National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Cowpens National Battlefield

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2020/2214

The production of this document cost $25,011 including costs associated with data collection, processing, analysis, and subsequent authoring, editing, and publication.

ON THE COVER
Photograph of the Scruggs house surrounded by colorful sumac in autumn. The landscape around the cabin is characteristic of the battlefield's landforms: undulating hills and shallow valleys with abundant vegetation.
National Park Service photograph.

THIS PAGE
Photograph of the 1932 US Monument at Cowpens National Battlefield. Almost a century of wear and acidic rain are slowly muting the edges and inscriptions on the monument.
National Park Service photograph.

Cowpens National Battlefield

Geologic Resources Inventory Report

Natural Resource Report NPS/NRSS/GRD/NRR—2020/2214

Trista L. Thornberry-Ehrlich

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

December 2020

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

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

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Geologic Resources Inventory publications site and the Natural Resource Report publication series site. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov

Please cite this publication as:

Thornberry-Ehrlich, T. L. 2020. Cowpens National Battlefield: Geologic resources inventory report. Natural Resource Report NPS/NRSS/GRD/NRR—2020/2214. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/nrr-2283636.

NPS 331/174937, December 2020

Contents

Figures

Tables

Executive Summary

The Geologic Resources Inventory (GRI) provides geologic map data and pertinent geologic information to support resource management and science-informed decision making in more than 270 natural resource parks throughout the National Park System. The GRI is one of 12 inventories funded by the National Park Service (NPS) Inventory and Monitoring Program. The Geologic Resources Division of the NPS Natural Resource Stewardship and Science Directorate administers the GRI.

This report synthesizes discussions from a scoping meeting held in 2005 and a follow-up conference call in 2019 (see Appendix A). Chapters of this report discuss the geologic setting and distinctive geologic features and processes within Cowpens National Battlefield, highlight geologic issues facing resource managers, describe the geologic history leading to the present-day landscape, and provide information about the previously completed GRI map data. A GRI map poster (separate document) illustrates these data.

Cold morning air settled through towering trees on British forces as they climbed a gentle rise toward waiting Americans at the start of the battle of Cowpens. Cowpens National Battlefield is part of the Piedmont province, characterized by muted, rolling hills and gentle swales. Featuring prominently on the park's landscape are boggy wetlands that inhibited troop movement during the pivotal battle for American independence from Britain. The park's trails (interpretive [battlefield] and natural) and evocative history attracts a wide swath of visitor uses.

The landscape of Cowpens National Battlefield preserves hundreds of millions of years of Earth's history. The underlying geology is part of a large sheet of rock that once lined the bottom of an ocean basin before it was smeared onto the North American continental margin as the continent grew slowly larger throughout the Paleozoic Era. Those rocks were squeezed and heated into metamorphic schists during the mountain-building orogenies that built the Appalachian and Ouachita mountains. This deformation is reflected in the park's geologic faults and folds. For more than 200 million years, the rocks beneath Cowpens National Battlefield have been deeply weathered producing a thick layer of overlying saprolite that became part of the area's soils. Earth surface processes continue to change the landscape, lowering the highest elevations, and reworking sediments along the stream channels.

This report is supported by GRI-compiled digital geologic maps of the bedrock of Cowpens National Battlefield, originally mapped as two separate products by the South Carolina Geological Survey. The park boundaries and surrounding 7.5-minute quadrangles are part of the data set herein referred to as the GRI GIS data.

Only two geologic map units, both ancient metamorphic rocks, are mapped in the park. The regional trend of folds, faults, valleys, and ridges is northeast to southwest. This report provides descriptions that are applicable to the entire map coverage area with specific emphasis on those occurring within park boundaries. A table breaks out the geologic features, processes, and resource management issues per geologic map unit presented in the GRI GIS data.

Geologic features, processes, and resource management issues identified during the 2005 GRI scoping meeting and follow-up 2019 conference call include the following:

- Fluvial Features, Processes, and Issues
- Ravine Erosion
- Old Scruggs Lake and Fossil Pollen Record
- Restoration of 1781-era Wetlands, Green River Road, and Monuments
- Bedrock Outcrops
- Geologic Hazards
- Faults and Folds

Products and Acknowledgments

The NPS Geologic Resources Division partners with the Colorado State University Department of Geosciences to produce GRI products. The South Carolina Geological Survey developed the source maps and, along with NPS staff, reviewed GRI content. This chapter describes GRI products and acknowledges contributors to this report.

GRI Products

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

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

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

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

Acknowledgments

Additional thanks to: Robby Morrow (South Carolina Geological Survey), Ginny Fowler and Sarah Cunningham (Cowpens National Battlefield) for being so helpful and willing to thoroughly review this report during the COVID-19 pandemic. The geologic significance of small parks like Cowpens National Battlefield is commonly overlooked or underemphasized, but vital to the park's story.

Review

Virginia Fowler, Park Ranger, Cowpens National Battlefield

Sarah Cunningham, Acting Superintendent, Southern Campaign of the American Revolution Parks Group

Robby Morrow, Geologist, South Carolina Geological Survey

Jason Kenworthy, GRI Program Coordinator, NPS Geologic Resources Division

Editing

Rebecca Port (NPS Geologic Resources Division)

Report Formatting and Distribution

Chelsea Bitting (National Park Service)

Source Maps

I. B. Boland and C. S. Howard, South Carolina Geological Survey

GRI GIS Data Production

Andrea Croskrey (National Park Service)

Heather Stanton (Colorado State University)

GRI Map Poster Design

Sarah Lowe (Colorado State University)

GRI Map Poster Editing

Georgia Hybels (Colorado State University)

Jake Suri (Colorado State University)

Rebecca Port (NPS Geologic Resources Division)

Michael Barthelmes (Colorado State University)

Chelsea Bitting (NPS Geologic Resources Division)

Jason Kenworthy (NPS Geologic Resources Division)

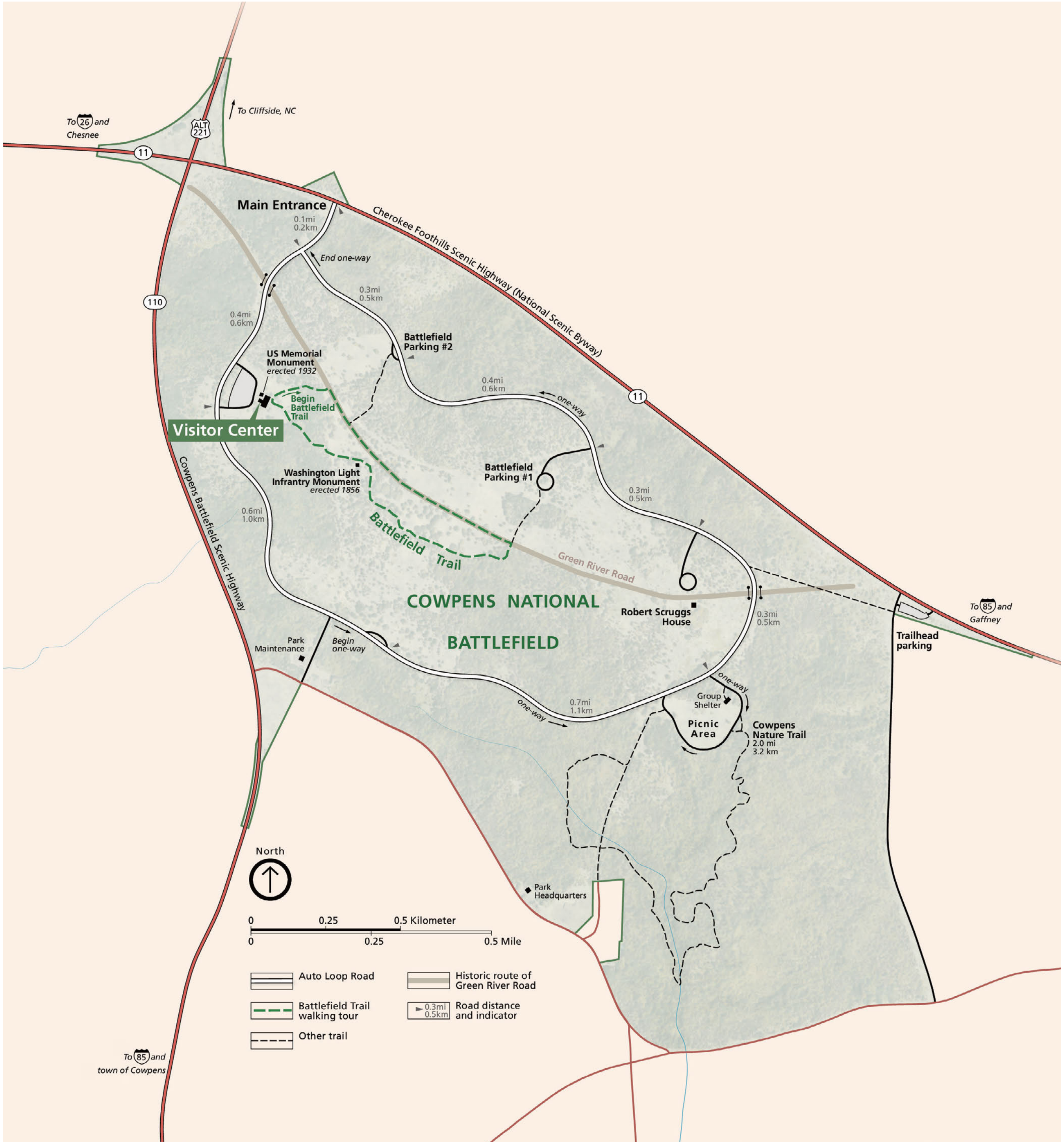

Figure 1. Map of Cowpens National Battlefield.
The battlefield is about 13 km (8 mi) north of the town of Cowpens, South Carolina. National Park Service map from the Harpers Ferry Center available at: https://www.nps.gov/carto/app/#!/maps/alphacode/COWP.

Geologic Setting and Significance

This chapter describes the regional geologic setting of the park and summarizes connections among geologic resources, other park resources, and park stories. A glossary follows with definitions of geologic terms.

Park Establishment

An echoing resonance of past gunshots and men shouting is part of a visit to Cowpens National Battlefield. Cowpens was a well-known crossroads and frontier pasturing ground (National Park Service 2014). Here, nearly 240 years ago, American troops under Brigadier General Daniel Morgan unexpectedly triumphed over the forces of British Lieutenant Colonel Banastre Tarleton during the latter part of the Southern Campaign of the American Revolution. The winter battle, fought on 17 January 1781, was a turning point of the war in the south and ultimately of the Revolution, which would end shortly after the last major battle in Yorktown, Virginia (treaty signed 3 September 1783). Established originally as part of the War Department on 4 March 1929, Cowpens National Battlefield was intended to preserve and interpret the Revolutionary War Battle of Cowpens. The battlefield became part of the National Park Service on 10 August 1933. The national battlefield, hereafter referred to as the "park," covers more than 340 ha (840 ac) of northwestern South Carolina (fig. 1) in Cherokee County near the North Carolina border (Binkley and Davis 2002). The nearest large city is Spartanburg, South Carolina, 27 km (17 mi) southwest of park. Park visitation fluctuates around 200,000 annual recreational visitors (National Park Service 2018).

Cowpens National Battlefield protects and commemorates for inspiration and education the history and landscape where on 17 January 1781, the American victory during the Southern Campaign was crucial to the ultimate outcome of the American Revolutionary War (National Park Service 2014). The park contains traces of Colonial-period roads associated with routes marched by troops, two historic monuments (the 1856 Washington Light Infantry Monument and the 1932 U.S. Monument), historic structures, a battlefield trail, a nature trail, a battlefield-perimeter auto route, and other visitor use facilities (National Park Service 2014).

The park is located on an interfluve between the Pacolet River to the south and the main branch of the Broad River to the north—all of which is ultimately part of the greater Broad River watershed. Local streams include Zekial, Island, Cudds, and Big Horse creeks—all beyond park boundaries. Long Branch of Island Creek, Suck Creeks 1-3, Little Buck Creek, Island Creek, and an unnamed tributary to the Pacolet River flow through and originate within the battlefield (Worsham et al. 2012). Local topography is muted. Topographic relief within the park is 33 m (107 ft), with elevations ranging from 301 m (987 ft) to less than 268 m (880 ft). Landforms, topography, and underlying geology were all important components in the battle history of Cowpens National Battlefield.

Geologic Setting and History

South Carolina comprises three major physiographic provinces: Blue Ridge, Piedmont, and Atlantic Coastal Plain provinces (fig. 2). Cowpens National Battlefield is in the Piedmont province, which extends 1,600 km (1,000 mi) from Alabama northeastward to southern New York. The Piedmont contains highly complex metamorphic and igneous rocks that have been weathered and eroded for millions of years to produce a rolling, hilly, muted landscape adjacent to the rugged Blue Ridge to the west and the nearly flat coastal plain to the east. The heavily deformed Brevard zone separates the Piedmont from the metamorphic rocks and igneous plutons of the Blue Ridge province. The boundary between the Piedmont and Atlantic Coastal Plain provinces is called the "fall line." It is a low, east-facing escarpment that parallels the Atlantic coastline from New Jersey to South Carolina. An escarpment is a long, steep slope that faces one direction breaking the continuity of the land by separating two adjacent surfaces and is commonly produced by erosion or faulting. This erosional scarp, 160 km (100 mi) southeast of Cowpens National Battlefield, formed where the hard, resistant metamorphic rocks of the Piedmont and the unconsolidated sediments of the Atlantic Coastal Plain, approximately 120 to 140 km (75 to 90 mi) inland from the coast, were juxtaposed. The fall line is the site of many waterfalls that yielded flume- and waterwheel-powered industries in colonial times and thus became the location of major cities such as Columbia, Philadelphia, Baltimore, Washington DC, and Richmond (US Geological Survey 2000).

Appalachian Mountains geologic story

The geologic story of Cowpens National Battlefield is tied to the greater history of the Appalachian Mountains. According to Hatcher (2005), the Appalachians were created over hundreds of millions of years during three or more mountain-building events, called orogenies, during the Paleozoic Era that began 541 million years ago (table 1 and fig. 3). Prior to this

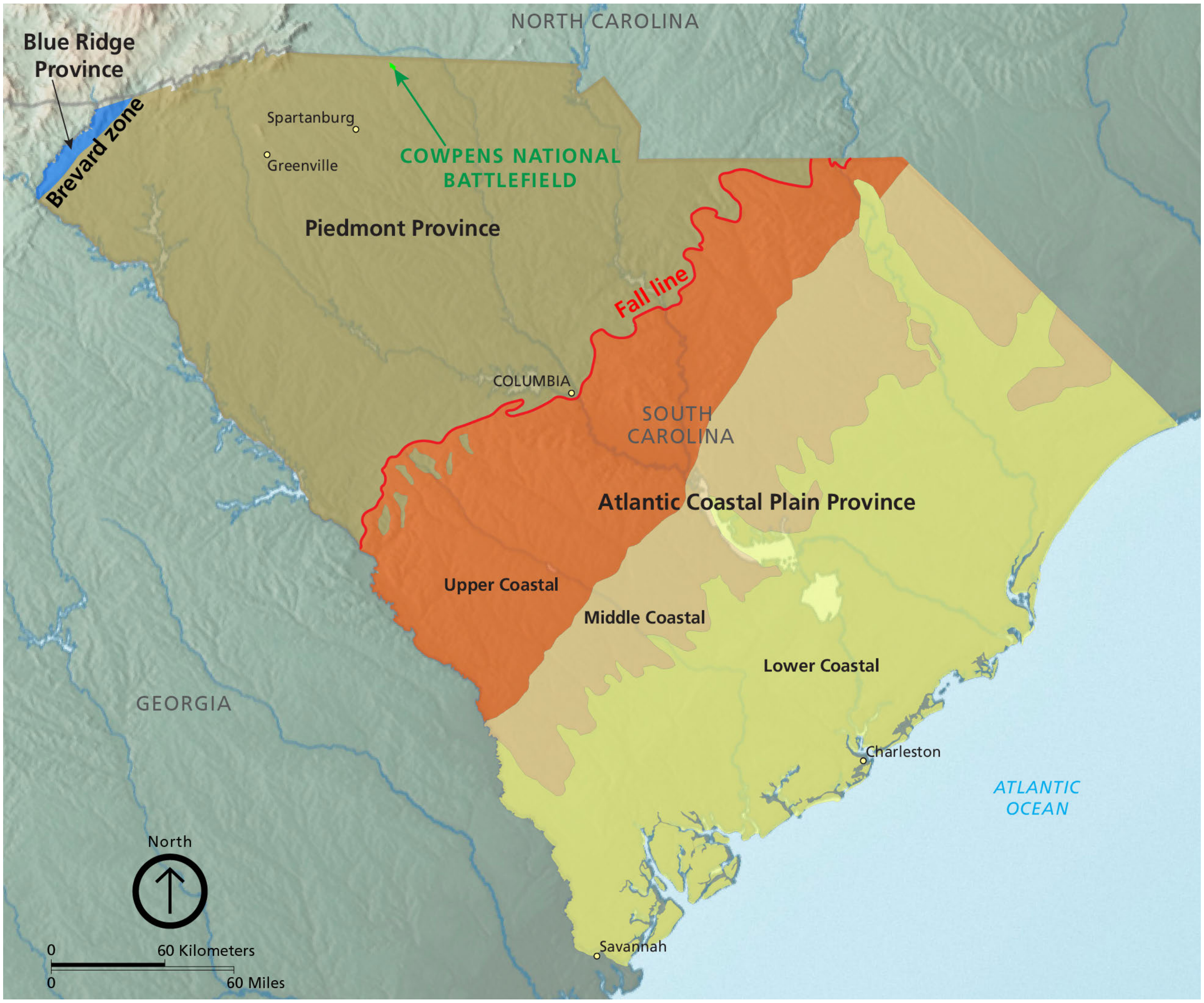

Figure 2. Map of physiographic provinces of South Carolina.
Cowpens National Battlefield (bright green area) is located within the Piedmont province between the Blue Ridge province to the west and the Upper Coastal subprovince of the Atlantic Coastal Plain Province to the east. Bold red line denotes the fall line between the Piedmont and the Atlantic Coastal Plain provinces. Provinces extend beyond state boundaries along the eastern US. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) using GIS data from the South Carolina Geological Survey, available at http://www.dnr.sc.gov/GIS/descgeolrp.html. Basemap by Tom Patterson (National Park Service), available at: http://www.shadedrelief.com/physical/index.html.

