National Park Service
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Natural Resource Program Center

Manassas National Battlefield Park

Geologic Resource Evaluation Report

Natural Resource Report NPS/NRPC/GRD/NRR—2008/050

ON THE COVER:
Cannons at Battery Heights, Manassas National Battlefield, Virginia

NPS Photo by Bryan Gorsira

Manassas National Battlefield Park

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Geologic Resources Division
Natural Resource Program Center
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Executive Summary

This report accompanies the digital geologic map for Manassas National Battlefield Park in Virginia, which the Geologic Resources Division produced in collaboration with its partners. It contains information relevant to resource management and scientific research.

Manassas National Battlefield Park preserves one of the landscapes where the historic struggle between the forces in favor of secession, the Confederates, and those in favor of restoring the United States, the Union, took place during the U.S. Civil War. This landscape includes the stream banks of Bull Run, the slopes of Henry Hill, Chinn Ridge, Matthews Hill, and Battery Heights, the marshlands around the streams and old stone bridge, the unfinished railroad grade, and the monuments erected to commemorate individuals and events. Some of the principal geologic issues and concerns for the park are relevant in protecting these features.

The battles at Manassas Junction were pivotal during the Civil War. The Battle of First Manassas in 1861 was for many a first taste of the hardships of war life. In 1862, the Battle of Second Manassas pitted hardened men against each other again in the pastoral setting of fields, slopes, and forests in Manassas. Here, the geology influenced the outcome, favoring soldiers who knew the terrain, including the river crossings and fords, wetlands and forests, mountain gaps, and gentle topographic differences. These men used knowledge of the landscape to their advantage, planning strategies to minimize losses and maximize opportunities during the battles of Manassas.

Geologic processes play a role in today's environments, history, and scenery. They give rise to a landscape composed of rock formations, ridges and hills, wetlands, slopes, valleys, ravines, and streams. These processes develop a setting that influences human use patterns. Local geology influenced the railroads, roads, river fords, and site of the bridge over Bull Run and the subsequent setting of Civil War battles. Today Manassas National Battlefield Park attracts visitors in search of a historical touchstone and recreation opportunities. Emphasis on geologic resources can enhance the visitor's experience and protect the historic legacy of the area. Knowledge of geologic resources can inform resource management decisions that address geologic issues, scientific research, and interpretive needs associated with the park.

Humans continue to significantly modify the landscape surrounding Manassas National Battlefield Park. Consequently, humans have modified the geologic system in this area of Virginia. This system is dynamic and capable of noticeable change within a human life span. Geologic processes continue to change the landscape, making park preservation and resource management a challenge.

The following issues, features, and processes were identified as having the most geologic importance and the highest level of significance for management of the park:

- Erosion and slope processes

  The relatively wet climate of the eastern United States, combined with severe storms and the marshy wetlands along the banks of Bull Run and other local streams, creates a setting which is especially susceptible to slumping, slope creep, and erosion of stream banks. The lack of stabilizing plant growth frequently contributes to high rates of erosion during intense seasonal storms. Runoff can dramatically alter the landscape, creating new hazards and undermining historic features.

- Geology and biodiversity

  Manassas National Battlefield Park is famous for its forest biodiversity, including at least eight forest types. This diversity is a direct result of the geology and climate of the area. Protecting the ecosystems found in wetlands, meadows, hill slopes, and ridge tops, as well as understanding the relationships between geology and biology throughout the park is key to resource management.

- Recreational demands

  Visitors come to the park for a glimpse into the history of the Civil War, and to enjoy the beauty of eastern Virginia. Facilities catering to visitors include trails, museums, historic buildings, picnic areas, and visitor centers. Visitors place increasing demands upon the geologic resources at the park.

  High-use areas, such as trails, are at risk of environmental degradation and pollution. Geologic change may also compromise the manmade structures and the preserved historical context. This threat applies to trails, the old stone bridge over Bull Run, historic buildings, and the unfinished railroad grade on the western side of the park. Weathering and erosion are relentlessly changing the landscapes of the park.

Other geologic parameters and issues such as water quality and hydrogeology, historic landscapes, restoration and preservation, and geology education and research, were also identified as geologic resource management concerns for Manassas National Battlefield Park. These are described in detail in the *Geologic Issues* section of this report.

Introduction

The following section briefly describes the National Park Service Geologic Resource Evaluation Program and the regional geologic setting of Manassas National Battlefield Park.

Purpose of the Geologic Resource Evaluation Program

The Geologic Resource Evaluation (GRE) Program is one of 12 inventories funded under the NPS Natural Resource Challenge designed to enhance baseline information available to park managers. The program carries out the geologic component of the inventory effort from the development of digital geologic maps to providing park staff with a geologic report tailored to a park's specific geologic resource issues. The Geologic Resources Division of the Natural Resource Program Center administers this program. The GRE team relies heavily on partnerships with the U.S. Geological Survey, Colorado State University, state surveys, and others in developing GRE products.

The goal of the GRE Program 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 GRE team is systematically working towards providing each of the identified 270 natural area parks with a geologic scoping meeting, a digital geologic map, and a geologic report. These products support the stewardship of park resources and are designed for non-geoscientists. During scoping meetings the GRE team brings together park staff and geologic experts to review available geologic maps and discuss specific geologic issues, features, and processes.

The GRE 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. As a companion to the digital geologic maps, the GRE team prepares a park-specific geologic report that aids in use of the maps 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 up to date GRE contact information please refer to the Geologic Resource Evaluation Web site (http://www.nature.nps.gov/geology/inventory/).

History of Manassas National Battlefield Park

Manassas National Battlefield Park, located in Prince William County, Virginia, was established on May 10, 1940, by an act of Congress to preserve and commemorate the sacrifices made during the American Civil War (fig. 1). In fact, commemorative and preservation efforts had been in progress since 1861, when soldiers from Colonel Francis S. Bartow's Confederate brigade placed a marble column on Henry Hill six weeks after the First Battle of Manassas.

Manassas National Battlefield Park preserves the setting of two pivotal and significant battles of the American Civil War. The Battles of First and Second Manassas were fought in the pastoral Virginia countryside on July 21, 1861, and August 28–30, 1862, respectively. The first battle ended northern hopes of a quick rout of the Confederacy. The second battle heightened southern hopes of a victory at enormous costs.

Commemorative efforts occurred at Manassas long before it was designated a national park in 1940. Only six weeks after the First Battle of Manassas, soldiers from Colonel Francis S. Bartow's brigade marked his sacrifice by placing a marble column on Henry Hill. This monument was the first of a great number of memorials erected by individuals and governments at the Manassas battlefields (Zenzen 1998).

The boundaries of the park have changed several times since its beginning (April 17, 1954; October 30, 1980; and November 10, 1988). The 5,073.17 acre park attracted 584,926 visitors in 2007.

Geologic Setting

Geology affected the Manassas battles on regional and local levels. Two large regional rivers, the Rappahannock and the Rapidan, shaped the course of military movements in the area before the battles. Safe river crossings were vital to military success during the Civil War. Three smaller streams played a significant role in the actual fighting at Manassas: Bull Run and its tributaries, Little Bull Run, Broad Run, and Dogan Run created important topographic differences and tactical targets such as railroad bridges, crossings, gaps, gulleys, and protective cover. On the gentle landscape of Manassas, even the smallest swell or depression was utilized to the troops' advantage (Zen and Walker 2000).

Within the battlefield, significant yet subtle ridges such as Chinn Ridge, Henry Hill, Bald Hill, Buck Hill, Matthews

Hill, Dogan Ridge, and Battery Heights, range in elevation from 82–88 m (270–290 ft) above sea level. These are separated by ravines of waterways eroding through the sedimentary rocks of the Culpeper Basin. Larger ridges underlain by resistant igneous rocks, such as Stony Ridge and Stuart Hill, are about 100–105 m (330–340 ft) high and were of vital importance during the Battles of First and Second Manassas.

Four parallel ridges (from west to east, Swains Mountain, Watery and Piney Mountains, Pignut Mountain, and Bull Run Mountain [Catoctin Mountains]), were significant in troop movement prior to the battles of Manassas. These ridges, composed of materials such as Weverton Quartzite and Catoctin Greenstone, are relatively resistant to erosion.

