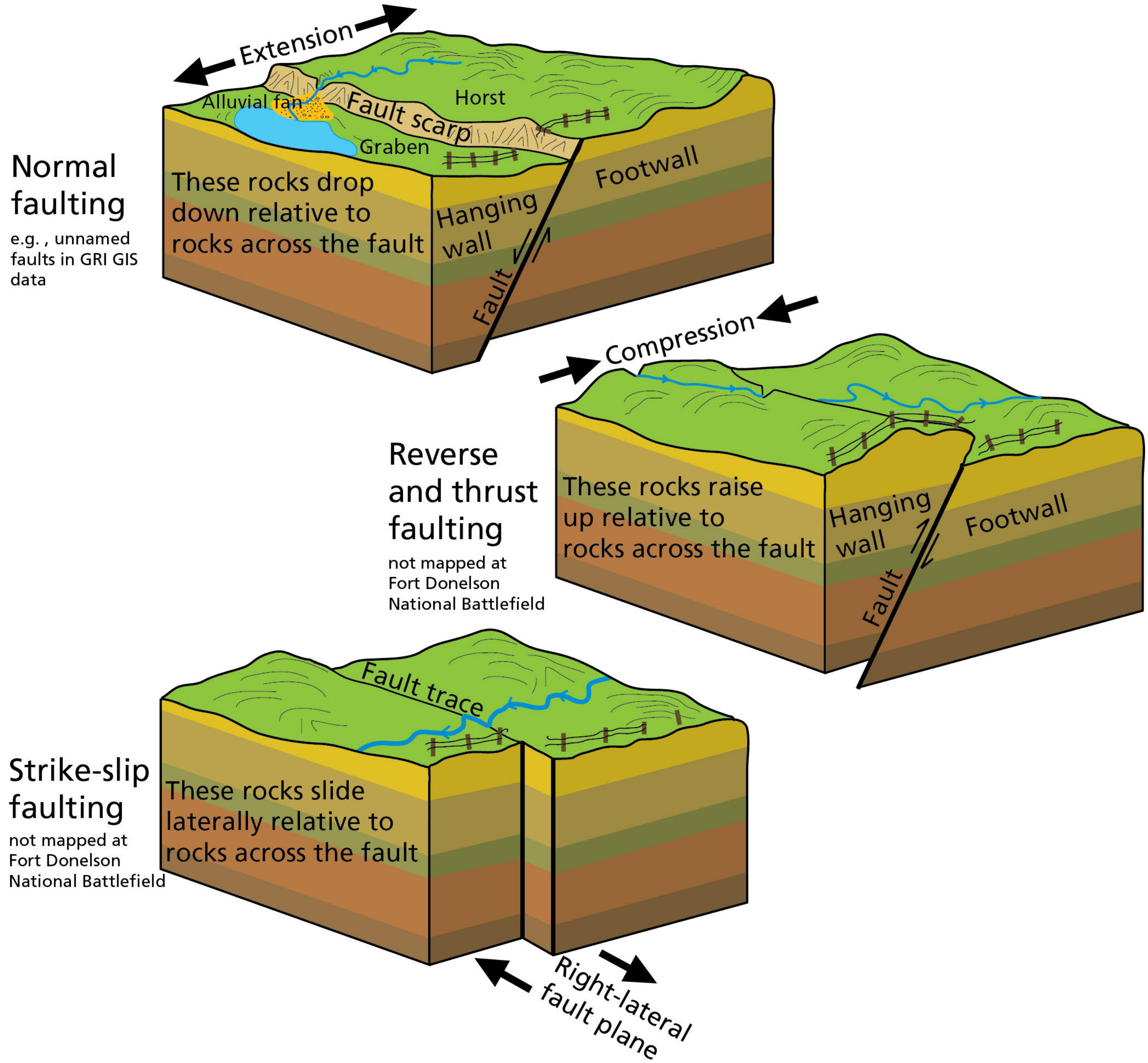


Figure 11. Diagram of fault types.
Faults are part of the GRI GIS data; only normal fault types are mapped in the GRI GIS data with other fault segments mapped as unknown offset/displacement. Faults accommodated deformation in the bedrock. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University).

- US Geological Survey Earthquakes Hazards website: http://earthquake.usgs.gov/.
- US Geological Survey New Madrid seismic zone fact sheet, Frankel et al. (2009): https://pubs.usgs.gov/fs/2009/3071/.
- Seismic hazard maps: Petersen et al. (2008).
- Monitoring seismicity: Braile (2009).
- GRI GIS data: https://irma.nps.gov/DataStore/Reference/Profile/1049322.

