National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Kings Mountain National Military Park

Geologic Resources Inventory Report

Natural Resource Report NPS/NRPC/GRD/NRR—2009/129

THIS PAGE:
The Centennial Monument erected in 1880 was the result of a massive effort by descendents and state governments to recognize those who fought at the Battle of Kings Mountain.

ON THE COVER:
The monadnock known as Kings Mountain was the scene of the 1780 Battle of Kings Mountain. The rocky slopes helped provide cover for the patriot forces as they encircled the loyalist forces under Major Patrick Ferguson.

NPS Photos courtesy Chris Revels (Kings Mountain NMP)

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Geologic Resources Division
Natural Resource Program Center
P.O. Box 25287
Denver, Colorado 80225

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U.S. Department of the Interior
National Park Service
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Executive Summary

This report accompanies the digital geologic map for Kings Mountain National Military Park in South Carolina, which the Geologic Resources Division produced in collaboration with its partners. It contains information relevant to resource management and scientific research. This document incorporates preexisting geologic information and does not include new data or additional fieldwork.

The battle on the slopes at Kings Mountain was an inspirational victory for American patriots during the Revolutionary War. It was a turning point in the southern campaign. Here, the geology influenced the outcome, favoring the men who knew the terrain and used it to their advantage. The experience of the park begins with its geology, with the processes that established the groundwork from which today's environments, history, and scenery arise. The park and its neighboring state parks (Kings Mountain State Park, South Carolina, and Crowders Mountain State Park, North Carolina) protect a large section of the Carolina Piedmont—an area known for complex geology.

Knowledge of the geologic resources is important in making resource management decisions about future scientific research projects, interpretive needs, and economic resources associated with the park. This Geologic Resources Inventory report is intended to support science-based decision making on the part of resource managers.

Humans have modified the landscape surrounding Kings Mountain National Military Park, South Carolina, by building dams, roads, trails, mines, and housing developments. This dynamic system can show noticeable change within a human life span. Geological processes also continue to change the landscape, making preservation and park upkeep a challenge. The following features, issues, and processes are of primary geological importance and have a high level of management significance for the park:

- Mineral deposits and mining history. The discovery of mineral resources strongly influenced the early development of the Kings Mountain region. The remarkable variety of mineral deposits in the Kings Mountain sequence includes kyanite, marble, manganese, iron, gold, barite, silver, pyrite, cassiterite, mica, spodumene, clay, and feldspar. Mine features within the park include clay pits, a shaft used to extract manganese, and some open pits. Current interest focuses on pegmatite that contains valuable lithium reserves. The southeastern United States is underexplored for mineral resources that have good potential for exploration. Mining has the potential to negatively impact natural resources in the area of the park.
- Water issues. In the area of the park, water wells tap regional aquifers in the weathered and fractured crystalline metamorphic rocks and granitic plutons, which are recharged by precipitation percolating through thick layers of regolith. Rapid development of the surrounding areas threatens water resources with contamination and overuse. An ongoing drought in the upstate area of South Carolina is increasing the demand for clean water, which could lower the water table beyond the extent of regional wells.
- Erosion and slope processes. Topographic relief within the park and surrounding areas is high in some places, and landslides, slope creep, and debris flows are common. Heavy rainfall can quickly saturate slopes and generate rapidly moving debris flows that may destroy parts of roads, trails, and historic features, impacting visitor experience and access. In relatively erosion-resistant units underlying ridges, rockfall hazards exist. Anthropogenic changes to the landscape, such as those produced by mining, may also exacerbate erosion and slope processes.

Geologic processes give rise to rock formations, mountains, slopes, valleys, springs, and streams. These processes formed the landscape that attracted the loyalist forces to the high ground at Kings Mountain. Now the park attracts visitors in search of a historical touchstone and recreation opportunities. Understanding the geologic setting would enhance the visitor's experience.

The park is located within the Kings Mountain sequence of the Carolina terrane, adjacent to the Inner Piedmont terrane in north-central South Carolina. A series of northeast-trending terranes is characteristic of Piedmont geology in the Carolinas. This area has complex geology, including structures such as shear zones, normal faults, and folds, myriad rock types, and areas of varying metamorphic grade. Geologists use these features to interpret the geologic history of the region.

The geologic history of the southern Appalachians has been the subject of intense study and debate among geologists. The setting of the Kings Mountain sequence along the boundary between two terranes makes understanding the geology of the area vital to regional studies of geologic history. The metasedimentary and meta-igneous geologic units within the park are Neoproterozoic (late Proterozoic) in age and contain such features as folds, cleavage, and foliation recording at least five phases of deformation and mineral assemblages indicating several pulses of metamorphism.

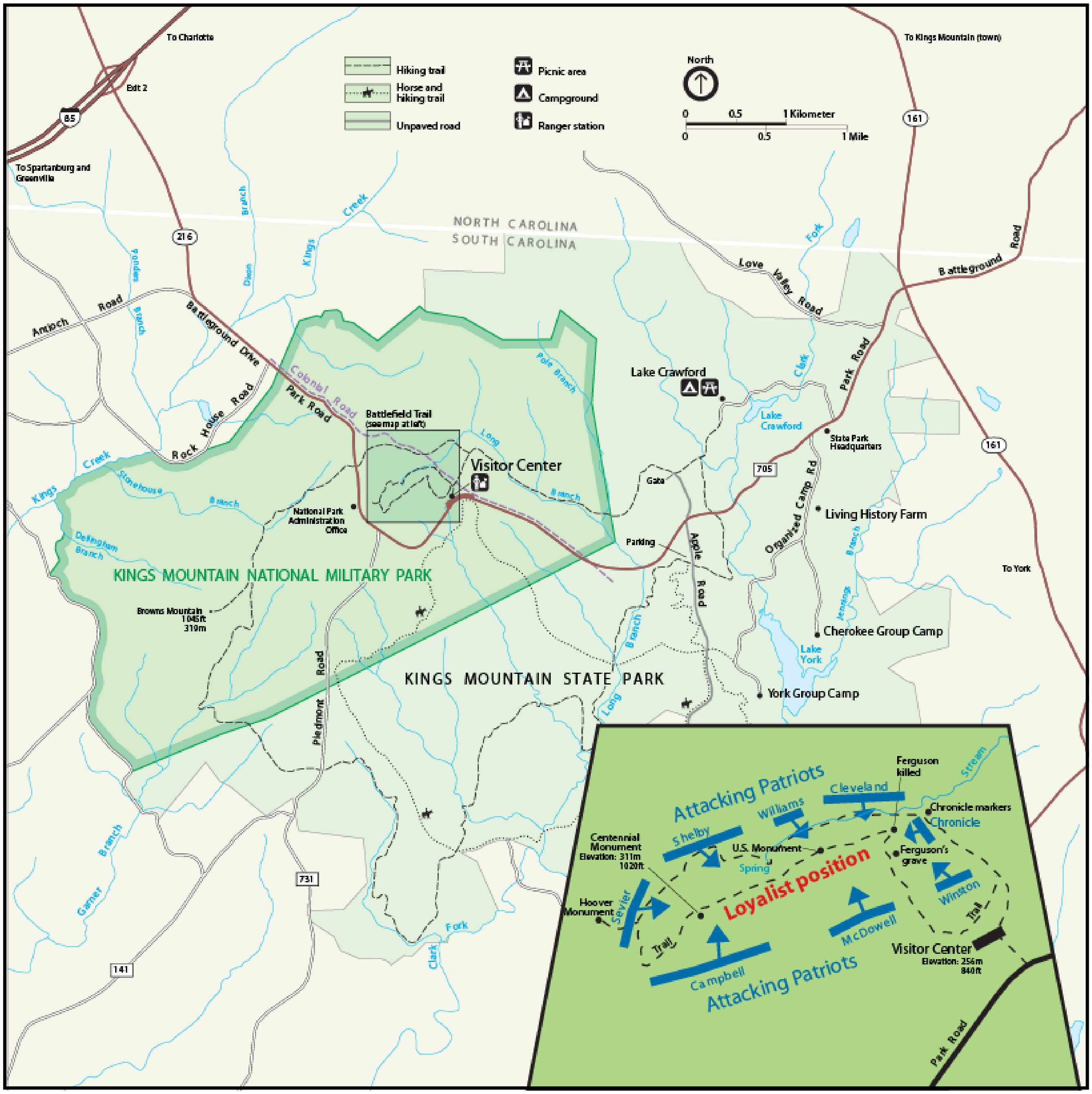


Figure 1. Map of Kings Mountain National Military Park and adjoining Kings Mountain State Park. NPS graphic with adaptations by Trista L. Thornberry-Ehrlich (Colorado State University). Inset map in lower-right corner shows troop positions at the time of the battle at Kings Mountain.

Introduction

The following section briefly describes the National Park Service Geologic Resources Inventory and the regional geologic setting of Kings Mountain National Military Park.

Purpose of the Geologic Resources Inventory

The Geologic Resources Inventory (GRI) is one of 12 inventories funded under the National Park Service (NPS) Natural Resource Challenge designed to enhance baseline information available to park managers. The program carries out the geologic component of the inventory effort. The Geologic Resources Division of the Natural Resource Program Center administers this program. The GRI team relies heavily on partnerships with the U.S. Geological Survey, Colorado State University, state surveys, and others in developing GRI products.

The goal of the GRI is to increase understanding of the geologic processes at work in parks and provide sound geologic information for use in park decision making. Sound park stewardship relies on understanding natural resources and their role in the ecosystem. Geology is the foundation of park ecosystems. The compilation and use of natural resource information by park managers is called for in section 204 of the National Parks Omnibus Management Act of 1998 and in NPS-75, Natural Resources Inventory and Monitoring Guideline.

To realize this goal, the GRI team is systematically conducting a scoping meeting for each of the identified 270 natural area parks and providing a park-specific digital geologic map and geologic report. These products support the stewardship of park resources and are designed for nongeoscientists. Scoping meetings bring together park staff and geologic experts to review available geologic maps and discuss specific geologic issues, features, and processes.

The GRI mapping team converts the geologic maps identified for park use at the scoping meeting into digital geologic data in accordance with their Geographic Information Systems (GIS) Data Model. These digital data sets bring an interactive dimension to traditional paper maps by providing geologic data for use in park GIS and facilitating the incorporation of geologic considerations into a wide range of resource management applications. The newest maps come complete with interactive help files. This geologic report aids in the use of the map and provides park managers with an overview of park geology and geologic resource management issues.

For additional information regarding the content of this report and current GRI contact information, please refer to the Geologic Resources Inventory Web site (http://www.nature.nps.gov/geology/inventory/).

History of Kings Mountain National Military Park

Kings Mountain National Military Park preserves the setting of a pivotal victory on October 7, 1780, by American patriots over American loyalists during the Southern Campaign of the Revolutionary War. The victory effectively halted the British advance into North Carolina. It destroyed the left wing of Lord Cornwallis' army and effectively ended loyalist ascendance in the Carolinas. This forced Cornwallis to retreat from Charlotte into South Carolina. It also gave General Nathanael Greene the opportunity to reorganize the scattered American Army of patriots.

An act of Congress (46 Stat. 1508) established Kings Mountain National Military Park on March 3, 1931, "in order to commemorate the Battle of Kings Mountain." Executive Order No. 6166 (June 10, 1933) transferred authority from the War Department to the Department of the Interior. The site is located in the southern Appalachian Mountains, southeast of Great Smoky Mountains National Park, just south of the North Carolina–South Carolina border (fig. 1). Kings Mountain National Military Park shares a common boundary with Kings Mountain State Park and is only a few miles southeast of Crowders Mountain State Park, in North Carolina. All three parks protect a picturesque area that stretches along the eastern Appalachian foothills of the Carolina Piedmont. The National Park Service is charged with preserving the 1,596 hectares (3,945 acres) of historic battleground at Kings Mountain National Military Park and has supportive relationships and coordination with the neighboring state parks. Together, these three parks protect approximately 6,070 hectares (15,000 acres) of mixed hardwood forest. The park attracts more than 200,000 visitors annually. The attraction of Kings Mountain extends beyond the history of the famous battle. The area's topography and geology are unique and complex and form a major component of a scenic recreation area and diverse ecosystem.

Geologic Setting

Kings Mountain National Military Park is within part of the Piedmont physiographic province. The "Fall Line," or "Fall Zone," marks the updip extent and inland termination of the Atlantic Coastal Plain. The Piedmont encompasses the Fall Line and extends west from there to the Blue Ridge Mountains (Harris et al. 1997). The Piedmont formed by a combination of accretion, folding, faulting, uplift, and erosion. The present physiography is the result of weathering and erosion of an ancient mountain system that rivaled the modern Himalayas. Today, erosion exposes only the root of the mountain system (C. S. Howard, written communication, 2009).

A series of northeast-trending terranes is characteristic of Piedmont geology in the Carolinas. These terranes were affected by low-grade (greenschist facies) to high-grade (amphibolite facies) metamorphism, evident as alternating, parallel bands trending roughly northeast-southwest (Horton 2008). This report uses the terrane definitions outlined in Horton et al. (1994) wherein the Carolina terrane (a large component of the "Carolina Zone" of Hibbard et al. 2002) includes rocks traditionally assigned to the Carolina slate belt, Charlotte belt, Kiokee belt, Belair belt, and the Kings Mountain sequence. The Inner Piedmont is a composite terrane bounded on the northwest by the Brevard fault zone and on the southeast by the Towaliga, Lowndesville, Kings Mountain (described below), and Eufola fault zones (Horton et al. 1994).

