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Wilson's Creek National Battlefield

Geologic Resources Inventory Report

Wilson's Creek flows over limestone of the Elsey Formation, near the Gibson's Mill site. The namesake stream is accessible at several locations at the battlefield, and the exposed bedrock along the banks is an opportunity to spot fossils of Mississippian marine animals.

COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES

Wilson's Creek National Battlefield: Geologic resources inventory report

Science Report NPS/SR—2025/255

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Abstract

Geologic Resources Inventory (GRI) reports provide information and resources to help park managers make decisions for visitor safety, the planning and protection of infrastructure, and the preservation of natural and cultural resources. Information in GRI reports may also be useful for interpretation. This report synthesizes discussions from a scoping meeting held in 2011 and a follow-up meeting in 2023. The chapters of this report discuss the geologic heritage, geologic history, geologic features and processes, and geologic resource management issues of Wilson's Creek National Battlefield. Guidance for resource management and information about the previously completed GRI GIS data and poster (separate products) are also provided.

Acknowledgments

The Geologic Resources Inventory team thanks the participants of the 2011 scoping meeting and the 2023 follow-up meeting for their assistance in this inventory. The lists of participants (below) reflect the names and affiliations of those participants at the times of the meetings. Because the Geologic Resources Inventory team does not conduct original geologic mapping, we are particularly thankful to the Missouri Geological Survey for its maps of the area. This report and accompanying GIS data could not have been completed without them. Thank you to Justin Tweet, Denny Capps, and Anthony Gallegos of the Geologic Resources Division for reviewing parts of this report.

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Executive Summary

Comprehensive park management to fulfill the National Park Service (NPS) mission requires an accurate inventory of the geologic features of a park unit, but park managers may not have the needed information, geologic expertise, or means to complete such an undertaking; therefore, the Geologic Resources Inventory (GRI) provides information and resources to help park managers make decisions for visitor safety, planning and protection of infrastructure, and preservation of natural and cultural resources. Information in the GRI report may also be useful for interpretation.

Wilson's Creek National Battlefield (referred to as the "battlefield" throughout this report) preserves the site of the first battle of the American Civil War fought west of the Mississippi River. It was also the first battle in which a Union general—Brigadier General Nathaniel Lyon—was killed.

This report is supported by a GRI-compiled map of the geology of the battlefield and surrounding area. The source maps used to compile the GRI GIS data were completed by the Missouri Department of Natural Resources between 1981 and 2001.

This report contains the following chapters:

Introduction—This chapter provides background information about the history of the battlefield and its establishment as an NPS unit. This chapter also introduces the GRI process and products, and recognizes GRI collaborators. A geologic map in GIS format is the principal deliverable of the GRI. This chapter highlights the source maps used by the GRI team in compiling the GRI GIS data for the battlefield and provides specific information about the use of these data. It also calls attention to the poster that illustrates these data.

Geologic Heritage—This chapter highlights the significant geologic features, landforms, landscapes, and stories of the battlefield, preserved for their heritage values. It also draws connections between geologic resources and other park resources and stories, such as the landscape's role in the battle and human history of the region.

Geologic History—This chapter describes the chronology of geologic events that formed the present landscape.

Geologic Features, Processes, and Resource Management Issues—This chapter describes the geologic features and processes of significance for the battlefield and discusses any potential resource management issues associated with those features and processes. Issues include (1) bedrock features, including paleontological resources; (2) fluvial features and processes, including water quality and flooding hazards, and springs; (3) caves and karst, including sinkholes and caves as habitat for threatened species; (4) faults and seismicity, including the inactive Battlefield Fault Zone; (5) disturbed lands, which include the entire history of farming and battle as well as an abandoned quarry; and (6) a table summarizing risks posed by geologic hazards at the battlefield.

Guidance for Resource Management and Additional References, Resources, and Websites—These chapters are a follow up to the "Geologic Features, Processes, and Resource Management Issues" chapter. They provide resource managers with a variety of methods to find and receive management assistance with geologic resources. A summary of laws, regulations, and policies that apply to geologic resources is also provided.

Literature Cited—This is a bibliography of references cited in this GRI report. Many of the cited references are available online, as indicated by an Internet address included as part of the reference citation.

If battlefield managers are interested in other investigations and/or a broader search of the scientific literature, the NPS Geologic Resources Division has collaborated with—and funded—the NPS Technical Information Center (TIC) to maintain a subscription to GeoRef (the premier online geologic citation database). This database can be accessed by NPS staff through multiple portals. Battlefield staff may contact the GRI team or the NPS Geologic Resources Division for instructions on how to access GeoRef.

Introduction

The purpose of this report is to familiarize readers with the geologic features, processes, history, and best practices for managing geologic resources for Wilson's Creek National Battlefield (also referred to as the "battlefield" throughout this report). The Geologic Resources Inventory (GRI), which is administered by the Geologic Resources Division (GRD) of the National Park Service (NPS) Natural Resource Stewardship and Science Directorate, 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 funded by the NPS Inventory and Monitoring Program.

Battlefield Background and Establishment

The battlefield, consisting of 824 hectares (2,036 acres) in southwestern Missouri, was established as a National Battlefield Park on 22 April 1960 to "commemorate the Battle of Wilson's Creek, preserve the associated battlefield, and interpret the battle within the context of the Civil War in the Trans-Mississippi West" (National Park Service 2017, p. 5). The battlefield was redesignated as a National Battlefield on 16 December 1970.

The American Civil War battle, which occurred on 10 August 1861, resulted in the defeat of a Union force of about 5,400 soldiers by a Confederate force of 12,000 soldiers. Additionally, General Nathaniel Lyon became the first Union general killed in action. The defeat emphasized the need for additional Union reinforcements in Missouri and set the stage for the battle of Pea Ridge in Arkansas nine months later, where a decisive Union victory effectively ended the Confederate impact in Missouri.

Significant sites of the battlefield include the two remaining structures that were present at the time of the battle, the Ray House and the Ray Springhouse; major historic sites of the battle, including troop positions and batteries; and the visitor center and museum, which houses the largest collection of materials related to the Civil War west of the Mississippi River. These sites are connected by the tour road, a 7.9 km (4.9 mi) road featuring pullouts at significant sites that can be driven, hiked, or bicycled. The tour road and sites of interest are marked on the GRI poster (see "GRI Products"). Visitors can also hike and, in some cases, horseback ride on trails throughout the park. In 2023, the battlefield welcomed 316,770 recreational visitors (Ziesler and Spalding 2024).

The state of Missouri is generally characterized by relatively flat-lying beds of sedimentary rock deposited in the Paleozoic Era, between 539 million and 252 million years ago. The battlefield is located in the Springfield Plateau physiographic region (Figure 1), in the Interior Highlands province. The Springfield Plateau is underlain by limestone bedrock with abundant cave and karst (the distinct topography formed from the dissolution of soluble bedrock by water; see the Caves and Karst section of the "Geologic Features, Processes, and Resource Management Issues" chapter) features, including springs and sinkholes. The Salem Plateau physiographic region, to the east, is underlain by older bedrock. The bedrock of the Osage Plains province to the north and west is younger. Once covered by prairie, the relatively level expanses of the Springfield and Salem Plateaus have been extensively developed for agriculture and, more recently, urban growth.

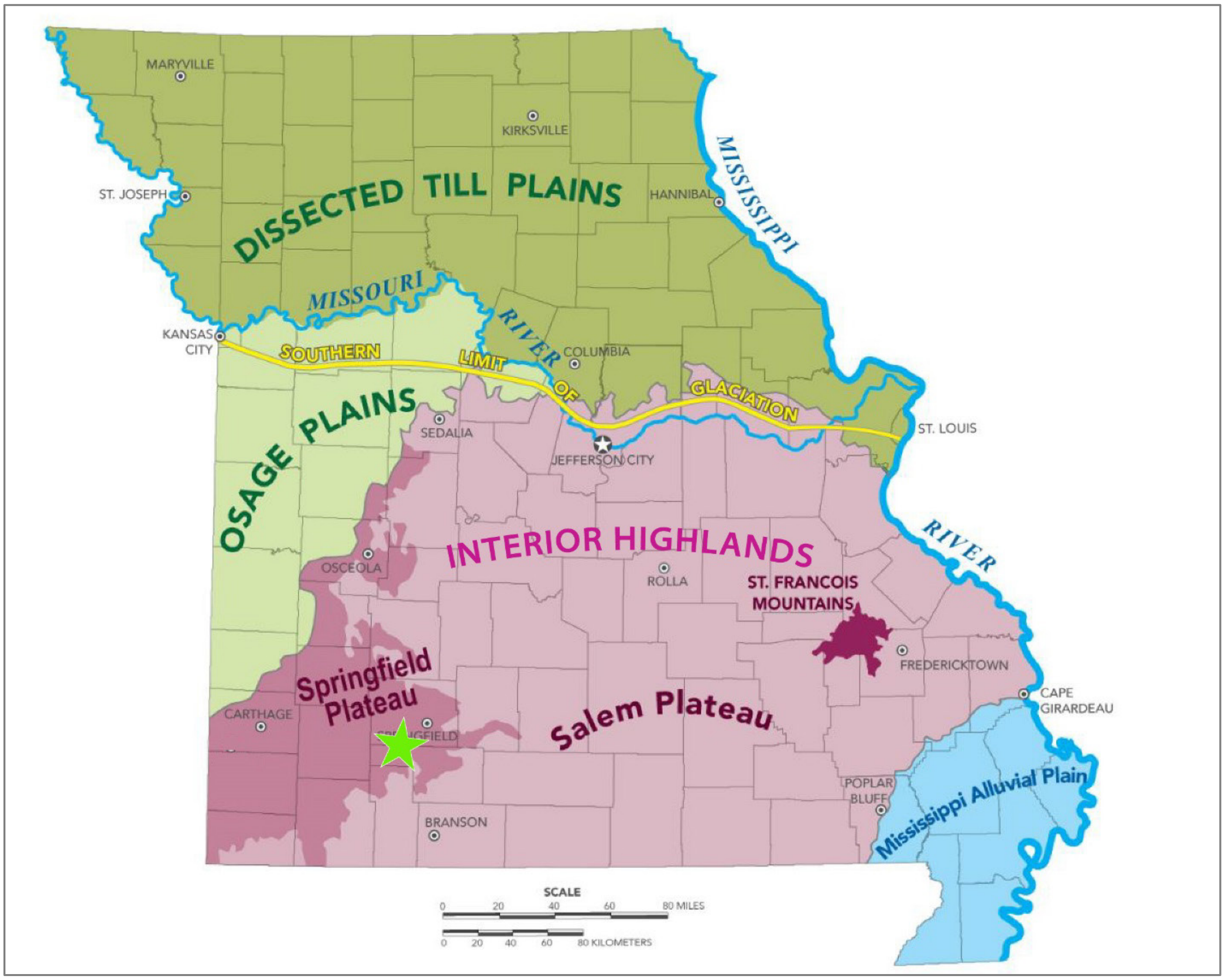

Figure 1. Map of the physiographic regions of Missouri. In the northern part of the state—the Dissected Till Plains—the bedrock is covered by thick layers of glacially deposited sediment (till) that have been carved and shaped by rivers and streams. The Springfield Plateau region, where the battlefield is located (indicated by a green star), and the Salem Plateau were not flattened by glaciers, and the topography is a mix of rolling hills interspersed by steep escarpments. ADAPTED FROM CONTENT ORIGINALLY PUBLISHED BY THE MISSOURI DEPARTMENT OF NATURAL RESOURCES

According to the battlefield's foundation document (National Park Service 2017, p. 6), the following factors warrant the battlefield's inclusion in the National Park System:

- The Battle of Wilson's Creek was the second battle of the Civil War and the first major battle west of the Mississippi River.
- Wilson's Creek National Battlefield was the site of the death of General Nathaniel Lyon, the first Union general killed in the Civil War. Lyon's death focused national attention on the potential loss of Missouri to the Confederacy.

