National Park Service
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Natural Resource Program Center

Moores Creek National Battlefield

Geologic Resource Evaluation Report

Natural Resource Report NPS/NRPC/GRD/NRR—2006/012

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Geologic Resources Division
Natural Resource Program Center
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Executive Summary

This report has been developed to accompany the digital geologic map produced by Geologic Resource Evaluation staff for Moores Creek National Battlefield in North Carolina. It contains information relevant to resource management and scientific research.

The battle at Moores Creek Bridge in eastern North Carolina was a pivotal victory for American Patriots over Highlander Loyalists during the Revolutionary War. It was a turning point in the southern campaign in 1776 and led to the Patriots declaration of independence. The battle was fought on the banks of Moores Creek and over a partially dismantled bridge. The geology and hydrology in the area influenced the outcome of the battle, favoring the men who knew the terrain, including the river crossing, wetlands, and topographic differences. The soldiers used this knowledge to their advantage by planning strategies to minimize losses and maximize opportunities. Geologic and hydrologic processes combined to create the rock formations, topography, wetlands, and streams of Moores Creek each of these environmental elements contributed to the history preserved there today.

The site of the bridge over Moores Creek and the setting of the battle attract visitors in search of a historical touchstone and those in search of recreational opportunities. Knowledge of the geologic resources and associated issues is beneficial to resource management, future scientific research projects, and interpretive opportunities in the park.

Moores Creek National Battlefield offers an opportunity for visitors to study the historic struggle by American patriots for independence from England. This history is reflected on the streambanks of Moores Creek, the marshlands around the creek and bridge, the monuments erected to commemorate individuals and events, and the land those men were fighting for hundreds of years ago. It is not surprising then that some of the principal geologic issues and concerns pertain to protecting these features.

Humans have significantly modified the landscape surrounding Moores Creek National Battlefield by installing a ditch and tile system to drain the wetlands in the park. This hydrogeologic system is dynamic and capable of noticeable change within a human life span. Geological processes continue to change the landscape, making preservation and park upkeep a challenge.

The following selected features, issues, and processes may warrant consideration during land- use planning, for park resource management, and to enhance visitor experiences in the park:

- Pine Savanna Wetlands. The pine savanna wetland habitats just west of the visitor center in the Moores Creek National Battlefield once contained diverse and rare plant communities. These types of wetlands have been known to contain more than 40 species per square meter. However, the wetland in the National Battlefield was drained in the early 20th century converting the area to a meadow dominated by weeds and non- indigenous plant life. The park's goal has been to restore the drained meadow back to the pre-disturbance pine savanna wetland system. Its restoration and preservation are key components to reestablish the cultural landscape and historical context of the battlefield.
- Recreational Demands. Visitors come to Moores Creek National Battlefield to experience the history of the Revolutionary War, but also to enjoy the natural beauty of eastern North Carolina. Visitor facilities include two self- guided trails, a boardwalk, picnic area, visitor center, battle monuments, Caswell's Camp, and a reconstructed bridge over Moores Creek. Increasing demands placed upon geologic and other resources in the park make their management of utmost concern.

  Along with a detailed geologic map and a road or trail log, a guidebook that ties Moores Creek National Battlefield to the other parks in the Southern Appalachian region would enhance a visitor's appreciation of the geologic history and dynamic processes that shaped the landscape and impacted the outcome of the battle.
- Erosion and Slope Processes. Geologic processes can affect the manmade structures and the cultural landscape, especially the reconstructed bridge over Moores Creek and the patriot earthworks on the east side of the bridge. Weathering and erosion are continually changing the landscape of the park.

  The relatively wet climate of the eastern U.S. combined with severe storms, and the marshy wetlands at Moores Creek, create a setting, which is especially susceptible to slumping, slope creep, and streambank erosion. This is often due to the relatively frequent occurrence of intense seasonal rainstorms, and substantial seasonal runoff combined with a lack of stabilizing vegetative cover. This runoff can dramatically alter the landscape, creating new hazard areas in the process, and undermining historic features in the park.

Other geologic management concerns for Moores Creek National Battlefield include water issues, preserving the historic landscape, and general geological research. These issues as well as recommendations for inventories, monitoring, and research are described in this report.

Introduction

The following section briefly describes the regional geologic setting and the National Park Service Geologic Resource Evaluation program.

Purpose of the Geologic Resource Evaluation Program

Geologic features and processes serve as the foundation of park ecosystems and an understanding of geologic resources yields important information for park decision making. The National Park Service (NPS) Natural Resource Challenge, an action plan to advance the management and protection of park resources, has focused efforts to inventory the natural resources of parks. Ultimately, the inventory and monitoring of natural resources will become integral parts of park planning, operations and maintenance, visitor protection, and interpretation.

The Geologic Resource Evaluation (GRE) Program, which the NPS Geologic Resources Division administers, carries out the geologic component of the inventory. Staff associated with other programs within the Geologic Resources Division (e.g., the abandoned mine land, cave, coastal, disturbed lands restoration, minerals management, and paleontology programs) provide expertise to the GRE effort. The goal of the GRE Program is to provide each of the identified 270 "natural area" parks with a digital geologic map, a geologic resource evaluation report, and a geologic bibliography. Each product is a tool to support the stewardship of park resources and is designed to be user friendly to non-geoscientists.

GRE teams hold scoping meetings at parks to review available data on the geology of a particular park and to discuss specific geologic issues affecting the park. Park staff are afforded the opportunity to meet with park geology experts during these meetings. Scoping meetings are usually held for individual parks although some address an entire Vital Signs Monitoring Network.

Bedrock and surficial geologic maps and information provide the foundation for studies of groundwater, geomorphology, soils, and environmental hazards. Geologic maps describe the underlying physical framework of many natural systems and are an integral component of the physical inventories stipulated by the NPS in its Natural Resources Inventory and Monitoring Guideline (NPS- 75) and the 1997 NPS Strategic Plan. The NPS GRE is a cooperative implementation of a systematic, comprehensive inventory of the geologic resources in National Park System units by the Geologic Resources Division; the Inventory, Monitoring, and Evaluation Office of the Natural Resource Program Center; the U.S. Geological Survey; and state geological surveys.

For additional information regarding the content of this report, please refer to the Geologic Resources Division of the National Park Service, located in Denver, Colorado. Up- to- date contact information is available on the GRE website (http://www2.nature.nps.gov/geology/inventory/).

Geologic Setting

Moores Creek National Battlefield is located in Pender County in eastern North Carolina. The national battlefield borders Moores Creek, a tributary of the Black River, which is part of the larger Cape Fear watershed and lies within the Atlantic Coastal Plain province. The national battlefield covering 88 acres was established in 1926 to preserve the setting of a pivotal and significant victory by American Patriots over mostly Scottish Highlander Loyalists during the Southern Campaign of the Revolutionary War. The battle of Moores Creek Bridge, fought on February 27, 1776, is considered a decisive event that lead to the signing of the Declaration of Independence in July 1776. The victory ended Royal Governor Josiah Martin's hopes of regaining the colony for the British crown. North Carolina was the first colony to vote for independence on April 12, 1776.

The battle was fought on the Moores Creek bridge and in the surrounding area. The bridge was partially dismantled by the time approximately 1,600 Loyalists charged across it into nearly 1,000 North Carolina Patriots with cannons and muskets. "King George and Broadswords!" was their cry. Expecting to find an inadequate foe, the Loyalists were stunned to find themselves outgunned, leaderless, and in confusing retreat. The Patriots were able to seize wagons, weapons, and British sterling worth more than $1 million (present-day value).

Remnants of the battle are on display at the park today. These include the road used by Patriot and Loyalist forces in 1776, the historic bridge site over Moores Creek, reconstructed patriot earthworks, various early monuments, and Caswell's campsite. A 1.6 km (1 mile) trail with wayside exhibits leads through the battlefield and across Moores Creek. Another trail, the ½ km (1/3 mile) Tar Heel trail, explains the naval stores industry and is located just east of Moores Creek Drive.

Moores Creek National Battlefield was established on June 2, 1926 as a National Military Park. It was first under the jurisdiction of the War Department and transferred to the National Park Service in 1933. The park was officially renamed Moores Creek National Battlefield on September 8, 1980. Commemorative and preservation efforts at the park have been in progress since the mid 1800's. The first memorial celebration was held February 27, 1856. In 2003, the park attracted 70,738 visitors.

The following is a general description of the different physiographic provinces of the Appalachian Mountains. This information is relevant to understanding the geologic history of Moores Creek National Battlefield.

Atlantic Coastal Plain Physiographic Province

The easternmost province, the Atlantic Coastal Plain province, is primarily flat terrain with elevations ranging from sea level to about 60 m (197 ft). The present Atlantic coastline defines the province's eastern limit and the western edge is the intersection of the sedimentary layers with the metamorphic rocks of the Piedmont physiographic province, described below. Sediments eroding from the Appalachian Highlands to the west formed the province.

These sediments were intermittently deposited in a wedge- shaped sequence of sediments during periods of higher sea level over the past 100 million years. These deposits were then reworked by fluctuating sea levels and the continual erosive action of waves along the coastline. Moores Creek National Battlefield lies within this province and is composed of thick deposits of unconsolidated to partially cemented sands, silts and clays. shed from nearby Appalachian highlands.

Piedmont Physiographic Province

The "Fall Line" or "Fall Zone" marks a transitional zone where the less consolidated sedimentary rock of the Coastal Plain to the east, intersects the more resilient metamorphic rock to the west, forming an area of ridges, waterfalls, and rapids. This zone covers over 27 km (17 miles) of many of the major rivers flowing to the Atlantic Ocean.

Historically this area was an obstacle to upriver transportation. Westward of the Fall Line, stretching toward the Blue Ridge Mountains, is the Piedmont physiographic province (Harris et al. 1997). In the vicinity of North Carolina, the Piedmont is subdivided into several parallel belts. The Brevard Fault Zone separates the Inner Piedmont (Acadian metamorphic core of the Southern Appalachians) from the Blue Ridge. The eastward- sloping Piedmont Plateau was formed through a combination of folding, faulting, uplift, and erosion. These processes resulted in a landscape of gently rolling hills starting at 60 m (197 ft) that become gradually steeper westwards towards the edge of the province at approximately 300 m (984 ft) above sea level.

Blue Ridge Physiographic Province

Further westward, the Blue Ridge province forms the eastern edge of the Appalachian Mountains. The highest elevations in the Appalachian Mountains are in the Great Smoky Mountains National Park. Precambrian and Paleozoic igneous and metamorphic rocks were uplifted during several orogenic events to form the steep terrain. of the Blue Ridge province. Resistant Cambrian quartzites form Blue Ridge, whereas Precambrian metamorphic rocks underlie the valleys (Nickelsen 1956).

Valley and Ridge Physiographic Province

Located west of the Blue Ridge province, the landscape of the Valley and Ridge physiographic province is characterized by long, parallel ridges separated by valleys. Resistant sandstone ridges bordering more easily erodable shale and carbonate formations characterize this province. Areas dominated by carbonate formations exhibit karst topography. Karst is a term used to describe a process whereby the underlying bedrock, composed of limestone or dolomite is partially dissolved by surface- or groundwater, creating a distinctive landscape characterized by sinkholes, caves and caverns.

Geologic Issues

A Geologic Resource Evaluation scoping session was held for Moores Creek National Battlefield on April 6, 2000, to discuss geologic resources, to address the status of geologic mapping, and to assess resource management issues and needs. The following section synthesizes the scoping results, in particular, those issues that may require attention from resource managers.

Introduction

Issues in this section are identified in relative order of resource management significance with the most critical listed first. Potential research projects and topics of scientific interest are presented at the end of this section.

Pine Savanna Wetlands

Moores Creek National Battlefield lies in a lowland marshy area on the coastal plain of eastern North Carolina (figures 1 and 2). The area just west of the visitor center was once a floristically diverse and rare plant community called a pine savanna wetland. Pine savannas can include more than 40 vegetative species per square meter. A pine savanna wetland was present west of the present- day visitor's center in 1776 but was artificially drained for agriculture and other uses in the early 20th century and reverted to a meadow dominated by weeds and non- indigenous plant life. Portions of this meadow still contain relic populations of pitcher plants (*Sarracenia spp*.), and Carolina bog mint (*Macbridea caroliniana*) among other pine savanna species (Wagner 2001).

The National Park Service Water Resources Division, the North Carolina Heritage Program, the U.S. Environmental Protection Agency (Region IV) and The Nature Conservancy have been working with Moores Creek National Battlefield park staff to restore approximately 3.3 acres of the drained meadow to the historic pine savanna wetland system. Restoration and preservation are key components to reestablish the landscape and historical context of the battlefield.

In 1996, the Water Resources Division installed hydrologic monitoring wells to measure fluctuations in the water table during existing (disturbed) and future (restored) conditions. In 1998, a 200- foot segment of the drainage ditch was plugged to raise water levels to historic, pre- drainage conditions. After installation of the plug, the water level fluctuated in a similar range as in nearby undisturbed pine savanna wetlands (Wagner 2001; Woods and Wagner 2001). This project has reconnected the hydrologic systems between the hillslope behind the visitor center and the lower meadow. The wetland hydrologic regime has been restored and revegetation of the native grasses is nearly complete.