Along the North Carolina–South Carolina border, the Inner Piedmont is west of the Carolina terrane, separated from the Blue Ridge to the west by the Brevard fault zone. The allochthonous Inner Piedmont is composed of layered schist, gneiss, migmatite, and minor amphibolite. It contains numerous granitoid intrusions as layers, dikes, and small plutons (Goldsmith 1981). The Kings Mountain shear zone is the eastern boundary of the Inner Piedmont and consists of a distinctive interlayered sequence of sheared metasedimentary rocks. The shear zone truncates rock units and juxtaposes rocks of different metamorphic grades. The Carolina terrane is a fault-bounded, structurally complex amalgamation of igneous, meta-igneous, and metasedimentary rocks that extends from south-central Virginia to west-central Georgia (Secor et al. 1998).

On the western flank of the Carolina terrane is the Kings Mountain sequence (informal name), which contains a great variety of rock types and reaches its widest extent near the South Carolina–North Carolina border (Horton 2008). Including the Neoproterozoic (a geologic time era from 1,000 to 542 million years ago) Battleground and Blacksburg formations, the sequence contains metasedimentary, metavolcanic, and plutonic rocks (fig. 2) (Horton 1981a). The extent of the Kings Mountain sequence is difficult to define, and the Kings Mountain shear zone cannot be continuously mapped (C. S. Howard, written communication, 2009). It extends northeastward into North Carolina, to the Winston-Salem area, and perhaps as far south as the Georgia border (Lowndesville shear zone). There a narrow zone of cataclastic (faulted) rocks about 600 m (2,000 ft) wide extends another 26 km (16 mi) into Georgia (Rozen 1981) The shear zones have similar deformation fabrics, are approximately on strike with one another, and form the eastern boundary of the Inner Piedmont (Nelson 1981).

Moderately dissected uplands of relatively low relief characterize the topography in the area of the park (Horton 2008). Linear ridges and hills underlain by erosion-resistant quartzite and quartz-pebble conglomerate rise abruptly 30–240 m (100–800 ft) above the surrounding rolling hills and form precipitous cliffs at nearby Crowders Mountain and the Pinnacle (Horton 2006, 2008). Elevation in the park ranges from 197 m (646 ft) at the northwest park boundary at Kings Creek to 323 m (1,060 ft) at the top of Brushy Ridge, a linear ridge underlain by erosion-resistant siliceous metatuff. Brushy Ridge is a spur of the Kings Mountain Range. The trail from the visitor center to the loyalist position on the ridge offers a panorama of the hillslopes that the patriot army charged up to fight.

Thick saprolite mantles much of the local bedrock, and regolith fills in the areas of lower relief (Horton 2008). Streams in the area of the park cut through the overburden, locally exposing some bedrock along their courses. From the heights of Brushy Ridge, Kings Creek and its tributaries including Stonehouse Branch and Dellingham Branch drain the western side of the park, whereas Long Branch and Pole Branch drain the eastern side. The Garner Branch watershed is on the southern side of Kings Mountain National Military Park.

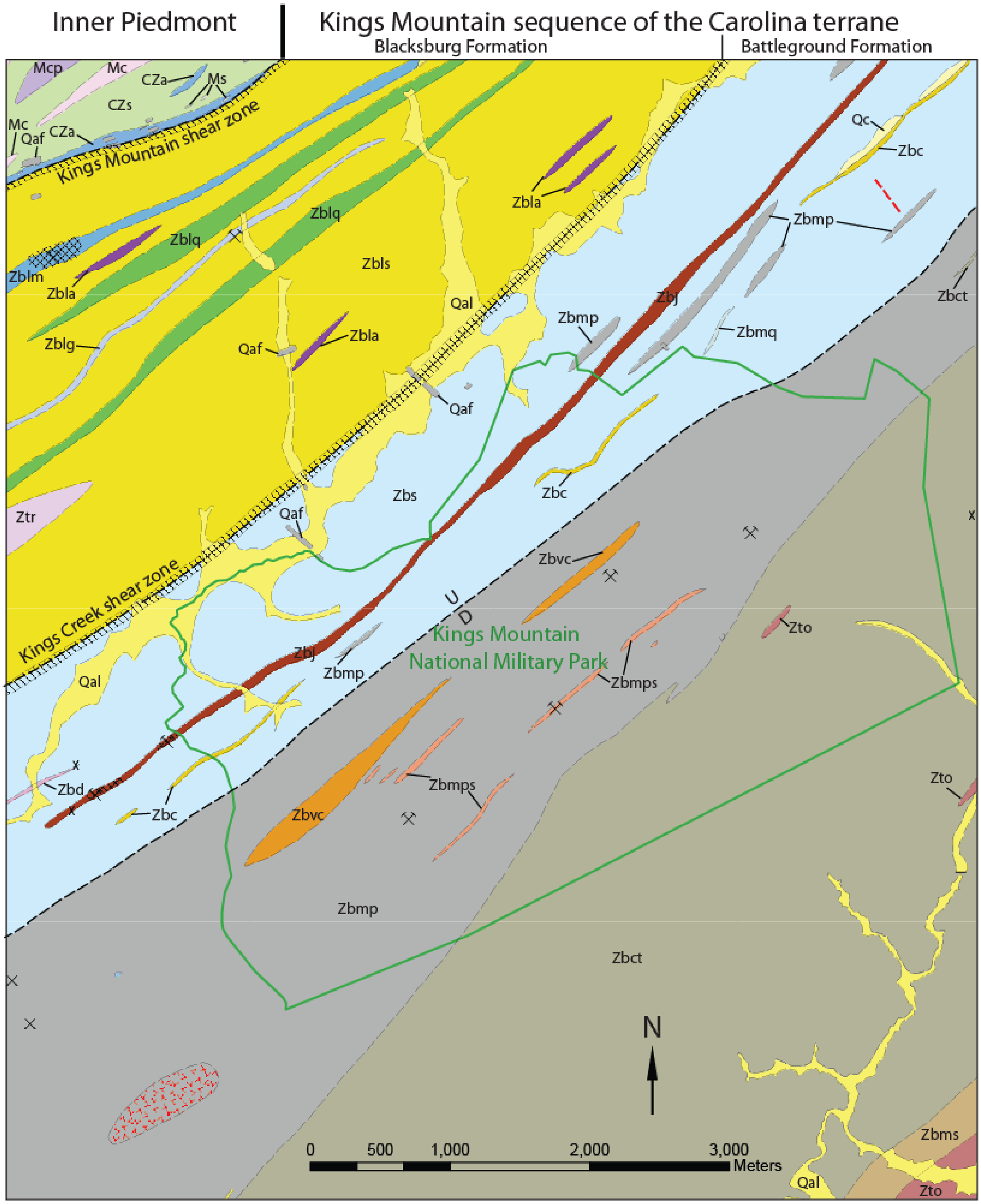


Figure 2. Geologic map of Kings Mountain National Military Park and immediate vicinity. See next page for the map legend. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University), using data from the GRI digital geologic map (see "Map Unit Properties Table").

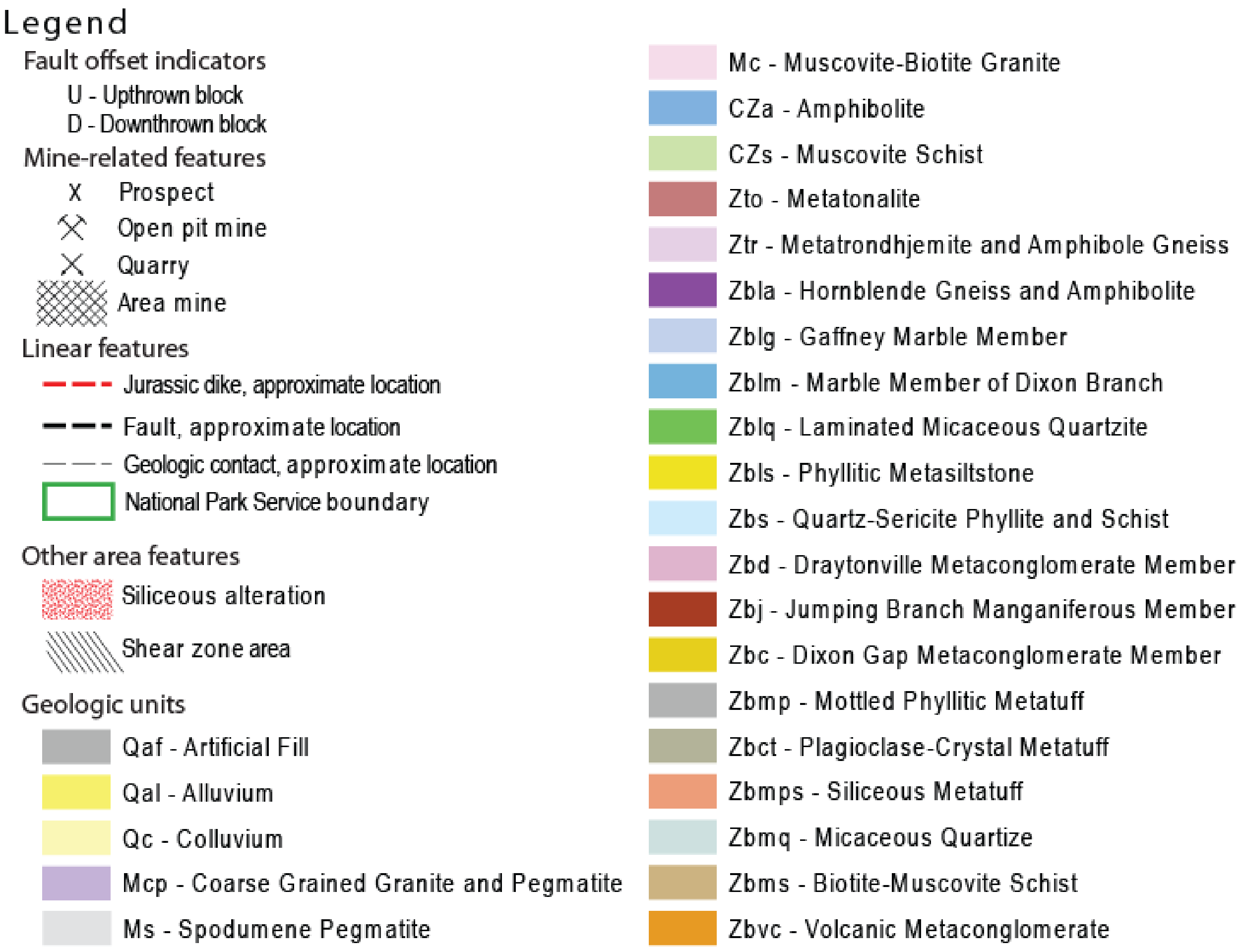


Figure 2, continued. Legend for geologic map of Kings Mountain National Military Park and immediate vicinity. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University), using data from the GRI digital geologic map (see "Map Unit Properties Table").

Figure 3. A Civilian Conservation Corps flagstone quarry operating on Kings Mountain during the 1930s. Historically, the rocks of the park provided a variety of geological resources including minerals as well as building stones. NPS Photo courtesy Chris Revels (NPS Kings Mountain NMP).

Geologic Issues

The Geologic Resources Division held a Geologic Resources Inventory scoping session for Kings Mountain National Military Park on September 19, 2000, to discuss geologic resources, address the status of geologic mapping, and assess resource management issues and needs. This section synthesizes the scoping results, in particular those issues that may require attention from resource managers.

Mineral Deposits and Mining History

Mining strongly influenced the early development of the Kings Mountain region and continues today (Horton and Butler 1981). The Kings Mountain sequence includes a remarkable variety of mineral deposits for such a small area. U.S. Geological Survey Professional Paper 1462, (Gair 1989a, 1989b, 1989c; Gair et al. 1989a, 1989b; Goldsmith et al. 1989; Horton, 1989a, 1989b, 1989c) describes the mineral resources of the area. Like most of the region's geologic units, these deposits are in northeast-trending linear bands. The region's mineral products include kyanite, marble, manganese, iron, gold, barite, silver, pyrite, cassiterite, mica, spodumene, clay, and feldspar. Pegmatite bodies in the sequence contain large lithium reserves. Eighty minerals were identified at the Foote Mineral Company spodumene mine near Kings Mountain, North Carolina (Horton and Butler 1977). According to LaPoint (1992a), the southeastern United States is underexplored terrane having potential for commodities that could be economically mined with modern technologies. Park managers should be aware of exploration activities within the park area. The park does own the mineral rights within park boundaries (C. Revels, personal communication, 2009).

Gold in South Carolina was first discovered in 1802 in Greenville County, prompting a gold rush (Murphy 1995). More recent gold mining produced a significant amount of gold. For example, more than 100,000 oz (≈3,000 kg) of gold was produced in the southeastern United States in 1989 (Cook 1990). Most of this was from mines in the eastern Carolina terrane (Haile-Brewer and Ridgway mines) (C. S. Howard, written communication, 2009). This is significantly more than was produced during any other period since 1800 (Cook 1990). There are also more than 75 abandoned or inactive gold mines and prospects in the Kings Mountain sequence, with most of the activity concentrated in western York County and adjacent Cherokee County (Horton and Butler 1977, 1981).