- Wilson's Creek National Battlefield's comprehensive cultural landscape and rural character evoke the setting at the time of the battle, which allows for interpretation and understanding of events.
- Wilson's Creek National Battlefield's extensive research library, archives, and museum collections represent a nationally prominent and in-depth record of the battle and the Civil War in the Trans-Mississippi West.

Although none of these values explicitly mentions geology, the "Geologic Heritage" chapter in this report explores the connection between geology and the significance of the battlefield. In particular, the "cultural landscape and rural character" have direct connections to the geologic processes that shaped the landscape and influenced human use and settlement.

Geologic Resources Inventory

The GRI was established in 1998 by the GRD and the NPS Inventory and Monitoring Program [Division] to meet the NPS need for geologic mapping and related information. Geologic maps were identified as one of 12 natural resource data sets critical for long-term science-informed park management. From the beginning, the GRI has worked with long-time NPS partner Colorado State University to ensure products are scientifically accurate and utilize the latest in geographic information system (GIS) technology. For additional information regarding the genesis of the program and its early focus, refer to National Park Service (1992, 1998, 2009).

GRI Products

The GRI team—which is a collaboration between the GRD of the NPS, Colorado State University's Department of Geosciences, and University of Alaska Fairbanks Museum of the North—completed the following tasks as part of the GRI process for the battlefield: (1) conducted a scoping meeting and provided a scoping summary (Graham 2011); (2) provided geologic map data in a GIS format; (3) created a poster to display the GRI GIS data; and (4) provided a GRI report (this document).

GRI products—GIS data, map posters, scoping summaries, and reports—are available on the "Geologic Resources Inventory—Products" website and through the NPS DataStore (see "Access to GRI Products"). The information provided in GRI products is not a substitute for site-specific investigations. Ground-disturbing activities should neither be permitted nor denied based on the information provided in GRI products. Minor inaccuracies may exist regarding the locations of geologic features relative to other geologic or geographic features in the GRI GIS data or on the poster. Based on the source map scales (1:24,000) and US National Map Accuracy Standards, geologic features represented in the GRI are horizontally within 12 m (40 ft) of their true locations.

<u>Scoping Meeting</u>

On 5 April 2011, the NPS held a scoping meeting for the battlefield at the park headquarters. The scoping meeting brought together battlefield 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 for inclusion in the final GRI report. A scoping summary (Graham 2011) summarizes the findings of that meeting.

GRI GIS Data

Following the scoping meeting, the GRI team compiled the GRI GIS data for the battlefield. These data are the principal deliverable of the GRI. The GRI team did not conduct original geologic mapping but compiled existing geologic information (i.e., paper maps and/or digital data) into the GRI GIS data (Figure 2). Scoping participants and the GRI team identified the best available source maps based on coverage (area mapped), map scale, date of mapping, and compatibility of the mapping to the current geologic interpretation of an area.

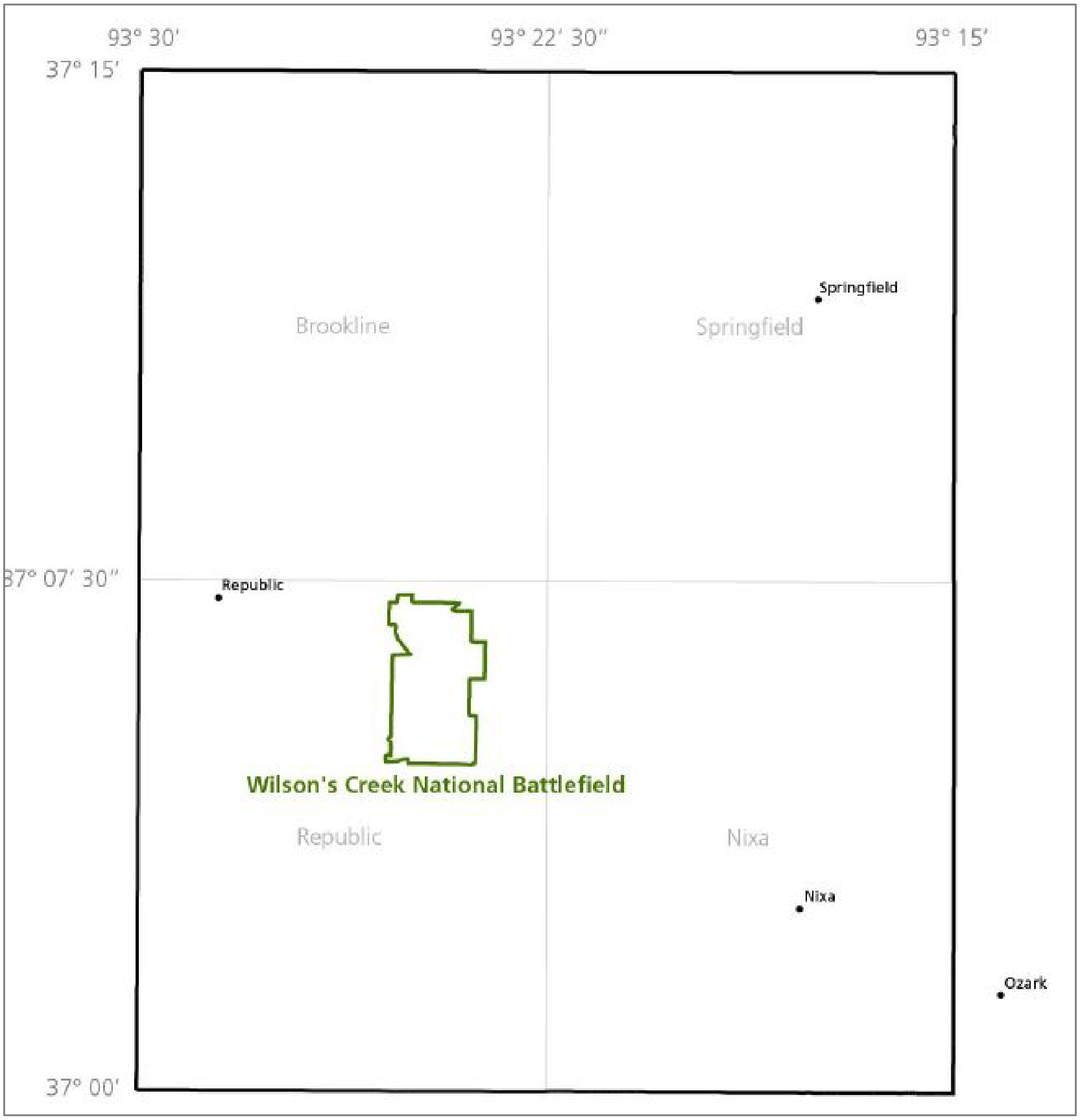

Figure 2. Index map of the GRI GIS data. This map shows the extent of the GRI GIS data in the context of 7.5-minute quadrangles. These data extend beyond the boundaries of the battlefield in the Republic quadrangle to include the Brookline (to the north), Springfield (to the northeast), and Nixa (to the east) quadrangles and provide regional geologic context. COLORADO STATE UNIVERSITY / RON KARPILO

The GRI GIS data for the battlefield were compiled from the following source maps:

- Geologic map of the Springfield 7.5' Quadrangle, Missouri (Robertson 1992)
- Geologic map of the Brookline 7.5' Quadrangle, Missouri (Robertson 1990)
- Geologic map of the Nixa 7.5' Quadrangle, Missouri (Thomson 1981)
- Geologic map of the Republic 7.5' Quadrangle, Missouri (Work and Robertson 1991)
- Geologic map of the Springfield 30' × 60' Quadrangle, Missouri (Wedge 2001)

GRI Poster

A poster of the GRI GIS data draped over a shaded relief image of the battlefield and surrounding area is the primary figure referenced throughout this GRI report. The poster is not a substitute for the GIS data but is supplied as a helpful tool for office and field use and for users without access to ArcGIS. Geographic information and selected park features have been added. Digital elevation data and added geographic information are not included in the GRI GIS data but are available online from a variety of sources.

GRI Report

On 4 December 2023, the GRI team hosted a combined follow-up meeting for both Wilson's Creek National Battlefield and George Washington Carver Monument staff and interested geologic experts. The meeting provided an opportunity to get back in touch with park staff, introduce "new" (since the 2011 scoping meeting) staff to the GRI process, and update the list of geologic features, processes, and resource management issues for inclusion in the final GRI report.

This GRI report is the culmination of the GRI process. It synthesizes discussions from the scoping meeting in 2011, the follow-up meeting in 2023, and additional geologic research. The selection of geologic features and processes highlighted in this report was guided by the previously completed GRI map data, and the writing reflects these data and the interpretation of the source map authors. When applicable to the battlefield's geologic resources and resource management, information was also included from the battlefield's foundation document (National Park Service 2017).

Geology is a complex science with many specialized terms. This report provides definitions of complex geologic terms at first mention, typically in parentheses following the term. Additionally, the GRI report links the GRI GIS data to the geologic features and processes discussed in the report using map unit symbols; for example, the Elsey Formation has the map symbol **Me**. Capital letters indicate age, and the lowercase letters that follow symbolize the unit name. "**M**" represents the Mississippian Period (~358.9 million to 323.2 million years ago), and "**e**" represents the Elsey Formation. A geologic time scale is provided as a table in this report (see "Geologic History" chapter).