Once the restoration is completed the park will need to perform prescribed burns every 3 to 5 years to maintain the wetland as a savanna rather than a forested area (personal communication Joel Wagner, NPS WRD, 3/15/06).

Inventory, Monitoring, and/or Research Needs for Pine Savanna Wetlands

- Investigate whether there are changes in the hydrologic regime in other areas of the park.
- Pursue further restoration activities such as reintroducing native species and planning and initiating prescribed burns.
- Complete backfilling the ditch in the pine savanna wetland west of the visitors center. Determine, based on nearby soil and substrate, the appropriate material to use for restoring the landscape, and for permanently plugging the man- made drainage.

Recreational Demands

The National Park Service protects park resources and provides opportunities for visitors to enjoy those resources. Moores Creek National Battlefield provides numerous recreational opportunities such as hiking, fishing, bicycling, picnicking, and photography.

Park visitation peaks during the summer months. Park visitors are placing increasing demands on the park's natural resources. Management concerns range from trail erosion to preservation and maintenance of the cultural landscape and monuments.

Two trails in the park wind through preserved biological, historical, and geological environments. Many of these areas are especially fragile and off- trail hiking could degrade their natural resources. Several streams enhance the natural beauty of the park and provide numerous fishing opportunities. Overuse of these areas may lead to contamination and increased stream- edge erosion.

Inventory, Monitoring, and/or Research Needs for Recreational Demands

- Develop resource management plans that include inventorying and monitoring to identify human impacts to springs, wetlands and marsh flora within the park.
- Design wayside exhibits to educate park visitors and to encourage responsible use of park resources.
- Monitor water quality in streams and wells for possible contamination.

Water Issues

In the moist climate of eastern North Carolina, water seems present everywhere from runoff, and in streams, wetland areas, springs and groundwater. Annual precipitation at Moores Creek averages 145 cm (57 inches) per year with most of the rain occurring during summer storms. The unconsolidated sand, silt and clay deposits of the Atlantic Costal Plain filter contaminants and act as a groundwater reservoir for the water resources in the park.

The biggest threat to surface and ground water resources in the park is from existing and future developments in the vicinity of the park. The streams and wetlands could be contaminated by surface runoff. The water table at Moores Creek is typically a meter or so below the surface. This shallow depth to groundwater makes the groundwater very susceptible to contamination from surface sources.

Increased sediment loads, created by periodic floods, tropical storms, and hurricanes may degrade water quality and harm the aquatic ecosystems in the park. Environments that are already stressed may deteriorate further from the contamination and increased sediment loads.

Where fertilizers and pesticides are used for agricultural purposes nitrogen levels in the water could become elevated. Knowledge of the chemicals used in regional agriculture and an understanding of the hydrogeologic system, including groundwater flow patterns, are essential to protect the park's ecosystem. Surface runoff from roadways often has high levels of petroleum products and other contaminants, which could harm park waterways and wetlands by seeping into the soil and groundwater system. Other sources of contaminants include wind, surface runoff, groundwater transport, sewage outfalls, landfills, and fill dirt.

The streams that flow through the park collect runoff from the upstream areas of the Cape Fear watershed and provide a measure of the status of the watershed's hydrologic system. The park needs to monitor its water quality to assess the impacts that may be occurring from upstream sources. In addition, identifying potential contaminant sources in and near the park could help the park minimize contamination to downstream areas.

Development surrounding Moores Creek affects the watershed in a variety of ways that are not related to water contamination. The hydrogeologic system changes in response to increased surface runoff where undeveloped natural areas are covered with impervious surfaces such as parking lots, roads and buildings. Surface runoff from a parking lot on a hot summer day is at a much higher temperature than from a grassy slope. In addition sedimentation increases as a result of land clearing activities.

Inventory, Monitoring, and/or Research Needs for Water Issues

- Establish working relationships with the U.S. Geological Survey, the North Carolina Geological Survey, and nearby universities to study and monitor the park's watershed. Hydrogeology, slope creep, streambank erosion, and other geologic hazards are topics that could be studied.
- Determine sources of runoff of pollutants and sediments. Monitor ground and surface water quality and determine their impacts on the historic battleground areas (for preservation purposes) and on downstream areas.
- Map and quantify groundwater recharge zones.
- Work with the NPS Air Resources Division and EPA to determine atmospheric inputs such as nitrogen and mercury and their effects on park resources.

Cultural Landscapes

One of the overall goals of the Moores Creek National Battlefield is to maintain the historical context of the area that includes the battleground and settlement by Native Americans and early settlers. Maintaining these cultural landscapes is put under constant pressure by natural processes such as erosion, weathering, urbanization, and increased park visitation. Issues may arise between conflicting priorities in managing cultural and natural resources in the park.

The park includes historic features from the battle and later preservation efforts including the reconstructed bridge, Caswell's campsite, as well as monuments erected to commemorate figures and events related to the battle (figure 3). These historic features require protection from geologic processes, regional development, and from impacts related to park visitation.

The geology of Moores Creek National Battlefield is also part of its history. At the time of the battle, the creek and its surrounding wetlands with bottomland hardwood forest and pine savanna wetlands dominated the landscape. Drainage with a ditch and tile system and mowing converted the site to a partially drained wet meadow dominated by weeds and other invasive species for much of the last century. A restoration project by Moores Creek in cooperation with the Water Resources Division of the NPS has begun to return the landscape to its historic condition by reestablishing the natural hydrologic system.

Inventory, Monitoring, and/or Research Needs for Cultural Landscapes

- Map development and changing land uses in the vicinity of the park, including construction, deforestation, and other land cover changes.
- Assess the environmental impacts of proposed construction near park boundaries via photo points or aerial photography.

- Monitor human impacts at the picnic area, along designated and social trails, fishing sites, and other recreational areas within the park.
- Use sediment coring, tree ring studies, soils data, and other historical information to develop chronologies of past floods and their impacts, and then document future frequency and potential extent of flood impacts, including changes to the morphology of the streambank, riparian areas and the position and nature of the substrate, and ecosystem recovery. Where possible, data should also be collected during storm and flood events to monitor their immediate effects.

Erosion and Slope Processes

Geologic hazards are a concern at the park where slope creep and streambank erosion can affect park visitors and damage or destroy roads, trails, and historic features.

Many of the river valleys within and around the park have high slopes. This makes them susceptible to rock falls, landslides, slumps, and slope creep. An elevated concern exists for the weaker rock units such as the unconsolidated sands, silts and clays underlying the park.

Unconsolidated alluvium is especially vulnerable to failure when exposed. Heavy rainstorms, common in the eastern U.S., can quickly saturate valley slopes. On slopes that lack stabilizing vegetation, rock and soil may mobilize and move downhill resulting in slumps or debris flows.

Inventory, Monitoring, and Research Needs for Erosion and Slope Processes

- Use shallow (10- inch) and deeper core data to monitor rates of sediment accumulation and erosion in the park's streams and springs, and analyze changes in chemical constituents of the sediments.
- Monitor hazards to staff and visitors from unstable slopes and streambanks.
- Monitor erosion rates by establishing sites for repeat profile measurements to document rates of erosion or deposition, and if possible, remeasure these sites shortly after major storm events. Repeat photography may be a useful tool.
- Perform a comprehensive study of the erosion/weathering processes active at the park, taking into account the different sediment deposit compositions versus slope aspects, location and likelihood of instability.
- Inventory areas susceptible to flooding and develop management actions in these areas to protect park infrastructure, and park resources, including the cultural landscape.
- Inventory the condition of park trails and determine which trails are in need of rehabilitation. Close and revegetate social trails that are harming park resources.

General Geology

Inventory, Monitoring, and Research Needs for General Geology

- Work with the NPS Geologic Resources Division to have the digital soils map for Pender County, North Carolina completed by the Natural Resource Conservation Service (NRCS).
- Collaborate with the U.S. Geological Survey, North Carolina Geological Survey, and nearby universities to conduct and integrate geological studies of the rivers draining the Piedmont throughout the Atlantic Coastal Plain. These studies would improve an understanding of Cenozoic tectonics along the Atlantic coast.
- Perform detailed geologic mapping within the park to determine if the boundary between the Socastee and Wando Formations (described below) is distinguishable in the sediments.
- Develop interpretive exhibit(s) describing sedimentary deposits underlying the park, their origins, and their significance to the physiography of the area, especially concerning the battle fought there in 1776.

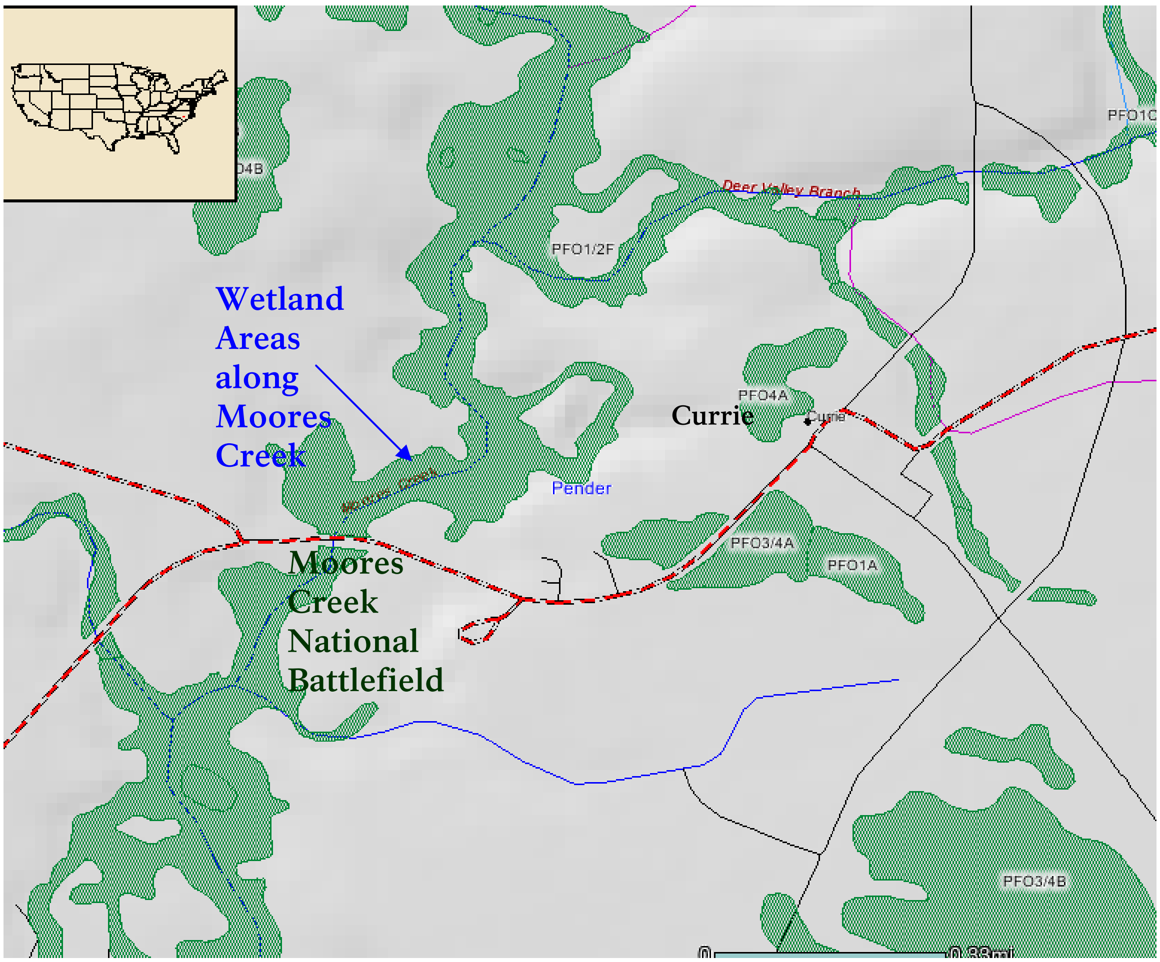

Figure 1. Map showing wetland areas relative to major roads and streams in the Moores Creek National Battlefield area. Graphic courtesy of: U.S. Fish and Wildlife Service, Wetlands Mapper: http://www.nwi.fws.gov/mapper_tool.htm

