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Fort Larned National Historic Site

Geologic Resources Inventory Report

The quartermaster's storehouse (front) and arsenal/commissary (rear) buildings of Fort Larned, constructed from locally quarried sandstone of the Dakota Formation and Greenhorn Limestone. The open expanse of prairie beyond the buildings allowed soldiers at the fort ample time to spot approaching threats.

COLORADO STATE UNIVERSITY / MICHAEL BARTHELMES

Fort Larned National Historic Site: Geologic resources inventory report

Science Report NPS/SR—2024/125

Michael Barthelmes

Colorado State University Research Associate
National Park Service Geologic Resources Division
Geologic Resources Inventory
PO Box 25287
Denver, Colorado 80225

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

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Acknowledgements

The GRI team thanks the participants of the 2008 scoping meeting and 2021 follow-up meeting for their assistance in this inventory. The lists of participants (below) reflect the names and affiliations of those participants at the time of the meeting and call. Because the GRI team does not conduct original geologic mapping, we are particularly thankful to the Kansas Geological Survey for its maps of the area. This report and accompanying GIS data could not have been completed without them. Many gracious thanks to George Elmore (Fort Larned National Historic Site) for showing this author around the fort in 2021. Thanks to Rex Buchanan (Kansas Geological Survey) for review comments. Thanks to Shannon Fasola (University of Kansas) for a thoughtful and thorough review of the discussion of seismicity. Thank you to Justin Tweet and Forrest Smith of the Geologic Resources Division for reviewing parts of this report.

Scoping Participants

Rex Buchanan (Kansas Geological Survey)

Nick Callaghan (Kansas Geological Survey and Data Access and Support Center [DASC])

Tim Connors (NPS Geologic Resources Division)

Katie KellerLynn (Colorado State University)

Rolfe Mandel (University of Kansas and Kansas Geological Survey)

Kevin McMurry (Fort Larned National Historic Site)

Lisa Norby (NPS Geologic Resources Division)

Bob Sawin (Kansas Geological Survey)

Follow-up Meeting Participants

Michael Barthelmes (Colorado State University)

Heather Brown (Tallgrass Prairie National Preserve)

Rex Buchanan (Kansas Geological Survey)

Chris Buczko (NPS Geologic Resources Division)

Anthony Capizzo (The Nature Conservancy)

Tim Connors (NPS Geologic Resources Division)

Victoria F. Crystal (NPS Geologic Resources Division)

Thom Curdts (Colorado State University)

George Elmore (Fort Larned National Historic Site)

Kristen Hase (Tallgrass Prairie National Preserve)

Tim Henderson (NPS Geologic Resources Division)

Kyle W. Hinds (NPS Geologic Resources Division)

Kurt Edwardson (Tallgrass Prairie National Preserve)

Darin L. McCullough (Tallgrass Prairie National Preserve)

Rebecca Port (NPS Geologic Resources Division)

Justin Tweet (NPS Geologic Resources Division)

Report Review

Rolfe Mandel (Kansas Geological Survey)

Bob Sawin (Kansas Geological Survey)

George Elmore (Fort Larned National Historic Site)

Report Editing

Suzanne McKetta (Colorado State University)

Report Formatting and Distribution

Michael Barthelmes (Colorado State University)

Rebecca Port (NPS Geologic Resources Division)

Cullen Scheland (NPS Geologic Resources Division)

Source Maps

William (Bill) Johnson (Kansas University)

Terri Woodburn (Park University)

GRI GIS Data Production

Georgia Hybels (Colorado State University)

Stephanie O'Meara (Colorado State University)

GRI Poster Design

Lucas Chappell (Colorado State University)

Thom Curdts (Colorado State University)

Kajsa Holland-Goon (Colorado State University)

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.

Fort Larned National Historic Site (referred to as the "historic site" throughout this report) preserves the original and reconstructed buildings of a United States military fort in Kansas, which operated from 1859 to 1884. The fort served as a permanent outpost on the Santa Fe Trail, operating as a guardian of post and commerce between Missouri and New Mexico. A second unit of the historic site, about 9 km (5.5 mi) south of the fort, preserves an unbroken tract of prairie with visibly entrenched wagon ruts from the Santa Fe Trail.

The westward acquisition of territories following the Mexican American War (1846–1848) and the gold rushes of 1849 and 1858 greatly increased traffic along the Santa Fe Trail. The indigenous peoples of the plains, seeing their way of life and very existence threatened, responded by attacking travelers and raiding commerce and mail shipments. The US Army set up a series of military posts to provide protection and escort for the Santa Fe Trail. In 1859, a temporary camp six miles west of the junction of the Pawnee and Arkansas Rivers was established, and in May 1860, the sod-and-adobe fort was named Fort Larned for the US Army Paymaster-General Colonel Benjamin F. Larned.

The decision to move the location upstream was based on the landscape and geologic resources of the Pawnee River valley. The location took advantage of the river's meandering characteristics to form natural defenses. The fort is bordered on two sides by the Pawnee River and on a third side by the deep trench of an abandoned meander channel. The fourth side of the fort faces a flat, open expanse of the river valley, which provided ample warning of any approaching enemies.

As the army became increasingly concerned about the threat of a large-scale war, the sod-and-adobe buildings of the fort were replaced with stone structures between 1865 and 1868. The building stone was sourced from local bedrock exposed in the slopes on the side of a hill two miles east bordering the river valley. The Greenhorn Limestone and the sandstone of the Dakota Formation, both originally deposited during the Cretaceous Period between 145 million and 65 million years ago when the area was covered by shallow seas, were quarried and used to construct the fort buildings. Fossil clam shells in the Greenhorn Limestone recall a time when the landscape of Kansas looked very different from that experienced by soldiers at the fort or visitors to the historic site.

This report is supported by a GRI-compiled map of the geology of Fort Larned National Historic Site. The source map used to compile the GRI GIS data was completed by the Kansas Geological Survey in 2015.

This report contains the following chapters:

Introduction to the Geologic Resources Inventory—This chapter provides background information about the GRI, highlights 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 historic site 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 historic site, 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 fort placement and the locally quarried building stone used in historic structures.

Geologic History—This chapter describes, in the form of a geologic time scale, 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 historic site and discusses any potential resource management issues associated with those features and processes. Issues include (1) disturbed lands, such as local quarries, sand and gravel extraction from rivers, and historic wells; (2) energy development, including the impact of wind turbines and power lines on the historic viewscape; (3) eolian features and processes; (4) fluvial features and processes associated with the Pawnee River drainage; (5) paleontological resources in the building stone; (6) seismicity, which has become increasingly common as a result of oil-field activity in Kansas and Oklahoma; (7) the entrenched Santa Fe Trail wagon ruts; and (8) a table summarizing risks posed by geologic hazards at the historic site.

Guidance for Resource Management—This chapter is a follow up to the "Geologic Features, Processes, and Resource Management Issues" chapter. It provides resource managers with a variety of ways to find and receive management assistance with geologic resources. Also provided are a list of laws, regulations, and NPS policies that specifically apply to geologic resources in the National Park System. The NPS Geologic Resources Division can provide policy assistance and technical expertise regarding the historic site's geologic resources.

Additional References, Resources, and Websites—This chapter provides a thorough list of additional sources of information (e.g., websites, tools, publications, organizations) that may be useful to further explore the topics presented in this report.

Literature Cited—This chapter 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.

Introduction to the Geologic Resources Inventory

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.

GRI Products

The GRI team—which is a collaboration between the GRD of the NPS and Colorado State University's Department of Geosciences—completed the following tasks as part of the GRI process for Fort Larned National Historic Site (referred to as the "historic site" throughout this report): (1) conducted a scoping meeting and provided a scoping summary (KellerLynn 2008), (2) provided geologic map data in a geographic information system (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 Integrated Resource Management Applications (IRMA) portal (see "NPS Reference Tools"). Information provided in GRI products is not a substitute for site-specific investigations. Ground-disturbing activities should neither be permitted nor denied based upon 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 scale (Johnson and Woodburn 2015; 1:50,000) and US National Map Accuracy Standards, geologic features represented in the GRI are horizontally within 25 m (82 ft) of their true locations.

Scoping Meeting

On 14 May 2008, the NPS held a combined scoping meeting for the historic site and for Tallgrass Prairie National Preserve in Cottonwood Falls, Kansas. The scoping meeting brought together historic site staff and geologic experts, who reviewed and assessed available geologic maps, developed a geologic mapping plan, and discussed geologic features, processes, and resource management issues to be included in the final GRI report. A scoping summary (KellerLynn 2008) summarizes the findings of that meeting.