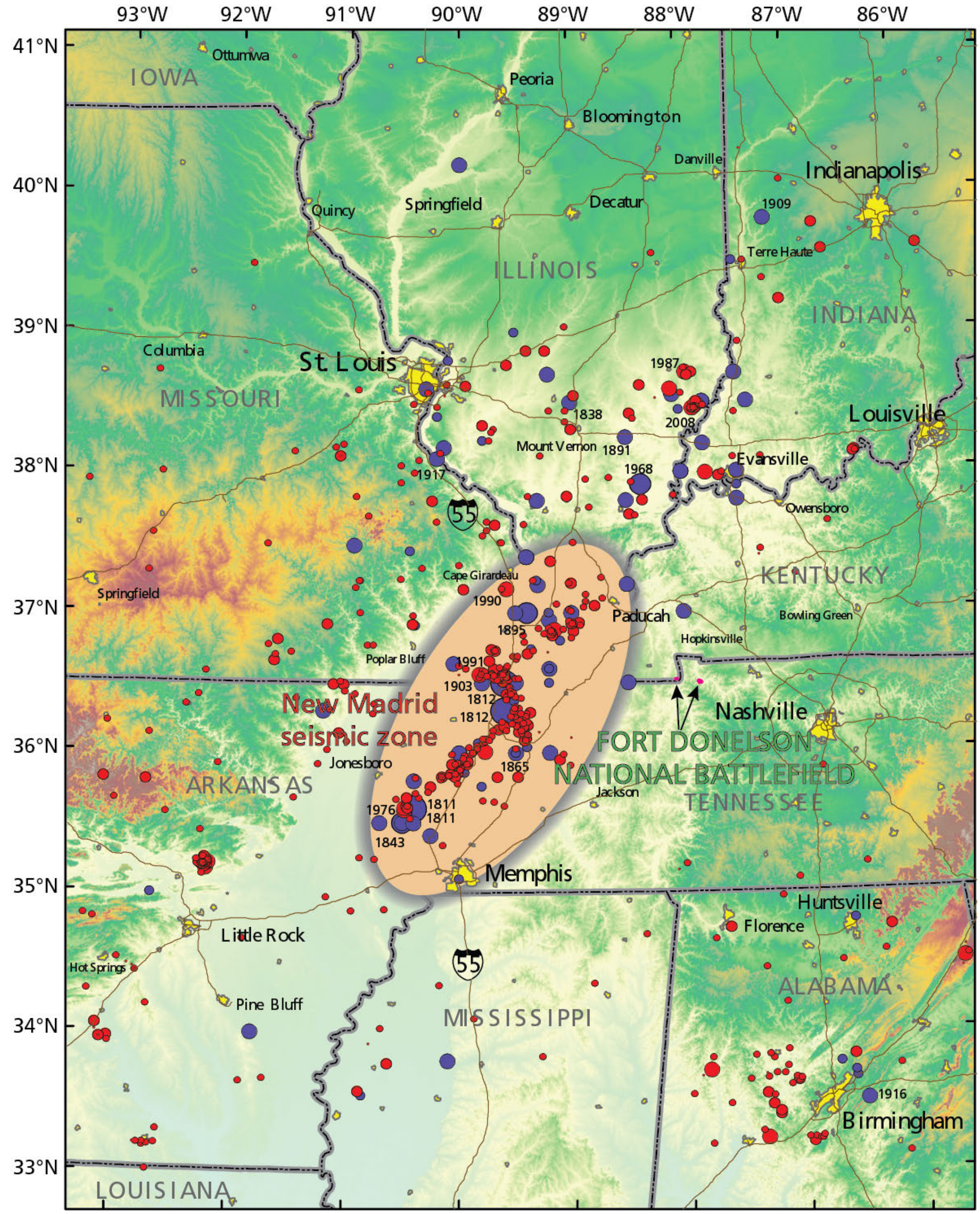


Figure 12. Topographic map showing earthquake centers in the central United States.
The New Madrid seismic zone is the central, ovoid orange area. Red circles are earthquake epicenters that occurred after 1972. Larger earthquakes are represented by larger circles. Minimum magnitude is 2.5. Note the proximity to Fort Donelson National Battlefield (small pink areas with black arrows). Graphic is an unnumbered figure presented by Frankel et al. (2009) modified by Trista L. Thornberry-Ehrlich (Colorado State University).