Table 1. Geologic time scale.

The divisions of the geologic time scale are organized stratigraphically, with the oldest divisions at the bottom and the youngest at the top. GRI map abbreviations for each time division are in parentheses. The Quaternary, Neogene, and Paleogene periods are part of the Cenozoic Era. The Triassic, Jurassic, and Cretaceous periods are part of the Mesozoic Era. The periods from Cambrian through Permian are part of the Paleozoic Era. Age ranges are millions of years ago (MYA). National Park Service graphic using dates from the International Commission on Stratigraphy (http://www.stratigraphy.org/index.php/ics-chart-timescale).

Geologic Time Unit	MYA	Geologic Map Units	Local Geologic Events
Quaternary Period (Q)	2.6–today	**Qal** deposited and reworked along modern streams	Human history; fluvial meandering, incision, and deposition Ice age glaciations; weathering and incision accelerated
Tertiary (T); Neogene Period (N)	23.0–2.6	None mapped	Ongoing erosion and weathering
Tertiary (T); Paleogene Period (PG)	66.0–23.0	None mapped	Ongoing erosion and weathering
Cretaceous Period (K)	99.6–66.0	**MZq** formed along discrete fault zones	**Global mass extinction** at end of Cretaceous (dinosaurs extinct)
Jurassic Period (J)	201.3–145.0	**MZq** formed along discrete fault zones	Ongoing erosion and weathering
Triassic Period (TR)	252.2–201.3	**MZq** formed along discrete fault zones	**Global mass extinction** at end of Triassic Breakup of Pangaea begins; Atlantic Ocean opened
Permian Period (P)	298.9–252.2	None mapped	**Global mass extinction** at end of Permian. Supercontinent Pangaea intact.
Carboniferous; Pennsylvanian Period (PN)	323.2–298.9	All units deformed and/or metamorphosed	Alleghany (Appalachian) Orogeny
Carboniferous; Mississippian Period (M)	358.9–323.2	None mapped	Erosion and weathering of overlying sediments
Devonian Period (D)	419.2–358.9	Dsm intruded local bedrock	**Global mass extinction** at end of Devonian
Silurian Period (S)	443.8–419.2	All units deformed and/or metamorphosed	Ongoing marine sedimentation Neoacadian Orogeny
Ordovician Period (O)	485.4–443.8	All units deformed and/or metamorphosed	**Global mass extinction** at end of Ordovician; deeper marine settings Sea level fluctuations; marine and nearshore settings Taconic Orogeny; open marine settings
Cambrian Period (C)	541.0–485.4	**CZms**, **CZb**, **CZa**, and **CZmm** deposited or emplaced	Extensive oceans covered most of proto-North America (Laurentia); sediments accumulated in ocean basin; erosion and weathering
Proterozoic Eon; Neoproterozoic (Z)	1,000–541	**CZms**, **CZb**, **CZa**, and **CZmm** deposited or emplaced	Supercontinent Rodinia rifted apart; erosion and uplift
Proterozoic Eon; Mesoproterozoic (Y)	1,600–1,000	None mapped	Formation of early supercontinent; Grenville Orogeny
Proterozoic Eon; Paleoproterozoic (X)	2,500–1,600	None mapped	None reported
Archean Eon	~4,000–2,500	None mapped	Oldest known Earth rocks
Hadean Eon	4,600–4,000	None mapped	Formation of Earth approximately 4,600 million years ago

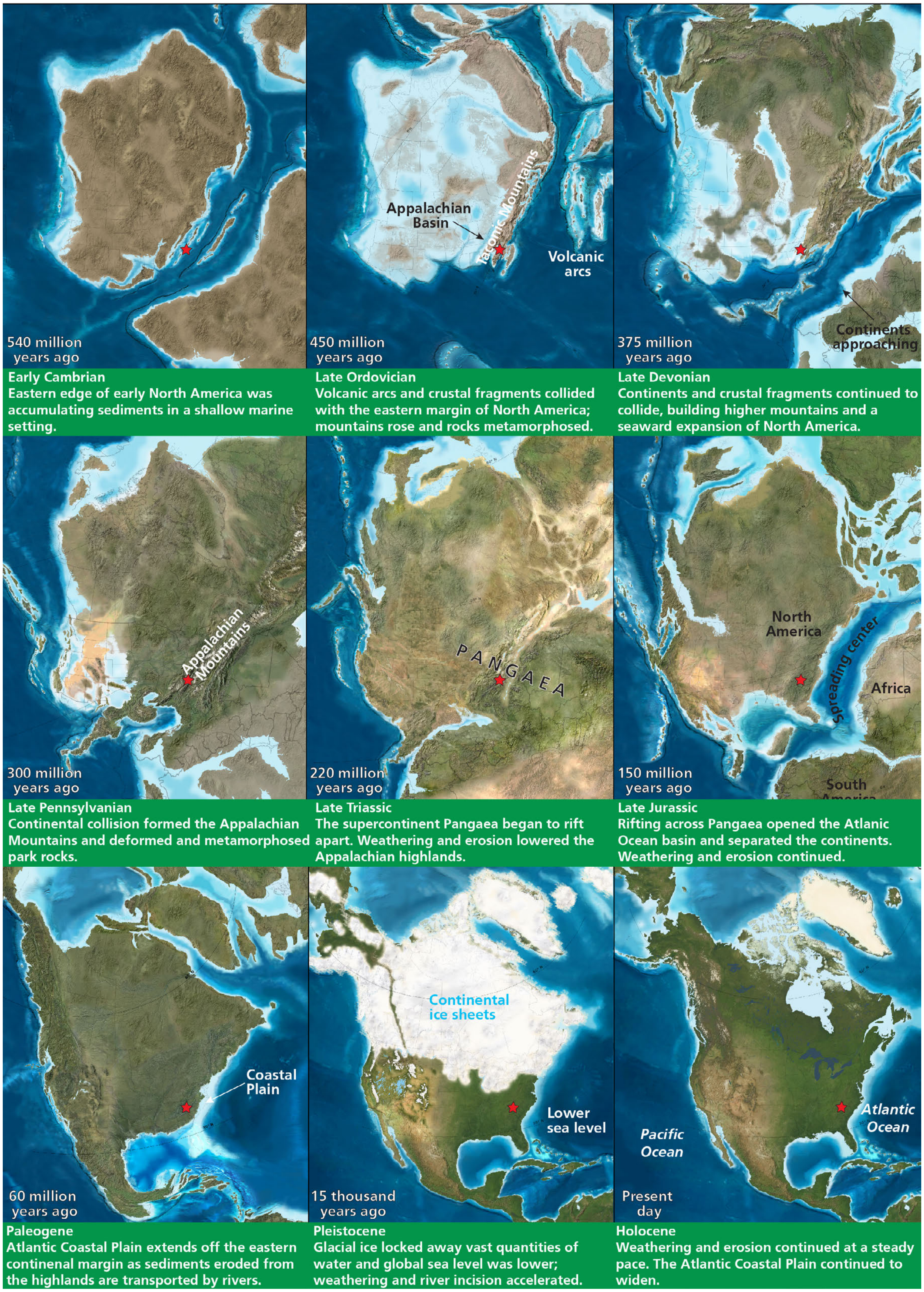

Figure 3. Paleogeographic maps of North America.
The red star indicates the approximate location of Cowpens National Battlefield. Graphic complied by Trista L. Thornberry-Ehrlich (Colorado State University). Base paleogeographic maps created by Ron Blakey (Colorado Plateau Geosystems, Inc.), information is available at http://deeptimemaps.com/map-room-non-profit/.

time, the North American craton (old, stable core of the continent) was part of a supercontinent called Rodinia that formed 1.2–1 billion years ago. The supercontinent broke apart or rifted along the entire southern-central Appalachian margin about 565 million years ago (fig. 4A). Rifting opened an ocean basin (Iapetus Ocean) that began accumulating sediment weathered away from the continents and experienced some igneous activity as molten rock welled up into Earth's crust from the mantle. A carbonate platform developed in the passive margin setting of the Cambrian Period (541 million to 485.4 million years ago).

During the Ordovician Period (485.4 million to 443.8 million years ago), crustal extension gave way to compression as bits of land, oceanic rocks, volcanic arcs, and subcontinents began to collide with what would become North America (figs. 4B and C; Hatcher 2005; Robby Morrow, South Carolina Geological Survey, geologist, written communication, 12 August 2020). The Taconic Orogeny caused widespread obduction and accretion of terranes (e.g., Tugaloo terrane) along the eastern edge of the continent. A terrane is a group of rocks with similar characteristics and geologic history that differ from those around it, and commonly formed somewhere other than its present location. Terranes are associated with continent-scale plate tectonic forces that displace, squeeze, or rip apart large bodies of rock across distances ranging from a few to thousands of kilometers. Examples of terranes may include fragments of continents, volcanic arcs, and oceanic basins.

The Piedmont of South Carolina is broadly divisible into terranes that accreted to the growing edge of ancient North America. The rocks at Cowpens National Battlefield are part of the Tugaloo (oceanic and arc assemblages) and Cat Square (immature, deepwater sandstones) terranes, both part of the Inner Piedmont (fig. 5; Hatcher 2005; Robby Morrow, South Carolina Geological Survey, geologist, written communication, 12 August 2020). The terranes are further broken into individual thrust sheets, piles of rock that slid westward along major thrust faults. Cowpens National Battlefield is part of the Six Mile thrust sheet (fig. 6). Bounding the Six Mile thrust sheet are the Laurens thrust stack to the east and the Walhalla thrust sheet to the west. Shallowly-dipping thrust faults separate individual sheets of rocks that are Late Proterozoic to Early Paleozoic in genesis. The rocks of the Six Mile thrust sheet were likely deposited as a mix of marine sediments and volcanic material—analogous to the Pacific northwest setting today (see fig. 4C; GRI scoping

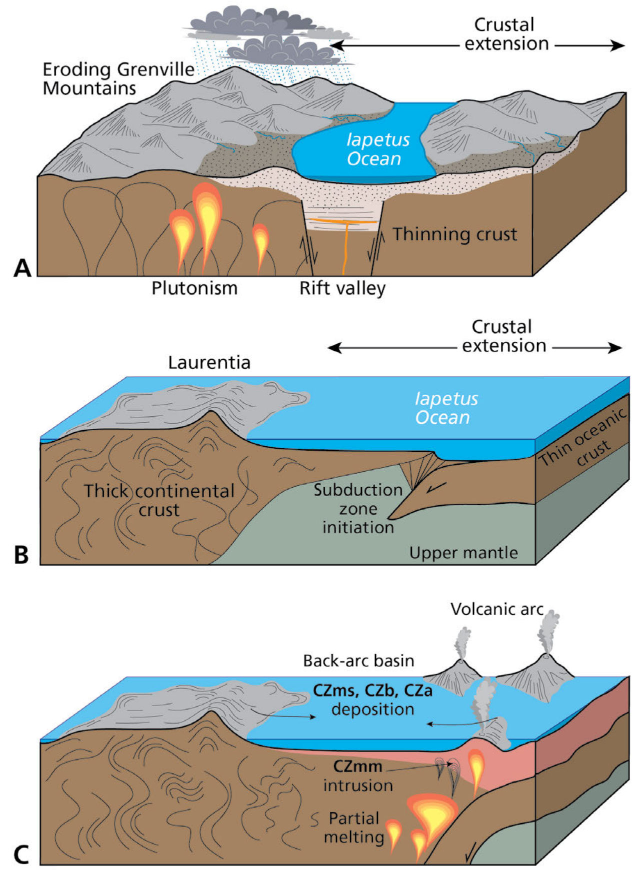

Figure 4A–C. Illustration of the evolution of the landscape and geologic foundation of Cowpens National Battlefield.
(A) In the Neoproterozoic, the supercontinent was rifting apart and the Iapetus ocean basin collected mixed sediments and igneous rocks. (B and C) By the Cambrian and Ordovician, crustal extension and rifting changed to compression as a subduction zone developed in the Iapetus. The rocks of the Six-Mile thrust sheet were accumulating at this time and volcanic arcs were moving toward the western edge of Laurentia (proto-North America). Graphics are not to scale. Colors are standard colors approved by the US Geological Survey to indicate different time periods on geologic maps and correspond to the colors on the geologic time scale. Map symbols are included for the geologic map units mapped in the GRI GIS data. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) with information from Bobyarchick et al. (1988), Barineau et al. (2015), Hawkins (2013), and GRI GIS source data.

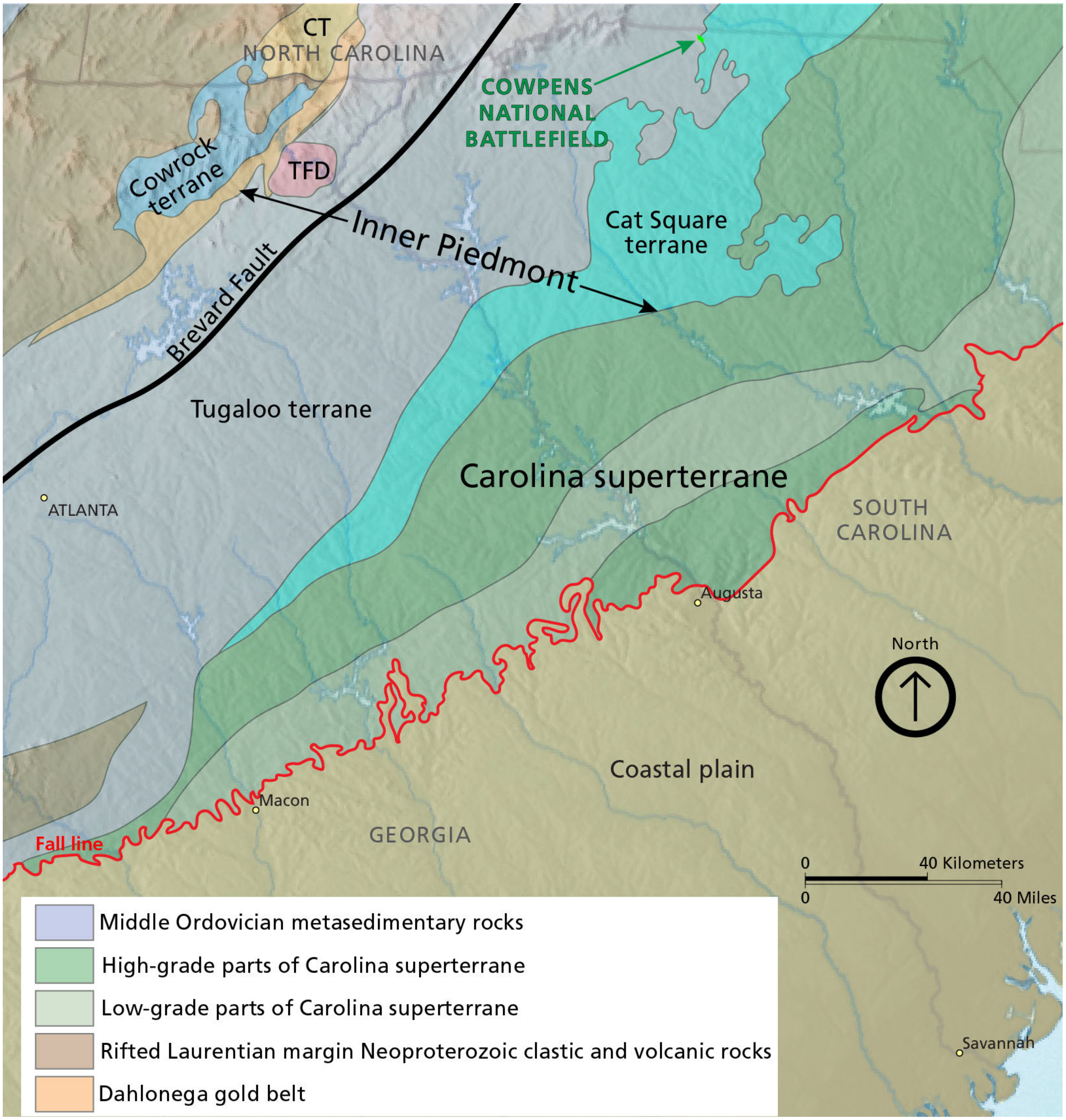

Figure 5. Map of the major terranes of South Carolina and Georgia.
Cowpens National Battlefield is located along the border between the Tugaloo (purple area) and Cat Square (aqua area) terranes, which in this part of the east coast are in the Inner Piedmont. The smaller terranes are then divided into thrust sheets bound by large-scale faults. TFD refers to the Tallulah Falls Dome. CT is part of the Cartoogechaye terrane. Graphic by Trista L. Thornberry-Ehrlich adapted from figure 3 in Hatcher (2005).