Throughways in these ridges, known as gaps, were vital transport routes and therefore targets for Civil War soldiers. Broad Run crosses Bull Run Mountain at Thoroughfare Gap as a superposed drainage. The gap was significant prior to Second Manassas because lack of Union defense allowed reinforcement of Confederate troops through the gap. The Little River runs through another gap between the north end of Bull Run Mountain and the south end of Hogback Ridge (Zen and Walker 2000).

Manassas National Battlefield Park is located in the Culpeper Basin, a distinctive geological province that is one of a series of Triassic trough-like depressions (described below). Relatively low relief, gently rolling hills, and flat fields characterize the basin.

The battles of Manassas involved fighting and maneuvering over four physiographic provinces. The Culpeper Basin separates the Blue Ridge province from the Piedmont province. The following is a general description of the different physiographic provinces of the Appalachian Mountains, including a regional province, the Culpeper Basin.

Atlantic Coastal Plain Province

The Atlantic Coastal Plain province is primarily flat terrain with elevations ranging from sea level to about 100 m (300 ft) in northern Virginia. It extends from New York to Mexico. Sediments eroding from the Appalachian Highland areas to the west were intermittently deposited on the Atlantic Coastal Plain over the past 100 million years, forming a wedge-shaped sequence during periods of higher sea level. These deposits were then reworked by fluctuating sea levels and the continual erosive action of waves along the coastline.

The Atlantic Coastal Plain province stretches from the Fall Line east to the Chesapeake Bay and Atlantic Ocean. Atlantic Coastal Plain surface soils are commonly sandy or sandy-loams that are well-drained. Large streams and rivers in the Atlantic Coastal Plain province, including the James, York, and Potomac Rivers, are often influenced by tidal fluctuations.

Piedmont Province

The "Fall Line," or "Fall Zone," marks a transitional zone where the softer, less-consolidated sedimentary rocks of the Atlantic Coastal Plain to the east intersect the harder, more resilient metamorphic rocks to the west, forming an area of ridges and waterfalls and rapids. This zone covers more than 27 km (17 mi) of the Potomac River from Little Falls Dam, near Washington, D.C., west to Seneca, Maryland. Examples of this transition are evident in the Potomac Gorge of the Chesapeake and Ohio Canal National Historic Park. Encompassing the Fall Line, westward to the Blue Ridge Mountains, is the Piedmont physiographic province.

The eastward-sloping Piedmont Plateau was formed through a combination of folding, faulting, uplift, and erosion. These processes resulted in an eastern landscape of gently rolling hills starting at 60 m (200 ft) in elevation that become gradually steeper towards the western edge of the province at 300 m (1,000 ft) above sea level. Soils in the Piedmont Plateau are highly weathered and generally well drained.

Culpeper Basin

The Culpeper Basin is one of a series of basins that fringe the boundary between the Blue Ridge and Piedmont along the length of the Appalachian Mountains. The basin formed during the Mesozoic as an intermountain basin during a tensional tectonic event. It trends northeast–southwest and is about 120 km (75 mi) long and 30 km (20 mi) wide. The rocks in the basin are largely flat-lying sedimentary sandstone, siltstone and shale and include some igneous diabase and basalt.

The boundary of the Culpeper Basin with the Piedmont Plateau is defined by a depositional contact that is best indicated by a topographic change from the rolling hills of the Piedmont to relatively flat ground in the basin. The western boundary of the basin, west of which lies the Blue Ridge province, is defined sharply by a system of faults, locally culminating in the large Bull Run fault (Zen and Walker 2000).

Blue Ridge Province

The Blue Ridge Province extends from Georgia to Pennsylvania along the eastern edge of the Appalachian Mountains. It contains the highest elevations in the Appalachian Mountain system in North Carolina, near Great Smoky Mountains National Park. Precambrian and Paleozoic igneous and metamorphic rocks were uplifted during several orogenic events to form the steep, rugged terrain. Resistant Cambrian quartzite forms Blue Ridge, Bull Run Mountain, South Mountain, and Hogback Ridge, whereas Precambrian metamorphic rocks underlie the valleys (Nickelsen 1956).

Eroding streams have caused the narrowing of the northern section of the Blue Ridge Mountains into a thin band of steep ridges, climbing to heights of more than 1,200 m (3,900 ft). The Blue Ridge province is typified by steep terrain covered by thin, shallow soils, resulting in rapid runoff and low ground-water recharge rates. Many of the streams dominating the landscape around

Manassas begin along the slopes of the Blue Ridge, dissecting them into ridges and ravines.

Valley and Ridge Province

The landscape of the Valley and Ridge physiographic province is characterized by long, parallel ridges separated by valleys. These valleys were formed where resistant sandstone ridges border more easily eroded shale and carbonate formations.

Areas dominated by carbonate formations exhibit karst topography. “Karst” is a term used to describe a region of irregular topography characterized by sinks, underground streams, caves, and springs formed by water percolating through water-soluble rock.

The eastern part of the Ridge and Valley province is part of the Great Valley (Shenandoah Valley). It is connected to the Piedmont province by streams that cut through the Blue Ridge Mountains.

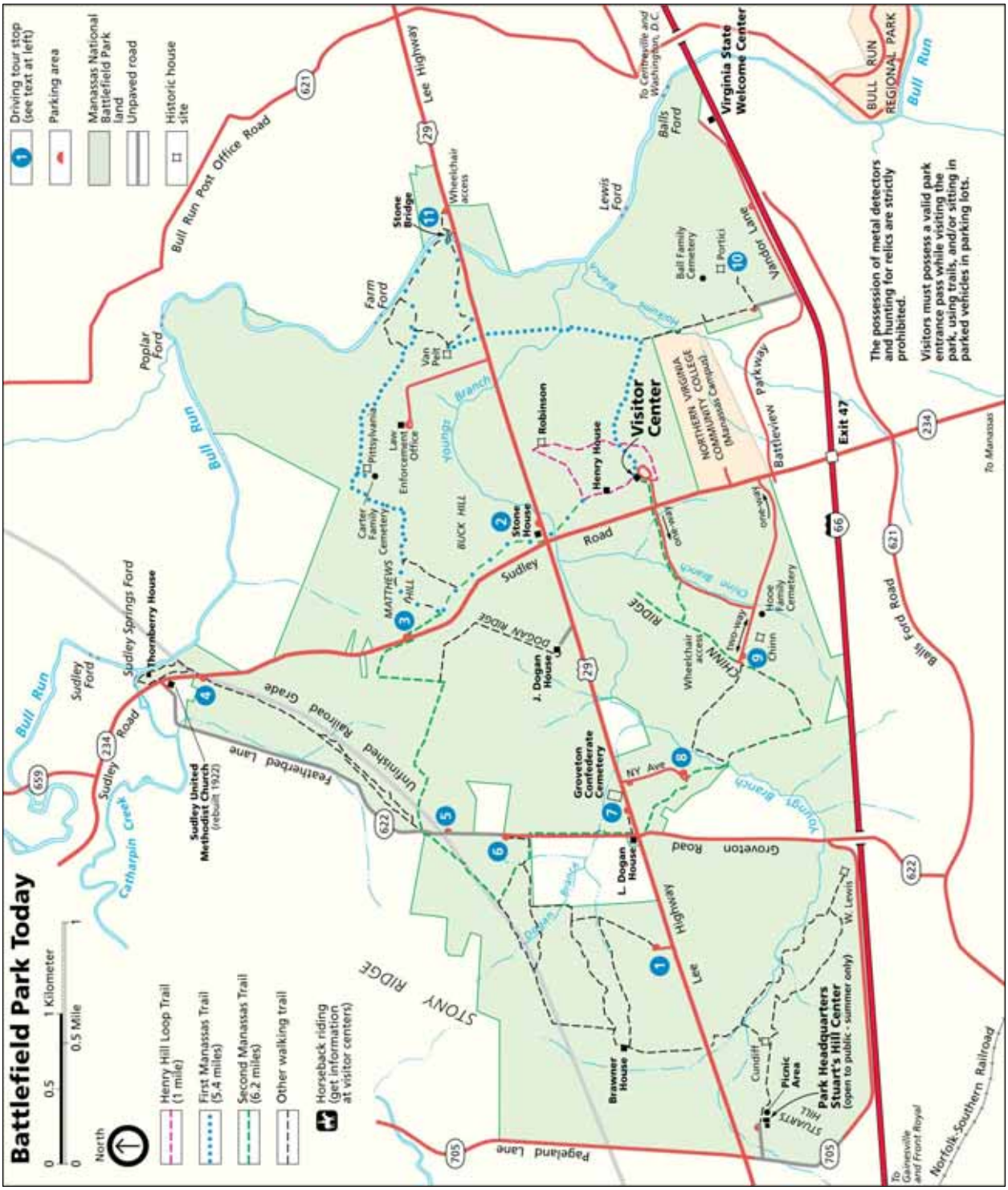

Figure 1. Modern Location Map of Manassas National Battlefield Park.