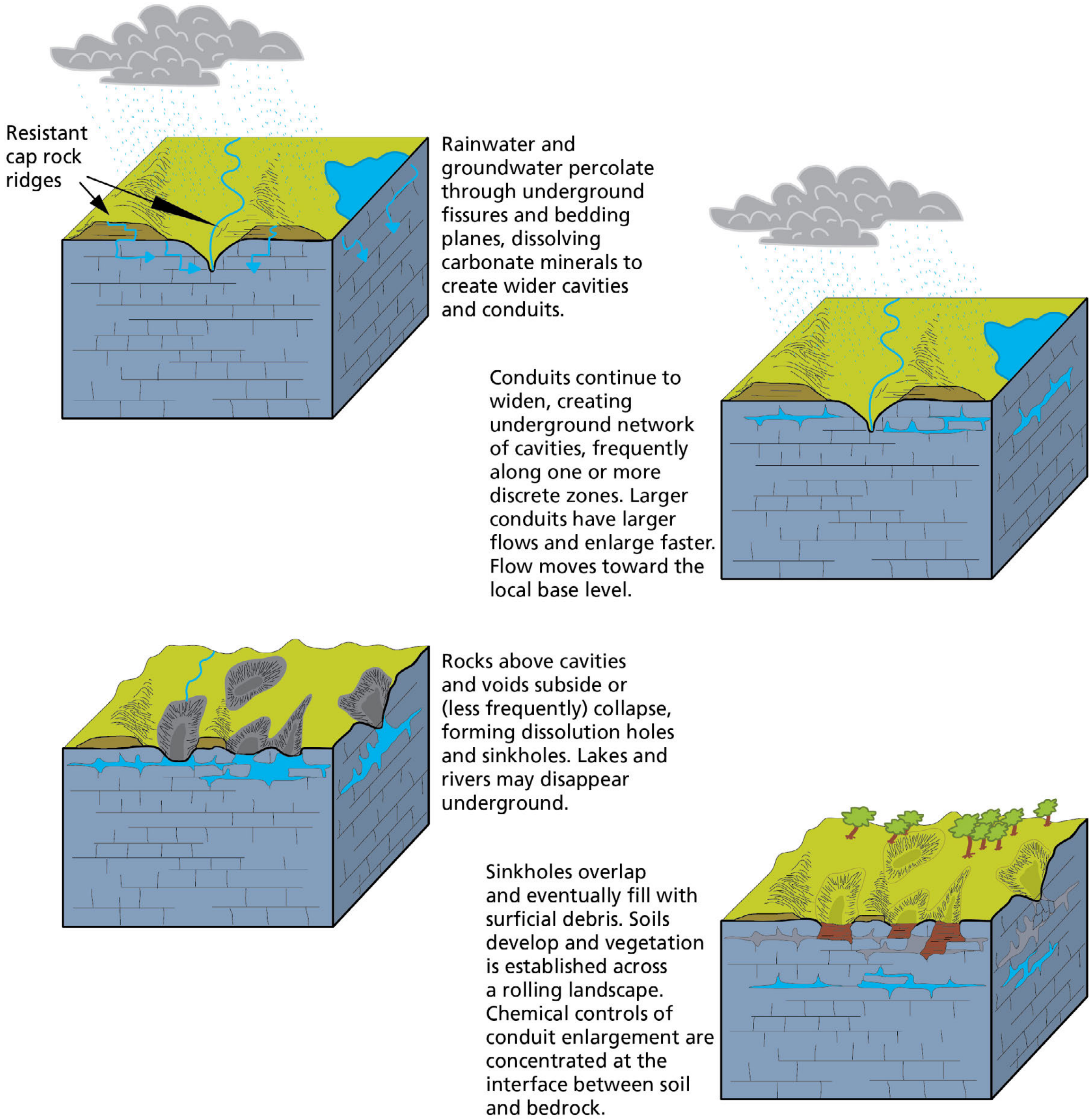


Figure 13. Three-dimensional illustration of karst landscape formation.
Resistant cap rocks such as sandstone layers are largely lacking in the park area, so the possibility of major karst-feature (such as a long cave) development is slim, but the likelihood of mature karst development is greater. A solution cave, spring, and other small-scale karst occurs at Fort Donelson National Battlefield. Karst landscapes continue to develop today in the Mississippian dolomite and limestone (geologic map units Mfp, Mw, and Msl). Graphic by Trista L. Thornberry-Ehrlich (Colorado State University), created using information from Hack (1974).

Karst Features

Karst is a landscape that forms through the dissolution of soluble rock, most commonly carbonates such as limestone or dolomite. Caves, dolines (sinkholes), disappearing streams, and springs are characteristic features of karst landscapes (fig. 13; Toomey 2009). Cave and karst features require four geologic conditions to form: soluble rocks; flowing groundwater (as a solvent); hydrogeologic framework (hydraulic gradient); and time. Cave features are non-renewable resources. Caves are ecologically fragile environments with features that are easily disturbed (Matt Crawford, Kentucky Geological Survey, geologist, written communication, 10 March 2020). All caves on NPS lands are considered significant. As of September 2017, cave and/or karst resources are documented in 159 NPS areas, including Fort Donelson National Battlefield, which has at least one solution cave and other “less significant” karst.

Newly acquired land near Dudley Hill contains a sinkhole within a wooded area. The sinkhole is a large depression in the ground with a drain hole that is less than 1 m (3 ft) in diameter. The sides of the sinkhole are steep, muddy, and dangerous (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call, 16 April 2018). According to Land et al. (2013), 91% of the park area is karst. Hickman Spring on the Circle Loop Trail is another karst feature in the park (Thornberry-Ehrlich 2009). North of the park, the St. Louis Limestone and Warsaw Limestone (**Msl** and **Mw**, respectively) contain considerable karst features (e.g., Mammoth Cave National Park; see Thornberry-Ehrlich 2011). Collier Cave is located just east of the Fort Donelson park unit (Marcher et al. 1965a).

Karst Issues

The karst features in the park may serve to funnel precipitation and contaminants quickly into local rivers. The potential for the development of more karst features in the park is high, particularly in the Warsaw and St. Louis limestones (geologic map units **Mw** and **Msl**, respectively). Hazards associated with karst features include sinkhole flooding, sinkhole collapse, cave instability, and exposure to radon in caves.

The following resources may provide further guidance for karst management:

- National Cave and Karst Research Institute: http://www.nckri.org/.
- NPS Geologic Resources Division Cave and Karst Resources website: https://www.nps.gov/subjects/caves/index.htm
- In the Geological Monitoring chapter about caves and associated landscapes, Toomey (2009) described methods for inventorying and monitoring cave-related vital signs, including the following: (1) cave meteorology, such as microclimate and air composition; (2) airborne sedimentation, including dust and lint; (3) direct visitor impacts, such as breakage of cave formations, trail use in caves, graffiti, and artificial cave lighting; (4) permanent or seasonal ice; (5) cave drip and pool water, including drip locations, rate, volume, and water chemistry, pool microbiology, and temperature; (6) cave microbiology; (7) stability issues associated with breakdown, rockfall, and partings; (8) mineral growth of speleothems, such as stalagmites and stalactites; (9) surface expressions and processes that link the surface and the cave environment, including springs, sinkholes, and cracks; (10) regional groundwater levels and quantity; and (11) fluvial processes, including underground streams and rivers.
- Cave and karst general information: Palmer (2007) and White (1988).
- GRI GIS data: https://irma.nps.gov/DataStore/Reference/Profile/1049322.