Geologic Heritage

Geologic heritage (also called "geoheritage") evokes the idea that the geology of a place is an integral part of its history and cultural identity. Geologic heritage exists at the overlap of geology and humanity and encompasses important aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific qualities. This chapter highlights the geologic features, landforms, landscapes, and stories of the battlefield valued for their geologic heritage qualities. It also draws connections between geologic resources and other park resources and stories.

In 2015, in cooperation with the American Geosciences Institute (AGI), the GRD, which administers the GRI (see "Introduction" chapter), published *America's Geologic Heritage: An Invitation to Leadership* (National Park Service and American Geosciences Institute 2015). That booklet introduced the American experience of geologic heritage and included five key principles and concepts:

- America's geologic landscape is an integral part of its history and cultural identity, and Americans have a proud tradition of exploring and preserving geologic heritage.
- America's geologic heritage, as shaped by geologic processes over billions of years, is diverse and extensive.
- America's geologic heritage holds abundant values—aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific—for all Americans.
- America's geologic heritage benefits from established conservation methods developed around the world and within the United States.
- America's geologic heritage engages many communities, and involvement by individuals will ensure its conservation for future generations.

The foundation document for the battlefield identifies fundamental resources and values, or those aspects of the battlefield that are essential to achieving its purpose and maintaining its significance (National Park Service 2017). Some of these include geologic connections:

- Battlefield landscape and historic views. The landscape was formed through geologic processes, and some geologic features—such as the sinkhole that was used as a burial site and the limestone glade on Bloody Hill where General Lyon was killed—are key stops along the tour road.
- Ray House and Ray Springhouse. The springhouse is built entirely of locally quarried Burlington-Keokuk limestone, and the spring that it is constructed around is a feature of the karst landscape that characterizes the area.
- Rural setting. This refers to the current viewshed and setting as similar to what they would have been at the time of the battle.

The foundation document (National Park Service 2017) also identifies other important resources or values, which are aspects of the battlefield that may be unrelated to their significance but are nonetheless important to consider in planning processes. Some of these also include geologic connections:

- Archeological resources. These resources provide evidence of human habitation in the Wilson's Creek area for at least 5,000 years. These resources include stone tools and weapons—chert arrowheads are common—and indicate that the geologic setting was generally favorable for human existence for thousands of years before settlers arrived.
- Cave resources. There are a small number of caves at the battlefield that were likely explored by humans in the past and that may contain paleontological resources; however, the locations of caves are not shared with the public to protect species that live in caves, including the federally listed endangered gray bat.

Threatened and endangered species. Two federally listed species (the Missouri bladderpod and the gray bat) are present at the battlefield. The habitats for both species are geologic features—caves, for the gray bats (*Myotis grisescens)*, and glades, or dry areas with shallow soil and exposed bedrock, which are the preferred habitat of the Missouri bladderpod (*Physaria filiformis*). The northern long-eared bat (*Myotis septentrionalis*) is likely present as well but has not been officially documented at the battlefield (Jennifer Haack-Gaynor, NPS Heartland Network, personal communication, 21 August 2024).

Finally, the foundation document lists as an interpretative theme the idea that the "battle outcome (was) the result of many interrelated factors," including terrain (National Park Service 2017, p. 9). The terrain, which includes Wilson's Creek and its tributaries, the associated valleys, and the rolling landscape typical of a karst region, is a direct result of the geological processes that have shaped and continue to shape the battlefield.

Other geologic heritage connections at the battlefield include fossils in the bedrock and springs that relate to the human history of settlement and development. These connections could be explored through interpretative programming or signage at the battlefield.

Battlefield Landscape, Historic Views, and Rural Setting

The battle took place on a rolling, agricultural landscape, and the terrain and vegetation influenced the conflict, where seizing and commanding the high ground was crucial. The battery locations on hilltops along the tour road—Pulaski Arkansas, Fort Smith, Bledsoe's, Guibor's, Totten's, and Du Bois's—illustrate this (see poster). Visitors who hike up the slopes to the batteries (particularly on a characteristically hot and humid Missouri summer day, as this author will attest) can appreciate the challenge that soldiers would have faced trying to charge up those hills. And that is without any cannonballs in the mix!

Similarly, once a visitor has reached the battery, they can survey the landscape and understand the commanding views and tactical advantage offered by the high ground positions. The rolling terrain that creates these strategic highpoints is a feature of karst landscapes, which are created through the dissolution of soluble rocks (such as limestone) by groundwater (see the "Caves and Karst" section for more information). Karst landscapes are also characterized by caves, springs, and sinkholes, all of which are present at the battlefield, and played an important role in the human history of the landscape.

For example, after the battle, soldiers used the sinkhole at Bloody Hill as a “natural grave” and placed the bodies of the fallen into the sinkhole. The sinkhole has been excavated several times—first in 1867 after the creation of the Springfield National Cemetery (Jeff Patrick, Wilson’s Creek National Battlefield, personal communication, 29 August 2024) and most recently in 1973 (Graham 2011)—and does not currently contain bodies (see the “Sinkholes” subsection for more information about sinkholes at the battlefield).

An important aspect of the battlefield is that the landscape is preserved as it was historically used at the time of the battle. Visitors can walk through agricultural fields (e.g., Gibson Oatfield, Ray Cornfield, Sharp Cornfield) and appreciate the rural setting that became a battlefield. The agricultural tradition of the area is due in part to the glacial history of North America. Although the ice did not extend as far south as southern Missouri, the fine, wind-blown sediments known as “loess” blanketed the area and contributed to rich soil development (see Figure 1). Combined with abundant surface water and groundwater, the region was ideally suited for agricultural development. The Steele estate, which was purchased and developed by John Ray into a house and large farm, may have been situated where it was because of the proximity to a spring. Springs exist where the water table intersects with the landscape, providing sources of cool, fresh water. The Rays built a springhouse around the spring, using it to store food as well as drinking water.

Building Stone

Bedrock quarried from southwest of the Ray House (see the “Disturbed Lands” section for more information about the quarry) was likely used as building stone in the Ray Springhouse (Figure 3), which is constructed entirely of Burlington-Keokuk limestone (**Mbk**). See the “Geologic History” chapter for more information about the origins of the bedrock. The **Mbk** limestone is fossiliferous, and fossils may be present in the building stone, although this had not been observed by the time of this report. The Ray House includes a stone chimney; however, it is made of sandstone that is not found in the region and may have been imported from quarries in Arkansas (Graham 2011).

Figure 3. Photograph of Ray Springhouse interior. Constructed entirely of locally quarried Burlington-Keokuk limestone, the springhouse partially impounds a spring and, using the cool temperature of the spring water, provided a place for the Ray family to store food. The spring was also a source of fresh drinking water for the family and their animals.
COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES

Fossils

Fossils (preserved evidence of past life; see the "Paleontological Resources" subsection) are present within the battlefield boundaries and can be observed in most bedrock exposures, especially in the Elsey Formation (**Me**) along Wilson's Creek and in various outcrops of Burlington-Keokuk limestone (**Mbk**) along the tour road (see poster). The most common fossil at the battlefield are fragments of crinoid stalks, which typically appear as ring-shaped fossils (Figure 4) in all of the mapped rock units (**Mbk**, **Me**, and the Reeds Spring Formation [**Mrs**]). Coral fragments (in **Mbk** and **Me**) and brachiopods (**Me**) are also present in the rocks that underlie that battlefield (Hunt et al. 2008). These paleontological resources are evidence of a time when "Missouri" was partially submerged beneath a shallow sea and the Earth looked very different and may be opportunities for visitors to appreciate the scale of geologic time compared to human history in the context of the American Civil War.

Figure 4. Photograph of a crinoid fossil in the Burlington-Keokuk limestone. Photograph was taken at a roadcut along the tour road. A fossilized fragment of a crinoid stalk (circled) is visible in the rock; these are the most common type of fossil that can be found at the battlefield. They are present in all of the rock units that are exposed. A 9 cm (3.5 in) pocketknife provides scale.
COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES

Geologic History

This chapter describes the geologic events that formed the present landscape of the battlefield and surrounding area. The geologic story at the battlefield is long, beginning hundreds of millions of years ago. In the Lower Mississippian Period (358.9 million to 346.7 million years ago), Laurentia (the landmass that would become the North American continent) was covered in a warm, shallow sea (Figure 5). The calcium carbonate ($CaCO_3$) shells of invertebrate creatures like crinoids and brachiopods were among the marine sediments that were deposited in the area. Over time, these sediments hardened into horizontal beds of limestone.