GRI GIS Data

Following the scoping meeting, the GRI team compiled the GRI GIS data for the historic site. 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 1). 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. The GRI GIS data for the historic site was compiled from the following source map:

Surficial geology of Pawnee County, Kansas; text, geologic-unit descriptions, and cross-section geology by C.M. Phillips-Lander (Johnson and Woodburn 2015)

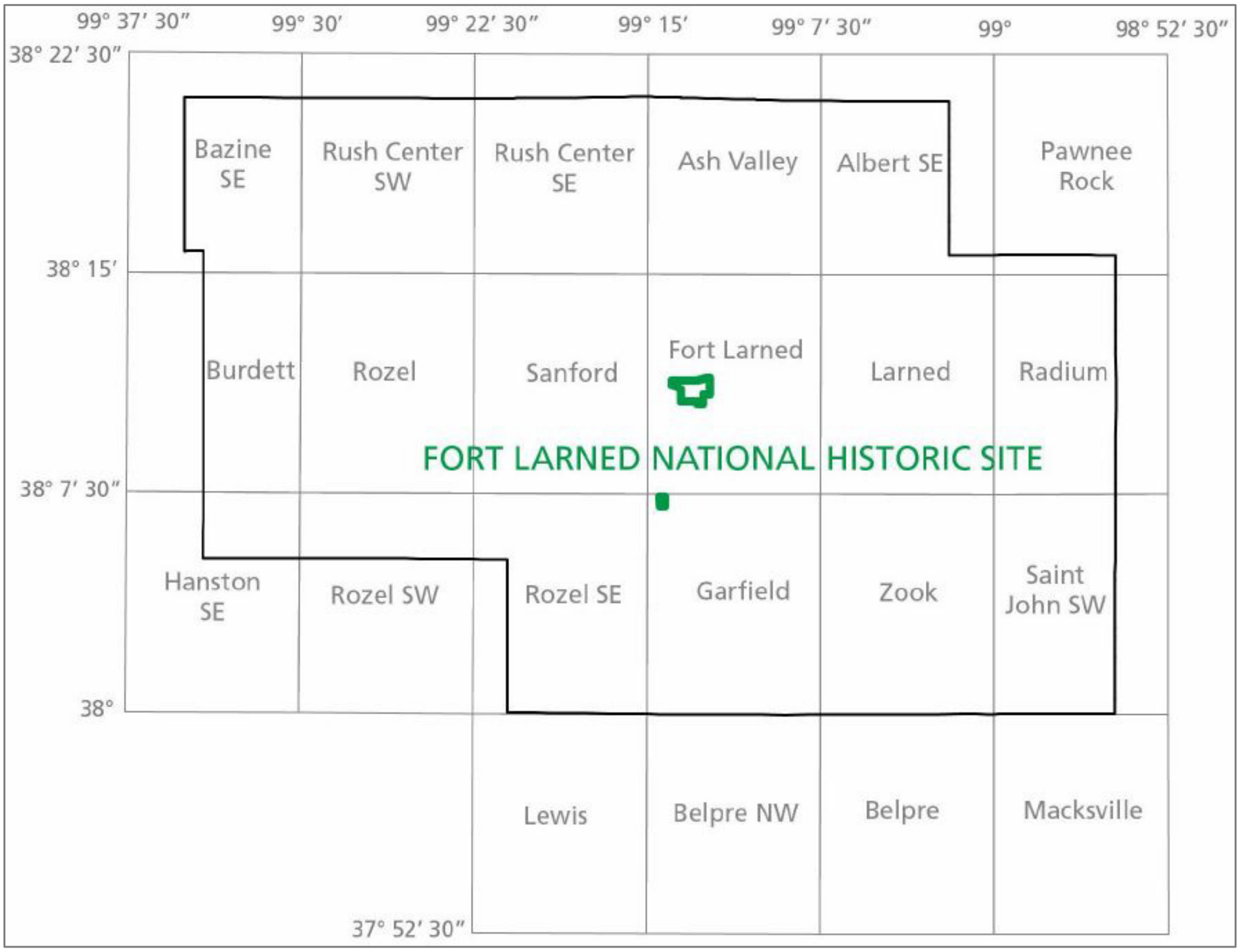

Figure 1. Index map of the GRI GIS data for Fort Larned National Historic Site. This map shows the extent of the GRI GIS data in the context of 7.5-minute quadrangles. The data extends beyond the boundaries of both units of the historic site, in the Fort Larned and Garfield quadrangles, to cover the entirety of Pawnee County and provide regional geologic context. Index map by Lucas Chappell and Stephanie O'Meara (Colorado State University).

GRI Poster

A poster of the GRI GIS data draped over a shaded relief image of the historic site 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 8 December 2021, the GRI team hosted a combined follow-up meeting for both Tallgrass Prairie National Preserve and the historic site staff and interested geologic experts. The meeting provided an opportunity to get back in touch with park staff, introduce "new" (since the 2008 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 a culmination of the GRI process. It synthesizes discussions from the scoping meeting in 2008, the follow-up conference call in 2021, 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 writing reflects the data and interpretation of the source map author. Information from the historic site's foundation document (National Park Service 2017) and the foundation document for the Santa Fe National Historic Trail (National Park Service 2021) was also included where applicable to the historic site's geologic resources and resource management.

Geology is a complex science with many specialized terms. This report provides definitions of geologic terms at first mention, typically in parentheses following the term. In addition, 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 Dakota Formation mapped in the historic site has the map symbol **Kd**. Capital letters indicate age and the following lowercase letters symbolize the unit name. "**K**" represents the Cretaceous Period (~145.0 million to 66.0 million years ago) and "**d**" represents Dakota Formation. A geologic time scale, which lists all the map units in the historic site, is provided as a table in this report.

Geologic Heritage

Geologic heritage (also called "geoheritage") encompasses the significant geologic features, landforms, and landscapes characteristic of our nation, which are preserved for the full range of values that society places on them, including scientific, aesthetic, cultural, ecosystem, educational, recreational, tourism, and other values. This chapter highlights the geologic features, landforms, landscapes, and stories of the historic site valued for their geologic heritage qualities. It also draws connections between geologic resources and other park resources and stories.

Currently, the United States has no comprehensive national registry that includes all geoheritage sites, but all NPS areas possess at least some aspect of geologic heritage, and many of them are worthy of conservation for the benefit of present and future generations. Although park units are not currently established with geoheritage values in mind, any geologic component of a park's enabling legislation, planning, and management documents can be considered as a part of America's geoheritage. Geoheritage sites generally have great potential for scientific studies, use as outdoor classrooms, and enhancing public understanding and enjoyment. Such sites are fundamental to understanding dynamic earth systems, the succession and diversity of life, climatic changes over time, the evolution of landforms, and the origin of mineral deposits.

Historic Site Background and Establishment

The historic site, consisting of two units about 3 km (5 mi) apart in central Kansas, was established by Congress and signed into law by President Lyndon B. Johnson on 31 August 1964 to preserve, protect, and interpret "the original structures and landscape of Fort Larned, as well as remains of the Santa Fe [National Historic] Trail, commemorating the significant role they played in opening the American West (National Park Service 2017, p.6)." Then-Congressman Bob Dole (R-KS) introduced the enabling legislation with Senator Frank Carlson (R-KS) and remained an outspoken advocate through his time in the Senate. In 2022, the historic site welcomed 26,219 recreational visitors (Ziesler and Spalding 2023).

The fort was established in 1859 as one of several military posts constructed to provide protection and escort service for travelers on the Santa Fe Trail. The trail was a commercial highway connecting Missouri to Santa Fe, New Mexico from 1821 to 1880. The trail fell out of use with the expansion of the rail system, and traffic virtually ceased when the first locomotive reached Santa Fe (National Park Service 2021). In 1884, the buildings and land were sold at auction and existed as a privately-owned ranch until it became a national historic site. Today, the historic site preserves and interprets the original character of the fort between 1860 and 1884, a period that includes the American Civil War and "Western Front Indian Wars" eras (National Park Service 2017).

The historic site is located just east of the interface of the Smoky Hills and Arkansas River Lowlands physiographic regions (Figure 2), in the floodplain of the Pawnee River. The river and an oxbow (abandoned bend in the river channel) formed natural defenses for the wall-less fort. The river valley is made up of Quaternary (2.6 million years ago to present) alluvial sediments—gravel, sand, silt, and clay—underlying the floodplain (**Qal**) and terraces (**Qt1**) and with higher ground blanketed in fine, windblown, sediment known as loess (**Ql**). Underlying the Quaternary sediments, the bedrock is

Cretaceous (145 million to 66 million years ago) shale and limestone (**Kc**, **Kgg**, **Kd**). Greenhorn Limestone (**Kgg**) and sandstone of the Dakota Formation (**Kd**) were quarried to construct the stone buildings of the fort.

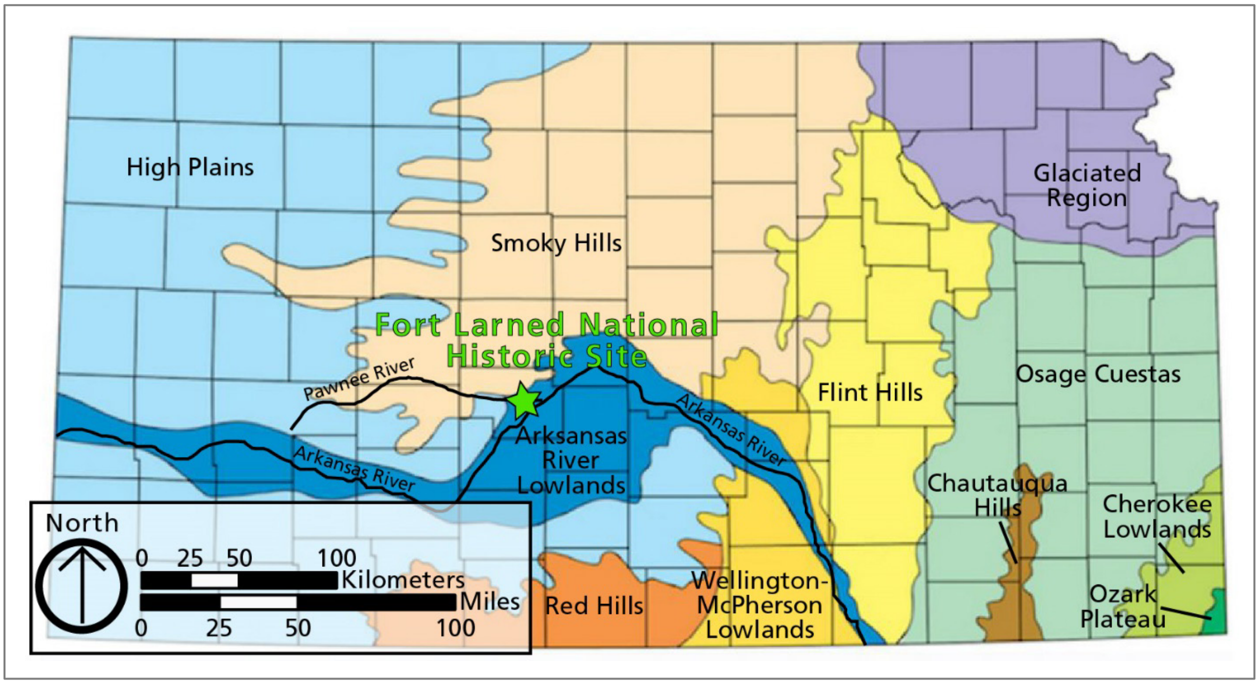

Figure 2. Map of the physiographic regions of Kansas. The historic site exists at the meeting of the Pawnee and Arkansas Rivers, and the meeting of the Smoky Hills, Arkansas River Lowlands, and High Plains regions.

