National Park Service
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Natural Resource Program Center

Gettysburg National Military Park & Eisenhower National Historic Site

Geologic Resources Inventory Report

Natural Resource Report NPS/NRPC/GRD/NRR—2009/083

THIS PAGE:
North Carolina State Monument (NPS Photo)

ON THE COVER:
Gettysburg NMP, looking toward Cemetery Ridge

Cover photo by Bill Dowling, courtesy of the Gettysburg Foundation

Gettysburg National Military Park and Eisenhower National Historic Site Geologic Resources Inventory Report

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Natural Resource Program Center
P.O. Box 25287
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Executive Summary

This report accompanies the digital geologic map for Gettysburg National Military Park and Eisenhower National Historic Site in Pennsylvania, 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 designations of Gettysburg National Military Park and Eisenhower National Historic Site are synonymous with national pride, sacrifice, and unity. Efforts to commemorate the American Civil War battlefield at Gettysburg began almost immediately following the three-day battle in 1863. The beauty of the surrounding landscape inspired Dwight D. Eisenhower to settle here in 1951. In addition to cultural and historic significance, these two units preserve and protect abundant natural resources.

The military park and historic site are within the Gettysburg basin between the Piedmont Plateau and Blue Ridge physiographic provinces. The Gettysburg basin is one of a series of northeast-southwest trending Mesozoic-age extensional basins that fringe the length of the eastern side of the Appalachian Mountains. The geologic units in this province are relatively young, gently dipping, and undeformed in contrast to the rocks to the east and west. The rocks in the basin include sedimentary sandstones, siltstones, and shales intruded by igneous sills, dikes, and irregular igneous bodies.

The primary geologic issues facing resource managers at Gettysburg National Military Park and Eisenhower National Historic Site are preserving the historic context of the landscape in a way that is harmonious with natural resource protection and preventing negative impacts from surrounding development. Because geology provides the foundation of the entire ecosystem, these goals require knowledge of the geology and geologic processes active on the landscape. The following issues have a high level of management significance within the military park and/or historic site:

- Issues with Surrounding Development
  Local populations are steadily increasing. Anthropogenic impacts include pipelines, power lines, roads, buildings, industrial waste, invasive species, acid rain, and air and water pollution. Knowledge of the hydrogeologic system in the area is important for resource management in order to better predict ecosystem response to changing inputs and extreme conditions.
- Geologic Hazards
  Geologic hazards in the area include seismicity, arsenic contamination, and radon gas. Earthquakes are associated with local faults as well as the Lancaster Transverse seismic zone. Seismic shaking could damage historic resources and dislodge boulders on slopes. Arsenic is a natural component of the black, pyretic shales underlying the area. Weathering of these shales could release arsenic into the groundwater system. Other rock units contain radioactive components that release radon gas into the substrate. This gas concentrates in basements and low-lying areas. Regular sampling of arsenic in groundwater in addition to radon gas in unlined basements and foundations in park buildings would locate any problem areas in need of remediation.

Secondary geologic issues for management at Gettysburg National Military Park and Eisenhower National Historic Site include disturbed lands, slope processes, and paleontological resources. Disturbed lands include several local active quarries in addition to historic excavation within NPS boundaries. The extraction of mineral resources is relevant to the history of the area and could be an interpretive target. Geologic processes are constantly changing the landscape at the military park and historic site. Erosion naturally diminishes higher areas, distorting the historical context of the landscape. Deforested fields and clearings are more susceptible to erosion, especially on slopes. Geologic formations within the two units contain fossil resources. An inventory of fossil resources will add to the understanding of the geologic history of the greater Gettysburg area.

In addition to their influence on the physical landscape, geologic features and processes dictated the history of the Gettysburg area. The campaigns leading up to the battle used topographic features such as the Blue Ridge, Cashtown Gap, Turners Gap, and the Great Valley to transport troops and conceal strategic movements. During the battle, ridges and low hills underlain by resistant igneous diabase and sandstone, respectively, played pivotal roles in the outcome of the three-day struggle. Later, Dwight D. Eisenhower would transform a collection of small farms into a country retreat and successful agricultural operation taking advantage of the area's fertile soil and gently undulating landscape.

Within the Gettysburg basin, geologic surface exposures consist primarily of Late Triassic to Early Jurassic conglomerates, sandstones, and shales of the New Oxford and Gettysburg formations. Deposited in an extensional basin formed after the major mountain building events of the Appalachians, these geologic units hold clues to the geologic history of the area.

Introduction

The following section briefly describes the National Park Service Geologic Resources Inventory and the regional geologic setting of Gettysburg National Military Park and Eisenhower National Historic Site.

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 innovative Geographic Information Systems (GIS) Data Model. These digital data sets bring an exciting 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/).

Geologic Setting

In the area of Gettysburg National Military Park and Eisenhower National Historic Site, the eastern United States is divided into 5 physiographic provinces with associated local subprovinces. These provinces are, from east to west, the Atlantic Coastal Plain, the Piedmont, the Blue Ridge, the Valley and Ridge, and the Appalachian Plateaus (fig. 1). The two NPS units are part of the Piedmont physiographic province, which encompasses the Fall Line westward to the Blue Ridge Mountains. The Fall Line is a significant geographical and geological location that separates the Coastal Plain and Piedmont provinces; rapids and waterfalls in the rivers and streams that cross the Fall Line clearly mark this boundary. The eastward-sloping Piedmont Plateau formed through a combination of folds, faults, uplifts, and erosion. The resulting landscape is a series of gently rolling hills starting at 60 m (200 ft) in elevation becoming gradually steeper and higher (300 m [980 ft] above sea level) toward the western edge of the province. The Piedmont Plateau is composed of hard crystalline, igneous, and metamorphic rocks such as schists, phyllites, slates, gneisses, and gabbros.

More specifically, Gettysburg is located in a Triassic rift basin superposed on the Piedmont as part of the Triassic Lowland section also known as the Gettysburg-Newark Lowland section (see fig. 1). The Gettysburg basin is one of a series of basins that intermittently fringe the boundary between the Blue Ridge and Piedmont along the length of the Appalachian Mountains from Nova Scotia to South Carolina—a distance of 2,000 km (1,200 mi). The basin formed during the Mesozoic Era as an intermountain basin during a tensional tectonic event. It trends northeast-southwest and is about 225 km (140 mi) long, 6–50 km (4–30 mi) wide, and 5 km (3 mi) deep. The rocks in the basin are mostly gently dipping sedimentary sandstones, siltstones, and shales with igneous intrusive diabase sills, dikes, and irregular igneous bodies, as well as basalt flows.

A depositional contact and topographic change define the boundary between the Gettysburg basin and the Piedmont Plateau; the rolling hills of the Piedmont change to relatively flat ground in the basin. A normal fault system sharply delineates the western boundary of the basin, west of which lies the Blue Ridge province (fig. 2). The sedimentary strata within the basin dip towards the western border fault.

Gettysburg National Military Park

The commemoration of the Battle of Gettysburg began almost immediately after the Civil War battle took place on July 1–3, 1863. The battle is widely considered the turning point in the struggle to maintain national unity.

This battle caused 51,000 casualties and inspired President Abraham Lincoln's most famous address. Established on February 11, 1895, and transferred to the National Park Service from the War Department on August 10, 1933 (during President Franklin Delano Roosevelt's administration), the park covers almost 2,430 ha (6,000 ac) of battleground, farms, forests, hillsides, and riparian areas. Adjoining the battlefield is a national cemetery with more than 7,000 interments dating back to October 1863. The park also contains the commemoration of the great battle by Civil War veterans.

Gettysburg is located 24 km (15 mi) east of South Mountain. This ridge rises to 610 m (2,000 ft) above sea level and dominates the western viewshed. The landscape within the park contains rolling hills and valleys with elevations between 152 and 177 m (500 and 580 ft). The underlying geology influenced the battleground history of the area. Topographic high points include Big Round Top, Little Round Top, and Culps Hill along the southeastern side of the battlefield (fig. 3). These rise some 40–60 m (140–200 ft) above the surrounding landscape. Seminary Ridge, on the western side, forms a long, narrow north-south trending high ground only some 9–18 m (30–60 ft) above the adjacent pastoral fields. The area's major streams drain southward with Rock Creek draining the eastern side of the battlefield. Tributaries of this stream include Stevens Run and Plum Run (fig. 3).

As per the park's 1999 general management plan/environmental impact statement, the National Park Service is responsible for rehabilitating the 1863 cultural and natural features that influenced the three-day battle fought there. A keen understanding of the geology of the area is vital to this effort. In the development of this plan, park staff thoughtfully considered the methods of landscape change to create the least amount of impact on natural resources including wetlands, riparian communities, and forested and grassland habitats.

Eisenhower National Historic Site

In 1967, two years before his death, General Dwight D. Eisenhower donated his 76-ha (189-ac) home to the National Park Service in order that it would become a national historic site. An act of Congress authorized the site on December 2, 1969, during the Johnson administration, to commemorate Eisenhower, the 34th president and World War II commander. Eisenhower's farm now sits amidst 280 ha (690 ac) of federally protected pastoral fields, meadows, riparian areas, and oak-hickory forest on the southwestern side of the Gettysburg battleground (figs. 3 and 4).

The rural, idyllic landscape at Eisenhower National Historic Site contains flat open fields and pastures dissected by rolling hills, forested areas, meadows, wetlands, riparian zones, vernal pools, and local stream valleys such as Marsh Creek and Willoughby Run. The geologic units at the site are generally flat lying and undeformed red shales, sandstones, and thin limestone beds with surface variations due to erosion and incising of rivers through these nearly horizontal layers. The westerly view from Eisenhower's farm includes Culp Ridge, Green Ridge, South Mountain, Jacks Mountain, and Piney Mountain (fig. 5).

The National Park Service preserves and protects the resources of Eisenhower National Historic Site, which involves an intimate knowledge of landscape evolution and continuing natural processes. As listed in the site's 2007 Centennial Strategy, the scope of the historic site is to rehabilitate the landscape to reflect the appearance at the time of the Eisenhower occupancy (http://www.nps.gov/gett/parkmgmt/upload/EISE_Centennial_Strategy.pdf).

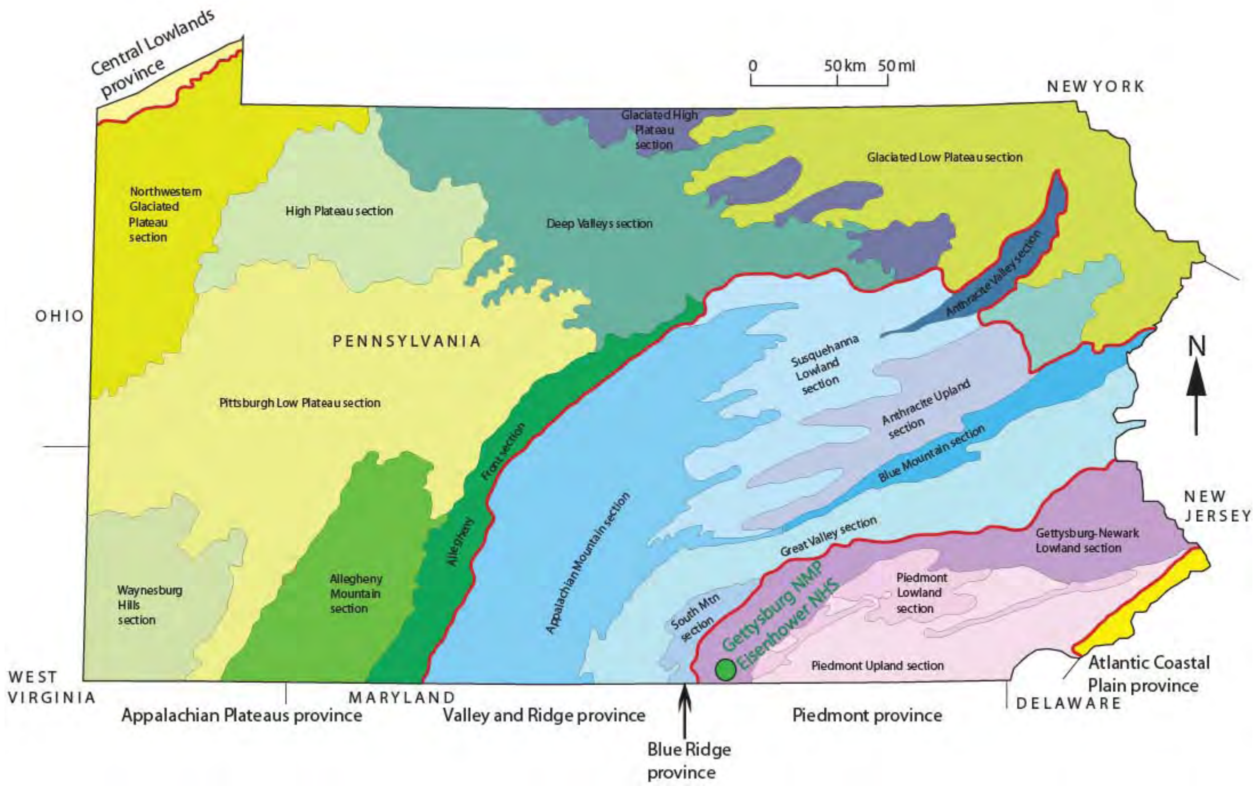

Figure 1. Physiographic Provinces of Pennsylvania. The map graphic shows the physiographic setting of Gettysburg National Military Park and Eisenhower National Historic Site. The green circle marks the location of the park and historic site. Red lines indicate boundaries between major physiographic provinces. The black arrow locates the northern terminus of the Blue Ridge province. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University) after Sevon (2000).

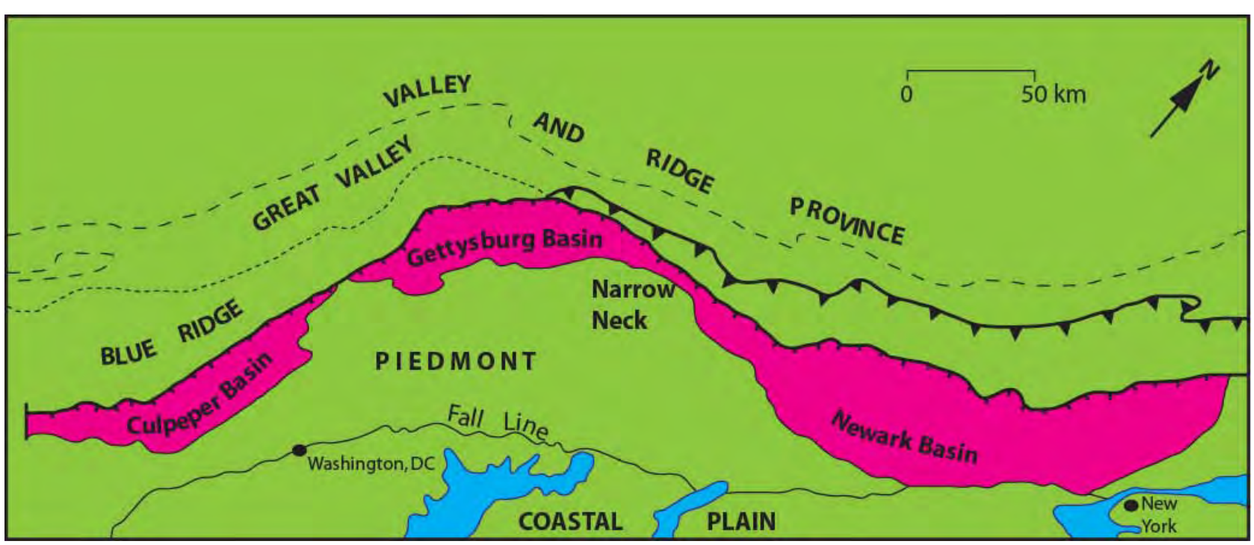

Figure 2. Mesozoic Rift Basins. The graphic shows Mesozoic rift basins related to the structural patterns along the East Coast. Note how the trend of the basins is roughly parallel to the overall geologic trend of the surrounding physiographic provinces. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University) after figure 1 in Root (1989).

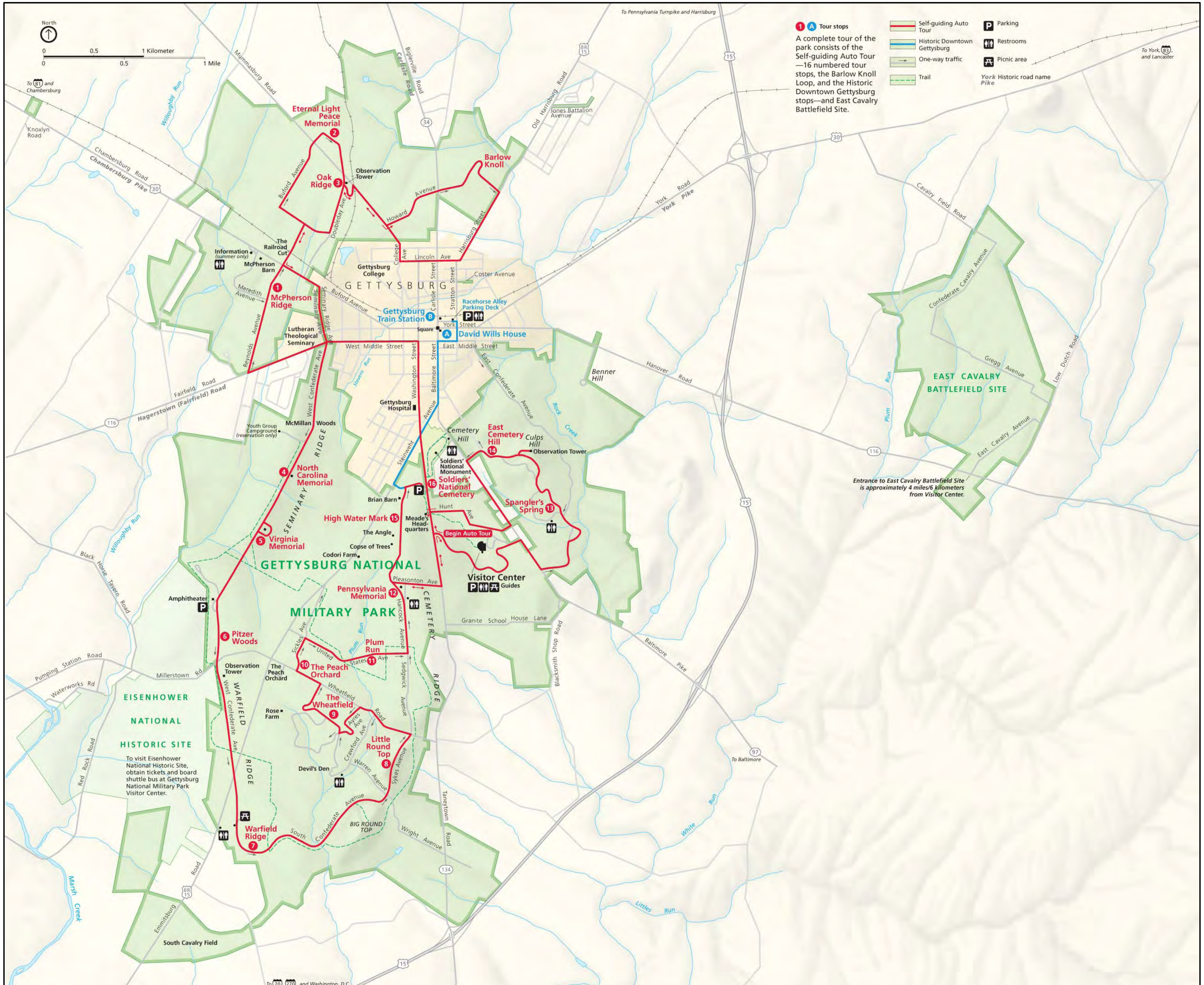

Figure3. Map of Gettysburg National Military Park and Eisenhower National Historic Site. NPS Map produced by the Harpers Ferry Center, April 2008.