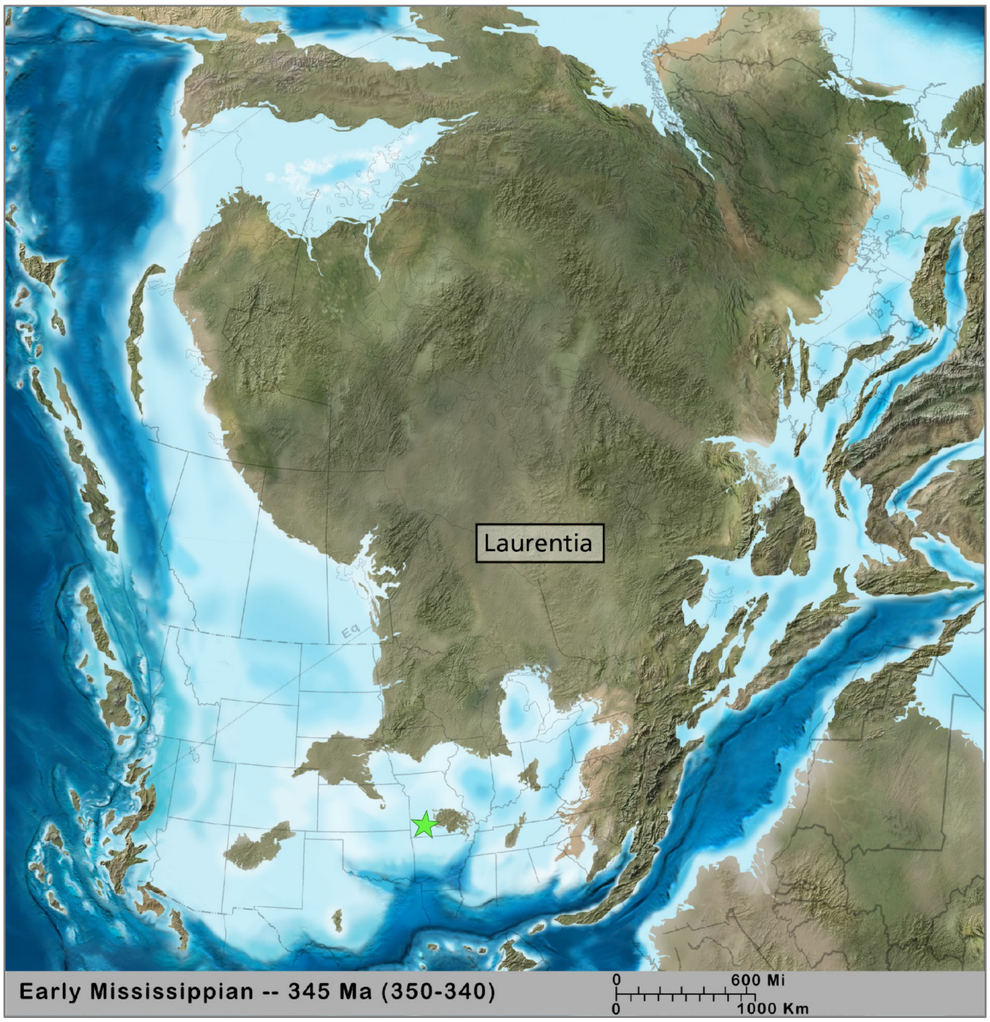

Figure 5. Paleogeographic map of North America during the early Mississippian Period. The bedrock that underlies southwestern Missouri and the battlefield (marked with green star) is sedimentary rock that was deposited during the Lower Mississippian Period (359 million to 347 million years ago), when Earth's climate was much warmer, and a shallow sea covered much of the proto-North American continent. Limestone, formed from the slow accumulation of sediments, including the remains of organisms, was deposited beneath these seas. RON BLAKEY, NORTH AMERICAN KEY TIME SLICES © 2013 COLORADO PLATEAU GEOSYSTEMS INC., USED UNDER LICENSE WITH ANNOTATION BY COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES

In the considerable time following the Mississippian Period (more than 300 million years ago; Table 1)—which saw the rise and fall of the dinosaurs, the separation of Laurentia and subsequent formation and breaking apart of Pangea, and the eventual assembly of the North American continent and the uplift of the Rocky Mountains—any additional rocks deposited on top of the Mississippian limestones have been eroded away. The exception is one small area of undescribed Pennsylvanian Period (323.2 million to 298.9 million years ago) rocks (**PNr**), which are mapped outside of the battlefield boundary to the northeast (see poster).

Table 1. Geologic time scale. The geologic time scale puts the divisions of geologic time in stratigraphic order, with the oldest divisions at the bottom and the youngest at the top. Colors correspond to USGS suggested colors for geologic maps. The letters in parentheses are abbreviations for geologic time units. Where no geologic time subdivision exists, "N/A" indicates not applicable. The rocks in the GRI GIS data for the battlefield are from the Mississippian (M) and Pennsylvanian (PN) Periods of the Paleozoic Era.

Eon	Era(s)	Period(s)	Epoch(s)	MYA [A]
Phanerozoic	Cenozoic	Quaternary (Q)	Holocene (H)	0.0117–today
	Cenozoic	Quaternary (Q)	Pleistocene (PE)	2.6–0.0117
	Cenozoic	Neogene (N)	Pliocene (PL)	5.3–2.6
	Cenozoic	Neogene (N)	Miocene (MI)	23.0–5.3
	Cenozoic	Paleogene (PG)	Oligocene (OL)	33.9–23.0
	Cenozoic	Paleogene (PG)	Eocene (E)	56.0–33.9
	Cenozoic	Paleogene (PG)	Paleocene (EP)	66.0–56.0
	Mesozoic	Cretaceous (K)	Upper, Lower	145.0–66.0
	Mesozoic	Jurassic (J)	Upper, Middle, Lower	201.3–145.0
	Mesozoic	Triassic (TR)	Upper, Middle, Lower	251.9–201.3
	Paleozoic	Permian (P)	Lopingian, Guadalupian, Cisuralian	298.9–251.9
	Paleozoic	Pennsylvanian (PN)	Upper, Middle, Lower	323.2–298.9
	Paleozoic	Mississippian (M)	Upper, Middle, Lower	358.9–323.2
	Paleozoic	Devonian (D)	Upper, Middle, Lower	419.2–358.9
	Paleozoic	Silurian (S)	Pridoli, Ludlow, Wenlock, Llandovery	443.8–419.2
	Paleozoic	Ordovician (O)	Upper, Middle, Lower	485.4–443.8
	Paleozoic	Cambrian (C)	Furongian, Miaolingian, Series 2, Terreneuvian	538.8–485.4
Proterozoic	Neoproterozoic (Z)	Ediacaran, Cryogenian, Tonian	N/A	1,000–538.8
	Mesoproterozoic (Y)	Stenian, Ectasian, Calymmian	N/A	1,600–1,000
	Paleoproterozoic (X)	Statherian, Orosirian, Rhyacian, Siderian	N/A	2,500–1,600

[A] Boundary ages are millions of years ago (MYA) and follow the International Commission on Stratigraphy (2023).

Table 1 (continued). Geologic time scale. The geologic time scale puts the divisions of geologic time in stratigraphic order, with the oldest divisions at the bottom and the youngest at the top. Colors correspond to USGS suggested colors for geologic maps. The letters in parentheses are abbreviations for geologic time units. Where no geologic time subdivision exists, "N/A" indicates not applicable. The rocks in the GRI GIS data for the battlefield are from the Mississippian (M) and Pennsylvanian (PN) Periods of the Paleozoic Era.

Eon	Era(s)	Period(s)	Epoch(s)	MYA [A]
Archean	Neo-, Meso-, Paleo-, Eo-archean	N/A	N/A	4,000–2,500
Hadean	N/A	N/A	N/A	4,600–4,000

[A] Boundary ages are millions of years ago (MYA) and follow the International Commission on Stratigraphy (2023).

During the Pleistocene Epoch (2.6 million to 10,000 years ago) of the Quaternary Period (2.6 million years ago to present), glaciers advanced over much of North America, although the extent of ice did not reach the battlefield location in southern Missouri (see Figure 1). Therefore, the region is not characterized by the features typical of a glaciated landscape. However, the glaciers ground the rocks and sediments beneath them into fine dust. As the glaciers retreated, these sediments were blown by the wind and deposited as loess beyond the extent of glaciation, including the region of the battlefield. Agricultural development has reworked or removed the loess deposits in the area, and the GRI GIS data does not map them. However, the former presence of loess contributed to the rich soil and rural tradition that characterized the region at the time of the American Civil War.

Today, bedrock is now exposed primarily on slopes and in valleys where rivers and streams of the Missouri and Mississippi watersheds incise and rework surficial deposits. Karst processes, which dissolve limestone and create features such as caves and sinkholes, shape the landscape into low, rolling hills.

Geologic Features, Processes, and Resource Management Issues

The geologic features and processes highlighted in this chapter are significant to the battlefield's landscape and history. The selection of these features and processes was based on input from scoping and follow-up meeting participants, analysis of the GRI GIS data, and research of scientific literature and NPS reports.

Some geologic features, processes, or human activities may require management for human safety, the protection of infrastructure, and the preservation of natural and cultural resources. The GRD provides technical and policy assistance for these issues (see "Guidance for Resource Management"). The issues are discussed, along with the features and processes with which they are associated. The geologic hazards in the park are summarized at the end of this chapter.

Since the GRI scoping meeting in 2008, the NPS has completed a foundation document (National Park Service 2017), an environmental assessment (Commonwealth Heritage Group and Sargent 2018), a natural resource condition assessment (Annis et al. 2011) for the battlefield, and a two-volume cultural landscape report (John Milner Associates, Inc. et al. 2004). Because these documents are primary sources of information for resource management, they were used to draw connections between geologic features and fundamental resources and values.

Bedrock and Paleontological Features

The GRI GIS data and poster show four bedrock units in the area of the battlefield: the Reeds Spring Formation (**Mrs**), the Elsey Formation (**Me**), the Burlington-Keokuk limestone (**Mbk**), and undifferentiated Pennsylvanian rocks (**PNr**). The entire battlefield is underlain by the Lower Mississippian (**Mbk**, **Me**, **Mrs**) rock units. East of the boundary on the north end of the battlefield, a small area of Pennsylvanian rock (**PNr**) is included in the GRI GIS data. Table 2 describes the GRI GIS rock units, including detailing where they are mapped in relation to the battlefield.

Table 2. Geologic units in the GRI GIS data. This table describes the bedrock geologic units that are included in the GRI GIS data. The bedrock units underlying the battlefield and surrounding area were deposited in the Mississippian Period (359 million to 323 million years ago) and the Pennsylvanian Period (323 million to 299 million years ago); the units are presented here stratigraphically (oldest at the bottom). All unit descriptions are from Wedge (2001). Colors correspond to USGS suggested colors for geologic maps.

Period	Geologic Unit	Description	Locations in the battlefield
Pennsylvanian (323 million to 299 million years ago)	Pennsylvanian Rocks (**PNr**)	No description of **PNr** was given in the source maps (Work and Robertson 1991; Wedge 2001) and is not included in the GRI GIS data.	**PNr** is mapped in one location to the northeast of the battlefield. It occurs within a much larger area mapped as **Mbk**. The contact between the units is inferred, meaning the physical contact was not observed in the field but inferred from other measurements. An inferred fault crosses **PNr**.
Lower Mississippian (359 million to 347 million years ago)	Burlington-Keokuk limestone (**Mbk**)	Mbk is a gray limestone made up of thick beds that contain fossils of crinoids. Nodules and thin, discontinuous layers of chert are also present. At its thickest, **Mbk** is 61 m (200 ft).	**Mbk** underlies most of the battlefield. Outcrops can be observed along the tour road, at the glade at Bloody Hill, at the abandoned quarry near the Ray House, and at the sinkhole that is marked on the poster.
	Elsey Formation (**Me**)	**Me** is light gray limestone that contains chert nodules and fossils of crinoids and brachiopods.	**Me** is exposed at the battlefield along the streambeds of Wilson's Creek, Skegg's Branch (Shuyler Creek), and Terrell Creek, except in the far south, where the streams have incised deeper to expose **Mrs**. The most accessible exposures are in and along Wilson's Creek at the Gibson's Mill Site and along the southern extent of the tour road just before it crosses Wilson's Creek.
	Reeds Spring Formation (**Mrs**)	**Mrs** is another gray limestone with chert nodules and marine invertebrate fossils.	**Mrs** is only exposed at the southern end of the battlefield boundary, along the Wilson's Creek streambed, and the confluence with Terrell Creek. The best observation point is where Wilson Rd/County Rd ZZ-4 crosses Wilson's Creek.