The historic site's foundation document (National Park Service 2017) justifies the designation as a unit of the national park system with the following significances:

- Historic Fort Buildings and Setting
- Protecting the Santa Fe Trail and Westward Expansion
- Hub of Cultural Interchange

Although none of these values explicitly mention geology, this chapter about geologic heritage explores the connection between geology, the historic site's cultural story, and the value placed upon them.

Geologic Heritage Sites and Conservation

In 2015, the NPS's GRD staff, in cooperation with the American Geosciences Institute, published a booklet introducing the American experience with geoheritage, geodiversity, and geoconservation: "America's Geologic Heritage: An Invitation to Leadership" (National Park Service and American Geosciences Institute 2015). This publication introduces key principles and concepts of America's geoheritage, which are the focus of ongoing collaboration and cooperation on geologic conservation in the United States.

Geologic heritage connections at the historic site include the strategic placement of the fort near the Pawnee River for defense and water supply, the presence of Santa Fe Trail wagon ruts, and the use of local bedrock (**Kgg**, **Kd**) to construct the fort buildings. The following table (table 1) presents connections between some of the historic site's historic and cultural resources with its geologic resources.

Table 1. Geoheritage connections at Fort Larned.

Historical Site Resource	**Geoheritage Connections**
Fort placement	The placement of the fort was strategic, using the natural landforms as defenses against potential enemies. The Pawnee River borders the fort on two sides, and an abandoned meander, or oxbow, borders a third. The fourth side of the fort faces the flat, open river valley. Those natural landforms are the result of the river's erosional and depositional processes acting on the landscape over time. The nearby accessibility of building stone may have also influenced the fort's placement.
Santa Fe Trail wagon ruts	The wagon ruts, embedded in the thick loess (**Ql**), preserve the path of travelers on the Santa Fe Trail.
Building stone	The Cretaceous bedrock that was used as building stone contains evidence of past life in the form of Inoceramid clam shells and presents the opportunity for interpretation of a time when "Kansas" was under a shallow tropical sea.

Geoheritage sites are conserved so that their lessons and beauty will remain as a legacy for future generations. Such areas generally have great potential for scientific studies, use as outdoor classrooms, and the ability to enhance public understanding and enjoyment. Geoheritage sites are fundamental to understanding dynamic earth systems, the succession and diversity of life, climatic changes over time, the evolution of landforms, and the origin of mineral deposits.

Geologic History

This chapter describes the geologic events that formed the present landscape of the historic site and surrounding area. The geologic history reflected in the GRI GIS data can generally be grouped into three events: sedimentary bedrock deposition during the Cretaceous Period, Rocky Mountain fluvial outwash deposition during the Neogene Period, and the ongoing erosion and reworking of those deposits during the Quaternary Period (Table 2). During the Cretaceous Period (145 million to 66 million years ago), the area was inundated with a shallow sea (Figure 3). Near-shore and marine sedimentary rocks (**Kd**, **Kgg**, **Kc**) were deposited. During the Neogene Period (23 million to 2.6 million years ago), the Ogallala Formation was deposited as uplift in the Rocky Mountains to the west triggered erosion and outwash of large amounts of sediments to the Great Plains. During the Quaternary Period (the last 2.6 million years), streams and wind have reworked those sedimentary rocks. Table 3 describes the GRI GIS map units, the geologic events they are associated with, and where they are mapped in relation to the historic site.

Table 2. 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. Boundary ages follow the International Commission on Stratigraphy (2022). Colors correspond to United States Geological Survey (USGS) suggested colors for geologic maps. Letters in parentheses are abbreviations for geologic time units. The Periods are further divided into Epochs; tables in this section of the report put the geologic units of the park into the context of these Periods. The oldest rocks included in the GRI GIS data are from the Cretaceous Period (K) of the Mesozoic Era.

Era	Period	Millions of Years Ago
Cenozoic	Quaternary (Q)	2.6–today
	Neogene (N)	23.0–2.6
	Paleogene (PG)	66.0–23.0
Mesozoic	Cretaceous (K)	145.0–66.0
	Jurassic (J)	201.3–145.0
	Triassic (TR)	251.9–201.3
Paleozoic	Permian (P)	298.9–251.9
	Pennsylvanian (PN)	323.2–298.9
	Mississippian (M)	358.9–323.2
	Devonian (D)	419.2–358.9
	Silurian (S)	443.8–419.2
	Ordovician (O)	485.4–443.8
	Cambrian (C)	538.8–485.4
Precambrian [A]	n/a	~4,600–538.8

[A] Precambrian is an informal name representing all geologic time before the Cambrian Period; it is not a formal era.

Figure 3. Paleogeographic map of North America during the Cretaceous Period. The bedrock that underlies central Kansas is sedimentary rock that was deposited during the Cretaceous Period (145 million to 66 million years ago), when Earth's climate was much warmer and a shallow sea covered the interior of the proto-North American continent. The sea varied in depth over the almost 80 million years of the Cretaceous, and the rocks being deposited reflect those changes. Sandstones, like those of the Dakota Formation, are deposited in shallower water while shales and limestones, including the Greenhorn Limestone, are deposited in deeper water. More recently, during the Quaternary Period (2.6 million years ago to present), the sedimentary bedrock of Kansas has been covered in windblown sand and glacial loess. The bedrock is now exposed primarily on slopes and in valleys where streams incise and rework surficial deposits. Paleogeographic map by Ron Blakey, North American Key Time Slices © 2013 Colorado Plateau Geosystems Inc., used under license with annotation by Michael Barthelmes (Colorado State University).

Table 3. Bedrock and surficial geologic units in the GRI GIS data. The units underlying the historic site are relatively modern (Quaternary Period, younger than 2.6 million years); however, older bedrock units underly the historic landscape and in some cases were used in construction of the fort buildings. The oldest units included in the GRI GIS data were deposited in the Cretaceous Period (145 million to 66 million years ago); the units are presented here stratigraphically. Unless otherwise noted, all information is from Johnson and Woodburn (2015).

Period [A]	Geologic Unit	Description	Geologic Events	Locations
Quaternary (2.6 million years ago to today)	Alluvium (**Qal**)	Thick (20–42 m [65–138 ft]) deposits of sand, gravel, silt, and clay. The **Qal** mapped along the Pawnee River valley has an upper layer that consists primarily of fine-grained alluvium. **Qal** associated with the Arkansas River consists of a relatively thin mantle of fine-grained alluvium above sand and gravel.	Alluvium is actively being deposited along river and stream valleys as sediments are transported from upstream.	The Pawnee and Arkansas Rivers streambeds, as well as the oxbow lake feature, are mapped as **Qal**. Other active streams and drainages included in the park boundary are also mapped as **Qal**.
	Upland intermittent lake (playa) deposits (**Qp**)	Shallow basins ranging in size from less than an acre to tens of acres. The basins form from a combination of wind deflation, animal activity, and dissolution, and are filled with redeposited silt and fine sand. The average thickness of **Qp** in the basins is 2 m (6 ft).	The processes creating **Qp** are ongoing, and the deposits are typically less than 20,000 years old.	**Qp** is mapped in the upland loess deposits (Ql) to the north and south of the historic site. **Qp** is not mapped within the boundaries of the historic site.
	Eolian dune sand (**Qds**)	Sand dunes composed of fragments of quartz, silt, and clay derived from the Arkansas River valley are present to the south of the Arkansas River. The dunes are grass-covered and largely inactive. **Qds** deposits can be as thick at 15 m (50 ft).	The sand dunes formed at least 30,000 years ago and have gone through many cycles of reactivation. Some of the sand dunes have been stabilized by vegetation.	**Qds** is mapped extensively to the south and east of the historic site, across the Arkansas River, but not within the historic site boundaries.
	Active sand (**Qas**)	Areas within the dunes (**Qds**) that are actively being reworked and redeposited by wind.	Sand dunes that are not stabilized by vegetation susceptible to erosion and remobilization of the sand.	Active sand is mapped in a few small areas within the dune sand unit (**Qds**)
	Sheet sand (**Qss**)	Sheet sands are older remnants of dunes that are flatter and have developed thick soil.	Sand that was included in the sediment washed out from the Rocky Mountains and has been eroded from the local bedrock was transported by wind and formed dunes in the areas south and east of the Arkansas River. **Qss** represents sand dunes that have been stabilized by vegetation and have formed an upper layer of soil.	**Qss** is mapped extensively to the south and east of the historic site, across the Arkansas River, but not within the historic site boundaries.

[A] Colors correspond to USGS suggested colors for geologic maps. Boundary ages follow the International Commission on Stratigraphy (2022).

Table 3 (continued). Bedrock and surficial geologic units in the GRI GIS data. The units underlying the historic site are relatively modern (Quaternary Period, younger than 2.6 million years); however, older bedrock units underly the historic landscape and in some cases were used in construction of the fort buildings. The oldest units included in the GRI GIS data were deposited in the Cretaceous Period (145 million to 66 million years ago); the units are presented here stratigraphically. Unless otherwise noted, all information is from Johnson and Woodburn (2015).