Figure 4. Rendering of the Eisenhower Farm, Eisenhower National Historic Site. NPS Graphic created by the Harpers Ferry Center, April 2005.

Figure 5. Eisenhower National Historic Site. View is to the southwest from the observation tower at Gettysburg National Military Park. Photo by Andrew Maul.

Geologic Issues

A Geologic Resources Inventory scoping session was held for Gettysburg National Military Park and Eisenhower National Historic Site on June 23–24, 2004, to discuss geologic resources, address the status of geologic mapping, and assess resource management issues and needs. The following section synthesizes the scoping results, in particular those issues that may require attention from resource managers.

Introduction

This section discusses the management of natural resources at Gettysburg National Military Park and Eisenhower National Historic Site with the most critical topics listed first. Inventory, monitoring, and research suggestions discussed during scoping appear as part of appropriate sub-sections.

Surrounding Development

The population of the area surrounding Gettysburg is growing rapidly (figs. 6 and 7). Increasing populations and subsequent development in the area makes conservation of existing forest, wetland, and meadow community types a critical concern. Low-lying areas, including wetlands, accumulate peat and sediment that record climate, vegetation, and land-use changes. Because wetlands are indicators of overall ecosystem health, scoping participants suggested that park staff or cooperators research and periodically monitor this resource. The NPS Water Resources Division could assist in the development of appropriate wetland research and monitoring plans for the parks.

In rapidly growing areas that rely on limited groundwater aquifers as the primary water supply, developers need to consider the ramifications of potential contamination and the groundwater system's capacity for remediation (Svitana and Krissek 2005). The military park and historic site utilize groundwater and surface water resources as the public drinking water supply. The Gettysburg Municipal Authority is located on Marsh Creek, just north of the Eisenhower National Historic Site boundary. This particular system has seven wells and a surface water intake on Marsh Creek; it serves a population of approximately 12,000 people. The Adams County Watershed Alliance provides water quality testing of this system (http://www.nps.gov/eise/naturescience/). Recharge to the area's aquifers is through precipitation. The average annual precipitation from 1872–1993 at Eisenhower National Historic Site was 110 cm (43 in); however, only a portion of this eventually percolates into the groundwater supply (Low et al. 2000).

The hydrogeologic system is a significant factor in resource management decisions. The geology and hydrogeologic system beneath the biotic communities is vital to management. Management of the landscape for historic preservation at Gettysburg National Military Park and Eisenhower National Historic Site compliments the preservation of natural systems. Knowledge of how water is traveling through the subsurface hydrogeologic systems into, under, and from the military park and historic site is necessary to predict hydrologic responses to inputs such as contaminants. Further information about the nature of the underlying substrate, including structure, stratigraphy, composition, permeability and porosity, is obtainable with cores.

As available land around the Gettysburg area becomes scarcer, subsequent increase in property value may make the lands around the military park and historic site too expensive to consider attaining for federal inclusion. A listed goal in the military park's 2007 Centennial Strategy is to identify areas of land not currently in park possession that significantly contribute to the preservation and interpretation of the Battle of Gettysburg and to coordinate with partners or federal sources for the acquisition of these areas. Plans would then ensue to rehabilitate these areas in accordance with the park's 1999 general management plan (http://www.nps.gov/gett/parkmgmt/upload/GETT_Centennial_Strategy.pdf). The general management plan involved "the construction of a new museum and visitor center; the rehabilitation of the battlefield landscape to appearance at the time of the battle; preservation and protection of the park's collections of artifacts and archives; and providing high quality interpretative and educational opportunities for park visitors." In pursuance of these goals, the NPS dedicated the new visitor center in 2008. Cooperating with neighboring partners to mitigate impacts from surrounding development is vital to fulfilling park goals.

Anthropogenic impacts from surrounding development continue today as pipelines, power lines, roads, buildings, invasive species, acid rain, and air and water pollution take their toll on the landscape. Park infrastructure, trails, and visitor use areas also have impacts on park resources. Many roads including Business Route U.S. 15, State Highways 116, 34, and 97, as well as U.S. Highway 30 cross portions of the military park (Becher 1989). These roads increase the likelihood of introducing contaminants such as hydrocarbons, salts, roadside herbicides, and car waste into the local streams and aquifers. Monitoring the composition of system inputs such as rainfall and outputs such as streamflow improves modeling and understanding of the movement of nutrients and contaminants through the hydrogeologic system. Other input sources include wind, surface runoff, groundwater transport, sewage outfalls, landfills, and fill dirt. Streams in effect integrate the surface runoff and groundwater flow of their watersheds. Thus, they provide a cumulative measure of the status of the watershed's hydrologic system (Hickman 1987).

Consistent measurement of these parameters is crucial to establishing baselines for comparison as development occurs.

Nearby development and industrial sites such as the Westinghouse Elevator Plant (constructed in 1968) incurred local soil and groundwater contamination problems. The Westinghouse plant is now a Superfund site; its southern boundary is located adjacent to Gettysburg National Military Park. The manufacture of elevator and escalator components at the plant utilized solvents such as trichloroethene and 1,1,1-trichloroethane, in addition to lubricating oils, paints, and insulation board. Water and soil samples collected in 1983–1984 confirmed the presence of volatile organic compounds in on-plant and off-plant groundwater and soils.

A comprehensive description of this site and subsequent Environmental Protection Agency (EPA) involvement is part of an EPA record of decision (March 31, 1995). An earlier EPA record of decision, issued on June 30, 1992, selected extraction and treatment of groundwater, air stripping of contaminants from ground water, and carbon adsorption of contaminants as possible measures for remediation. In 1995, the EPA's selected remedy for the soils at the Westinghouse Elevator Plant was "No Additional Action" as considered alternatives would produce little or no environmental benefit at substantial cost (Environmental Protection Agency 1995). Military park personnel need to be aware of this contamination threat to the groundwater system and understand the potential mobility of these contaminants in soil. A keen understanding of the hydrogeologic system of Gettysburg is vital to this end.

In cooperation with the EPA, the U.S. Geological Survey detailed the hydrogeology and groundwater flow models at the Gettysburg Elevator Plant Superfund Site (Low et al. 2000). At this location, the groundwater system consists of two zones. The upper zone is thin and shallow, composed of soil, clay, and weathered regolith. The lower zone is fractured bedrock (siltstone, shale, and sandstone) with little to no weathering, and acts as a confined aquifer. Diabase dikes in the Gettysburg area are barriers to lateral groundwater flow within the lower zone. Water tends to flow from west to east towards Rock Creek with flow concentrated along dipping (23° NW) bedding and secondary near-vertical and horizontal openings and fractures. Findings indicate that some areal recharge (contaminated) onsite will still move to offsite extraction wells. The extraction system captures about 67% of the groundwater recharge at the contaminated site (Low et al. 2000).

This level of hydrogeologic detail and groundwater flow modeling would be very helpful for resource management at Gettysburg National Military Park and Eisenhower National Historic Site. Scoping participants suggested that park managers source this reference and promote similar hydrogeologic study across both park units to improve prediction of environmental response to contaminants. Understanding how the water tables might change over time is also important. The installation of several wells throughout the military park and historic site could be useful for monitoring of groundwater quality. Tracer studies in these wells could reveal the rate and direction of water movement through the systems.

Inventory, Monitoring, and Research Suggestions

- Consult with the NPS Water Resources Division to develop an appropriate wetland and groundwater quality monitoring strategy.
- Work with local developers to minimize impacts near park areas. This could involve education programs of environmentally sound methods of developing land parcels including only partial clearing of trees and construction only on stable slopes.
- Map and quantify water subterranean recharge zones especially in areas near wastewater treatment and septic systems. Use this information to create hydrogeologic models for the military park and historic site to better manage the groundwater resources and predict the system's response to contamination.
- Define the influences of underlying sedimentary strata, geologic structures, and topography on local watersheds.
- Consult and cooperate with local, state, and federal conservation groups regarding efforts to increase the areas of relevant parklands and protect more of the region from the adverse impacts of development.

Geologic Hazards

Seismicity

The Gettysburg basin is one of a series of many north-northeast trending, fault-bounded structural basins along the eastern edge of the Appalachian Mountains in the Piedmont Plateau physiographic province. This area experiences a low rate of seismic activity. Notable earthquakes in 1889, 1984, and 1994 were concentrated in the Lancaster Transverse seismic zone. This diffuse zone of epicenters in southeastern Pennsylvania trends roughly north-south for about 50 km (30 mi) and is among the most active zones in the eastern United States (Seeber and Armbruster 1985; Wise 1998; Scharnberger 2006). The zone crosses the narrow neck between the Gettysburg and Newark basins—an area of strong east-west oriented tensile stress (Scharnberger 2006).

The rupture plane of the 1984 earthquake (magnitude 4.1) runs at a high angle to the predominant northeast-trending structures, faults, and Jurassic basaltic dikes, which suggests a strong correlation (Seeber and Armbruster 1985). The 1994 event in Cacoosing Valley was a magnitude-4.6 earthquake near the northern end of the seismic zone (Wise and Faill 2002). Other earthquakes (magnitude 2.4 and 3.0) with accompanying aftershocks occurred in York County on June 16, 1997, and Lancaster County on November 13, 1997, respectively. Diffuse events such as these indicate that seismicity in this area is associated with a combination features including the margins of the Gettysburg basin, reactivated deeper detachment structures (possibly related to the Taconic orogeny), intrabasin small-scale faults, and igneous intrusion margins serving as stress concentrators (Wise 1998; Scharnberger et al. 1999; Wise and Faill 2002; Scharnberger 2006).

North-northeast trending faults and igneous dikes also cut the Gettysburg area. Seismic activity would threaten resources, cracking or damaging building foundations, disturbing rock fences, and dislodging boulders and other vulnerable rock outcrops. Sudden failure on slopes could threaten visitor safety and park infrastructure. Large seismic events are not beyond the realm of possibility in the region. During the past 400 years, approximately 90 large earthquakes (magnitude >6.0) have occurred in regions of relative tectonic stability (Scharnberger et al. 1999). Earthquakes associated with the Lancaster Transverse seismic zone are diffuse and not linked with discrete surficial features. This makes predictions of future earthquake locations and seismic risk assessment difficult for the region (Wise and Faill 2002). Resource managers need to be aware of the potential for seismic activity in the area and identify areas at risk of failure in the case of an earthquake.

Arsenic Contamination

Where bedrock containing local concentrations of certain elements (e.g., arsenic) is exposed to weathering and groundwater flow, contamination can occur naturally. Elevated concentrations of arsenic in groundwater spatially correlate with specific geologic units of the Gettysburg–Newark Lowland section. The high iron-oxide content of some rocks renders them susceptible to arsenic reductive desorption or dissolution. Some units contain black pyretic shales that may also release arsenic by pyrite oxidation (Burkert and Peters 2006). Park resource managers need to be aware of the potential for natural contamination of groundwater by arsenic released from black, pyretic shales.

Radon Gas

Radon, a gaseous product of radioactive decay, is present in the subsurface in the Gettysburg area. Radon is especially dangerous for dwellings with dirt foundations and basements. Basements constructed with a York Haven diabase lining appear to mitigate radon accumulation (Smith and Keen 2004).

Inventory, Monitoring, and Research Suggestions

- Promote the installation of radon detectors in park buildings and the surrounding community.
- Use GIS to compare bedrock geology to groundwater chemistry. Groundwater information is available from the U.S. Geological Survey and Pennsylvania Department of Environmental Protection.
- Perform regular sampling of arsenic in groundwater to locate any problem areas.
- Test for radon gas in unlined basements and foundations in park buildings and remediate with proper ventilation where needed.

Disturbed Lands and Mining

The rocks of the Gettysburg basin have attracted mining interest for well over a century. Several older quarries located within the park predate the Civil War; later development of the park and monuments utilized these quarries (GRI, scoping notes, 2004). The silty shale and mudstone of the Gettysburg Formation quarried for brick making provided early building materials to the community. The brick quarry northeast of the railroad cut, near U.S. Route 30, is now a fish pond (Hoff et al. 1987). This pond is not inside park boundaries. An old copper mine shaft is located in the basement of the Catholic Church in Gettysburg. The status of this feature including its jurisdiction is unknown (GRI, scoping notes, 2004). The National Park Service removed other disturbed lands that were once within the park including the Rock Creek dam and the mill pond (GRI, scoping notes, 2004).

Crushed stone and aggregate quarries are active outside park boundaries. Campbell's Quarry (also known as Teeter's Quarry) is located 3.6 km (2.2 miles) southeast of Center Square in Gettysburg. The entrance to this site is located on U.S. Route 140. This location contains a suite of quality zeolite minerals such as epidote (in vugs), magnetite, orthoclase (in vugs), albite, calcite, chabazite, hematite, titanite, tremolite, heulandite, laumontite, natrolite, quartz, sericite, stilbite, and pyrite. Weathering causes these minerals to become other attractive minerals such as bright green malachite, blue-green chrysocolla, red cuprite (and associated native copper), and goethite (Hoff 1978). The quarry is located in a contact-metamorphosed section of the Gettysburg Formation. Heating of this area occurred during emplacement of the large Gettysburg diabase sill (Hoff 1978). Collectors go to Campbell's Quarry in search of interesting mineral specimens. Zeolite minerals and vuggy hornfels also attract collectors to Valley Industries' Gettysburg Quarry on the base of South Mountain, facing the Gettysburg battlefields (Downs 2001). The rocks quarried in the area are also located within Gettysburg National Military Park, which may pose a resource management issue if demand increases.

Mineral specimens are non-renewable resources that require park protection. Collecting, rockhounding, and gold panning of rocks, minerals, and paleontological specimens, for either recreational or educational purposes is generally prohibited in all units of the National Park System (36 C.F.R. § 2.1(a) and § 2.5(a)). Violators of this prohibition are subject to criminal penalties.

Inventory, Monitoring, and Research Suggestions

- Identify stones used for historic buildings to incorporate into an interpretive theme.
- Highlight the local brick making history in the area as part of an interpretive story about historic land use.
- Monitor accessible mineral resources within the park to prevent commercial and or casual collecting and educate visitors about regulations protecting these resources.

Erosion, Slope Processes, and Flooding

One of the major goals of the military park and historic site is to present the historical context of their respective areas; this includes preserving open battlefield and agricultural areas as well as restoring and preserving any old buildings and the landscapes around them. Maintaining cultural resources and historic landscapes often means working against natural geologic changes, which presents several resource management challenges. Even slight alterations to vegetation along steep, exposed slopes lead to changes in the hydrogeologic regime and geomorphic processes. At Gettysburg National Military Park, recent efforts to restore the historic landscape include tree removal (V. L. Santucci, written communication, November 22, 2008). Targeted monitoring of erosion in these areas would provide useful data for mitigating adverse impacts to the archaeological resources associated with the battle and to better understand hydrogeologic changes.

Geologic processes such as landsliding, slumping, chemical weathering, freeze-thaw cycles, rain and surface sheet flow, and slope creep are constantly changing the landscape at the military park and historic site. Runoff erodes sediments from open areas and carries them down streams and gullies such as Rock Creek, Plum Run, Stevens Run, Marsh Creek, and Willoughby Run (fig. 8). Erosion naturally diminishes higher areas such as ridges and hills, undermines building foundations, degrades bridge foundations, erodes streams, and fills low areas such as trenches, ditches, and ravines distorting the historical landscape.

In general, the slopes surrounding the battlefields, monuments, pastures, and buildings at Gettysburg National Military Park and Eisenhower National Historic Site are moderate and partially forested. Many of the features with steeper slopes within the battlefield such as Little Round Top, Round Top, and Culps Hill are composed of resistant igneous rock formations, but have loose blocks and boulders on their flanks (fig. 9). Heavy runoff of seasonal thunderstorms and freeze-thaw events may dislodge these blocks, creating rockfall hazards and areas of slumping.

In contrast to the slopes of Little Round Top, the topographic expression at Eisenhower National Historic Site is more gentle and muted. However, slopes at the historic site are still prone to gullying and erosion from runoff into local streams.