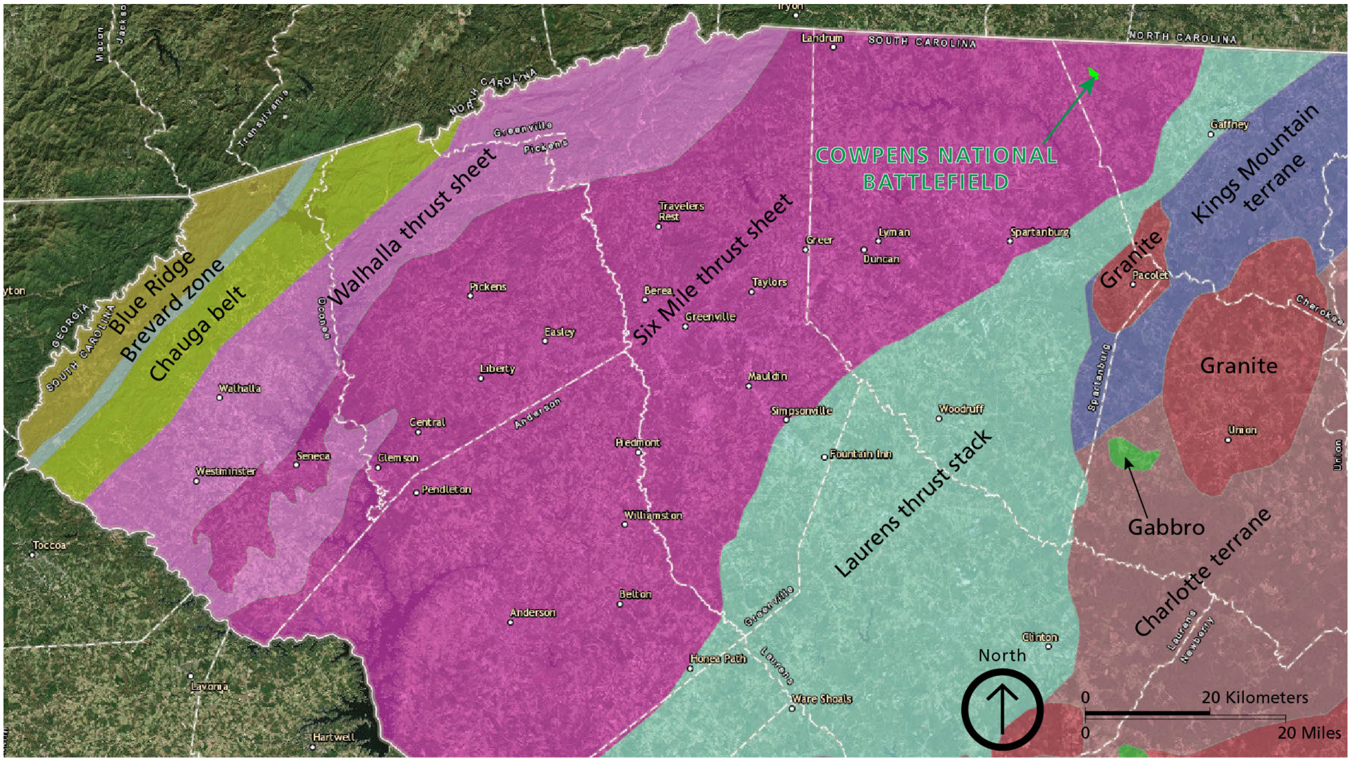

Figure 6. Map of regional geology of northwestern South Carolina.
Cowpens National Battlefield (bright green area) is located within the Six Mile thrust sheet between the Laurens thrust stack to the east and the Walhalla thrust sheet to the west. All three thrust packages are part of the Inner Piedmont block that accreted to the continent during Paleozoic mountain building, separated from the Blue Ridge by the highly deformed Brevard zone. Graphic annotated by Trista L. Thornberry-Ehrlich (Colorado State University) produced using the map viewer from the South Carolina Geological Survey, available at http://scdnr.maps.arcgis.com/apps/Viewer/index.html?appid=735411a2f5714f28a424422296f77bb1.

meeting, 26—28 April 2005; South Carolina Geological Survey 2019).

Compression along the continental margin continued in the Silurian and Devonian Periods (443.8 million to 358.9 million years ago) and groups of rock such as the Six Mile thrust sheet were all metamorphosed, deformed, intruded by granitic magmas, and thrust westward (fig. 7A). The Neoacadian Orogeny caused deformation, metamorphism, and more accretions as the Carolina Terrane (east of the Cat Square terrane) was added to North America (Hatcher 2005).

Continental collision culminated in the formation of a supercontinent, Pangaea, and ultimately in the maximum height of the Appalachian Mountains during the Alleghanian Orogeny in the Pennsylvanian to Permian Periods, 323.2 million to 252.2 million years ago (fig. 7B; Hatcher 2005; Boland 2006). The mountains were uplifted, folded, and deformed, and thrust sheets were pushed westward (Hatcher 2005; Robby Morrow, South Carolina Geological Survey, geologist, written communication, 12 August 2020). The Appalachian Mountains traversed the interior of the supercontinent and may have rivaled the modern Himalayas with elevations potentially exceeding 6,100 m (20,000 ft) (Harris et al. 1997; Southworth et al. 2009). Pangaea incorporated all the major continents in existence. Pangaea was not to last but endured for about 80 million years. During the Late Triassic Epoch, approximately 185 million years ago after the Alleghany Orogeny (Southworth et al. 2009), the supercontinent Pangaea began rifting (separating) into landmasses that would form the modern continents.

During Late Triassic rifting, weathering and erosion became the dominant processes shaping the Appalachian Mountains because the mountains were no longer being pushed upward by collisional tectonic forces (fig. 7C). The Piedmont landscape, including the battlefield at Cowpens, was beveled into undulating hills and the very core of the ancient mountain range was exposed. The topography of Cowpens National Battlefield is controlled by the underlying geology and

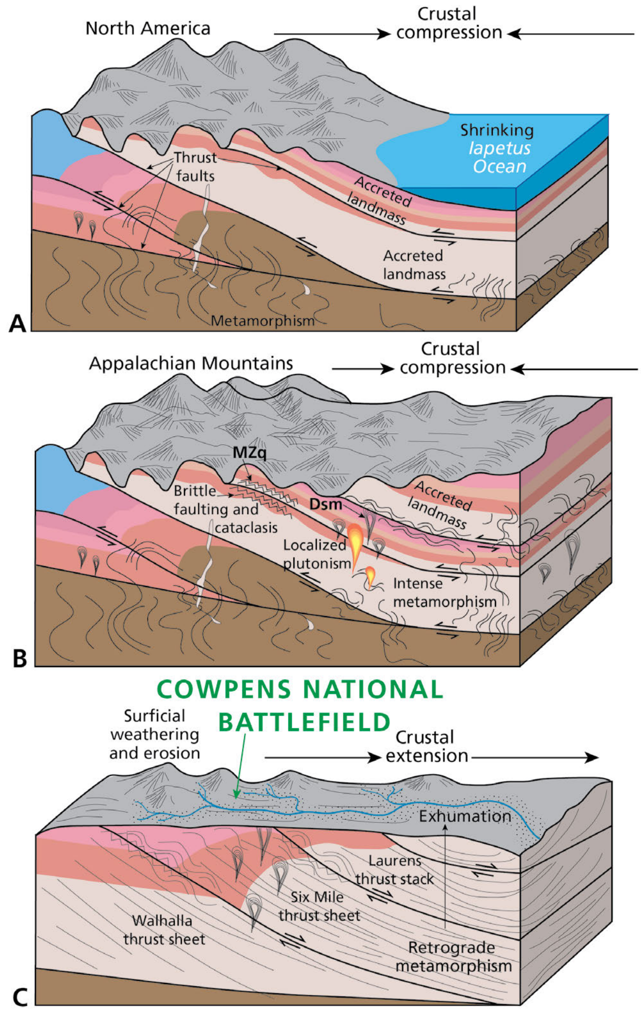

Figure 7A–C. Illustration of the evolution of the landscape and geologic foundation of Cowpens National Battlefield.
(A) In the Ordovician and Silurian, periodic collisions of volcanic arcs and microcontinents were building out the eastern margin of Laurentia. (B) By the Pennsylvanian, major continental collision pushed the Appalachians up to their highest point and all the accreted landmasses and thrust sheets were deformed and metamorphosed. (C) Since the Triassic, when the landmasses began to break apart, the landscape at Cowpens National Battlefield has been subjected to continuous weathering and erosion. Sediments are transported eastward to become part of the Coastal Plain. Graphics are not to scale. Colors are standard colors approved by the US Geological Survey to indicate different time periods on geologic maps and correspond to the colors on the geologic time scale. Map symbols are included for the geologic map units in the GRI GIS data. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) with information from Bobyarchick et al. (1988), Barineau et al. (2015), and GRI GIS source data.

little changed from the time of the Battle of Cowpens (Boland 2006).

Cowpens National Battlefield geologic story

The bedrock mapped in the GRI GIS data reflect a long geologic history of deposition, metamorphism, mountain building, and weathering. Interlayered, folded, and faulted schist, gneiss, granite, and metagranite underly the mapped area (Boland and Howard 2000; Boland 2006; see “GRI Map Poster”) and reflect ocean sediments that were lithified (turned into hard rock), buried, metamorphosed, pushed up as part of the Six Mile thrust sheet, and folded and faulted during the formation of the Appalachian Mountains (Hatcher 2005; Boland and Howard 2000; Boland 2006; Robby Morrow, South Carolina Geological Survey, geologist, written communication, 12 August 2020). Within park boundaries, biotite gneiss (geologic map unit **CZb**) and mica schist (**CZms**) alternate in northeast-southwest trending bands reflecting southeast-to-northwest directed tectonic forces (compression) at work during mountain building (Boland and Howard 2000; Howard 2010).

Cowpens National Battlefield is on a topographic high relative to the surrounding area, with a radial drainage pattern away from its center. Weathered quartz-rich mica schist (**CZms**) underlies the eminence as part of an east-west trending ridge. This ridge forms the hinge of a series of tightly folded northeast-southwest trending double plunging folds that includes Thickety Mountain—another Revolutionary-War era landmark (Boland 2006). Biotite gneiss (**CZb**) underlies the valleys and is only visible in stream beds (Boland 2006; Boland and Howard 2010). Geologic processes are still active on the landscape at Cowpens National Battlefield. Park streams are slowly incising their channels ever upslope. Slope wash is moving material from higher areas to lower areas, further muting the battle landscape.

Geologic Connections to other Park Resources

The Battlefield Landscape

The landscape at Cowpens National Battlefield and its mosaic of cultural and historical features, including prehistoric routes, are among its fundamental resources presented in the foundation document (National Park Service 2014). The characteristic grassy prairies and savanna areas were first conceived and maintained by fire clearing and management by American Indians. When they were displaced by European settlers, cattle grazing was a natural practice to take advantage of the native cane, grasses, and natural springs of these clearings (Worsham et al. 2012).

At the latter part of the Southern Campaign, the backcountry of the American colonies was essentially

Figure 8. Photographs of cold and cloudy mornings at Cowpens National Battlefield. It is easy to imagine the scene in January 1781 as British troops marched up a subtle slope behind which American troops were waiting, hidden behind a low ridge. All images are National Park Service photographs available at https://www.nps.gov/cowp/learn/photosmultimedia/photogallery.htm.

a civil war as the population split between American patriots and British loyalists. Conflicts occurred between neighbors and extensive knowledge of the landscape became critical to military success. The backcountry war devastated the countryside with more than 200 battles fought in South Carolina alone (National Park Service 2014). The name "cowpens," endemic to such South Carolina pastureland, referred to frontier cow pens or pasturing ground, where cattle were kept and fed prior to taking them to market (GRI scoping meeting, 26—28 April 2005). They were natural grassy areas (native grasses and peavine) at the time, dotted with trees and devoid of undergrowth, reportedly known then as Hannah's Cow-pens (National Park Service 2014; Town of Cowpens 2019). At the time of the Revolutionary War, the cowpens provided a convenient open area in otherwise thick forest. The Green River Road (avenue of approach) was a wagon and market trail running along a slightly higher ground between watersheds (interfluve) in the Cowpens area. The road led from the Pacolet River into North Carolina, crossing the Green River, tracing a steep climb through Mills Gap and connecting with the Buncombe Turnpike from Tennessee. In this way, the road connected the backcountry to a larger network of early American wagon and market roads (National Park Service 2014).

On the cold, winter morning of 17 January 1781, exhausted British forces under Tarleton's command approached the battlefield from the east on a road that rises up a gentle slope (fig. 8). This gentle slope hid the numbers of the Americans waiting just beyond (Ginny Fowler, Cowpens National Battlefield, lead interpretive ranger, conference call, 18 December 2019). Swales harboring wet-weather springs and wetlands flanked both sides of the soggy, rutted road. Tarleton figured the undulating, park-like terrain (fig. 9) would be ideal for his dragoons and thought American commander Daniel Morgan to be desperate to choose such a place. Formation was ordered on the Green River Road for the attack (National Park Service 2014). Wet weather that winter had activated the springs making the swales' bottoms boggy and unable to support the easy movement of men, and certainly not horses or cannon (Boland 2006). Having arrived a day earlier and noting that the creeks and springs would prevent British flanking movements, Morgan decided to make a stand with the flood-swollen Broad River 10 km (6 mi) to his back (National Park Service 2014). The Continental troops and backcountry militia under command of Morgan knew the local landscape, including the low, obscuring ridge behind which their numbers were not visible, and used that specific topography to their advantage laying a tactical trap and quickly defeating the British who chose to attack head on and suffered severe losses to riflemen (Boland 2006; National Park Service 2014; Cowpens National Battlefield staff, conference call, 18 December 2019). The Cowpens field itself was square like, about 500 m (500 yd) long and wide (National Park Service 2014). Most of the battle took place on folded mica schist (geologic map unit **CZms**; Howard 2010). Differences in erosion resistance throughout the unit caused by spatial variations (e.g., compositional/mineralogical differences and geologic structures such as folds) likely influenced the battlefield topography, as well as the placement of trails and roads. The battle ended with a perfectly timed, double envelopment (surrounding their flanks) of the British infantry—demoralizing the British cause and leading to their surrender at Yorktown 10 months later (National Park Service 2014).

Following the battle at Cowpens, the area was part of an active settlement enterprise and efforts to commemorate the battle and preserve the battlefield began almost immediately. The site included stores, houses, old Highway 11, and paved historic roadbeds (fig. 10; GRI scoping summary). Today, a portion of the Overmountain Victory National Historic Trail passes through the park boundary as does a portion of the Carolina Thread Trail. These were listed as other important resources and values in the park's foundation document, National Park Service (2014).

Ecosystem Connections

In addition to the historical connections briefly presented here, geologic features and processes are fundamentally connected with vegetation patterns, some animal habitats, soils, and water resources. Within park boundaries, about 75% is forest, and 18% is grassy areas and fields that highlight the battlefield sections (Worsham et al. 2012). According to the park's foundation document, part of its importance is due to the large population of *Hexastylis naniflora* (dwarf-flowered heartleaf), which is currently a federally listed species (National Park Service 2014). This is an "other important resource or value" to Cowpens National Battlefield and thrives in park drainages and along the nature trail (fig. 11).

Geology gives rise to soil formation. Soil resources are beyond the scope of this report and the subject of another natural resource inventory in the National Park Service. Soil resources inventory products for Cowpens National Battlefield were updated in 2004–2005 and are available at: https://irma.nps.gov/DataStore/Reference/Profile/1048848. The park fosters significant biodiversity within its boundaries for fish, bird, mammal, and herpetofaunal communities (Worsham et al. 2012).

According to Worsham et al. (2012), 13 vegetation communities are mapped within the park. Four were present at the time of the battle in 1781: piedmont granitic white oak-black oak woodland, floodplain canebrake, interior southern red oak-white oak forest, and shortleaf pine early successional forest. Their ties to the substrate and geologic units are not known. Geospatial vegetation inventory data for Cowpens National Battlefield are available at: https://irma.nps.gov/DataStore/Reference/Profile/2233270 and https://irma.nps.gov/DataStore/Reference/Profile/2166394.