Period [A]	Geologic Unit	Description	Geologic Events	Locations
Quaternary (2.6 million years ago to today) (continued)	Loess (**Ql**)	Very fine particles of windblown sediment derived from the valley floors of rivers and the Ogallala Formation (**No**). **Ql** deposits range in thickness from 2–3 m (6–10 ft).	Loess forms when large amounts of unconsolidated fine sediment, primarily silt, are carried and deposited by wind. The surficial loess included in the GRI GIS data was deposited between about 23,000 and 12,000 years ago (Bettis et al. 2003).	Ql is mapped on the hills to the north of the fort and included in the park boundary. The Santa Fe Wagon Ruts Site is mapped entirely as **Ql**.
	Terrace valley fill, upper (**Qt1**)	Alluvial fill derived from weathered sedimentary rocks, including fragments of the Greenhorn Limestone (**Kgg**), Carlile Shale (**Kc**), and Dakota Formation (**Kd**), is deposited along streams.	Between 2,000 and 500 years ago, the Pawnee River incised into the existing floodplain (Mandel 1994), leaving those deposits to form **Qt1** and establishing the modern stream valley.	Most of the “fort” area of the Historic Site is built on **Qt1**.
	Terrace valley fill, lower (**Qt2**)	Alluvial fill derived from weathered sedimentary rocks, including fragments of the Greenhorn Limestone (**Kgg**), Carlile Shale (**Kc**), and Dakota Formation (**Kd**), is deposited along streams.	Terraces represent former floodplains that have since been incised into as rivers and streams establish new floodplains. **Qt2** was likely deposited between 9,000 and 5,000 years ago (Mandel 1994).	**Qt2** is mapped at higher elevations above the Pawnee River valley floor to the west of the historic site along Sawmill Creek.
Neogene (23 million to 2.3 million years ago)	Ogallala Formation (**No**)	The Ogallala Formation is made up of silt, sand, and gravel that were transported by streams from the Rocky Mountains.	The Ogallala Formation was deposited as an episode of tectonic uplift in the Rocky Mountains delivered massive amounts of outwash sediments to the Great Plains (Willett et al. 2018). These sediments were deposited as braided streams, with coarser sands and gravels in channels and finer sand and silt as overbank flood deposits. The sediments of the Ogallala Formation buried much of the landscape over 15 million years of deposition and set the stage for the ongoing Quaternary erosion and reworking that represents the modern landscape.	**No** occurs extensively throughout the High Plains of North America; however, in the GRI GIS data, **No** only appears at the far southwestern extent and is not mapped within historic site boundaries.

[A] Colors correspond to USGS suggested colors for geologic maps. Boundary ages follow the International Commission on Stratigraphy (2022).

Table 3 (continued). Bedrock and surficial geologic units in the GRI GIS data. The units underlying the historic site are relatively modern (Quaternary Period, younger than 2.6 million years); however, older bedrock units underly the historic landscape and in some cases were used in construction of the fort buildings. The oldest units included in the GRI GIS data were deposited in the Cretaceous Period (145 million to 66 million years ago); the units are presented here stratigraphically. Unless otherwise noted, all information is from Johnson and Woodburn (2015).

Period [A]	Geologic Unit	Description	Geologic Events	Locations
Cretaceous (145 million to 66 million years ago)	Carlile Shale (**Kc**)	The Fairport Chalk Member of the Carlile Shale, the only member that is mapped in Pawnee County, is fossiliferous and made up of shale, chalk, and chalky limestone.	The shales, chalks, and limestones of the Carlile Shale were deposited in the shallow sea that covered parts of North America during the middle and late Cretaceous.	**Kc** crops out north of the Pawnee River valley along stream valleys. **Kc** is not mapped within the historic site boundaries.
	Greenhorn Limestone and Graneros Shale, undivided (**Kgg**)	The Greenhorn Limestone and Graneros Shale are poorly exposed and undifferentiated. The fossiliferous fencepost limestone bed is located near the top of the Greenhorn Limestone Formation.	The layered shales and limestones of **Kgg** were deposited in the shallow sea that covered parts of North America during the middle and late Cretaceous. Limestone forms by the accumulation of calcium carbonate ($CaCO_3$) shells and skeletons of organisms; fossil clam shells (*Inoceramus*) are present in the Greenhorn Limestone.	**Kgg** is mapped in the uplands to the north and south of the Pawnee River valley, primarily along stream beds. Although it is not mapped within the historic site boundaries, **Kgg** was quarried and used as building stone in constructing the fort.
	Dakota Formation (**Kd**)	The Dakota Formation made up of yellow and brown sandstone, sandy clay, and clay. The sandstone exposures are generally ripple-marked and cross-bedded.	The sands and clays of the Dakota Formation were deposited in the early Cretaceous as beaches and rivers draining into the nascent Cretaceous interior seaway. Ripple marks and crossbedding provide evidence of the depositional environment.	**Kd** underlies most of Pawnee County and crops out in isolated locations near Burdett, Garfield, and Larned. Although the formation is primarily sandy clay and clay, the outcrops, which form bluffs and benches, are dominated by blocky sandstone. **Kd** was not mapped in the park but was quarried from bluffs near Larned and is the primary building stone used in the fort.

[A] Colors correspond to USGS suggested colors for geologic maps. Boundary ages follow the International Commission on Stratigraphy (2022).

Geologic Features, Processes, and Resource Management Issues

The geologic features and processes highlighted in this chapter are significant to the historic site's landscape and history. Selection of these features and processes was based on input from scoping and conference-call participants, analysis of the GRI GIS data, and research of the scientific literature and NPS reports.

Some geologic features, processes, or human activities may require management for human safety, protection of infrastructure, and 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 with the features and processes that they are associated with. Geologic hazards in the historic site are summarized at the end of this chapter.

Since scoping in 2008, the NPS has completed a foundation document (National Park Service 2017) and a natural resource condition assessment (Struthers et al. 2014) for the historic site, as well as a foundation document for the Santa Fe National Historic Trail (National Park Service 2021). Because these documents are primary sources of information for resource management, they were used to draw connections between geologic features and "core components" such as "fundamental resources and values."

Disturbed Lands

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 historic site preserves disturbed lands—the fort is a development constructed of quarried bedrock, and the wagon ruts are a permanent impression of a travel corridor.

Modern land disturbance occurs primarily outside of the NPS boundaries but is a management concern for the historic site. Greenhorn limestone (**Kgg**) is quarried northwest of the historic site, and the Dakota Formation (**Kd**) is quarried in Larned (Figure 4). A more pressing concern is the potential for sand and gravel extraction, which already occurs in the Arkansas River southeast of the historic site, to occur in the Pawnee River valley upstream of the historic site. Such extraction would impact the sediment load of the Pawnee River, damaging the riparian habitat, which is already rated as "non-functional and of significant concern" (Struthers et al. 2014, p. 161). Similarly, a sediment check dam downstream of the historic site is currently keeping the riparian habitat at an artificially stable state, and the potential removal of said dam could trigger rapid incision and bank instability (Martin and Wagner 2016). See the "Fluvial Features and Processes" section of this chapter for more information. All of these operations are outside of the NPS boundaries but have the potential to impact environments within the historic site.

Figure 4. Photographs of Cretaceous bedrock quarries. Quarries, an example of disturbed lands and geologic heritage features near the historic site, are both an historical feature and an ongoing process. The photograph on the left shows a modern quarry of Greenhorn Limestone (**Kgg**) northwest of the fort; the photograph on the right is of a Dakota Formation (**Kd**) sandstone quarry in the town of Larned. Both types of rock were used in constructing the fort buildings: Dakota Formation sandstone for the wells and walls and Greenhorn Limestone for the lintels and sills. Photographs by Bob Sawin (Kansas Geological Survey).

Historic water wells exist in the park, lined with sandstone from the Dakota Formation (**Kd**). The wells are currently capped (i.e., not operating). Sandstone blocks of the Dakota Formation were cut into curved blocks to line the wells. Conference call participants expressed interest in developing interpretive material about the wells.

Energy Development

The landscape and weather of Kansas make the area a prime location for wind energy development. Construction of wind turbines or associated transmission lines near the historic site would impact the historic viewshed and threaten the fundamental resource and value of "Setting/Cultural Landscape," which specifically identifies "the generally open, undisturbed rural setting surrounding the fort" (National Park Service 2017, p.8). The Grain Belt Express, an ongoing multi-state transmission project, includes planned construction of power lines to the west of the historic site.

Gas wells surround the historic site (KellerLynn 2008). The Kansas Geological Survey maintains a database of oil and gas activities in the state (https://www.kgs.ku.edu/PRS/petroDB.html, accessed 28 August 2023). The historic site is situated immediately south of the Fort Larned field which contains 18 natural gas wells that were drilled between 1973 and 1981; all but one well are listed as "plugged and abandoned." According to the Kansas Geological Survey database, the well closest to the historic site boundary has been converted to saltwater disposal, although at depths (500 m to 600 m [1600 ft to 2000 ft]) unlikely to affect groundwater salinity levels.

The Eddy field, between the fort and the wagon ruts, consists of 38 oil and gas wells. Thirty-three have been plugged and abandoned, converted to saltwater disposal or injection, or are otherwise inactive. Five are currently producing oil, as of 2023. The small Elkmeier field, adjacent to the north of the wagon ruts site, consists of plugged and abandoned wells.

Eolian Features and Processes

Eolian refers to windblown erosion, transportation, and deposition of sediments (Lancaster 2009). Features created by eolian processes may include depositional landforms and deposits such as dunes, loess, and sand sheets (sand that is too large, or wind velocity too low, for dunes to form), as well as erosional forms.

Loess, or fine-grained windblown sediment (mostly silt), forms extensive deposits across the Midwest and dates to the late Pleistocene (about 190,000 years ago to 11,700 years ago; Maat and Johnson 1996; Bettis et al. 2003). The hills to the north and south of the Pawnee River valley are blanketed with loess (**Ql**), including the Santa Fe Trail Ruts Site of the historic site. To the southeast of the historic site, across the Arkansas River, the landscape consists almost entirely of eolian sediments that form dunes (**Qds**) and sheet sands (**Qss**), or older remnants of dunes that have formed a thick layer of soil. These sand features, which are mostly farmed, increase in age further south and east from the river (Bob Sawin, Kansas Geological Survey, scoping meeting, 14 May 2008).