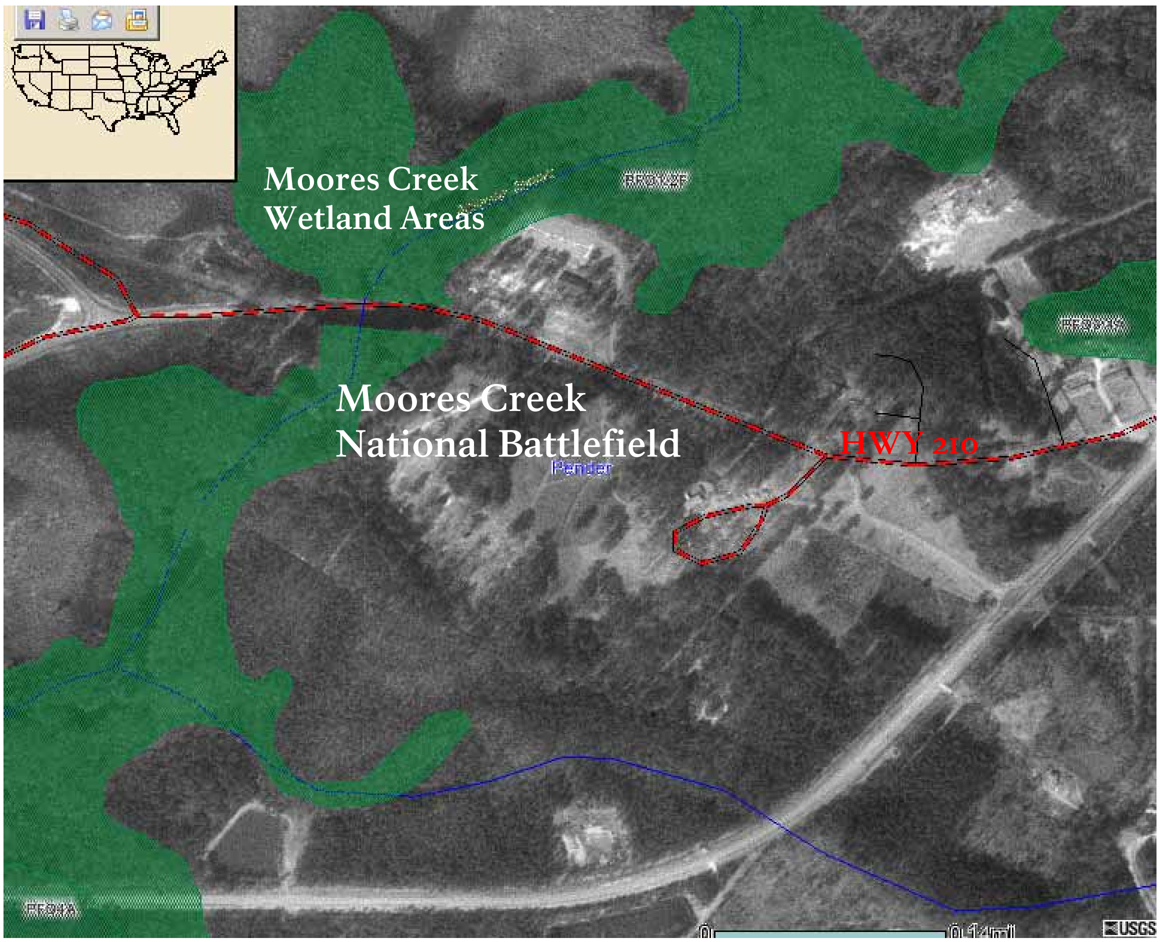

Figure 2. Map showing wetlands areas and satellite land imagery of Moores Creek National Battlefield. Note open areas within the park and the broad wetland areas (in green) straddling the streams. Graphic adapted from: U.S. Fish and Wildlife Service, Wetlands Mapper: http://www.nwi.fws.gov/mapper_tool.htm

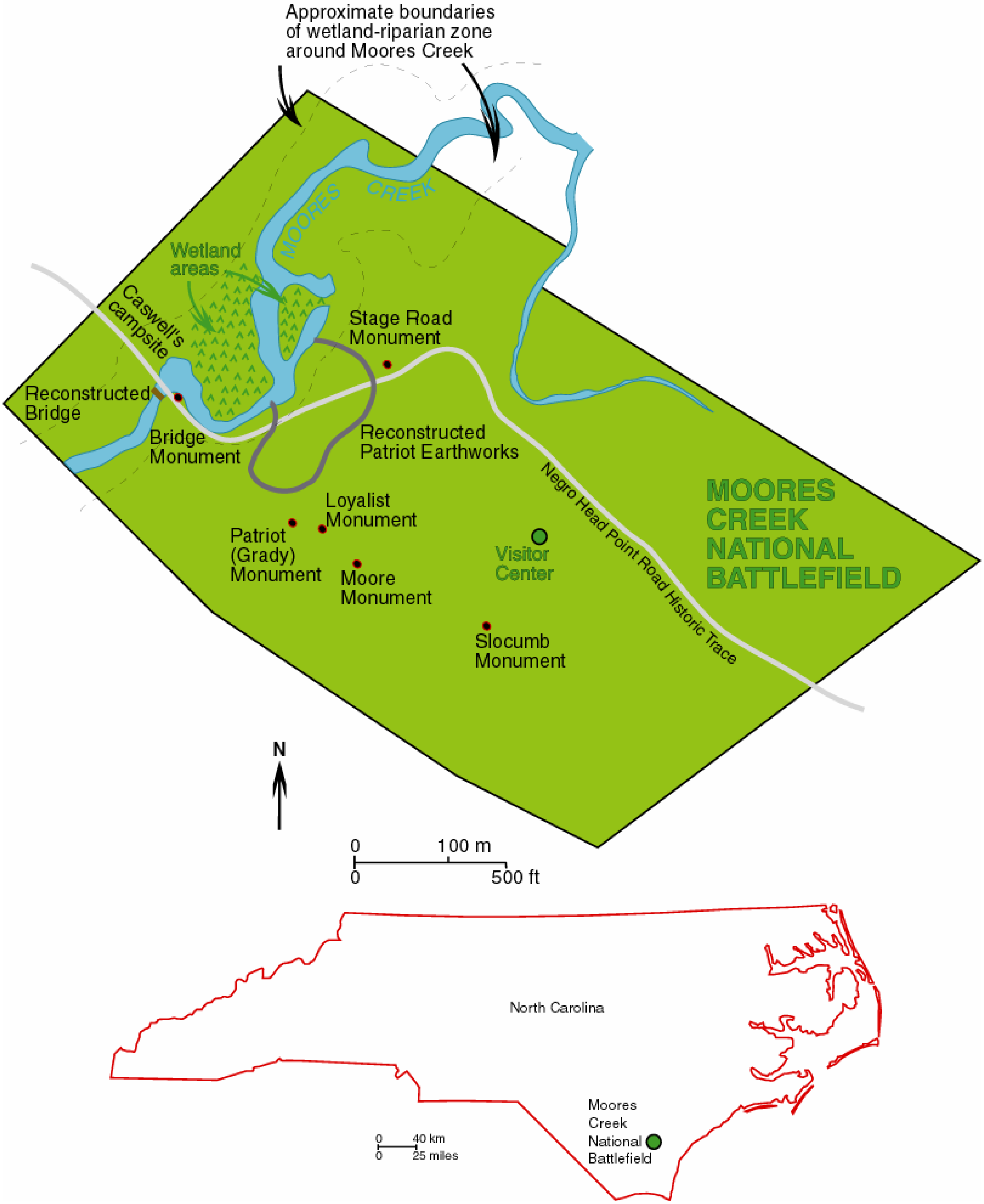

Figure 3. Map of Moores Creek National Battlefield with rough extent of wetlands areas, monuments, and historic features noted as well as the location of Moores Creek. Index map of North Carolina with location of Moores Creek National Battlefield included.

Geologic Features and Processes

This section provides descriptions of the most prominent and distinctive geologic features and processes in Moores Creek National Battlefield.

Geology and the Battle of Moores Creek Bridge

In 1776, Widow Moore's Creek (named after an early settler) was a meandering stream through a marshy wetland. The interplay of the climate, hydrology, and geology of the area created the historic setting. A bridge, necessary for crossing the boggy wetlands and the stream was a focal point of troop and supply movement for the Loyalist and Patriot forces in 1776.

The Patriots got to the bridge first and the Loyalists rushed to meet them. Colonel Richard Caswell of the militia and Colonel James Moore of the First North Carolina Continentals were attempting to thwart a meeting and joining of forces between 1,600 Scottish Highlanders and British troops waiting off the coast of North Carolina (figure 4). Caswell, Moore, and a force of 150 Wilmington militiamen under Colonel Alexander Lillington dug earthworks on either side of Moores Creek.

Just before dawn on February 27, 1776, Loyalists completed their 9.7 km (6 miles) march to Moores Creek Bridge. There they discovered abandoned earthworks on the west side of the creek, near Caswell's camp. While attempting to cross the bridge they discovered the Patriots had removed planks from the bridge and greased the stringers, making the crossing difficult. The Loyalists faced fire from two cannons behind the eastern earthworks and well- prepared militiamen. They quickly retreated in panic, and many men drowned in Moores Creek. When it was all over, approximately 30 Loyalists were killed, 40 wounded, and 850 or so were captured in the following days. It was a huge and lopsided victory for the Patriot forces. In the end, North Carolina was not secured for the British (Capps and Davis 1999).

While the Highlander Loyalists appeared ever confident in the superiority of their troops, it was the Patriot's familiarity with the terrain and their manipulation of the focal point, the Moores Creek Bridge that decided the battle's outcome. The wetland landscape and topography at Moores Creek is defined by hydrology and geology. In addition to influencing battles, the landscape and topography also affected how troops and supplies were transported during the Revolutionary War (Wagner 2000).

One of the major goals of the park is to present the historical context of the area, including preserving and restoring historic buildings and the cultural landscape around them (figure 5). Maintaining the historic landscape often means controlling geologic processes, which can present resource management challenges.

Geologic slope processes such as landsliding, slumping, chemical weathering, block sliding and slope creep are constantly changing the landscape at the park. Runoff erodes sediments and carries them downstream. Erosion removes sediment from higher areas such as earthworks, degrades bridge foundations, and fills in the lower areas and changes the appearance of the historic landscape.

Atlantic Coastal Plain and the Cape Fear Arch

The unconsolidated deposits of the Atlantic Coastal Plain record a series of marine transgressive - regressive sequences (periods of sea level rising and falling). These are dominated surficially by backbarrier- barrier sediments. In the Moores Creek area, older sequences lie some distance inland from the modern shoreline near Wilmington, while younger sequences are located at progressively lower elevations closer to the present shore (figure 6). These sequences typically include a thin basal marine unit with thicker overlying beds consisting of beach or barrier sands, estuarine- backbarrier sands and clays, and the sands and clays deposited as alluvial flood plains. The overlying units record the regression of the shoreline (Soller 1988).

The surface of these transgressive sequences is relatively flat. Given their planar surface expression, they impart a step- like character to the regional topography. Each transgressive sequence is mapped as a separate unit. In the Moores Creek area, there are seven mapped transgressive units (formations). From youngest to oldest these are called the Wando, Socastee, Canepatch, Penholoway, Waccamaw, Bear Bluff, and Duplin Formations ranging in age from <0.1 to 3.25 Ma (McCartan et al. 1982; DuBar et al. 1974).

Moores Creek is part of the Black Creek sub- watershed, which in turn is part of the larger Cape Fear watershed. This system begins in the Blue Ridge Mountains to the west. This system has eroded the Late Proterozoic to Permian metamorphic, igneous and sedimentary rocks of the Blue Ridge and Piedmont physiographic provinces and transported these sediments to the east, adding to the Atlantic Coastal Plain.

The North Carolina, and by extension eastern North American, coastline has long been considered a passive margin. The series of level marine terraces, assumed to be the product of single periods of higher sea levels, were cited as evidence of a very passive margin. However, recent studies regarding the river channel geomorphology and sediment thickness reveal that this margin is not passive at all.

The Cape Fear River valley runs on both sides of a broad tectonic feature called the Cape Fear arch. This tectonic feature has been persistent over time along the east coast near the North Carolina – South Carolina border. Tectonic warping of the arch axis is deforming Cenozoic sediments and influencing sedimentation patterns throughout the entire region (figure 7). The arch effects sedimentation patterns, topography and drainage of local rivers flowing across the Atlantic Coastal Plain in the Moores Creek area. This feature is deep- seated (located far below the earth's surface) as illustrated by the geological structure contours reflected from the top of the basement, or hard, crystalline, rock that lies below the thick, unconsolidated sediments. Elevations range from 457 m (1,500 ft) below sea level on the arch axis near Wilmington, North Carolina, to 1,829 m (6,000 ft) below sea level along the Outer Banks of North Carolina.

Uplift of at least a portion of the arch has continued throughout the Cenozoic Era (over the last 65 million years). The portion of the arch northeast of the Cape Fear River drainage has been uplifting and warping, causing a southwestward migration of the Cape Fear River valley. This migration is reflected in the preservation of river terraces and large tributaries that only occur to the northeast of the Cape Fear River.

In addition, an anticlinal fold (flexure) roughly perpendicular to the Cape Fear arch uplifted the upper reaches of the river valley beginning more than 750 thousand years ago. The lower portions of the valley were subsiding. The overall trend of persistent regional uplift is the reason the elevated transgressive marine shorelines are preserved in the area. Far from being a passive margin collecting sediment, the Cape Fear area is part of a regional tectonic uplift that has persisted for millions of years.