Geologic hazards include slumping and slope creep. Much of the underlying substrate contains loose, rounded, reworked sediments derived from the Gettysburg Formation and its shale-rich Heidlersburg Member. Clay-rich shale units may slip or swell in wet conditions. These units can be prone to fail when exposed on even moderate slopes, resulting in a slide or slump. Shrink-and-swell clays (swell when wet, shrink upon drying) undermine the stability of the ground by their change in volume. When relatively resistant geologic units such as sandstone or limestone are located above clay-rich units, the potential for large slump development exists. The clearing of trees and their stabilizing roots for historical restoration or by fire can lead to increased sediment load in nearby streams and could potentially contribute to slumps and landslides. Hiking trails and other high-use areas are also at risk of erosion.

Flooding is also a concern at Gettysburg National Military Park and Eisenhower National Historic Site where the inherent stream migration may degrade the cultural landscape. Flooding and channel erosion are naturally occurring along small streams within the military park and historic site. This flooding and erosion threatens wetlands and visitor facilities. As erosion increases so does the sediment load carried by the local streams and rivers.

Inventory, Monitoring, and Research Suggestions

- Study erosion rates and processes in the rolling hills, ravines, and fields of the area to relate to the overall sediment budget of the Rock Creek watershed.
- Identify and create a vulnerability index for any slopes prone to fail during intense storm events.
- Determine if historic features are at risk due to slope processes at Gettysburg National Military Park and Eisenhower National Historic Site.
- Perform sediment load studies and relate to aquatic ecosystem health to determine if increased erosion is negatively affecting aquatic biota in the area’s streams.
- Monitor the development of social trails and evaluate the potential for increased erosion.

Paleontological Resources

Fossils are the remains of past life preserved in a geologic context. Studying these remains adds to the understanding of the geologic history of the Gettysburg basin. Certain fossils are useful to correlate units across time and space. Others give clues as to the depositional environment they inhabited. Still others provide post-burial information, including geochemical changes, deformational regimes, and changes in bedding orientation. Fossil resources are nonrenewable resources and when present must be carefully inventoried and protected. Gettysburg National Military Park is an example of a “cultural park” with natural resource management challenges that include managing paleontological resources (Santucci and Hunt 1995).

Investigators have not conducted a formal field study of paleontological resources in the military park or historic site. A paleontological resource inventory, compiled from literature, exists for Gettysburg National Military Park and Eisenhower National Historic Site (see Kenworthy et al. 2006). Paleontological resources are present within the building stones of historic structures and monuments at the military park and historic site and merit resource-management attention.

Fossils are rather rare in the Gettysburg basin. However, the geologic units located in the Gettysburg National Military Park and Eisenhower National Historic Site area contain microfossils, invertebrates, plants, fossil pollen, and various invertebrate and vertebrate trace fossils

(Kenworthy et al. 2006). Notable finds include Upper Triassic dinosaur footprints, remains of phytosaur reptiles, and metoposaurid amphibians (Hoff 1978). Two capstones, quarried locally (outside park boundaries), on the bridge over Plum Run show casts of reptile footprints from a *Coelophysis*-like dinosaur (figs. 10–12) (Hoff et al. 1987). Park files, based on 1930s interpretations, identify the tracks as *Grallator* and *Anchisauripus*; however, recent interpretations identify the tracks representing the ichnogenus *Atreipus*, ichnospecies *A. mil-fordensis* (Santucci and Hunt 1995). Studies of tracks like these provide much information about behavior, locomotion, and paleoecology in Earth's past (Santucci and Hunt 1995).

The rocks of two local quarries—the Trostle Quarry in Adams County, and another quarry near Goldsboro in York County—host dinosaur tracks (Santucci and Hunt 1995). Similar Triassic and Jurassic sedimentary rocks deposited in the Gettysburg basin crop out within both the military park and historic site (figs. 13 and 14). Erosion is constantly exposing fossils in outcrop exposures.

The federal government, veterans, and families of veterans who participated in the battle have erected more than 1,400 commemorative monuments, markers, and tablets at Gettysburg National Military Park. Some of the regimental monuments contain stone quarried from the regiment's home state. At least 10 of these monuments contain limestone or marble and as such may be fossiliferous (Kenworthy et al. 2006). One of the most famous monuments on the battlefield is the Peace Memorial dedicated in 1938 at the 75th anniversary of the battle and last veteran reunion at Gettysburg. Portions of this memorial contain fossiliferous Mississippian Rockwood Limestone from Franklin County, Alabama. Likewise, the 14th Indiana Infantry Monument contains rocks from the Mississippian Salem Formation from Bedford, Indiana. Fossils include foraminifera, crinoid columnals, the bryozoan *Archimedes*, and various shells (figs. 15 and 16) (Kenworthy et al. 2006; V. L. Santucci, written communication, November 22, 2008).

These exposures and monuments may contain fossils that are attractive to collectors. Fossil theft and degradation would be a concern to any in situ paleontological resources or those in historic monuments and structures at the military park and historic site.

Inventory, Monitoring, and Research Suggestions

- Perform a comprehensive onsite inventory of fossils resources at the military park and historic site.
- Attempt to locate any samples removed from parklands and curate them into onsite collections.
- Monitor specific paleontological outcrops as erosion and slope processes expose fossils.
- Develop an interpretive program that incorporates the fossil story along with the geologic history of the area; discusses the inevitability of resource change due to natural processes to educate the public on resource management at the military park and historic site.
- Develop a plan to protect fossil resources from degradation and theft.

Figure 6. Aerial View of Gettysburg National Military Park and Surrounding Developments. View is to the northwest. Photograph is courtesy of the National Park Service.

Figure 7. Detailed Aerial View of Gettysburg National Military Park. The cyclorama exhibit is the circular building to the left; the visitor center is behind, in the trees. The observation tower to the right overlooks the cemetery. Photograph is courtesy of the National Park Service.

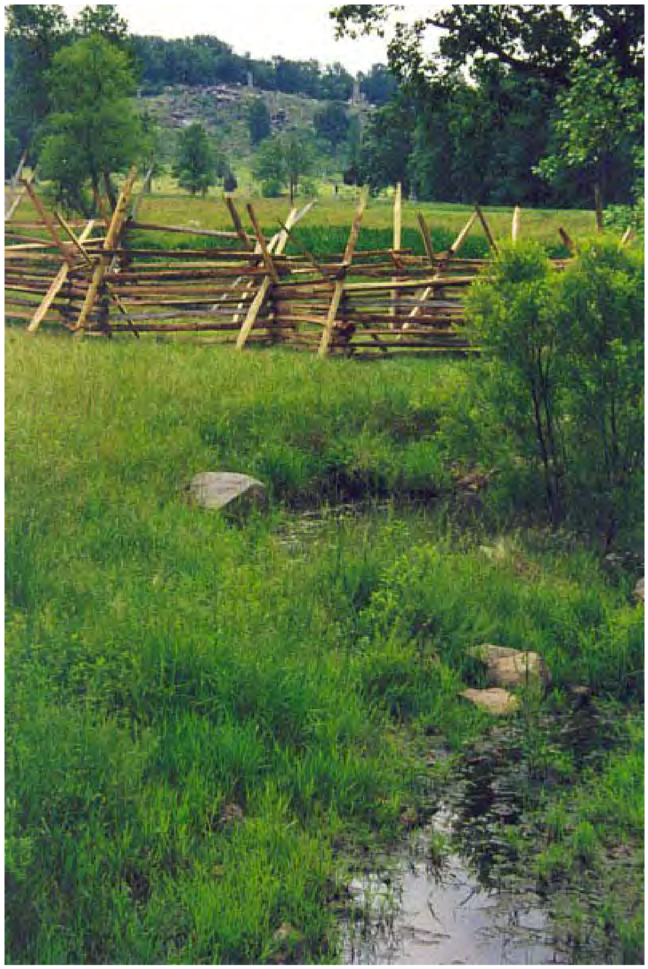

Figure 8. Plum Run Traversing Gettysburg Battlefield. Riparian habitat flanks the battlefield. View is to the southeast with Little Round Top in the background. Photograph by Katie Lawhon courtesy of the National Park Service

Figure 9. Little Round Top in Winter. Loose, rounded diabase boulders cover the slopes. Photograph by John Heiser courtesy of the National Park Service

Figure 10. Dinosaur Tracks. Paleontological resources at Gettysburg National Military Park include the trace fossil *Atreipus milfordensis*. Image provided by Vince Santucci (National Park Service).

Figure 11. Dinosaur Tracks. The ichnospecies *Atreipus mil-fordensis* dons the Bridge on South Confederate Avenue. Image provided by Vince Santucci (National Park Service).

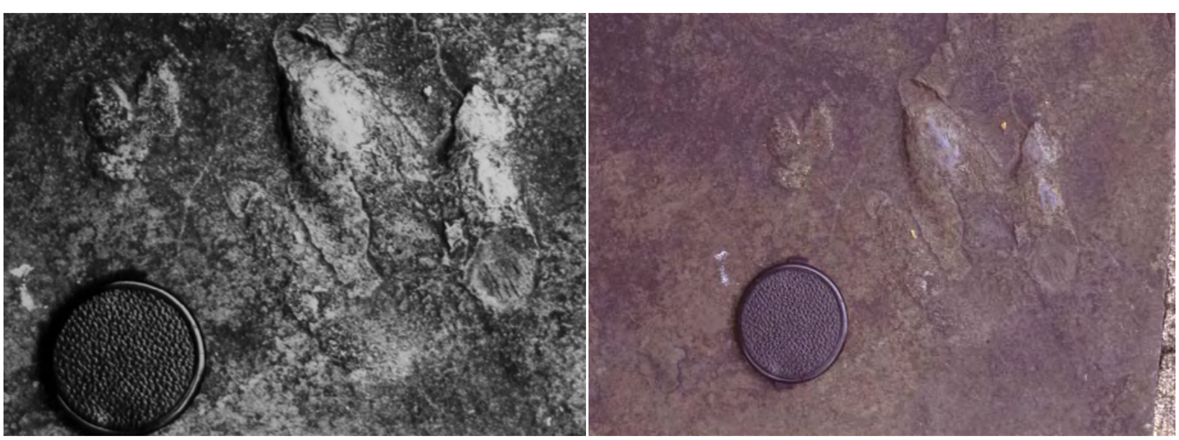

Figure 12. Dinosaur Tracks from the Bridge on South Confederate Avenue. Images provided by Vince Santucci (National Park Service).

Figure 13. Exposed Sedimentary Strata. Exposed strata from the Gettysburg basin at Gettysburg National Military Park may contain fossil resources. Image provided by Vince Santucci (National Park Service).

Figure 14. Exposed Sedimentary Strata. The railroad cut in Gettysburg National Military Park exposes strata from the Gettysburg basin. Image provided by Vince Santucci (National Park Service).

Figure 15. Peace Memorial at Gettysburg National Military Park. A portion of the memorial is constructed of limestone from Indiana. Image provided by Vince Santucci (National Park Service).

Figure 16. Fossil Remains. The limestone of the Peace Memorial at Gettysburg National Military Park hosts marine fossils such as bryozoans. Image provided by Vince Santucci (National Park Service).

Geologic Features and Processes

This section describes the most prominent and distinctive geologic features and processes in Gettysburg National Military Park and Eisenhower National Historic Site.

The diversity of geologic phenomena and historical influences in the Gettysburg National Military Park and Eisenhower National Historic Site area illustrate many geologic concepts in a learning environment. The concept of geologic time is readily accessible in the resistant rocks capping ridges and rift-basin sediments exposed in ravines and gullies within the parks. Rocks and their fossils indicate depositional environments and conditions of life in the distant past. Relating geology to human concerns such as floods, radon gas, slope failures, siltation, water pollution, waste management, and urban development would help make the science meaningful to park visitors (Nikitina 2003). Relating geology and geologic processes to the history of the Battle of Gettysburg and Eisenhower's legacy lends deeper meaning to the human history of the area.

Gettysburg Formation

Type sections refer to the originally described sequence of strata that constitute a geologic unit; they serve as an objective standard for comparison of spatially separated parts of that same unit. Preferably, a type section describes an exposure in an area of maximum unit thickness and completeness. The Gettysburg Formation (named in 1929 by Stose and Bascom) is the dominant geologic unit in the battlefield area. Its type locality is actually a composite of measured sections in and around Gettysburg, Adams County, Pennsylvania (http://ngmdb.usgs.gov/Geolex/NewUnits/unit_1784.html). The Late Triassic–Early Jurassic Gettysburg Formation conformably overlies the New Oxford Formation. The boundary between the two units, marked by increasing shale content, is somewhat arbitrary because the units are so similar lithologically. Within the Gettysburg basin, the Gettysburg Formation is 6,700 m (22,000 ft) thick with the uppermost 200 m (660 ft) being lowermost Jurassic in age (Root 1988).

The red, brown, and gray siltstone; red to yellowish brown shale; and reddish brown, fine to medium grained sandstone of the Gettysburg Formation along with a 610-m- (2,000-ft-) thick concordant diabase sill and two nearly vertical 15-m- (50-ft-) thick dikes form the bedrock framework below much of the Gettysburg area (Becher 1989; Low et al. 2000). A prominent middle member of the Gettysburg Formation, the Heidlersburg Member, is red shale with some green, gray, and black shale interbeds and gray to white calcareous sandstone (Low et al. 2000). The diabase intrusions are virtually impermeable until weathered and fractured. On the surface, these dense, massive bodies crop out as rounded boulders (Becher 1989).

The bedding planes (dipping 20° to the northwest), joints, and fractures near the surface of the Gettysburg Formation diabase bedrock framework contain a shallow water-table aquifer that is connected to deep, discontinuous tabular aquifers in underlying fractured beds (Becher 1989). Wells into these aquifers supply the drinking water to Gettysburg National Military Park and Eisenhower National Historic Site. Groundwater flow in this area is anisotropic parallel to the strike of depositional bedding in both the shallow and deep aquifers of the Gettysburg Formation and diabase dikes. Though not a significant source of recharge, some groundwater flows through intergranular pore spaces where carbonate cement has dissolved away (Becher 1989).

Rift basins are often favored sites for hydrocarbon accumulation. Geologists studied the Gettysburg Formation within the substantial Gettysburg basin for hydrocarbon potential. Sandstone layers throughout the sequence serve as potential reservoirs for hydrocarbon accumulation (Root 1988). The lenticular geometry of the bedding in concert with local geologic structures such as faults and folds provide structural and stratigraphic traps; however, compaction and cementation reduced sandstone porosity. Source-rock shales are generally geochemically "overmature;" that is, low in total organic carbon content and not producers of viable hydrocarbons (Root 1988).

Geology and Connections with History

Early Settlement

The history of the area and its geology are intimately tied. Long before the first settlers started farming here, the area's rivers and tributaries cut through the layered Triassic to Jurassic sedimentary rocks of the Gettysburg basin, forming the gently rolling landscape of hills, ridges, valleys, gullies, and ravines that characterize the area.

The earliest known evidence of human activity in the area is prehistoric quarrying of Proterozoic greenstones (Jones and Schlegel 2004). Approximately 12,500 years ago, during the Late Woodland Period, Native Americans quarried weapons-grade metarhyolite from the Cashtown Gap–South Mountain area (along present U.S. Route 30). Quarrying continued locally until Colonial contact (Smith and Keen 2004). Native Americans used this area to provide food, shelter, some tool material, and travel and trade routes along the basin lowlands.

European settlement began as early as 1736, when the family of William Penn purchased land from the Iroquois Indians; this land now comprises the center of Adams County. At that time, settlers, many of whom were Scots-Irish escaping English persecution in Northern Ireland, referred to the area as Marsh Creek after the main tributary. By 1761, Samuel Gettys established a tavern in the area and 25 years later, his son James laid out a town of 210 lots surrounding the tavern with a central town square (http://www.gettysburg.travel/history.asp). This family leant their name to the town—Gettysburg.

When local settlers first began their farming activities, vast, dense forests covered the landscape. Settlers cleared these forests for pasture and agriculture. Farming and homestead activities created an unnatural landscape that persists today at the military park and historic site. Minor irrigation features, removal of soil and rocks, stone fences, grazed pastures, extensive logging, and other homestead features dot the landscapes. This immediately changed the prehistoric landscape including forest size and shape, topographic expression, soil composition, species distribution, and drainage patterns.

Bituminous coal deposits from the Mesozoic rift-system basins, including the Newark-Gettysburg basin played an important role in the early economic history of the area. In the immediate Gettysburg area, these coal deposits are likely at great depths; therefore, early mining efforts focused elsewhere. These Late Triassic coal beds are faulted, steeply dug, with relatively high sulfur contents. Extraction of these coals was difficult and dangerous (Robbins et al. 1983; Robbins et al. 1988). At present, coal mining is not active in the area, although methane from these beds may be a future economic resource (Robbins et al. 1988).

Ore deposits within the Gettysburg basin include lead, zinc, skarn-magnetite, and copper (Krohn et al. 1985; Hoff et al. 1987). South Mountain, towering above the Gettysburg battlefield, was once home to several productive copper mines. Native copper is still attractive to collectors in the area (Downs 2001). The population surge for regional mining significantly affected the early development of the Gettysburg community.

Campaign and Battle of Gettysburg

Gettysburg was the first battle re-interpreted from a geologic perspective (Doyle 2006). Because the influence of geology on the military activity leading up to and during the Battle of Gettysburg is so obvious and important, many studies have focused on this topic. Inners et al. (2006) produced an excellent geologic guidebook for the battlefield. A short summary follows here.

The Battle of Gettysburg was the largest battle ever fought on American soil and proved a major turning point in the Civil War (1861–1865). The underlying geology and surface topography were major influences on the flow of the battle as well as its outcome (Cuffey et al. 2006). Skillful use of the terrain of the battlefield, including the transportation of supplies and personnel, maneuvering of troops, and procurement of adequate water and construction materials for field fortifications, relied on an understanding of geologic principles (Kiersch and Underwood 1998; Doyle 2006). Union and Confederate forces had access to geologic and topographic maps, and surveys and knowledge of science, including geology, was an asset in battle (Larson et al. 2004). Books on military geology as well as geology courses appeared at military academies in the United States during the 19th century (Kiersch and Underwood 1998). Today this concept of terrain analysis is still important in military strategy. Analyzing terrain from a military perspective has more or less remained the same since the 1860s and includes the following principles: (1) key terrain, (2) observation and fields of fire, (3) cover and concealment, (4) obstacles, and (5) avenues of approach (modern acronym KOCOA) (http://www.nps.gov/gett/parknews/gett-battlefield-rehab.htm).