Because of the park's small size, land-use practices within its viewshed and surrounding areas can strongly impact the ecosystem and visitor experience within the park. Agriculture adjacent to park boundaries tends to result in cleared lands, impounded drainages

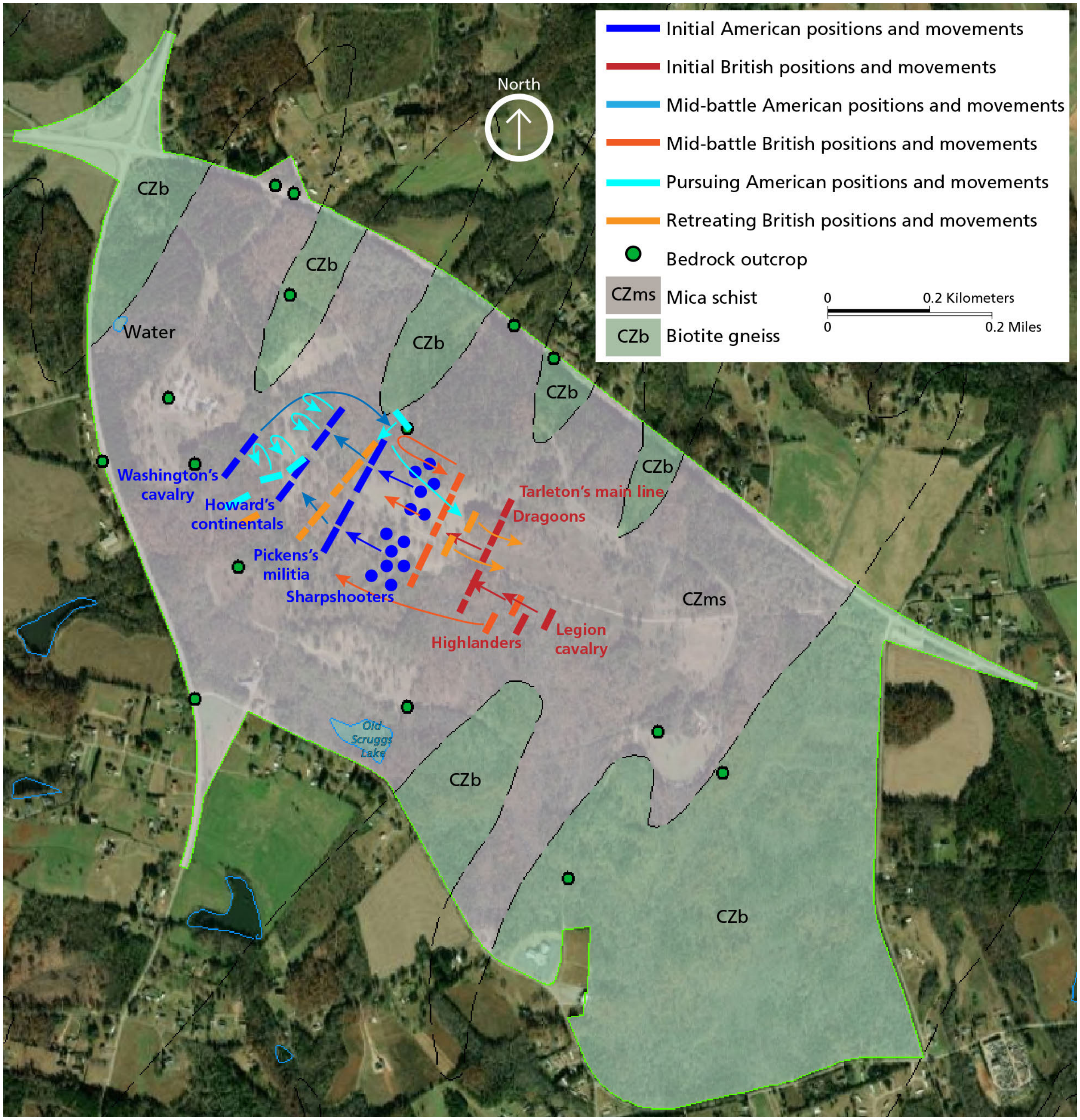

Figure 9. Aerial image of Cowpens National Battlefield with geology and troop movements.
Most of the battle took place spanning the Green River Road on the geologic map unit, CZms. Landforms, including swamps and rivers, surrounding the battlefield played pivotal roles in funneling the troops to this place. Note, the location of Old Scruggs Lake is indicated in the western side of the park. The lake has since been reclaimed and is a vegetated area. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) with information from GRI GIS source data, the NPS Harpers Ferry Center (available at https://www.nps.gov/carto/app/#!/maps/alphacode/COWP), and aerial imagery from ESRI.

Figure 10. Photographs of vintage scenes at Cowpens National Battlefield.
A) A traveling artist, Benson Lossing, sketched the scene at the historic Scruggs House in 1849. Significant forest clearing predated his visit. B) Old (date unknown) photograph of the US 1932 Monument, possibly predating its encasement in concrete. C) Photograph of the park area in 1956, at which time, the battlefield was largely cleared and houses dotted the landscape. D) Photograph of the park sign in 1962 at which time the park was undertaking efforts to restore the battle era landscape, including re-routing Highway 11 (late 1970s). Image A is from Lossing (1859). Images B, C, and D are National Park Service photographs available at https://www.nps.gov/cowp/learn/photosmultimedia/photogallery.htm.

(farm ponds), and animal waste. Housing and other suburban developments typically involve an increase in impervious surfaces such as buildings, parking lots, streets, and sidewalks. Impervious surfaces cause runoff to flow quickly and unnaturally into the system rather than infiltrating the soil and slowly becoming part of the groundwater system. Increased impervious surfaces cause increased stormwater runoff, local erosion, sedimentation, and degradation of stream habitat and biodiversity. Land cover and land use change were addressed in Worsham et al. (2012) as part of the ecological monitoring framework for Cowpens National Battlefield.

The climate is temperate with an annual mean temperature of 15.4°C (59.7°F) and mean precipitation

Figure 11. Photograph of the nature trail at Cowpens National Battlefield.
The nature trail focuses on the ecosystem protected within park boundaries. This mix of forest and meadow provides vital habitat for local species. Image is a National Park Service photograph available at https://www.nps.gov/cowp/learn/photosmultimedia/photogallery.htm.

of 133 cm (52.3 in) (Worsham et al. 2012). Predicted climate change will impact the rate and severity of geologic process which may in turn impact the ecosystem at Cowpens National Battlefield. In comparing recent climate values within the context of historical conditions, temperatures are increasing, and overall precipitation is decreasing at Cowpens National Battlefield (Monahan and Fisichelli 2014). Increased evaporation combined with decreased precipitation will dry the local wetlands underlain by fine-grained clays. Recent climatic conditions are already shifting beyond the measured, historical range of variability and extreme climate events will increase in severity and frequency. The park is already noting an increase in the frequency and severity of intermittent drought conditions (Boland 2006). Droughts followed by heavy precipitation during storms will decrease stabilizing vegetation and lead to erosion increases. According to Monahan and Fisichelli (2014), ongoing and future changes in climate will affect all aspects of park management including natural resource protection, park operations, and visitor experience. Understanding the triggers and outcomes of these changes is crucial to protecting the natural and cultural resources at the park.

Additional information about other natural resources is available from the following sources:

- Web soil survey https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- Water quality data summary https://irma.nps.gov/DataStore/Reference/Profile/2229840
- Weather and climate inventory https://irma.nps.gov/DataStore/Reference/Profile/649202
- Future warming and visitation https://irma.nps.gov/DataStore/Reference/Profile/2222814
- Biotic stressors at the park https://irma.nps.gov/DataStore/Reference/Profile/2219457
- Information regarding the park's water resources is available from the NPS Water Resources Division (http://go.nps.gov/waterresources)
- Inventory and characterization of wetlands https://irma.nps.gov/DataStore/Reference/Profile/652117
- The NPS Cumberland Piedmont Network currently inventories and monitors natural resources such as climate, land cover, fire ecology, aquatic invertebrates, fish communities, spring communities, plant communities, and invasive exotic plants (https://www.nps.gov/im/cupn/index.htm).

Geologic Terms

accretion. The addition of island-arc or continental material to a continent via collision, welding, or suturing at a convergent plate boundary.

biotite. A dark-colored, shiny silicate mineral (silicon + oxygen) of the mica group composed of magnesium and/or iron, $K(Mg,Fe)Si^3O^{10}(OH)^2$; characterized by perfect cleavage, readily splitting into thin sheets.

channel. The bed of a stream or river. Also, a natural passageway or depression of perceptible extent containing continuously or periodically flowing water, or forming a connecting link between two bodies of water.

crust. Earth's outermost layer or shell.

fault. A break in rock characterized by displacement of one side relative to the other.

fold. A curve or bend in an originally flat structure, such as a rock stratum, bedding plane, or foliation; usually a product of deformation.

gneiss. A foliated metamorphic rock with alternating bands of dark and light minerals. Varieties are distinguished by texture (e.g., augen gneiss), characteristic minerals (e.g., hornblende gneiss), or general composition (e.g., granite gneiss).

granite. A coarse-grained, intrusive igneous rock in which quartz constitutes 10%–50% of the felsic ("light-colored") components and the alkali feldspar/total feldspar ratio is generally restricted to the range of 65% to 90%; perhaps the best known of all igneous rocks.

hinge line. The axis along which the curvature of a fold is greatest. Also, a line or boundary between a stable region and one undergoing upward or downward movement.

igneous. Describes a rock or mineral that solidified from molten or partly molten material; also, describes processes leading to, related to, or resulting from the formation of such rocks. One of the three main classes or rocks—igneous, metamorphic, and sedimentary.

immature sandstone. A sandstone whose clasts are of a variety of mineralogical compositions, textures, degrees of angularity, and sizes. The grains were not thoroughly reworked or winnowed prior to deposition and are poorly sorted.

interfluve. The area between rivers, especially the relatively undissected upland or ridge between two adjacent valleys containing streams flowing in the same general direction.

magma. Molten rock beneath Earth's surface capable of intrusion and extrusion.

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

metamorphism. The mineralogical, chemical, and structural changes of solid rocks generally imposed at depth below the surface zones of weathering and cementation.

mica. A group of abundant silicate (silicon + oxygen) minerals characterized by perfect cleavage, readily splitting into thin sheets. Examples include "biotite" and "muscovite."

mineral. A naturally occurring inorganic crystalline solid with a definite chemical composition or compositional range.

obduction. The overriding of oceanic crust onto the leading edge of a continental lithospheric plate.

orogeny. A mountain-building event.

paleogeography. The study, description, and reconstruction of the physical landscape in past geologic periods.

physiography. The subfield of geography that studies physical patterns and processes of Earth. It aims to understand the forces that produce and change rocks, oceans, weather, and global flora and fauna patterns. Physiographic provinces or regions are defined by and share such characteristics.

plunge. Plunge is the vertical angle between the horizontal plane and the axis or line of maximum elongation of a feature. Plunge is measured along the axis of a fold, whereas dip is measured along the limbs

pluton. A deep-seated igneous intrusion.

rift. A region of Earth's crust where extension results in formation of many related normal faults, commonly associated with volcanic activity.

runoff. The draining away of water (or substances carried in it) from the surface of an area of land or structure.

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

sediment. An eroded and deposited, unconsolidated accumulation of rock and mineral fragments.

sedimentation. The process of forming or accumulating sediment into layers, including the separation of rock particles from parent rock, the transportation of these particles to the site of deposition, the actual deposition or settling of the particles, the chemical and other changes occurring in the sediment, and the ultimate consolidation of the sediment into solid rock.

slope wash. Soil and rock material that is or has been transported down a slope under the force of gravity and assisted by running water not confined to channels; also, the process by which slope-wash material is moved.

tectonic. Describes a feature or process related to large-scale movement and deformation of Earth's crust.

thrust fault. A dip-slip fault with a shallowly dipping (less than 45°) fault surface where the hanging wall moves up and over relative to the footwall.

volcanic arc. A large-scale (hundreds of kilometers) generally curved belt of volcanoes above a subduction zone.

watershed. Any surface area from which runoff resulting from precipitation is collected and drained through a common point. Synonymous with a drainage basin or catchment area.

Geologic Features, Processes, and Issues

These geologic features and processes are significant to the park's landscape and history. Features and processes may pose resource management issues. Some geologic features, processes, or human activities may require management for human safety, protection of infrastructure, and preservation of natural and cultural resources. The NPS Geologic Resources Division provides technical and policy assistance for these issues.

Geologic resources, including the small streams, wetland areas, and low topography at Cowpens National Battlefield are fundamental to its history and modern preservation and interpretation (GRI scoping meeting, 26—28 April 2005). During the 2005 scoping meeting and 2019 conference call, participants (see Appendix A) identified the following features, processes, and resource management issues (roughly in order of significance): fluvial features and processes; ravine erosion; old Scruggs Lake and fossil pollen record; restoration of 1781-era wetlands; bedrock outcrops; geologic hazards; and faults and folds. Each is discussed with regard to the relevant geologic map units and include geologic-term definitions. Table 2 describes the geologic map units in the GRI GIS data and identifies the geologic features, processes, and resource management issues associated with each. Resources, references, and suggestions for park managers follows.

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

Detailed descriptions of each unit are in the COWP_geology.pdf in the GRI GIS map data.

Map Unit (symbol)	Description and Spatial Distribution	Features, Processes, and Potential Resource Management Issues
Quaternary alluvium (**Qal**)	**Qal** is not mapped along Long Branch of Island Creek within the park. This reflects the scale of mapping and is not necessarily an indication that alluvium is absent in these locations. It is mapped along Zekial Creek and its tributaries south of the park, as well as Broad River and its tributaries north of the park. It consists of unconsolidated clay, silt, and sand	**Fluvial Features and Processes** **Qal** is being deposited, eroded, and reworked by modern rivers and streams. Alluvium lines the modern stream channels. **Potential for Flooding** Low-lying areas of **Qal** may flood. **Geologic Hazards** Earthquakes may destabilize unconsolidated deposits such as **Qal**.
Silicified Quartz Breccia (**MZq**)	**MZq** is not mapped within the park. It occurs along Cowpens Creek in the extreme southeast corner of the mapped area. **MZq** formed along a fault zone where rocks were crushed into angular fragments and cemented with quartz.	**Faults and folds** Breccias such as **MZg** form along faults, as rocks slide against each other and fracture.
Sandy Mush granite (**Dsm**)	**Dsm** is not mapped within the park. **Dsm** is mapped north of the park. **Dsm** is a biotite rich granite with little to no foliation (layering). It is weakly metamorphosed.	**Potential for Flooding** Low-lying areas of **Dsm** may be prone to flooding. **Faults and folds** **Dsm** is a prominent, folded unit within the Six-Mile thrust sheet.
Megacrystic metagranite (**CZmm**)	**CZmm** is not mapped within the park. It occurs west of the park along the Pacolet River. **CZmm** is a biotite-rich granite with large feldspar crystals up to the size of the average finger.	**Faults and folds** **CZmm** is a prominent, folded unit within the Six-Mile thrust sheet.
Amphibolite gneiss (**CZa**)	**CZa** is not mapped within the park. It occurs northwest of the town of Cowpens, South Carolina. **CZa** is a gneiss or foliated metamorphic rock rich in plagioclase feldspar and dark hornblende minerals.	**Faults and folds** **CZa** is folded within layers of **CZb** and **CZms**.

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

Map Unit (symbol)	Description and Spatial Distribution	Features, Processes, and Potential Resource Management Issues
Biotite gneiss (**CZb**)	**CZb** is mapped inside park boundaries. It underlies 22% of the park. **CZb** has bands of alternating dark and light minerals (quartz and feldspar), is rich in biotite, and contains garnet crystals.	**Bedrock outcrops** Four **CZb** outcrops are mapped within the park. **Faults and folds** **CZb** is a prominent, folded unit within the Six-Mile thrust sheet underlying the park. Attitude measurements such as schistosity and foliation within **CZb** suggest the folds trend northeast-southwest and that the movement of the thrust sheet toward the continent was directed from the southeast northwestward.
Mica schist (**CZms**)	**CZms** is mapped inside park boundaries. It underlies 78% of the park. **CZms** is a mix of flaky muscovite and biotite minerals (micas) and minerals such as quartz and sillimanite with garnet locally. A subtle ridge in this unit allowed the Americans to hide their numbers from the British frontal attackers during the Battle of Cowpens.	**Bedrock outcrops** Eleven mapped within the park. **Faults and folds** **CZms** is folded as layers within **CZb** and **Dsm**. Attitude measurements such as schistosity and foliation within **CZms** suggest the folds trend northeast-southwest and that the movement of the thrust sheet toward the continent was directed toward the northwest.

Geologic Terms

breccia. A coarse-grained, generally unsorted sedimentary rock consisting of cemented angular clasts more than 2 mm (0.08 in) across formed by crushing or breaking a rock into angular fragments.

feldspar. A group of abundant silicate (silicon + oxygen) minerals, comprising more than 60% of Earth's crust and occurring in all types of rocks.

hornblende. A silicate (silicon + oxygen) mineral of sodium, potassium, calcium, magnesium, iron, and aluminum; commonly black and occurring in distinct crystals or in columnar, fibrous, or granular forms in hand specimens. The most common mineral of the amphibole group.

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

schistosity. The foliation in schist or other coarse-grained, crystalline rock resulting from the parallel alignment of platy mineral grains of mica or inequant crystals of other minerals.

Fluvial Features, Processes, and Issues

Fluvial features are those which are formed by flowing water (fig. 12). Fluvial resources include the features associated with a stream, such as its riparian zone, hydrologic system, and habitats. Fluvial processes both construct (deposit alluvium; geologic map unit **Qal**) and erode landforms (e.g., the local streams and river channels).

Figure 12. Photograph of a stream and bridge. The battlefield sits astride an interfluve where streams originate and flow outwards away from the battlefield. National Park Service photograph available at https://www.nps.gov/cowp/learn/photosmultimedia/photogallery.htm.

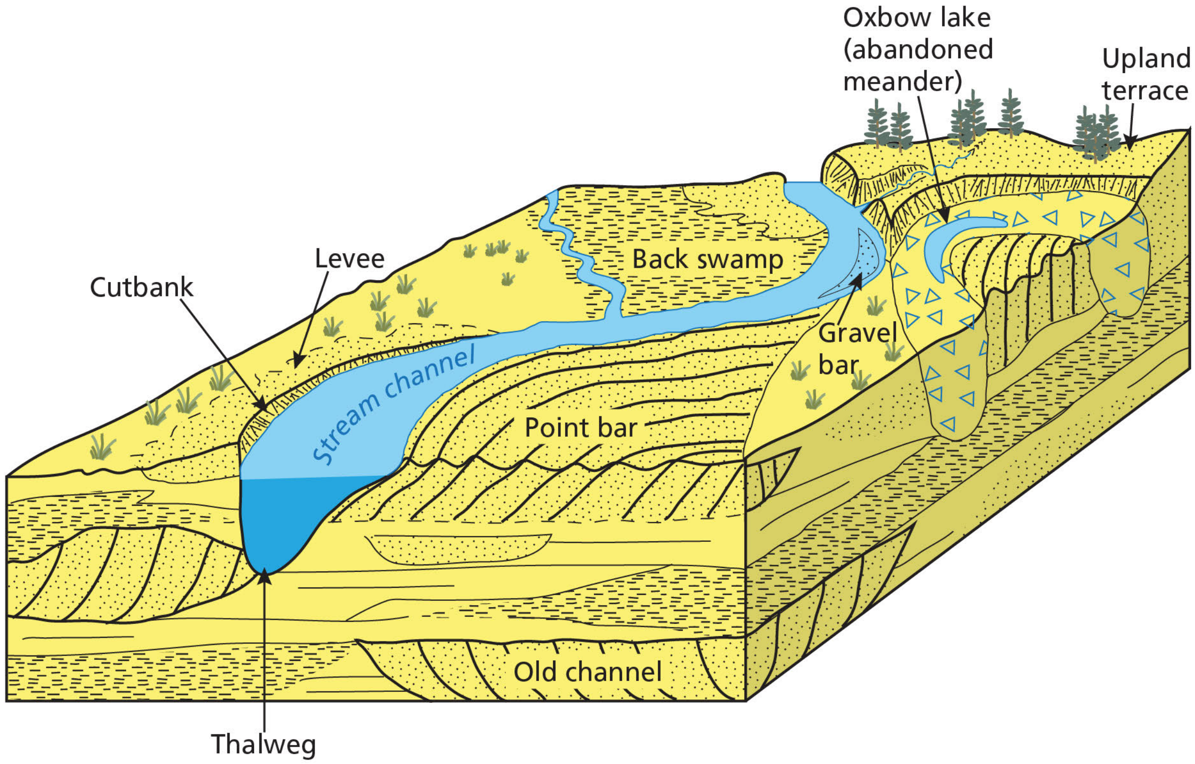

Figure 13. Schematic graphic of generalized fluvial features.
The streams at Cowpens National Battlefield are short and narrow; however, many of these features occur at a smaller scale along their length such as cutbanks, riparian zones, back swamps, and gravel bars. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University).