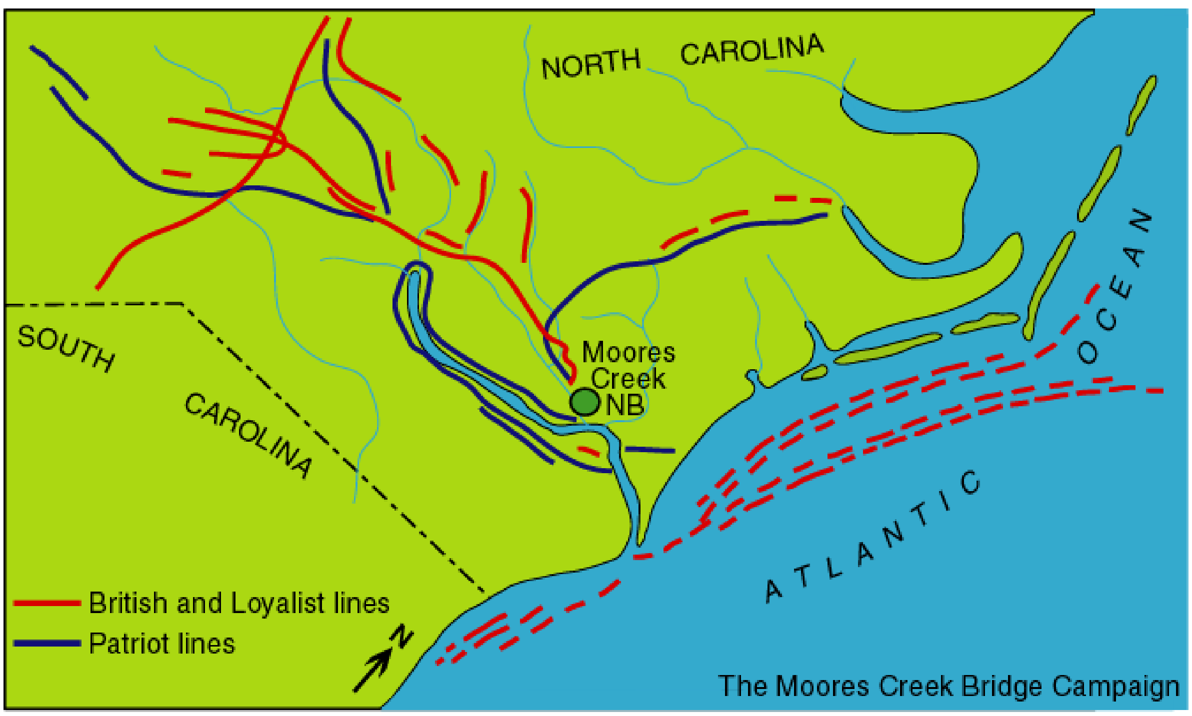

Figure 4. Map of British and Loyalist lines versus Patriot positions in the vicinity of Moores Creek prior to the battle of Moores Creek Bridge. Figure adapted from Capps and Davis, 1999.

Figure 5. Photo showing a soldier re-enactment amidst the forested terrain at Moores Creek National Battlefield. This setting no doubt played a role in strategy and battle planning as well as influencing troop movements and transport of supplies in 1776.

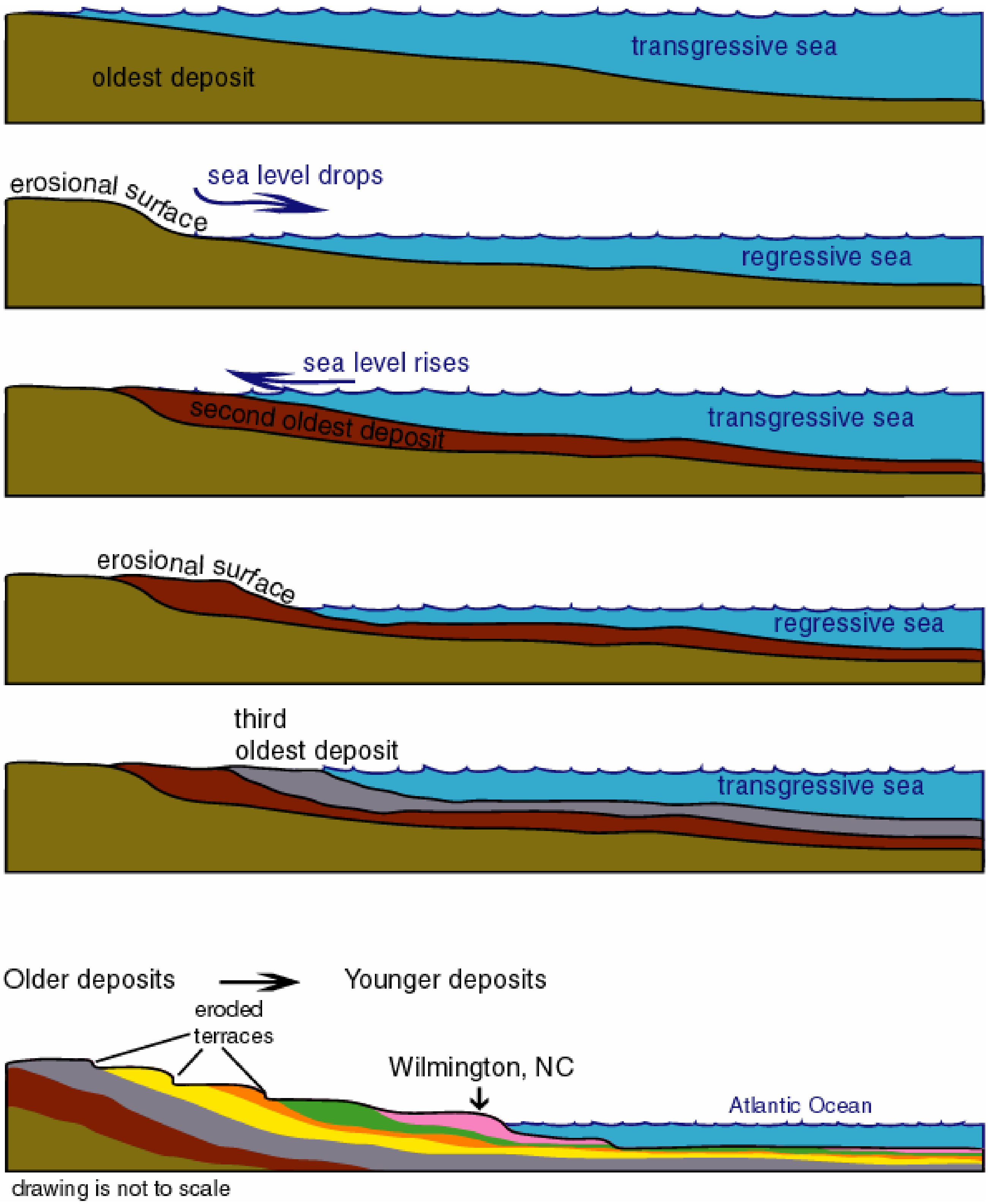

Figure 6. Diagram showing a cross section view of progressively younger terraces from marine transgressions along the coastal areas of North Carolina. The deposits in the Moores Creek area are older than those located in the Wilmington area. Diagram by Trista L. Thornberry-Ehrlich (Colorado State University).

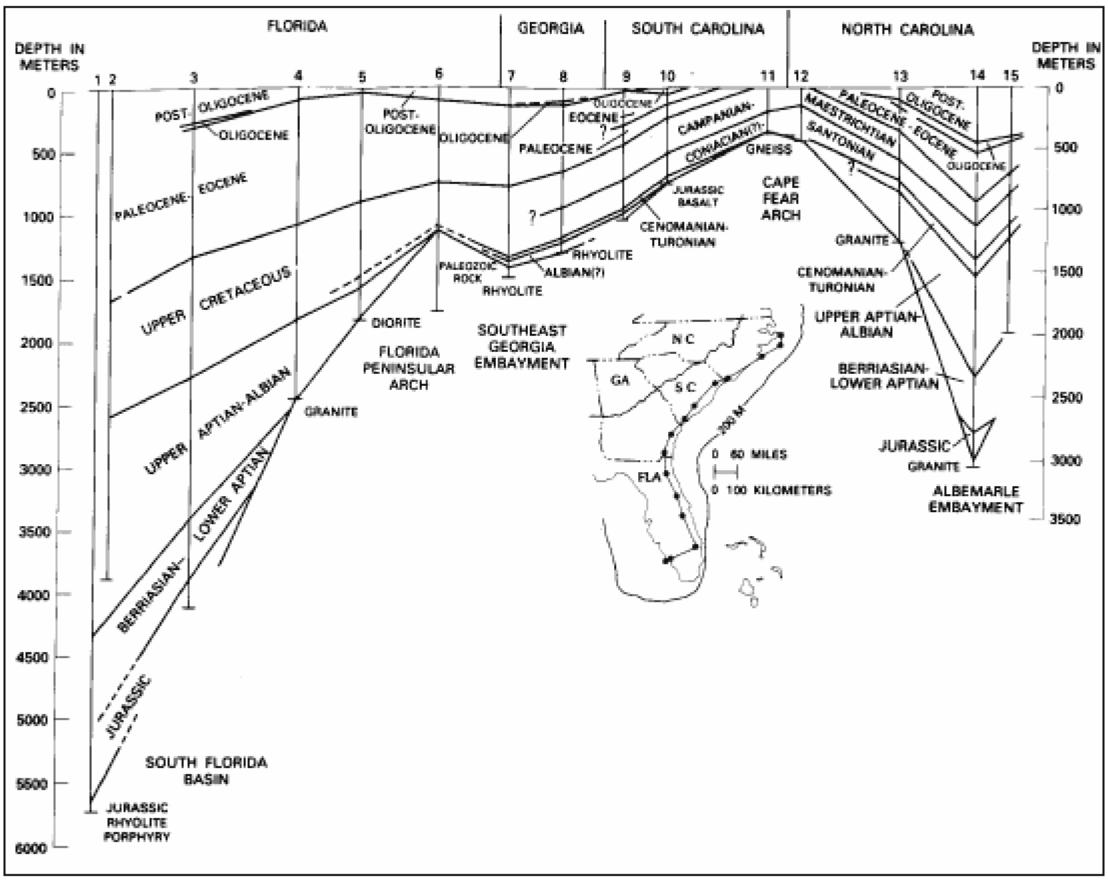

Figure 7. Generalized stratigraphic cross-section along the modern coast line (Note location of Cape Fear Arch near the South and North Carolina border) from Florida to North Carolina. Graphic is courtesy of the U.S. Geological Survey: http://pubs.usgs.gov/of/2004/1013/setting.html (accessed March 27, 2006).

Map Unit Properties

This section provides a description for and identifies many characteristics of the map units that appear on the digital geologic map of Moores Creek National Battlefield. The table is highly generalized and is provided for informational purposes only. Ground disturbing activities should not be permitted or denied on the basis of information contained in this table. More detailed unit descriptions can be found in the help files that accompany the digital geologic map or by contacting the NPS Geologic Resources Division.

Compared to the hills and ridges of the Piedmont and Blue Ridge Mountains, the geology at Moores Creek is flat- lying and relatively young. The geology in this part of the Atlantic Coastal Plain is comprised of unconsolidated deposits representing a series of separable transgressive- regressive sequences. In most areas these sequences are flat- lying, and parallel to the coastline, except where they occur near the area's many large river systems including the Cape Fear River drainage of which Moores Creek is a tributary.

The unconsolidated to partially cemented deposits are separated regionally into seven units. From oldest to youngest these are called the Duplin, Bear Bluff, Waccamaw, Penholoway, Canepatch, Socastee, and Wando Formations (McCartan et al. 1982; DuBar et al. 1974).

The Duplin Formation, of Pliocene age (~3.25 Ma) lies at an elevation of about 55 m (180 ft) or more. The Bear Bluff Formation lies seaward of the Duplin at 30 to 37 m (100 - 120 ft) above sea level. These are shallow marine sediments, dominated by sand are weathered with well developed soil horizons (Soller 1988).

The Waccamaw Formation outcrops at elevations up to 32 m (105 ft) above sea level. It is considered to be a single transgressive unit of early to middle Pleistocene age (1.75 Ma). The Penholoway Formation is sometimes considered part of the upper units of the Waccamaw Formation. The Canepatch and Socastee Formations are represented by an extensive backbarrier- barrier complex at elevation up to 12 m (40 ft) above sea level (Soller 1988).

The Socastee Formation is widely recognized and exposed in the Moores Creek area. It has both marine and nonmarine facies. Its type locality is on the lower reaches of the Waccamaw River.

The base of the Socastee consists largely of reworked shells, fine gravel, coarse sand, and some occasional woody pieces. The upper layers include sands and peaty clays. All of the deposits are fossiliferous (Owens 1989). The upper section of the Socastee Formation is sometimes associated with the Wando Formation. The Wando Formation is the youngest river terrace recognized in the area. It is late Pleistocene (0.1 Ma) in age and its surface does not exceed 5 m (16 ft) above sea level regionally (Soller 1988).

These unconsolidated marine transgressive deposits include a thin basal marine unit with a thicker overlying series of coarser deposits preserved during regression of the sea. These deposits include beach or barrier sands, estuarine- backbarrier sands and clays, and sands and clays deposited in the floodplains of regional rivers (Soller 1988). These deposits and terraces are carved locally by rivers, transporting alluvium further downstream. This Holocene age alluvium consists of interbedded dark clays and light colored sands interbedded with an occasional gravel layer. Woody material and other organic matter is common, as well as bog deposits, local colluvium, minor dunes, and slope deposits (Owens 1989). These Holocene age sediments are the youngest sedimentary deposits found at Moores Creek.