Slope Movements, Hazards, and Risks

Slope movements, also called "mass movements" or referred to generally as "landslides" are the downslope movement of soil, rock, or some combination of both (fig. 14). Slope movements have occurred and will continue to occur in the park. Although most landslides are not without some human-induced modification, gravitational forces and natural geologic and geomorphic characteristics with associated rainfall are the root of slope movement in the park area. Slope modification and increases in pore water pressure from rainfall can impose stresses on a slope whereby the shear strength of the soil will be exceeded, causing movement (Matt Crawford, Kentucky Geological Survey, geologist, written communication, 10 March 2020). Slope movements can occur very rapidly (e.g., debris flows or rockfall) or over long periods of time (e.g., slope creep or slumps). The magnitude of slope failures depends on slope, aspect, soil type, and geology. Within the park, most of the landscape is moderate to steep slopes; however, the slopes are heavily vegetated making slope movements such as slumps less likely. Historically, the occupying army cleared the landscape of large trees to obtain lumber for building shelters (fig. 15) and defensive obstacles. The park has no plans to remove trees to restore historic landscape conditions beyond keeping the view of the Cumberland River unobstructed (Thornberry-Ehrlich 2009). Just outside the park boundaries, a neighboring landowner cut into the hillside, creating a nearly vertical face which weathers off in large sections (fig. 16). This area of Dellrose soil (clayey soil as defined by the US Department of Agriculture) is now approaching the park (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call, 16 April 2018).

Slope Management

Slope movements are natural processes; they pose a risk and become hazards when visitors are exposed to potentially unstable slopes (hiking near the base of steep slopes or under rock overhangs, for example). Particularly hazardous areas are those with visible cracks, loose material (e.g., **Ql** or **QTc**), or overhangs. Slope movements also impact infrastructure such as trails, roads, parking lots, and other facilities. Many natural factors contribute to slope movements and instability such as pore-water pressure increase, frost weathering, plant-root wedging, streambank erosion, and differential erosion. Areas with

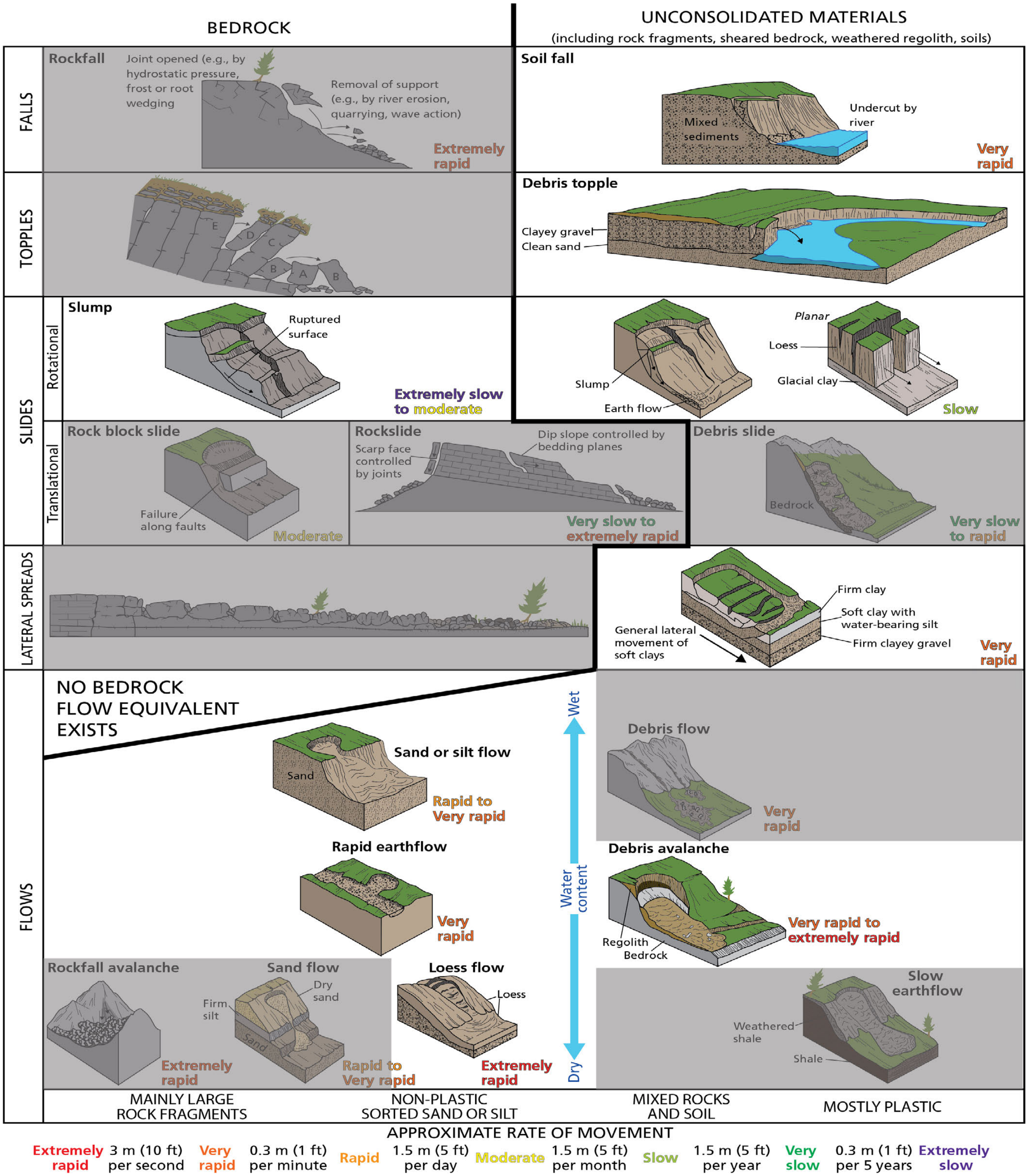


Figure 14. Schematic illustrations of slope movements.
Different categories of slope movement are defined by material type, nature of the movement, rate of movement, and moisture content. Grayed areas depict conditions unlikely to exist at Fort Donelson National Battlefield. The abundant vegetation in the park stabilizes many slopes, but active slides are possible on slopes undercut by erosion or water saturated. 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).

denuded or disturbed vegetation are susceptible to increased erosion which can reduce slope stability. Human activities may also trigger slope movements. Undercutting the toe of slopes for residential development, roads, or railroads may cause slope failure.