Geologic Issues

A Geologic Resource Evaluation scoping session was held for Manassas National Battlefield Park on April 30–May 2, 2001, to discuss geologic resources, address the status of geologic mapping, and assess resource management issues and needs. This section synthesizes the scoping results, in particular those issues that may require attention from resource managers.

Erosion and Slope Processes

Intense erosion of steep slopes is responsible for the development of hilltops, ridges, ravines, and river valleys in Manassas National Battlefield Park (fig. 2). Natural geomorphological process, including landslides and debris flows, also cause several geologic hazards that can pose management issues. These hazards have the potential to endanger park staff and visitors and damage infrastructure including roads, trails, and historic features.

Steep slopes in the area include Stuart's Hill, Chinn Ridge, Buck Hill, Battery Heights, and Matthews Hill. These sites are all vulnerable to landslides and debris flows. Many of the river and tributary valleys within and around the park are also at risk because of steep slopes (fig. 3). The likelihood of slope hazards increases with high levels of precipitation and the undercutting of slopes by roads and trails. Lack of stabilizing vegetation often contributes to the mobilization of rock and soil downslope as massive slumps or debris flows. In the vicinity of streams and rivers, severe erosion can lead to bank erosion, increased sediment load, gullying, and the threat of destruction for trails, bridges, and historic features.

Slope hazards are amplified in areas of weaker rock units, such as fractured siltstone and weathered diabase. Unconsolidated alluvium is also quite vulnerable to failure when exposed on a slope. Landslide hazard models and maps could help park managers assess the relative risk for landslide occurrence in specific areas. These tools use information about geology, topology, and climate to identify hazardous areas.

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

- Monitor unstable slopes and streambanks for hazards to staff and visitors.
- Monitor erosion rates at key sites using repeated profile measurements.
- Develop a landslide hazard map or model for the park.

Geology and Biodiversity

Natural areas protect many plant and animal species. They are segments of wildlife corridors that link increasingly scarce natural habitat and provide a haven where migratory wildlife can rest and feed. These areas also serve as outdoor classrooms for the public to learn about natural systems. Understanding the factors that lead to biodiversity, such as geology, climate, topography, and hydrology, is critical to understanding the distribution of unique habitats and ecosystems and managing them effectively for preservation and restoration.

NPS units, such as Manassas National Battlefield Park, that were established for their cultural or historical resources can also add to the biological diversity of an entire region, especially in areas of heavy development. Many of these parks are islands of critical natural areas in otherwise discontinuous and developed landscapes.

In 2002, a study by the Virginia Department of Conservation and Recreation classified 8 types of forest in Manassas National Battlefield Park:

- Piedmont/Mountain Swamp Forest,
- Upland Depression Swamp,
- Piedmont/Mountain Bottomland Forest,
- Basic Mesic Forest,
- Basic Oak Hickory Forest,
- Acidic Oak Hickory Forest,
- Eastern White Pine/Hardwood Forest, and
- Eastern Red Cedar Successional Forest.

The area surrounding Manassas National Battlefield Park is becoming increasingly populated. As development continues, conservation of forest community types becomes a critical concern. The geology beneath the forest communities may be key to their management.

In 1997–98, the Virginia Department of Conservation and Recreation, in conjunction with the Division of Natural History, inventoried Manassas National Battlefield Park for rare, threatened, and endangered species as well as for significant natural communities. Four rare or significant habitats were identified in the park: the Upland Depression Swamp, Oak-Hickory, Eastern White Pine, and Piedmont Mountain Swamp Forests. Manassas National Battlefield Park is also host to rare flora and fauna. More than 700 taxa were inventoried in the 1997–98 study. Some of the rare plants include Blue-hearts (*Buchnera americana*), Mead's Sedge (*Carex meadii*), Hoary Puccoon (*Lithospermum canescens*), Hairy Beardtongue (*Penstemon hirsutus*), Purple Milkweed (*Asclepias purpurascens*), Appalachian

Quillwort (*Isoetes appalachiana*) and Buffalo Clover (*Trifolium reflexum*).

The geologic features of the Culpeper Basin–Piedmont are significant factors in occurrence and distribution of the flora and fauna protected within the park. The ecosystem can vary greatly in response to slope aspect, elevation, soil type and permeability, degree of slope fluctuations, and exposure to climatic conditions (e.g., wind). An understanding of the distribution of these factors and their corresponding flora and fauna connections can be used to help model additional habitat locations and manage future restoration and preservation efforts. Because geology is an important element of the ecosystem, correlation with geological features and resources is often helpful to biological inventory and monitoring efforts.

Inventory, Monitoring, and Research Suggestions for Geology and Biodiversity

- Measure and document changes in the hydrologic regime in areas of the park where human activity has impacted the natural system.
- Identify reference sites for rare and significant habitats to accurately restore the environment at Manassas.
- Complete compilation of data for vascular plants and vertebrates with attention to relationship between their geographic distribution and geologic materials. Sources for these data include museum records of voucher specimens, previous studies, and park databases.
- Once established, monitor changes in geologic controls on species distribution, including hydrologic systems, slopes, and human development.

Recreational Demands

Manassas National Battlefield Park provides numerous recreational possibilities, including Civil War study, hiking, fishing, bicycling, picnicking, and photography. The park promotes activities that do not damage the park's resources or endanger other visitors.

The park receives many visitors, especially during the summer months (fig. 4). These visitors place increasing demands on the resources of the park. Management concerns vary from trail erosion to maintaining historic landscape and monument integrity.

Park trails wind through a variety of preserved biological, historical, and geological environments. Many of these are especially fragile, and off-trail hiking promotes their degradation. The park designates trails and picnic areas to limit the impacts of recreation. Visitor use in non-designated areas places delicate ecosystems at risk for damage and contamination (figs. 5 and 6).

Several streams enhance the natural beauty of the park. These streams also played a significant role in the battlefield history and thus have a role in the cultural experience. As with hiking, overuse of certain areas can lead to contamination and degradation of the ecosystem and increased erosion of stream banks.

Inventory, Monitoring, and Research Suggestions for Recreational Demands

- Develop resource management plans including inventory and monitoring to further identify human impacts on any springs, wetlands, battlefield sites, and marsh flora within the park.
- Design wayside exhibits to encourage responsible use of park resources.
- Monitor water in streams and wells for contamination in high-use areas.

Restoration and Preservation of the Landscape

The mission at Manassas includes restoration and preservation of the battlefield's natural and pastoral setting. In 1996, Manassas National Battlefield Park and the Smithsonian Institution collaborated on a wetland mitigation project. This project addressed the Smithsonian's objective to maintain a wetland within the watershed and helped to achieve the park's goal to preserve the historic landscape and integrity of the battlefield site.

The wetland project area is in the southwestern part of the park, where part of the battle of Second Manassas took place. Today it is part of the Stuart's Hill Tract, encompassing 558 acres of land bounded by Groveton Road to the east, Interstate 66 to the south, Lee Highway to the north, and Pageland Lane to the west. Although a historic wetland, this area was severely altered by a land development company that built a road, recontoured the landscape, and established a drainage network before the park acquired the land in 1988. Wetland areas were filled, and the hydrologic system of the area was significantly altered (Zenzen 1998).