Gold typically occurs in the upper parts of intrusive igneous rocks that formed at shallow depth and altered zones of metavolcanic rocks and quartz-mica schist (Gair 1989a). The gold-pyrite mineralization at the Kings Mountain gold mine is hosted by carbonate rocks at the contact between the Battleground and Blacksburg formations on the Kings Creek shear zone (Gair 1989a; LaPoint 1992b). Renewed interest and exploration at the old Kings Mountain gold mine (originally opened in 1834 and located about 3.5 km, or 2.2 mi, south of the town of Kings Mountain) in the early 1990s (LaPoint 1992b) did not result in any further development because prospectors found no economically minable deposits. This mine is on private property just beyond the park boundaries (LaPoint 1992b). Although gold is not presently mined in or near Kings Mountain National Military Park, gold mining and prospecting are of considerable historical interest and merit interpretative attention (J. W. Horton, written communication, 2009). Works by LaPoint (1992b) and Murphy (1995) contain detailed histories of gold discovery and exploration in South Carolina and would provide excellent references for interpretive projects.

Local mining also targeted rich deposits of kyanite, marble, manganese, iron, and barite. This mining has historical and environmental significance (J. W. Horton, written communication, 2009). Iron deposits and marble (for flux and lime) of the Kings Mountain sequence have been a target for miners since before the Revolutionary War. Settlers from Pennsylvania worked "the Old Iron District" around Blacksburg (Moss 1981). The iron works in Lincoln, Cleveland, and Catawba counties made major contributions to the Confederate army during the Civil War. However, by the late 1890s the iron industry in the region had ended due to stiff competition from other, more iron-rich areas, such as the Great Lakes region (Horton and Butler 1981).

The first local production of barite was from small open pits at Kings Creek in 1885 (Sharp 1981). Barite deposits occur within the Battleground Formation in quartz-sericite schist (originally pyroclastic rock) in layers and pods typically about 30 cm (12 in.) thick (Horton 1989b). Over several decades, the mining evolved from open pits to inclined shafts and back to open quarries in 1953. Among the various uses of barite was as a weighting agent in flour and sugar until the Pure Food and Drug Act was passed in 1923 (Sharp 1981).

An abandoned kyanite mine at Henry Knob (just east of Kings Mountain State Park), worked in 1935 and from 1948 through 1966, produced significant amounts of kyanite (≈293,000 short tons; 266,000 metric tons) (Horton and Butler 1981; Horton 1989c). This mine also produced pyrite (a sulfide mineral) as a byproduct from 1962 through 1966. This operation made South Carolina the nation's second largest kyanite producer in the 1960s (Horton and Butler 1981). Kyanite and sillimanite occurrences similar to that at Henry Knob are widespread in the Kings Mountain sequence in beds and lenses of high-alumina kyanite quartzite or sillimanite quartzite interlayered with quartz-sericite schist of the

Battleground Formation (Horton 1989c). These minerals are a component in the manufacture of refractory materials.

Interest in lithium began on a large scale in the mid-1940s. Recent mining activity in the Kings Mountain region is targeting rich lithium deposits in pegmatite containing the minerals spodumene and cassiterite (a source of tin). Foote Mineral Company has a large mine and processing plant 3 km (2 mi) southwest of Kings Mountain (Horton and Butler 1981). Additionally, scrap mica, feldspar, silica, clay, and crushed stone are produced from the Kings Mountain sequence and Inner Piedmont terrane. Companies such as the Kings Mountain Mica Company and Huber Corporation found these resources in thick saprolite and partially weathered granitic rocks located throughout the region (Horton and Butler 1981).

Many abandoned mines, prospects, and mine dumps are associated with local mining (J. W. Horton, written communication, 2009). Within the park boundaries are an abandoned 30-m- (100-ft-) long mine shaft (for manganese ore), abandoned clay pits, and at least four other abandoned open-pit mines (Horton 2006; P. Enzi, written communication, 2009). The manganese deposits occur in a single, nearly continuous stratigraphic unit—the Jumping Branch Manganiferous Member of the Battleground Formation (unit Zbj or Zbjp; see fig. 2 and Appendix A) (Horton 1989c, 2006; Howard 2004). This unit transects the park, the manganese occurring as lenticular veins and masses of oxides in weathered zones (Horton 1989c). The manganiferous schist locally provided brown pigment used in brick manufacturing (Horton 1989c). Flagstone was obtained from the four open-pit mines within the park. The Civilian Conservation Corps operated various quarries within the park during the 1930s (fig. 3) and the Henry Howser House (fig. 4) was constructed of local stone from the park (C. Revels, personal communication, 2009).

Associated with local mining are potential environmental problems ranging from erosion to acid mine drainage, which can affect the soils, ground water, and small streams and springs in the park. Acid mine drainage develops when sulfides (such as pyrite) react with water and lower the pH to produce sulfuric acid (H_2SO_4), sulfate (SO_4^{2-}), and reduced iron (Fe^{2+}). This increased acidity raises the solubility of some potentially harmful metals. Heavy metals in piles of mine waste are exposed and therefore made available for dissolution by rain and runoff in the vicinity of Kings Mountain National Military Park. In general, ground and surface water transports these metals from the vicinity of a mine as dissolved ions, suspended sediment, or part of the bedload in a stream (Madison et al. 1998). The metals pose a potential threat to the water quality in the area and therefore to the ecosystems associated with those water sources. Abandoned shafts and open pit mines can be significant hazards to visitor safety although no specific hazards associated with the park's abandoned features were identified (J. Burghardt, written communication, 2009).

Open-pit quarries for crushed stone and other resources, whether active or abandoned, affect the regional environment. When stabilizing vegetation is removed and the ground is disturbed by quarrying, erosion is accelerated and causes subsequent increases in sediment load in local streams. Removal of vegetation and exposure of saprolite and weathered crystalline rocks increase the likelihood of mass wasting as described below under "Erosion and Slope Processes".

Inventory, Monitoring, and Research Recommendations for Mineral Deposits and Mining History

- Periodically sample and test surface and ground water and soil to detect heavy metals in those resources. Monitoring of drinking water is especially important.
- Thoroughly investigate any ore-bearing (manganese, copper, gold, etc.) beds throughout the park, including descriptions, ore assays, and outcrop locations.
- Inventory the ore content of the recent unconsolidated deposits and soils as well as ore-bearing rocks.
- Develop an interpretive program relating the mining history of the area, how geologic resources directed settlement of the region, and how mining continues to affect the landscape. Contact the South Carolina Geological Survey for assistance (C. S. Howard, written communication, 2009).
- Develop a program that will help a lay audience understand how the wide variety of rock types at King's Mountain fits into the geologic history of the Piedmont. Contact the South Carolina Geological Survey for assistance (C. S. Howard, written communication, 2009).
- Contact the Abandoned Mineral Lands (AML) staff at the Geologic Resources Division office, Denver, Colorado, for resource management questions.

Water Issues

In the humid climate of the central-southern Appalachian Mountains, water seems present everywhere—in streams, rivers, runoff, springs, and the ground. Wells tap regional aquifers in the weathered and fractured crystalline metamorphic and igneous rocks near Kings Mountain National Military Park (Castro et al. 1987). The resistant metamorphic and igneous rocks are overlain by regolith. The regolith acts as a filter through which water slowly percolates to recharge the bedrock aquifer through a network of fractures and joints (Castro et al. 1987).

Because of the rapid development of the surrounding areas, water resources are under constant threat of contamination and overuse. An ongoing drought in the upstate area of South Carolina is increasing the demand for clean water (C. S. Howard, written communication, 2009). Increased drawdown by wells lowers the regional water table of the slowly recharging aquifer. Because the aquifer is subject to reduced recharge from decreased precipitation, wells that are too shallow may run dry and deeper wells may become less productive (Castro et al. 1987).

The water quality at the park is threatened by housing and recreational developments, visitors, and the geology itself. Rainwater made acidic by air pollution, combined with the effect of locally acidic bedrock, threatens the water supply and, by extension, the aquatic ecosystems dependent upon it. Borderline environments may become inhospitable to organisms. As mentioned in the previous section, mine tailings expose heavy metals that are dissolved by precipitation and the runoff can lower the pH of local streams.

Urban development surrounding Kings Mountain affects the watershed in a variety of ways. One way is by increasing runoff from impervious surfaces such as parking lots, roads, and buildings. Sedimentation also increases due to clearing of land and mining. Water temperature increases because of the heat-retaining nature of impervious surfaces. For example, runoff from a parking lot on a hot July day is much warmer than runoff from a grassy slope.

Where agricultural remnants and other wastes are stored, nitrogen, phosphate, and ammonia levels in the water can reach dangerous levels (C. S. Howard, written communication, 2009). Runoff from roadways commonly contains high levels of oil and other car emissions, which are carried into park waterways and seep into the soil. Knowledge of the potential contaminants and an understanding of the hydrogeologic system, including ground-water flow patterns, are essential to protect the park's ecosystem.

The movement of nutrients and contaminants through the ecosystem may be traceable by monitoring system inputs, such as rainfall, and outputs, such as streamflow. Other input sources include wind, surface runoff, ground water, mine drainage, sewage, landfills, and fill dirt. Streams in effect integrate the surface runoff and ground-water flow of their watersheds. In doing so, they provide a cumulative measure of the status of the watershed's hydrologic system. The park may need to monitor its own water sources for discharge and contaminant levels. Sampling consistency is necessary to establish baselines for comparison.

Inventory, Monitoring, and Research Recommendations for Water Issues

- Establish working relationships with the U.S. Geological Survey and the South Carolina Geological Survey to study and monitor the park's watershed, fracture systems, and the hydrology of the area for applications in hydrogeology, landsliding, and other geologic hazards.
- Map and quantify ground-water recharge zones.
- Install monitoring stations to measure atmospheric inputs of important chemical components (such as nitrogen, mercury, and pH-affecting components) and outputs to streams and ground water.
- Contact Water Resources Division (WRD) staff in Denver, Colorado, for resource management questions.

Erosion and Slope Processes

Erosion and slope processes are primary geologic forces sculpting the landscape at Kings Mountain. However, they are also the cause of mass wasting, an important geological resource management issue. Topography and elevation differences within and surrounding the park are considerable along Brushy Ridge (fig. 5). Precipitation increases the likelihood of mass wasting because water-saturated soil and regolith are more susceptible to failure. In the wet, mountainous terrain of Kings Mountain, landslides, slope creep, and debris flows are common. Slope failure is common in geologic units not necessarily associated with cliffs. For example, unconsolidated colluvium is especially vulnerable to failure where exposed on a slope, as are undercut alluvial deposits.

Heavy rainfall from hurricanes, cloudbursts, and thunderstorms can quickly saturate slopes and generate rapidly moving debris flows that are among the most dangerous and damaging types of landslides (Wieczorek and Morgan 2008). A debris flow is a rapidly moving mass of fragmented rock and soil in which more than half of the particles are larger than sand size (Wieczorek and Morgan 2008). These flows may destroy parts of roads, trails, and historic features, impacting visitor experience and access. A debris flow most frequently travels along pre-existing drainageways and streams, incorporating additional unconsolidated material along its course (Wieczorek and Morgan 2008).

Steep slopes and cliffs along stream valleys within and around the park are highly susceptible to landslides, slumps, and slope creep. This is a major concern in the weaker rock units, such as weathered metamorphic rocks. In stronger rocks, such as quartzite, silicified metatuff, and metaconglomerate (Nystrom 2003; Howard 2004; Horton 2006) rockfall is a potential hazard because of fracturing within the rocks exacerbated by frost wedging and plant root wedging. Rockfall and topple are greater issues along the precipitous cliffs of neighboring Crowders Mountain State Park than at Kings Mountain National Military Park (J. W. Horton, written communication, 2009).

In addition to natural erosion, roads, trails, and other artificially altered land also increase the likelihood of landslides by deforesting, altering, and/or undercutting slopes. On slopes that lack stabilizing vegetation, rock and soil may mobilize and slide downhill as a massive slump or debris flow. According to maps showing landslide incidence and susceptibility, the Kings Mountain area is within a moderate to high incidence and susceptibility zone (Wieczorek and Morgan 2008).

Prediction of debris flows on the basis of rainfall thresholds alone is highly problematic (Wieczorek and Morgan 2008). Geologic structural controls, such as extensive fracturing and jointing, and the wetting requirements of regolith overlying various rock types also play important roles in slope dynamics (Wieczorek and Morgan 2008). Mitigation of debris-flow hazards may be improved by careful placement of infrastructure and visitor areas away from locations most susceptible to slope failure and inundation (Wieczorek and Morgan 2008).

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

- Use shallow (25-cm; 10-in.) and deeper core data to monitor rates of sediment accumulation and erosion in local streams and springs.
- Monitor steep slopes for rock movement and manage any undercut areas appropriately.
- Monitor erosion and deposition rates by establishing key sites for repeated profile measurements. Repeated photography may be a useful tool.
- Using a topographic map, geologic maps, and rainfall information, determine the relative potential for landslide occurrence. The GRI digital geologic map could provide a foundation for GIS analysis employing other spatial data.
- Study erosion and weathering processes active at the park. Take into account the different rock formations as they may relate to slope, location, and likelihood of instability.
- Map rockfall susceptibility by plotting rock unit versus slope aspect in a GIS, and use the map to help plan future development and current resource management. Contact the South Carolina Geological Survey for assistance (C. S. Howard, written communication, 2009).
- Inventory areas that are susceptible to flooding from runoff; relate the findings to climate and confluence areas.
- Evaluate trails for stability and determine which trails are most at risk and in need of further stabilization.
- Contact the U.S. Geological Survey Landslide Program for information, publications, and educational tools at the Web site http://landslides.usgs.gov.
- Contact the Geohazards staff at the Geologic Resources Division office, Denver, Colorado, for resource management questions.