The following pages present a tabular view of the stratigraphic column and an itemized list of features for each map unit. This sheet includes several properties specific to each unit present in the stratigraphic column including: map symbol, name, description, resistance to erosion, suitability for development, hazards, potential paleontologic resources, cultural and mineral resources, potential karst issues, recreational use potential, and global significance.

Map Unit Properties Table

Age	Unit Name (Symbol)	Features and Description	Erosion Resistance	Suitability for Development	Hazards	Potential Paleontologic Resources	Potential Cultural Resources	Mineral Specimens	Mineral Resources	Habitat	Recreation Potential	Global Significance
QUATERNARY	Alluvium (Qal)	Assorted silts, sands, gravels and clays typically present along Moores Creek as floodplain and river deposits	Very low	Unconsolidated deposits could fail if water saturated; should not be used for waste facilities and large structures, especially if on a slope; wetland areas should be avoided	Slumps, slides, flash flooding, gullying, and debris flows	Modern specimens possible	Valley fills on present land surface, ancient campsites, battle relics, earthworks	None	Sand, gravel, clay	Pine savanna wetlands abundant	Good for all uses unless site of a wetland	Correlation between battle and geology; hosts rare wetland habitat
	Holocene deposits (Qh)	Holocene sediments are confined to major drainages. Small dunes are widespread on most flood plains. Sediments vary in thickness from a feather edge to 15 m. Fluvial sediments are typically interbedded dark clays and light sand, commonly containing a thin gravel layer at the base. Clays are mostly dark gray to dark green and micaceous. Major clay minerals are illite- smectite with lesser amounts of kaolinite. Quartz and feldspar are the major sand components.	Very low to low	Unconsolidated deposits could fail if water saturated; should not be used for waste facilities and large structures, especially if on a slope; wetland areas should be avoided	Slumps, slides, flash flooding, gullying, and debris flows	Woody debris common throughout; large logs locally	Ancient relics such as pottery shards and arrowheads; bullets, other battle items	None	Sand, gravel, clay	Wetlands habitat for flora and fauna	Good for all uses unless on a slope; avoid wetland areas	Correlation between battle and geology, hosts rare wetland habitat
	Wando Formation (Qwa)	Formation consists of sandy deposits that form a single barrier. Lower part of barrier contains massive to crudely bedded, very shelly strata. Surrounding sand is stained a deep orange to rust- brown. The upper part of barrier consists of thick to thin, humate- cemented sands. Quartz is the major component of sands. Feldspar (mostly K- feldspar) ranges from 1 to 6 % of sand fraction. Hornblende, epidote, and lesser amounts of garnet, are abundant in the sand in upper 1.5 m of the surface.	Very low to low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads	Slumps, slides, flash flooding, gullying, and debris flows	Some bleached shell beds; small amounts of wood; *Crassostrea virginica* (oyster), foraminifera	None documented	Garnet, hornblende, and epidote detritus	Sand, gravel, clay	Coastal wetlands and riverine environments	Good for all uses unless on a slope or unit is undercut creating an unstable surface	Dates uplift along Cape Fear Arch; records marine transgression
QUATERNARY	Socastee Formation (Qs)	Formation has both marine and non- marine facies. Surface is characterized by a well- developed ridge- and- swale topography. Ridges, or barriers, are closely spaced. The base commonly consists of 0.3 to 1 m of reworked shells, fine gravel, coarse sand, and, occasionally, woody fragments; remainder consists of interbedded sands and clays. The clay layers rich in peat. Sands are often clayey and poorly sorted, ranging from massive to well cross- stratified. Quartz is major component with feldspar (mostly K- feldspar) less than 15 % of sand fraction. Heavy mineral assemblages contain significant concentrations of hornblende and epidote.	Low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads	Slumps, slides, flash flooding, gullying, and debris flows	Vertical tree trunks, woody fragments; *Crassostrea virginica* (oyster), *Callianassa* (crab), *Tagelus plebeius, Mulinia lateralis* (clams), *Nassarius obsoletus* (gastropod), *Memeneria merceneria (bivalve)*	Ancient relics such as pottery shards, arrowheads; bullets, other battle items	Epidote and hornblende detritus	Sand, gravel, clay	Ridge- and- swale topography provides variety of habitat	Good for all uses unless on a slope creating loose, unstable, surface	Correlation between battle and geology. Dates uplift along Cape Fear Arch; records marine transgression
QUATERNARY	Penholoway Formation (Qph)	Formation is largely a barrier and backbarrier system. Barrier sands are thin, typically about 3 to 4.5 m thick. Sand is mainly quartz with less than 10 % feldspar. Heavy mineral assemblages typically have high concentrations of resistant minerals: staurolite, sillimanite, kyanite, zircon, tourmaline, and rutile. Base of back- barrier facies typically has a thin reworked sediment zone. Most of back- barrier sediments are interbedded clay, clayey sand, and sand. Beds downdip are mostly sand, with fine gravel dispersed throughout. Epidote and hornblende locally major constituents in the backbarrier beds.	Low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads	Slumps, slides, flash flooding, gullying, and debris flows	Shells, wood, sharks teeth, vertebrate remains	None documented	Staurolite, sillimanite, kyanite, zircon, tourmaline, rutile, epidote, hornblende	Sand, gravel, clay	None documented	Good for all uses unless on a slope creating loose, unstable, surface	Dates uplift along Cape Fear Arch; records marine transgression

Age	Unit Name (Symbol)	Features and Description	Erosion Resistance	Suitability for Development	Hazards	Potential Paleontologic Resources	Potential Cultural Resources	Mineral Specimens	Mineral Resources	Habitat	Recreation Potential	Global Significance
QUATERNARY	Waccamaw Formation (Qw)	Formation is largely a barrier and backbarrier sequence that crops out 21 to 30 m above sea level. Barriers are commonly fine to coarse interbeds of poorly to well- sorted sands. Lower few meters are commonly reworked sediments from underlying units. The barrier sands are mostly quartz; feldspars are present only in the base of the barrier sands. Southwest barriers are characterized by large amounts of staurolite, sillimanite, and kyanite, with epidote occurring locally. In general, the backbarrier facies are interbeds of clayey silts and clayey sands, which may have reworked shells at the base. Clays in the backbarriers are mostly illite- smectite and small amounts of kaolinite.	Low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads; locally high clay concentrations are unsuitable for building roads, trails or structures.	Clay units can be very unstable on slopes resulting in slumps, slides, flash flooding, gullying, and debris flows.	Mulinia-dominated shell assemblages; logs in backbarrier facies; peat; Ostrea *sculpturata* (oyster), *Noetia limula* (bivalve), *Mulinia lateralis*, pollen (clam)	None documented	Staurolite, sillimanite, kyanite, and epidote detritus	Sand, gravel, clay	Terraced landform with unconsolidated deposits for burrows, and a variety of habitats	Good for all uses unless on a slope creating an unstable, unconsolidated surface	Dates uplift along Cape Fear Arch; records marine transgression
TERTIARY	Bear Bluff Formation (Tb)	The marine facies consists of a basal shelly horizon. These beds occur locally in deep narrow trenches, particularly in the downdip areas. These entrenched shelly beds are commonly leached and cemented by calcite into hard masses. The shell beds in most areas grade up into thick beds of bluish- green to dark gray, very clayey silt - a complex intercalations of sand and silty clay beds. The barrier facies is very thin and averages about 4.5 m thick. Laminated to thin-bedded, burrowed tidal- flat deposits locally overlie cross- bedded sands of tidal inlet deposits . Minerals in the sand fraction of the barriers are varied; the less weathered deposits have 15- 35% feldspar content. The opaque heavy minerals are dominated by the weathering products of ilmenite, pseudorutile, and leucoxene. The non- opaque heavy minerals are mostly zircon, tourmaline, rutile, staurolite, sillimanite, and kyanite. The fluvial facies has abundant silt beds overlying a very gravelly unit. Sand fraction is mostly quartz and feldspar. The non- opaque heavy minerals contain high concentrations of epidote. Monazite is notably abundant in the extreme updip areas. Interfingering of the fluvial, barrier and backbarrier facies of the Bear Bluff is evident in boreholes.	Moderately low to low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads	Slumps, slides, flash flooding, gullying, and debris flows	Shells, wood fragments, *Ophiomorpha* burrows (shrimp), *Noetia limula* (bivalve), *Anadara improcera* (mollusk), *Ostrea sculpturata* (oyster)	None documented	Zircon, tourmaline, rutile, staurolite, sillimanite, kyanite, and epidote detritus	Limestone, sand, gravel, clay	None documented	Good for all uses unless on a slope creating an unstable, unconsolidated surface	Dates uplift along Cape Fear Arch; records marine transgression
TERTIARY	Duplin Formation (Td)	Formation is about 21.3 m thick; basal beds of gravelly sand are typically about 3 to 4.5 m thick. Gravelly beds are capped locally by interbedded, thin, dark-gray clay and silt and light yellow sand. Sands typically are poorly exposed. The sandy facies are very deeply weathered. Kaolinite is the major clay mineral. The local mineral indicators of intense weathering, gibbsite and vermiculite, are well developed, but they are absent in most profiles. Heavy minerals in the sandy facies have only the resistant zircon- tourmaline- rutile and staurolite- sillimanite- kyanite mineral suites.	Low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads; locally high clay concentrations are unsuitable for building roads, trails or structures.	Slumps, slides, flash flooding, gullying, and debris flows	Pollen, dinoflagellates, shells, scattered *Ophiomorpha*, *Ostrea raveneli* (oyster), *Noetia rigintinaria* (bivalve), *Glucemeris subovata*, *G. Americana* (mollusks), *Paracytheridea mucra*, *Murrayina barclayi* (ostracodes)	None documented	Kaolinite, vermiculite, resistant minerals	Sand, gravel, clay	None documented	Good for all uses unless on a slope creating an unstable, unconsolidated surface	Oldest marine terrace locally, dates timing of uplift along Cape Fear Arch and records a marine transgression
CRETACEOUS	Cretaceous, undivided (Ku)	Undifferentiated Cretaceous sedimentary rocks	Low	None documented	None documented	None documented	None documented	None documented	None documented	None documented	None documented	None documented

Age	Unit Name (Symbol)	Features and Description	Erosion Resistance	Suitability for Development	Hazards	Potential Paleontologic Resources	Potential Cultural Resources	Mineral Specimens	Mineral Resources	Habitat	Recreation Potential	Global Significance
CRETACEOUS	Peedee Formation (Kpd)	Unit is a massive to thick- bedded, dark gray to gray- green, slightly to very clayey, micaceous, calcareous, glauconitic quartz sand. Deposits extensively bioturbated. Locally, thin (30- 100 cm) ledges of impure limestone are present. Most of the glauconite- rich beds are massive, some are locally cross- bedded. The Peedee is separated from the underlying unit by a reworked zone containing abundant phosphatic pebbles and phosphatic organic remains; light sand fraction mostly quartz. Feldspars typically less than 10 %. Non- opaque heavy mineral assemblages have moderate concentrations of zircon, tourmaline, rutile, staurolite, and kyanite and unusually high concentration of garnet. The clay minerals are principally illite- smectite, and kaolinite.	Moderate to low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads; locally high clay concentrations are unsuitable for building roads, trails or structures.	Slumps, slides, flash flooding, gullying, and debris flows	*Exogyra costata* (oyster), *Belemnitella Americana* (cephalopod), *Globotruncana ganserri*, *Globotruncana aegyptiaca* (forams), *Rugoglobigerina macrocephala*, *Heterolhelix glabrans* (forams), *Haustator bilira* (mollusk)	None documented	Zircon, tourmaline, rutile, staurolite, kyanite, and garnet detritus	Sand, gravel, clay	Limestone ledges may provide local bird habitat	Good for all uses unless on a slope creating an unstable, unconsolidated surface	Records provenance of sediments of Atlantic Coastal Plain
CRETACEOUS	Donoho (Creek) Formation (Kdc)	Formation is a massive, fossiliferous sand deposit. The base of this massive unit is marked by a thin zone of small reworked quartz and phosphate pebbles. Deposits in the Cape Fear River valley are largely dark gray, medium- grained sands. Much of the formation has a mottled appearance from bioturbation. The non- opaque heavy minerals mostly zircon, tourmaline, rutile, staurolite, and kyanite. Accessory minerals are garnet, chloritoid, and, to a lesser extent, epidote and monazite. Ilmenite is most abundant opaque mineral, and its weathering products, pseudorutile and leucoxene. Quartz is most abundant light mineral; feldspar less than 5%. Illite- smectite principal clay fraction, with lesser kaolinite.	Low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads; locally high clay concentrations are unsuitable for building roads, trails or structures.	Slumps, slides, flash flooding, gullying, and debris flows	Invertebrate remains, shells, *Exogyra cancellata* (oyster)	None documented	Garnet, epidote, zircon, tourmaline, rutile, staurolite, and kyanite detritus	Sand, gravel, clay	None documented	Good for all uses unless on a slope creating an unstable, unconsolidated surface	Records provenance of sediments of Atlantic Coastal Plain
CRETACEOUS	Bladen Formation (Kb)	Formation consists of the intercalated sand- clay sequences about 44 m thick. The basal beds consist of thin intercalated sand and clay beds with woody fragments, some burrows, and coarse mica flakes. Some cross- bedded sand and massive black clay beds locally present . The mostly quartz sand, with feldspar comprising up to 15%. The non- opaque heavy minerals are zircon, tourmaline, rutile, staurolite, and kyanite. Garnet is present locally in moderate amounts and epidote in lesser amounts. Chloritoid, monazite, and andalusite accessory minerals.	Low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads	Slumps, slides, flash flooding, gullying, and debris flows	Burrows, woody fragments, lignitic logs, *Ophiomorpha*, invertebrate remains, *Exogyra ponderosa* (oyster)	None documented	Zircon, tourmaline, rutile, staurolite, kyanite, andalusite, epidote, and garnet detritus	Sand, gravel, clay	None documented	Good for all uses unless on a slope creating an unstable, unconsolidated surface	Records provenance of sediments of Atlantic Coastal Plain
CRETACEOUS	Tar Heel Formation (Kth)	Many facies within unit including thin- to thick- bedded, black clays and thin to thick, light- colored sand beds. Carbonaceous matter ranges from finely dispersed grains through log- sized fragments. The sands are massive to cross- bedded and micaceous. In Cape Fear valley, strata are more characteristic of a delta front. Locally beds contain marine fossils and glauconite intercalated with thin- bedded, clay- sand sequences. A heavy- mineral assemblage characterized by resistant minerals (zircon and others) and, locally, large concentrations of garnet. The clay mineral suites are mixtures of illite- smectite and kaolinite in fresh samples. Where weathered, kaolinite is the only major clay mineral.	Moderately low to low	Suitable for most development unless unit is water saturated, exposed on a steep slope or undercut by rivers, trails or roads; locally high clay concentrations are unsuitable for building roads, trails or structures.	Slumps, slides, flash flooding, gullying, and debris flows	Marine fossils, woody fragments, logs, dinoflagellates, ostracodes	None documented	Glauconite, kaolinite, and garnet detritus	Sand, gravel, clay	None documented	Good for all uses unless on a slope creating an unstable, unconsolidated surface	Records provenance of sediments of Atlantic Coastal Plain