The Mississippian rocks are sedimentary, deposited in a shallow sea between 359 million and 347 million years ago, and contain marine fossils typical of limestone from this period (see the "Paleontological Resources" subsection). Within the battlefield, rock units crop out (are exposed at the surface; Figure 6) in the streambed, along the tour road, in areas where sinkholes have formed (see "Caves and Karst"), and in glades (dry areas with shallow soil and exposed bedrock). The glades at the battlefield are generally underlain by Burlington-Keokuk limestone (**Mbk**).

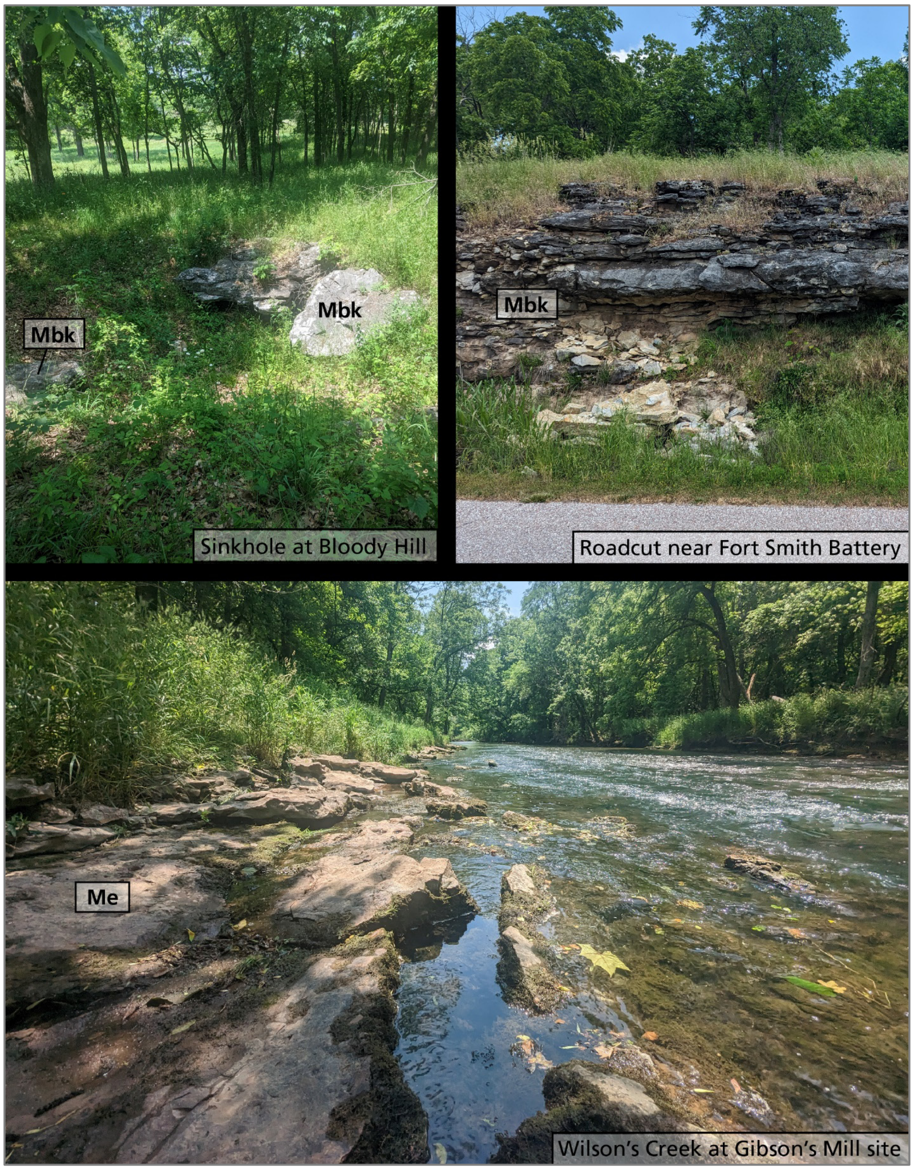

Figure 6. Photographs of bedrock outcrops. The battlefield is underlain by Mississippian-age limestone. The Burlington-Keokuk limestone (Mbk) accounts for most of the bedrock and can be observed in areas where sinkholes (top left photograph, taken at the historic sinkhole location) or erosion have exposed the bedrock and along the tour road (top right photograph, taken near the Fort Smith Battery). The stratigraphically lower Elsey Formation (Me) is exposed along the streambed of Wilson's Creek and some of its tributaries (bottom photograph, taken near the Gibson's Mill Site).
COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES

Paleontological Resources

Paleontological resources (fossils) are any evidence of life preserved in a geologic context (Santucci et al. 2009). They may be body fossils (any remains of the actual organism such as bones, teeth, shells, or leaves) or trace fossils (evidence of an organism's activity such as nests, burrows, tracks, or feces). Fossils may occur *in situ* (in rocks or unconsolidated deposits), in museum collections, or in other cultural contexts, such as building stone. Fossils are nonrenewable resources.

The Mississippian-age bedrock (**Mbk**, **Me**, **Mrs**) that underlies the battlefield and surrounding area contains marine invertebrate fossils that reflect the ancient shallow sea in which those rocks were deposited. Keen observers can spot fossils in areas where the bedrock is exposed, primarily fragments of crinoids, corals, and brachiopods (Figure 7). Fossils may also be present in the stone of the Ray Springhouse, which was constructed of **Mbk**; however, they have not been observed by the time of this report.

Pleistocene (2.58 million to 11,700 years ago) fossils may be present within the caves at the battlefield (Hunt et al. 2008) but have not been observed at the time of this report. Similar caves in the area, including a cave in Greene County (10.5 km [6.5 mi] away from the battlefield), have yielded fossil trackways, coprolites (fossil feces), and bones of extinct Pleistocene fauna (Hunt et al. 2008).

Collection of fossils from NPS land is illegal under the Paleontological Resources Preservation Act of 2009. The types of fossils (marine invertebrates) found at the battlefield are abundant in the region.

Figure 7. Photographs of fossils at the battlefield. Brachiopod and crinoid fossils are common in the limestone bedrock that underlies the battlefield. The top photograph is of a brachiopod (outlined) in the Elsey Formation (Me), taken on the edge of Wilson’s Creek near the Gibson’s Mill Site. A 9 cm (3.5 in) pocketknife is included for scale; between the fossil and the knife is an example of a chert nodule. The lower photograph shows a jumbled collection of crinoid fragments in the Burlington-Keokuk limestone (Mbk) and was taken at the abandoned quarry near the Ray House. The tip of a mechanical pencil provides scale. Top photograph: COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES; bottom photograph: COLORADO STATE UNIVERSITY / JOHN GRAHAM

Fluvial Features and Processes

Fluvial features at the battlefield include Wilson's Creek (Figure 8) and its minor—some of which originate as springs within the battlefield—and major tributaries, including named streams Terrell Creek and Skegg's Branch (Shuyler Creek) (see poster). Wilson's Creek originates in Springfield, and that urban setting drives the two main management concerns associated with Wilson's Creek: flooding and contamination. Flooding along Wilson's Creek is a concern as it causes bank erosion. Contamination of Wilson's Creek occurs on the macroscale—trash is washed downstream from the city during periods of high flow—and on the microscale, as toxicity threatens the water quality (Commonwealth Heritage Group and Sargent 2018). Resource managers may find the "Fluvial Geomorphology" chapter (Lord et al. 2009) of *Geological Monitoring* (Young and Norby 2009) useful.

Figure 8. Photograph of Wilson's Creek. View looking upstream at Wilson's Creek as it flows under the bridge at the southern extent of the tour road. Although the water quality is rated "impaired," the stream is generally clear, and visitors can see the bedrock of the Elsey Formation (Me) along the streambed. Bank erosion can be observed along the right side of the stream in the photo, which was taken in February 2024. COLORADO STATE UNIVERSITY / MATTHEW HARRINGTON

Water Quality

The water quality of Wilsons' Creek is classified as "impaired," and water samples have shown toxicity from unknown pollutants and bacteria (Commonwealth Heritage Group and Sargent 2018), as well as excessive levels of *E. coli* bacteria (National Park Service 2017). The flow of Wilson's

Creek is dependent on approximately 12 billion gallons (45.4 billion liters) of treated wastewater from Springfield, immediately northeast of the battlefield; intermittent improvements to the water treatment plant beginning in 1977 and most recently in 2016 have generally improved the water quality (Annis et al. 2011; Bowles 2010; National Park Service 2017), although it remains poor. Non-point sources of contamination, such as urban and agricultural runoff, also contribute to the impaired character of Wilson's Creek (Steidl-Pulley et al. 1998). An environmental assessment report from 2004 (Commonwealth Heritage Group and Sargent 2018) recommended using riparian buffers and vegetative filter strips along the watercourses and sources of runoff, respectively, to reduce the impact of non-point sources of contamination within the battlefield. As of this report, these have not been implemented.

Skegg's Branch and Terrell Creek are reported to have generally good water quality, although the upstream expansion of both cattle grazing and the city of Republic, immediately west of the battlefield, may be impacting Skegg's Branch in similar ways that Springfield impacts Wilson's Creek (Bowles 2010).

Flooding

Urban flooding, which occurs when rainfall in an urban area does not permeate into the ground because of the high number of impermeable surfaces associated with city infrastructure (e.g., roads and parking lots), is the main cause of flooding at the battlefield (Michael DeBacker, Heartland Network, December 4, conference call). Even modest-volume rainfall in Springfield translates into flashiness (increased frequency and rapidity of short-term changes in streamflow) at the battlefield (Richards and Johnson 2002). Floods exacerbate erosion and can pose a threat to cultural resources and park infrastructure. Floods originating in the Springfield area also carry large amounts of trash into the battlefield.

Climate change trends and predictions for the area include increased precipitation and an increased quantity and severity of storms, which could drive higher and more intense flooding (Gonzalez 2015). The NPS Climate Change Response Program prepared a report (Climate Change Response Program 2024) outlining the impacts of climate change on the battlefield under both the "Warm Wet" and "Hot Dry" possible climate futures. Both scenarios predict an increase in average temperatures and highly variable changes in precipitation, potentially leading to very wet and very dry years in the future. Because the baseflow of Wilson's Creek at the battlefield is effluent-dominated from the wastewater treatment plant in Springfield, low flow rates during dryer periods are somewhat mitigated by the constant discharge (Annis et al. 2011).