Figure 4. Historic image of Henry Howser House (built approximately 1803). Howser was a stone mason and built his house from local stone quarried within the park. NPS Photo courtesy Chris Revels (NPS Kings Mountain NMP).

Geologic Features and Processes

This section describes the most prominent and distinctive geologic features and processes in Kings Mountain National Military Park.

Geology and the Battle at Kings Mountain

"God Almighty can't get me off this mountain," was British Major Patrick Ferguson's famous boast. Ferguson was the only non-American present at the battle of Kings Mountain between American patriots and American loyalists. He was on his way to Charlotte, North Carolina, to join forces with British commander Cornwallis when he received notice of an approaching patriot army crossing the Blue Ridge Mountains from Tennessee. Because of the legendary mountain crossings by these patriots, they earned their reputation as the "over-mountain men."

Little did Ferguson know that his position atop Kings Mountain was not secure. The topography was to play to the patriots' advantage. On the afternoon of October 6, 1780, Ferguson elected to wait atop Kings Mountain for reinforcements. This decision proved unwise because the patriot forces at nearby Cowpens traveled through the night in a pouring rain storm and surrounded the mountain around noon the next day.

The battle started around 4:00 p.m. It was to last only one hour and led to a resounding patriot victory. Among the dead were 157 loyalists; another 163 were wounded, and approximately 700 were captured. In comparison, only 28 patriots died and 64 more suffered wounds. It was one of the turning points in the American Revolution (Wagner 2000), decisively weakening the British position in the southern campaign.

From the outset, the battle was between the British bayonet and the rifles of the American patriots. However, the topography at Kings Mountain was the ultimate deciding factor in the struggle. Kings Mountain is a classic monadnock, or erosional remnant, which rises about 18 m (60 ft) above the surrounding landscape. More resistant metasedimentary quartzite, metaconglomerate, and certain metavolcanic rocks underlie ridges and mountaintops. A narrow ridge, 18–30 m (60–100 ft) wide, defines the top and is underlain by erosion-resistant siliceous metatuff (Wagner 2000; Horton 2006). This terrain was advantageous for the riflemen. As Ferguson ordered bayonet charges, the over-mountain men fell back, seeking shelter and cover behind the trees and rocks covering the hillsides (see front cover and figs. 5 and 6). They were then free to fire well-aimed rounds from both sides of the ridge into the organized lines of loyalists (Wagner 2000).

While Ferguson appeared ever confident in the superiority of his troops and their position, in the end it was the patriots' familiarity with the Kings Mountain terrain that gave them the advantage and ultimately the victory. In addition to influencing battles, the topography also affected the transportation of troops and supplies during the Revolutionary War (Wagner 2000).

One of the overall goals of the Kings Mountain National Military Park is to maintain a sense of the historical context of the area. This comprises many historic features from the 1780 battle, including the slopes and ridges, well-preserved remnants of Colonial-era roads and trails, as well as monuments (including the Chronicle Marker—the second oldest battlefield monument in the United States, circa 1815) erected to commemorate figures in the battle and certain events. However, the context of the park also extends back hundreds of years to the American Indians inhabiting the area, and encompasses both natural and cultural resources. This goal is countered both by the continuous natural processes of erosion and weathering and increasing local population and urban development. Erosional processes are constantly changing the landscape at the park. Erosion lowers higher areas and subsequent deposition fills in lower areas.

Issues also arise from opposing values between cultural and natural resource management. All the historic features in the park require protection from geologic processes. Maintaining this battle landscape often means resisting natural geologic changes. At the same time, the historic landscape and restoration efforts need to fit in harmoniously with the landscape, natural resources, and historical context.

Regional Structures

In the area of Kings Mountain National Military Park, several ductile shear zones or zones of steeply dipping metamorphosed phyllonitic and mylonitic rocks are present along both margins of the Kings Mountain sequence as well as within it (Horton 1981a). These zones include the Kings Mountain shear zone, Kings Creek shear zone, Long Creek shear zone, Blacksburg shear zone, and Boogertown shear zone (Goldsmith et al. 1988; Horton 1981a). Many, but not all, of these zones coincide with lithologic boundaries or contacts between geologic units and have brittle faulting superimposed on mylonitic fabrics (Horton 1981a; Schaeffer 1981). The Kings Mountain sequence is also deformed into several broad regional folds having subsidiary structures on their limbs (fig. 7).

Kings Mountain Shear Zone

The Kings Mountain sequence underlies Kings Mountain National Military Park. The Kings Mountain shear zone separates the allochthonous sequence from the Inner Piedmont terrane to the west and defines part of the northwestern boundary of the Carolina terrane (Horton and Butler 1977; Mittwede 1987; Butler and

Secor 1991; Horton 2008). This is a significant terrane boundary in the southern Appalachians, being both a metamorphic discontinuity and a structural one (Butler 1981). On either side of the shear zone, juxtaposed geologic units show differences in stratigraphy, intrusive suites, structure, isotopic relationships, and metamorphic grade (Butler 1981; Butler and Secor 1991). The characteristic structures within the Inner Piedmont, west of the shear zone, are gentle to moderately dipping units and recumbent to inclined folds, whereas the characteristic structures east of the shear zone are steeply dipping and essentially upright folds (Horton 1981b). Dips of units within the Inner Piedmont steepen abruptly near the shear zone, and dips of units within the Kings Mountain sequence are nearly parallel to the shear zone (Goldsmith et al. 1988; Horton 2008).

Deformed rocks, including phyllonite, mylonite, protomylonite, breccia, silicified breccia, and minor schist occurring in a belt 50–200 m (165–655 ft) thick, mark the Kings Mountain shear zone (Butler 1981). It strikes northeast and dips steeply to moderately for at least 60 km (37 mi) (Horton 1981b; Willis et al. 1983). Several phases of deformation created large- and small-scale structures within the King's Mountain shear zone. These structures include a predominantly northeast striking metamorphic fabric (schistosity or foliation), multiple generations of folding, ductile shearing, mylonitization, brittle faulting, and crenulation cleavage (Schaeffer 1981).

The Kings Mountain shear zone truncates units in both the Kings Mountain sequence and the Inner Piedmont. This suggests that displacement may be on the order of kilometers, but timing of fault movements remains somewhat enigmatic. A spodumene pegmatite in the Carolina tin-spodumene belt (currently a source for lithium) dates to 352 ±10 million years (Mississippian) by Rubidium-Strontium (Rb-Sr) isotopic dating (Horton 1981b, 2008). Field relationships suggest that this age may closely approximate the time of late-stage semibrittle deformation and may represent a minimum date for deformation in the shear zone (Horton 1981b).

Kings Creek Shear Zone and Other Local Shear Zones

The Kings Creek shear zone truncates the southeast limb of the Cherokee Falls synform (described below) and is the boundary between the Blacksburg and Battleground formations of the Kings Mountain sequence (Schaeffer 1981; Horton 2008). The Kings Creek shear zone is nearly vertical and strikes roughly parallel to the Kings Mountain shear zone (Horton 2008). Its trace runs just west of the park boundary. This zone of high strain appears to be part of a regional fault system in the central Piedmont of the southern Appalachians (Horton 1981b).

The Boogertown shear zone extends along the somewhat arbitrary eastern boundary of the Kings Mountain sequence, separating it from the rest of the Carolina terrane (Schaeffer 1981; Horton 1981b). The shear zone is intermittently exposed along strike and is locally mappable (at 1:24,000-scale) . In the vicinity of Gastonia, North Carolina, the Boogertown shear zone runs for about 25 km (16 mi) but does not appear to be a profound discontinuity (Horton 1981b; Butler and Secor 1991).

Along many of the other en echelon shear zones within the Kings Mountain sequence, gold, pyrite, and iron deposits occur in layers parallel to the pervasive mylonitic foliation (Horton 1981a). Notable examples are the productive gold deposits of the Kings Creek shear zone mined at Kings Mountain mine and the massive pyrite layers within the Long Creek shear zone mined at the Oliver pyrite mine (Horton 1981a).

Regional Folds

Within the Kings Mountain sequence, folds—and faults that are subparallel to fold limbs—are the predominant geologic structures. At least four regional gently plunging, upright, tight to isoclinal folds are mappable in the Kings Mountain sequence (Horton and Butler 1981). From east to west, these include the South Fork antiform, the McKowns Creek antiform, and the Cherokee Falls synform (Murphy and Butler 1981; Butler 1981). An inferred synform separates the South Fork and the northeast trending and plunging McKowns Creek antiforms (Schaeffer 1981). The South Fork and Cherokee Falls structures are the largest fold structures in the area; subsidiary folds exist on the flanks of these structures.

The South Fork antiform is a tightly folded, north-northeast-plunging structure. It is near the eastern edge of the Kings Mountain sequence. On the western flanks of the South Fork antiform are the isoclinal to tight Sherrars Gap synform and the Crowders Mountain antiform (Horton 1981a, 2006).

Large regional folds and other features, such as small-scale isoclinal folds, schistosity, crenulations, and kink bands define at least five intervals of ductile and semi-brittle deformation (Butler and Secor 1991). Regionally, fold patterns show disruption on all scales; numerous discontinuities tend to parallel the regional strike. Isolated fold hinges, disrupted fold limbs, and truncations on all scales attest to extreme deformation (Butler 1981).

Metamorphism of the Kings Mountain Sequence

The metamorphic grade within the Kings Mountain sequence is generally lower than that of the Inner Piedmont or adjacent rocks within the Carolina terrane (Horton and Butler 1981). The metamorphic grade of the Inner Piedmont of North and South Carolina is generally low to medium (garnet to kyanite zones) on the flanks and high (sillimanite-muscovite zone) in the central part of the terrane (Goldsmith 1981). In the area immediately west of Kings Mountain National Military Park, mineral assemblages of the layered metamorphic rocks of the Inner Piedmont are typical of the amphibolite facies (kyanite and sillimanite zones) (Horton 2008). Large areas of greenschist-facies metamorphism in the Kings Mountain sequence are not present in nearby rocks of the Inner Piedmont and Carolina terrane (Horton and Butler 1981). High-grade metamorphosed areas do exist within the sequence as evidenced by rocks metamorphosed to the sillimanite zone or upper amphibolite facies (Horton 1981a).

Metamorphic isograds transect stratigraphy units and many regional structures. This pattern of metamorphism indicates that the Kings Mountain sequence cannot represent a simple structural window of low-grade rocks rimmed by higher grade metamorphic rocks (Horton and Butler 1981; Horton 1981a). Interpretations of the metamorphic patterns are still subjects of debate. Several metamorphic pulses, perhaps even at different times, may have resulted in the complex pattern in the Kings Mountain area (Horton 1981a).

In the Blacksburg and Battleground formations, mineral assemblages show a generally westward decrease in metamorphic grade from upper amphibolite facies (sillimanite zone) near the High Shoals Granite (described below) to upper greenschist facies (epidote-amphibolite) in the south-central part of the sequence, near the Kings Mountain shear zone (Horton 2008). Within the Kings Mountain sequence (dominating the area north of Kings Mountain National Military Park) is the High Shoals Granite batholith, which consists of coarse-grained biotite granite having a strong, nearly vertical, gneissic foliation. According to Horton et al. (1987), field relationships suggest that the granite intruded the surrounding rocks during the late stages of regional folding in the Pennsylvanian-age temperature peak of amphibolite-facies metamorphism (late Paleozoic Alleghanian Orogeny). Uranium-Lead (U-Pb) isotopic dates of zircons within the granite yield an age of 317 millions of years old, whereas Argon-Argon isotopic ages of hornblende from metamorphic rocks of amphibolite to upper amphibolite facies from elsewhere within the Kings Mountain sequence are 323–318 million years old (Sutter et al. 1984; Horton et al. 1987). This similarity in age demonstrates the synchronicity of the intrusion of the High Shoals granite and the predominant regional metamorphism of the Kings Mountain sequence in the area of the park (Horton et al. 1987).

Deformation and metamorphism associated with the Alleghanian Orogeny (see "Geologic History" section) in the Kings Mountain sequence were superimposed on older deformational and metamorphic features, such as foliation (Horton and Butler 1981; Horton et al. 1987). On the basis of comparisons with areas east of the Kings Mountain sequence, in the Carolina terrane, Alleghanian metamorphism may be considered localized. This is part of a complex relationship among thrust and strike-slip fault systems, regional metamorphism, and magmatic intrusions during the Alleghanian Orogeny in the southern Appalachian Piedmont (Butler et al. 1985; Horton et al. 1987). Bands of medium- to high-grade Alleghanian metamorphism evident in rocks that crop out in the area could be the result of folding and faulting of paleo-isothermal surfaces (Horton et al. 1987).