The wetland mitigation consisted of excavation and grading to reestablish 1862 contours consistent with the natural hydrology of the area. The mitigation project began in June 2003 and finished in November 2003. The work covered 106 acres, including 30 acres of mixed forest and shrub-scrub wetland, and 15 acres of emergent wetland. The project included restoration of stream corridors and drainages, and planting of appropriate vegetation.

As determined from study of historic records, this environment now approximates its state in 1862, during the Second Battle of Manassas. For more information on this project, please see the following document: http://www.cr.nps.gov/history/online_books/mana/adhi.htm (Accessed August 2008).

Water Quality and Hydrogeology

In the humid eastern climate of Virginia, water seems present everywhere in streams, rivers, runoff, springs, and wells. Annual precipitation at Manassas averages 99 cm (39 in) per year with almost half of the rain coming in the summer months during short, intense storms.

Because of rapid development in the surrounding area, water resources are under constant threat of contamination and overuse. Streams in effect integrate

the surface runoff and groundwater flow of their watersheds. Thus, they provide a measure of the status of the hydrologic system.

Where agricultural remnants (herbicides, pesticides, animal wastes) and other pollutants are stored, nitrogen levels in the water reach dangerous levels. Runoff from roadways commonly contains high levels of oil and other car emissions, which are carried into park waterways and seep into the soil. Knowledge of the chemicals used in regional agriculture and of the hydrogeologic system, including groundwater flow patterns, are essential to protect the park's ecosystem.

Suburban development surrounding Manassas affects the watershed in a variety of ways not related to water contamination. For instance, the hydrogeologic system changes in response to increased surface runoff. This increase results from addition of impervious surfaces such as parking lots, roads and buildings. Sedimentation also increases due to clearing land for development and water temperature increases because of the insulating nature of impervious surfaces. Base flows of streams decrease because impervious surfaces prevent infiltration into the aquifer. Thus, the difference between base and peak streamflow typically increases as a consequence of development in the absence of mitigation measures such as detention ponds.

The Audubon Naturalist Society has conducted water-quality workshops at Manassas since 1999. These programs educate the public and concentrate on protecting and restoring local watersheds. The information gathered at these workshops adds to the water-quality data for Manassas.

Inventory, Monitoring, and Research Suggestions for Water Quality and Hydrogeology

- Work with the NPS Water Resources Division (WRD) to design and implement an appropriate water quality monitoring program.
- Work with the U.S. Geological Survey, Virginia Geological Survey, and conservation groups, to study the park's watershed and the hydrology of the area for applications in hydrogeology, slope creep, stream bank erosion, and other geologic hazards.
- Map and quantify water subterranean recharge zones.
- Use sediment coring, tree-ring studies, and historical data to develop chronologies of past floods and their impacts. Document predictions for frequency and extent of future floods and their impacts, including changes to stream channel morphology and position, nature of the substrate, post-flood changes, and ecosystem recovery. Where possible, data should also be collected during storms and floods to monitor immediate effects.

Historical Landscapes

One goal of the Manassas National Battlefield Park is to maintain a sense of the historical context of the area, which includes the battlegrounds. It also includes natural and cultural resources associated with early European settlement and Native Americans inhabiting the area. The continuous natural processes of erosion and weathering and the demands of increasing local population and urban development constantly challenge the parks ability to achieve this goal. Issues may also arise from opposing values between cultural and natural resource management.

Much of the landscape within Manassas National Battlefield Park maintains a wartime character. For instance, Henry Hill is still cleared of large trees much as it was during the heavy fighting at First Manassas. The Stone House (ca. 1828) overlooks the intersection of the Warrenton Turnpike with the Sudley-Manassas Road. The unfinished railroad cut, vital to Confederate success at Second Manassas, still runs through the woods in the northern edge of the park. Thornberry House still stands near Sudley Springs (fig. 4). Other features, such as the Chinn Farm, and the Carter Cemetery, are but remnants. These historic features may require protection from geologic processes.

However, at the time of the battle, thick forests and fields with wetlands and river bottoms dominated the landscape. Drainage of wetlands, mowing and farming, trail and road construction, monument construction, facilities management and other activities since the early part of the commemorative effort at the park have changed the landscape and the geologic system (fig. 5).

Paleontology

Manassas National Battlefield Park has not had a formal paleontological inventory and there are no collections of paleontological material in the park's museum. However, a number of fossil discoveries have been made within the rocks of the park and collected specimens are currently housed at the Smithsonian Institution's National Museum of Natural History and the USGS headquarters in Reston, VA (Kenworthy and Santucci 2004).

Fossils have been discovered in the Groveton Member of the Bull Run Formation in the park. The Groveton is characterized by thick red shales, siltstones and some sandstones, interbedded with thin gray shales. These sediments probably were deposited in lacustrine to playa flat depositional environments. The Groveton has produced abundant notostracans (*Triops* cf. cancriformis; tadpole shrimp) along with conchostracans (*Cyzicus* sp.; clam shrimp), and ostracodes (*Darwinula* sp.). These fossils tend to be very small. For example, the notostracan fossils ranged in size from 0.25–0.5 inches (6.5–13.5 mm). The notostracan fossils collected within Manassas National Battlefield Park are of particular interest and scientific significance because they are the first reported from Triassic-aged rocks in North America. The only previous report of notostracans from North America was from Permian-aged rocks (290–248 Ma) in Oklahoma. Worldwide, fossil notostracans are very rare and not well studied (Kenworthy and Santucci 2004).

The Bull Run Formation within Manassas National Battlefield Park has also produced the only insect

remains known from the Culpeper Basin. This insect has been identified as a probable staphylinid beetle. Additionally, some disarticulated fish scales and bones, fragmentary plant remains, spores and pollen, and lacustrine stromatolites have been found. Ichnofossils (fossil footprints or trackways) including *Gwyneddichnium majore* (footprints of the aquatic lizard *Gwyneddosaurus*) are also known from the Groveton Member within the park (Kenworthy and Santucci 2004).

Fossils are non-renewable resources that require park protection. Fortunately, fossil theft does not appear to be a problem for the park at this time. Scientific interest in the paleontology of Manassas National Battlefield may afford the park an opportunity to partner with researchers and develop interpretive programs and materials explaining this aspect of the parks geologic history.

Inventory, Monitoring, and Research Suggestions for Paleontology

- Monitor known fossil localities to protect them from potential poachers.
- Collaborate with the scientific community to develop interpretive paleontological themes for talks and exhibits.
- Be aware of formations containing fossil resources when planning infrastructure projects in the park.

Geology Education and Research

A detailed geologic map and a road or trail log and a guidebook linking Manassas National Battlefield Park to the other parks in the Central Appalachian region would enhance a visitor's appreciation of the geologic history and dynamic processes that not only created the landscape but also impacted the battle history showcased at the park. Strategically placed wayside exhibits would also help explain the geology to visitors.

Inventory, Monitoring, and Research Suggestions for General Geology

- Collaborate with other agencies, such as the U.S. Geological Survey and the Virginia Geological Survey, to complete and integrate geologic studies of the rivers draining the Piedmont. Such studies would improve an understanding of Cenozoic tectonics along the East Coast.
- Support detailed geologic mapping within the park to determine if the boundary between the Culpeper Basin and the Piedmont is conformable on a local scale.
- Develop interpretive exhibits discussing sedimentary deposits and igneous rocks underlying the park, their origins, and their significance for the geomorphology of the area, especially with regard to the battles fought there in 1861 and 1862.