The battle, fought in a 39-km^2 (15-mi^2) area, was a climax of a military campaign that covered an area of about 28,000 km^2 (11,000 mi^2) starting at Fredericksburg, Virginia, on June 3, 1863, and ending when the Confederate Army re-crossed the Potomac River on July 14 (fig. 17) (Brown 1961, 1962; Cuffey et al. 2004). In the weeks leading up to the three-day battle, Confederate and Union forces were moving northward from previous battles in eastern Virginia. The Confederate Army of Northern Virginia, under the leadership of Robert E. Lee, was using the Blue Ridge-Catoctin-South Mountain ridgeline as a shielding barrier, staying to the west of the ridge and marching in the wide, fairly level Great Valley. The high, narrow ridge is composed of tightly folded quartzites, gneisses, and metavolcanics. Union forces remained on the east side of the ridge and consequently were often unsure as to the contending army's whereabouts. The rocky roads of the Piedmont region east of the Blue Ridge were difficult to pass and this region was generally avoided (Brown 1962).

Faulting and erosion created gaps such as Chester, Ashbys, and Snickers in Virginia; Cramptons and Turners in Maryland; and Fairfield, Cashtown, and Carlisle in Pennsylvania. Because these were the only places where the armies could cross the mountains, they influenced the Gettysburg Campaign. Confederates used the gaps in Virginia to cross over into the Great Valley (Brown 1962; Doyle 2006). Ordovician shale and limestone underlie the Great Valley. This fertile region not only provided a level marching corridor but also an abundance of supplies. The Confederate Army reached the concentration point of Chambersburg, Pennsylvania, in excellent condition. Lee selected this area to gather based on the geology of Cashtown Gap to the east. A fault (Carbaugh–Marsh Creek fault) running through this gap made the rocks locally less resistant to erosion; this was the only gap wide enough to permit the passage of a large force with artillery and wagons (Brown 1962; Hoff et al. 1987).

Union forces used breaks in topography such as Turners Gap to ascertain Confederate positions. On June 28, 1863, Union General George Meade moved into Taneytown and established a strong defensive position behind Pipe Creek (better described as Parrs Ridge), which is composed of schists and quartzites. Parrs Ridge forms a divide between the Monocacy River drainage (of which Pipe Creek is a minor tributary) to the west and direct drainage towards Chesapeake Bay to the east. The ridge is about 240 m (800 ft) above sea level in the Pipe

Creek area (Brown 1962). Meade sent nearly half of his army towards Gettysburg. The town of Gettysburg is located on a wide, level plain in the Gettysburg basin. In 1863, the town was a hub for 10 roads, and any Confederate movement would have to pass through Gettysburg. Meade never used his Pipe Creek defensive position, but his choice shows his keen sense of geology and topography (Brown 1962).

On July 1, 1863, as Lee's forces neared Gettysburg, a Confederate unit in search of supplies ran into Union troops and both sides began to skirmish for position along the rolling ridges north and west of the town (Brown 1962). North-south trending ridges such as Oak, McPherson, Herr, Seminary, Warfield, and Cemetery as well as Culps Hill, Little Round Top, and Round Top defined the major topographic landforms on the battlefield (figs. 18 and 19). The fighting on this first day was concentrated on the open rolling terrain of Herr and McPherson ridges (Doyle 2006; Cuffey et al. 2006). These ridges are composed of relatively erosion-resistant sandstone (argillite) layers in the Gettysburg Formation (Heidlersburg Member) (Smith and Keen 2004). Tilted belts of contrasting lithologies produce these distinct parallel ridges (Potter 1999). In the aftermath of intense fighting, Union troops withdrew southward through town to the high ground of Cemetery Hill and the north end of Cemetery Ridge. The Gettysburg sill—a large diabase intrusion—underlies these two features (fig. 19) (Cuffey et al. 2006).

On the dawn of the second day of the battle, Union troops occupied Cemetery Ridge and Cemetery Hill south of Gettysburg while Confederates were in position along Seminary Ridge, south and west of Gettysburg. The resistant Rossville Diabase dike, exposed in the railroad cut near U.S. Route 30, underlies Seminary Ridge (Brown 1962; Hoff et al. 1987; Cuffey et al. 2006). This intrusive igneous feature postdates the larger diabase intrusion of Cemetery Ridge (i.e., York Haven Diabase some 760 m [2,500 ft] thick). The Rossville Diabase is a fine-grained gray to black diabase with centimeter-size plagioclase feldspar crystals and chilled marginal contacts with the surrounding red sediments (Hoff et al. 1987). Looking across the lowland between the two positions, the topography is subdued (fig. 20). Seminary Ridge rises 9 m (30 ft) above the lowland, and Cemetery Ridge rises 18 m (60 ft). However, even minor differences in elevation were militarily significant during the battle because soldiers had to carry heavy loads in near 100° temperatures under artillery fire from higher positions (Cuffey et al. 2006).

Foiled Confederate attempts to dislodge the Union troops from the high ground of Little Round Top and Culps Hill dominated the second day of fighting. Initially the attacks focused on either end of the Union position (Brown 1962). To the north, Confederates targeted Culps Hill on the evening of the second day. Earlier that same day, Confederates in Devils Den and the Peach Orchard attacked at the southern end of the Union line on Little Round Top. The Union line along Cemetery Ridge, anchored by Little Round Top and Culps Hill, resembled an upside-down fishhook (Brown 1962, 1997; Cuffey et al. 2006).

On the third and final day of the battle, Confederate cavalry swept north and east to attack Union troops on Culp's Hill. Simultaneously, infantry troops mounted a frontal assault (Pickett's Charge) from their position on Seminary Ridge across the cultivated, open lowlands—underlain by soft red shales and siltstones of the Gettysburg Formation—towards the Union positions along Cemetery Ridge. Soldiers had to cross roads, fences, and maneuver through diabase boulders, slowing them considerably (Doyle 2006). The high-ground advantage held by the Union troops atop the diabase sill comprising Cemetery Ridge, Culps Hill, and Little Round Top allowed them to decimate the Confederate ranks with heavy artillery shelling (Kiersch and Underwood 1998; Cuffey et al. 2006). The Army of Northern Virginia retreated southward under nightfall and heavy rains on July 4, 1863. The northern "invasion" was over. A few months after the battle, President Abraham Lincoln came to Gettysburg to give his famous address at the new national cemetery there.

Eisenhower's Legacy and Preservation

Major goals of Eisenhower National Historic Site are to preserve the historical context of the area, including home sites, gardens, fences, paths, and views; and to restore the landscape to the conditions present during Eisenhower's tenure. The historic site includes four distinct farms. The first farm, purchased by General and Mrs. Eisenhower in 1951 from Allen Redding, includes an extensive ornamental landscape. Eisenhower jointly used the second and third farms, purchased by W. Alton Jones, a friend and business partner to Eisenhower, in the Eisenhower Farms cattle and agricultural operations. The National Park Service acquired an adjoining property, the Clement Redding Farm, to preserve the historic scene and western views (Stakely et al. 2005).

According to Eisenhower upon his purchase, the farm was "run down," the soil (derived in part from weathered Gettysburg Formation) was depleted, but his view of the Appalachian Mountains to the west was "good." Early improvements to the property included a new farmhouse, ornamental landscape, exotic trees and shrubs, and development of cattle pasture and agricultural fields. Eisenhower supported soil conservation and improvement (Stakely et al. 2005). The new farmhouse included some stonework in its construction (fig. 21). The stonework may provide a geological interpretative target. Data regarding the construction materials is contained in the National Register of Historic Places (http://www.nps.gov/history/NR/) nomination form for the site (V. L. Santucci, written communication, November 22, 2008).

The farms at the historic site are closely tied to the geologic features and processes of the landscape. Topography and natural features such as the higher ground of Seminary Ridge to the east and the lower drainage of Marsh Creek to the west guided the spatial organization of roads, buildings, fields, and property boundaries. Buildings tend to cluster on higher areas whereas the gentle slopes within the Gettysburg basin (underlain by the Gettysburg Formation) support open, well-drained land for fields and pastures (Stakely et al. 2005).

Maintaining a historic landscape often means resisting natural geologic changes. Processes such as slumping, chemical weathering, riverine erosion, and slope creep are constantly changing the landscape at the historic site. Runoff erodes sediments from any open areas and carries them down streams and gullies. Erosion naturally diminishes higher areas and fills in the lower areas, distorting the historical context of the landscape. In cooperation with the Olmsted Center for Landscape Preservation, the National Park Service compiled *Cultural Landscape Report for Eisenhower National Historic Site* in 2005. Both volumes of this document are an invaluable resource in the treatment and long-term management of cultural landscapes such as that at the historic site. This document includes a comprehensive history of the landscape, identifies important features, compares historic and existing conditions, emphasizes the cultural significance of the site, and provides recommendations for future development and preservation.

For visitors to Eisenhower National Historic Site, an interpretive program highlighting the area's underlying geologic units and structures as well as focusing on how the geology affects terrain, landscape evolution, and ultimately Eisenhower's decision to settle and farm there would contribute to a deeper understanding of the history of the farm.

Devils Den and Little Round Top

Devils Den is located in the southeastern portion of Gettysburg Battlefield. Geologically, it is an exposure of large rounded masses of Triassic igneous diabase rock (figs. 22 and 23) (Cuffey et al. 2006). The exposure is approximately 80 m (260 ft) across and varies from 6–12 m (20–40 ft) in width (Blauvelt 1978). Petrologically, the diabase is ophitic to subophitic in texture and contains plagioclase, pyroxene, apatite, biotite, orthoclase, quartz, and opaque minerals. In outcrop, this light gray, massive unit contains weathered fracture systems related to the tensional forces occurring within the intrusive mass during cooling stages, as well as post-intrusion structural deformation. Some primary fractures are mineralized (quartz and tremolite) and preferentially resist weathering. Large blocks (as much as 8 m [26 ft] across) separated by voids represent later fractures. The column-like blocks have three to five vertical faces and extend to the base of the exposed outcrop (Blauvelt 1978). Weathering and exfoliation rounded these columns. Voids, formed during periglacial conditions via permafrost wedging and solifluction, separate the columns (Cuffey et al. 2006). This unique outcrop strongly influenced the Battle of Gettysburg as Confederate snipers hid among the columns and targeted Union troops atop Little Round Top (Cuffey et al. 2006).

Little Round Top is a prominent hill rising some 200 m (650 ft) above sea level and nearly 45 m (150 ft) above the lowland valley floor. Settlers cleared trees from the western slope of this hill a year before the battle; dense forest covers the remaining slopes. Boulders from the York Haven Diabase of the Gettysburg sill litter the slopes. The diabase in the thick sill is relatively coarse-grained in contrast to the Rossville dike beneath Seminary Ridge. In outcrop, it appears mottled black and white, with gray plagioclase and black augite as the primary minerals (Cuffey et al. 2006). The outcrop pattern of the York Haven Diabase on Round Top defines the famous "fishhook" of the Union defensive line (Doyle 2006).

Little Round Top, initially unoccupied, proved a critically significant vantage point during the second and third days of the battle and anchored the Union Army's southern position. Because of the underlying resistant, igneous rocks, little to no soil development occurs; therefore, "digging in" was not possible for protection from gunfire. Stone fences and hastily constructed breastworks were the only shelter available (Doyle 2006; Cuffey et al. 2006).

Frost Wedging

Outcrops of igneous diabase rocks appear throughout the battlefield area atop hills and ridges; boulders of the diabase flank the slopes. Relative to the soft red beds (shales and siltstones) of the Gettysburg Formation underlying the adjacent lowlands, these rocks are resistant to erosion. They were initially molten magma forced upwards into shallow intrusions. Upon cooling and solidification, decreases in volume caused tensional forces that led to the development of fracture systems throughout the diabase. The diabase of the York pluton and Rossville dike is characteristically impermeable to water except along joints and fractures.

The diabase intrusive bodies break down in a unique way, causing distinct rounded masses and columns of rock to remain standing. This happens via the wedging action of water in cracks, joints, and fractures. Meltwater from snow trickles through cracks in the rock and freezes at night during the colder months. The expansion of the ice in the cracks works in concert with tree and other plant roots to wedge the rocks apart.

Frost wedging was especially active during the periglacial conditions of the Pleistocene Epoch. Thousands of boulders and smaller rocks littered the bases of rock outcrops as talus and, when caught up in a water-saturated mass, slid down the slopes with frozen layers of ground in a process known as solifluction (fig. 24) (Means 1995). These stony remnants litter the slopes below Little Round Top and Round Top. The rounded mounds of diabase at Devils Den were wedged apart by ice and separated into distinct masses by slope creep in a water-saturated substrate (Cuffey et al. 2006).

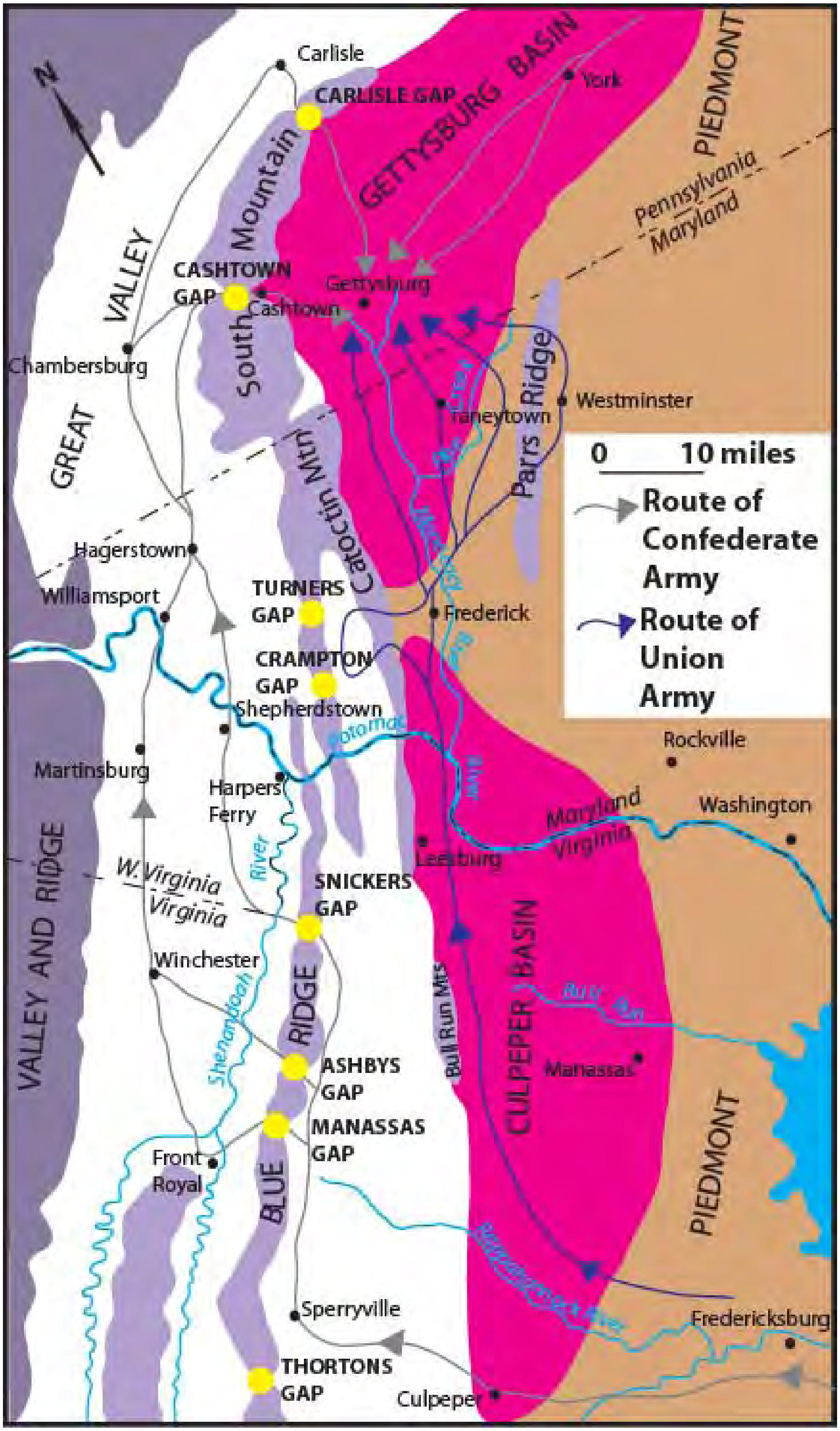

Figure 17. Gettysburg Campaign. This generalized map shows the military campaign leading up to the Battle of Gettysburg. Yellow dots mark the locations of gaps through the ridges. Map is roughly to scale. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University) after figure 1 in Brown (1961).