Figure 5. Hillslope below the U.S. Monument at Kings Mountain National Military Park. View is from the perspective of the attackers (along a visitor trail) under the command of Col. James Williams advancing toward the loyalist position atop Brushy Ridge. Photograph is included with permission by Ethan Rafuse, available at http://civilwarriors.net/wordpress/wp-content/uploads/kings-mountain1.jpg (accessed February 27, 2009).

Figure 6. Forested slopes at Kings Mountain National Military Park. Photograph is included with permission by Chris Steude, available at http://farm2.static.flickr.com/1022/932449097_f42b5f0ca8.jpg?v=0 (accessed February 27, 2009).

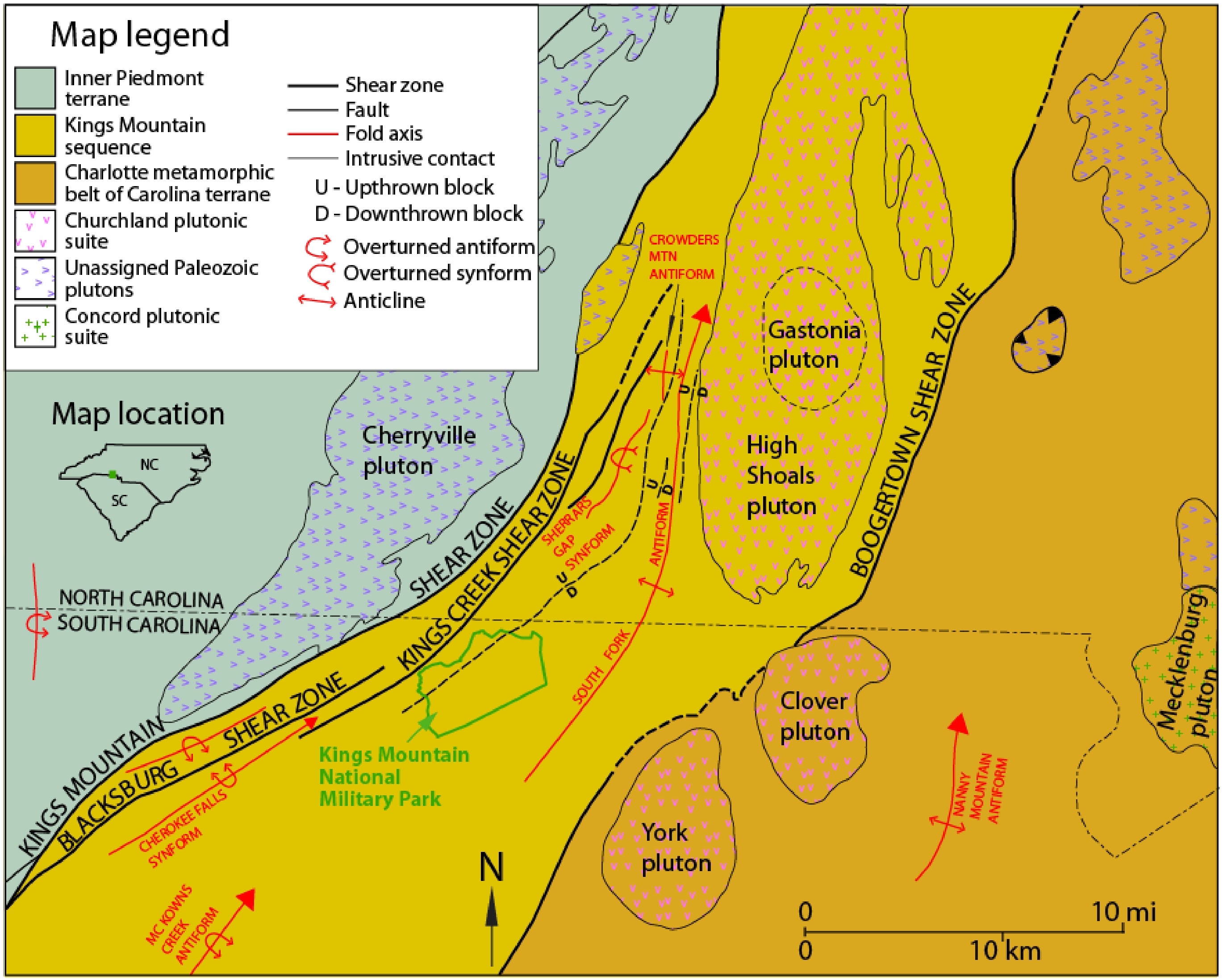


Figure 7. Tectonic map of Kings Mountain National Military Park area showing geologic structures mentioned in the text. Graphic is adapted from Goldsmith et al. (1988) with data from Horton (2006), Nystrom (2003), and Howard (2004).

Map Unit Properties

This section identifies characteristics of map units that appear on the Geologic Resources Inventory digital geologic map of Kings Mountain National Military Park. The accompanying table is highly generalized and for background purposes only. Ground-disturbing activities should not be permitted or denied on the basis of information in this table.

Geologic maps facilitate an understanding of Earth, its processes, and the geologic history responsible for its formation. Hence, the geologic map for Kings Mountain National Military Park informed the “Geologic History,” “Geologic Features and Processes,” and “Geologic Issues” sections of this report. Geologic maps are essentially two-dimensional representations of complex three-dimensional relationships. The various colors on geologic maps illustrate the distribution of rocks and unconsolidated deposits. Bold lines that cross or separate the color patterns mark structures such as faults and folds. Point symbols indicate features such as dipping strata, sample localities, mines, wells, and cave openings.

Incorporation of geologic data into a Geographic Information System (GIS) increases the usefulness of geologic maps by revealing the spatial relationships to other natural resources and anthropogenic features. Geologic maps are indicators of water resources because they show which rock units are potential aquifers and are useful for finding seeps and springs. Geologic maps do not show soil types and are not soil maps, but they do show parent material, a key factor in soil formation. Furthermore, resource managers have used geologic maps to make connections between geology and biology; for instance, geologic maps have served as tools for locating sensitive, threatened, and endangered plant species, which may prefer a particular rock unit.

Although geologic maps do not show where earthquakes will occur, the presence of a fault indicates past movement and possible future seismic activity. Geologic maps do not show where the next landslide, rockfall, or volcanic eruption will occur, but mapped deposits show areas that have been susceptible to such geologic hazards. Geologic maps do not show archaeological or cultural resources, but past peoples may have inhabited or been influenced by various geomorphic features that are shown on geologic maps. For example, alluvial terraces may preserve artifacts, and formerly inhabited alcoves may occur at the contact between two rock units.

The geologic units listed in the following table correspond to the accompanying digital geologic data. Map units are listed in the table from youngest to oldest. Please refer to the geologic timescale (fig. 9) for the age associated with each time period. This generalized table highlights characteristics of map units such as susceptibility to hazards; the occurrence of fossils, cultural resources, mineral resources, and caves; and the suitability as habitat or for recreational use. Some conclusions are conjectural and meant to serve as a suggestion for further investigation.

The GRI digital geologic maps reproduce essential elements of the source maps including the unit descriptions, legend, map notes, graphics, and report. The following references are source data for the GRI digital geologic map for Kings Mountain National Military Park:

Nystrom, P G., Jr. 2003. *Geologic Map of the Filbert 7.5-minute quadrangle, York County, South Carolina*. Scale 1:24,000. Geologic Quadrangle Map GQM-25. Columbia, SC: South Carolina Geological Survey.

Howard, C. S. 2004. *Geologic Map of the Kings Creek 7.5-minute quadrangle, Cherokee and York Counties*. Scale 1:24,000. Geologic Quadrangle Map GQM-16. Columbia, SC: South Carolina Geological Survey.

Horton, J. W., Jr. 2006. *Geologic Map of the Kings Mountain and Grover quadrangles, Cleveland and Gaston Counties, North Carolina, and Cherokee and York Counties, South Carolina*. Scale 1:24,000. Open-File Report OFR 2006–1238. Reston, VA: U.S. Geological Survey.

South Carolina Geological Survey. 2007a. *Digital Geologic Map of the Filbert quadrangle, York County, South Carolina*. Scale 1:24,000. Digital Geologic Data DGD-13. Columbia, SC: South Carolina Geological Survey.

South Carolina Geological Survey. 2007b. *Digital Geologic Map of the Kings Creek quadrangle, Cherokee and York Counties, South Carolina*. Scale 1:24,000. Digital Geologic Data DGD-14. Columbia, SC: South Carolina Geological Survey.

The GRI team implements a geology-GIS data model that standardizes map deliverables. This data model dictates GIS data structure including data layer architecture, feature attribution, and data relationships within ESRI ArcGIS software, increasing the overall quality and utility of the data. GRI digital geologic map products include data in ESRI personal geodatabase, shapefile, and coverage GIS formats, layer files with feature symbology, Federal Geographic Data Committee (FGDC)-compliant metadata, a Windows help file that contains all of the ancillary map information and graphics, and an ESRI ArcMap map document file that easily displays the map. GRI digital geologic data are included on the attached CD and are available through the NPS Data Store (http://science.nature.nps.gov/nrdata/).

Geologic Units within Kings Mountain National Military Park

As can be seen on the digital geologic map, the Neoproterozoic Battleground Formation is the most widespread geologic unit in Kings Mountain National Military Park. Three units within the Battleground Formation, mapped as quartz-sericite phyllite and schist (unit Zbs), mottled phyllitic metatuff (unit Zbmp), and plagioclase-crystal metatuff (unit Zbct), cover the greatest aerial extent within the park (Horton 2006).

The quartz-sericite phyllite and schist (also called quartz schist, metasiltstone, and phyllite) is quartz- and feldspar-rich rock interlayered with quartz schist, meta-arenite, metasiltstone, and metaconglomerate containing darker bands of phyllite (Howard 2004; Horton 2006). This unit appears very light gray with bluish and yellowish areas and has very fine grained to medium-grained textures (Horton 2006). Accessory and trace minerals within this unit include plagioclase, biotite, garnet, chloritoid or staurolite, kyanite, andalusite, chlorite, graphite, tourmaline, zircon, pyrite, and hematite (Horton 2006). The local mineral assemblages are indicative of metamorphic grade.

Separated from the quartz-sericite phyllite and schist by a normal fault running through the park, mottled phyllitic metatuff is a light- to dark-gray, micaceous rock containing some bluish bands and distinctive rounded and elliptical clasts and lapilli (lacking abundant opaque oxides), which produce the mottled appearance (Howard 2004; Horton 2006). Minerals within this rock include quartz, plagioclase, sericitic white mica, iron-titanium oxides, paragonite and muscovite, and lesser amounts of chloritoid, chlorite, epidote, and margarite (Horton 2006).

Massive to schistose, medium-gray to dark-gray, andesitic to dacitic metamorphosed volcaniclastic rocks are characteristic of the plagioclase-crystal metatuff unit in the area of the park (Horton 2006). The unit contains plagioclase crystals and some rounded quartz crystals in a very fine grained matrix of plagioclase, quartz, white mica, epidote, chlorite, calcite, biotite, pyrite, and other opaque minerals (Nystrom 2003; Horton 2006). Foliation defined by micaceous bands is characteristically poorly developed in this unit (Howard 2004). Past mining interest focused on barite from layers within the metatuff at Kings Creek (Howard 2004).

Smaller pods, lenses, and bands of other geologic units of the Battleground Formation also crop out within Kings Mountain National Military Park. These include the Jumping Branch Manganiferous Member (unit Zbj or Zbjp), the Dixon Gap Metaconglomerate Member (unit Zbc), volcanic metaconglomerate (unit Zbvc), and siliceous metatuff (unit Zbmps). The Jumping Branch Manganiferous Member is brownish gray and contains abundant manganese oxides, spessartine-almandine garnets, and other accessory minerals (Howard 2004; Horton 2006). This unit was mined within the park boundaries (P. Enzi, written communication, 2009). The Dixon Gap Metaconglomerate Member includes coarse-grained, clast-supported quartz-pebble (as many as 90% of clasts are white quartz) metaconglomerate in poorly developed, graded beds (Horton 2006). The volcanic metaconglomerate is yellowish gray in outcrop and has myriad pebble compositions, including gray, ferruginous quartz, biotite-muscovite schist, and massive metatuff (unit Zbct). This unit displays relict flow layering in some places (Horton 2006). The siliceous metatuff is the quartzose equivalent of the mottled phyllitic metatuff (unit Zbmp). It is relatively resistant to erosion and underlies linear ridges, such as Brushy Ridge and the site of the 1780 Battle of Kings Mountain (Horton 2006).

An isolated lens of Neoproterozoic metatonalite (unit Zto) is present within the plagioclase-crystal metatuff (unit Zbct) along the eastern edge of the park. This may have originated locally as shallow igneous intrusions within the Battleground Formation (Horton 2006). It has medium- to coarse-grained, weakly foliated to schistose textures and is gray to tan in outcrop. Major minerals include oligoclase, blue quartz, biotite, muscovite, and hornblende (Nystrom 2003; Howard 2004; Horton 2006).

Alluvium (unit Qal)—a surficial map unit—occurs within the park boundaries at Kings Mountain. The Quaternary alluvium includes poorly sorted, fine-grained to very coarse grained quartz sand, silt, and clay in the valleys and flood plains of local streams (Nystrom 2003; Howard 2004; Horton 2006). Thicker alluvial deposits (≈6 m, or 20 ft, thick) locally have the potential for commercial sand and gravel production (Nystrom 2003).