Figure 2. Gullying beneath a small footbridge near the unfinished railroad grade and Thornberry House. Intense seasonal storms create erosive torrents of runoff that scour the unconsolidated soil and other surficial deposits at Manassas. These processes threaten trails, buildings, slopes, monuments and other visitor facilities. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 3. Buttressing along the banks of Bull Run. Structures such as this are placed to preserve a stream bank from erosion. One of the park's most traveled trails is atop this structure. Slopes along the banks of Bull Run can be high, accelerating erosion. Erosion has already exposed the tree roots (visible in lower right part of photograph). Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

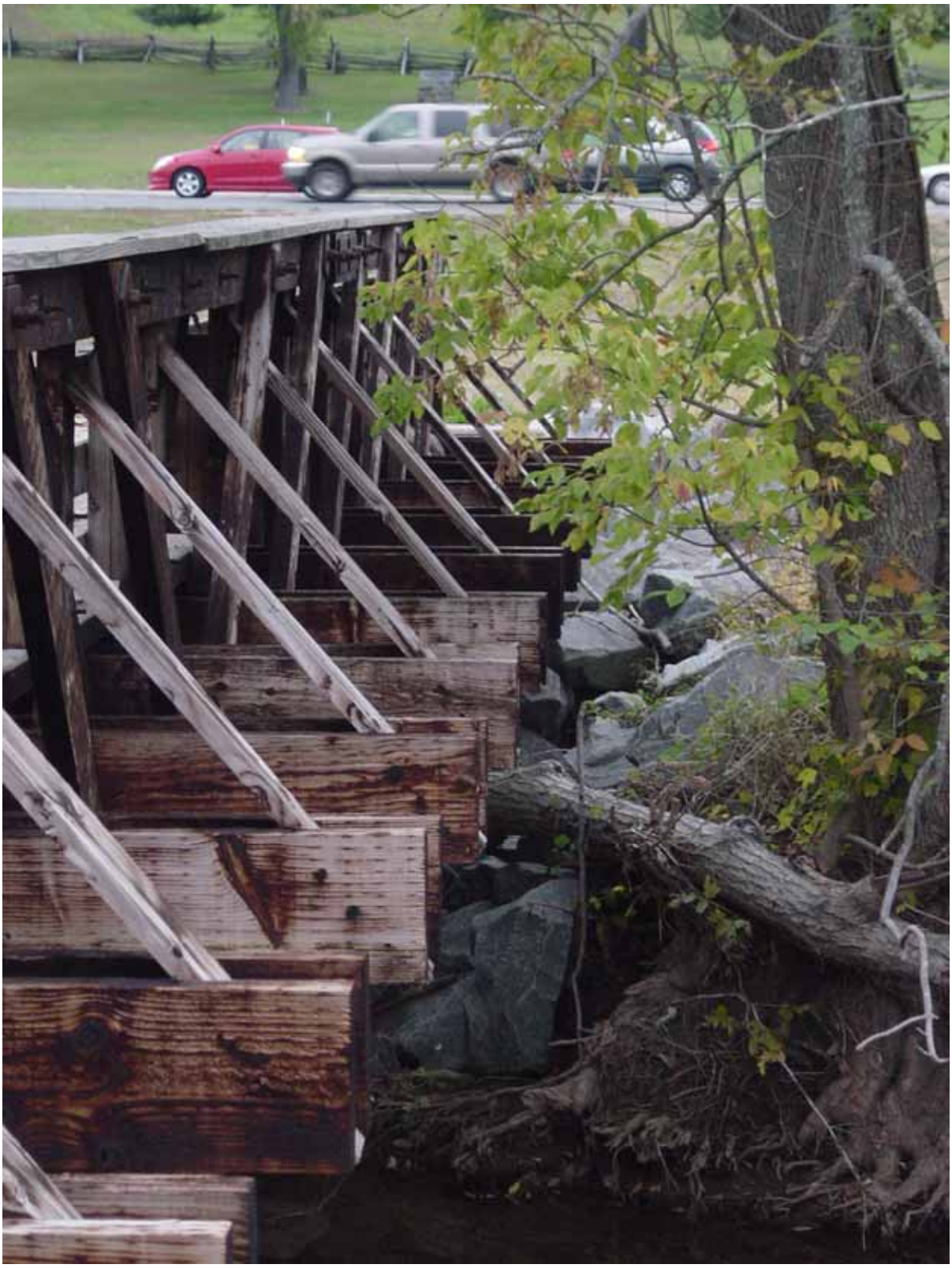

Figure 4. A foot bridge near the Stone House accommodates pedestrian traffic on the popular trails at Manassas National Battlefield Park. Large rocks were placed along the stream banks as a foundation for the bridge to prevent erosion from undermining the structure. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 5. Erosion and widening of a popular trail (First Manassas Battlefield walking tour) at Manassas National Battlefield Park. Local seeps and springs create natural wet areas, which are especially prone to erosion. Stairs were built to concentrate foot traffic along this part of the trail, but the traffic has widened the trail beyond the stairs. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 6. A temporary drain over a trail. Plastic piping is used to keep runoff from eroding trail and trail edges. Remedies such as this are temporary and often damaged by foot traffic. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 7. Restoration and preservation efforts at the Thornberry House, near Sudley Springs Ford in the northernmost corner of the park. The building was used as a residence, field hospital, and post office during its long history dating back to before the Civil War. Efforts include stabilizing the foundation and restoring slopes around the structure. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 8. Intersection of State Route 234 (running north-south; formerly the Manassas Sudley Road) and U.S. Highway 29 (running east-west; formerly the Warrenton Turnpike). These two roads traverse the park in both directions and carry heavy traffic all day. This traffic is a hazard for visitors crossing the roads on trails and introduces waste, litter, exhaust, and noise pollution, among other problems. Balance between access and preservation of the park's battlefield setting are at odds in this situation. Note erosion of slope in foreground of photograph as well as sparse, unhealthy vegetation. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Geologic Features and Processes

This section describes the most prominent and distinctive geologic features and processes in Manassas National Battlefield Park.

Geologic Setting of the Battles of Manassas

In the two battles fought at Manassas, familiarity with the terrain and taking advantage of the natural features of the area—the gaps, ravines, cuts, hills, and ridges—were critical to the outcome (fig. 9). Geology and geologic processes created the rolling hills and gentle landscape and topography at Manassas. In addition to influencing the course of battle, the landscape and topography also affected how troops and supplies were transported during the Civil War (figs. 10 and 11).

Geologic slope processes such as landsliding, slumping, chemical weathering, block sliding, and slope creep are constantly changing the landscape at the park. Runoff erodes sediments from any open areas and carries them down streams and gullies. Erosion naturally diminishes higher areas (e.g., ridges and hills, foundations, and earthworks), degrades bridge foundations, and fills in lower areas (e.g., railroad cuts and stream ravines) distorting the historical landscape.

First Manassas

For the 35,000 Union troops under General Irvin McDowell, the ultimate objective was Richmond and a painless seizure of the Confederate capital. The railroad junction at Manassas was vital to overland access to Richmond. There, the Orange and Alexandria Railroad met the Manassas Gap Railroad, which led west through Manassas Gap to the Shenandoah Valley. The mountain gaps—formed through a variety of geologic processes including downcutting of river valleys, breaks in rock type, and faulting—allowed troop movement through the hills, ridges, and mountains and provided sufficiently level routes for railroad construction.

This junction was the reason for the staging of First Manassas. The ≈32,000 Confederate troops under the commands of Generals Pierre G.T. Beauregard and Joseph E. Johnston were set up along the banks of Bull Run at the six fords and the stone bridge that crossed the stream (fig. 10). River crossings, controlled by underlying geology, were vital for troop, artillery, and supply movement, making them key defensive points.

The Union troops staged a diversion attack on the stone bridge while a larger force was preparing to attack the northern Confederate line at Sudley Springs Ford. Matthews Hill, a low rise of sedimentary rocks cut by erosional valleys, was one of the first areas struggled over. Initially, McDowell's men were successful, forcing southern troops under Colonel Nathan Evans, Barnard Bee, and Francis Bartow to flee back to Henry Hill held by General Thomas Jackson and his men. On Henry Hill, the famous line, "There stands Jackson like a stone wall! Rally behind the Virginians!" was shouted to encourage southern troops and a legend was born.

After several hours of fighting for Henry Hill, the Confederate forces reorganized and launched an attack on the Union right flank on Chinn Ridge. The Confederates held Henry Hill and sent the Union army withdrawing towards Bull Run and the road to Washington. The road was jammed with day trippers and a panic-stricken rout ensued. However, the Confederates were too disorganized to follow up on their success, and the Union army was safe in Washington the next morning.