Geologic History

This section highlights the map units (i.e., rocks and unconsolidated deposits) that occur in Moores Creek National Battlefield and puts them in a geologic context in terms of the environment in which they were deposited and the timing of geologic events that created the present landscape.

Southern Appalachian Mountains

The recorded history of the southern Appalachian Mountains begins in the Proterozoic Eon (figure 8). In the mid Proterozoic, during the Grenville orogeny 1,100 Ma, a supercontinent formed that comprised most of the continental crust in existence at that time, including the crust of North America and Africa. The regional sedimentation, deformation, plutonism (the intrusion of igneous rocks), and volcanism are represented in the metamorphic gneisses in the core of the modern Blue Ridge Mountains (Harris et al. 1997). These rocks were deposited over a period of 100 million years and are more than a billion years old, placing them among the oldest rocks known from this region. They form the basement upon which all other rocks of the Appalachians lie (Southworth et al. 2001).

The late Proterozoic, roughly 750- 600 Ma, was a period of extensional, rifting in the area (figure 9). The supercontinent broke up and a basin formed that eventually became the Iapetus Ocean (Carter et al. 1993). Locally, the Ocoee basin formed on the margin of the supercontinent in what are now the western Carolinas, eastern Tennessee and northern Georgia. Muds, silts, and sands shed from the Grenville highlands would eventually form the rocks of the Appalachian Mountains (Moore 1988). The basin subsided with further sedimentation in the basin during at least two prolonged pulses (Tull 1998).

Associated with the shallow marine setting along the eastern continental margin of the Iapetus Ocean were sands, silts and muds that were deposited in nearshore, deltaic, barrier island, and tidal flat areas (Schwab 1970; Kauffman and Frey 1979; Simpson 1991). A thick sequence of marine deposits that thickened eastward was laid down on a large platform that persisted during the Cambrian and Ordovician Periods (545- 480 Ma). At the end of the Proterozoic, flood basalts and other igneous rocks such as diabase and rhyolite were also deposited. These igneous rocks were intruded through cracks in granitic gneisses of the Blue Ridge core and extruded onto the land surface during the break- up of the continental land mass (Southworth et al. 2001).

The volcanism was concentrated in areas of present- day Virginia, the Carolinas, and Georgia. This igneous activity is largely responsible for the economic deposits of copper, zinc, iron, and sulfur in the eastern U.S. that formed when hot, metal- bearing fluids were deposited onto the floor of the Ocoee basin (Clark 2001).

Several additional mountain building episodes and periods of continental collision occurred after the Grenville orogeny and were responsible for the creation of the Appalachian Mountains. These orogenies contributed to the heat and pressure that deformed and metamorphosed the sediments, intrusives, and basalts into schists, gneisses, marbles, slates, and migmatites (Southworth et al. 2000).

During Early Cambrian through Early Ordovician time orogenic activity along the eastern margin of the continent began. This involved the closing of the ocean, subduction of oceanic crust, the creation of volcanic arcs and the uplift of continental crust during the first stages of the Taconic orogeny. The Mid to Late Devonian Taconic orogeny (~445- 435 Ma) was the first of three major orogenic events following the closure of the Iapetus Ocean. In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards creating a deep basin (the Appalachian basin) that filled with mud and sand eroded from the highlands to the east (Harris et al. 1997). These infilling sediments covered the carbonate platform (Southworth et al. 2001).

During the Late Ordovician, the marine sediments of the shrinking Iapetus Ocean were thrust westward onto other deepwater sediments of the western Piedmont. Sandstones, shales, siltstones, and limestones were deposited in the shallow marine to deltaic environment of the Appalachian basin. These rocks which were later metamorphosed currently underlie the Valley and Ridge physiographic province. The Piedmont metasediments record the transition from non- orogenic, passive margin sedimentation to extensive, syn- orogenic clastic sedimentation during Ordovician time (Fisher 1976). By the end of the Taconic Orogeny a volcanic arc and continental crust were thrust onto the eastern edge of the North American continent (Moore 1988, Connelly 1990).

The Mid to Late Devonian Acadian orogeny (~375- 355 Ma) continued the mountain building of the Taconic orogeny as the African continent move toward North America by continental drift (Harris et al. 1997). This orogeny was focused in the north- central Appalachian Mountains. The last significant mountain building event of the Appalachians was the collision between the African and North American continents during the Pennsylvanian- Permian Alleghenian orogeny (~300- 220 Ma).

There are several proposed crustal sutures in the Southern Appalachians. A crustal suture is a feature that represents a major joining of previously unconnected terranes. These frequently form during orogenic events when portions of oceanic or continental crust are thrust against other terranes and eventually form a continuous landmass. Regional crustal sutures include: 1) central Blue Ridge (Fries- Hayesville faults), 2) Brevard zone, 3) central Piedmont (Kings Mountain- Lowndesville- Middleton (or Towaglia) shear zones), and 4) beneath the Atlantic Coastal Plain physiographic province (Horton 1981; Butler et al. 1985).

Thrusting along these sutures occurred during all three major Appalachian orogenies, but more so during the Taconic and Alleghenian orogenies. Taconic thrusting placed oceanic deposits onto a continental margin sequence which was covering the Grenvillian crust. Alleghenian deformation was more widespread in the area, affecting most of the exposed Appalachians. Thrusts were deeper, involving Grenvillian crust and other Precambrian rocks. The Acadian orogeny is associated primarily with metamorphism and magmatism in the Piedmont of the Southern Appalachians (Butler et al. 1985).

The deformation associated with the Alleghenian orogeny modified many geologic structures that had formed in the southern Appalachians. Pre- existing Paleozoic faults were reactivated by the Great Smoky thrust fault, which is exposed far to the west of Moores Creek National Battlefield. This activity combined with the extremely large strains and lack of strain markers makes restoration of any pre- Alleghenian deformation difficult (Connelly 1990, Connelly and Woodward 1992).

During the Alleghenian orogeny, rocks of the Great Valley, Blue Ridge, and Piedmont provinces were thrust westward onto younger rocks of the Valley and Ridge province. Estimates range from 20- 50 percent shortening which translates into 125–350 km (75- 125 miles) of movement (Harris et al. 1997). Deformed rocks in the eastern Piedmont were also folded and faulted and existing thrust faults were reactivated as both strike slip and thrust faults during the Alleghanian orogeny (Southworth et al. 2001).

Following the Alleghenian orogeny (late Triassic, 230- 200 Ma), a period of rifting began as the deformed rocks of the joined continents began to break apart. Several undeformed basaltic dikes present in the Greensboro, North Carolina area record the tensional stresses during the post- Paleozoic continental breakup (White and Almy 1977). The rock assemblage was then extensively folded and faulted. This faulting may have initiated during regional rifting that occurred about 200 Ma.

The supercontinent Pangaea split into roughly the continents that persist today. This episode of rifting initiated the formation of the current Atlantic Ocean and caused many block- fault basins to develop with accompanying volcanism (Harris et al. 1997; Southworth et al. 2001). Following the initial breakup of Pangaea, large alluvial fans and streams carried debris from the uplifted Blue Ridge and Piedmont highlands. These nonmarine shales and sandstones were deposited in fault- created troughs in the western Piedmont. Most of the younger rocks were eroded during the Mesozoic (Moore 1988).

The large faults that formed the western boundaries of the basins provided an escarpment that was quickly covered with eroded debris. Igneous intrusions such as sills (igneous intrusion emplaced parallel to adjacent rocks), and dikes (igneous intrusion that cuts across the structure of the adjacent rocks) extend beyond the basins into adjacent rocks (Clark 2001). After these igneous rocks were intruded at approximately 200 Ma, the region underwent a period of slow uplift and erosion. Isostatic adjustment within the crust forced the continental crust upwards and exposed it to erosion.

Post-Orogenic Geologic Events at Moores Creek National Battlefield

The sedimentary deposits at Moores Creek are relatively young compared to ancient rocks exposed in the Piedmont and Blue Ridge provinces. Thick deposits of unconsolidated gravel, sand, and silt were shed from the eroded mountains. These were deposited as alluvial fans and spread eastward to become part of the Atlantic Coastal Plain underlying Moores Creek National Battlefield (Duffy and Whittecar 1991; Whittecar and Duffy 2000; Southworth et al. 2001). The amount of material removed and transported from the now- exposed metamorphic rocks must have been immense. Many of the rocks exposed at the surface were at least 20 km (~10 miles) below the surface prior to regional uplift and erosion.

Throughout the Cenozoic, the primary geologic processes were erosion and weathering. The once craggy peaks were worn away by rain, ice, rivers, rooted plants, streams, dissolution, mass wasting, and landslides (Schultz 1997).

The erosion continues today along regional drainages developed during the early Cenozoic Era. Large rivers and tributaries such as the Cape Fear River and Moores Creek are eroding the Coastal Plain sediments, lowering the mountains, and depositing sediments as alluvial terraces and in the floodplains, creating the present landscape (Moore 1988). Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. The isostatic adjustments that uplifted the continent after the Alleghenian orogeny continued at a slower rate throughout the Cenozoic Era (Harris et al. 1997).
As the rivers transported sediments further eastward, the transgressions and regressions of the Atlantic Ocean also left their mark on the landscape at Moores Creek National Battlefield. The sediments moved by rivers are redistributed by ocean currents into the barrier island complex along coastline of North Carolina.

Marine transgressions (3.25 to 0.1 Ma) created distinct marine and strandline deposits at lower elevations in flat terraces paralleling the outer Coastal Plain in parts of North and South Carolina, (Soller 1988; Owens 1989). These transgressive – regressive sequences typically include a thin basal marine unit with thicker overlying beds of beach or barrier sands, estuarine- backbarrier sands and clays, and the sands and clays deposited in floodplains. This sequence of deposition records the flooding of the area by marine waters and the subsequent erosion and deposition of further material as the coastline receded (Soller 1988). These deposits were preserved because of uplift along the coast. As the land uplifted, subsequent transgressions did not proceed as far inland as the preceding marine encroachment. The river migration preserved these important markers from erosion and burial where local uplift has diverted the watershed (Soller 1988).

Downcutting by modern day rivers has exposed a tectonically active feature below Moores Creek and the Cape Fear watershed. This feature is called the Cape Fear Arch. For more information, see the Geologic Features and Processes section of this report. Differential uplift along its axis, focused northeast of the Cape Fear River, as well as warping in directions perpendicular to the arch which caused the southwestward migration of the watershed.

The North Carolina coastline, while geomorphologically active, was typically considered by many geologists to be a passive margin that was only being shaped by surficial processes such as deposition and erosion. New studies of the preserved former marine highstands and terraces in the Moores Creek area reveal deep- seated tectonic activity. This activity is as recent as uplift along the Cape Fear arch beginning only 750 thousand years ago.