Springs

The landscape at the battlefield is 100% karst (Land et al. 2013; see the "Caves and Karst" section for more information), a statistic that reflects the abundance of soluble limestone and flowing groundwater and manifests itself in the presence of springs in and around the battlefield. Springs occur where water-bearing rock units intersect with the land surface. The GRI GIS data and poster include two springs within the battlefield boundaries: Double Spring, which feeds into Terrell Creek, and Campground Spring, which feeds into Skegg's Branch. There are several smaller springs that are not mapped as part of these data, including the spring where the Ray Springhouse is built (Figure 9; see poster). The recharge rate and groundwater flow rate in the region are rapid and flush out any contaminants relatively quickly; the groundwater quality in southern Missouri karst regions is superior to anywhere else in the state (Graham 2011).

Figure 9. Photograph of spring water flowing out of the Ray Springhouse. The springhouse was built into a hillside and has a curved roof and sides with a front and back wall. The water flows toward a small, unnamed drainage and continues to join Wilson's Creek near the Pulaski Arkansas Battery site. COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES

Rader Spring, which issues from the Burlington-Keokuk limestone outside of the battlefield boundary about 8 km (5 mi) southwest of Springfield, is the second largest spring in Greene County and contributes significantly to the flow of Wilson's Creek. Prior to the establishment of the wastewater treatment plant in Springfield, flow from Rader Spring was likely the primary reason that Wilson's Creek existed as a perennial stream (Doug Gouzie, Missouri State University, personal communication, 22 August 2024).

Hydrologic investigations, including dye tracing studies (Vineyard 1970), revealed that Rader Spring is the primary resurgence for groundwater captured in the Springfield area and likely beyond, although this has not been confirmed by dye tracing (Vineyard and Feder 1982). An interesting and unusual feature of the Rader Spring system is the abundance of estavelles, or reverse sinks (Vineyard and Feder 1982). These karst features are sinkholes that capture water during dryer periods but discharge water as springs during rainy seasons (Figure 10).

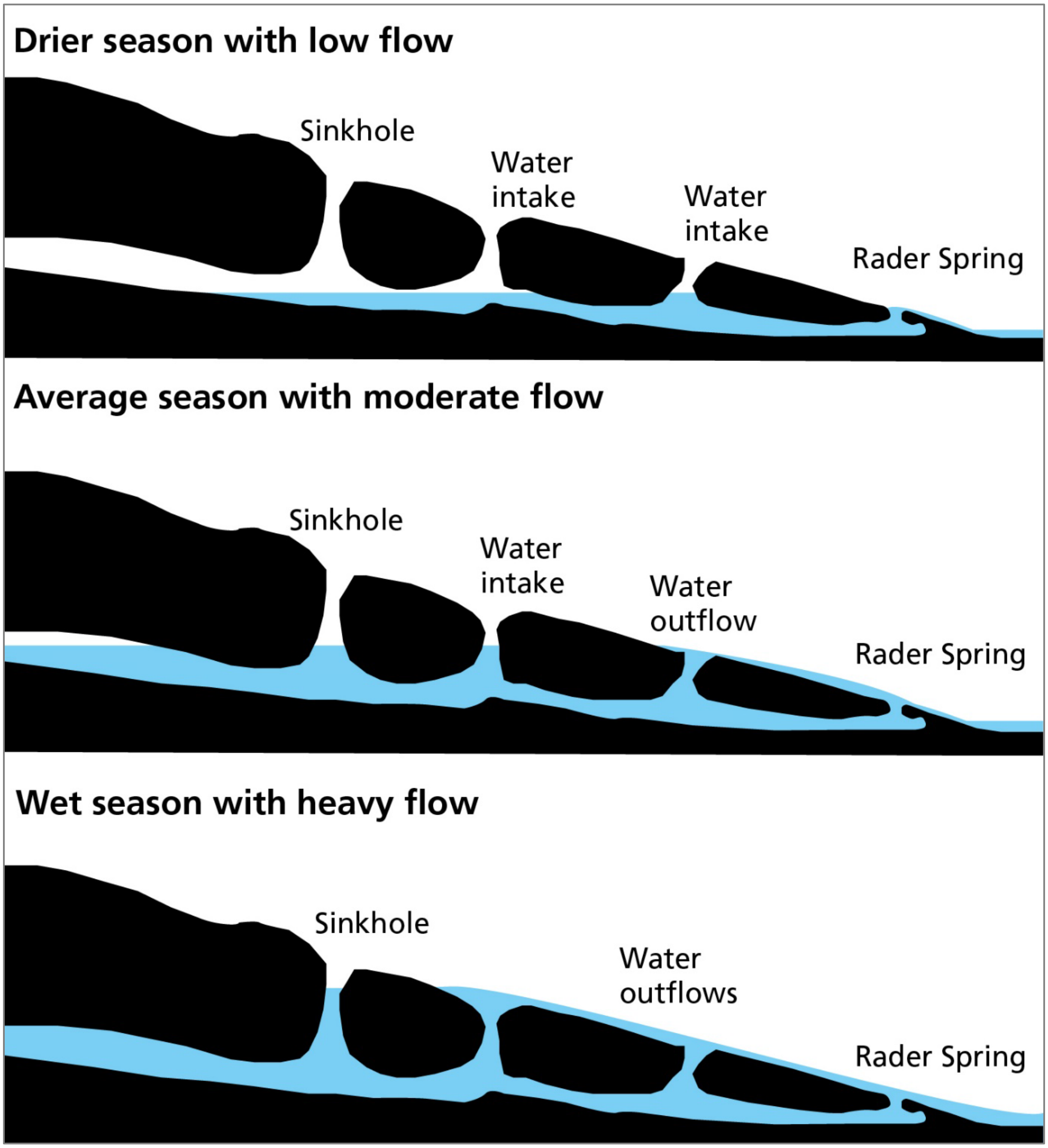

Figure 10. Generalized diagram of estavelles in the Rader Spring system. Changes in the level of the water table during wetter or dryer seasons cause sinkholes to alternate between water intakes and water outflows depending on their elevation in the spring system. Rader Spring is the “master spring” and remains a perennial spring. COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES, AFTER FIGURE 84 IN VINEYARD AND FEDER (1982)

Caves and Karst

Karst is a landscape that forms through the dissolution of soluble rocks, commonly carbonate rocks such as limestone or dolomite (Toomey 2009). Caves are naturally occurring underground voids, such as solutional caves (commonly associated with karst and formed through the dissolution of soluble rocks), lava tubes (tunnel-like caves in a lava flow after the lava has stopped flowing), sea caves (clefts or cavities in a sea cliff), talus caves (a void among collapsed boulders), regolith caves (formed by soil piping), and glacier caves (ice-walled caves) (Toomey 2009). The landscape at the battlefield is 100% karst (Land et al. 2013).

Caves occur in the region of the battlefield. The Federal Cave Resources Protection Act imposes civil and criminal penalties for harming a cave or cave resources and authorizes the government to regulate or restrict access to caves and their location information (see "Geologic Resource Laws, Regulations, and Policies"). Caves in the region—including at least one at the battlefield—are habitat for several species, including the bristly cave crayfish (*Cambarus setosus*) and the grotto salamander (*Eurycea spelaea*), which are classified as Missouri Species of Conservation Concern (Missouri Field Guide, https://mdc.mo.gov/field-guide, visited 31 July 2024), and the gray bat (*Myotis grisescens*), which is a state and federally listed endangered species. Bats are threatened by white-nose syndrome, which has no cure, is usually fatal, and can be spread inadvertently by visitors entering caves.

Sinkholes

Sinkholes, which are common in karst landscapes and form when the top of a cave or subterranean opening collapses inward, are the dominant geologic issue at the battlefield. Sinkholes vary in size and can form anywhere in a karst landscape, although they seem to form in areas where groundwater is rapidly replenished by surface water (Graham 2011). Sinkhole openings at the battlefield could threaten cultural resources and infrastructure, as well as pose a safety hazard to visitors and park staff.

At least three sinkholes have opened at the battlefield since 2011 (National Park Service 2017). Sigel's Sink, which opened between 2010 and 2011 near Sigel's Final Position, is less than 1 m (3 ft) in diameter (Graham 2011). Scoping participants observed Sigel's Sink in 2011, which has been covered by a metal grate and surrounded by a fence to protect visitors. Other sinkholes, like the one at Bloody Hill, were present at the time of the battle and are part of the interpretive material along the tour road.

Faults and Earthquakes

Faults are any fracture in the Earth's crust along which movement occurs. Earthquakes are produced when movement along fractures creates seismic waves and causes shaking. The inactive Battlefield Fault Zone, which includes the Sac River Battlefield Fault and an unnamed fault, intersects the northeast corner of the park (see poster). The nearest active faults are associated with the New Madrid Seismic Zone 350 km (217 mi) away in southeast Missouri, but anything short of a catastrophic quake in that region is unlikely to affect the area of the battlefield.

Disturbed Lands and Mining

Disturbed lands are those areas where the natural conditions and processes have been directly impacted by human activities such as mining, oil and gas production, development, agricultural practices, overuse, or inappropriate use. In a sense, the entirety of the battlefield has been “disturbed” by agricultural activity, historical development, and troop movements; however, these characteristics contribute to the historical landscape and views of the battlefield and are not “management issues” in the traditional sense. Southwest of the Ray House lies an abandoned quarry, which was active in the 1880s and is likely the source of the stone used for the Ray Springhouse.

Southwest Missouri has a history of mining beginning before the turn of the 20^{th} century, particularly for lead, iron, and zinc. There are several abandoned lead and zinc mines around Springfield to the northeast and Aurora to the southwest, but these do not present any management issues.

Geologic Hazards

The dynamic landscapes preserved at many National Park System units present a variety of natural hazards that pose a threat to NPS facilities, staff, and visitors. Many of these natural hazards are geologic in nature (e.g., volcanoes, earthquakes, and landslides). NPS Policy Memorandum 15-01 (Jarvis 2015) directs NPS managers and their teams to proactively identify and document facility vulnerabilities to climate change and other natural hazards. Table 3 summarizes the geologic hazards at the battlefield.