Nearly 3 km (2 mi) of perennial and seasonal streams flow through the park (see fig. 12) and include Suck Creek #2, Suck Creek # 3, Zekial Creek, Little Buck Creek, and Long Branch of Island Creek formerly flowing from now-remediated Old Scruggs Lake. All these streams originate in the park (Worsham et al. 2012; Cowpens National Battlefield staff, conference call, 18 December 2019).

Examples of the park's fluvial features include meandering channels, riparian zones, point bars, floodplains, gravel bars, and riffles (fig. 13). River channels are the perennial course of the flowing water flanked on either side by a riparian zone (the interface between land and a river or stream, but also a habitat to hydrophilic plants). As a river flows around curves the flow velocity (and thus erosive energy) is greatest on the outside of the bend. The river erodes into its bank on the outside of a curve and leaves point bar deposits on the inside of the bend. Point bars are crescent-shaped ridges of sand, silt, and clay deposited on the inside of meander loops where the water's velocity is slowest. As the process continues, the outside bend retreats farther, while the inside bend migrates laterally, thus creating migrating meanders across its floodplain or low-lying area adjacent to the channel that is subject to flooding. Meandering reaches its extreme, when the narrow neck of land between two bends is breached forming an oxbow lake (none present within the park). Gravel bars are coarse deposits that accumulate inside the channel. Sometimes water flowing over gravel bars create riffles. A riffle is a shallow landform in a flowing channel; riffles may provide specific habitat for aquatic species. Water moving over a riffle appears shallow and fast, with a wavy, disturbed water surface.

As part of the inventory and monitoring effort by the Cumberland Piedmont Network, four streams are monitored for overall condition and water quality: Long Branch of Island Creek, Little Buck Creek, Suck Creek #2, and Suck Creek #3 (Johnathan Jernigan, Cumberland Piedmont Network, physical scientist, written communication, 18 December 2019). Levels of *Escherichia coli* bacteria are sometimes elevated, but otherwise, water quality is considered normal and stream channel condition has remained largely unchanged (Cowpens National Battlefield staff, conference call, 18 December 2019). Surface water dynamics (i.e., discharge) is one of the natural resource attributes listed in the park's ecological monitoring framework (Worsham et al. 2012). Annual briefs for water monitoring in the park are available at: https://www.nps.gov/im/cupn/monitoring-reports.htm.

Potential for Flooding

Potential for flooding to impact park resources and values is low. Flooding occurs locally when narrow channels are overwhelmed by heavy rains funneled through the drainages. Cowpens National Battlefield is located at the headwaters of several small streams (GRI scoping meeting, 26—28 April 2005). Floods and seasonal runoff are the primary geomorphological processes shaping the fluvial environment. Floods shift alluvium (geologic map unit **Qal**) and have an important role in controlling the pattern of riparian vegetation along channels and floodplains. During high flows or floods, a stream deposits natural levees of sand and silt along its banks (see fig. 13). These deposits represent the relatively coarse-grained component of a river's suspended sediment load and form a high area on an alluvial region's land surface. Flooding is a natural process, but it becomes a resource management issue when significant cultural or natural resources are threatened. The low-lying areas mapped as geologic map unit **Dsm** could flood preferentially, howeverpark staff have not observed a history of significant flooding at this point (Cowpens National Battlefield staff, conference call, 18 December 2019).

Fluvial issues

A hydrological survey is a high-priority management need identified in the foundation document (National Park Service 2014). Park streams contribute flow and suspended sediment to the Broad River watershed. Excess sediment in the Broad River watershed is a long-standing watershed quality problem and negatively impacts the health of the aquatic ecosystem. Little to no sediment data for the basin exist. The South Carolina Geological Survey is engaged in a Broad River project, of which Cowpens National Battlefield is a participant. Its goal is "to generate new and useful sediment related data and assess how sediment associated issues impact aquatic resources and habitat in the Broad River Basin, South Carolina." The project proposes to improve the physical aquatic habitat and diversity of the system, identify sediment sources and possible methods to reduce excess sedimentation in some reaches, and develop policy guidelines for sediment management (contact Kerry Castle: castlek@dnr.sc.gov). Lord et al. (2009) provided general guidelines for fluvial geomorphology monitoring.

Geologic Terms

alluvium. Stream-deposited sediment.

clay. Minerals and sedimentary fragments that are less than 1/256 mm (0.00015 in) across.

floodplain. The surface or strip of relatively smooth land composed of alluvium and adjacent to a river channel, constructed by the present river in its existing regimen and covered with water when the river overflows its banks. A river has one floodplain and may have one or more terraces representing abandoned floodplains.

geomorphology. The study of the general configuration of surface landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.

gravel. An unconsolidated, natural accumulation of typically rounded rock fragments resulting from erosion; consists predominantly of particles larger than sand; that is, greater than 2 mm (1/12 in) across.

levee. A long broad low embankment of sand and coarse silt built by floodwater overflow along both banks of a stream channel.

point bar. A low ridge of sand and gravel deposited in a stream channel on the inside of a meander, where flow velocity slows.

riparian. Relating to or living or located on the bank of a natural watercourse (such as a river) or sometimes of a lake or a tidewater.

sand. A clastic particle smaller than a granule and larger than a silt grain, with a diameter ranging from 1/16 to 2 mm (0.0025 to 0.08 in).

seismicity. The phenomenon of movements in the Earth's crust. Synonymous with "seismic activity."

silt. Clastic sedimentary material intermediate in size between fine-grained sand and coarse clay, 0.0039 to 0.063 mm (0.00015 to 0.0025 in) across.

Ravine Erosion

Surface water flowing over the battlefield landscape has eroded small ravines that drain into seasonal and perennial streams (GRI scoping meeting, 26—28 April 2005). Erosion is exacerbated where vegetation is disturbed, or social trail use has degraded the ground cover. Continued erosion of these ravines or gullies will further alter the 1781-era landscape (see "Restoration of 1781-era Wetlands, Green River Road, and Monuments" section). A ditch (not mentioned at the time of the battle) of unknown provenance is located adjacent to the park's battlefield trail (see "Restoration of 1781-era Wetlands, Green River Road, and Monuments" section). While subject to Earth surface processes, park staff have not noticed any dramatic changes over the past 30 years. Park staff would like to know the provenance of this feature before deciding on a management approach (Cowpens National Battlefield staff, conference call, 18 December 2019).

Figure 14. Photograph of Old Scruggs Lake.
Image shows a person standing on the now-vegetated, former bank of Scruggs Lake. Park staff plans to allow natural forest succession to continue to restore a battle-era appearance. National Park Service photograph by Ginny Fowler, taken 9 September 2020.

Geologic Terms

gully. A small channel produced by running water in unconsolidated material.

ravine. A small narrow steep-sided valley that is larger than a gully and smaller than a canyon and that is usually worn by running water.

Old Scruggs Lake and Fossil Pollen Record

The wetlands at Cowpens National Battlefield, including the remnants of Old Scruggs Lake (farm pond), may contain a fossil pollen (palynological) record that would be of value to archeologists in reconstructing prehistoric and historic plant successions and paleoclimates (GRI scoping meeting, 26—28 April 2005). Sometime between 1977 and 1980, after the battlefield had become part of the National Park Service, Scruggs Lake (post-dating the battle, but part of the later settlement story) was drained and impoundment dams were removed (Cowpens National Battlefield staff, conference call, 18 December 2019), but its sediments may still remain intact for fossil pollen. The pond area is now vegetated (fig. 14), and park staff plans to allow natural forest succession to continue to restore a battle-era appearance (Cowpens National Battlefield staff, conference call, 18 December 2019).

Restoration of 1781-era Wetlands, Green River Road, and Monuments

The topography at Cowpens National Battlefield is low and muted (fig. 15); however, those relatively small changes in underlying geology and elevation had large impacts on the battle. Pivotal landforms for the Battle of Cowpens included the boggy (wetland) swales between local ridges (fig. 16). Green River Road is also among the fundamental resources and values identified in the park's foundation document (National Park Service 2014). The park's foundation document also describes the entire park area as highly disturbed as a result of previous housing and agricultural activities on site. Though they could be considered a disturbance, the commemorative monuments are historic and require maintenance. Maintenance and restoration of the park's

Figure 15. Photographs showing the muted topography of the landscape.
Though subtle, the low ridges and shallow swales (upper photograph) were effective in hiding numbers of Americans from the approaching British troops. All images are National Park Service photographs available at https://www.nps.gov/cowp/learn/photosmultimedia/photogallery.htm.

Figure 16. Photographs showing the cane restoration and wetlands at the battlefield.
Top image shows an active restoration area. Bottom image shows cane growing in a low-lying boggy area. Boggy areas at the time of battle slowed troop movement and made cannons impossible. The Green River Road followed higher ground through the boggy lands. Cane breaks were a prominent feature in the boggy swales of the Cowpens at the time of the battle. The National Park Service is attempting to restore this native plant and further the battlefield era appearance. All images are National Park Service photographs available at https://www.nps.gov/cowp/learn/photosmultimedia/photogallery.htm.

landscape and wetlands to their 1781-era condition and appearance is a management priority.

Wetlands

Wetlands are transitional areas between land and water bodies, where water periodically floods the land or saturates the soil and includes marshes, swamps, seeps, pools, and bogs. Wetlands in the park are covered in shallow surface water (fig. 16) or have water within the root zone most of the year or are wet only seasonally. Wetlands provide several significant functions, including (1) provision of bird and other wildlife habitat, (2) surface water detention, (3) nutrient transformation, and (4) retention of sediments. According to Worsham et al. (2012), the park has 37 wetlands totaling around 5 ha (12 ac). Most of the park wetlands are spring-fed. Climate change (i.e., droughts) and withdrawal of groundwater via local wells have caused the wet-weather springs to cease flowing and many of the swales are now dry throughout the year (Boland 2006). A 1-m (3-ft) -deep ditch of unknown provenance and age parallels the Green River Road to the southwest (see "Ravine Erosion" section). A natural channel would contain a typical soil profile of black, reduced, poorly drained organic clay. The absence of this profile in addition to an orange-colored, oxidized, and well-drained soil suggests it is an anthropogenic feature, not a dry stream bed. This channel may have been used for irrigation or to drain or divert water away from boggy areas (Boland 2006).

Park managers wish to restore the 1781-era wetlands (GRI scoping meeting, 26—28 April 2005). The NPS Water Resources Division (http://go.nps.gov/waterresources) is a primary source for technical assistance. Roberts and Morgan (2006) presented an inventory and classification of wetlands for Cowpens National Battlefield wherein they were all classified as palustrine, forested, deciduous, and temporarily flooded. Thirty-two of the 37 were classified as slope wetlands (dictated by water table elevation) along stream drainages with a groundwater source (spring), the remaining five were depressions charged by precipitation and overland flow. An effort is currently underway to restore the native cane plants (fig. 16) that would have been growing in the wet areas in 1781 (Cowpens National Battlefield staff, conference call, 18 December 2019).

Green River Road and Battleground Refinement

According to the park's foundation document (National Park Service 2014), in an effort to further restore, understand, and refine the 1781-era battlefield landscape and Green River Road, park managers seek: LiDAR coverage, ground penetrating radar (GPR), resistivity surveys, and hydrologic studies. High resolution LiDAR would be able to detect minute topographical changes (e.g., anthropogenic features). This, overlain with geologic map coverage and the refined map of battle movements, would increase the understanding of how the battle commenced and determine areas at risk of degradation or loss from natural processes or anthropogenic activities. GPR and resistivity would identify abnormalities or anomalies below the ground surface. This may help detect burial sites. Blown down trees could expose swaths of soil and if located on the battlefield, could contain artifacts from the battle (fig. 17). A hydrology study to determine how water is moving above and below ground would help determine where roads should be breached to allow for

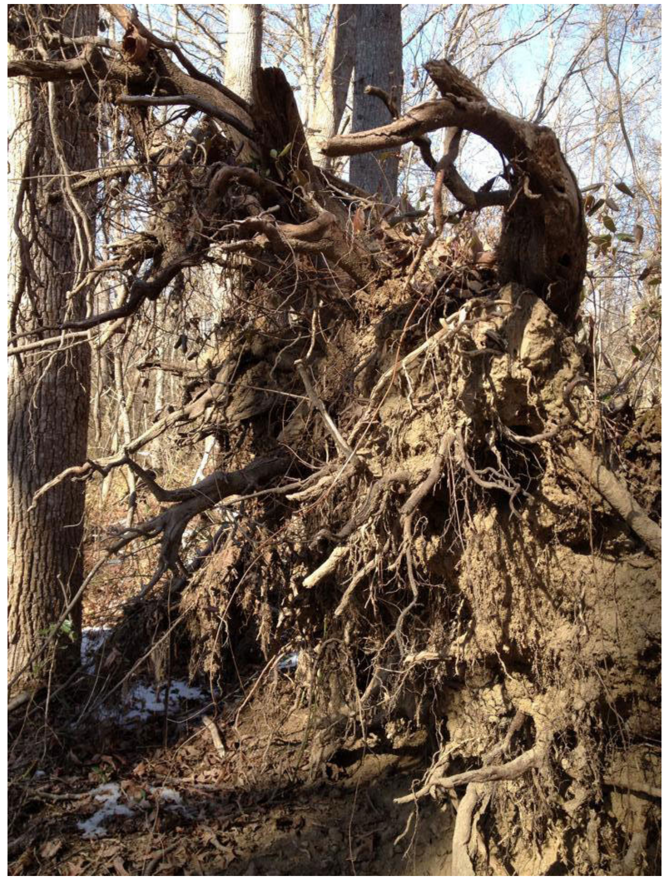

Figure 17. Photograph of a blown down tree at Cowpens National Battlefield.
This particular tree is along the park's nature trail and not on the battlefield itself. It was toppled by Hurricane Ivan in 2004. The large trees growing on the battlefield may also blow down in severe storms. This could expose battle-era artifacts and create areas of localized erosion. Images is a National Park Service photograph available at https://www.nps.gov/cowp/learn/photosmultimedia/photogallery.htm.

water to flow naturally and restore some of the original watersheds. These data needs were identified as high priority (National Park Service 2014).

Maintaining Historic, Commemorative Monuments

The ca. 1932 US Monument and ca. 1856 Washington Light Infantry Monument are listed as part of the National Register of Historic Places. They are among the oldest battlefield monuments established for a Revolutionary War battle. According to the park's foundation document (National Park Service 2014), the US Monument is in good condition, but requires continual maintenance, including repointing. The Washington Light Infantry Monument is listed in poor condition, deteriorating, and needing restoration but is hampered by a lack of restoration funds. It was originally constructed of Sullivan's Island tabby—a type of concrete made by burning oyster shells to create lime, then mixing it with water, sand, ash and broken oyster shells. Tabby was commonly used as building material by English colonists in coastal South Carolina (Sickels-Taves and Sheehan 1999; Cowpens National Battlefield staff, conference call, 18 December 2019). It has since been coated in concrete and requires cleaning and stabilization (Cowpens National Battlefield staff, conference call, 18 December 2019). This tabby could contain fossil resources putting the monument under the 2009 Paleontological Resources Preservation Act (see Appendix B), which states that all paleontological resources are non-renewable and subject to science-informed inventory, monitoring, protection, and interpretation. Leaching, acid rain, and improper visitor use are among the threats to the integrity of the monuments. Though historic structure reports exist, both monuments would benefit greatly from a historic structure preservation plan and maintenance standards. These data needs were identified as high priority (National Park Service 2014; Cowpens National Battlefield staff, conference call, 18 December 2019).

Geologic Terms

anthropogenic. Originating in human activity.

bog. Wet spongy ground; a poorly drained usually acid area rich in accumulated plant material.

marsh. An area of low-lying land which is flooded in wet seasons, and typically remains waterlogged at all times.

oxidation. The process of combining with oxygen.

palustrine. Relating to a system of inland, nontidal wetlands characterized by the presence of trees, shrubs, and emergent vegetation (vegetation that is rooted below water but grows above the surface).

reduction. A chemical reaction that involves the gaining of electrons by one of the atoms involved in the reaction between two chemicals.

seep. A place where flowing groundwater emerges at the surface in a slow, constant manner.

swale. A low or hollow place, especially a marshy depression between ridges.

water table. The surface between the saturated zone and the unsaturated zone. Synonymous with "groundwater table" and "water level."