Geologic History

This section describes the rocks and unconsolidated deposits that appear on the digital geologic map of Kings Mountain National Military Park, the environment in which those units were deposited, and the timing of geologic events that created the present landscape.

Proterozoic Eon

More than one billion years ago, the Grenville Orogeny deformed and metamorphosed a continental mass ancestral to North America called Laurentia (see fig. 9 for a geologic time scale). Beginning about 750–700 million years ago, rifting of Laurentia led to the opening of the Iapetus Ocean and formed a new eastern margin of the continent. The Iapetus was one of several proto-Atlantic ocean basins that closed episodically during the Paleozoic. Other basins included the Theic and Rheic oceans (Horton and Zullo 1991; Nance and Linnemann 2008).

During the Neoproterozoic (which spanned from 1,000 to 545 million years ago), volcanic rocks, clastic and carbonate sediments, and hydrothermally altered volcanic materials that would become units within the Blacksburg and Battleground formations in the Kings Mountain sequence were deposited (Goldsmith et al. 1988). In the late Proterozoic(?), tonalite and trondhjemite magmas associated with volcanism (units Zto and Ztr) shallowly intruded the lower part of the mixed deposits of the Battleground Formation (Goldsmith et al. 1988; Nystrom 2003; Howard 2004; Horton 2006). These intrusions were roughly synchronous with widespread eruption of mafic volcanic materials in other parts of the terrane, possibly associated with an episode of arc-rifting dated at 570 million years ago (Hibbard et al. 2002). The depositional environment for the Kings Mountain sequence of rocks may have been a volcanic arc-basin complex (LeHuray 1986; Goldsmith et al. 1988). Intrusions within the Carolina terrane (primarily east of Kings Mountain) record a major plutonic episode lasting from about 650 to 600 million years ago, which could correlate with an intrusive center of a magmatic arc (Faggart and Basu 1987; Butler and Secor 1991).

Paleozoic Era

Throughout the Paleozoic, fragments of oceanic crust and basin sediments, volcanic island arcs, and other continental land masses collided with the eastern edge of the North American continent. Many of these myriad fragments accreted to Laurentia in several episodes of compression accompanied by metamorphism and magmatism. These compressional orogenic events of varying duration and intensity affected different but overlapping segments of the eastern edge of North America (Horton and Zullo 1991).

During the early Paleozoic, subduction-related volcanic arcs, slabs of oceanic crust, and basin sediments were amalgamating off the eastern margin of the North American continent. Within the Carolina terrane, high-grade metaplutonic rocks, which had been deeply buried, were juxtaposed against shallow, low-grade metavolcanic and metasedimentary rocks along major ductile shear zones (Secor et al. 1998). Several phases of deformation occurred within the Carolina terrane before it collided with North America by means of intraplate events associated with tectonically active volcanic arcs (Butler and Secor 1991).

Many of the terranes foreign to Laurentia (those previously amalgamated, as well as others) and now located northwest of the Carolina terrane were accreted, deformed, and metamorphosed during the Ordovician Taconic Orogeny, from about 470 to 440 million years ago (Horton et al. 1988, 1989a, 1989b; Horton and Zullo 1991). The Taconic Orogeny involved a volcanic arc–continent convergence and closure of the Iapetus Ocean (Nance and Linnemann 2008). Oceanic crust and the volcanic arc were thrust onto the eastern edge of the North American continent along major thrust faults (Moore 1988; Connelly and Woodward 1990). From approximately 415 to 385 million years ago, a major group of plutons intruded the Carolina terrane east of Kings Mountain (Butler and Secor 1991). Devonian tectonothermal activity in the southern Appalachian region occurred approximately 380–340 million years ago and appears younger than events associated with the Acadian Orogeny that primarily affected New England (Horton et al. 1989a).

The Rheic Ocean opened during the Early Ordovician following rifting along the northern margin of Gondwana in the Middle to Late Cambrian (Nance and Linnemann 2008). It widened at the expense of the Iapetus Ocean as the Carolina terrane drifted towards Laurentia (Nance and Linnemann 2008). The Pennsylvanian-Permian Alleghanian Orogeny (≈330–270 million years ago) involved the continental collision between Laurentia and Gondwanaland (a composite continent consisting of South America, Africa, Madagascar, Antarctica, India, other parts of South Asia, and Australia), forming a supercontinent called Pangaea and closing the Rheic Ocean (fig. 8) (Horton and Zullo 1991; Nance and Linneman 2008; C. S. Howard, written communication, 2009).

The deformation associated with the Alleghanian Orogeny overprints many previous structures in the southern Appalachians, resulting in flexural-slip folds, kink folds, and extensional crenulation cleavage (part of the Alleghanian dextral shear system) (Schaeffer 1982; C. S. Howard, written communication, 2009). In the Carolinas, in the vicinity of the Kings Mountain sequence, effects of this collision were varied. Major changes included (1) widespread plutonism, (2) westward transport of native and accreted terranes of the Piedmont as part of a composite crystalline thrust sheet, (3) amphibolite-facies regional metamorphism and penetrative deformation, and (4) predominantly right-lateral strike-slip faulting (along northeast-trending ductile shear zones) that sliced and shifted accreting terranes (Horton et al. 1989a, 1989b; Horton and Zullo 1991; Butler and Secor 1991; Nance and Linnemann 2008).

Approximately 317 million years ago, the High Shoals granitic batholith intruded the metasedimentary and metavolcanic rocks of the Kings Mountain sequence (LeHuray 1986; Horton et al. 1987; Goldsmith et al. 1988). Gneissic foliation developed within the granite during deformation accompanying emplacement (Horton et al. 1987). A zone of sillimanite-grade metamorphic rock surrounds the granitic batholith, and a zone of regional metamorphism extends beyond the immediate vicinity of the granite, overprinting evidence of an older, lower grade Paleozoic metamorphic event (Goldsmith et al. 1988). The relatively undeformed Gastonia granite, one of many late Alleghanian (325–254 million years ago) intrusive bodies throughout the Piedmont, in turn intrudes the High Shoals batholith (Sutter et al. 1984; LeHuray 1986; Goldsmith et al. 1988).

Accretion of the Carolina terrane to Laurentia is a critical unresolved problem in the study of southern Appalachian tectonics (Hibbard 2000). Data for Paleozoic igneous rocks that have paleomagnetic poles similar to Carboniferous (Mississippian-Pennsylvanian) poles from the North American craton show that the magmatic-arc terrane had sutured to the continent by approximately 300 million years ago (Butler and Secor 1991). The Kings Mountain shear zone coincides in age with outcrops of pegmatite and deformed the Cherryville Granite of the Inner Piedmont to the west and other plutons aged 340–285 million years. These relations imply a late Alleghanian age for some of the local deformation and plutonism along the Kings Mountain shear zone associated with the collision of North America and Gondwanaland (LeHuray 1986; Butler and Secor 1991). Other geologists favor a Late Ordovician to Silurian time of accretion based on the presence of a Silurian unconformity on the Laurentian margin, extensive tonalitic to granodioritic magmatism in the Piedmont at that time, and Argon isotope cooling ages calculated from mica showing a Middle to Late Ordovician and Silurian tectonic uplift event (Hibbard 2000; Hibbard et al. 2002). A study by Hibbard et al. (2002) summarizes this debate and presents a comprehensive history of the entire Carolina Zone that is beyond the scope of this report.

Mesozoic Era

During the Mesozoic, extensional tectonic forces rifted Pangaea into roughly the same continental masses and Atlantic Ocean that persist today. Along the eastern margin of North America, normal faulting opened rift basins that rapidly filled with sediment eroded from the Alleghanian highlands. Brittle faults, joints, and cataclasite zones developed across the Inner Piedmont and Carolina terranes during multiple episodes of mid-Mesozoic brittle deformation that accompanied continental rifting (Garihan et al. 1993). Associated with the extension was widespread igneous activity that is locally evident as Early Jurassic olivine diabase dikes (map unit Jd) and some localized hydrothermal activity throughout the Piedmont in the Carolinas (Schaeffer 1982; Horton and Zullo 1991; Nystrom 2003; Howard 2004; Horton 2006). There are nearly vertical olivine diabase dikes within the park and surrounding areas dating to this time (C. S. Howard, written communication, 2009). These later intrusions locally overprinted (contact metamorphism) pre-existing features (Schaeffer, 1982).

After this magma intruded the surrounding metamorphic and plutonic rocks during the Jurassic, at approximately 200 million years ago, the region underwent a period of slow uplift and erosion. The uplift was in response to isostatic adjustments within the crust that forced the continental crust upwards and exposed it to erosion (Harris et al. 1997). Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. Cenozoic tectonism in South Carolina is manifested in ways such as uplift, subsidence, and faulting (Prowell and Obermeier 1991). Most of this faulting is concentrated in broad, alternating arches (upwarps) and embayments (downwarps) along the southeastern coast (Horton and Zullo 1991).

Cenozoic Era

Running water and wind transported thick deposits of unconsolidated gravel, sand, and silt from the eroding highlands. These were deposited at the base of the mountains as alluvial fans and spread eastward to become part of the Atlantic Coastal Plain to the east of Kings Mountain National Military Park. With fluctuating relative sea level and tectonism throughout the Cenozoic, sediments were regionally deposited and eroded in alternating events. Today the Fall Line, a sinuous boundary, defines the current western extent of the Atlantic Coastal Plain deposits (Horton and Zullo 1991). The former western extent of the Coastal Plain is unknown and is still a matter of debate. Some geologists theorize it may have extended to the Blue Ridge escarpment (C. S. Howard, written communication, 2009). The amount of material inferred from the now-exposed metamorphic rocks throughout the Piedmont and Blue Ridge is immense. Many of the rocks exposed at the surface must have been at least 20 km (≈10 mi) below the surface prior to regional uplift and erosion.

Throughout the Cenozoic, the primary geologic processes at work in the Southern Appalachians were erosion and weathering. Erosion continues today along regional drainage patterns developed during the early Cenozoic Era, the large rivers and tributaries stripping sediments, lowering the mountains, and depositing alluvial terraces and alluvium (unit Qal) along the rivers and forming the present landscape (Moore 1988; Nystrom 2003; Howard 2004; Horton 2006). Rain, frost, rooted plants, rivers and streams, chemical dissolution, and mass wasting are wearing away the once-craggy peaks. Layers of resistant rocks, such as quartzite, siliceous metatuff, and metaconglomerate, underlie local ridges and mountains. The more resistant rocks create ledges commonly associated with waterfalls near Kings Mountain National Military Park (Schultz and Seal 1997).

From about 1.6 million to 11,000 years before the present, the Pleistocene ice ages resulted in significant changes to the Earth's landscape. Though glaciers never reached the southern Appalachians, the colder climates of the ice ages played a role in the geomorphology of the area. The landforms and deposits are probably late Neogene to Quaternary in age, when a wetter climate, sparse vegetation, and frozen ground caused increased precipitation and runoff that fed ancestral rivers. These conditions enhanced downcutting and erosion (Schultz and Seal 1997). Many of the concentrations of boulders, block fields, and fine-textured colluvium on the forested mountainsides of the Southern Appalachians record the process of frost-wedging.