Far from geologically static, the geologic features and processes at Moores Creek National Battlefield have been affected by tectonic events interacting with surficial geologic processes, which influenced the location of Moores Creek, the sedimentary deposits and stratigraphy in the park, the development of its bogs and wetlands, the historic setting for the battle, and its current physiography.

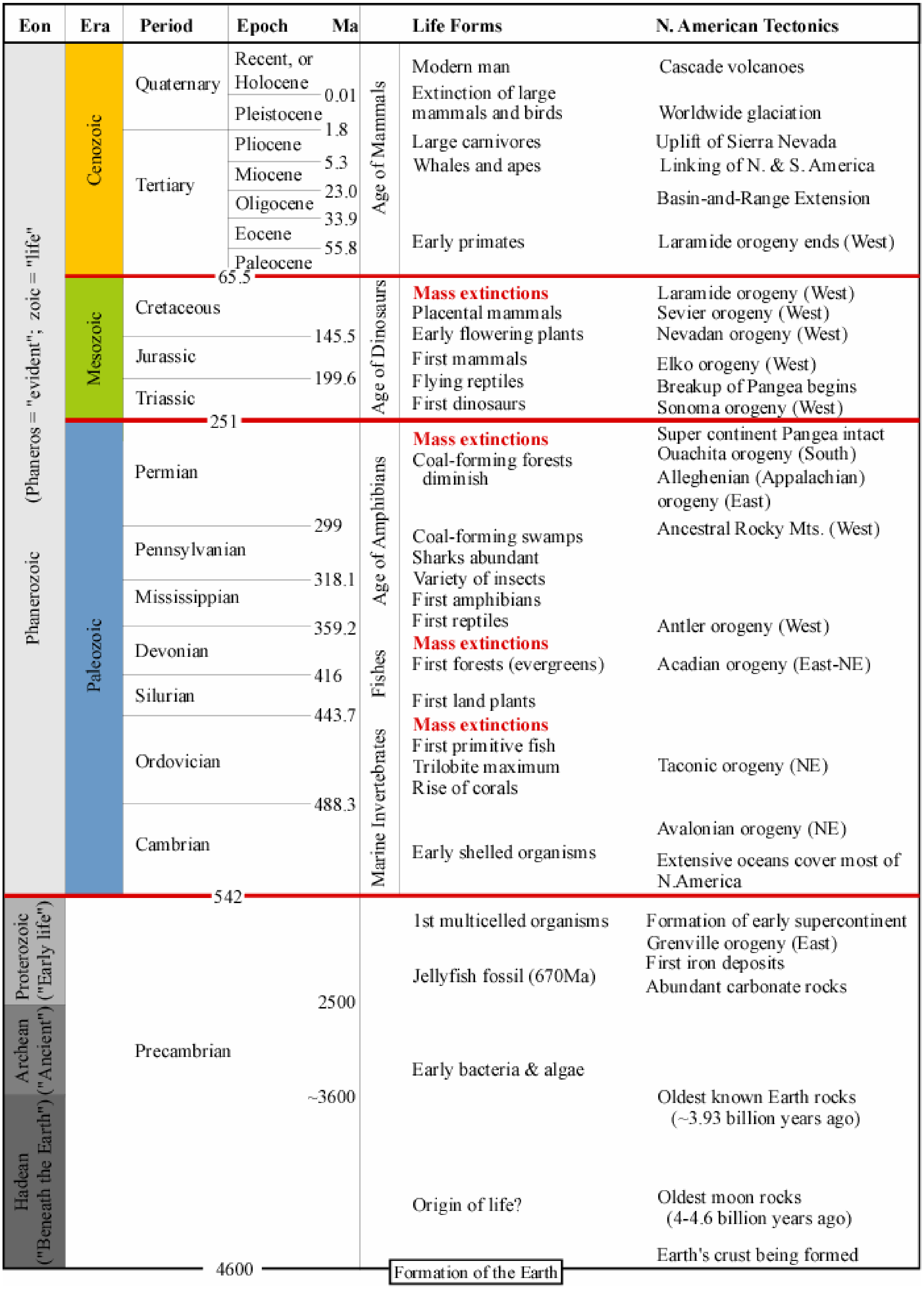

Figure 8. Geologic time scale; adapted from the U.S. Geological Survey. Red lines indicate major unconformities between eras. Included are major events in life history and tectonic events occurring on the North American continent. Absolute ages shown are in millions of years.

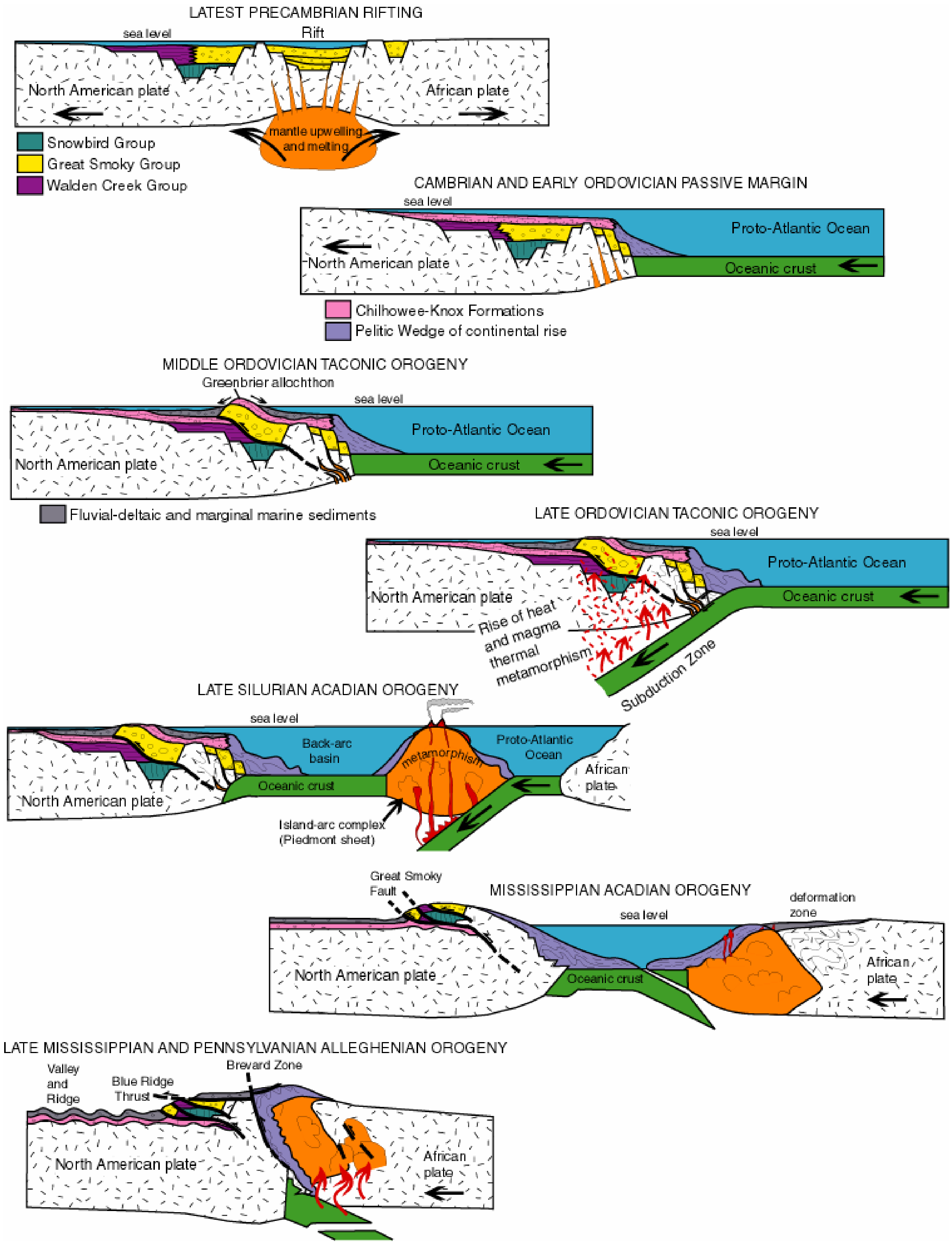

Figure 9. Cross sectional views of the evolution of the Southern Appalachian Mountains from the Precambrian to Pennsylvanian. Following Precambrian rifting and passive margin deposition, the Taconic orogeny was responsible for regional metamorphism. The Acadian orogeny involved collision with an island arc which continued into the Alleghenian orogeny with the collision of the African continental plate and the development of the Blue Ridge and Valley and Ridge deformation. Adapted from DeWindt, 1975.

Glossary

This glossary contains brief definitions of technical geologic terms used in this report. Not all geologic terms used are referenced. For more detailed definitions or to find terms not listed here please visit http://wrgis.wr.usgs.gov/docs/parks/misc/glossarya.html.

active margin. A continental margin where significant volcanic and earthquake activity occurs; commonly a convergent plate margin.

alluvial fan. A fan- shaped deposit of sediment that accumulates where a high gradient stream flows out of a mountain front into an area of lesser gradient such as a valley.

alluvium. Stream- deposited sediment that is generally rounded, sorted, and stratified.

aquifer. Rock or sediment that is sufficiently porous, permeable, and saturated to be useful as a source of water.

baseflow. Stream flow supported by groundwater flow from adjacent rock, sediment, or soil.

baselevel. The lowest level to which a stream can erode its channel. The ultimate base level for the land surface is sea level, but temporary base levels may exist locally.

basement. The undifferentiated rocks, commonly igneous and metamorphic, that underlie the rocks of interest.

basin (sedimentary). Any depression, from continental to local scales, into which sediments are deposited.

braided stream. A stream, clogged with sediment that forms multiple channels that divide and rejoin.

clastic. Rock or sediment made of fragments or pre-existing rocks.

clay. Clay minerals or sedimentary fragments the size of clay minerals (<2 cm).

conglomerate. A coarse- grained sedimentary rock with clasts larger than 2 mm in a fine- grained matrix.

continental crust. The type of crustal rocks underlying the continents and continental shelves; having a thickness of 25- 60 km (16- 37 mi) and a density of approximately 2.7 grams per cubic centimeter.

convergent boundary. A plate boundary where two tectonic plates are moving together (i.e., a zone of subduction or obduction).

cross-bedding. Uniform to highly- varied sets of inclined sedimentary beds deposited by wind or water that indicate distinctive flow conditions.

cross section. A graphical interpretation of geology, structure, and/or stratigraphy in the third (vertical) dimension based on mapped and measured geological extents and attitudes depicted in an oriented vertical plane.

crust. The outermost compositional shell of Earth, 10- 40 km (6- 25 mi) thick, consisting predominantly of relatively low- density silicate minerals (also see oceanic crust and continental crust).

crystalline. Describes the structure of a regular, orderly, repeating geometric arrangement of atoms

delta. A sediment wedge deposited at a stream's mouth where it flows into a lake or sea.

divergent boundary. A tectonic plate boundary where the plates are moving apart (e.g., a spreading ridge or continental rift zone).

drainage basin. The total area from which a stream system receives or drains precipitation runoff.

estuary. The seaward end or tidal mouth of a river where fresh and sea water mix. Many estuaries are drowned river valleys caused by sea level rise (transgression) or coastal subsidence.

facies (sedimentary). The depositional or environmental conditions reflected in the sedimentary structures, textures, mineralogy, etc. of a sedimentary rock.

fan delta. An alluvial fan that builds into a standing body of water. The landform differs from a delta in that a fan- delta is next to a highland and typically forms at an active margin.

fault. A subplanar break in rock along which relative movement occurs between the two sides.

formation. Fundamental rock- stratigraphic unit that is mappable and lithologically distinct from adjoining strata and has definable upper and lower contacts.

fracture. Irregular breakage of a mineral; also any break in a rock (e.g., crack, joint, fault)

geology. The study of Earth including its origin, history, physical processes, components, and morphology.

island arc. A line or arc of volcanic islands formed over and parallel to a subduction zone.

lacustrine. Pertaining to, produced by, or inhabiting a lake or lakes.

lamination. The finest stratification or bedding as seen in shales and siltstones (syn: lamina or laminae) or the formation of lamina.

landslide. Any process or landform resulting from rapid mass movement under relatively dry conditions.

levees. Raised ridges lining the banks of a stream; may be natural or artificial.

longshore current. A current parallel to a coastline caused by waves approaching the shore at an oblique angle.

meanders. Sinuous lateral curves or bends in a stream's channel.

mechanical weathering. The physical breakup of rocks without change in composition (syn: physical weathering).

member. A lithostratigraphic unit with definable contacts that subdivides a formation.

metamorphism. Literally, "change in form". Metamorphism occurs in rocks with mineral alteration, genesis, and/or recrystallization from increased heat and pressure.

orogeny. A mountain- building event, particularly a well-recognized event in the geological past (e.g. the Laramide orogeny).

outwash. Glacial sediment transported and deposited by meltwater streams.

overbank deposits. Alluvium deposited outside a stream channel during flooding.

paleogeography. The study, description, and reconstruction of the physical geography from past geologic periods.

paleontology. The study of the life and chronology of Earth's geologic past based on the phylogeny of fossil organisms.