The GRI process identified sinkhole formation and flooding as the primary geologic hazards for the battlefield; however, the risk of infrastructure or resources being damaged by flooding is low. Other potential hazards at the battlefield include earthquakes associated with the New Madrid Seismic Zone (low hazard); shrink/swell soils, which occur when changes in moisture cause pronounced changes in soil volume (low hazard); and radon, which occurs from the natural breakdown of uranium in soil and rocks and emits carcinogenic particles (medium hazard). The “Guidance for Resource Management” and “Additional References, Resources, and Websites” chapters provide additional information and resources for managing and understanding these hazards.

Table 3. Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published US Geological Survey or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or NEPA analysis. Ground-disturbing activities should neither be approved nor denied based on the information here. This table is modeled after the Natural Hazard Checklist (see National Park Service 2015 and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the battlefield.

Hazard Type	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Earthquake	Potential Hazard	Falling objects Damage to and/or collapsing structures, including historical buildings such as the Ray House or Ray Springhouse Inoperability of building systems (e.g., water, power, sewer)	DOI Strategic Hazard Identification and Risk Assessment (SHIRA) Risk Mapper Report NPS GRI Scoping Summary (Graham 2011) International Building Code United State Geological Survey (USGS) Earthquake Probability Map Missouri Department of Natural Resources
Slope movements (landslide/avalanche)	Not applicable	Not applicable	Not applicable
Permafrost	Not applicable	Not applicable	Not applicable
Cave/karst	Known hazard	Sinkhole formation under infrastructure or resources Injury to visitors and/or park staff navigating difficult terrain	NPS GRI Scoping summary (Graham 2011) Missouri Department of Natural Resources USGS
Shrink/swell soils	Potential Hazard	Damage to structures “Heaving” of ground beneath structure	NPS Soil Resources Inventory Web Soil Survey Natural Resources Conservation Service (NRCS) Gridded Soil Survey Geographic (gSSURGO) data sets
Coastal storm surge/ sea or lake level change/shoreline erosion	Not applicable	Not applicable	Not applicable
Tsunami	Not applicable	Not applicable	Not applicable

Table 3 (continued). Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published US Geological Survey or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or NEPA analysis. Ground-disturbing activities should neither be approved nor denied based on the information here. This table is modeled after the Natural Hazard Checklist (see National Park Service 2015 and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the battlefield.

Hazard Type	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Riverine Flood	Known Hazard	Flooding (e.g., snowmelt, rainfall, etc.) Destruction of infrastructure Stream channel migration Stream bank erosion	Federal Emergency Management Agency (FEMA) Map Service Center Missouri geological survey DOI SHIRA Risk Mapper Report NPS GRI Scoping Summary (Graham 2011) Natural Resource Condition Assessment (Annis et al. 2011)
Flash Flood	Known Hazard	Sudden rising water (i.e., dry wash) Loss of life due to unexpected flooding Destruction of infrastructure	FEMA Map Service Center Missouri geological survey DOI SHIRA Risk Mapper Report NPS GRI Scoping Summary (Graham 2011) Natural Resource Condition Assessment (Annis et al. 2011)
Volcanic eruption	Not applicable	Not applicable	Not applicable
Hydrothermal activity	Not applicable	Not applicable	Not applicable
Radon	Known hazard	Health hazard	Missouri Department of Natural Resources EPA Map of Radon Zones

Guidance for Resource Management

This chapter provides information to assist resource managers in addressing geologic resource management issues and applying NPS policy. The compilation and use of natural resource information by park managers is called for in the 1998 National Parks Omnibus Management Act (§ 204), NPS 2006 Management Policies, and the Natural Resources Inventory and Monitoring Guideline (NPS-75).

Access to GRI Products

- GRI products (scoping summaries, GIS data, posters, and reports): http://go.nps.gov/gripubs
- GRI products are also available on the NPS DataStore accessed through the Integrated Resource Management Applications (IRMA) portal: https://irma.nps.gov/DataStore/Search/Quick. Enter "GRI" as the search text and select a park from the unit list.
- GRI GIS data model: http://go.nps.gov/gridatamodel
- Additional information regarding the GRI, including contact information: https://www.nps.gov/subjects/geology/gri.htm

Three Ways to Receive Geologic Resource Management Assistance

- Contact the GRD (https://www.nps.gov/orgs/1088/contactus.htm). GRD staff members provide coordination, support, and guidance for geologic resource management issues in three emphasis areas: (1) geologic heritage, (2) active processes and hazards, and (3) energy and minerals management. GRD staff can provide technical assistance with resource inventories, assessments, and monitoring; impact mitigation, restoration, and adaptation; hazards risk management; laws, regulations, and compliance; resource management planning; and data and information management.
- Formally request assistance at the Solution for Technical Assistance Requests (STAR) webpage: https://irma.nps.gov/Star/ (available on the Department of the Interior [DOI] network only). NPS employees (from a park, region, or any other office outside of the Natural Resource Stewardship and Science [NRSS] Directorate) can submit a request for technical assistance from NRSS divisions and programs.
- Submit a proposal to receive geologic expertise through the Scientists in Parks program (SIP; see https://www.nps.gov/subjects/science/scientists-in-parks.htm). Formerly the Geoscientists-in-the-Parks program, the SIP program places scientists (typically undergraduate students) in parks to complete science-related projects that may address resource management issues. Proposals may be for assistance with research, interpretation and public education, inventory, and/or monitoring. The GRD can provide guidance and assistance with submitting a proposal. The Geological Society of America and Environmental Stewards are partners of the SIP program. Visit the internal SIP website to submit a proposal

at https://doimspp.sharepoint.com/sites/nps-scientistsinparks (only available on DOI network computers).

Geological Monitoring

Geological Monitoring (Young and Norby 2009) 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. Chapters are available online at https://www.nps.gov/subjects/geology/geological-monitoring.htm.

Park-Specific Documents

The park's Foundation Document (National Park Service 2017), Natural Resource Condition Assessment (Annis et al. 2011), and Cultural Landscape Report/Environmental Assessment (Commonwealth Heritage Group and Sargent 2018) are primary sources of information for resource management within the battlefield boundaries. These documents guided the writing of this GRI report.

NPS Natural Resource Management Guidance and Documents

- National Parks Omnibus Management Act of 1998: https://www.congress.gov/bill/105th-congress/senate-bill/1693
- NPS-75: Natural Resources Inventory and Monitoring guideline: https://irma.nps.gov/DataStore/Reference/Profile/622933
- NPS Management Policies 2006 (Chapter 4: Natural Resource Management): https://www.nps.gov/subjects/policy/management-policies.htm
- NPS Natural Resource Management Reference Manual #77: https://irma.nps.gov/DataStore/Reference/Profile/572379
- Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager: https://irma.nps.gov/DataStore/Reference/Profile/2283597

Geologic Resource Laws, Regulations, and Policies

The following sections, which were developed by the GRD, summarize laws, regulations, and policies that specifically apply to NPS geologic resources, geologic processes, energy, and minerals. The first section summarizes law and policy for geoheritage resources, which includes caves, paleontological resources, and geothermal resources. The energy and minerals section includes abandoned mineral lands, mining, rock and mineral collection, and oil and gas operations. Active processes include geologic hazards (e.g., landslides), coastal processes, soils, and upland and fluvial processes (e.g., erosion). Laws of general application (e.g., Endangered Species Act, Clean Water Act, Wilderness Act, NEPA, or the National Historic Preservation Act) are not included, but the NPS Organic Act is listed when it serves as the main authority for protection of a particular resource or when other, more specific laws are not available.

Geoheritage Resource Laws, Regulations, and Policies

Caves and Karst Systems

Resource-specific laws:

- **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.

Resource-specific regulations:

- **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.

NPS Management Policies 2006:

- **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 the 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.

Geothermal

Resource-specific laws:

- **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.

Resource-specific regulations:

- **43 CFR Part 3200** requires BLM to include stipulations when issuing, extending, renewing, or modifying leases or permits to protect significant thermal features in NPS-administered areas (see 43 CFR §3201.10), prohibit the bureau from issuing leases in areas where geothermal operations are reasonably likely to result in significant adverse effects on significant thermal features in NPS-administered areas (see 43 CFR §3201.11 and §3206.11), and prohibit BLM from issuing leases in park units.

NPS Management Policies 2006:

- **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.

<u>Paleontological Resources</u>

Resource-specific laws:

- **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.
- **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.

Resource-specific regulations:

- **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** contains the DOI regulations implementing the Paleontological Resources Preservation Act, which apply to the NPS.

NPS Management Policies 2006:

- **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.

Energy and Minerals Laws, Regulations, and Policies

<u>Abandoned Mineral Lands and Orphaned Oil and Gas Wells</u>

Resource-specific laws:

- **The Bipartisan Infrastructure Law**, **Inflation Reduction Act**, and **NPS Line Item Construction** program all provide funding for the reclamation of abandoned mineral lands and the plugging of orphaned oil and gas wells.

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- None applicable.

<u>Coal</u>

Resource-specific laws:

- **Surface Mining Control and Reclamation Act (SMCRA) 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.

Resource-specific regulations:

- **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.

NPS Management Policies 2006:

- None applicable.

<u>Common Variety Mineral Materials (Sand, Gravel, Pumice, etc.)</u>

Resource-specific laws:

- **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.

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- **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 the 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.

Federal Mineral Leasing (Oil, Gas, and Solid Minerals)

Resource-specific laws:

- **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 Glen Canyon National Recreation Area, which is the only park unit that contains a STSA.
- **Exceptions:** Glen Canyon National Recreation Area (NRA) (16 USC § 460dd et seq.), Lake Mead NRA (16 USC § 460n et seq.), and Whiskeytown-Shasta-Trinity NRA (16 USC § 460q et seq.) authorize 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.

Resource-specific regulations:

- **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.
- 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 of coal from Indian Tribal and Allotted leases.
- **43 CFR Part 3160** governs onshore oil and gas operations, which are overseen by the BLM.

NPS Management Policies 2006:

- **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.

<u>Mining Claims (Locatable Minerals)</u>

Resource-specific laws:

- **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.

Resource-specific regulations:

- **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.

NPS Management Policies 2006:

- **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.

<u>Nonfederal Minerals other than Oil and Gas</u>

Resource-specific laws:

- NPS Organic Act, 54 USC §§ 100101 and 100751

Resource-specific regulations:

- **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 business operation (§ 5.3) or for construction of buildings or other facilities (§ 5.7), and to comply with the solid waste regulations at Part 6.

NPS Management Policies 2006:

- **Section 8.7.3** states that operators exercising rights in a park unit must comply with 36 CFR Parts 1 and 5.

<u>Nonfederal Oil and Gas</u>

Resource-specific laws:

- **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.)