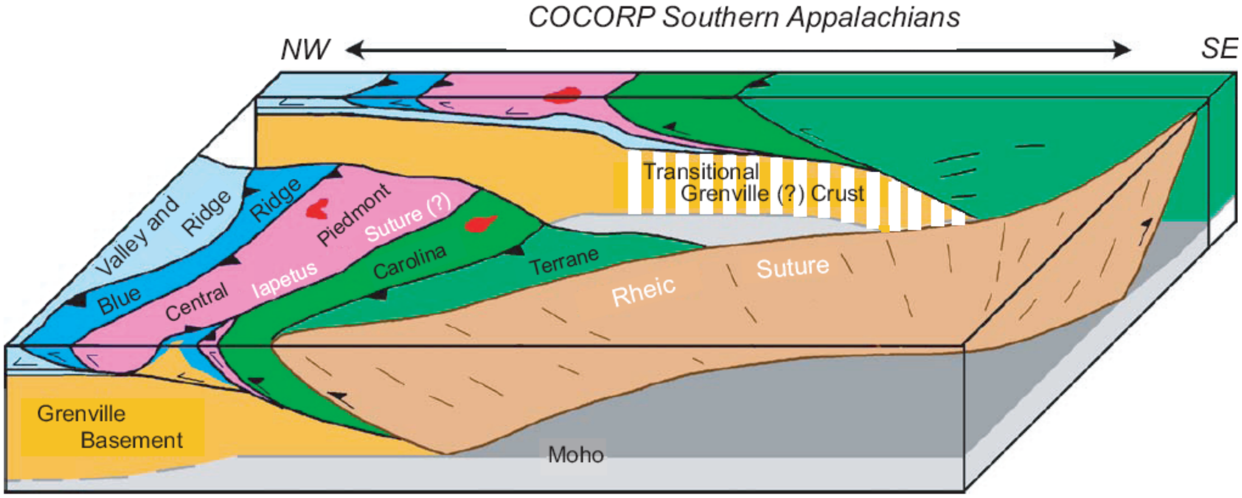
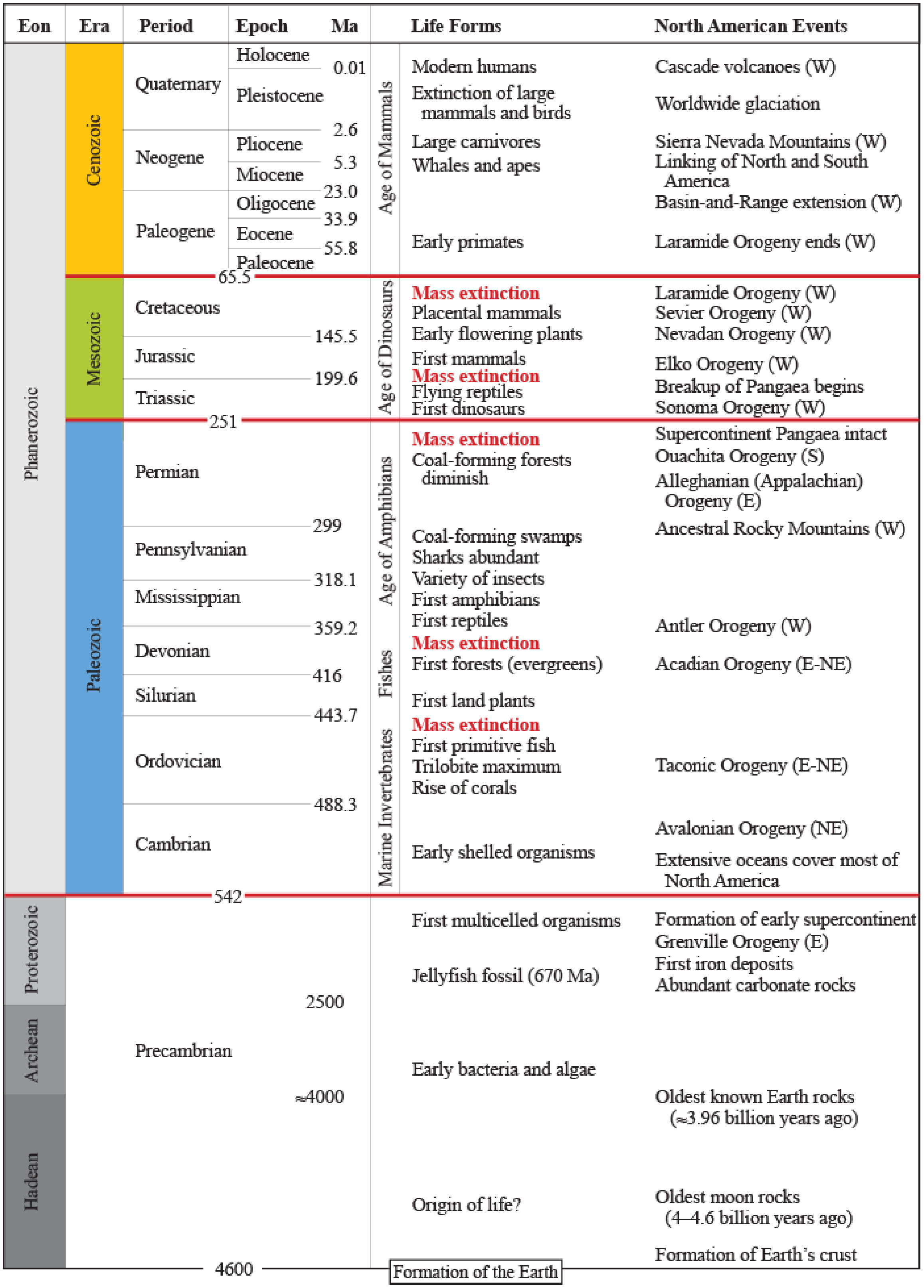


Figure 8. Generalized schematic block diagram of the crustal structure of the southeastern Appalachians based on reprocessed data from the Consortium for Continental Reflection Profiling (COCORP) reflection survey. Kings Mountain National Military Park is located near the western edge of the Carolina Terrane. Sutures represent boundaries between terranes that were once separated by wide ocean basins such as the Iapetus and Rheic. Shear zones commonly mark the trace of a suture. Graphic is figure 8 from Nance and Linnemann (2008).



Eon	Era	Period	Epoch	Ma		Life Forms	North American Events
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	Age of Mammals	Modern humans	Cascade volcanoes (W)
			Pleistocene	2.6		Extinction of large mammals and birds	Worldwide glaciation
		Neogene	Pliocene	5.3		Large carnivores	Sierra Nevada Mountains (W) Linking of North and South America
			Miocene	23.0		Whales and apes	
		Paleogene	Oligocene	33.9			Basin-and-Range extension (W)
			Eocene	55.8		Early primates	Laramide Orogeny ends (W)
			Paleocene	65.5			
	Mesozoic	Cretaceous		145.5	Age of Dinosaurs	**Mass extinction** Placental mammals Early flowering plants	Laramide Orogeny (W) Sevier Orogeny (W) Nevadan Orogeny (W)
		Jurassic		199.6		First mammals	Elko Orogeny (W)
		Triassic		251		**Mass extinction** Flying reptiles First dinosaurs	Breakup of Pangaea begins Sonoma Orogeny (W)
	Paleozoic	Permian		299	Age of Amphibians	**Mass extinction** Coal-forming forests diminish	Supercontinent Pangaea intact Ouachita Orogeny (S) Alleghanian (Appalachian) Orogeny (E)
		Pennsylvanian		318.1		Coal-forming swamps Sharks abundant Variety of insects	Ancestral Rocky Mountains (W)
		Mississippian		359.2		First amphibians First reptiles	Antler Orogeny (W)
		Devonian		416	Fishes	**Mass extinction** First forests (evergreens)	Acadian Orogeny (E-NE)
		Silurian		443.7		First land plants	
		Ordovician		488.3	Marine Invertebrates	**Mass extinction** First primitive fish Trilobite maximum Rise of corals	Taconic Orogeny (E-NE)
		Cambrian		542		Early shelled organisms	Avalonian Orogeny (NE) Extensive oceans cover most of North America
Proterozoic		Precambrian		2500		First multicelled organisms Jellyfish fossil (670 Ma)	Formation of early supercontinent Grenville Orogeny (E) First iron deposits Abundant carbonate rocks
Archean				≈4000		Early bacteria and algae	Oldest known Earth rocks (≈3.96 billion years ago)
Hadean				4600		Origin of life? Formation of the Earth	Oldest moon rocks (4–4.6 billion years ago) Formation of Earth's crust

Figure 9. Geologic time scale. Included are major events in the history of life on Earth and tectonic events occurring on the North American continent. Red lines indicate major unconformities between eras. Absolute ages shown are in millions of years (Ma, or mega-annum). Compass directions in parentheses indicate the regional location of individual geologic events. Adapted from the U.S. Geological Survey, http://pubs.usgs.gov/fs/2007/3015/.

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://geomaps.wr.usgs.gov/parks/misc/glossarya.html.

absolute age. The geologic age of a fossil, rock, feature, or event in years; commonly refers to radiometrically determined ages.

allochthonous. Describes rocks or materials formed elsewhere than in their present location.

alluvial fan. A fan-shaped deposit of sediment that accumulates where a hydraulically confined stream flows to a hydraulically unconfined area. Commonly out of a mountain front into an area such as a valley or plain.

alluvium. Stream-deposited sediment.

amphibolite. A rock produced by metamorphic recrystallization, consisting mostly of amphibole and plagioclase with little or no quartz.

anticline. A fold, generally convex upward, whose core contains the stratigraphically older rocks.

anticlinorium. A composite anticlinal structure of regional extent composed of lesser folds.

aquifer. A rock or sedimentary unit that is sufficiently porous that it has a capacity to hold water, sufficiently permeable to allow water to move through it, and currently saturated to some level.

arc. See "volcanic arc" and "magmatic arc."

ash (volcanic). Fine pyroclastic material ejected from a volcano (also see "tuff").

asthenosphere. Weak layer in the upper mantle below the lithosphere where seismic waves are attenuated.

authochthonous. Formed or produced in the location where now found. Similar to "authigenic," which refers to constituents rather than whole formations.

axis (fold). A straight-line approximation that when moved parallel to itself generates the shape of a fold (see and use "hinge line").

basement. The undifferentiated rocks, commonly igneous and metamorphic, that underlie the rocks exposed at the surface.

basin (structural). A doubly plunging syncline in which rocks dip inward from all sides.

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

batholith. A massive, discordant pluton, greater than 100 km^2 (40 mi^2), and commonly formed from multiple intrusions.

bed. The smallest sedimentary strata unit, commonly ranging in thickness from one centimeter to a meter or two and distinguishable from beds above and below.

bedding. Depositional layering or stratification of sediments.

bedrock geology. The geology of underlying solid rock as it would appear with the sediment, soil, and vegetative cover stripped away.

block (fault). A crustal unit bounded by faults, either completely or in part.

breccia. A coarse-grained, generally unsorted sedimentary rock consisting of cemented angular clasts greater than 2 mm (0.08 in).

brittle. Describes a rock that fractures before sustaining significant deformation.

calcareous. Describes rock or sediment that contains calcium carbonate.

carbonate. A mineral that has CO_3^{-2} as its essential component (e.g., calcite and aragonite).

carbonate rock. A rock consisting chiefly of carbonate minerals (e.g., limestone, dolomite, or carbonatite).

cataclastic. Describes structures in a rock produced by bending, breaking, or crushing of minerals, which result from tremendous stresses during metamorphism.

cementation. Chemical precipitation of material into pores between grains that bind the grains into rock.

chemical sediment. A sediment precipitated directly from solution (also called nonclastic).

chemical weathering. Chemical breakdown of minerals at the Earth's surface via reaction with water, air, or dissolved substances; commonly results in a change in chemical composition more stable in the current environment.

clast. An individual grain or rock fragment in a sedimentary rock, produced by the physical disintegration of a larger rock mass.

clastic. Describes rock or sediment made of fragments of pre-existing rocks.

clay. Can be used to refer to clay minerals or as a sedimentary fragment size classification (less than 1/256 mm [0.00015 in]).

cleavage (mineral). The tendency of a mineral to break preferentially in certain directions along planes of weaknesses in the crystal structure.

cleavage (rock). The tendency of rock to break along parallel planes that correspond to the alignment of platy minerals.

conglomerate. conglomerate. A coarse-grained, generally unsorted, sedimentary rock consisting of cemented rounded clasts larger than 2 mm (0.08 in).

continental crust. The crustal rocks rich in silica and alumina that underlie the continents; ranging in thickness from 35 km (22 mi) to 60 km (37 mi) under mountain ranges.

continental shield. A continental block of Earth's crust that has remained relatively stable over a long period of time and has undergone only gentle warping compared to the intense deformation of bordering crust.

convergent boundary. An active boundary where two tectonic plates are colliding.

country rock. The rock surrounding an igneous intrusion. Also, the rock enclosing or traversed by a mineral deposit.

craton. The relatively old and geologically stable interior of a continent (also see "continental shield").

creep. The slow, imperceptible downslope movement of mineral, rock, and soil particles under gravity.

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 a vertically oriented plane.

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

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

debris flow. A moving mass of rock fragments, soil, and mud, more than half the particles of which are larger than sand size.

deformation. A general term for the process of faulting, folding, and shearing of rocks as a result of various Earth forces such as compression (pushing together) and extension (pulling apart).

dike. A tabular, discordant igneous intrusion.

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

discordant. Having contacts that cut across or are set at an angle to the orientation of adjacent rocks.

divergent boundary. An active boundary where tectonic 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.

ductile. Describes rock that is able to sustain deformation before fracturing.

en echelon. Describes geologic features (particularly faults) that overlap in a step-like pattern.

escarpment. A steep cliff or topographic step resulting from vertical displacement on a fault or by mass movement (syn: scarp).

extrusive. Of or pertaining to the eruption of igneous material onto the Earth's surface.

facies (metamorphic). The pressure-temperature regime that results in a particular, distinctive metamorphic mineralogy (i.e., a suite of index minerals).

fault. A break in rock along which relative movement has occurred between the two sides.

foliation. A preferred arrangement of crystal planes in minerals; in metamorphic rocks, the term commonly refers to a parallel orientation of planar minerals such as micas.

footwall. The mass of rock beneath a fault surface (also see "hanging wall").

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

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

frost wedging. The breakup of rock due to the expansion of water freezing in fractures.

graywacke. A term commonly used in the field for a dark gray to dark green, very hard, dense sandstone of any composition but with a chlorite-rich matrix; these rocks have undergone deep burial.

groundmass. The material between the phenocrysts in a porphyritic igneous rock; also, the matrix of a sedimentary rock.

hanging wall. hanging wall. The mass of rock above a fault surface (also see "footwall").

hinge line. A line or boundary between a stable region and one undergoing upward or downward movement.

igneous. Refers to a rock or mineral that originated from molten material; one of the three main classes or rocks—igneous, metamorphic, and sedimentary.

intrusion. A body of igneous rock that invades (pushes into) older rock. The invading rock may be a plastic solid or magma.