Fluvial Features and Processes

Fluvial features and processes are related to flowing water in rivers and streams. Fluvial processes are the main driver of landscape evolution in the historic site. Fluvial features in the historic site include the active Pawnee River channel, an abandoned oxbow feature, and an abandoned channel of the Pawnee River. Outside of the historic site boundaries but situated between the fort and the trail ruts is another former channel of the Pawnee River, which is now occupied by an intermittent stream, Sawmill Creek.

The historic site's foundation document (National Park Service 2017, p. 8) includes "gallery forest along the banks of the Pawnee River, a remnant oxbow, (and) riparian areas" as aspects of the "setting/cultural landscape" fundamental resource or value. Resource managers may find the "fluvial geomorphology" chapter (Lord et al. 2009) of *Geological Monitoring* (Young and Norby 2009) useful.

Oxbow

The Pawnee River is a meandering stream, meaning the river is composed of a single channel that winds its way snakelike across the landscape, so that the channel length (distance the stream flows) is substantially greater than the valley length ("as the crow flies"). A feature of meandering streams is the formation of oxbows (Figure 5). The bends of a meander will migrate via flooding and erosion until only a thin neck of land separates them. During floods or other high-flow events, the river may breach the neck of land and the flow will bypass the meander entirely, leaving a bend-shaped body of water known as an oxbow lake. These oxbow lakes may be partially or entirely filled in with sediments that wash or blow in over land. The oxbow at the historic site is dry and partially filled in (Figure 6).

The oxbow feature was important in the placement of the wall-less fort. Along with the deep channels (4.5 to 7.6 m [15 to 25 ft]; Martin and Wagner 2016) of the active channel of the Pawnee River, these features formed natural barriers on three of the four sides of the fort. Any enemies would have been forced to approach from the south, where they could have been seen at a distance across the flat expanse of the Pawnee River valley.

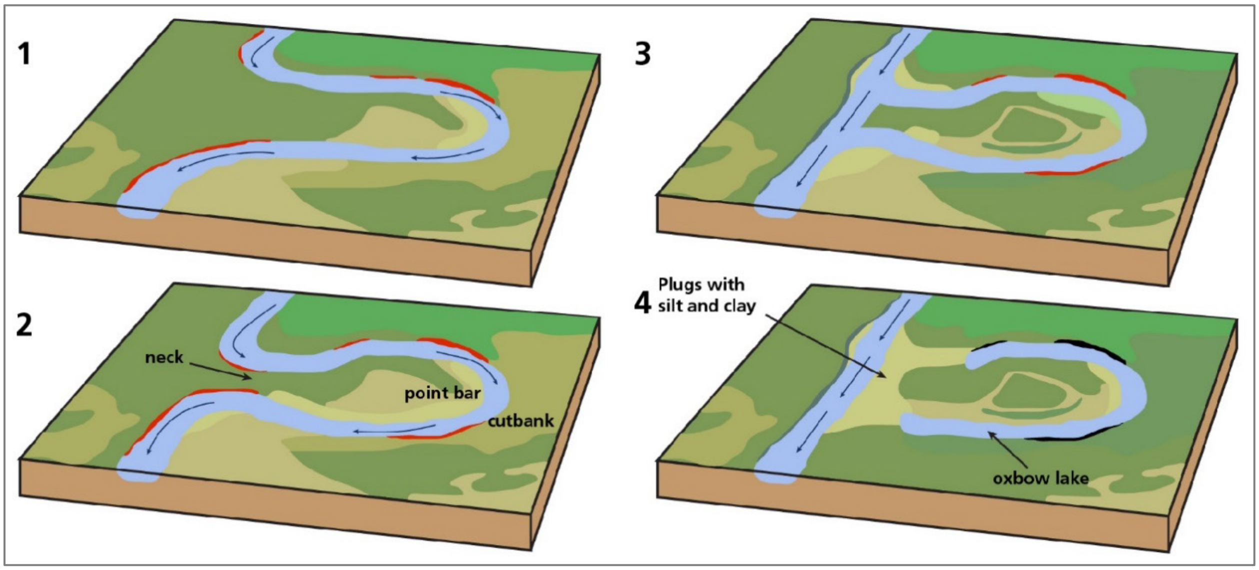

Figure 5. Graphic of meandering river with oxbow formation. In this series of four diagrams showing the evolution of a meandering stream, the "neck" of the meander becomes narrower until a flood causes the river to breach the gap and close off the neck. Sediment (silt and clay) slowly plugs the up- and down-stream sides of the cutoff meander, creating an oxbow lake to the side of the new flow path. Subsequent floods may inundate the oxbow, accumulating sediment. In the case of the Pawnee River at Fort Larned, the stream flow and water table are low enough that the "lake" is a dry oxbow. NPS graphic by Phil Reiker.

Figure 6. Photographs of oxbow feature at Fort Larned. Two photographs of the oxbow feature from different vantage points. The upper photograph looks at the fort from across the oxbow, emphasizing the width and depth of the trench that provided a natural defensive barrier. The lower photograph is an aerial view with the visible section of the oxbow shaded in gray. The Pawnee River, visible between the trees, provided the natural defense for two more sides of the fort. The red-and-white circle shows the position on the oxbow "neck" where the upper photograph was taken. Top photograph by Michael Barthelmes (Colorado State University) in 2021; lower photograph by the National Park Service in 2014, annotated by Michael Barthelmes (Colorado State University).

Riparian Condition

The historic site is just upstream from the eastern end of the Pawnee River drainage basin where it flows into the Arkansas River (Figure 2). The modern riparian area of the Pawnee River at Fort

Larned was rated as being in “nonfunctional” condition in a 2016 assessment by Martin and Wagner. The report cited the “lack of connection between the stream channel and the local water table” (Martin and Wagner 2016, p.v) resulting in an inability of the channel to support perennial vegetation and aquatic and wetland habitat. Water wells along the Pawnee River valley have lowered the water table below the riverbed so that precipitation now moves from the stream to the aquifer (Jenkins and Pabst, 1977). Additionally, pumping and surface water diversions have reduced the flow of the Pawnee River (Mandel 1994). Local residents reported that prior to the development of pump irrigation, the Pawnee River flowed continuously (Mandel 1994). However, the USGS gaging station at Rozel, which is about 20 km [12 mi] upstream of the historic site, commonly reports extended periods of no flow. Now, the river only flows for short periods during and immediately after precipitation (Figure 7).

Figure 7. Photographs of the Pawnee River. A combination of pump irrigation and erosion control dams along tributaries results in extended periods of no flowing water in the Pawnee River, as seen in the left photograph taken in April 2008. However, during and immediately after precipitation, the Pawnee River fills with water and sediment. The right photograph was taken in June 2021, shortly after a summer thunderstorm. Left picture by Bob Sawin (Kansas Geological Survey); right picture by Michael Barthelmes (Colorado State University).

A sediment check dam 150 m (500 ft) downstream of the historic site boundary is affecting the character of the Pawnee River at the historic site, holding the riparian system at an artificially stable early successional state (Martin and Wagner 2016). The dam results in low velocity flow and diminished erosive power with an accumulating wedge of sediment stretching upstream from the dam to the historic site. Removal of the dam, whether through catastrophic failure or intentionally, without management of the accumulated sediment would result in rapid incision of the Pawnee River, potentially threatening bridge foundations and buried utilities (Martin and Wagner 2016).

Flooding

Although the fort grounds flooded historically, modern levees and historical irrigation ditches prevent and mitigate modern flooding (George Elmore, Fort Larned National Historic Site, chief ranger, conference call, 8 December 2021). The two highest magnitude floods occurred in 1951 and

1935, and by the mid-1960s, the frequency of high-flow events began to diminish with the lowering of the water table (Martin and Wagner 2016). Despite the decreased frequency, flooding is still possible at the fort following intense rainstorms.

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. All fossils are nonrenewable resources.

A paleontological inventory of the Southern Plains Network (Tweet et al. 2015) found no *in situ* paleontological resources within the historic site. Both the fort and the wagon ruts units exist on Quaternary sediments (**Qt1**, **Ql**) and no bedrock is exposed within the historic site boundaries. A detailed study of the Pawnee River valley (Mandel 1994) sampled cores that penetrated the valley fill sediments beneath the upper terrace (**Qt1**) that the fort is built on. That study found a buried paleosol (a former surface that developed soil before being buried) with the potential for cultural and paleontological resources. A pollen sampling study in 1973 (Scott 1977) found ephedra, conifer, and angiosperm pollen, along with shells and cultural artifacts. The pollen and shells illustrate the potential for additional discoveries if further pollen investigations are conducted at the historic site (Tweet et al. 2015).

The early Late Cretaceous (95 million to 90 million years ago) Dakota Formation (**Kd**) and Greenhorn Limestone (**Kgg**) quarried outside of the historic site was used in the fort's construction. The Dakota Formation (**Kd**) is the primary building stone used in constructing the fort, and a fossil leaf impression was found in a sandstone block that is most likely the Dakota Formation (**Kd**) in 2013 (Tweet et al. 2015). The Greenhorn Limestone (**Kgg**) is fossiliferous, and fossil clam shells (*Inoceramus*) are present in the building stone as lintels, sills, and blocks (Figure 8). These fossils could be included in interpretive materials.

Figure 8. Photographs of fossil clams in building stone. The fort and the wagon ruts exist on thick accumulations of unconsolidated sediments; any in situ paleontological resources are deeply buried and remain undiscovered. However, the Greenhorn Limestone (**Kgg**) bedrock that was used as sills, lintels, and other “filler” material in the building of the fort does contain many fossil clam shells (*Inoceramus*). The photograph on the left is of a loose piece of Greenhorn Limestone used as a doorstop behind officer’s row. The photograph on the right is a close-up of a shell in a door sill. Left photo by Michael Barthelmes (Colorado State University); right photograph by Bob Sawin (Kansas Geological Survey).