Resource-specific regulations:

- **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 in parks outside of Alaska to:
    - Demonstrate valid right to develop mineral rights;
    - Submit an Operations Permit Application to NPS describing where, when, and how they intend to conduct operations;
    - Prepare/submit a reclamation plan; and
    - Submit financial assurance 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.

NPS Management Policies 2006:

- **Section 8.7.3** requires operators to comply with 9B regulations.

<u>Recreational Collection of Rocks and Minerals</u>

Resource-specific laws:

- **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).

Resource-specific regulations:

- **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 National Recreation Area.
- **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.

NPS Management Policies 2006:

- **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.

Transpark Petroleum Product Pipelines

Resource-specific laws:

- The **Mineral Leasing Act, 30 USC § 181** et seq., and the **Mineral Leasing Act for Acquired Lands, 30 USC § 351** et seq. authorize new rights of way across some federal lands for pipelines, excluding NPS areas.
- The only parks with the legal authority to grant new rights of way for petroleum product pipelines are:
    - Natchez Trace Parkway (16 USC §460a)
    - Blue Ridge Parkway (16 USC §460a-8)
    - Great Smoky Mountains National Park (P.L. 107-223 – 16 U.S.C. §403 notes)
    - Klondike Gold Rush National Historical Park (16 USC §410bb(c) (limited authority for the White Pass Trail unit)
    - Gulf Islands National Seashore—enabling act authorizes rights-of-way for pipelines for oil and gas transported across the seashore from outside the unit (16 USC §459h-3)
    - Gateway National Recreation Area—enabling act authorizes rights-of-way for gas pipelines in connection with the development of methane gas owned by the City of New York within the unit (16 USC §460cc-2(i))
    - Denali National Park—2013 legislation allows for issuance of right-of-way permits for a natural gas pipeline within, along, or near the approximately 7-mile segment of the George Parks Highway that runs through the park (Public Law 113–33)

Resource-specific regulations:

- NPS regulations at **36 CFR Part 14 Rights of Way**

NPS Management Policies 2006:

- **Section 8.6.4** states that new rights of way through, under, and across NPS units may be issued only if there is specific statutory authority and there is no practicable alternative.

Uranium

Resource-specific laws:

- **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.

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- None applicable.

Active Processes and Geohazards Laws, Regulations, and Policies

<u>Coastal Features and Processes</u>

Resource-specific laws:

- **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.

Resource-specific regulations:

- **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.

NPS Management Policies 2006:

- **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 putting new developments in areas subject to natural shoreline processes unless certain factors are present.

<u>Geologic Hazards</u>

Resource-specific laws:

- **National Landslide Preparedness Act, 43 USC §§ 3101–3104** strengthens the mandate to identify landslide hazards and reduce losses from landslides. Established the National Landslide Hazards Reduction Program. "… the United States Geological Survey and other Federal agencies, shall – identify, map, assess, and research landslide hazards;" Reduce landslide losses, respond to landslide events.

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- **Section 4.8.1.3**, Geologic Hazards
- **Section 9.1.1.5**, Siting Facilities to Avoid Natural Hazards
- **Section 8.2.5.1**, Visitor Safety
- **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.

<u>Soils</u>

Resource-specific laws:

- **Soil and Water Resources Conservation Act, 16 USC §§ 2001–2009** 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).

Resource-specific regulations:

- **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.

NPS Management Policies 2006:

- **Section 4.8.2.4** requires NPS to (1) prevent unnatural erosion, removal, and contamination; (2) conduct soil surveys; (3) minimize unavoidable excavation; and (4) develop/follow written prescriptions (instructions).

<u>Upland and Fluvial Processes</u>

Resource-specific laws:

- **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**).

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- **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.
- **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.

Additional References, Resources, and Websites

Missouri Geology

- Missouri Department of Natural Resources: https://dnr.mo.gov/land-geology

Climate Change Resources

- Intergovernmental Panel on Climate Change: http://www.ipcc.ch/
- NPS Climate Change Response Strategy (2023 Update): https://www.nps.gov/subjects/climatechange/response-strategy.htm
- NPS Green Parks Plan: https://www.nps.gov/subjects/sustainability/green-parks.htm
- NPS National Climate Change Interpretation and Education Strategy: https://www.nps.gov/subjects/climatechange/nccies.htm
- NPS Policy Memorandum 12-02—Applying NPS Management Policies in the Context of Climate Change: https://npspolicy.nps.gov/PolMemos/policymemoranda.htm
- NPS Policy Memorandum 15-01—Addressing Climate Change and Natural Hazards for Facilities: https://npspolicy.nps.gov/PolMemos/policymemoranda.htm
- U.S. Global Change Research Program: http://www.globalchange.gov/home

Days to Celebrate Geology

- Geologist Day—the first Sunday in April (marks the end of the winter and beginning of preparation for summer field work; formally celebrated in Ukraine, Kazakhstan, Belarus, Kyrgyzstan, and Russia)
- National Cave and Karst Day—6 June, also known as International Day of Caves and Subterranean World
- International Geodiversity Day—6 October: https://www.geodiversityday.org/
- Earth Science Week—typically the second full week of October: https://www.earthsciweek.org/
- National Fossil Day—the Wednesday of Earth Science Week: https://www.nps.gov/subjects/fossilday/index.htm

Disturbed Lands Restoration

- Geoconservation—Disturbed Lands Restoration: https://www.nps.gov/articles/geoconservation-disturbed-land-restoration.htm

Earthquakes

- Missouri Department of Natural Resources: http://dnr.mo.gov/land-geology/hazards/earthquakes

- ShakeAlert: An Earthquake Early Warning System for the West Coast of the United States (USGS sponsored): https://www.shakealert.org/
- USGS Did You Feel It? reporting system: https://earthquake.usgs.gov/data/dyfi/
- USGS Earthquake Hazards Program unified hazard tool: https://earthquake.usgs.gov/hazards/interactive/
- USGS ShakeMap: https://earthquake.usgs.gov/data/shakemap/

Geologic Heritage

- NPS America's Geologic Heritage: https://www.nps.gov/subjects/geology/americas-geoheritage.htm
- NPS Geoheritage Sites — Examples on Public Lands, Natural Landmarks, Heritage Areas, and The National Register of Historic Places: https://www.nps.gov/subjects/geology/geoheritage-sites-listing-element.htm
- NPS Museum Collection (searchable online database): https://museum.nps.gov/ParkPList.aspx
- NPS National Natural Landmarks Program: https://www.nps.gov/subjects/nnlandmarks/index.htm
- NPS National Register of Historic Places: https://www.nps.gov/subjects/nationalregister/index.htm
- NPS Stratotype Inventory: https://www.nps.gov/subjects/geology/nps-stratotype-inventory.htm
- UNESCO Global Geoparks: https://en.unesco.org/global-geoparks

Geologic Maps

- American Geosciences Institute (provides information about geologic maps and their uses): http://www.americangeosciences.org/environment/publications/mapping
- *General Standards for Geologic Maps* (Evans 2016)
- USGS MapView by National Geologic Map Database: https://ngmdb.usgs.gov/mapview
- USGS National Geologic Map Database: https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

Geological Surveys and Societies

- American Geophysical Union: http://sites.agu.org/
- American Geosciences Institute: http://www.americangeosciences.org/
- Association of American State Geologists: http://www.stategeologists.org/
- Geological Society of America: http://www.geosociety.org/
- Missouri Geological Survey: https://dnr.mo.gov/about-us/missouri-geological-survey

- US Geological Survey: http://www.usgs.gov/

NPS Geology

- NPS America's Geologic Legacy: http://go.nps.gov/geology. This primary site for information about NPS geology includes a geologic tour, news, and other information about geology in the NPS, and resources for educators and park interpreters.
- NPS Geodiversity Atlas: https://www.nps.gov/articles/geodiversity-atlas-map.htm. The NPS Geodiversity Atlas is a collection of park-specific webpages containing information about the park's geology and links to additional resources.
- NPS Geologic Resources Inventory: http://go.nps.gov/gri

NPS Reference Tools

- NPS Technical Information Center (TIC; repository for technical documents and means to receive interlibrary loans): https://www.nps.gov/orgs/1804/dsctic.htm
- GeoRef. The GRI team collaborates with TIC to maintain an NPS subscription to GeoRef (the premier online geologic citation database) via the Denver Service Center Library interagency agreement with the Library of Congress. Multiple portals are available for NPS staff to access these records. Park staff can contact the GRI team or GRD for access.
- NPS IRMA portal: https://irma.nps.gov/. *Note*: The GRI team uploads scoping summaries, maps, and reports to the DataStore on IRMA.

Relevancy, Diversity, and Inclusion

- NPS Office of Relevancy, Diversity, and Inclusion: https://www.nps.gov/orgs/1244/index.htm
- Changing the narrative in science & conservation: an interview with Sergio Avila (Sierra Club, Outdoor Program coordinator). Science Moab radio show/podcast: https://sciencemoab.org/changing-the-narrative/

Soils

- Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS): https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- WSS_four_steps (PDF/guide for how to use WSS): https://irma.nps.gov/DataStore/Reference/Profile/2305342.

USGS Reference Tools

- Geographic Names Information System (GNIS; official listing of place names and geographic features): http://gnis.usgs.gov/

- Geologic Names Lexicon (Geolex; geologic unit nomenclature and summary): http://ngmdb.usgs.gov/Geolex
- National Geologic Map Database (NGMDB): http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
- NGMDB Geochron Downloader: https://ngmdb.usgs.gov/geochron/
- Publications Warehouse: http://pubs.er.usgs.gov
- A Tapestry of Time and Terrain (descriptions of physiographic regions; Vigil et al. 2000): http://pubs.usgs.gov/imap/i2720/
- USGS Store (find maps by location or by purpose): http://store.usgs.gov

Literature Cited

These references are cited in this report. Contact the GRD for assistance in obtaining them.

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Bowles, D. E. 2010. Aquatic invertebrate monitoring at Wilson's Creek National Battlefield: 2005–2007 trend report. Natural Resource Technical Report NPS/HTLN/NRTR—2010/287. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/664206

Climate Change Response Program. 2024. Wilson's Creek National Battlefield climate futures summary. National Park Service. Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2304564

Commonwealth Heritage Group and Sargent, L. 2018. Wilson's Creek National Battlefield, Republic, Missouri, environmental assessment: implementation of cultural landscape report treatment recommendations. Prepared for National Park Service, Midwest Regional Office, Omaha, Nebraska. https://irma.nps.gov/DataStore/Reference/Profile/2252241

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