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

isograd. A line on a map joining points at which metamorphism proceeded at similar values of pressure and temperature as indicated by rocks containing a diagnostic mineral or mineral assemblage. Such a line represents the intersection of a reaction surface with the Earth's surface corresponding to the boundary between two contiguous zones of metamorphic grade.

isostasy. The process by which the crust "floats" at an elevation compatible with the density and thickness of the crustal rocks relative to underlying mantle.

isostatic adjustment. The shift of the lithosphere to maintain equilibrium between units of varying mass and density; excess mass above is balanced by a deficit of density below, and vice versa.

joint. A semi-planar break in rock without relative movement of rocks on either side of the fracture surface.

lamination. The finest stratification or bedding as in shale or siltstone; also the formation of laminae.

landslide. Any process or landform resulting from rapid, gravity-driven mass movement.

lava. Still-molten or solidified magma that has been extruded onto the Earth's surface though a volcano or fissure.

limb. Either side of a structural fold.

lithology. The physical description or classification of a rock or rock unit based on characters such as its color, mineralogic composition, and grain size.

mafic. Describes dark-colored rock, magma, or minerals rich in magnesium and iron.

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

magmatic arc. Zone of plutons or volcanic rocks formed at a convergent boundary.

mantle. The zone of the Earth's interior between the crust and core.

mass wasting. A general term for the downslope movement of soil and rock material under the direct influence of gravity.

matrix. The fine grained material between coarse (larger) grains in igneous rocks or poorly sorted clastic sediments or rocks. Also refers to rock or sediment in which a fossil is embedded.

mechanical weathering. The physical breakup of rocks without change in composition. Synonymous with physical weathering.

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

meta-. A prefix used with the name of a sedimentary or igneous rock, indicating that the rock has been metamorphosed.

metamorphic. Pertaining to the process of metamorphism or its results.

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

migmatite. Literally, "mixed rock" with both igneous and metamorphic characteristics due to partial melting during metamorphism.

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

Moho. The Mohorovičić discontinuity, the boundary between the Earth's crust and the mantle.

monadnock. An isolated erosional remnant rising above the surrounding landscape.

mylonite. A compact, chertlike rock with a streaky or banded structure produced by the extreme granulation or shearing of rocks that have been pulverized or rolled during intense dynamic metamorphism.

normal fault. A dip-slip fault in which the hanging wall moves down relative to the footwall.

obduction. The process by which the crust is thickened by thrust faulting at a convergent margin.

oceanic crust. The Earth's crust formed at spreading ridges that underlies the ocean basins. Oceanic crust is 6 to 7 km (3 to 4 miles) thick and generally of basaltic composition.

orogeny. A mountain-building event.

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

Pangaea. A theoretical, single supercontinent that existed during the Permian and Triassic periods.

parent rock. The original rock from which a metamorphic rock was formed. Can also refer to the rock from which a soil was formed.

passive margin. A margin where no plate-scale tectonism is taking place; plates are not converging, diverging, or sliding past one another. An example is the east coast of North America. (also see "active margin").

pegmatite. An exceptionally coarse-grained igneous rock, with interlocking crystals, usually found in irregular dikes, lenses, and veins, especially at the margins of batholiths.

permeability. A measure of the relative ease with which fluids move through the pore spaces of rocks or sediments.

phenocryst. A coarse crystal in a porphyritic igneous rock.

phyllite. A metamorphosed rock with a silky sheen, intermediate in composition between slate and mica schist.

plastic. Capable of being deformed permanently without rupture.

pluton. A body of intrusive igneous rock.

plutonic. Describes igneous rock intruded and crystallized at some depth in the Earth.

porphyry. porphyry. An igneous rock consisting of abundant coarse crystals in a fine-grained matrix.

porphyritic. An igneous rock characteristic wherein the rock contains conspicuously large crystals in a fine-grained groundmass.

provenance. A place of origin; specifically, the area from which the constituent materials of a sedimentary rock or facies were derived.

pyroclastic. Describes clastic rock material formed by volcanic explosion or aerial expulsion from a volcanic vent; also pertaining to rock texture of explosive origin. In the plural, the term is used as a noun.

radioactivity. The spontaneous decay or breakdown of unstable atomic nuclei.

radiometric age. An age in years determined from radioactive isotopes and their decay products.

recharge. Infiltration processes that replenish ground water.

regolith. General term for the layer of rock debris, organic matter, and soil that commonly forms the land surface and overlies most bedrock.

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

relative dating. Determining the chronological placement of rocks, events, or fossils with respect to the geologic time scale and without reference to their absolute age.

reverse fault. A contractional high-angle (greater than 45°) dip-slip fault in which the hanging wall moves up relative to the footwall (also see "thrust fault").

rift valley. A depression formed by grabens along the crest of an oceanic spreading ridge or in a continental rift zone.

sand. A clastic particle smaller than a granule and larger than a silt grain, having a diameter in the range of 1/16 mm (0.0025 in) to 2 mm (0.08 in.).

sandstone. Clastic sedimentary rock of predominantly sand-sized grains.

saprolite. Soft, often clay-rich, decomposed rock formed in place by chemical weathering.

scarp. A steep cliff or topographic step resulting from displacement on a fault, or by mass movement, or erosion.

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

sedimentary rock. A consolidated and lithified rock consisting of clastic and/or chemical sediment(s).

sequence. A major informal rock-stratigraphic unit that is traceable over large areas and defined by a major sea level transgression-regression sediment package.

shale. A clastic sedimentary rock made of clay-sized particles that exhibit parallel splitting properties.

silicate. A compound whose crystal structure contains the SiO_4 tetrahedra.

sill. A tabular, igneous intrusion that is concordant with the country rock.

silt. Clastic sedimentary material intermediate in size between fine-grained sand and coarse clay (1/256 to 1/16 mm [0.00015 to 0.002 in]).

siltstone. A variably lithified sedimentary rock composed of silt-sized grains.

slope. The inclined surface of any geomorphic feature or rational measurement thereof. Synonymous with gradient.

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

soil. Surface accumulation of weathered rock and organic matter capable of supporting plant growth and often overlying the parent material from which it formed.

spring. A site where water issues from the surface due to the intersection of the water table with the ground surface.

strata. Tabular or sheetlike masses or distinct layers of rock.

stratigraphy. The geologic study of the origin, occurrence, distribution, classification, correlation, and age of rock layers, especially sedimentary rocks.

stream. Any body of water flowing under gravity in a clearly confined channel.

stream channel. A long, narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.

stream terrace. One of a series of level surfaces in a stream valley, flanking and more or less parallel to the present stream channel. It is above the level of the stream and represents the dissected remnants of an abandoned floodplain, streambed, or valley floor produced during a former stage of erosion or deposition.

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

strike-slip fault. A fault with measurable offset where the relative movement is parallel to the strike of the fault. Said to be "sinistral" (left-lateral) if relative motion of the block opposite the observer appears to be to the left. "Dextral" (right-lateral) describes relative motion to the right.

structural geology. The branch of geology that deals with the description, representation, and analysis of structures, chiefly on a moderate to small scale. The subject is similar to tectonics, but the latter is generally used for the broader regional or historical phases.

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

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 the Earth's surface.

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

syncline. A downward curving (concave up) fold with layers that dip inward; the core of the syncline contains the stratigraphically-younger rocks.

synclinorium. A composite synclinal structure of regional extent composed of lesser folds.

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

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

terrace. A relatively level bench or steplike surface breaking the continuity of a slope (see "marine terrace" and "stream terrace").

terrane. A large region or group of rocks with similar geology, age, or structural style.

terrestrial. Relating to land, the Earth, or its inhabitants.

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

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

trace (fault). The exposed intersection of a fault with Earth's surface.

transgression. Landward migration of the sea as a result of a relative rise in sea level.

trend. The direction or azimuth of elongation of a linear geologic feature.

tuff. Generally fine-grained igneous rock formed of consolidated volcanic ash.

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.

volcanic. Related to volcanoes. Igneous rock crystallized at or near the Earth's surface (e.g., lava).

volcanic arc. A frequently curved, linear, zone of volcanoes above a subduction zone.

water table. The upper surface of the saturated zone; the zone of rock in an aquifer saturated with water.

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

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Appendix A: Geologic Map Graphic

The following page is a snapshot of the geologic map for Kings Mountain National Military Park. For a poster-size PDF of this map or for digital geologic map data, please see the included CD or visit the Geologic Resources Inventory publications Web page (http://www.nature.nps.gov/geology/inventory/gre_publications.cfm).

Appendix B: Scoping Summary

The following excerpts are from the GRI scoping summary for Kings Mountain National Military Park. The contact information and Web addresses in this appendix may be outdated. Please contact the Geologic Resources Division for current information.

Executive Summary

A geologic resources inventory workshop was held for Kings Mountain NMP (KIMO) on September 19, 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), NPS Kings Mountain NMP and United States Geologic Survey (GS), South Carolina GS, and North Carolina GS staff were present for the workshop.

This involved a half-day field trip to view the geology of the Kings Mountain NMP area led by Wright Horton (USGS) 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 Kings Mountain NMP 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.

Because of the potential for future expansion and the presence of other state land managing agencies as adjacent neighbors, the general consensus of KIMO staff was that they would like to have geologic maps completed for the following four quadrangles of interest to KIMO: Grover, Kings Mountain, Kings Creek, and Filbert.

Overview of Geologic Resources Inventory

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

A demonstration was presented of some of the main features of the digital geologic map for the Black Canyon of the Gunnison NP and Curecanti NRA in Colorado. 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 GRI (Geologic Resources Inventory) 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.

During the scoping session, each park is presented with a compiled, park specific geologic bibliography as compiled by GRI staff. The sources for this compiled information are as follows:

- AGI (American Geological Institute) GeoRef
- USGS GeoIndex
- ProCite information taken from specific park libraries

These bibliographic compilations are then validated by NPS staff to eliminate duplicate citations and typographical errors, and check for applicability to the specific park. After validation, they become part of a Microsoft Access database parsed into columns based on park, author, year of publication, title, publisher, publication number, and a miscellaneous column for notes.

From the Access database, they are exported as Microsoft Word Documents for easier readability, and eventually turned into PDF documents. They are then posted to the GRI website at: http://www2.nature.nps.gov/grd/geology/gri/products/geobib/ for general viewing.

Attendees

Erin Broadbent (KIMO Superintendent)
Tim Connors (Geologic Resources Division-GRI)
Chris Revels (KIMO, Chief Ranger)
Wright Horton (USGS, Geologist)
Scott Howard (SCGS, Geologist)
Bill Clendenin (SCGS, State Geologist)
Carl Merschat (NCGS, Geologist)
Kenny Bochniak (KIMO, exotic species specialist)
Bert Dunkerly (KIMO, Interpretation)

Geologic Mapping

Existing Geologic Maps

Wright Horton (USGS) has done extensive 1:24,000 mapping (both as dissertation and other unpublished work not quite ready for prime-time) of two of the four quadrangles of interest to KIMO (the Grover and Kings Mountain quadrangles) and reconnaissance mapping of the [third] Filbert quadrangle. Additionally, he says that the [fourth] Kings Creek quadrangle has been reconnaissance mapped by MS students from universities, but their work is preliminary at best.

Additionally, the USGS has published the Charlotte 1x2 degree sheet (scale 1:250,000 scale; USGS Map I-1251-E) as a small-scale map for the area in general, and USGS Professional Paper 1462 on the “Mineral Resources of the Charlotte 1x2 degree Quadrangle, NC and SC”, as well as a few other miscellaneous topical publications related to Kings Mountain.

Digital Geologic Map Coverage

Wright believes his Grover and Kings Mountain quadrangles are acceptable for digitization and even publishing as GQ maps, given some more of his time to refine map unit descriptions and general “house-cleaning” on these quadrangles.

He would like to see these maps digitized (with his oversight and guidance), assuming USGS management can be convinced that it is a good use of his time to work on this project. If necessary, the NPS staff, SCGS and NCGS are willing to write letters to request Wright’s assistance in this process. At present, it is believed that GRI funds could be used to fund this digitization by the USGS staff in Reston, VA.

As for the other two southern quadrangles (Kings Creek and Filbert), given the amount of clean-up necessary to make them useful, it was suggested to have the SCGS finish production on these quadrangles (both mapping and digitization), and to pursue GRI funding of this venture in conjunction with the SCGS. Details will need to be worked out in the upcoming months. To cut costs, it was suggested to pursue KIMO park housing for whoever may end up mapping the quadrangles.

Other Desired GIS Data

Soils maps are also of interest to KIMO staff. Tim Connors will check with Pete Biggam (NPS-Soil Scientist) on the status of soils mapping for the numerous counties in the area (Cherokee, York, Cleveland, and Gaston Counties); will require more follow-up.

Chris Revels is interested in producing a wetlands map with WRD for KIMO; needs follow-up.

Interpretation

Chris would like to see an interpretive exhibit produced that discusses the various rock types present in the park, their origins, and their significance to the physiography of KIMO and the Piedmont in general. Additionally, because of the rich mining history of the region, and specific mine features in KIMO, a display featuring the history of mining would also be desired at the Visitor Center. Both of these would contribute to both the cultural and natural history of KIMO.

The number of rock types (ashes, limestones, conglomerates) in such small area tell a good story about the geology and tectonics and should be somehow translated to the general public in terms they can understand.

Miscellaneous

SCGS is interested in seeing about the availability of park housing while mapping the area to cut down on travel time and such; needs follow-up.

Kings Mountain National Military Park

Geologic Resources Inventory Report

Natural Resource Report NPS/NRPC/GRD/NRR—2009/129

National Park Service
Acting Director • Dan Wenk

Natural Resource Stewardship and Science
Associate Director • Bert Frost

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 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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