Seismicity

The 2008 scoping summary (KellerLynn 2008) identified the risk of seismic activity affecting the historic site as “low.” Although this is generally true, when the subject was discussed 13 years later as part of the follow-up meeting, Rex Buchanan (Kansas Geological Survey, conference call, 8 December 2021) explained that “things have changed a lot since 2008” (Figure 9). Prior to 2013, Kansas rarely had more than one or two felt earthquakes in a given year. In 2014, this number dramatically increased to an average of four earthquakes larger than magnitude 3 per year (Rubinstein et al. 2018). The increase in seismic activity was primarily seen in southern Kansas (Harper and Sumner counties), less than 160 km (100 mi) from the historic site, and has been attributed to the injection of large volumes of saltwater (coproduced during oil and gas extraction) deep into the bedrock (e.g., Langenbruch et al. 2018; Rubinstein et al. 2018; Zhai et al. 2020). During the rise of seismicity in 2014, a MW 4.9 earthquake occurred in southern Kansas (170 km [106 mi] from the historic site), the largest recorded earthquake in Kansas, which cracked plaster, threw items from shelves, and did structural damage to some buildings of unreinforced masonry (Choy et al. 2016; Hearn et al. 2018).

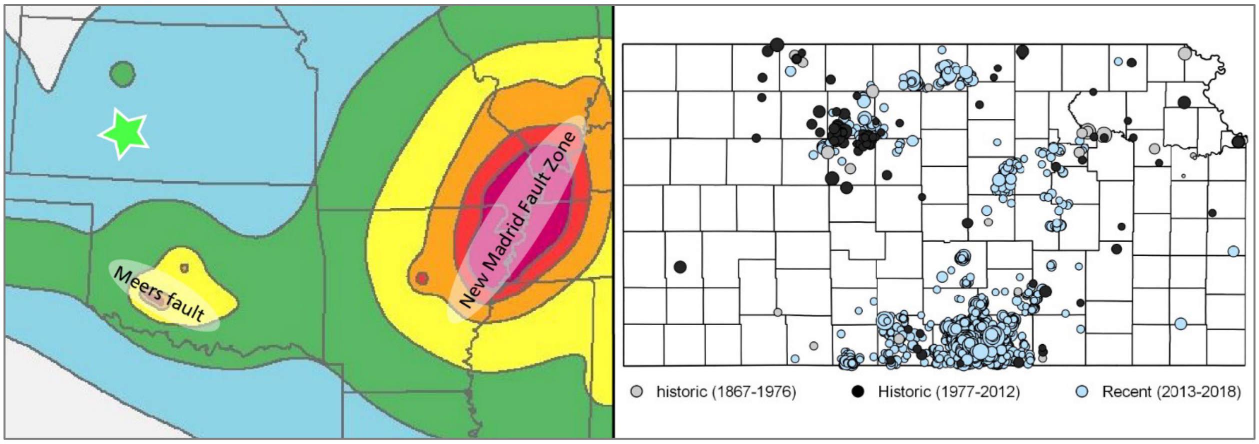

Figure 9. Seismic hazard map of central United States and earthquake map of Kansas. The left map is a portion of the 2018 long-term national seismic hazard map (US Geological Survey, https://www.usgs.gov/media/images/2018-long-term-national-seismic-hazard-map; accessed 27 February 2023), with the historic site location marked by a green star. Blue indicates almost no hazard; red indicates greater hazard. The historic site is far enough from the New Madrid Fault Zone and the Meers fault to be low risk. The right map of historic and recent earthquakes in Kansas (Kansas Geological Survey, https://www.kgs.ku.edu/Geophysics/Earthquakes/overview.html; accessed 27 February 2023) shows a recent (2013–2018; blue circles) increase in seismic activity in Kansas. Peterie et al. (2018) tied this to increased fluid injection in Oklahoma and Kansas, and Fasola et al. (2022) linked seismic activity to injection sites up to 90 km (55 mi) away. Fault labels and historic site location were added by Michael Barthelmes (Colorado State university).

While the historic site is within 50 km (30 mi) of 18 large volume injection wells (injecting over and average of 50,000 barrels per month) and injection-induced seismicity has been associated with earthquakes up to 90 km (55 mi) away from regions with high-rate disposal wells in Kansas (Peterie et al. 2018; Fasola et al. 2022), the historic site is located in a region of Kansas that has not seen an uptick in earthquakes. In fact, no earthquakes have been located within the historic site, nor within about a 50 km (30 mi) radius. Damage to structures within the historic site has not been directly correlated to seismic activity.

The Kansas Geological Survey maintains an interactive map of recent earthquakes, which may be of interest and use for resource managers at the historic site (see “Guidance for Resource Management”). In addition, the “Monitoring Seismic Activity” chapter (Braile 2009) in *Geological Monitoring* (Young and Norby 2009) discusses the relevance and rationale for seismic monitoring and provides information on vital signs and methods.

Santa Fe Trail Wagon Ruts

The entrenched historical wagon ruts unit to the south of the fort are a distinctive geoheritage resource. The wagon ruts are a remnant of the Santa Fe Trail traffic and are also a part of the Santa Fe National Historic Trail. The Trail’s foundation document includes route segments and historic sites—both aspects of Fort Larned National Historic Site—among the fundamental resources and values of the historic site (National Park Service 2021). Separate from the fort unit of the historic site, the wagon ruts are somewhat difficult to access (dirt country roads) and have only a small interpretive sign and elevated viewing structure (Figure 10). There is potential for more interpretative material through either the historic site or the trail.

Figure 10. Photograph of historic Santa Fe Trail wagon ruts. Located a short drive south of the historic fort on the loess (**Ql**) blanketed hills, an undisturbed area of prairie preserves entrenched wagon ruts of the Santa Fe National Historic Trail. The photograph on the left shows a piece of the Greenhorn Limestone—aptly nicknamed “fencepost limestone”—marking the area where visitors can observe the wagon ruts. To the left of the post in the distance is the wooden viewing platform, which provides a better angle to see the wagon ruts. The photograph on the right shows the wagon ruts, marked with red dashed lines. Photographs by Michael Barthelmes (Colorado State University).

The historic site excludes plowing, although prairie dog populations are notoriously nonchalant about NPS rules and regulations and could threaten the resource. Prairie dogs are an important part of a prairie ecosystem, both as prey and through grazing and burrowing (Struthers et al. 2014), meaning that a more robust prairie dog community is beneficial aside from the potential threat to the wagon ruts. In 2023 the Inventory and Monitoring Division conducted an inventory of the prairie dogs and the locations of their active burrow entrances across the Santa Fe Trail Ruts parcel.

Summary of Geologic Hazards

The dynamic landscapes preserved at many national park units present a variety of natural hazards that threaten 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. For the historic site, the primary geologic hazards identified during the GRI process are earthquakes and flooding. Table 4 summarizes the geologic hazards at the historic site.

Table 4. Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS, NPS, 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 National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2023 and Jarvis 2015). It is meant to provide general information to identify the full range of geologic hazard-based risks for the historic site.

Hazard Type	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Earthquake	**Potential Hazard**	Falling objects. Collapsing structures.	International Building Code United State Geological Survey (USGS) Earthquake Probability Map Kansas geological survey hazard maps NPS Technical Support Peterie et al. 2018 Fasola et al. 2022
Slope movements (landslide/avalanche)	Not applicable	Not applicable	Not applicable
Permafrost	Not applicable	Not applicable	Not applicable
Cave/karst	Not applicable	Not applicable	Not applicable
Shrink/swell soils	**Potential Hazard**	Damage to structure “heaving” of ground beneath structure	Kansas Geological Survey NPS Soil Resources Inventory Web Soil Survey Natural Resources Conservation Service (NRCS) Gridded Soil survey Geographic (gSSURGO) datasets NPS Technical Support
Coastal storm surge/ sea or lake level change/shoreline erosion	Not applicable	Not applicable	Not applicable

Table 4 (continued). Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS, NPS, 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 National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2023 and Jarvis 2015). It is meant to provide general information to identify the full range of geologic hazard-based risks for the historic site.

Hazard Type	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Tsunami	Not applicable	Not applicable	Not applicable
Riverine Flood	**Potential Hazard**	Flooding (i.e., snowmelt, rainfall, etc.) Destruction of infrastructure. Stream channel migration. Stream bank erosion.	Federal Emergency Management Agency (FEMA) Map Service Center State geological surveys NPS Technical Support
Flash Flood	**Potential Hazard**	Sudden rising water (i.e., dry wash) Loss of life due to unexpected flooding Destruction of infrastructure	Federal Emergency Management Agency (FEMA) Map Service Center State geological survey NPS Technical Support
Volcanic eruption	Not applicable	Not applicable	Not applicable
Hydrothermal activity	Not applicable	Not applicable	Not applicable
Radon	**Potential Hazard**	Health hazard	Kansas radon program Kansas Geological Survey EPA Map of Radon Zones NPS Technical Support

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 through the NPS Integrated Resource Management Applications (IRMA) portal: https://irma.nps.gov/. 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.

Assistance with Coastal and Climate Change-Related Issues

The GRD Coastal Geology program (https://www.nps.gov/subjects/geology/coastal-geology.htm) and the NPS Water Resources Division, Ocean and Coastal Resources program (https://www.nps.gov/orgs/1439/oceans.htm) share responsibility for assisting park managers with resource issues in 88 coastal parks across 23 states. Topics of interest include beach and coastal landforms, shoreline materials, dynamic coastal processes, engineering in the coastal environment, and coastal geohazards.