Bedrock Outcrops

"Bedrock" is the solid rock that underlies the park. Bedrock can be sedimentary, igneous, or metamorphic. Sedimentary rocks form from fragments of other rocks or chemical precipitation. Igneous rocks form by the cooling of molten material. Metamorphic rocks are those that have been altered by high temperature, high pressure, and/or fluids. Metamorphic bedrock is exposed in several areas of the park as captured in geologic observation localities in the GRI GIS data (see fig. 9; Howard 2010), typically along stream channels where erosion has removed overlying soil or other deposits. These localities were documented during the mapping project and their strike and dip and/or trend and plunge are included in the GRI GIS data (Robby Morrow, South Carolina Geological Survey, field geologist, conference call, 18 December 2019). Park rocks were originally mixtures of sedimentary and volcanic rocks that were metamorphosed during the course of accretion of the Six-Mile thrust sheet onto the eastern edge of North America during mountain building. Biotite gneiss (geologic map unit **CZb**; e.g., fig. 18) and mica schist (**CZms**; e.g., fig. 18) were mapped within park boundaries (Boland and Howard 2000; Howard 2010). The biotite gneiss is moderately to strongly banded in alternating layers of dark and light minerals with some garnet crystals. It tends to be a hard, metamorphic rock. The mica schist contains abundant, typically shiny, flaky minerals (e.g., biotite and muscovite). The alignment of these minerals causes the rock to be somewhat fissile (parts easily). Other common minerals in the mica schist include quartz, sillimanite (a mineral indicative of high pressure and high temperature metamorphism), and garnet (Boland and Howard 2000; Howard 2010; Robby Morrow, South Carolina Geological Survey, field geologist, written communication, 11 August 2020).

Geologic Terms

chemical precipitation. The creation of a solid from a solution. When the reaction occurs in a liquid solution, the solid formed is called the precipitate.

dip. The angle between a bed or other geologic surface and the horizontal plane.

garnet. A hard silicate (silicon + oxygen) mineral with a glassy luster, and commonly well-defined crystal faces; characteristically dark red but occurs in a variety of colors.

muscovite. A light-colored silicate (silicon + oxygen) mineral of the mica group, $KAl^3Si^3O^{10}(OH)^2$, characterized by perfect cleavage in one direction and the ability to split into thin, clear sheets.

outcrop. Any part of a rock mass or formation that is exposed or “crops out” at Earth’s surface.

quartz. Silicon dioxide, SiO^2. The only silicate (silicon + oxygen) mineral consisting entirely of silicon and oxygen. Synonymous with “crystalline silica.”

regolith. From the Greek “rhegos” (blanket) + “lithos” (stone), the layer of unconsolidated rock material that forms the surface of the land and overlies or covers bedrock; includes rock debris of all kinds, volcanic ash, glacial drift, alluvium, loess, and aeolian deposits, vegetal accumulations, and soil.

saprolite. A soft, earthy, typically clay-rich, thoroughly decomposed rock, formed in place by chemical weathering of igneous, sedimentary, and metamorphic rocks.

sillimanite. an aluminosilicate (aluminum and silicon rich) mineral typically occurring as fibrous masses, commonly in schist or gneiss.

strike. The compass direction of the line of intersection of an inclined surface with a horizontal plane.

trend. The direction or bearing of an outcrop of a geologic feature such as an ore body, fold, or orogenic belt.

Geologic Hazards

A geologic hazard (“geohazard”) is a natural or human-caused geologic condition or process that may impact park resources, infrastructure, or visitor safety. Risk is (1) the probability of a hazard to occur combined with (2) the expected degree of damage or loss that may result from exposure to a hazard, or the likelihood of a hazard causing losses (see Holmes et al. 2013). The primary geologic hazard for Cowpens National Battlefield is seismicity. Seismicity, or earthquakes, are ground vibrations—shaking—that occur when rocks suddenly move along a fault, releasing accumulated energy (Braile 2009). Earthquake intensity ranges from being imperceptible by humans to complete destruction of developed areas and alteration of the landscape. The “Richter magnitude” is a measure of the energy released by an earthquake; another way to measure earthquake intensity is via the Mercalli scale. Earthquakes can directly damage park infrastructure or trigger other hazards such as slope movements that may impact park resources, infrastructure, or visitor safety.

Figure 18. Photographs of hand samples of biotite gneiss and mica schist.
Biotite gneiss (top image) forms as a metamorphic rock with characteristic bands of dark minerals (e.g., biotite and hornblende) and bands of light minerals (e.g., quartz and feldspar). Mica schist (bottom image) is rich in flaky, aligned minerals which lend a planar appearance to the rock. These samples are representative of the rock types within the park. Images by James St. John, licensed under CC-BY-2.0, available at https://www.flickr.com/people/jsjgeology/.

Earthquakes

Based on the National Seismic Hazard Model (Petersen et al. 2020), the park is in an area of moderate seismic hazard (fig. 19). According to geologists at the South Carolina Geological Survey, the risk for earthquakes at Cowpens National Battlefield is low but exists (Robby Morrow, South Carolina Geological Survey, field geologist, conference call, 18 December 2019) as demonstrated by the 1913 Union County earthquake along the Eastern Piedmont fault system. Earthquakes with magnitudes between 2 and 3 are not uncommon as “microseismicity” as crustal adjustments occur on very old faults (Robby Morrow, South Carolina Geological Survey, field geologist, conference call, 18 December 2019).

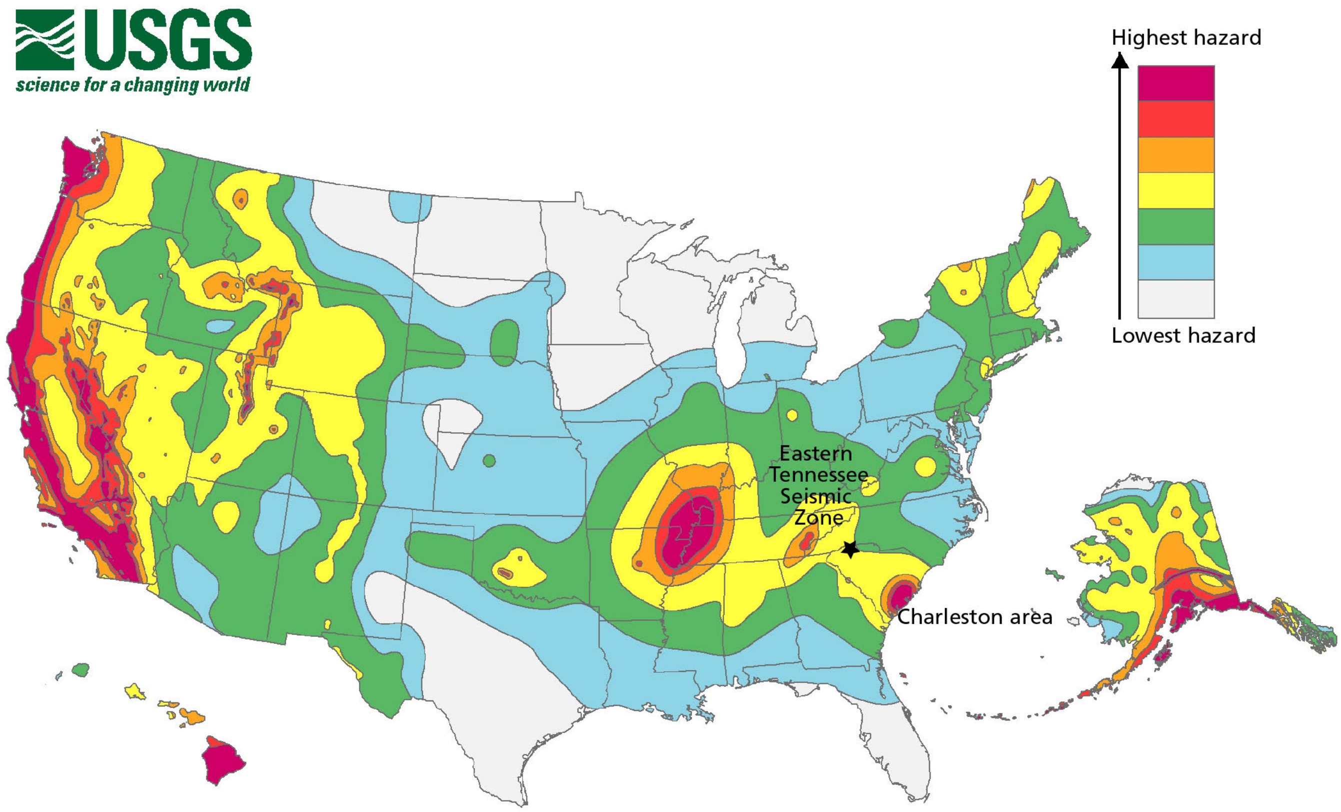

Figure 19. National seismic hazard map.
The map shows the relative nationwide hazard associated with potential earthquakes. The park (black star) is located in a moderate hazard area between two high hazard areas: the Eastern Tennessee Seismic Zone to the west and the Charleston area to the southeast. Locally the hazard may be greater than shown, because site geology may amplify ground motions. For detailed information on how the hazard was calculated, refer to the website below. Public domain graphic courtesy of the US Geological Survey; available at https://www.usgs.gov/media/images/2018-long-term-national-seismic-hazard-map. Annotation by Trista L. Thornberry-Ehrlich (Colorado State University).

Ancient faults occur throughout the area and are present in the GRI geologic map data. The park is located near a known active seismic zone—the Eastern Tennessee Seismic Zone (see fig. 19). It is one of the most active seismic zones in eastern North America; more than 44 detectable (felt by humans) earthquakes have occurred since 1982 (Chapman et al. 2002). Intra-plate seismic zones such as the Eastern Tennessee Seismic Zone are far from plate boundaries, which are the typical locations of earthquakes. The focal depths of most earthquakes in the seismic zone range from 5 to 22 km (3 to 13 mi), beneath large Paleozoic-aged detachment surfaces (faults) (Chapman et al. 2002). Fault movement in the Eastern Tennessee Seismic Zone is primarily lateral (strike-slip), with right-lateral motion on north–south-trending faults and left-lateral motion on east–west-trending faults (Chapman et al. 2002).

Charleston, South Carolina experienced strong (~7.3-magnitude) earthquakes in 1886. If an earthquake of this magnitude were to occur again in Charleston, US Geological Survey earthquake scenarios predict shaking at the park would be light (IV on the Mercalli Intensity scale: detectable indoors by many persons; windows and doors disturbed; cars rocking). Unconsolidated units such as alluvium (geologic map unit **Qal**) may become unstable during earthquakes. More information about earthquake scenarios can be found at: https://earthquake.usgs.gov/scenarios/. In 1913, southeast of Cowpens in Union County, an earthquake shook at intensity VI–VII on the Mercalli scale, causing widespread detection and panic, damage to buildings, and falling chimneys (von Hake 2009; Dart et al. 2010). A magnitude 4.4 earthquake occurred locally in 1924 (Robby Morrow, South Carolina Geological Survey, field geologist, conference call, 18 December 2019). On 9 August 2020, a 5.1-magnitude earthquake occurred near Sparta, North Carolina (Robby Morrow, South Carolina Geological Survey, field geologist, written communication, 11 August 2020). The 2011 Virginia earthquake caused major damage in an area that was likewise considered to be relatively inactive.

The South Carolina Geological Survey website (http://www.dnr.sc.gov/geology/) has records of earthquake epicenters since 2006. The NPS Geologic Resources Division Seismic Monitoring website (http://go.nps.gov/seismic_monitoring), and the US Geological Survey Earthquakes Hazards website (http://earthquake.usgs.gov/) provide more information about seismic hazards. In the *Geological Monitoring* chapter about earthquakes and seismic activity, Braile (2009) described the following methods and vital signs for understanding earthquakes and monitoring seismic activity: (1) monitoring earthquakes, (2) analysis and statistics of earthquake activity, (3) analysis of historical and prehistoric earthquake activity, (4) earthquake risk estimation, (5) geodetic monitoring and ground deformation, and (6) geomorphic and geologic indications of active tectonics.

Resources Related to Geologic Hazards in the Park

- South Carolina earthquake risk and vulnerability: URS Corporation et al. (2001)
- Geologic Resources Division Geohazards website (https://www.nps.gov/subjects/geohazards/index.htm)
- Natural hazards science strategy: Holmes et al. (2013)
- Geologic hazards mapping: contact Bill Clendenin at the South Carolina Geological Survey (clendeninb@dnr.sc.gov)

Geologic Terms

geodetic surveying. Surveying that takes into account the figure and size of Earth, with corrections made for curvature; used where the areas or distances involved are so great that the desired accuracy and precision cannot be obtained by plane (ordinary field and topographic) surveying.

slope. The inclined surface of any part of Earth's surface, such as a hillslope. Can also refer to the relative steepness of a particular surface.

Faults and Folds

Faults and folds occur where rocks have been compressed (squeezed), stretched, sheared, or fractured and moved. They are common structural features in areas where mountain building has occurred, such as the southern Appalachian Mountains and occur within all the mapped units included in the GRI GIS data (see table 2; Boland and Howard 2000; Howard 2010). A fault is a fracture in rock along which rocks have moved (fig. 20). When movement occurs along a fault, rocks may be

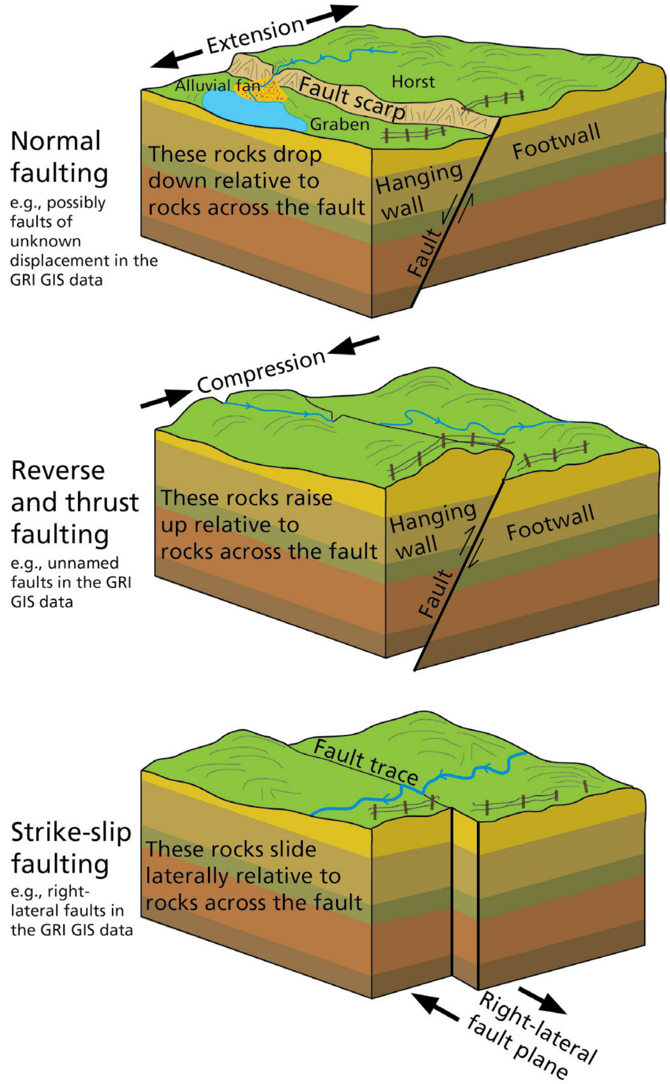

Figure 20. Illustrations of fault types. Strike-slip and thrust faults occur in the GRI GIS data for Cowpens National Battlefield (mapped outside of the park) and other faults are of "unknown offset/displacement". Movement occurs along a fault plane. Footwalls are below the fault plane and hanging walls are above. In a normal fault, crustal extension (pulling apart) moves the hanging wall down relative to the footwall (e.g., faults of unknown displacement in the GRI GIS data). In a reverse fault, crustal compression moves the hanging wall up relative to the footwall. A thrust fault is similar to a reverse fault but has a dip angle of less than 45° (e.g., unnamed faults in the GRI GIS data). In a strike-slip fault, the relative direction of movement of the opposing plate is lateral. When movement across the fault is to the right, it is a right-lateral (dextral) fault, as illustrated above (e.g., right-lateral faults in the GRI GIS data). When movement is to the left, it is a left-lateral (sinistral) fault. Graphic by Trista Thornberry-Ehrlich (Colorado State University).

fractured, friction melted, or smeared along the fault. Breccia (geologic map unit **MZq**) formed along a fault zone outside the park (Boland and Howard 2000). The three primary types of faults are normal faults, reverse faults, and strike-slip faults (fig. 20). Faults are classified based on motion of rocks on either side of the fault plane as described in fig. 20. Thrust faults are reverse faults with a low angle (<45°) fault plane. Décollements, or detachment faults, are very low angle (nearly horizontal) reverse and normal faults with large displacement (kilometers to tens of kilometers). Ancient thrust faults and right-lateral strike-slip faults are mapped in the GRI GIS data for Cowpens National Battlefield, but none are mapped within the park (see table 2; Boland 2000; Howard 2010). Some mapped faults are of unknown displacement; they could be normal faults. These likely date back to Paleozoic mountain building and are not considered seismically active by geologists today.

Folds are curves or bends in originally flat structures, such as rock strata, bedding planes, or foliation. The two primary types of folds are anticlines which are "A-shaped" (convex) and synclines which are "U-shaped" (concave) (fig. 21). Monoclines, another type of fold, are step-like structures consisting of a steeply dipping zone within otherwise relatively horizontal rock layers. All types of folds can be overturned—tilted past vertical—by continued or future tectonic forces. Folds frequently "plunge" meaning the fold axis tilts. As bedrock is compressed, anticlines and synclines form adjacent to each other, as is characteristic in the linear folds of the Piedmont and in the mapped area around and including the park. Unnamed fold axes were identified in the GRI GIS data outside park boundaries, for synforms (synclines) and antiforms (anticlines), as well as "tightly folded" and overturned folds (see table 2; Boland 2000). Folds exist in the park bedrock at many scales ranging from regional to microscopic.