Figure 15. Photograph of a typical battlefield shelter.
Vast swaths of forest were cleared to construct cabins and shelters such as this recreated example. Most of the chimneys were likely log or wicker basket types. Some local stones were used for chimneys of the area; an abandoned quarry is west of the present-day park (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, written communication, 13 April 2020). Cleared forests caused increased erosion and sedimentation into adjacent waterways. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University) taken in spring 2009.

The park submitted a technical assistance request for some local landslide areas. According to the Geologic Resources Division landslide specialist (contact: Eric Bilderback), the local bedrock map shows only limestone mapped, but the presence of thick residual soils and deeply weathered bedrock is not included on the map and changes the reality of slope movement potential. According to geologists with the Kentucky Geological Survey and Tennessee Division of Geology, the bedrock is deeply weathered at Fort Donelson, but varies in extent from 1–2 m (3-6 ft) to 10s of meters deep. Spatial knowledge of this depth to solid bedrock is vital for slope management at the park (GRI conference call participants, conference call, 16 April 2018).

The following resources may provide further guidance for slope movement (see fig. 14) management:

- Wieczorek and Snyder (2009) for slope movement monitoring.
- Highland and Bobrowsky (2008) presented a landslides guide.
- Landslides and Your Property, Potter et al., (2013), https://kgs.uky.edu/kgsweb/olops/pub/kgs/LandslidesBrochure.pdf.
- Kentucky Geological Survey Landslide Inventory: From Design to Application, Crawford (2014), https://kgs.uky.edu/kgsweb/olops/pub/kgs/IC31_12.pdf.
- Natural hazards science by Holmes et al. (2013).
- Slope movement hazards and climate change: Coe (2016).
- The US Geological Survey landslides website: http://landslides.usgs.gov/.
- GRD Slope Movement Monitoring https://go.nps.gov/geomonitoring.
- GRI GIS data: https://irma.nps.gov/DataStore/Reference/Profile/1049322.

Figure 16. Photographs of a headscarp encroaching on the park boundary.
A developer excavated into the lower slope of a hillside, destabilizing the slope, and resulting in erosion encroaching on the park boundary and key park resources. A site visit from an NPS geomorphologist to assess stability and potential impacts to park resources was scheduled for spring 2020 but postponed indefinitely due to the COVID-19 pandemic. Top photograph was taken 19 February 2016 and bottom photograph was taken almost a year later, on 23 January 2017. NPS photographs.

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. AML features are also those 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. Although there are no AML features from Fort Donelson National Battlefield documented in the NPS AML database as of September 2017 (Burghardt et al. 2014); some small limestone quarries to the south of the battlefield exist. Limonite iron ore occurs within the park. In the greater Land Between the Lakes area iron-rich deposits concentrate near the contact between the St. Louis Limestone (**Msl**) and the Warsaw Limestone (**Mw**).

Adjacent development continues to threaten the cultural and natural features at the park. Demand for local private land is high and the park essentially surrounds the Dover community (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call 16 April 2018). At the national cemetery, an adjacent housing development dominates the northeastern viewshed. Originally, the War department acquired lands for the military park to include only the Confederate Fort Donelson and the extensive outer earthworks. Most of combat or other significant areas were left to later additions made in the 1960s, 1980s, and early 2000s (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, written communication, 13 April 2020). Largely because of the 2004 Fort Donelson National Battlefield Expansion Act, the park nearly surrounds the Town of Dover, which alters the battle-era appearance. Much of the land now within the park was once subject to logging, grazing, and agriculture. These activities likely degraded some elements of historic landscape features. Hog rooting has occurred on recently acquired land, disturbing the surface (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call, 16 April 2018). The American Battlefield Trust organization continues to work with Fort Donelson, in consideration of buffering tracts of land around the park units including Union troop positions and breakout areas.

Abandoned Mineral Lands Management

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 Fort Donelson National Battlefield. 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.

Sundin et al. (2013) discussed landcover and its impacts on the park's ecology. Road density, population, housing, and impervious surfaces were among the parameters measured to determine disturbed/developed levels. Landcover development was such that some impervious surfaces may impact park geomorphology and some earthworks. Roads dissect the park's landscape. Landscape resources are increasingly under pressure from adjacent population growth and development.

Bedrock Exposures

Bedrock is the solid, very old rock that underlies the younger unconsolidated surficial deposits of the park. Here, bedrock was exposed to millennia of weathering and is not well exposed. Bedrock can be sedimentary, igneous, or metamorphic. Sedimentary rocks form from fragments of other rocks or chemical precipitation. Igneous rocks form by the cooling of molten material. Metamorphic rocks are those that have been altered by high temperature, high pressure, and/or fluids. All the bedrock in the park is sedimentary (tables 1 and 3) and was primarily deposited in marine, nearshore, or terrestrial settings (see "Geologic Setting, History, and Significance"). Mississippian sedimentary rocks within the park are primarily carbonate rocks such as limestone and dolomite with abundant chert layers and nodules. Along the north side of the national cemetery, a series of deeply weathered outcrops topped with gravely soil were once referenced by the Smithsonian Institution in the latter half of the nineteenth century as possible Native American burials under the rocky outcroppings. Today, these are presumed to be geologic features north of the national cemetery (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call, 16 April 2018). At Fort Heiman, along the river, bedrock appears as a nearly vertical rock face or bluff to the river (William Andrews, Kentucky Geological Survey, geologist, conference call 16 April 2018). The Cretaceous units are clastic sedimentary rocks that are the products of weathering, erosion,

Table 3. Sedimentary rock classification and characteristics.

Claystones and siltstones can also be called “mudstone,” or if they break into thin layers, “shale." Carbonate classification is based on Dunham’s textural classification scheme (Dunham 1962).