Park managers may benefit from the following NPS guidance and databases for managing coastal resources, including planning for the impacts of climate change:

- The NPS *Coastal Adaptation Strategies Handbook* (Beavers et al. 2016) provides guidance about climate change adaptation to coastal park managers. Focus topics of the handbook include NPS policies relevant to climate change; guidance on evaluating appropriate adaptation actions; and adaptation opportunities for planning, incident response, cultural resources, natural resources, facilities and assets, and infrastructure. The handbook also provides guidance on developing communication and education materials about climate change impacts and details case studies of the many ways that park managers are implementing adaptation strategies for threatened resources throughout the National Park System.
- The NPS *Ocean and Coastal Park Jurisdiction Handbook* (National Park Service 2016) guides coastal resource management by providing insight for parks with boundaries that may shift with changing shorelines.
- The NPS *Cultural Resources Climate Change Strategy* (Rockman et al. 2016) connects climate science with historic preservation planning and is related to coastal resource management and planning. The strategy identifies and describes seven options for climate change adaptation of cultural resources and cultural landscapes: (1) no active intervention, (2) offset stress, (3) improve resilience, (4) manage change, (5) relocate or facilitate movement, (6) document and prepare for loss, and (7) interpret the change.
- The “Coastal Features and Processes” chapter (Bush and Young 2009) of *Geological Monitoring* (Young and Norby 2009) discusses vital signs for monitoring the following coastal features and processes: (1) shoreline change, (2) coastal vegetation cover, (3) wetland position/acreage, and (4) coastal wetland accretion.

Historic Site-Specific Documents

The historic site's Foundation Document (National Park Service 2017), Natural Resource Condition Assessment (Struthers et al. 2014), and Riparian Condition Assessment (Martin and Wagner 2016) are primary sources of information for resource management. 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 tables (Table 5, Table 6, and Table 7), which were developed by the GRD, summarizes laws, regulations, and policies that specifically apply to NPS geologic resources, processes, and energy and minerals. Table 5 summarizes law and policy for geoheritage resources, which includes caves, paleontological resources, and geothermal resources. Table 6 addresses energy and minerals, which includes abandoned mineral lands, mining, rock and mineral collection, and oil and gas operations. Table 7 pertains to active processes such as geologic hazards (e.g., landslides), coastal processes, soils, and upland and fluvial processes (e.g., erosion). The tables do not include laws of general application (e.g., Endangered Species Act, Clean Water Act, Wilderness Act, NEPA, or the National Historic Preservation Act), but do include the NPS Organic Act when it serves as the main authority for protection of a particular resource or when other, more specific laws are not available.

Table 5. Geoheritage resources laws, regulations, and policies.

Resource	Resource-specific Laws	Resource-specific Regulations	NPS Management Policies 2006
Caves and Karst Systems	**Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309** requires Interior/Agriculture to identify "significant caves" on Federal lands, regulate/restrict use of those caves as appropriate, and include significant caves in land management planning efforts. Imposes civil and criminal penalties for harming a cave or cave resources. Authorizes Secretaries to withhold information about specific location of a significant cave from a Freedom of Information Act (FOIA) requester. **National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of cave and karst resources. **Lechuguilla Cave Protection Act of 1993, Public Law 103-169** created a cave protection zone (CPZ) around Lechuguilla Cave in Carlsbad Caverns National Park. Within the CPZ, access and the removal of cave resources may be limited or prohibited; existing leases may be cancelled with appropriate compensation; and lands are withdrawn from mineral entry.	**36 CFR § 2.1** prohibits possessing/ destroying/disturbing…cave resources…in park units. **43 CFR Part 37** states that all NPS caves are "significant" and sets forth procedures for determining/releasing confidential information about specific cave locations to a FOIA requester.	**Section 4.8.1.2** requires NPS to maintain karst integrity, minimize impacts. **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity. **Section 4.8.2.2** requires NPS to protect caves, allow new development in or on caves if it will not impact cave environment, and to remove existing developments if they impair caves. **Section 6.3.11.2** explains how to manage caves in/adjacent to wilderness.
Geothermal	**Geothermal Steam Act of 1970, 30 USC. § 1001** et seq. as amended in 1988, states: • No geothermal leasing is allowed in parks. • "Significant" thermal features exist in 16 park units (the features listed by the NPS at 52 Fed. Reg. 28793-28800 (August 3, 1987), plus the thermal features in Crater Lake, Big Bend, and Lake Mead). • NPS is required to monitor those features. • Based on scientific evidence, Secretary of Interior must protect significant NPS thermal features from leasing effects. **Geothermal Steam Act Amendments of 1988, Public Law 100--443** prohibits geothermal leasing in the Island Park known geothermal resource area near Yellowstone and outside 16 designated NPS units if subsequent geothermal development would significantly adversely affect identified thermal features.	**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.	**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.
Paleontological Resources	**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.	**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.	**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.

Table 6. Energy and minerals laws, regulations, and policies.

Resource	Resource-specific Laws	Resource-specific Regulations	NPS Management Policies 2006
Abandoned Mineral Lands and Orphaned Oil and Gas Wells	**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.	None applicable.	None applicable.
Coal	**Surface Mining Control and Reclamation Act of 1977, 30 USC § 1201** et. seq. prohibits surface coal mining operations on any lands within the boundaries of a NPS unit, subject to valid existing rights.	**SMCRA Regulations at 30 CFR Chapter VII** govern surface mining operations on Federal lands and Indian lands by requiring permits, bonding, insurance, reclamation, and employee protection. Part 7 of the regulations states that National Park System lands are unsuitable for surface mining.	None applicable.
Common Variety Mineral Materials (Sand, Gravel, Pumice, etc.)	**Materials Act of 1947, 30 USC § 601** does not authorize the NPS to dispose of mineral materials outside of park units. **Reclamation Act of 1939, 43 USC §387**, authorizes removal of common variety mineral materials from federal lands in federal reclamation projects. This act is cited in the enabling statutes for Glen Canyon and Whiskeytown National Recreation Areas, which provide that the Secretary of the Interior may permit the removal of federally owned nonleasable minerals such as sand, gravel, and building materials from the NRAs under appropriate regulations. Because regulations have not yet been promulgated, the National Park Service may not permit removal of these materials from these National Recreation Areas. **16 USC §90c-1(b)** authorizes sand, rock and gravel to be available for sale to the residents of Stehekin from the non-wilderness portion of Lake Chelan National Recreation Area, for local use as long as the sale and disposal does not have significant adverse effects on the administration of the national recreation area.	None applicable.	**Section 9.1.3.3** clarifies that only the NPS or its agent can extract park-owned common variety minerals (e.g., sand and gravel), and: • -Only for park administrative uses; • -After compliance with NEPA and other federal, state, and local laws, and a finding of non-impairment; • -After finding the use is park's most reasonable alternative based on environment and economics; • -Parks should use existing pits and create new pits only in accordance with park-wide borrow management plan; • -Spoil areas must comply with Part 6 standards; and • -NPS must evaluate use of external quarries. Any deviation from this policy requires a written waiver from the Secretary, Assistant Secretary, or Director.
Federal Mineral Leasing (Oil, Gas, and Solid Minerals)	**The Mineral Leasing Act, 30 USC § 181** et seq., and the Mineral Leasing Act for Acquired Lands, 30 USC § 351 et seq. do not authorize the BLM to lease federally owned minerals in NPS units. **Combined Hydrocarbon Leasing Act, 30 USC §181**, allowed owners of oil and gas leases or placer oil claims in Special Tar Sand Areas (STSA) to convert those leases or claims to combined hydrocarbon leases, and allowed for competitive tar sands leasing. This act did not modify the general prohibition on leasing in park units but did allow for lease conversion in GLCA, which is the only park unit that contains a STSA. **Exceptions: Glen Canyon NRA (16 USC § 460dd et seq.), Lake Mead NRA (16 USC § 460n et seq.), and Whiskeytown-Shasta-Trinity NRA (16 USC § 460q et seq.)** authorizes the BLM to issue federal mineral leases in these units provided that the BLM obtains NPS consent. Such consent must be predicated on an NPS finding of no significant adverse effect on park resources and/or administration. **American Indian Lands Within NPS Boundaries Under the Indian Allottee Leasing Act of 1909, 25 USC §396, and the Indian Leasing Act of 1938, 25 USC §396a, §398 and §399, and Indian Mineral Development Act of 1982, 25 USCS §§2101-2108**, all minerals on American Indian trust lands within NPS units are subject to leasing. **Federal Coal Leasing Amendments Act of 1975, 30 USC § 201** prohibits coal leasing in National Park System units.	**36 CFR § 5.14** states prospecting, mining, and…leasing under the mineral leasing laws [is] prohibited in park areas except as authorized by law. **BLM regulations at 43 CFR Parts 3100, 3400, and 3500** govern Federal mineral leasing. Regulations re: Native American Lands within NPS Units: • **25 CFR Part 211** governs leasing of tribal lands for mineral development. • **25 CFR Part 212** governs leasing of allotted lands for mineral development. • **25 CFR Part 216** governs surface exploration, mining, and reclamation of lands during mineral development. • **25 CFR Part 224** governs tribal energy resource agreements. • **25 CFR Part 225** governs mineral agreements for the development of Indian-owned minerals entered into pursuant to the Indian Mineral Development Act of 1982, Pub. L. No. 97-382, 96 Stat. 1938 (codified at 25 USC §§ 2101-2108). • **30 CFR §§ 1202.100-1202.101** governs royalties on oil produced from Indian leases. • **30 CFR §§ 1202.550-1202.558** governs royalties on gas production from Indian leases. • **30 CFR §§ 1206.50-1206.62 and §§ 1206.170-1206.176** governs product valuation for mineral resources produced from Indian oil and gas leases. • **30 CFR § 1206.450** governs the valuation coal from Indian Tribal and Allotted leases. • **43 CFR Part 3160** governs onshore oil and gas operations, which are overseen by the BLM.	**Section 8.7.2** states that all NPS units are closed to new federal mineral leasing except Glen Canyon, Lake Mead and Whiskeytown-Shasta-Trinity NRAs.

Table 6 (continued). Energy and minerals laws, regulations, and policies.