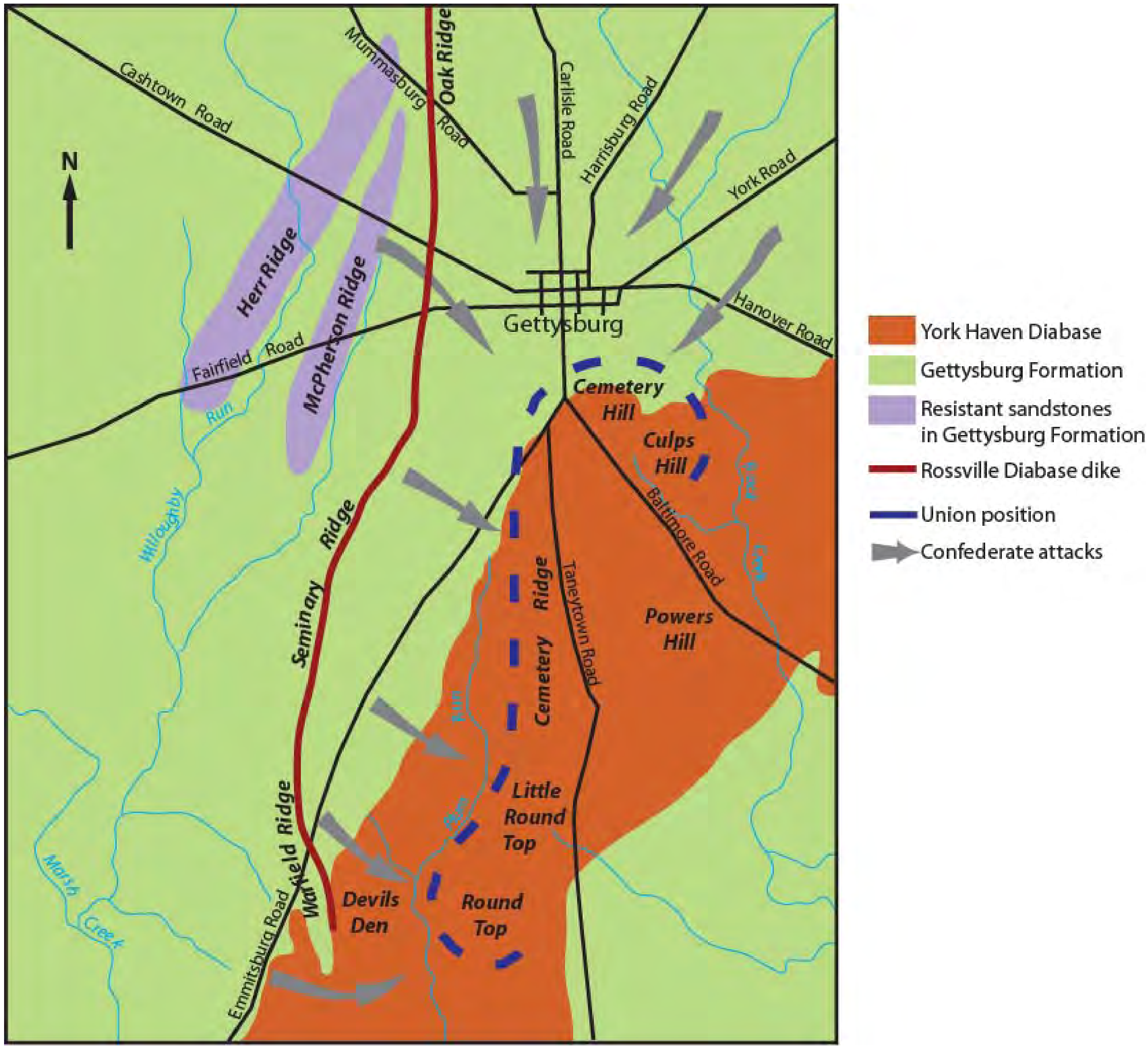

Figure 18. Gettysburg Battlefield. This generalized map across the Gettysburg battlefield shows Confederate attacks versus Union positions along the high ground underlain by resistant igneous diabase. Map is not to scale. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University) after figure 2 in Kiersch and Underwood (1998).

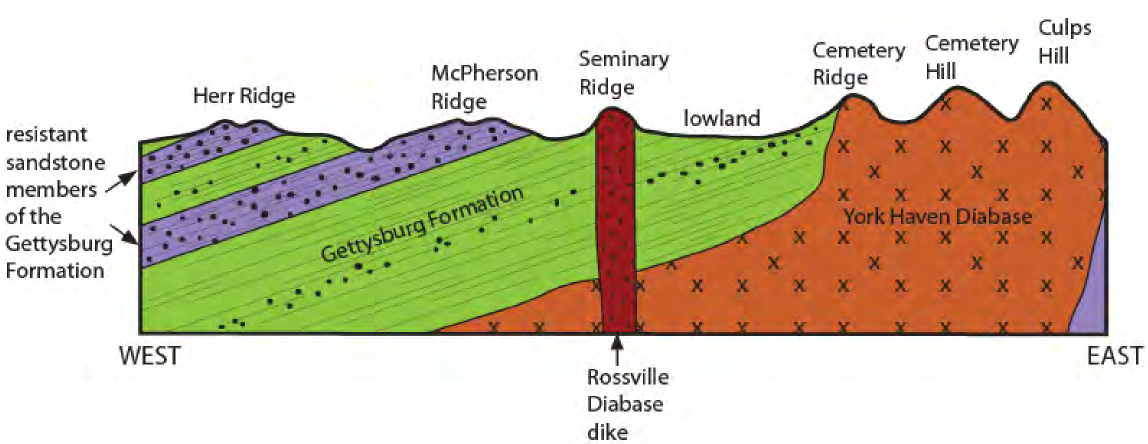

Figure 19. Generalized Cross Section across Gettysburg Battlefield. Graphic shows underlying structures responsible for topographic features which impacted the battle. Graphic is not to scale; lateral displacement between features is for demonstrative purposes. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University) after figure 6 in Cuffey et al. (2006).

Figure 20. Subdued Topographic Expression on the Battlefield at Gettysburg. Nearby ridges shed the large, rounded boulders in the photo. Photograph by Harry Waters courtesy of the National Park Service (http://www.nps.gov/gett/photosmultimedia/index.htm).

Figure 21. Farmhouse at Eisenhower National Historic Site. This photograph highlights the historic structure and ornamental landscape at the site. http://www.flickr.com/photos/piedmont_fossil/454421992/.

Figure 22. Exposed Rounded Boulders of Devils Den in Gettysburg National Military Park. Image provided by Vince Santucci (National Park Service).

Figure 23. Rock Surface Textures at Devils Den in Gettysburg National Military Park. Image provided by Vince Santucci (National Park Service).

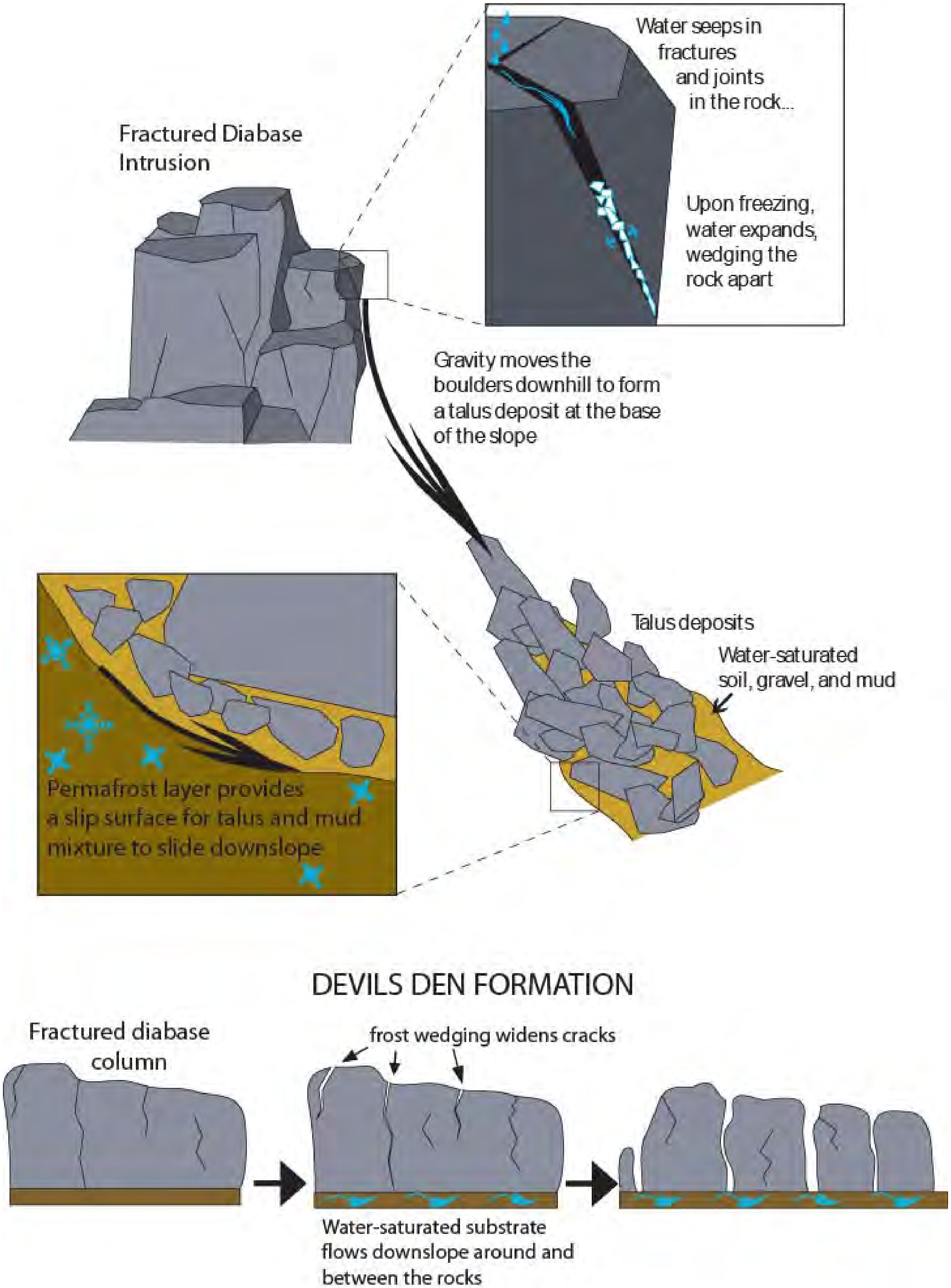

Figure 24. Weathering of Diabase Igneous Intrusive Rocks at Gettysburg National Memorial Park. Frost wedging is the primary driver in the breakdown of diabase. Bottom diagram shows the incremental formation of the Devils Den outcrop. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University).

Map Unit Properties

This section identifies characteristics of map units that appear on the Geologic Resources Inventory digital geologic map of Gettysburg National Military Park and Eisenhower National Historic Site. The accompanying table is highly generalized and is provided 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 Gettysburg National Military Park and Eisenhower National Historic Site 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. 25) for the age associated with each time period. This 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.

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 is source data for the GRI digital geologic map for Gettysburg National Military Park and Eisenhower National Historic Site:

Stose, G. W., and F. Bascom. 1929. *Fairfield-Gettysburg folio, Pennsylvania*. Scale 1:62,500. Folios of the Geologic Atlas 225. Reston, VA: U.S. 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/).

Map Unit Properties Table—Gettysburg National Military Park and Eisenhower National Historic Site

Age	Map Unit (Symbol)	Unit Description	Erosion Resistance	Suitability for Development	Hazards	Paleontologic Resources	Cultural Resources	Mineral Specimens	Mineral Resources	Habitat	Recreation	Global Significance
QUATERNARY	Alluvium (Qal); Terraces gravel and alluvial cones (QTt)	Qal lines most valleys and small ravines; contains fine silt, limestone, chert, and slate fragments, rounded fragments of rhyolite, sandstone, and quartz in sand, clay, and humus material. Depth depends on resistance of underlying bedrock. QTt is present along steep slopes and accumulates as wash deposits; may be perched on benches at various elevations as high as 300 m (980 ft) above the stream marking former stream courses; contains abundant gravel, cobbles, boulders, and pebbles of various lithologies including rhyolite, greenstone, quartzite, and conglomerate.	Very low	Suitable for light development; high permeability renders units poor for wastewater treatment	Prone to slumping if present on incised banks; floods associated with Qal; slope processes such as slumping, washes, and landslides in QTt	Contains humus and modern remains	May contain battlefield artifacts, Native American campsites	Larger clasts record provenance	Sand, gravel, silt, clay, cobbles, boulders	Riparian habitat lining all valleys and ravines	Suitable for most recreation unless incised or present on steep slopes	Records modern fluvial patterns and stream evolution
TRIASSIC	Diabase (TRdb); Diabase building stone (TRdbd); Basalt flow (TRb)	TRdb is present as larger bodies and thin sills identical in chemical composition, but larger bodies are coarse-grained, granular with white or gray plagioclase, black pyroxene, and accessory quartz, magnetite, hypersthene, biotite, and olivine. Units appear dark-gray to black in fresh exposures, but gray or light buff in weathered outcrops. Larger units display contact-metamorphism aureoles with interesting minerals (e.g., opals, garnets, sericite) and marble. TRb is composed of surface basalt flows interlayered with basin sediments; flows consist of mixed rounded masses or boulders.	Moderate to high	Coarse grained bodies weather to crumbly material that may be unstable as a base	Associated with ridges and may be susceptible to rockfall	None	Large crystals may have provided tool and trade material; ridges of these units played a significant role in battles	Magnetite, garnet, lime-iron garnet (contact metamorphism) chlorite, some columnar structure	Diabase (building stone), garnet (abrasives), marble (dimension stone), railroad ballast	May provide vugs for burrow habitat; supports deep rich red clay soils	Crumbly nature of units may be unstable base for trails or climbing	Records extension that produced large rift basins throughout the area; diabase intruded basin sediments
TRIASSIC	Limestone conglomerate lentil (TRl); Limestone conglomerate lentil: magnetite possible (TRlm); Arendtdtsville Fanglomerate lentil (TRa); Arendtdtsville Fanglomerate lentil: magnetite possible (Tram)	TRl is a conglomerate containing abundant limestone pebbles in sandstone. Pebbles are a few cm in diameter composed of light and dark gray to pink marble, gray dolomite, and laminated limestone. TRa contains coarse conglomerate of rounded cobbles and boulders of sandstone, quartzite, aporhyolite, and quartz in a red, sandy matrix; poorly cemented in areas and contains large (1 m [3.3 ft]) boulders.	Moderate	Suitable for most development unless present on a slope or highly fractured and/or weathered	Prone to mass wasting; dissolution of calcareous cements may render unit susceptible to rockfall as large boulders weather out	Possible fossils in pebbles	May have provided trade material; possible ornamental stone in historic structures	Saccharoidal marble; larger clasts record provenance	Quarried as ornamental stone where present in thick, compact layers; field lime, magnetite	May provide nesting pockets where boulders weathered out	May be too friable for heavy recreational use	Records rapid erosion and deposition into Triassic rift basin
TRIASSIC	Heidlersburg Member (TRh); Heidlersburg Member: magnetite possible (TRhm)	TRh contains sandstone and red shale with cyclically interlayered green, gray, and black shales. Some layers of gray to white sandstone are more resistant and form ledges	Moderate to high for sandstones	Heterogeneous nature of unit may prove unstable for heavy development if slopes are present	Prone to rockfall where weathered shale is beneath resistant sandstone ledges; black shale units may contain arsenic that could be released to groundwater and soils	None documented	None documented	White porcelanite, purple argillite, glauberite salt casts	Magnetite; gray quartzite may have provided ornamental stone	May form ledges for bird habitat	Suitable for most recreation unless undercut	Widespread member with abundant contact metamorphism records Triassic basin sedimentation and igneous intrusion
TRIASSIC	Gettysburg Shale (TRg); Gettysburg Shale: magnetite possible (TRgm); Gettysburg Shale: magnetite mined (TRgmm)	TRg is widespread, ~5,000 m (16,400 ft) thick, red shales interbedded with soft red sandstones; cut by a thick diabase sill and other small igneous bodies. Igneous intrusions are marked by contact-metamorphic aureoles of purple argillite. Some exposures contain conglomerate lenses, gray to white sandstones, green and yellow shale, impure limestone, and dark shale.	Moderate to high for argillite	Friable and brittle in some areas which may prove undesirable for heavy development	Splintery nature of weathered fragments are sharp for trail bases; heterogeneous layers may render unit susceptible to landslides and rockfalls on slopes	Organic material and residue	Sharp fragments may have provided tool material; historic mines may be associated with this unit	Argillite, white porcelanite	Magnetite mined locally	Supports hardwood forests	Suitable for most recreation unless sharp fragments are present	Described and named for exposures around Gettysburg; contains widespread record of basin depositional environments
TRIASSIC	New Oxford Formation (TRno); Lower part of New Oxford Formation (TRna); Quartzose conglomerate (TRnc)	Red shale and sandstone with interlayered micaceous sandstone, arkose, and conglomerate of light color; >2,000 m (6,560 ft) thick. Pebbles and boulders are quartzose in a red sandy matrix. Lower beds are rich in soft red shales and calcareous mudstone.	High to moderate for shale layers	Heterogeneous nature of unit may render unit unstable on slopes but suitable for most light development	Unit forms resistant ridges that may be prone to rockfall and landslides, especially where resistant sandstone layers are underlain by weathered red shales	Fossils possible in calcareous layers; shale contains shells of small freshwater animals	None documented	Mica	Red sandstone quarried for building stone	Forms ledges for bird habitat and supports ridgetop forests	Suitable for most recreation unless highly weathered and/or fractured	Records depositional environments from longstanding Triassic basin