Rock Type	Rock Name	Texture and Process of Formation	Fort Donelson geologic map unit examples
INORGANIC CLASTIC SEDIMENTARY ROCKS	Conglomerate (rounded clasts) and Breccia (angular clasts)	Cementation of clasts >2 mm (0.08 in) in size. Higher energy environment (e.g. rivers).	Conglomerate: **Kt**, **QTc** Breccia: none identified in mapping
	Sandstone	Cementation of clasts 1/16–2 mm (0.0025–0.08 in) in size.	**Km**, **TKcm**, **QTal**
	Siltstone	Cementation of clasts 1/256–1/16 mm (0.00015–0.0025 in) in size.	**Ql**
	Claystone	Cementation of clasts <1/256 mm (0.00015 in) in size. Lower energy environment (e.g. floodplains).	**Km**, **TKcm**, **QTal**
CARBONATE CLASTIC SEDIMENTARY ROCKS	Fossiliferous Limestone	Generic name for carbonate rock containing fossils.	**Mfp**, **Mw**, **Msl**
	Boundstone	Fossils, fossil fragments, or carbonate mud fragments cemented together during deposition (e. g. reefs).	None identified in mapping
	Grainstone	Grain (e.g., fossil fragments) supported with no carbonate mud. High energy environment. Components cemented together following deposition.	None identified in mapping
	Packstone	Grain (e.g., fossil fragments) supported with some carbonate mud. Lower energy than grainstone. Components cemented together following deposition.	None identified in mapping
	Wackestone	Carbonate mud supported with more than 10% grains and less than 90% carbonate mud. Lower energy than packstone. Components cemented together following deposition.	None identified in mapping
	Mudstone	Carbonate mud supported with less than 10% grains and more than 90% carbonate mud. Lower energy than wackestone. Components cemented together following deposition.	**Km**, **TKcm**, **QTal**
CHEMICAL SEDIMENTARY ROCKS	Limestone (Carbonate Mud)	Generic name. Formed by the precipitation of calcium (Ca) and carbonate (CO_3^{2}) ions from water (e. g. lakes or marine environments).	**Mfp**, **Mw**, **Msl**
	Travertine	Precipitation of calcium (Ca) and carbonate (CO_3^{2-}) ions from freshwater (e. g. terrestrial springs).	None identified in mapping
	Dolomite	Precipitation of calcium (Ca), magnesium (Mg), and carbonate (CO_3^{2-}) ions from water. Direct precipitation in shallow marine environments or post-depositional alteration by Mg-rich groundwater.	**Mfp**, **Msl**
	Chert	Dissolution of siliceous marine skeletons (e.g. sponge spicules) followed by precipitation of microcrystalline silica. Biochemical chert typically forms from marine invertebrates.	None identified in mapping
	Evaporites (i.e., gypsum)	Precipitation of salts to form evaporite minerals. Typical of hot, dry environments.	None identified in mapping
	Oolite	Precipitation of calcium carbonate in thin spherical layers around an original particle (e.g., fossil fragment) that is rolled back and forth by tides or waves. Typical of warm, shallow marine environments.	None identified in mapping
ORGANIC SEDIMENTARY ROCKS	Coal	Peat (partly decomposed plant matter) is buried, heated, and altered over time. Typical of lagoon, swamp, and marsh environments.	None identified in mapping

transportation, and deposition of rock fragments called "clasts." Clastic sedimentary rocks are named after the size of clasts (table 3). Higher-energy depositional environments, such as fast-moving streams, deposit larger (heavier) clasts while transporting smaller (lighter) clasts. Where water moves slowly or is stagnant, such as in lakes, the water cannot transport even the smallest clasts and they are deposited. Detailed descriptions of the bedrock map units are available in the ancillary map information document (fodo_geology.pdf) in the GRI GIS data.

Paleontological Resource Inventory, Monitoring, and Protection

Paleontological resources (fossils) are any evidence of life preserved in the geologic record (Santucci et al. 2009). Body fossils are any remains of the organism parts such as bones, teeth, shells, or stems and 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 August 2020, 277 parks had documented paleontological resources in at least one of these contexts. Fossils were noted within park boundaries as part of Mississippian geologic map units **Msl** and **Mw** (fig. 17). The potential for fossil remains exists in **Mfp**, **Km**, and **Kt**, wherein fossils are known from elsewhere in Tennessee and Kentucky. Paris Landing, just south of Fort Heiman in Tennessee is a known paleontological location (Lane and Sevastopulo 1981; Ausich and Smith 1982). Park staff have noticed "spiral-shaped" fossils along park trails (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call, 16 April 2018). All paleontological resources are nonrenewable and subject to science-informed inventory, monitoring, protection, and interpretation as outlined by the 2009 Paleontological Resources Preservation Act.

Paleontological Resource Management

Fort Donelson National Battlefield has geologic units known to be locally fossiliferous and 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 Fort Donelson National Battlefield. The summary was compiled through extensive literature reviews and interviews with park staff and professional geologists and paleontologists, but no field-based investigations. Resource-management recommendations from Hunt-Foster et al. (2009) for the park include:

- Encourage park staff to observe exposed gullies, other erosional bedrock, and streams for fossil material while conducting their usual duties.
- Document via photos and potentially monitor any occurrences of paleontological resources that may be observed in situ.
- Consider long-term monitoring of paleontological sites.
- Contact the NPS Geologic Resources Division for paleontological resource management assistance.

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.
- GRI GIS data: https://irma.nps.gov/DataStore/Reference/Profile/1049322.