Resource	Resource-specific Laws	Resource-specific Regulations	NPS Management Policies 2006
Mining Claims (Locatable Minerals)	**Mining in the Parks Act of 1976, 54 USC § 100731** et seq. authorizes NPS to regulate all activities resulting from exercise of mineral rights, on patented and unpatented mining claims in all areas of the System, in order to preserve and manage those areas. **General Mining Law of 1872, 30 USC § 21** et seq. allows US citizens to locate mining claims on Federal lands. Imposes administrative and economic validity requirements for "unpatented" claims (the right to extract Federally-owned locatable minerals). Imposes additional requirements for the processing of "patenting" claims (claimant owns surface and subsurface). Use of patented mining claims may be limited in Wild and Scenic Rivers and OLYM, GLBA, CORO, ORPI, and DEVA. **Surface Uses Resources Act of 1955, 30 USC § 612** restricts surface use of unpatented mining claims to mineral activities.	**36 CFR § 5.14** prohibits prospecting, mining, and the location of mining claims under the general mining laws in park areas except as authorized by law. **36 CFR Part 6** regulates solid waste disposal sites in park units. **36 CFR Part 9, Subpart A** requires the owners/operators of mining claims to demonstrate bona fide title to mining claim; submit a plan of operations to NPS describing where, when, and how; prepare/submit a reclamation plan; and submit a bond to cover reclamation and potential liability. **43 CFR Part 36** governs access to mining claims located in, or adjacent to, National Park System units in Alaska.	**Section 6.4.9** requires NPS to seek to remove or extinguish valid mining claims in wilderness through authorized processes, including purchasing valid rights. Where rights are left outstanding, NPS policy is to manage mineral-related activities in NPS wilderness in accordance with the regulations at 36 CFR Parts 6 and 9A. **Section 8.7.1** prohibits location of new mining claims in parks; requires validity examination prior to operations on unpatented claims; and confines operations to claim boundaries.
Nonfederal Minerals other than Oil and Gas	**NPS Organic Act, 54 USC §§ 100101 and 100751**	**NPS regulations at 36 CFR Parts 1, 5, and 6** require the owners/operators of other types of mineral rights to obtain a special use permit from the NPS as a § 5.3 business operation, and § 5.7 – Construction of buildings or other facilities, and to comply with the solid waste regulations at Part 6.	**Section 8.7.3** states that operators exercising rights in a park unit must comply with 36 CFR Parts 1 and 5.
Nonfederal Oil and Gas	**NPS Organic Act, 54 USC § 100751** et seq. authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights). **Individual Park Enabling Statutes**: • 16 USC § 230a (Jean Lafitte NHP & Pres.) • 16 USC §450kk (Fort Union NM) • 16 USC § 459d-3 (Padre Island NS) • 16 USC § 459h-3 (Gulf Islands NS) • 16 USC § 460ee (Big South Fork NRRA) • 16 USC § 460cc-2(i) (Gateway NRA) • 16 USC § 460m (Ozark NSR) • 16 USC§698c (Big Thicket N Pres.) • 16 USC §698f (Big Cypress N Pres.)	**36 CFR Part 6** regulates solid waste disposal sites in park units. **36 CFR Part 9, Subpart B** requires the owners/operators of nonfederally owned oil and gas rights in parks outside of Alaska to: • Demonstrate valid right to develop mineral rights; • Submit an Operations Permit Application to NPS describing where, when, how they intend to conduct operations; • Prepare/submit a reclamation plan; and • Submit 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.	**Section 8.7.3** requires operators to comply with 9B regulations.
Recreational Collection of Rocks and Minerals	**NPS Organic Act, 54 USC. § 100101** et seq. directs the NPS to conserve all resources in parks (which includes rock and mineral resources) unless otherwise authorized by law. **Exception: 16 USC. § 445c (c)** – Pipestone National Monument enabling statute. Authorizes American Indian collection of catlinite (red pipestone).	**36 C.F.R. § 2.1** prohibits possessing, destroying, disturbing mineral resources…in park units. **Exception: 36 C.F.R. § 7.91** allows limited gold panning in Whiskeytown. **Exception: 36 C.F.R. § 13.35** allows some surface collection of rocks and minerals in some Alaska parks (not Klondike Gold Rush, Sitka, Denali, Glacier Bay, and Katmai) by non-disturbing methods (e.g., no pickaxes), which can be stopped by superintendent if collection causes significant adverse effects on park resources and visitor enjoyment.	**Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.

Table 6 (continued). Energy and minerals laws, regulations, and policies.

Resource	Resource-specific Laws	Resource-specific Regulations	NPS Management Policies 2006
Transpark Petroleum Product Pipelines	**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 (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)	**NPS regulations at 36 CFR Part 14 Rights of Way**	**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	**Atomic Energy Act of 1954**: Allows Secretary of Energy to issue leases or permits for uranium on BLM lands; may issue leases or permits in NPS areas only if president declares a national emergency.	None applicable.	None applicable.

Table 7. Active processes and geohazards laws, regulations, and policies.

Resource	Resource-specific Laws	Resource-specific Regulations	NPS Management Policies 2006
Coastal Features and Processes	**NPS Organic Act, 54 USC § 100751** et. seq. authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights). **Coastal Zone Management Act, 16 USC § 1451** et. seq. requires Federal agencies to prepare a consistency determination for every Federal agency activity in or outside of the coastal zone that affects land or water use of the coastal zone. **Clean Water Act, 33 USC § 1342/Rivers and Harbors Act, 33 USC 403** require that dredge and fill actions comply with a Corps of Engineers Section 404 permit. **Executive Order 13089** (coral reefs) (1998) calls for reduction of impacts to coral reefs. **Executive Order 13158** (marine protected areas) (2000) requires every federal agency, to the extent permitted by law and the maximum extent practicable, to avoid harming marine protected areas.	**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.	**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.

Table 7 (continued). Active processes and geohazards laws, regulations, and policies.

Resource	Resource-specific Laws	Resource-specific Regulations	NPS Management Policies 2006
Geologic Hazards	**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	None applicable.	**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.
Soils	**Soil and Water Resources Conservation Act, 16 USC §§ 2011–2009** provides for the collection and analysis of soil and related resource data and the appraisal of the status, condition, and trends for these resources. **Farmland Protection Policy Act, 7 USC § 4201** et. seq. requires NPS to identify and take into account the adverse effects of Federal programs on the preservation of farmland; consider alternative actions, and assure that such Federal programs are compatible with State, unit of local government, and private programs and policies to protect farmland. NPS actions are subject to the FPPA if they may irreversibly convert farmland (directly or indirectly) to nonagricultural use and are completed by a Federal agency or with assistance from a Federal agency. Applicable projects require coordination with the Department of Agriculture's Natural Resources Conservation Service (NRCS).	**7 CFR Parts 610 and 611** are the US Department of Agriculture regulations for the Natural Resources Conservation Service. Part 610 governs the NRCS technical assistance program, soil erosion predictions, and the conservation of private grazing land. Part 611 governs soil surveys and cartographic operations. The NRCS works with the NPS through cooperative arrangements.	**Section 4.8.2.4** requires NPS to • -Prevent unnatural erosion, removal, and contamination; • -Conduct soil surveys; • -Minimize unavoidable excavation; and • -Develop/follow written prescriptions (instructions).
Upland and Fluvial Processes	**Rivers and Harbors Appropriation Act of 1899, 33 USC § 403** prohibits the construction of any obstruction on the waters of the United States not authorized by congress or approved by the USACE. **Clean Water Act 33 USC § 1342** requires a permit from the USACE prior to any discharge of dredged or fill material into navigable waters (waters of the US [including streams]). **Executive Order 11988** requires federal agencies to avoid adverse impacts to floodplains. (see also D.O. 77-2) **Executive Order 11990** requires plans for potentially affected wetlands (including riparian wetlands). (see also D.O. 77-1)	None applicable.	**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

Climate Change Resources

- Intergovernmental Panel on Climate Change: http://www.ipcc.ch/
- *Global and regional sea level rise scenarios for the Unites States* (Sweet et al. 2022): https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html.
- 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
- NPS Sea Level Change website: https://www.nps.gov/subjects/climatechange/sealevelchange.htm/index.htm
- NPS Sea Level Rise Map Viewer: https://maps.nps.gov/slr/
- *Sea level rise and storm surge projections for the National Park Service* (Caffrey et al. 2018): https://irma.nps.gov/DataStore/Reference/Profile/2253283
- 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

- Kansas Geological Survey, recent earthquakes: https://www.kgs.ku.edu/Geophysics/Earthquakes/index.html
- 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/
- Kansas Geological Survey: https://www.kgs.ku.edu/index.html
- USGS: 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 America's Geologic Heritage: https://www.nps.gov/subjects/geology/americas-geoheritage.htm
- 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 Geology subject sites:
    - Archeology: https://www.nps.gov/orgs/1038/index.htm
    - Coastal Geology: https://www.nps.gov/subjects/geology/coastal-geology.htm
    - Energy and Minerals Management: https://www.nps.gov/subjects/energyminerals/index.htm
    - Fossils and Paleontology: https://www.nps.gov/subjects/fossils/index.htm
    - Geohazards: https://www.nps.gov/subjects/geohazards/index.htm
    - Glaciers: https://www.nps.gov/subjects/glaciers/index.htm
    - Mountains—Geology and Physical Processes: https://www.nps.gov/subjects/mountains/geology.htm
    - Rivers and Streams—Fluvial Geomorphology: https://www.nps.gov/subjects/geology/fluvial-landforms.htm
    - Tectonic Landforms and Features: https://www.nps.gov/subjects/geology/tectonic-landforms.htm

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 Integrated Resource Management Applications (IRMA) portal: https://irma.nps.gov/. *Note*: The GRI team uploads scoping summaries, maps, and reports to IRMA. Enter "GRI" as the search text and select a park from the unit list.

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/2190427. *Note*: The PDF is contained within SRI_Detailed_Soils.zip, which also contains an index map of parks where SRIs have been completed. Download and extract all files.

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

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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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