Age	Map Unit (Symbol)	Unit Description	Erosion Resistance	Suitability for Development	Hazards	Paleontologic Resources	Cultural Resources	Mineral Specimens	Mineral Resources	Habitat	Recreation	Global Significance
ORDOVICIAN	Beekmantown Limestone (Ob); Beekmantown Limestone: garnet possible (Obg); Beekmantown Limestone: garnet abrasive mine (Obgm)	Mostly pure blue limestone with finely laminated impure layers, locally contains white to pink marble; weathers to buff shaly fragments and tripolite.	Moderate	May be highly dissolved in areas rendering it unsuitable for wastewater treatment facilities	May be associated with karst dissolution and processes; susceptible to rockfall if undercut on slope	Fossils possible	Garnet may have provided trade material and fueled historic mining activity	Garnet	Quarried and burned for lime locally; ornamental stone, garnet (abrasives), marble	Produces fertile residual soil	Suitable for most recreation; may attract speleologists if caves are present	Records calm depositional environment with intermittent igneous intrusions
ORDOVICIAN	Conestoga Limestone (Oc); Conestoga Limestone: impure limestone (Ocil); Shale and sandstone (Ocsd); Shale and sandstone: building sand (Ocsds); Sandy beds (Ocs)	Oc is impure blue limestone that appears buff colored on weathered outcrops; black to dark-gray shale and limestone dominate lower beds; middle beds are primarily hard blue dolomite and coarse white and pink marble with siliceous limestone interbedded; upper beds are light-gray sandy limestone interlayered with impure blue limestone and scant beds of black shale; maximum thickness ~300 m (980 ft); weathers to sand, chert nodules, and yellow sandy clay soils.	Moderate to moderately high for hard dolomite layers	Weathers easily to sand which may render it too permeable for septic systems or too unstable for heavy development	Associated with rockfalls and slumps when exposed on slopes, alternating resistant and weaker layers are prone to fail if undercut; black shale units may contain arsenic that could be released to groundwater and soils	Fossils possible	Hard white chert may have provided tool material	Pink marble	Limestone and sandstone for building stone, ornamental marble, building sand mined locally	Underlies deep sandy, well-drained soils	Friable which may be unstable base for trails on slopes	Records varied depositional environments
CAMBRIAN	Waynesboro Formation (Cwb); Tomstown Dolomite (Ct); Tomstown Dolomite: iron ore, paper clay, and building sand (Ctics)	Cwb is a ~300-m- (980-ft-) thick series of gray calcareous sandstones interbedded with hard purple to red shiny shale and limestone; lower beds are siliceous gray limestone; weathers to slabby porous sandstone. Ct contains coarse grained gray dolomite and limestone with shale interbedded in the lower portions. Limestone is dark blue in the middle portion. Some siliceous sericitic slate or schist is present locally.	Moderate to high for sandstone layers	Cwb forms hills and ridges that may be unstable if undercut. Ct is prone to dissolution and may be ill-suited for septic systems.	Disseminated slabs of sandstone from weathered units pose rockfall hazard; dissolution of calcareous units may lead to karst hazards	Early Cambrian fossils possible	Iron stained and rugose chert may have provided tool material	Cavities filled with drusy quartz, white vein quartz	Sandstone slabs for flagstones, magnesian limestone, iron ore, paper and tile clay, building sand	Contains cavities that may provide burrow habitat	Forms hills and ridges attractive for hikers and bikers	Contains ripple marks and cyclic deposits recording ancient Cambrian seas
CAMBRIAN	Antietam Sandstone (Ca); Antietam Sandstone: building sand and quartzite building stone (Casq); Harpers Schist (Ch); Harpers Schist: iron ore (Chi); Montalto Quartzite Member (Cma)	Ca caps ridges with pure coarse-grained sandstone with lower beds of dense quartzite of bluish to pink color and upper granular white or pinkish quartzite; siliceous sericite schist present in scant layers; upper layers weather to sands, siliceous clays, and pebbles. Ch contains gray hackly sandy phyllite and schist but is locally dominated with quartzite (Cma) in massive beds. Quartzite contains lower white vitreous quartzite with upper massive beds of softer white sadnstone. Weathered exposures show hackly clack slate, banded with white and gray schistose sandstone with darker ferruginous sandstone layers. Some green schist is present locally.	High	Caps ridges and is suitable for most development unless highly fractured and/or steep	Associated with steep slopes and rockfall	Skolithus tubes, fossil molds in rusty partings	Ca would have been significant for landmarks and trade routes	Bean shaped quartz pebbles, white vein quartz, octahedrons of magnetite, sericitic mica	Building sand mined from weathered exposures, quartzite building stone, iron ore in Chi	Forms ridges that provide nesting habitat and underlie sandy soils	Forms ridges attractive to climbers	Contains evidence of Early Cambrian age life; widespread throughout the area
CAMBRIAN	Weverton Sandstone (Cw); Loudoun Formation (Cl)	Cw contains ~250 m (820 ft) of gray to purple feldspathic sandstones, quartzites, and conglomerates; lower beds steeply dip and are dominated by massive quartzitic conglomerate ranging in color from purple to red and gray; fragments include rhyolite and vitreous quartz; thinner beds of sandstone and shale overly the conglomerate. Cl contains purplish arkosic conglomerate and sandstone interlayered with fine sericitic slate. Lower beds are dominated by purple schist and phyllite. Upper layers are dominated by schistose arkosic conglomerates and sandstone. Some layers contain large and small fragments of volcanic rhyolitic/tuff rocks, vitreous quartz grains and pebbles.	High to moderate for weathered shale-rich layers, Cl is low to moderate	Caps ridges; suitable for most development unless highly fractured and/or steep	Associated with block fall hazards on ridges overlying steep slopes. Rockfall is acerbated where resistant quartzites are underlain by weathered shales. Cl is extremely prone to mass wasting on slopes and is frequently mantled with slope debris.	None documented	Vitreous pebbles may have provided trade material, unit likely influenced trade routes	Vitreous white to pink quartz pebbles	Building stone, slabby quartz sandstone	Forms ridges that provide nesting habitat	Forms ridges attractive to climbers	Records depositional environments
CAMBRIAN	Ledger Dolomite (Clg); Ledger Dolomite: pure limestone (Clgpl); Limestone marble (Clm); Limestone marble: marble mined (Clmmb)	Clg contains hard, knotty dark gray dolomite overlain by pure limestone and dolomite. Pure, crystalline gray dolomite merges laterally with high-calcium mottled blue and white marble.	Moderate	Suitable for most development unless highly dissolved and/or fractured	May be associated with karst hazards if dissolution is prevalent. When undercut, unit poses rockfall hazard.	None documented	Historic mining activities in the area	Mottled marble, pure dolomite and limestone	Lime, marble mined locally	Mantled by thick soils	Suitable for most recreation	Records longstanding quiet, marine deposition
CAMBRIAN	Kinzers Formation (Ck); Vintage Dolomite (Cv)	Ck is soft, slightly greenish gray calcareous shale; sericite present in fine layers; weathers to buff and pink colored porous sandy shale. Cv contains light-blue limestone and dolomite in thin, impure layers.	Moderate	Unstable on slopes and should be avoided for heavy development	Forms low hills; weathered shale layers prone to mass wasting and landslides	None documented	May be associated with historic quarries	Sericite	Dolomite and limestone quarried locally	Weathers to well-drained sandy soils with abundant clay clasts	Suitable for most recreation unless steep slopes are present	Records deepwater to nearshore depositional environments

Age	Map Unit (Symbol)	Unit Description	Erosion Resistance	Suitability for Development	Hazards	Paleontologic Resources	Cultural Resources	Mineral Specimens	Mineral Resources	Habitat	Recreation	Global Significance
CAMBRIAN	Chickies Quartzite (Cc); Hellam Conglomerate Member (Chl)	Cc is hard white quartzite in massive beds interlayered with less pure sand and clay in lenticular masses; lower beds contain coarse conglomerate, arkose, and black slate (Chl) with upper layers dominated by sandstone; maximum thickness ~300 m (980 ft).	High	Avoid for development if highly fractured and/or weathered	Associated with rockfall	Skolithus tubes	May be associated with historic quarries	Pure white quartzite	Building stone	Weathers to produce well-drained soils	Suitable for most recreation unless steep slopes are present	Records beach and nearshore depositional environments
PRECAMBRIAN (ALGONKIAN)	Metabasalt (PCmb); Metabasalt: greenstone (PCbgs); Metabasalt: copper (PCbc); Metabasalt: monumental and jewelry stone (PCbsaj)	PCmb occurs in narrow belts in interlayered flows of greenstone composition; some areas are purplish to gray in color and aphanitic tuff beds are interbedded. Flows are either massive, schistose, or slaty with compact or amygdaloidal textures, and porphyritic or nonporphyritic habits.	Moderate	Suitable for most light development unless highly weathered	Where highly weathered and/or fractured, rockfall hazards exist	None documented	Amygdules may have provided trade material	Amygdules of quartz, epidote, lustrous chlorite	Greenstone, copper, monumental stone, jewelry stone	Weathers to Fe- and Mg-rich soils	May form ridges attractive to climbers; suitable for most recreation	Records extensional event of pervasive lava flows
PRECAMBRIAN (ALGONKIAN)	Rhyolitic breccia (PCrb); Rhyolitic breccia: monumental and jewelry stone (PCrbsaj); Rhyolitic breccia: whetstone (PCrbw)	PCrb is composed of flow breccia, tuff breccia, and layered tuffs. Flow breccias contain angular fragments up to several cm in diameter of high-silica rhyolitic magma. Tuff breccia appears bluish purple to red fragments in a tuff, fine grained matrix. Most of these beds have been metamorphosed to slate. Tuffs contain pyroclastic sediment.	Moderate to high	Suitable for most development unless K-rich clays are present, which could pose a radon problem for basements	May pose mass-wasting hazard if undercut on steep slopes and/or fractured and weathered	None documented	None documented	Sericite schist, breccia	Tuff whetstone, monumental and jewelry stone	Weathers to produce clast-rich clays	Suitable for most recreation	Records widespread volcanic activity
PRECAMBRIAN (ALGONKIAN)	Aporhyolite (PCrh); Aporhyolite: monumental and jewelry stone (PCrhsaj)	PCrh occurs as a belt of fine grained lavas, amygdaloidal flows, and pyroclastic rocks with sericite schists. Unit is dominated by hackly fractured, hard, dense lava of fine-grained, purple felsitic rhyolite; weathers to whitish gray, purple, pink, brick-red, buff, and light green color. Lavas are brittle with conchoidal fractures. Red, blue, and silvery green schists are associated with deformation and heating of the unit.	Moderate	Highly weathered and may pose a radon problem for basements if extensive clays are present; shrink and swell clays possible	May be susceptible to landslides and block falls if undercut or exposed on steep slopes	None documented	May have provided tool and trade material	Porphyritic feldspar crystals, pink and white phenocrysts, lithophysae	Monument stone, jewelry stone, copper ore	Weathers to produce silica-rich soils	Contains sharp, conchoidal fractures and edges that may be unsafe for recreation	Records widespread rhyolitic lava volcanic activity during the Precambrian and later deformation and metamorphism
PRECAMBRIAN (ALGONKIAN)	Sericite schist and vein quartz (PCsq); Sericite schist (PCsqss)	Largely altered to slate, epidosite and chlorite schist, and sericite schist. PCsqss contains altered volcanic rocks ranging from lavas to pyroclastic sediments. Lavas are rhyolitic to basalt, now altered to aporhyolite to metabasalt (greenstone). Original textures are preserved. Pyroclastic materials include breccias, tuff, flow breccias, and pumiceous bombs.	Moderate	Highly altered and may produce radon; shrink and swell clays; avoid heavily fractured areas for development	Slaty cleavage causes the rock to break apart in great slabs that are prone to rockfall and landslides	None documented	None documented	Vein quartz, piedmonite, sericite, epidote, hematite, leucoxene, kaolin, porphyritic feldspar crystals	Garden stones	Tilted beds may provide nest and burrow habitat	Suitable for most recreation unless present on undercut slope and/or highly altered	Records volcanic events; preserves remarkable original volcanic and flow textures

Geologic History

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

Gettysburg National Military Park and Eisenhower National Historic Site sit within a Triassic extensional basin. Bedrock under the battlefield and historic site originated within this rift basin, which is associated with the beginning of the present-day Atlantic Ocean and the formation of the Appalachian Mountains. Continental sediments, 6,100 m (20,000 ft) thick, filled the basin during Late Triassic time, immediately followed in the earliest Jurassic by rising magma intruding along bedding planes (sills) and vertical cross cuts (dikes) (Cuffey et al. 2006).

The geologic history of Gettysburg National Military Park and Eisenhower National Historic Site begins in the Proterozoic Era (fig. 25). During the Grenville Orogeny (mid-Proterozoic), most of the continental crust in existence at that time formed a supercontinent that included the crust of North America and Africa. The metamorphic granites and gneisses in the core of the modern Blue Ridge Mountains to the south and west of Gettysburg are a result of the sedimentation, deformation, plutonism, and volcanism that created the supercontinent (Harris et al. 1997). Deposited over a period of 100 million years, these metamorphic rocks are more than a billion years old, making them among the oldest rocks known from this region. Following their uplift and exposure to erosion, for hundreds of millions of years, these rocks formed a basement upon which all other rocks of the Appalachians accumulated (Southworth et al. 2001).

The oldest rock units in the Gettysburg area are the Precambrian (Algonkian) sericite schists, aporhyolites, rhyolitic breccias, and metabasalts (see "Map Unit Properties" section). These units contain evidence of abundant volcanic activity, which ranged from relatively passive basaltic lava flows to violent rhyolitic eruptions (Stose and Bascom 1929).

During the late Proterozoic (800–600 million years ago), crustal extension and rifting created fissures through which massive volumes of basaltic magma extruded onto the surface (fig. 26A). The volcanism lasted tens of millions of years and alternated between flood basalts and more silicic, rhyolitic eruptions with accompanying ash falls. The volcanic rocks covered the granitic/gneissic basement in south-central Pennsylvania and today are present in the Gettysburg area as Precambrian metabasalts, greenstones, and rhyolitic breccias (Stose and Bascom 1929). South Mountain, used to shield Confederate Army movements, has a greenstone and rhyolitic core from the volcanism associated with this rifting (Smith and Keen 2004).

Extensional tectonics caused the supercontinent to break up and a basin to form that eventually expanded to become the Iapetus Ocean. As this basin subsided, sediments deposited as alluvial fans, large submarine landslides, and turbidity flows filled the basin. These late Proterozoic to early Paleozoic sediments would eventually form many of the rock units of the Appalachian Mountains (fig. 26B). These units are exposed throughout southeastern Pennsylvania and preserve many characteristic features of the original landforms (Southworth et al. 2001).

Clean beach sands and deeper water deposits of the Chickies Quartzite and Hellam Conglomerate Member are among the first rocks deposited in the nascent Iapetus basin in the Gettysburg area. In addition, muds and sands of the Kinzers Formation, and limestone and dolomite of the Vintage Dolomite preserve a marine transgression into the area during the early Cambrian (Stose and Bascom 1929).

Marine environments persisted throughout the Cambrian with the deposition of the Ledger Dolomite and Limestone; Weverton Sandstone; and the mixed arkosic conglomerate, sandstone, and slate of the Loudoun Formation. The Harpers Schist contains sandy phyllite and schist from a deeper water environment whereas the pure, coarse-grained sandstone (now quartzite) of the Antietam Sandstone records a nearshore depositional environment (Stose and Bascom 1929). Resistant Antietam Sandstone caps many ridges throughout the area.

Extensive sands, silts, and muds deposited in nearshore, deltaic, barrier-island, and tidal flat settings were part of a shallow marine environment along the eastern continental margin of the Iapetus Sea (Schwab 1970; Kauffman and Frey 1979; Simpson 1991). In addition, widespread carbonates, sands, and muds such as the Cambrian Waynesboro Formation and Tomstown Dolomite (the last and youngest mapped Cambrian units in the area), and the Ordovician Conestoga and Beekmantown limestones were deposited within and on top of the Chilhowee Group. These units represent part of a grand marine platform that thickened to the east and persisted during the Cambrian and Ordovician periods (545–480 million years ago) (Stose and Bascom 1929; Means 1995). Other Paleozoic units, which elsewhere preserve the transition from carbonate platform to more nearshore terrestrial deposition associated with the beginning of the Taconic Orogeny, are missing from the Gettysburg area.

Taconic Orogeny

From Early Cambrian through Early Ordovician time, orogenic activity along the eastern margin of the continent metamorphosed the entire Cambrian-Ordovician sedimentary section, as well as intrusive rocks and basalts, resulting in schists, gneisses, marbles, slates, and migmatites (Southworth et al. 2000). The Taconic Orogeny (~440–420 million years ago in the central Appalachians) was associated with continental convergence. Oceanic crust and a volcanic arc from the Iapetus basin thrust onto the eastern edge of the North American continent. The Taconic Orogeny involved the closing of the ocean, subduction of oceanic crust, creation of volcanic arcs, and uplift of continental crust (Means 1995). During this orogenic event, Precambrian flood basalts and rhyolitic volcanic breccias metamorphosed into metabasalts and metarhyolites and the Chilhowee Group and other Cambrian deposits became quartzites, schists, and phyllites.

The crust bowed downwards in response to the overriding plate, creating the deep Appalachian basin, which was centered on what is now West Virginia. Infilling sediments eroded from the highlands to the east (fig. 26C) (Harris et al. 1997) covered the Cambrian carbonate platform (Southworth et al. 2001); these are Ordovician (505–440 million years ago) shales and sandstones, blue limestone, dark shale, and dolomite of the Conestoga Limestone; and pure blue limestone of the Beekmantown Limestone (Stose and Bascom 1929), which represent deeper water depositional environments.

During the Late Ordovician, oceanic sediments of the shrinking Iapetus Sea were thrust westward along the Pleasant Grove fault onto other deepwater sediments of the western Piedmont. Silurian sands, muds, silts, and carbonates settled in shallow marine and deltaic environments of the Appalachian basin. These rocks, now metamorphosed, underlie the Valley and Ridge physiographic province but are not exposed in the Gettysburg area (Fisher 1976).

Shallow marine and fluvial sedimentation continued intermittently for approximately 200 million years during the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian periods. This resulted in a thick sedimentary section. The source of these sediments was from the rising highlands to the east during the Taconian (Ordovician) and the Acadian (Devonian) orogenies. These layers are not exposed in the Gettysburg area; they were either buried or eroded away prior to the formation of the Triassic extensional basin.

Acadian Orogeny

As the African continent drifted towards North America, the Acadian Orogeny (~360 million years ago) continued the mountain building started by the Taconic Orogeny (Harris et al. 1997). The Acadian event involved land-mass collision, mountain building, and regional metamorphism similar to the preceding Taconic Orogeny (Means 1995). This event occurred north of present-day, south-central Pennsylvania and caused further uplift of Taconic highlands in central Pennsylvania. Erosion of these highlands provided more sediment, leading to the basin-wide deposition of Devonian units not exposed in the Gettysburg area.

The tectonic quiescence between the Acadian and Alleghenian orogenic events (see below) resulted in the accumulation of the abundant marsh and wetland deposits of the Mississippian and Pennsylvanian periods. After burial and compression, these deposits created the vast coal-bearing units of mining interest throughout central Pennsylvania (Berg et al. 1980; Miles et al. 2001).