Knowledge and use of terrain was a key to Confederate success at First Manassas. The Confederates established important defenses along strategic waterways, crossings, and transportation routes. They commanded the high ground and understood the importance of the subtle topographic differences on the slopes of Henry Hill and Matthews Hill. Geologic processes of erosion and uplift were responsible for these landforms.

Second Manassas

In August 1862, Union and Confederate troops battled for a second time on the fields and hills of Manassas. Again, it was the landforms that localized the fighting here and provided strategic barriers and pathways for both sides.

After the Union defeat at First Manassas, the Army of the Potomac embarked on the Peninsular Campaign in an effort to capture the Confederate capital at Richmond. Southern forces countered this move in a series of battles and pushed the Army of the Potomac back to the James River. Meanwhile the Union Army of Virginia under General John Pope was moving north of Richmond. Confederate General Robert E. Lee sent Stonewall Jackson northward to counter Pope.

Movement of troops through the landscape, which included three large rivers, the Rapidan, James, and the Rappahannock, was a game of outmaneuvering the opposing force. Therefore, river crossings were sites of extreme strategic importance.

As the Union forces attempted to join numbers, the Confederates were frantically trying to reinforce Jackson's troops in the Manassas Junction area. Troops funneled through Thoroughfare Gap, a geologic notch carved by Broad Run as a superimposed drainage through the Bull Run Mountains west of Manassas. Failure to protect this gap proved a crucial mistake for the Union forces. Jackson meanwhile attacked the Union supply depot at Manassas Junction.

To prevent a concentration of troops at Centreville, Jackson attacked Union forces at Brawner's Farm from Battery Heights, a sloping ridge created by erosional beveling of the flat-lying sedimentary rocks overlooking the Warrenton Turnpike near the First Manassas

battlefield. Pope, convinced that Jackson was isolated, ordered his troops to converge on Groveton to destroy the Confederate army.

By this time, Jackson's men, taking advantage of the local topography, were posted along an unfinished railroad grade. Pope's army could not fully breach Jackson's position, and reinforcements with General Longstreet would soon arrive to support the Confederates.

The next day, General Pope ordered his army to pursue the Confederates that he erroneously concluded were retreating. The pursuit was short-lived, as the Confederate troops were reinforced and ready. Pope in his overconfidence ordered a second attack on the unfinished railroad. The Confederate position was anchored by Stony Ridge, a diabase intrusion more resistant to erosion than the surrounding rocks. This attack was rebuffed and sent the Union troops back in a bloody withdrawl.

Further attacks by Longstreet's columns left the Union army on the brink of annihilation. The Union withstood charges on sloping Chinn Ridge and again on Henry Hill until darkness provided cover for the troops to cross Bull Run at Stone Bridge and head towards Washington. Their retreat signaled the first real Confederate opportunity to invade the north.

In the days prior to Second Manassas, the Confederate army relied heavily on geologic features, such as river crossings and fords, mountain gaps, and covering slopes, to maneuver and transport necessary men and supplies to the battlefield. Subtle slopes such as those on Henry Hill and the steeper grades on Stuart's Hill and Stony Ridge are defined by their geologic composition. The victorious Confederates best used the natural passages and thoroughfares leading up to the battle, as well as the subtle landforms on the battlefield.

Geologic Basis of Ecosystem Diversity

Climate and geology at Manassas Battlefield National Park create a setting that favors biodiversity. This region of Virginia is composed of mixed deciduous and coniferous forests that thrive in the temperate climate and relatively acidic soils. Many of the forest varieties require seasonally flooded sloughs, upland basins, and back swamps, such as those on the Bull Run floodplain and Young's Branch. Others require well-drained soils with a higher rock and sand content and moderate to high acidity. Upland areas underlain by hardpan clay support specific forests. Pines dominate the steepest slopes along ravines and bluffs that have relatively infertile soils. Successional species such as Red Cedar are found in clay-rich soils that contain few nutrients.

Sedimentary rocks, such as siltstone and sandstone, primarily underlie the park. The micaceous siltstone at the park is a red- to purplish-brown rock that forms the parent material for most of the soil in the eastern half of the park. Sedementary rocks in the park have been intruded by igneous dikes and sills of diabase. Diabase is much more extensive in the western half of the park. This diabase is dense, medium-grained, dark-gray to black mafic (low silica content) rock primarily composed of feldspar and pyroxene. Diabase rocks form the precursor for much of the soil in the western half of the park.

Some of the area's topsoil has been removed by erosion and/or agricultural uses. Soils derived from siltstone (79% of park soils) are generally strongly acidic, well-drained silt loams. Soils derived from diabase (19% of park soils) are typically loamy, very rich in clay minerals, and characterized by subsoil hardpan, or fragipan, layers that act as barriers to ground-water movement and thus limit soil permeability. The remaining 2% of soils in the park were mainly deposited by the local streams and would have been derived from the many different parent rocks along the river's length.

Any differences in soil types lead to differences in the vegetation that grows in them. Diabase soils, for example, support many rare grassland species. The level-lying, poorly drained nature of some of the soils in the park supports unique oak species that are far less common in other areas of the Culpeper Basin and Piedmont. Thus, an understanding of the small-scale geologic differences at Manassas and their interplay with the climate, topography, and soil types is important to managing both the historic landscape and the vegetation that defines much of the historic context of the battles fought there.

The Soil Resources Inventory (SRI) Program of the NPS Geologic Resources Division is working with the Natural Resources Conservation Service (NRCS) to complete a soil survey for Manassas Battlefield National Park. This project is underway and projected for completion in 2008. The SRI Program provides user-friendly products to park managers to facilitate effective resource management, as well as baseline information on soil resources for the Vital Signs Monitoring Program. Soil resource inventories equip parks with maps showing the locations and extent of soils; data about the physical, chemical, and biological properties of those soils; as well as information regarding potential uses and limitations of each kind of soil type. The products also can be used for park interpretive programs and to identify emerging Soil Program needs.

Regional Structure and the Culpeper Basin

Near the eastern margin of the Triassic-Jurassic Culpeper basin is the contact between the relatively young basin and the Piedmont physiographic province. Near Manassas National Battlefield, the contact is a high-angle normal fault trending N 7° E with a minimum displacement of 27 m (89 ft). Accompanying this fault are several high-angle faults within the Triassic rocks, which are subparallel to the larger border fault. Related to these smaller faults are a series of sedimentary slump features in the Triassic rocks (Leavy 1980).

The large border fault cuts across the foliation fabric within the metamorphic schist of the Piedmont rocks. Within the basin, slump features and small faults appear to have occurred during sediment deposition, but a few faults and sheared zones indicate movement after deposition as well (Leavy 1980). The predominant

structures within the Culpeper basin are a gentle, northwest-dipping homocline and a series of longitudinal and transverse flexures, faults, and igneous intrusions associated with the major structures (Froelich et al. 2000).

The Culpeper Basin formed along the eastern margin of North America during the Triassic to early Jurassic period (215–180 Ma). It formed because of regional extension much like the rift valley system of East Africa today. The entire system of basins, referred to as the Newark Basin, covered up to 11,000 km^2 (4,200 mi^2) in surface area. As a result of local subsidence, the basins were filled with elongate lakes, aligned more or less parallel to the northeastern trend of the Appalachian Mountains (Ridky and O'Connor 1979). The Culpeper Basin is one of the largest basins in the system (Gore 1988).

The basin is in a half graben, bound on the west by a large regional fault and a series of east-dipping, listric (curved) normal faults. The eastern boundary is in part a conformable(?) sedimentary overlap with the Piedmont and is in part fault bounded. Near Comptons Corner the eastern margin is a north-striking, west-dipping normal fault with displacement of as much as a few hundred meters (Drake et al. 1994).

The basin is a maximum of 20 km (12 mi) wide and 180 km (110 mi) long. The lakes filled with thousands of meters of sediment, all dipping toward the west (Gore 1988). Included in these depositional environments are lakes, swamps, and sand flats. Sequences of sediments more than 10,000 m (33,000 ft) thick are preserved in the Culpeper Basin. These are widely known as the Newark Supergroup. The supergroup is further divided locally into the Manassas Sandstone, the Balls Bluff Siltstone and the Bull Run Formation (Ridky and O'Connor 1979). These sedimentary rocks are interspersed with diabase dikes and sills, and basaltic flows (Froelich et al. 2000).