Geologic Terms

bedding. Depositional layering or stratification of sediments.

foliation. A preferred arrangement of crystal planes in minerals. Primary foliation develops during the formation of a rock and includes bedding in sedimentary rocks and flow layering in igneous rocks. In metamorphic rocks, the term commonly refers to a parallel orientation of planar minerals such as micas. Secondary foliation develops during deformation and/or metamorphism and includes cleavage, schistosity, and gneissic banding.

outcrop. Any part of a rock mass or formation that is exposed or "crops out" at Earth's surface.

shear. Deformation resulting from stresses that cause contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact.

strata. Tabular or sheetlike layers of sedimentary rock that are visually distinctive from other layers above and below. The singular form of the term is stratum but is less commonly used.

structure. The attitudes and relative positions of the rock masses of an area resulting from such processes as faulting, folding, and igneous intrusion.

Sources for Geologic Resource Management Guidance

The park has a Foundation Document (National Park Service 2014), a Natural Resource Condition Assessment (Worsham et al. 2012), and a Resource Stewardship Strategy summary (National Park Service 2020), all of which will be primary sources of information for resource management within the park. National Park Service (2014) listed the following fundamental resources and values, which are resource management priorities: battlefield landscape; Green River Road; 1932 U.S. Monument; 1856 Washington Light Infantry Monument; artifacts pertaining to the Battle of Cowpens and the Revolutionary War; archival material and documents related to the commemorations of the Battle of Cowpens; and archeological resources. Cultural landscape restoration, administration, and management are addressed in a number of publications including Binkley and Davis (2002), Bearss (1974), Irwin (2015), and National Park Service (1997). As of December 2019, the park was in the final stages of preparing a Cultural Landscape Restoration plan document. Some historic preservations plans exist for certain structures, but not the Green River Road (Cowpens National Battlefield staff, conference call, 18 December 2019). A Long Range Interpretive Plan remains a high resource management need at Cowpens National Battlefield (Cowpens National Battlefield staff, conference call, 18 December 2019).

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

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

Contact the division (http://go.nps.gov/grd) for assistance with resource inventories, assessments and monitoring; impact mitigation, restoration, and adaptation; hazards risk management; law, policy, and guidance; resource management planning; data and information management; and outreach and youth

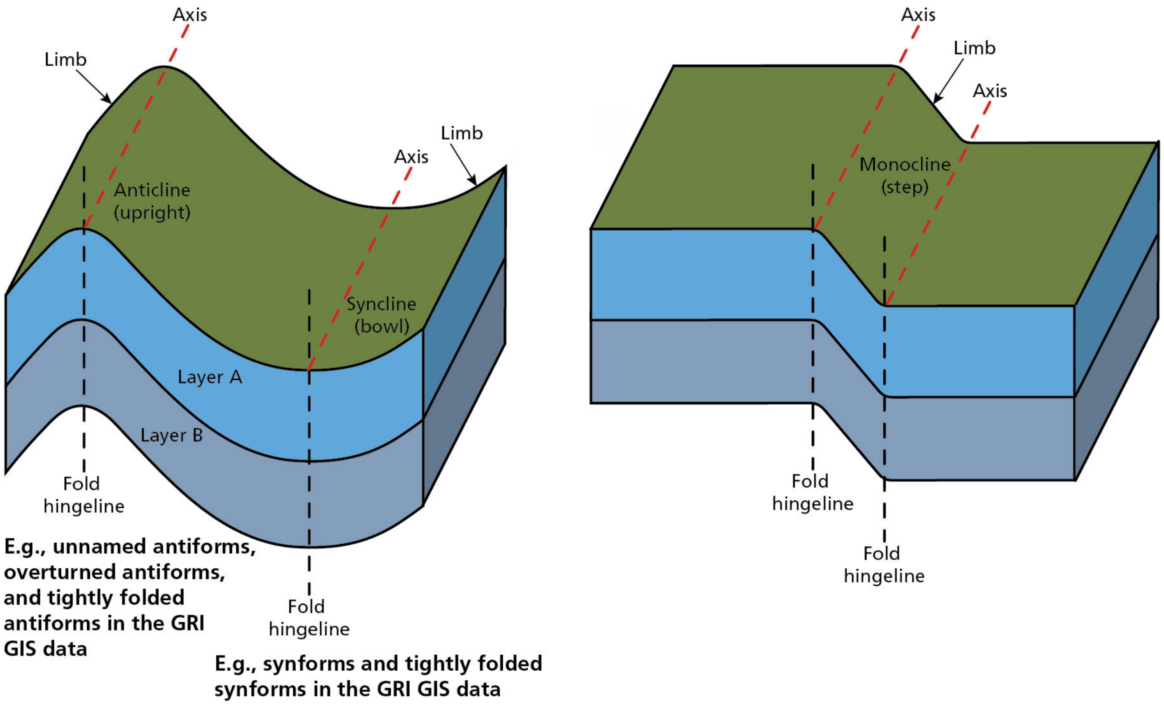

Figure 21. Illustrations of fold types.
Folds accommodate stress within the rocks without significant fracture (faulting). Axes for antiforms and synforms (related to anticlines and synclines, respectively) occur in the GRI GIS data for Cowpens National Battlefield (mapped outside the park). Graphic by Trista Thornberry-Ehrlich (Colorado State University).

programs (Geoscientists-in-the-Parks and Mosaics in Science). Park staff can formally request assistance via https://irma.nps.gov/Star/.

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

The Scientists in Parks (SIP) internship program (formerly Geoscientists-in-the-Park and Mosaics in Science programs) provides an easy to use mechanism by which NPS parks, networks, regions, and programs can hire non-federal interns to undertake projects that address natural resource management issues. Contact scientists_in_parks@nps.gov and refer to the program's website at https://doimspp.sharepoint.com/sites/nps-scientistsinparks (internal NPS site) for more information.

Additional geologic information regarding northern South Carolina is available from the following sources

- Garihan (1968) discussed geologic history of the western Inner Piedmont
- Secor and Wagener (1968) detailed stratigraphy, structure, and petrology (mineralogical composition) of the Piedmont
- Secor Jr. (1987) discussed mountain building as seen from the South Carolina Piedmont
- Wright et al. (1991) discussed the geology of the Carolinas
- Hatcher (2005) discussed the history of the southern Appalachian Mountains and the development of the Piedmont

The South Carolina Geological Survey serves publications on their website (http://www.dnr.sc.gov/geology). Their site also provides geological news, a record of recent earthquakes, rock and mineral kits, geologic hazards mapping, information about mineral resources, flood mitigation, water plans, groundwater models, and hydrology surveys.

Geologic Map Data

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

Geologic Maps

A geologic map is the fundamental tool for depicting the geology of an area. Geologic maps are two-dimensional representations of the three-dimensional geometry of rock and sediment at or beneath the land surface (Evans 2016). Colors and symbols on geologic maps correspond to geologic map units. The unit symbols consist of an uppercase letter indicating the age (see table 1) and lowercase letters indicating the formation's name. Other symbols depict structures such as faults or folds, locations of past geologic hazards that may be susceptible to future activity, and other geologic features. Anthropogenic features such as mines or quarries, as well as observation or collection locations, may be indicated on geologic maps. The American Geosciences Institute website, http://www.americangeosciences.org/environment/publications/mapping, provides more information about geologic maps and their uses.

Geologic maps are typically one of two types: surficial or bedrock. Surficial geologic maps typically encompass deposits that are unconsolidated and formed during the past 2.6 million years (the Quaternary Period). Surficial map units are differentiated by geologic process or depositional environment. Bedrock geologic maps encompass older, typically more consolidated sedimentary, metamorphic, and/or igneous rocks. Bedrock map units are differentiated based on age and/or rock type. GRI produced a bedrock map for Cowpens National Battlefield, which includes one surficial map unit **(Qal)**.

Source Maps

The GRI team does not conduct original geologic mapping. The team digitizes paper maps and compiles and converts digital data to conform to the GRI GIS data model. The GRI GIS data set includes essential elements of the source maps such as map unit descriptions, a correlation chart of units, a map legend, map notes, cross sections, figures, and references. These items are included in the cowp_geology.pdf. The GRI team used the following sources to produce the GRI GIS data set for Cowpens National Battlefield. These sources also provided information for this report. When applicable, this report references them collectively as "GRI GIS source data".

- Boland, I. B., with contributions from C. S. Howard (2000)
- Howard, C. S. (2010)

GRI GIS Data

The GRI team standardizes map deliverables by using a data model. The GRI GIS data for Cowpens National Battlefield was compiled using data model version 2.3, which is available is available at http://go.nps.gov/gridatamodel. This data model dictates GIS data structure, including layer architecture, feature attribution, and relationships within ESRI ArcGIS software. The GRI website, https://www.nps.gov/subjects/geology/gri.htm, provides more information about the program's map products.

GRI GIS data are available on the GRI publications website http://go.nps.gov/gripubs and through the NPS Integrated Resource Management Applications (IRMA) portal https://irma.nps.gov/Portal/. Enter "GRI" as the search text and select a park from the unit list.

The following components are part of the data set:

- A GIS readme file (cowp_gis_readme.pdf) that describes the GRI data formats, naming conventions, extraction instructions, use constraints, and contact information.
- Data in ESRI geodatabase GIS format;
- Layer files with feature symbology (table 3);
- Federal Geographic Data Committee (FGDC)–compliant metadata;
- An ancillary map information document (cowp_geology.pdf) that contains information captured from source maps such as map unit descriptions, geologic unit correlation tables, legends, cross-sections, and figures; and
- An ESRI map document (cowp_geology.mxd) that displays the GRI GIS data.

GRI Map Poster

A poster of the GRI GIS draped over a shaded relief image of the park and surrounding area is available on the IRMA portal (https://irma.nps.gov/Portal/) and included with printed copies of this report. Not all GIS feature classes are included on the poster (table 3).

Geographic information and selected park features have been added to the poster. Digital elevation data and added geographic information are not included in the GRI GIS data but are available online from a variety of sources. Contact GRI for assistance locating these data.

Use Constraints

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

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

Further Geologic and GIS Data Needs and Additional Sources

The GRI GIS data is restricted to bedrock coverage with one surficial unit, which is not mapped within the park; only two geologic units occur within park boundaries.

Additional Sources

- The most recent National Park Service boundary GIS layer is available at: https://irma.nps.gov/DataStore/Reference/Profile/2225713.
- National Park Service Soil Resources Inventory product is available at: https://irma.nps.gov/DataStore/Reference/Profile/1048848.

GIS and Other Data Needs

- A paleontological wetland map.
- A geologic map of the Overmountain-Victory Trail—a trail which recognizes the Revolutionary War Overmountain Men or colonials from what is now east Tennessee who crossed the Great Smoky Mountains and then fought in the battle of Kings Mountain in South Carolina.
- LiDAR coverage was listed in the park's foundation document as a data need for restoring the battlefield landscape.
- Ground penetrating radar and sensitivity studies to identify subsurface anomalies (possible burial sites).
- A hydrology study to determine where roads on the landscape should be breached to allow natural flows.

Table 3. GRI GIS data layers for Cowpens National Battlefield.

Data Layer	On Poster?
Faults	Yes
Folds	Yes
Geologic Cross Section Lines	No
Geologic Measurement Localities	No
Geologic Observation Localities	Partial
Geologic Attitude and Observation Localities	No
Geologic Contacts	Yes
Geologic Units	Yes

Literature Cited

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

Barineau, C., J. F. Tull, and C. S. Holm-Denoma. 2015. A Laurentian margin back-arc: The Ordovician Wedowee-Emuckfaw-Dahlonega basin. Diverse Excursions in the Southeast: Paleozoic to Present:21–78.

Bearss E. 1974. Cowpens National Battlefield: Historic grounds and resource study, Cowpens National Battlefield, National Park Service. Historic Grounds Report. Denver Service Center, Southeast Regional Office, National Park Service, Denver, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2188259 (accessed 7 June 2019).

Binkley, C. and S. Davis. 2002. Cowpens National Battlefield: Administrative History. Cultural Resource Stewardship, Southeast Regional Office, National Park Service, Atlanta, Georgia.

Bobyarchick, A. R., S. H. Edelman, and J. W. Horton, Jr. 1988. The role of dextral strike-slip in the displacement history of the Brevard Zone. Pages 53–104 *in* Southeastern geological excursions. South Carolina Geological Survey, Columbia, South Carolina.

Boland, I. B. 2006. The geology of Cowpens National Battlefield. Geological Society of America Abstracts with Programs 38(7):392.

Boland, I. B., with contributions from C. S. Howard. 2000. Geologic map of the Cowpens 7.5-minute quadrangle, Cherokee and Spartanburg counties, South Carolina (scale 1:24,000). Open-File Report OFR-127. South Carolina Geological Survey, Columbia, South Carolina.

Braile, L.W. 2009. Seismic monitoring. Pages 229–244 in R. Young, R. and L. Norby, editors. Geological monitoring. Geological Society of America, Boulder, Colorado. http://go.nps.gov/seismic_monitoring (accessed 11 April 2019).

Chapman, M. C., J. W. Munsey, S. C. Whisner, and J. Whisner. 2002. The eastern Tennessee seismic zone: small earthquakes illuminating major basement faults? Geologic Society of America Abstracts with Programs:21-9.

Dart, R. L., P. Talwani, and D. Stevenson. 2010. Earthquakes in South Carolina and vicinity 1698–2009. Open File Report 2010-1059. US Geological Survey, Reston, Virginia. https://pubs.usgs.gov/of/2010/1059/ (accessed 16 May 2019).

Evans, T. J. 2016. General standards for geologic maps. Section 3.1 *in* M. B. Carpenter and C. M. Keane, compilers. The geoscience handbook 2016. AGI Data Sheets, 5th Edition. American Geosciences Institute, Alexandria, Virginia.

Garihan, J. M. 1968. Paleozoic-Mesozoic tectonic history of the western Inner Piedmont based on superimposed structural relationships, South Carolina and nearby North Carolina, southern Appalachians. Bulletin 42. South Carolina Geological Survey, Columbia, South Carolina.

Harris, A.G., E. Tuttle, and S. D. Tuttle. 1997. Geology of national parks. Kendall/Hunt Publishing Company, Dubuque, Iowa, USA.

Hatcher, R. D., Jr. 2005. Southern and central Appalachians. Pages 72–81 *in* Selley, R. C., L. R. M. Cocks, and L. R. Plimer, editors. Encyclopedia of Geology: North America. Elsevier Ltd., Amsterdam, Netherlands.

Hawkins, J. F. 2013. Geology, petrology, and geochronology of rocks in the Our Town, Alabama Quadrangle. MS Thesis. Auburn University, Auburn, Alabama.

Holmes, R. R., Jr., L. M. Jones, J. C. Eidenshink, J. W. Godt, S. H. Kirby, J. J. Love, C. A. Neal, N. G. Plant, M. L. Plunkett, C. S. Weaver, A. Wein, and S. C. Perry. 2013. U.S. Geological Survey natural hazards science strategy—promoting the safety, security, and economic well-being of the nation. US Geological Survey, Reston, Virginia. Circular 1383-F. http://pubs.usgs.gov/circ/1383f/ (accessed Day Month Year).

Horton, J. R, J. Wright, and V. A. Zullo, editors. 1991. The Geology of the Carolinas: Carolina Geological Society Fiftieth Anniversary Volume. University of Tennessee Press, Knoxville, Tennessee.

Howard, C. S. 2010. Geologic map of the Chesnee 7.5-minute quadrangle, Cherokee and Spartanburg counties, South Carolina (scale 1:24,999). Open-File Report OFR-159. South Carolina Geological Survey, Columbia, South Carolina.

Irwin N. 2015. National Park Service Places Database Extract: Buildings. https://irma.nps.gov/DataStore/Reference/Profile/2225047 (accessed 7 June 2019).

Lord, M. L., D. Germanoski, and N. E. Allmendinger. 2009. Fluvial geomorphology: Monitoring stream systems in response to a changing environment. Pages 69–103 *in* R. Young and L. Norby, editors. Geological monitoring. Geological Society of America, Boulder, Colorado. http://go.nps.gov/fluvial_monitoring (accessed 24 October 2018).

Lossing, B. J. 1859. The Pictorial Field-Book of The Revolution or Illustrations by Pen and Pencil of the History, Biography, Scenery, Relics, and Traditions of the War for Independence. Harper & Brothers Publishers, New York, New York. https://archive.org/details/pictorialfieldbo02lossuoft (accessed 1 September 2020).

Monahan, W. B., and N. A. Fisichelli. 2014. Recent climate change exposure of Cowpens National Battlefield. Resource Brief. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2213428 (accessed 7 June 2019).

National Park Service. 1997. The national parks: lesser-known areas. US Department of the Interior, Washington, DC. https://irma.nps.gov/DataStore/Reference/Profile/2206368 (accessed 10 May 2019).

National Park Service. 2014. Foundation document: Cowpens National Battlefield, South Carolina. COWP 331/123339. National Park Service, Fort Collins, Colorado.

National Park Service. 2018. Park Reports. National Park Service visitor use statistics. National Park Service, Washington, DC. https://irma.nps.gov/Stats/Reports/Park/COWP (accessed 8 March 2019).

National Park Service. 2020. Resource Stewardship Strategy summary: Cowpens National Battlefield and Ninety Six National Historic Site, South Carolina. COWP 331/167046. National Park Service, Fort Collins, Colorado.