Alleghenian Orogeny

During the Late Paleozoic and following the Acadian Orogeny, the proto-Atlantic Iapetus Ocean closed as the North American continent collided with the African continent. This formed the supercontinent Pangaea and the Appalachian mountain belt. This mountain building episode, the Alleghanian Orogeny (~325–265 million years ago), is the last major orogeny of the Appalachians (fig. 26D) (Means 1995). The regional rock layers folded and fractured during as many as seven phases of deformation to produce the Sugarloaf Mountain anticlinorium and the Frederick Valley synclinorium in the western Piedmont, the Blue Ridge–South Mountain anticlinorium, and the numerous folds of the Valley and Ridge province (Nickelsen 1983; Southworth et al. 2001). Many of the faults and folds associated with the Alleghenian Orogeny are exposed today west of Gettysburg National Military Park and Eisenhower National Historic Site.

During this orogeny the North Mountain fault transported the rocks of the Great Valley, Blue Ridge, and Piedmont provinces as a massive block (Blue Ridge–Piedmont thrust sheet) westward onto younger rocks of the Valley and Ridge. The amount of crustal shortening was very large (20–50%) or 125–350 km (75–125 mi) of translation (Harris et al. 1997).

During the Alleghanian Orogeny deformed rocks in the eastern Piedmont folded and faulted, and preexisting faults (both strike slip and thrust) reactivated (Southworth et al. 2001). Estimated paleoelevations of the Alleghenian Mountains are 6,100 m (20,000 ft), which is analogous to the modern day Himalayas in Asia. Erosion beveled these mountains to elevations less than 730 m (2,400 ft) above sea level in south-central Pennsylvania today (Means 1995).

Mesozoic Extension to the Present

Following the Alleghenian Orogeny during the late Triassic (230–200 million years ago), a period of rifting began as the deformed rocks of the joined continents began to break apart, overprinting the Appalachian Orogeny (Schlische 1993). The supercontinent Pangaea segmented into roughly the continents that persist today. This episode of rifting initiated the formation of the current Atlantic Ocean and caused many block-fault basins and half grabens to develop along the east coast of North America with accompanying volcanism (fig. 26E) (Harris et al. 1997; Southworth et al. 2001). Preexisting

Paleozoic thrust faults and deformational structures reactivated, but as normal faults in an extensional setting. Some isolated sub-basins coalesced into larger basins as extension progressed (Root 1989; Schlische 1993). However local strike-slip faulting and north-south directed compressional structures indicate extension was not ubiquitous throughout the Mesozoic (Gates 1992).

The Gettysburg–Newark Lowland section (also called the Birdsboro basin) is a large component of this tectonic setting. This elongate basin contains two deep-end basins, the Gettysburg and Newark basins, connected by the "narrow neck" of the Furnace Hills sub-basin, which tapers to 6 km (4 mi) wide (Root and MacLachland 1999; Faill 2000). The Gettysburg end basin is a maximum of 29 km (18 mi) wide with strata dipping northwesterly at 25°–30° (Root and MacLachlan 1999). Large alluvial fans and streams carried debris shed from the uplifted Blue Ridge and Piedmont Plateau provinces and deposited it as nonmarine shales and sandstones in fault-created extension basins such as the Frederick Valley in central Maryland, the Culpeper basin in the western Piedmont of central Virginia, and the Gettysburg-Newark (Birdsboro) basin of southeastern Pennsylvania (Faill 2000). Many of these rifted areas became lacustrine basins filled with thick silt and sand deposits.

Larger basins such as the Gettysburg basin collected deeper water sediments such as the muds and sands of the New Oxford Formation, the playa–shallow lacustrine sediments (soft red beds) of the Gettysburg Formation, and its fluvial sandstone-rich Heidlersburg Member (Stose and Boscum 1929; Cuffey et al. 2006). Alternating layers of subaerial and subaqueous sediments indicate fluctuating water levels in the basin during deposition (Yocum and De Wet 1994). Deeper water areas also collected chemically precipitated freshwater carbonate deposits of limestones and dolomites exposed in the Gettysburg area (Stose and Bascom 1929; Yocum and De Wet 1994). These sediments were more than 6,100 m (20,000 ft) thick during Late Triassic time (Cuffey et al. 2006). In the New Oxford Formation, features such as vertisols, calcretes, and alpha-type microfabrics in carbonate nodules alternating with lake deposits indicate semiarid to more humid climatic fluctuations during Late Triassic time in the Gettysburg basin (De Wet et al. 1998).

An unconformity of more than 200 million years separates the Ordovician units from the Triassic New Oxford Formation—quartzose alluvial fan conglomerate, carbonate lacustrine strata, red shales (overbank mudstones), and fluvial sandstones (Stose and Bascom 1929; De Wet et al. 1998). Triassic sedimentary and igneous rocks throughout the area preserve an extensional rift basin. As the rift basin widened and deepened, thick layers of sediments eroded from the neighboring highlands and filled the basin. These sediments included the red shales and sandstones of the widespread Gettysburg Shale and the interlayered green, gray, and black shales and sandstone of the Heidlersburg Member (Stose and Bascom 1929; Cuffey et al. 2006).

As a marine incursion spread across the Triassic rift basin, limestone conglomerates alternated with subaerial conglomerate, sandstone, quartzite, and aporhyolite of the Arentdtsville fanglomerate. Widespread igneous intrusion and eruption accompanied rifting. Intrusive rocks include sills, dikes, and larger bodies of diabase (Stose and Bascom, 1929; Cuffey et al., 2006). This resistant unit is present on the battlefield and influenced the battle at Gettysburg. Basalt flows are also present locally.

The characteristic structural form of the basin is a tilted, fault-bounded block or half graben (fig. 27) (Root and MacLachlan 1999). The large, low-angle, extensional faults, which formed the western boundaries of the basin, provided an escarpment that was quickly covered with eroded debris. Vertical displacement along the parallel, northeast-trending, southeast-dipping border fault system of the Gettysburg basin approaches 10 km (6 mi) (Root 1985, 1989). This fault developed parallel to the trend of Paleozoic structural cleavage, overprinting earlier compressional tectonic events (Root 1989). Other pre-Mesozoic faults, including the Shippensburg fault, reactivated Alleghenian thrusts within the basin as normal faulting (Root 1989). The Lisburn fault is a lesser fault that offsets the border fault and is associated with dips of 60° to the southeast. This fault was active during deposition and affected distribution of coarse fluvial sediments. Many intrabasinal faults occur parallel to the structural grain within and beyond the basin (Root and MacLachlan 1999). The geometry of underlying, reactivated structures likely controls the character of internal deformation within the basin (Ratcliffe and Burton 1985).

Accompanying intrabasin extension caused small-scale faulting and the intrusion and extrusion of igneous rocks such as diabase and basalt (Stose and Bascom 1929; Schlische 1993). Diabase magma intruded into the strata as sills, irregular igneous bodies, and dikes that extend beyond the basins into adjacent rocks. The local 500-m- (1,640-ft-) thick Gettysburg sill is among the largest of these diabase bodies (Root 1989). The edges of these intrusions heated the surrounding country rock, baking it to produce hard, aphanitic hornfels (Cuffey et al. 2006).

After these igneous intrusions (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, which forced the continental crust upwards exposing it to erosion. The igneous rocks, being harder than the surrounding sedimentary rocks, resisted erosion and now hold up some of the higher ridges, hills, and slopes in the Gettysburg battlefield area including Seminary Ridge, Culp's Hill, and Little Round Top (Cuffey et al. 2006).

Thick deposits of unconsolidated gravel, sand, and silt sloughed from the eroding Alleghenian Mountains and settled eastward at the base of the mountains as alluvial fans. These deposits became part of the Atlantic Coastal Plain (Duffy and Whittecar 1991; Whittecar and Duffy 2000; Southworth et al. 2001). The incredible amount of material eroded from the now-exposed metamorphic rocks of the Blue Ridge province and deposited on the coastal plain indicates that many of the rocks now exposed at the surface must have been at least 20 km (10 mi) below the surface prior to regional uplift and erosion (fig. 26F). Erosion continues to create the present landscape with the Potomac, Monocacy, Delaware, and Shenandoah rivers and their tributaries eroding, transporting, and depositing sediments as alluvial terraces and deltaic fans.

The North American plate has continued to drift toward the west since the breakup of Pangaea and the uplift of the Appalachian Mountains. The isostatic adjustments that uplifted the continent after the Alleghenian Orogeny continued at a lesser rate throughout the Cenozoic Era (Harris et al. 1997). During the Eocene Epoch, regional rifting produced bimodal volcanics in areas of Virginia and West Virginia (Smith and Keen 2004). This rifting—evidence of continued crustal tension throughout the area—is responsible in part for occasional seismicity.

The present geomorphic landscape of the Gettysburg area is the result of erosion and deposition along the area's streams and rivers for at least the last 5 million years (Southworth et al. 2001). Floodplain alluvium and ancient river terraces record the historical development of the local drainage systems. The gentle sways and steeper ridges and ravines present at Eisenhower National Historic Site and Gettysburg National Military Park attest to this downward cutting and overprinting.

Glaciers from the Pleistocene Ice Ages never reached south-central Pennsylvania, but the colder climates of the ice ages played a role in the formation of the landscape in the Gettysburg area. The higher ridges in the area experienced periglacial conditions that included discontinuous permafrost, tundra-like vegetation, and many freeze-thaw cycles. Freeze-thaw cycles led to the ice wedging of thousands of boulders and smaller rocks from the ridge tops. Ice would melt during the day and meltwater would seep into cracks, freeze at night, expand, and force the rocks apart. These rocks moved downslope creating talus piles. The permafrost provided a slip surface for the talus and mud mixture; water-saturated debris slid over the partially frozen layer via a process known as solifluction (see fig. 24) (Means 1995). Diabase boulders now litter the slopes below Little Round Top and Round Top. Periglacial conditions including frost wedging are also responsible for creating the voids between the rounded diabase masses of the unique rock outcrop of Devils Den (Cuffey et al. 2006).

The Ice Age climate also may have affected the morphology of the area's river valleys. The periglacial conditions that existed at high altitudes intensified weathering and other erosional processes, yielding higher sediment loads in local streams and rivers (Harris et al. 1997). In addition to frozen ground, a wetter climate and sparse vegetation caused increased precipitation to drain into the ancestral river channels, enhancing downcutting and erosion by waterways such as Rock Creek and the Monocacy River (Means 1995).

Today Quaternary deposits cover most of the land surface; sediments include terrace gravel, alluvial cones, and alluvium along streams. Alluvium contains gravel-sized fragments of rhyolite, sandstone, and quartz in a matrix of sand, clay, and organic material (Stose and Bascom 1929).

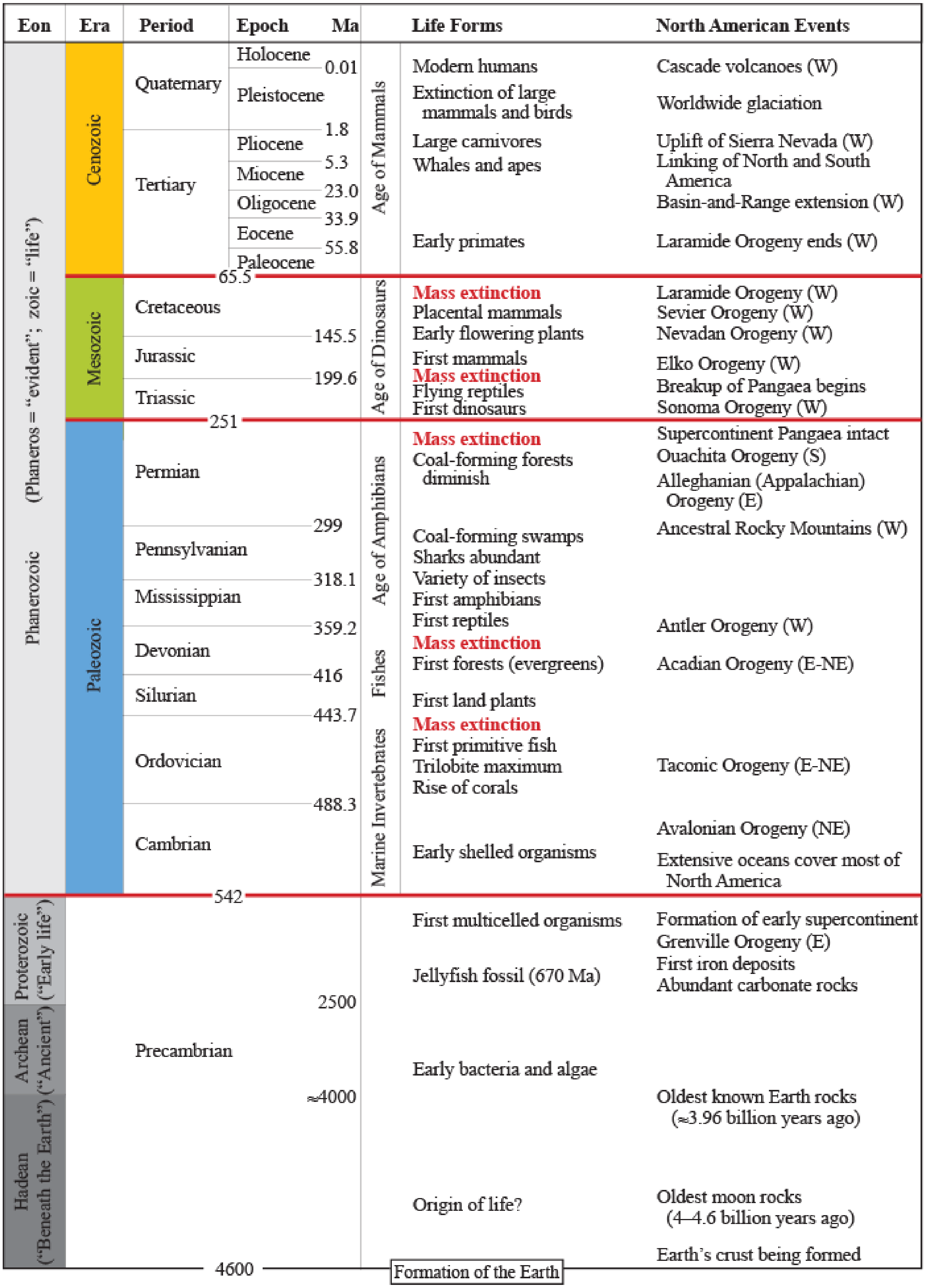

Figure 25. Geologic Time Scale. Adapted from the U.S. Geological Survey (http://pubs.usgs.gov/fs/2007/3015/). Red lines indicate major unconformities between eras. Included are major events in life history and tectonic events occurring on the North American continent. Absolute ages shown are in millions of years (Ma).

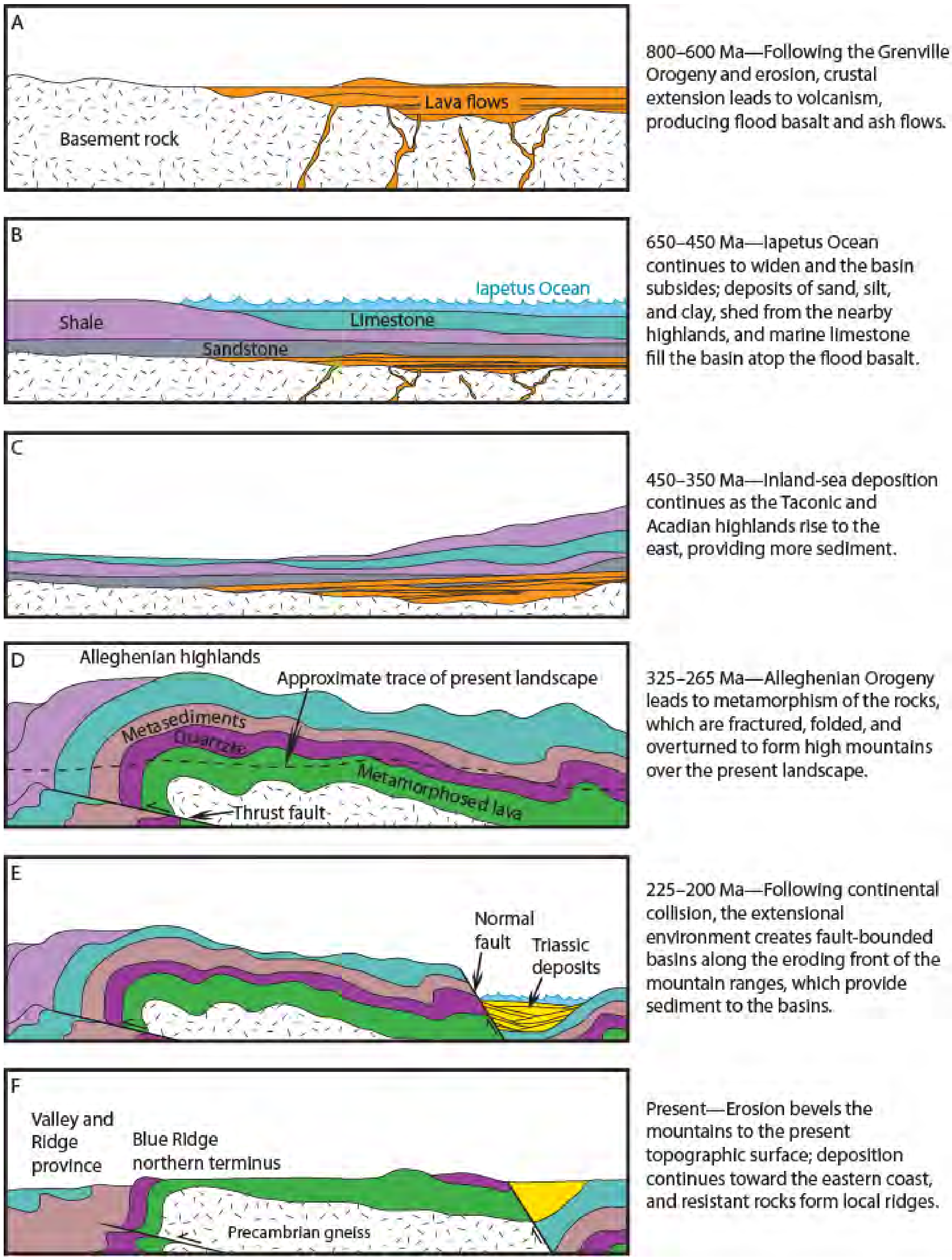

Figure 26. Evolution of the Landscape in South-Central Pennsylvania. The graphic shows tectonic changes from the Precambrian through the present. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University) after Means (1995) and Fedorko et al. (2004).