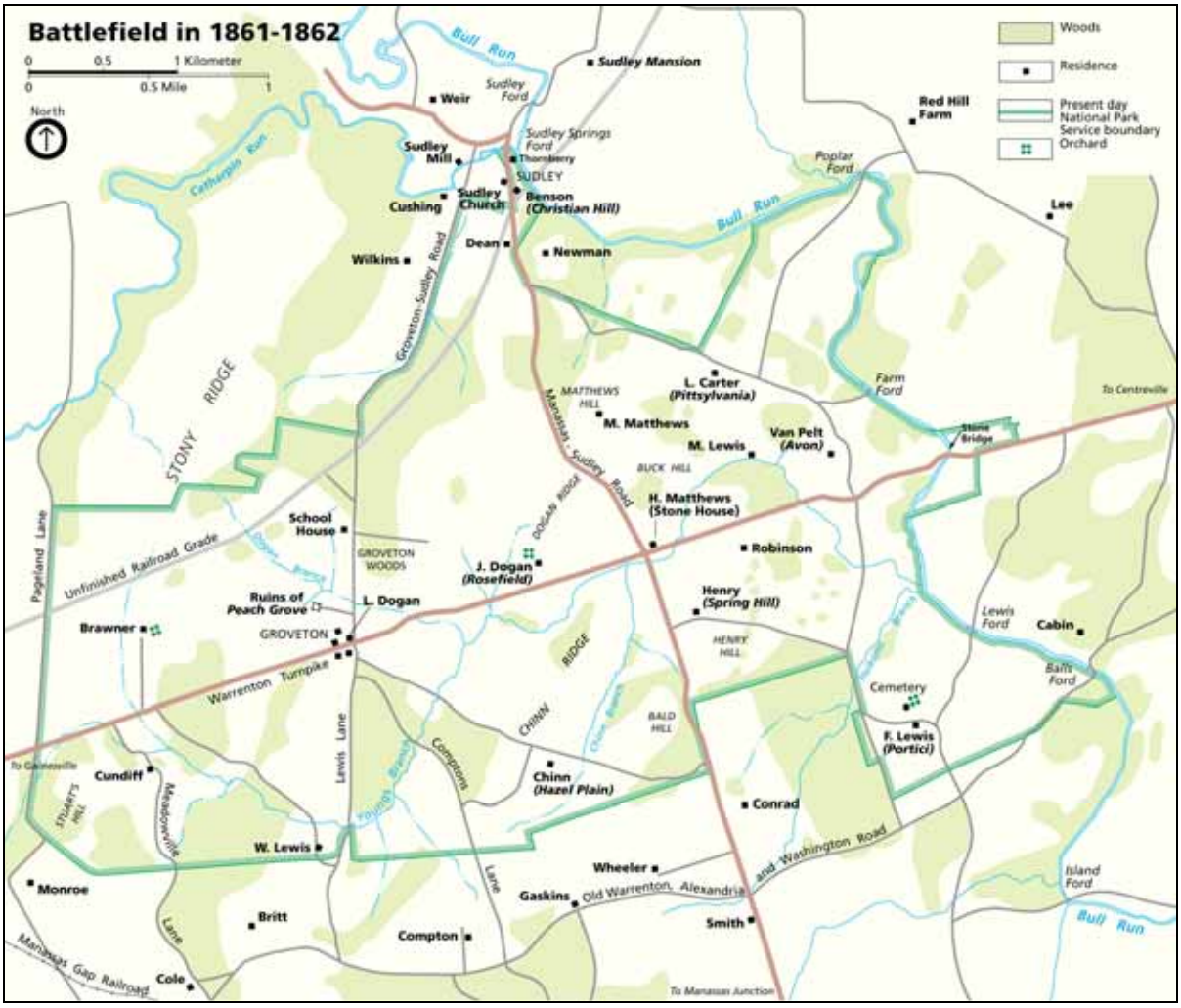

Figure 9. Manassas National Battlefield Area 1861-1862.

Figure 10. The old Stone Bridge over Bull Run. The bridge is located on an outcrop of Balls Bluff Siltstone. Because this siltstone is locally fractured there is the potential for instability of the bridge's foundation. Bridges were commonly situated in areas of exposed stone to provide a stable construction base. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 11. Cannons on the crest of Battery Heights. Here, Confederate General Jackson attacked Union troops marching on the Warrenton Turnpike. Gentle slopes such as this are typical at Manassas National Battlefield Park where erosion has beveled the flat-lying sedimentary layers. Steeper slopes are typically upheld by more resistant igneous diabase. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Map Unit Properties

This section identifies characteristics of map units that appear on the Geologic Resource Evaluation digital geologic map of Manassas National Battlefield Park. 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 Manassas National Battlefield Park informed the "Geologic History," "Geologic Features and Processes," and "Geologic Issues" sections of this report. Geologic maps are essentially two-dimensional representations of complex three-dimensional relationships. The various colors on geologic maps represent rocks and unconsolidated deposits. Bold lines that cross and separate the color patterns mark structural features such as faults and folds. Point symbols indicate features such as dipping strata, sample localities, mine features, wells, and cave openings.

Incorporation of geologic data into a geographic information system (GIS) increases the utility of geologic maps and clarifies 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 correlations between geology and biology. For instance, geologic maps have served as tools for locating threatened and endangered plant species.

Although geologic maps do not show where future earthquakes will occur, the presence of a fault indicates past movement and possible future seismic activity. Geologic maps will 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. As examples, alluvial terraces may preserve artifacts, and inhabited alcoves may occur at the contact between two rock units.

The features and properties of the geologic units in the following table correspond to the accompanying digital geologic data. Map units are listed from youngest to oldest. Please refer to the geologic time scale (fig. 12) 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 following are source data for the GRE digital geologic map:

Southworth, S., and D. Denenny. 2006. *Geologic map of the national parks in the National Capital Region, Washington D.C., Virginia, Maryland and West Virginia*. Scale 1:24,000. Open-File Report OF 2005-1331. Reston, VA: U.S. Geological Survey.

Using ESRI ArcGIS software, the Geologic Resource Evaluation team created a digital geologic map from this source. GRE digital geologic-GIS map products include data in ESRI personal geodatabase, shapefile, and coverage GIS formats, layer files with feature symbology, FGDC metadata, a Windows HelpFile that contains all of the ancillary map information and graphics, and an ESRI ArcMap map document file that easily displays the map.

GRE digital geologic data are included on the attached CD and are available through the NPS Data Store (http://science.nature.nps.gov/nrdata/).

Three groups of geologic map units are found in the Manassas National Battlefield Park area. Piedmont rocks located on the eastern edges of the area, Mesozoic rocks, including those of the Culpeper Basin, and Quaternary unconsolidated deposits, such as artificial fill, alluvium, and terrace deposits.

The Culpeper Basin is filled with Upper Triassic and Lower Jurassic continental clastic rocks (sediments of the Newark Supergroup). Usage and nomenclature of geologic units vary, but in the Manassas area, these rocks include the Manassas Sandstone, the Balls Bluff Siltstone, and the Bull Run Formation (Ridky and O'Connor 1979). The Manassas Sandstone contains the basal deposits of the Culpeper Basin of coarse-grained conglomerate and sandstone (Froelich et al. 2000). The upper part of the Manassas Sandstone was deposited ≈221 Ma (lower Norian). It is correlative with the Newfound Member of the Doswell Formation in the Taylorsville basin of Virginia (Litwin and Weems 1992).

The hydrothermally altered Upper Triassic Balls Bluff Siltstone in the Culpeper Basin records the incipient rift basin environment (Gore 1988; Froelich et al. 2000). Igneous intrusions accompanied rifting throughout the basin. Metamorphic minerals, such as cordierite, epidote, chlorite, and tourmaline are present in the basin, recording the percolation of hot fluids during intrusions through vertical conduits in the growing, sediment-filled basin (Weems and Wiggs 1991; Junium et al. 2000.