Pangaea. A theoretical, single supercontinent that existed during the Permian and Triassic Periods (also see Laurasia and Gondwana).

passive margin. A tectonically quiet continental margin indicated by little volcanic or seismic activity.

plate tectonics. The theory that the lithosphere is broken up into a series of rigid plates that move over Earth's surface above a more fluid asthenosphere.

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

progradation. The seaward building of land area due to sedimentary deposition.

provenance. A place of origin. The area from which the constituent materials of a sedimentary rock were derived.

recharge. Infiltration processes that replenish groundwater.

regression. A long- term seaward retreat of the shoreline or relative fall of sea level.

relative dating. Determining the chronological placement of rocks, events, fossils, etc. from geological evidence.

seafloor spreading. The process in which tectonic plates diverge and new lithosphere is created at oceanic ridges.

silt. Clastic sedimentary material intermediate in size between fine- grained sand and coarse clay (1/256- 1/16 mm).

siltstone. A variable- lithified sedimentary rock with silt-sized grains.

slope. The inclined surface of any geomorphic feature or rational measurement thereof (syn: gradient).

slump. A generally large, coherent mass movement with a concave- up failure surface and subsequent backward rotation relative to the slope.

subduction zone. A convergent plate boundary where oceanic lithosphere descends beneath a continental or oceanic plate and is carried down into the mantle.

subsidence. The gradual sinking or depression of part of Earth's surface.

suture. The linear zone where two continental landmasses become joined due to obduction.

tectonic. Relating to large- scale movement and deformation of Earth's crust.

tectonics. The geological study of the broad structural architecture and deformational processes of the lithosphere and asthenosphere (also see structural geology).

terraces (stream). Step- like benches surrounding the present floodplain of a stream due to dissection of previous flood plain(s), stream bed(s), and/or valley floor(s).

tongue (stratigraphy). A member of a formation that extends and wedges out away from the main body of a formation (also see formation, member, and bed).

topography. The general morphology of Earth's surface including relief and location of natural and anthropogenic features.

trace fossils. Sedimentary structures, such as tracks, trails, burrows, etc., that preserve evidence of organisms' life activities, rather than the organisms themselves.

transgression. Landward migration of the sea due to a relative rise in sea level.

type locality. The geographic location where a stratigraphic unit is well displayed, is formally defined as a typical section, and derives its name.

unconformity. A surface within sedimentary strata that marks a prolonged period of nondeposition or erosion.

uplift. A structurally high area in the crust, produced by movement that raises the rocks.

water table. The upper surface of the saturated (phreatic) zone.

weathering. The set of physical, chemical, and biological processes by which rock is broken down in place.

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This section provides a listing of references cited in this report. It also contains general references that may be of use to resource managers. A more complete geologic bibliography is available and can be obtained through the NPS Geologic Resources Division.

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Appendix A: Geologic Map Graphic

The following page provides a preview or "snapshot" of the geologic map for Moores Creek National Battlefield. For a poster size PDF of this map or for digital geologic map data, please see the included CD or visit the GRE publications webpage: http://www2.nature.nps.gov/geology/inventory/gre_publications.cfm

Moores Creek National Battlefield
North Carolina

National Park Service
U.S. Department of the Interior

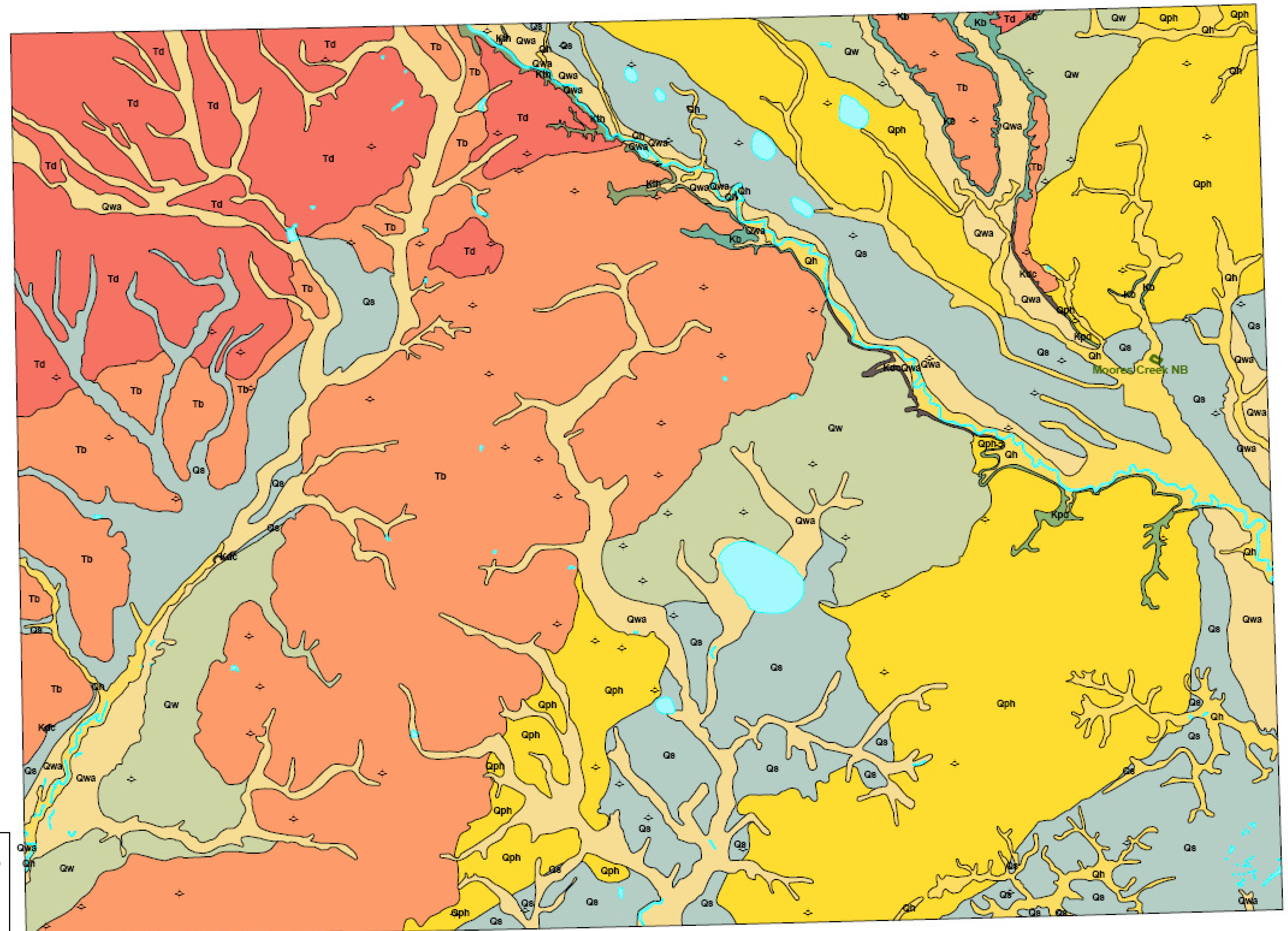
Geologic Map of Moores Creek NB and Vicinity

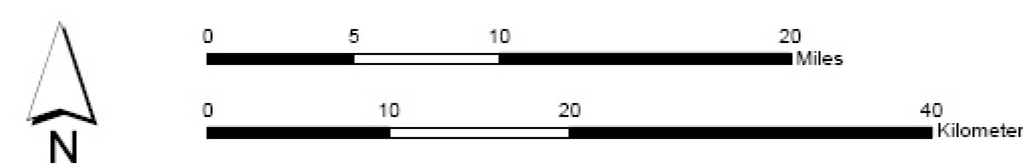
Moores Creek NB

Mine Point Features
- drill hole

Geologic Contacts
- known or certain
- map boundary
- shoreline

Geologic Units
- Qh - Holocene deposits
- Qwa - Wando Formation
- Qs - Socastee Formation
- Qph - Penholoway Formation
- Qw - Waccamaw Formation
- Tb - Bear Bluff Formation
- Td - Duplin Formation
- Kpd - Peedee Formation
- Kdc - Donoho Creek Formation
- Kb - Bladen Formation
- Kth - Tar Heel Formation
- WATER





The original maps digitized by NPS to create this product were:

Owens, James P., 1989, Geologic Map of The Cape Fear Region, Florence 1 x 2 Quadrangle and Northern half of the Georgetown 1 x 2 Quadrangle, North Carolina and South Carolina: USGS, I-1948-A, scale 1:250,000.

Soller, David R., 1988, Geology and Tectonic History of the Lower Cape Fear River Valley, Southeastern North Carolina, USGS, PP-1466-A, scale 1:250,000.

Digital geologic data and cross sections for Moores Creek National Battlefield, and all other digital geologic data prepared as part of the Geologic Resources Divisions Geologic Resource Evaluation program, are available online: http://www2.nature.nps.gov/geology/inventory/gre_publications.cfm

Produced by Geologic Resources Division

June 2006

Appendix B: Scoping Summary

The following excerpts are from the GRE scoping summary for Moores Creek National Battlefield. The scoping meeting occurred on April 6, 2000 and was very brief, focusing solely on the mapping component of the inventory program.

A geologic resources inventory workshop was held for Moores Creek National Battlefield (MOCR) on April 6, 2000 to view and discuss the park's geologic resources, to address the status of geologic mapping for compiling both paper and digital maps, and to assess resource management issues and needs. Cooperators from the NPS Geologic Resources Division (GRD), and NPS Moores Creek NB were present for the roundtable discussion for the workshop.

This involved a half- day field trip to view the geology of the Moores Creek NB area, and another half- day scoping session to present overviews of the NPS Inventory and Monitoring (I&M) program, the Geologic Resources Division, and the on- going Geologic Resources Inventory (GRI). Round table discussions involving geologic issues for Moores Creek NB included interpretation, paleontologic resources (or lack thereof), and the status of geologic mapping efforts, sources of available data, geologic hazards, and action items generated from this meeting.

Overview of Geologic Resources Evaluation

This is an overview of the Geologic Resources Division, the NPS I&M Program, the status of the natural resource inventories, and the GRE in particular.

A demonstration of some of the main features of the digital geologic map for the Black Canyon of the Gunnison NP and Curecanti NRA in Colorado was presented. This has become the prototype for the NPS digital geologic map model as it reproduces all aspects of a paper map (i.e. it incorporates the map notes, cross sections, legend etc.) with the added benefit of being geospatially referenced.

It is displayed in ESRI ArcView shape files and features a built- in help file system to identify the map units. It can also display scanned JPG or GIF images of the geologic cross sections supplied with the map. Geologic cross section lines (ex. A- A') are subsequently digitized as a line coverage and are hyperlinks to the scanned images.

The developing NPS theme browser was also demonstrated for adding GIS coverage's into projects "on- the- fly". With this functional browser, numerous NPS themes can be added to an ArcView project with relative ease. Such themes might include geology, paleontology, hypsography (topographic contours), vegetation, soils, etc.

The NPS GRE (Geologic Resources Evaluation) has the following goals:

- to assemble a bibliography of associated geological resources for NPS units with significant natural resources ("GRBIB"), and to compile and evaluate a list of existing geologic maps for each unit,
- to conduct a scoping session for each park,
- to develop digital geologic map products, and
- to complete a geological report that synthesizes much of the existing geologic knowledge about each park.

It is stressed that the emphasis of the inventory is *not* to routinely initiate new geologic mapping projects, but to aggregate existing "baseline" information and identify where serious geologic data needs and issues exist in the National Park System. In cases where map coverage is nearly complete (ex. 4 of 5 quadrangles for Park "X") or maps simply do not exist, then funding may be available for geologic mapping.

Geologic Mapping

Existing Geologic Maps and Publications

1. Moores Creek National Battlefield: Archeological Overview and Assessment, by Lou Groh with contributions by Patricia Dietrich, published by NPS Southeast Archeological Center, 1998.
2. USGS PP- 1466- a: Geology and Tectonic History of the Lower Cape Fear River Valley, Southeastern North Carolina by Dave Soller.
3. USGS i- 1948- a "Geologic Map of the Cape Fear Region, Florence 1x2 degree quadrangle and northern half of the Georgetown 1x2 degree quadrangle, North Carolina and South Carolina."

Moores Creek National Battlefield

Geologic Resource Evaluation Report

Natural Resource Report NPS/NRPC/GRD/NRR—2006/012
NPS D-215, July 2006

National Park Service

Director • Fran P. Mainella

Natural Resource Stewardship and Science

Associate Director • Michael A. Soukup

Natural Resource Program Center

The Natural Resource Program Center (NRPC) is the core of the NPS Natural Resource Stewardship and Science Directorate. The Center Director is located in Fort Collins, with staff located principally in Lakewood and Fort Collins, Colorado and in Washington, D.C. The NRPC has five divisions: Air Resources Division, Biological Resource Management Division, Environmental Quality Division, Geologic Resources Division, and Water Resources Division. NRPC also includes three offices: The Office of Education and Outreach, the Office of Inventory, Monitoring and Evaluation, and the Office of Natural Resource Information Systems. In addition, Natural Resource Web Management and Partnership Coordination are cross-cutting disciplines under the Center Director. The multidisciplinary staff of NRPC is dedicated to resolving park resource management challenges originating in and outside units of the national park system.

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Editing • Lisa Norby and Sid Covington
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