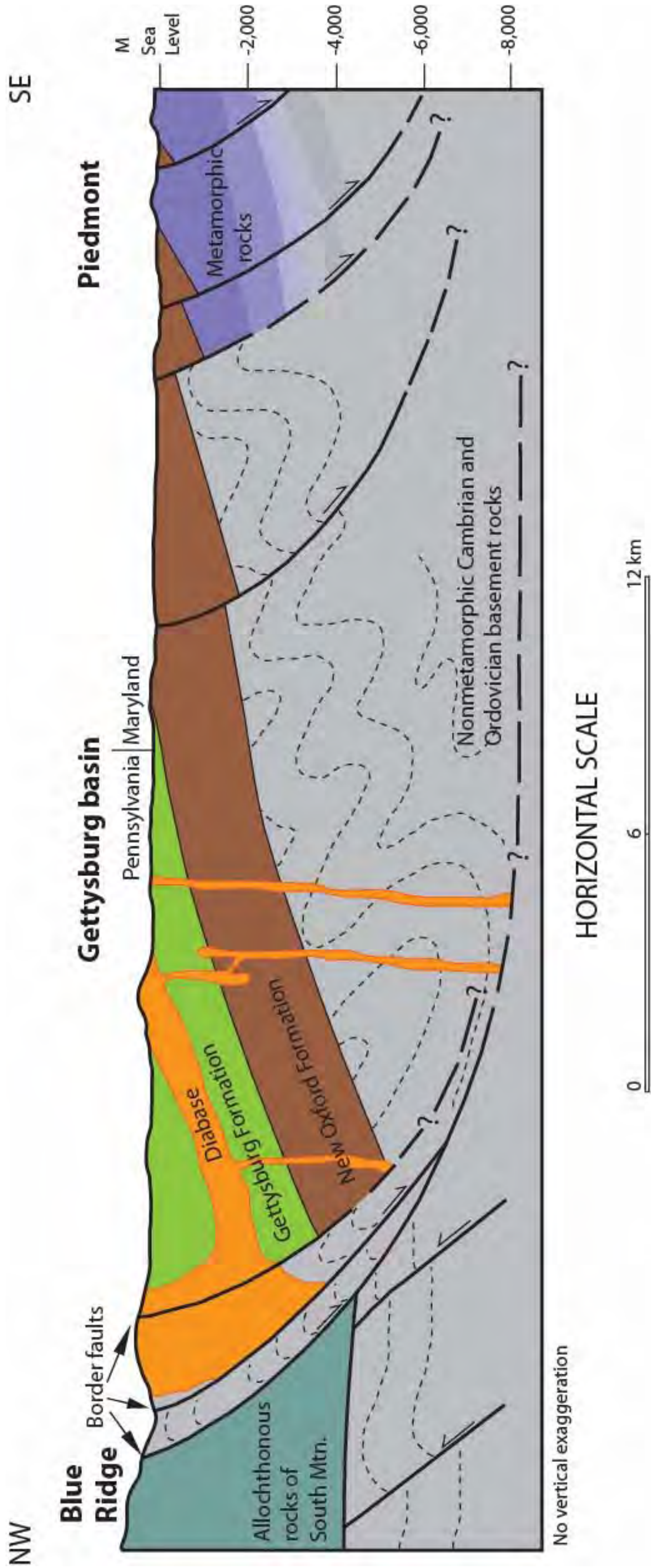

Figure 27. Geologic Cross Section through the Gettysburg Basin. Diagram shows the half graben structure, uniform dip of Mesozoic units, and intrabasinal faults. Graphic is by Trista L. Thornberry-Ehrlich (Colorado State University) after figure 21-5 of Root and MacLachlan (1999).

Glossary

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

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

active margin. A continental margin where significant volcanic and seismic activity occurs; commonly a convergent boundary.

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

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

anisotropic. Having some physical property that varies with direction.

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

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

barrier island. A long, low, narrow island formed by a ridge of sand that parallels the coast.

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

bed. The smallest lithostratigraphic 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.

breccia. A coarse-grained, generally unsorted, sedimentary rock consisting of cemented angular clasts.

calcareous. Rock or sediment containing 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).

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

chemical weathering. Chemical breakdown of minerals at 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.

clay. Clay minerals or sedimentary fragments the size of clay minerals (<1/256 mm [0.00015 in]).

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

concordant. Strata with contacts parallel to the attitude of adjacent strata.

conglomerate. A coarse-grained sedimentary rock with clasts >2 mm (0.08 in) in a fine-grained matrix.

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

continental drift. The concept that continents have shifted in position (see and use "plate tectonics").

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

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

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.

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

crystalline. Having a regular molecular structure (orderly, repeating arrangement of atoms) that may be outwardly expressed by plane faces.

deformation. A general term for the process of faulting, folding, shearing, extension, or compression of rocks as a result of various Earth forces.

delta. A sediment wedge deposited where a stream flows into a lake or sea.

dike. A tabular, discordant igneous intrusion.

dip. The angle between a structural surface and a horizontal reference plane measured normal to their line of intersection.

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

exfoliation. The breakup, spalling, peeling, or flaking of layers or concentric sheets from an exposed rock mass caused by differential stresses due to thermal changes or pressure unloading.

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

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

fanglomerate. A sedimentary rock of heterogeneous materials that were originally deposited in an alluvial fan and have since been cemented into solid rock.

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

footwall. The mass of rock beneath a fault, orebody, or mine working, especially the wall rock beneath an inclined vein or fault.

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

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

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

graben. A down-dropped structural block bounded by steeply dipping, normal faults (also see "horst").

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

hanging wall. The overlying side of an orebody, fault, or mine working, especially the wall rock above an inclined vein or fault.

horst. An uplifted structural block bounded by high-angle normal faults.

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 older rock. The invading rock may be a plastic solid or magma that pushes its way into the older rock.

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

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

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

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

lava. Fluid rock that issues from a volcano or fissure; also, the same material solidified by cooling.

lithosphere. Earth's relatively rigid outmost shell, 50–100 km (30–60 mi) thick, that encompasses the crust and uppermost mantle.

magma. Molten rock material capable of intrusion and extrusion.

matrix. The groundmass of an igneous rock or the finer grained material enclosing the larger grains in a sedimentary rock; also the rock or sediment in which a fossil is embedded.

meander. Sinuous lateral curve or bend in a stream channel.

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

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

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

metamorphism. Literally, "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.

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

oceanic crust. Earth's crust formed at spreading ridges that underlies the ocean basins. Oceanic crust is 6–7 km (3–4 mi) 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 Earth's surface.

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

Pangaea. The single supercontinent that existed during the Permian and Triassic periods.

parent material. Geologic material from which soils form. Parent material is one of five soil-forming factors: climate, organisms, relief (topography), parent material, and time.

parent rock. Rock from which sediments or other rocks are derived.

permeability. A measure of the ease or rate at which fluids move through rocks or sediments.

phenocryst. A coarse crystal in a porphyritic igneous rock.

plastic. Capable of being deformed permanently without rupture.

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

pluton. A body of intrusive igneous rock.

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

porosity. The proportion of void space (e.g., pores or voids) in a volume of a rock or sediment deposit.

porphyry. An igneous rock with abundant coarse 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. Pertaining to clastic rock material formed by volcanic expulsion from a volcanic vent; also pertaining to rock texture of explosive origin. In the plural, the term is used as a noun.

recharge. Infiltration processes that replenish groundwater.

red bed. Sedimentary strata composed largely of sandstone, siltstone, and shale that are predominantly red due to the presence of ferric oxide (hematite) coating individual grains.

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

rock. An aggregate of one or more minerals.

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

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

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

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

sheet flow. An overland flow or downslope movement of water taking the form of a thin, continuous film over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills.

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 (1/256–1/16 mm [0.00015–0.002 in]).

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

skarn. Calcium-bearing silicates derived from nearly pure limestone and dolomite with the introduction of large amounts of Si, Al, Fe, and Mg.

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

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

strata. Tabular or sheet-like 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 moving under gravity flow 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 that an inclined surface makes with a horizontal plane.

strike-slip fault. A fault with measurable offset where the relative movement is parallel to the strike of the fault.

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.

syncline. A fold of which the core contains the stratigraphically younger rocks; it is generally concave upward.

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

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

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

terrace. A relatively level bench or step-like surface breaking the continuity of a slope (see "stream terrace").

terrestrial. Relating to Earth or Earth's dry land.

thrust fault. A contractional, dip-slip fault with a shallowly dipping fault surface ($<45^\circ$) where the hanging wall moves up and over relative to the footwall.

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

trace fossil. A sedimentary structure (e.g., track, trail, or burrow) that preserves evidence of an organism's life activities but not the organism itself.

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

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

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

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

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

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

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

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

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

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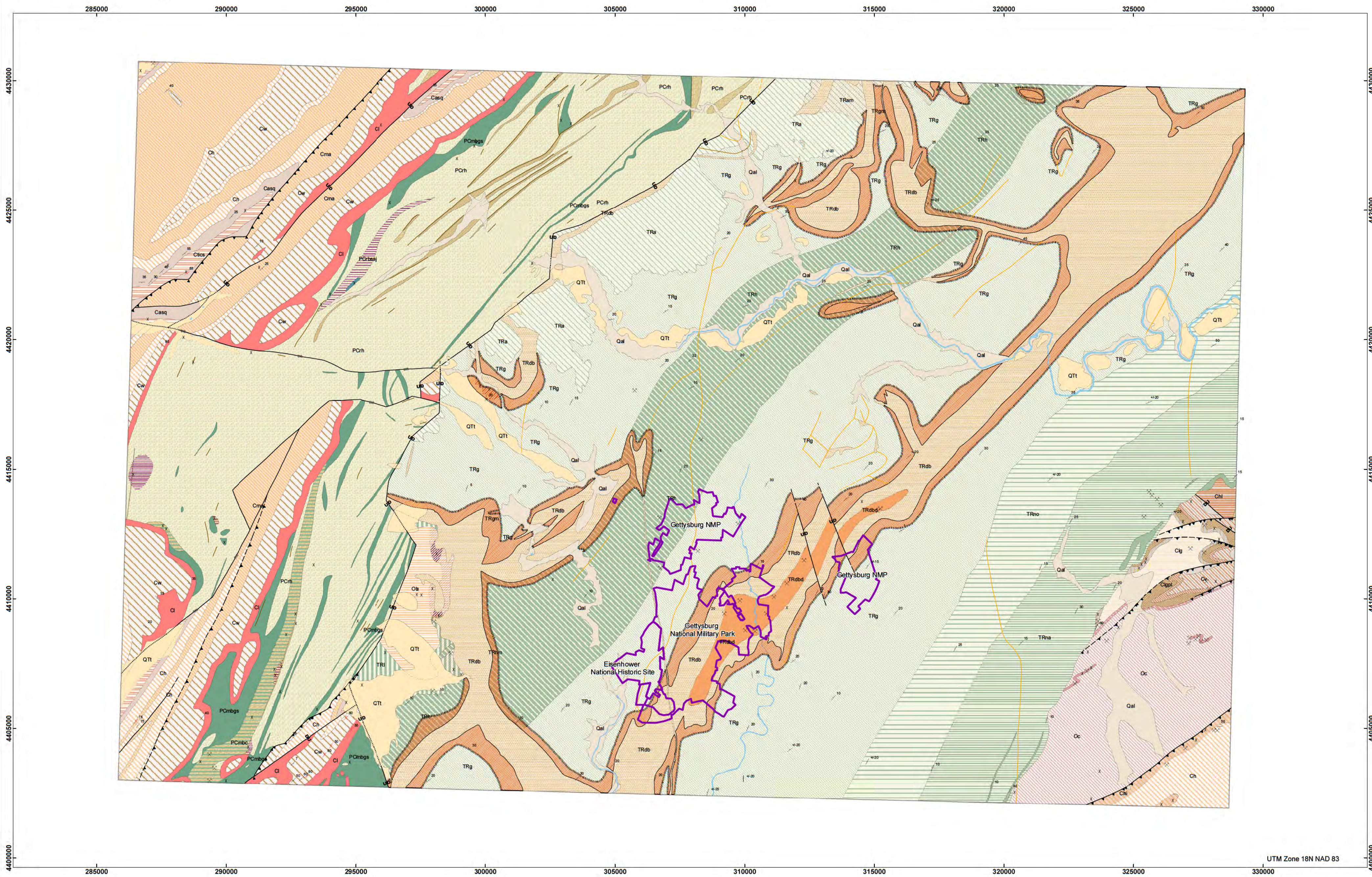
Appendix A: Geologic Map Graphic

The following page is a snapshot of the geologic map for Gettysburg National Military Park and Eisenhower National Historic Site. 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).

Geologic Map of Gettysburg NMP & Eisenhower NHS



Geologic Units

- Water
- Qal - Alluvium
- QTt - Terraces gravel and alluvial cones
- TRdb - Diabase
- TRdbd - Diabase, building stone
- TRl - Gettysburg Shale, Limestone conglomerate lentil
- TRlm - Gettysburg Shale, Limestone conglomerate lentil, magnetite possible
- TRlgm - Gettysburg Shale, Limestone conglomerate lentil
- TRa - Gettysburg Shale, Arendtsville fanglomerate lentil
- TRam - Gettysburg Shale, Arendtsville fanglomerate lentil, magnetite possible
- TRh - Gettysburg Shale, Heidlersburg member
- TRhm - Gettysburg Shale, Heidlersburg member, magnetite possible
- TRg - Gettysburg Shale
- TRgm - Gettysburg Shale, magnetite possible
- TRgmm - Gettysburg Shale, magnetite
- TRno - New Oxford Formation
- TRna - New Oxford Formation, New Oxford arkose
- TRnc - New Oxford Formation, New Oxford conglomerate
- Ob - Beekmantown Limestone
- Obg - Beekmantown Limestone, garnet possible
- Obgm - Beekmantown Limestone, garnet abrasive
- Oc - Conestoga Limestone
- Ocsds - Conestoga Limestone, Conestoga shale and sand, building sand
- Ocs - Conestoga Limestone, Conestoga sandy beds
- Ctics - Tomstown Dolomite, brown iron ore, white paper clay and building sand
- Clg - Ledger Dolomite
- Clgpl - Ledger Dolomite, pure limestone
- Clmmb - Ledger Dolomite, Ledger Limestone Marble, marble
- Ck - Kinsers Formation
- Cv - Vintage Dolomite
- Ca - Antietam Sandstone
- Casq - Antietam Sandstone, building sand and quartzite building stone
- Ch - Harpers Schist
- Chi - Harpers Schist, iron ore
- Cma - Harpers Schist, Montalto Quartzite member
- Cw - Weverton Sandstone
- Cl - Loudoun Formation
- Cc - Chickies Quartzite
- Chl - Chickies Quartzite, Hellam conglomerate member
- PCmb - Metabasalt
- PCmbgs - Metabasalt, greenstone
- PCmbc - Metabasalt, copper
- PCmbsaj - Metabasalt, monumental and jewelry stone
- PCrbsaj - Rhyolitic breccia, monumental and jewelry stone
- PCrbw - Rhyolitic breccia, whetstone
- PCrh - Aporhyolite
- PCrhsaj - Aporhyolite, monumental and jewelry stone
- PCsq - Sericite Schist and vein quartz
- PCsqss - Sericite Schist and vein quartz, sericite schist

NPS Boundary

Geologic Attitude and Observation Localities

- strike and dip of inclined beds
- strike and dip of inclined overturned beds
- strike of vertical beds
- strike of beds, dip amount unspecified

Mine Point Features

- prospect
- mine

Fault Map Symbology

- fault up 'U' indicator
- fault down 'D' indicator
- fault block movement direction arrows (right-lateral)
- fault block movement direction arrows (left-lateral)

Linear Dikes

- TRdb - diabase, known or certain
- TRdb - diabase, approximate
- TRdb - diabase, concealed
- TRb, Basalt Lava Flow, known or certain
- TRb, Basalt Lava Flow, concealed
- PCsq - Sericite schist and vein quartz, known or certain

Faults

- normal or strike-slip fault, known or certain
- normal fault, approximate
- normal or strike-slip fault, concealed
- thrust fault, known or certain
- thrust fault, approximate
- thrust fault, concealed

Alteration and Metamorphic Area Boundaries

- known or certain
- concealed
- gradational
- quadrangle boundary

Alteration and Metamorphic Areas

- area of contact metamorphism

Geologic Contacts

- known or certain
- approximate
- concealed
- inferred
- gradational
- quadrangle boundary
- water or shoreline
- subaqueous (inferred)

This map graphically presents digital geologic data prepared as part of the NPS Geologic Resources Division's Geologic Resources Inventory. The source map used in creation of the digital geologic data product was:

Stose, G.W. and F. Bascom. 1929. Geologic Atlas of the United States, Fairfield-Gettysburg Folio No. 225, Pennsylvania. Scale 1:62,000. Department of the Interior, U.S. Geological Survey.

Digital geologic data and cross sections for Gettysburg NMP & Eisenhower NHS, and all other digital geologic data prepared as part of the Geologic Resources Inventory, are available online at the NPS Data Store: http://science.nature.nps.gov/nrdata/

0 4 8 16 Kilometers

0 2 4 8 Miles

N

Produced by the Geologic Resources Inventory

January 2009

Gettysburg National Military Park and Eisenhower National Historic Site
Geologic Resources Inventory Report

Natural Resource Report NPS/NRPC/GRD/NRR—2009/083

National Park Service

Acting Director • Dan Wenk

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