Sources for Geologic Resource Management Guidance

The park's Foundation Document (National Park Service 2019a), Long Range Interpretive Plan (National Park Service 2019b), and Natural Resource Assessment (Sundin et al. 2013) are primary sources of information for resource management within the park, including national battlefield legislation and recommendations. Sundin et al. (2013) did not encompass the entire park, leaving a resource management need. A cultural landscape inventory and report, resource stewardship strategy, and asset management plan remain resource management needs at the park. A historic resource study is ongoing (Brian McCutchen, Fort Donelson National Battlefield, Superintendent, conference call 16 April 2018).

The Geologic Resources Division provides technical and policy support for geologic resource management issues in three emphasis areas:

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

Contact the division (http://go.nps.gov/grd) 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. Park staff can formally request assistance via https://irma.nps.gov/Star/.

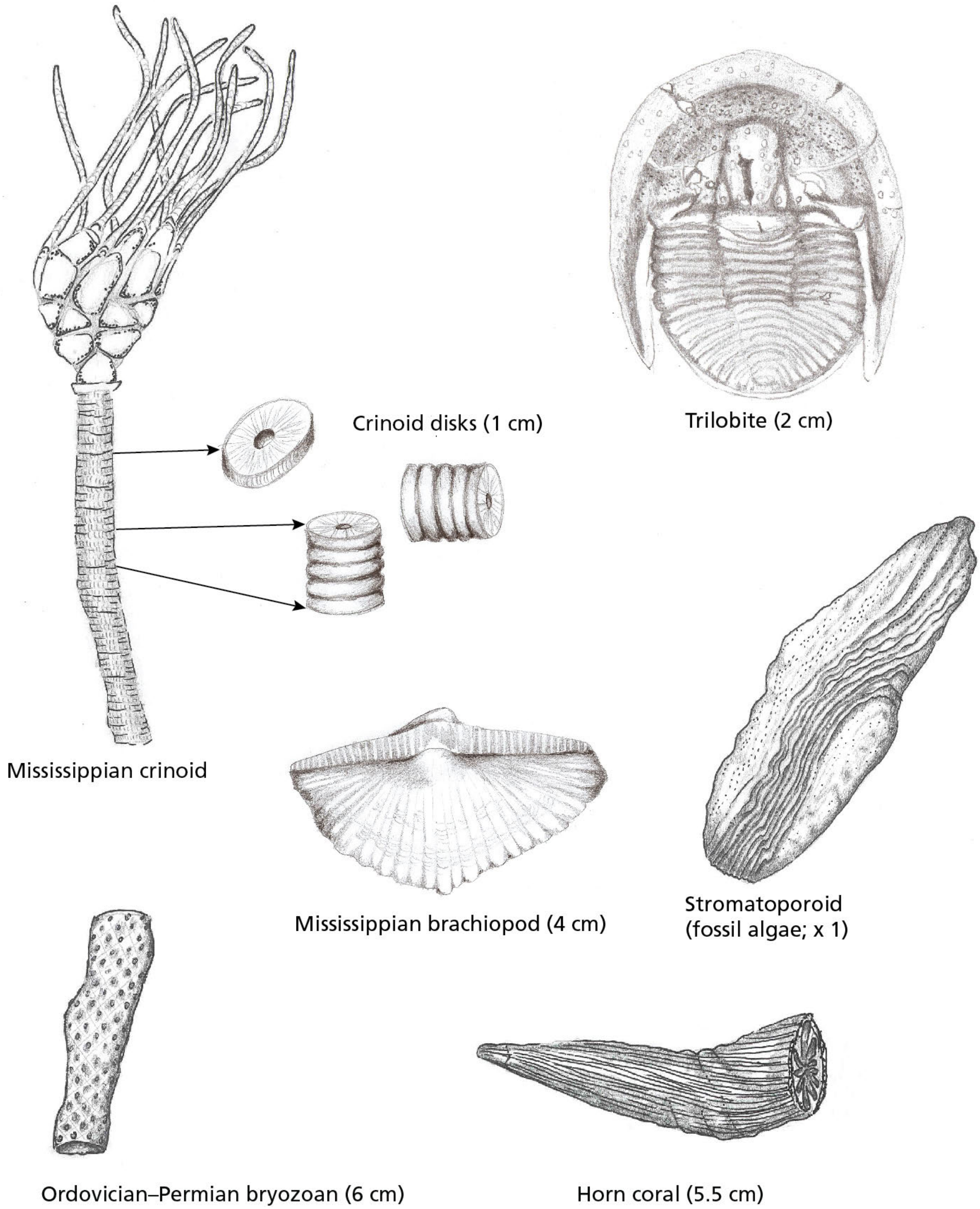


Figure 17. Fossil sketches.
These representative fossils may occur within the mapped units (Mfp, Mw, and Msl) of Fort Donelson National Battlefield, but are not necessarily from within the park. Mississippian crinoid disks and brachiopods are the most common fossils known from these units. Sketches by Trista L. Thornberry-Ehrlich (Colorado State University).

Resource managers may find *Geological Monitoring* (Young and Norby 2009; http://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 Scientists in Parks (SIP) internship program (formerly Geoscientists-in-the-Park program) and Mosaics in Science program provide easy to use mechanisms by which NPS parks, networks, regions, and programs can hire non-federal interns to undertake projects that address natural resource management issues. No projects have yet been attempted at Fort Donelson National Battlefield have included (as of September 2016). Contact scientists_in_parks@nps.gov and refer to the programs' websites at https://doimspp.sharepoint.com/sites/nps-scientistsinparks (internal NPS only site) or https://go.nps.gov/mosaics for more information.

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 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 table 1) 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 with some surficial units for Fort Donelson National Battlefield.

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 fodo_geology.pdf. The GRI team used the following sources to produce the GRI GIS data set for Fort Donelson National Battlefield. These sources also provided information for this report.