Petersen, M. D., A. M. Shumway, P. M. Powers, C. S. Mueller, M. P. Moschetti, A. D. Frankel, A. D., S. Rezaeian, D. E. McNamara, N. Luco, O. S. Boud, K. S. Rukstales, K. S. Jaiswal, E. M. Thompson, S. M. Hoover, B. S. Clayton, A. H. Field, and Y. Zeng. 2020. The 2018 update of the US National Seismic Hazard Model: Overview of model and implications. Earthquake Spectra, 36(1), 5–41. https://doi.org/10.1177/8755293019878199

Roberts, T. H., and K. L. Morgan. 2006. Inventory and Classification of Wetlands at Cowpens National Battlefield, Chesnee, South Carolina. Center for the Management, Utilization, and Protection of Water Resources, Cookeville, Tennessee.

Secor, D. T., and H. D. Wagener. 1968. Stratigraphy, structure and petrology of the Piedmont in central South Carolina. Geologic Notes 12(4). Division of Geology, South Carolina State Development Board, Columbia, South Carolina.

Secor Jr., D. T., editor. 1987. Anatomy of the Alleghanian orogeny as seen from the Piedmont of South Carolina and Georgia. Carolina Geological Society guidebook. South Carolina Geological Survey, Columbia, South Carolina.

Sickels-Taves, L. B., and M. S. Sheehan. 1999. The lost art of tabby redefined: preserving Olgethorpe's architectural legacy. Architectural Conservation Press, Southfield, Michigan.

South Carolina Geological Survey. 2019. Geology of South Carolina. South Carolina Geological Survey, Columbia, South Carolina. http://scdnr.maps.arcgis.com/apps/Viewer/index.html?appid=735411a2f5714f28a424422296f77bb1 (accessed 15 April 2019).

Southworth, S., J. N. Aleinikoff, C. M. Bailey, W. C. Burton, E. A. Crider, P. C. Hackley, J. P. Smoot, and R. P. Tollo. 2009. Geologic Map of the Shenandoah National Park Region, Virginia (scale 1:100,000). Open-File Report 2009-1153. US Geological Survey, Reston, Virginia, USA. http://pubs.er.usgs.gov/publication/ofr20091153 (accessed 1 May 2013).

Town of Cowpens. 2019. Cowpens, SC, history. Cowpens, South Carolina. https://www.townofcowpens.com/history/ (accessed 16 April 2019).

URS Corporation, Durham Technologies, Inc., ImageCat, Inc., Pacific Engineering & Analysis, and S&ME, Inc. 2001. Comprehensive seismic risk and vulnerability study for the state of South Carolina. Final report prepared for South Carolina Emergency Preparedness Division.

US Geological Survey. 2000. A tapestry of time and terrain: the union of two maps—geology and topography. The fall line. Online information. US Geological Survey, Washington, DC, USA. https://pubs.usgs.gov/imap/i2720/ (accessed 31 August 2020).

von Hake, C. A. 2009. South Carolina earthquake history. South Carolina earthquake information. US Geological Survey, Reston, Virginia.

Worsham, L., G. Sundin, N. P. Nibbelink, M. T. Mengak, and G. Grossman. 2012. Natural resource condition assessment for Cowpens National Battlefield. Natural Resource Report NPS/COWP/NRR—2012/521. National Park Service, Fort Collins, Colorado. http://npshistory.com/natural_resources.htm#nrca (accessed 31 August 2020).

Young, R. and L. Norby, editors. 2009. Geological monitoring. Geological Society of America, Boulder, Colorado. http://go.nps.gov/geomonitoring (accessed 24 October 2018).

Additional References

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

Geology of National Park Service Areas

- NPS Geologic Resources Division (Lakewood, Colorado) Energy and Minerals; Active Processes and Hazards; Geologic Heritage: http://go.nps.gov/grd
- NPS Geologic Resources Division Education Website: http://go.nps.gov/geoeducation
- NPS Geologic Resources Inventory: http://go.nps.gov/gri
- NPS Scientists in Parks (SIP) internship program: https://doimspp.sharepoint.com/sites/nps-scientistsinparks (internal NPS site)

NPS Resource Management Guidance and Documents

- Management Policies 2006 (Chapter 4: Natural resource management): http://www.nps.gov/policy/mp/policies.html
- 1998 National parks omnibus management act: http://www.gpo.gov/fdsys/pkg/PLAW-105publ391/pdf/PLAW-105publ391.pdf
- NPS-75: Natural resource inventory and monitoring guideline: https://irma.nps.gov/DataStore/Reference/Profile/622933
- NPS Natural resource management reference manual #77: https://irma.nps.gov/DataStore/Reference/Profile/572379
- Geologic monitoring manual (Young, R., and L. Norby, editors. 2009. Geological monitoring. Geological Society of America, Boulder, Colorado): http://go.nps.gov/geomonitoring
- NPS Technical Information Center (TIC) (Denver, Colorado; repository for technical documents): https://www.nps.gov/dsc/technicalinfocenter.htm

Climate Change Resources

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

Geological Surveys and Societies

- South Carolina Geological Survey: http://www.dnr.sc.gov/geology/
- US Geological Survey: http://www.usgs.gov/
- Geological Society of America: http://www.geosociety.org/
- American Geophysical Union: http://sites.agu.org/
- American Geosciences Institute: http://www.americangeosciences.org/
- Association of American State Geologists: http://www.stategeologists.org/

US Geological Survey Reference Tools

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

Tapestry of time and terrain (descriptions of physiographic provinces): http://pubs.usgs.gov/imap/i2720/

Appendix A: Scoping Participants

The following people attended the GRI scoping meeting, held on 26–28 April 2005, or the follow-up report writing conference call, held on 18 December 2019. Discussions during these meetings supplied a foundation for this GRI report. The scoping summary document is available on the GRI publications website: http://go.nps.gov/gripubs.

2005 Scoping Meeting Participants

Name	Affiliation	Position
Paul Carson	Overmountain Victory National Historic Trail/ Cowpens National Battlefield and Ninety Six National Historic Site	Superintendent/acting superintendent
Bill Clendenin	South Carolina Geological Survey	Geologist
Art Cohen	University of South Carolina	Not recorded
Tim Connors	NPS Geologic Resources Division	Geologist, GRI maps coordinator
Joe DeVivo	NPS Southeastern Coast Network	Inventory and monitoring
Will Doar	South Carolina Geological Survey	Not recorded
Rick Dorrance	NPS Fort Sumter National Historical Park	Not recorded
Bill Eiser	South Carolina DHEC-OCRM	Not recorded
Scott Howard	South Carolina Geological Survey	Geologist
Bill Hulsander	NPS Congaree National Park	Not recorded
Mike Katuna	College of Charleston	Geologist
Shepard McAninch	NPS Inventory and Monitoring	Not recorded
Sandy Pusey	NPS Fort Sumter National Historical Park	Not recorded
Chris Saylor	NPS Congaree National Park	Not recorded
David C. Shelley	University of South Carolina/South Carolina Geological Survey	Not recorded
John Tucker	NPS Fort Sumter National Historical Park	Not recorded
Ralph Willoughby	South Carolina Geological Survey	Geologist
Linda York	NPS Southeast Regional Office	Not recorded

2019 Conference Call Participants

Name	Affiliation	Position
Sarah Cunningham	NPS–Southern Campaign of the American Revolution Parks Group	Acting Superintendent, Chief of Integrated Resources and Facilities
Ginny Fowler	NPS Cowpens National Battlefield	Lead interpretive ranger
Georgia Hybels	Colorado State University	Layouts coordinator
Jason Kenworthy	NPS Geologic Resources Division	Geologist, GRI program coordinator
Johnathan Jernigan	NPS Cumberland Piedmont Network	Physical scientist
Robby Morrow	South Carolina Geological Survey	Field Geologist
Rebecca Port	NPS Geologic Resources Division	Geologist, GRI reports coordinator
Vanessa Smiley	NPS–Southern Campaign of the American Revolution Parks Group	Chief of Interpretation
Trista L. Thornberry-Ehrlich	Colorado State University	Geologist, report writer, graphic designer

Appendix B: Geologic Resource Laws, Regulations, and Policies

The NPS Geologic Resources Division developed this table to summarize laws, regulations, and policies that specifically apply to NPS minerals and geologic resources. The table does not include laws of general application (e.g., Endangered Species Act, Clean Water Act, Wilderness Act, National Environmental Policy Act, or National Historic Preservation Act). The table does include the NPS Organic Act when it serves as the main authority for protection of a particular resource or when other, more specific laws are not available. Information is current as of April 2020. Contact the NPS Geologic Resources Division for detailed guidance.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Caves and Karst Systems	**Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309** requires Interior/ Agriculture to identify "significant caves" on Federal lands, regulate/ restrict use of those caves as appropriate, and include significant caves in land management planning efforts. Imposes civil and criminal penalties for harming a cave or cave resources. Authorizes Secretaries to withhold information about specific location of a significant cave from a Freedom of Information Act (FOIA) requester. **National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of cave and karst resources. **Lechuguilla Cave Protection Act of 1993, Public Law 103-169** created a cave protection zone (CPZ) around Lechuguilla Cave in Carlsbad Caverns National Park. Within the CPZ, access and the removal of cave resources may be limited or prohibited; existing leases may be cancelled with appropriate compensation; and lands are withdrawn from mineral entry.	**36 CFR § 2.1** prohibits possessing/ destroying/ disturbing…cave resources…in park units. **43 CFR Part 37** states that all NPS caves are "significant" and sets forth procedures for determining/releasing confidential information about specific cave locations to a FOIA requester.	**Section 4.8.1.2** requires NPS to maintain karst integrity, minimize impacts. **Section 4.8.2 requires NPS to protect geologic features from adverse effects of human activity.** **Section 4.8.2.2** requires NPS to protect caves, allow new development in or on caves if it will not impact cave environment, and to remove existing developments if they impair caves. **Section 6.3.11.2** explains how to manage caves in/adjacent to wilderness.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
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** (in development) will contain the DOI regulations implementing the Paleontological Resources Preservation Act.	**Section 4.8.2 requires NPS to protect geologic features from adverse effects of human activity.** **Section 4.8.2.1** emphasizes Inventory and Monitoring, encourages scientific research, directs parks to maintain confidentiality of paleontological information, and allows parks to buy fossils only in accordance with certain criteria.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Recreational Collection of Rocks Minerals	**NPS Organic Act, 54 USC. § 100101 et seq.** directs the NPS to conserve all resources in parks (which includes rock and mineral resources) unless otherwise authorized by law. **Exception: 16 USC. § 445c (c) – Pipestone National Monument enabling statute**. Authorizes American Indian collection of catlinite (red pipestone).	**36 C.F.R. § 2.1** prohibits possessing, destroying, disturbing mineral resources… in park units. **Exception: 36 C.F.R. § 7.91** allows limited gold panning in Whiskeytown. **Exception: 36 C.F.R. § 13.35** allows some surface collection of rocks and minerals in some Alaska parks (not Klondike Gold Rush, Sitka, Denali, Glacier Bay, and Katmai) by non-disturbing methods (e.g., no pickaxes), which can be stopped by superintendent if collection causes significant adverse effects on park resources and visitor enjoyment.	**Section 4.8.2 requires NPS to protect geologic features from adverse effects of human activity.**
Geothermal	**Geothermal Steam Act of 1970, 30 USC. § 1001 et seq.** as amended in 1988, states -No geothermal leasing is allowed in parks. -"Significant" thermal features exist in 16 park units (the features listed by the NPS at 52 Fed. Reg. 28793-28800 (August 3, 1987), plus the thermal features in Crater Lake, Big Bend, and Lake Mead). -NPS is required to monitor those features. -Based on scientific evidence, Secretary of Interior must protect significant NPS thermal features from leasing effects. **Geothermal Steam Act Amendments of 1988, Public Law 100--443** prohibits geothermal leasing in the Island Park known geothermal resource area near Yellowstone and outside 16 designated NPS units if subsequent geothermal development would significantly adversely affect identified thermal features.		**Section 4.8.2.3** requires NPS to -Preserve/maintain integrity of all thermal resources in parks. -Work closely with outside agencies. -Monitor significant thermal features.

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Mining Claims (Locatable Minerals)	**Mining in the Parks Act of 1976, 54 USC § 100731 et seq.** authorizes NPS to regulate all activities resulting from exercise of mineral rights, on patented and unpatented mining claims in all areas of the System, in order to preserve and manage those areas. **General Mining Law of 1872, 30 USC § 21 et seq.** allows US citizens to locate mining claims on Federal lands. Imposes administrative and economic validity requirements for "unpatented" claims (the right to extract Federally-owned locatable minerals). Imposes additional requirements for the processing of "patenting" claims (claimant owns surface and subsurface). Use of patented mining claims may be limited in Wild and Scenic Rivers and OLYM, GLBA, CORO, ORPI, and DEVA. **Surface Uses Resources Act of 1955, 30 USC § 612** restricts surface use of unpatented mining claims to mineral activities.	**36 CFR § 5.14** prohibits prospecting, mining, and the location of mining claims under the general mining laws in park areas except as authorized by law. **36 CFR Part 6** regulates solid waste disposal sites in park units. **36 CFR Part 9, Subpart A** requires the owners/ operators of mining claims to demonstrate bona fide title to mining claim; submit a plan of operations to NPS describing where, when, and how; prepare/submit a reclamation plan; and submit a bond to cover reclamation and potential liability. **43 CFR Part 36** governs access to mining claims located in, or adjacent to, National Park System units in Alaska.	**Section 6.4.9** requires NPS to seek to remove or extinguish valid mining claims in wilderness through authorized processes, including purchasing valid rights. Where rights are left outstanding, NPS policy is to manage mineral-related activities in NPS wilderness in accordance with the regulations at **36 CFR Parts 6** and **9A**. **Section 8.7.1** prohibits location of new mining claims in parks; requires validity examination prior to operations on unpatented claims; and confines operations to claim boundaries.
Nonfederal Oil and Gas	**NPS Organic Act, 54 USC § 100751 et seq.** authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights). Individual Park Enabling Statutes: **16 USC § 230a** (Jean Lafitte NHP & Pres.) **16 USC §450kk** (Fort Union NM), **16 USC § 459d-3** (Padre Island NS), **16 USC § 459h-3** (Gulf Islands NS), **16 USC § 460ee** (Big South Fork NRRA), **16 USC § 460cc-2(i)** (Gateway NRA), **16 USC § 460m** (Ozark NSR), **16 USC§698c** (Big Thicket N Pres.), **16 USC §698f** (Big Cypress N Pres.)	**36 CFR Part 6** regulates solid waste disposal sites in park units. **36 CFR Part 9, Subpart B** requires the owners/operators of nonfederally owned oil and gas rights outside of Alaska to -demonstrate bona fide title to mineral rights; -submit an Operations Permit Application to NPS describing where, when, how they intend to conduct operations; -prepare/submit a reclamation plan; and -submit a bond to cover reclamation and potential liability. **43 CFR Part 36** governs access to nonfederal oil and gas rights located in, or adjacent to, National Park System units in Alaska.	**Section 8.7.3** requires operators to comply with 9B regulations.

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

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Nonfederal minerals other than oil and gas	**NPS Organic Act, 54 USC §§ 100101 and 100751**	**NPS regulations at 36 CFR Parts 1, 5, and 6** require the owners/operators of other types of mineral rights to obtain a special use permit from the NPS as a **§ 5.3** business operation, and **§ 5.7** – Construction of buildings or other facilities, and to comply with the solid waste regulations at **Part 6**.	**Section 8.7.3** states that operators exercising rights in a park unit must comply with **36 CFR Parts 1** and **5**.
Coal	**Surface Mining Control and Reclamation Act of 1977, 30 USC § 1201 et. seq.** prohibits surface coal mining operations on any lands within the boundaries of a NPS unit, subject to valid existing rights.	**SMCRA Regulations at 30 CFR Chapter VII** govern surface mining operations on Federal lands and Indian lands by requiring permits, bonding, insurance, reclamation , and employee protection. **Part 7** of the regulations states that National Park System lands are unsuitable for surface mining.	
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.		

Resource	Resource-specific Laws	Resource-specific Regulations	2006 Management Policies
Common Variety Mineral Materials (Sand, Gravel, Pumice, etc.)	**Materials Act of 1947, 30 USC § 601** does not authorize the NPS to dispose of mineral materials outside of park units. **Reclamation Act of 1939, 43 USC §387**, authorizes removal of common variety mineral materials from federal lands in federal reclamation projects. This act is cited in the enabling statutes for Glen Canyon and Whiskeytown National Recreation Areas, which provide that the Secretary of the Interior may permit the removal of federally owned nonleasable minerals such as sand, gravel, and building materials from the NRAs under appropriate regulations. Because regulations have not yet been promulgated, the National Park Service may not permit removal of these materials from these National Recreation Areas. **16 USC §90c-1(b)** authorizes sand, rock and gravel to be available for sale to the residents of Stehekin from the non-wilderness portion of Lake Chelan National Recreation Area, for local use as long as the sale and disposal does not have significant adverse effects on the administration of the national recreation area.	None applicable.	**Section 9.1.3.3** clarifies that only the NPS or its agent can extract park-owned common variety minerals (e.g., sand and gravel), and: -only for park administrative uses; -after compliance with NEPA and other federal, state, and local laws, and a finding of non-impairment; -after finding the use is park's most reasonable alternative based on environment and economics; -parks should use existing pits and create new pits only in accordance with park-wide borrow management plan; -spoil areas must comply with **Part 6** standards; and -NPS must evaluate use of external quarries. Any deviation from this policy requires a written waiver from the Secretary, Assistant Secretary, or Director.

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

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

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

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

NPS 331/174937, December 2020

National Park Service
U.S. Department of the Interior

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

https://www.nps.gov/nature/index.htm