- Marcher and Larson (1965), Marcher et al. (1965a), Marcher et al. (1965b), Blade (1966), Marcher et al. (1967), and Tyra (2002)

GRI GIS Data

The GRI team standardizes map deliverables by using a data model. The GRI GIS data for Fort Donelson National Battlefield was compiled using data model version 2.1, which is available 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 website (http://go.nps.gov/gri) provides more information about the program's 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 (fodo_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 4);
- Federal Geographic Data Committee (FGDC)–compliant metadata;
- An ancillary map information document (fodo_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 (fodo_geology.mxd) that displays the GRI GIS data.

GRI Map Poster

A poster of the GRI GIS data draped over a shaded relief image of the park and surrounding area is included with printed copies this report and available to download through the IRMA portal https://irma.nps.gov/App/Portal/Home. Enter “GRI” as the search text and select a park from the unit list. 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 4. GRI GIS data layers for Fort Donelson National Battlefield.

Data Layer	On Poster?
Geologic Attitude and Observation Points	No
Caves	No
Geologic Measurement Localities	No
Map Symbology	Yes
Mine Point Features	No
Faults	Yes
Geologic Cross Section Lines	Yes
Mississippian Erosional Surface	No
Mine Area Feature Boundaries	No
Mine Area Features	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 maps’ 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.

Further Geologic Data Needs

Detailed geomorphic mapping and depth to bedrock mapping would provide useful baselines of current conditions to be applied to future monitoring efforts of slope movements and landform change. LiDAR surveys might reveal the presence of subtle sinkholes and other karst landforms.

National Park Service (2019a) and participants during the 2018 conference call identified the following digital data needs:

- Thorough topographic/geomorphic survey of the newly acquired 66 ha (164 ac) Dudley Hill area
- GIS battle/troop movement data layers
- GIS historic features data layers
- LiDAR coverage of the entire park

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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/grd
- NPS Geoscience Concepts: http://go.nps.gov/geoeducation
- NPS Geodiversity Atlas: http://go.nps.gov/geodiversity_atlas
- 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 Mosaics in Science internship program: http://go.nps.gov/mosaics

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: https://irma.nps.gov/DataStore/Reference/Profile/622933
- NPS Natural resource management reference manual #77: https://irma.nps.gov/DataStore/Reference/Profile/572379
- 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

- Kentucky Geological Survey: http://www.uky.edu/KGS/
- 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 16 April 2018. Discussions during these meetings supplied a foundation for this GRI report. The scoping summary document is available on the GRI publications website: http://go.nps.gov/gripubs.

2009 Scoping Meeting Participants

Name	Affiliation	Position
Stacy Allen	NPS Shiloh National Military Park	Chief of interpretation and 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 and Cumberland Piedmont networks	Hydrologist
Lisa Norby	NPS Geologic Resources Division	Geologist
Trista Thornberry-Ehrlich	Colorado State University	Geologist/report author/graphic designer
Ron Zurawski	Tennessee Division of Geology	State geologist

2018 Conference Call Participants

Name	Affiliation	Position
William Andrews	Kentucky Geological Survey	Geologist
Vince Antonacci	Tennessee Division of Geology	Geologist
Eric Bilderback	NPS Geologic Resources Division	Geologist
David Hamby	NPS Fort Donelson National Battlefield	Chief of resources and facilities
Jason Kenworthy	NPS Geologic Resources Division	Geologist, GRI reports coordinator
Brian McCutchen	NPS Fort Donelson National Battlefield	Superintendent
Joe Meiman	NPS Cumberland Piedmont Network	Hydrologist
Lima Soto	NPS Geologic Resources Division	GIP and Mosaics program assistant
Trista Thornberry-Ehrlich	Colorado State University	Geologist/report author/graphic designer
Ron Zurawski	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 2019. 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.

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

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
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.	None applicable.	**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.
Mining Claims (Locatable Minerals)	**Mining in the Parks Act of 1976, 54 USC § 100731 et seq.** authorizes NPS to regulate all activities resulting from exercise of mineral rights, on patented and unpatented mining claims in all areas of the System, in order to preserve and manage those areas. **General Mining Law of 1872, 30 USC § 21 et seq.** allows US citizens to locate mining claims on Federal lands. Imposes administrative and economic validity requirements for "unpatented" claims (the right to extract Federally-owned locatable minerals). Imposes additional requirements for the processing of "patenting" claims (claimant owns surface and subsurface). Use of patented mining claims may be limited in Wild and Scenic Rivers and OLYM, GLBA, CORO, ORPI, and DEVA. **Surface Uses Resources Act of 1955, 30 USC § 612** restricts surface use of unpatented mining claims to mineral activities.	**36 CFR § 5.14** prohibits prospecting, mining, and the location of mining claims under the general mining laws in park areas except as authorized by law. **36 CFR Part 6** regulates solid waste disposal sites in park units. **36 CFR Part 9, Subpart A** requires the owners/operators of mining claims to demonstrate bona fide title to mining claim; submit a plan of operations to NPS describing where, when, and how; prepare/submit a reclamation plan; and submit a bond to cover reclamation and potential liability. **43 CFR Part 36** governs access to mining claims located in, or adjacent to, National Park System units in Alaska.	**Section 6.4.9** requires NPS to seek to remove or extinguish valid mining claims in wilderness through authorized processes, including purchasing valid rights. Where rights are left outstanding, NPS policy is to manage mineral-related activities in NPS wilderness in accordance with the regulations at **36 CFR Parts 6 and 9A**. **Section 8.7.1** prohibits location of new mining claims in parks; requires validity examination prior to operations on unpatented claims; and confines operations to claim boundaries.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
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.
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).

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*

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National Park Service
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Natural Resources Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

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