Mapped within the park is the Chatham Group, Groveton Member of the Bull Run Formation (Ridky and O'Connor 1979; Southworth and Denenny 2006). This unit contains gray-brown and red siltstone and sandy shale in thin beds with some lacustrine clays. This Triassic age unit in the Culpeper Basin records the open rift basin environment.

Intruding the Culpeper Basin rocks are dikes, sills, and other igneous bodies of diabase. These rocks were formed during regional extension. As cracks formed in the tensional environment, molten rock and hot fluids were injected into the overlying sedimentary rocks, locally metamorphosing them. These igneous rocks, which are also relatively resistant, are now present as caprock on ridges at Manassas.

The most recent geologic units present within Manassas National Battlefield Park are unconsolidated terrace and alluvium deposits. Terrace deposits concentrate near stream confluences and contain some coarser cobbles and pebbles, whereas alluvial deposits line active streams throughout the area containing finer grained sand, silt, and clay (Southworth and Denenny 2006).

Map Unit Properties Table

Age	Map Unit (Symbol)	Unit Description	Erosion Resistance	Suitability for Development	Hazards	Paleontologic Resources	Cultural Resources	Mineral Specimens	Karst Issues	Mineral Resources	Habitat	Recreation	Global Significance
QUATERNARY (HOLOCENE)	Alluvium (Qa)	Unit Qa contains broad deposits of sand, gravel, clay, and silt layers flanking active stream channels.	Very low	Avoid stream edge/riparian areas for heavy development, especially for wastewater-treatment facilities due to proximity to water and high permeability.	Unit Qa is associated with stream banks and riparian zones and may be unstable if exposed on a slope or saturated with water.	Modern remains	May contain artifacts and/or settlement sites along major waterways.	None documented	None	Sand, gravel, silt, clay.	Riparian zones and burrow habitat.	Unit Qa is suitable for some trail development.	Unit Qa contains a record of modern stream-valley development throughout the Quaternary.
QUATERNARY (HOLOCENE AND PLEISTOCENE)	Terrace deposits, low level (Qt)	Unit Qt deposits are concentrated near stream confluences and contain reworked alluvial sand, gravel, silt, and clay as well as larger colluvium clasts.	Very low	Avoid most terrace deposits for heavy development due to instability of slopes and high permeability.	Unit is associated with stream-edge slopes deposited by gravity and water.	May contain modern remains and plant fragments, pollen(?).	May contain artifacts and/or settlement sites along major waterways.	None documented	None	Cobbles, gravel, sand.	Forms upland areas supporting larger trees and bushes with more soil development along waterways.	Suitable for most recreation unless unstable slopes are present.	Terrace units record the evolution of local waterways and changes in channel morphology.
EARLY JURASSIC AND LATE TRIASSIC	Diabase dikes and sills (JTRd)	Unit contains linear, nearly vertical dikes and nearly horizontal sheets (sills) of dark to black diabase. These intrusions are rimmed with gray hornfels (JTRtm) formed through contact metamorphism. Units are cut by normal faults and are commonly marked by light-gray, subrounded cobbles and boulders of float. Most cobbles weather to a rust color.	Very high	Unit acts as an aquitard.	Rockfall possible where unit is exposed on high-angle slopes.	None	Cobbles may have been used as weapons of last resort during Civil War battles.	Coarse-grained crystalline diabase.	None	Attractive fieldstone.	Unit retards percolating water and commonly hosts perched swamp areas.	Cobbles and boulders of unit present at the surface may be unstable trail base.	Unit is cut by normal faults providing a relative dating of extension in the area. Ar40/Ar39 age of amphibole grains is ≈200 million years.
LATE JURASSIC AND EARLY TRIASSIC	Thermally metamorphosed rocks (JTRtm)	Unit is hornfels formed through contact metamorphism upon intrusion of dikes and sills of unit JTRd. Hornfels was originally siltstone, shale, and sandstone and appears light-grayish green, very fine grained, and brittle. Siltstone and shale were metamorphosed to cordierite-spotted hornfels in the inner aureole closest to the diabase. The outer aureole is epidote-chlorite hornfels. Sandstone was metamorphosed to tourmaline granofels and quartzite.	High	Suitable for most forms of development unless brittle and highly fractured.	Units may pose rockfall hazard if exposed on slopes.	None documented	Unit underlies strategic ridges (Battery Heights, Stony Ridge, for example) at Manassas used for advantage during Civil War battles; cobbles were also used as weapons of last resort.	Porphyroblast minerals include cordierite, epidote, chlorite, tourmaline.	None	Quartzite for building material, abrasives.	Unit supports upland forest development.	Suitable for most recreation unless highly fractured.	Unit records extensive intrusion during Triassic basin extension.
TRIASSIC	Chatham Group, Groveton Member of the Bull Run Formation (TRbg)	Unit contains gray-brown and red siltstone and sandy shale. These layers are present in thin beds with silty and sandy shale interlayered with clayey and sandy siltstone in cyclic sequences as much as 33 ft thick. Some dark-gray lacustrine clays are poorly exposed and weather to reddish or gray soils.	Moderate	Suitable for most development except in clay-rich areas and fractured layers.	Unit may contain slippery shrink-and-swell clays; heterogeneous nature of unit may render it unstable on slopes and prone to mass wasting.	Fish fossils (teeth and scales), notostracans (*Triops* cf. *cancriformis;* tadpole shrimp) conchostracans (*Cyzicus* sp.; clam shrimp), ostracodes (*Darwinula* sp.), insects (staphylinid beetle), plant remains, spores, pollen, lacustrine stromatolites, ichnofossils (*Gwyneddichnium majore)*, crustaceans, mollusks, reptile footprints, gastroliths, parasuchian remains.	Red shale from this unit was used to construct several historical structures in the area as well as the stone bridge at Bull Run.	None documented	Not enough carbonate present.	Red shale and sandstone make good dimension stone for building material.	Unit weathers to a shale-rich soil.	Unit is suitable for most recreation unless rich in clay.	Unit records lacustrine environments in basins during active Triassic extension events.

Geologic History

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

The recorded history of the Appalachian Mountains begins in the Proterozoic (figs. 12 and 13*A*). In the mid-Proterozoic, during the Grenville orogeny, a supercontinent formed that consisted of most of the continental crust in existence at that time, including the crust of North America and Africa. Sedimentation, deformation, plutonism, and volcanism are all manifested in the metamorphic gneiss in the core of the modern Blue Ridge Mountains east of Manassas (Harris et al. 1997). These rocks formed over a period of 100 million years and are more than a billion years old, making them among the oldest rocks known in this region. They form a basement upon which all other rocks of the Appalachians were deposited (Southworth et al. 2001).

The late Proterozoic (fig. 13*B*), roughly 600 Ma, brought extensional rifting to the area. The supercontinent broke up, and a sea basin formed that eventually became the Iapetus Ocean. This basin collected many of the sediments that later formed the Appalachian Mountains. Some of the sediments were deposited as large submarine landslides and turbidity flows, which today preserve their depositional features. These early sediments are exposed on Catoctin Mountain, Short Hill–South Mountain, and Blue Ridge–Elk Ridge. Also, in this extensional environment, flood basalts and other igneous rocks, such as diabase and rhyolite, were added to the North American continent. These igneous rocks were intruded through cracks in the granitic gneiss of the Blue Ridge core and extruded onto the land surface during the breakup of the continental land mass (Southworth et al. 2001).

Associated with the shallow marine setting along the eastern continental margin of the Iapetus were large deposits of sand, silt, and mud in near-shore, deltaic, barrier-island, and tidal-flat areas (fig. 13*C*). Some of these are present as the Antietam Formation in central Virginia (Schwab 1970; Kauffman and Frey 1979; Simpson 1991). In addition, huge masses of carbonate rocks record a grand platform, thickening to the east, that persisted during the Cambrian and Ordovician Periods (545–480 Ma) (fig. 14*A*).

Somewhat later, 540, 470, and 360 Ma, amphibolite, granodiorite and pegmatite, and lamprophyre, respectively, intruded the sedimentary rocks. Several episodes of mountain building and continental collision that resulted in the Appalachian Mountains contributed to the heat and pressure that deformed and metamorphosed the entire sequence of sediments, intrusive rocks, and basalt into schist, gneiss, marble, slate, and migmatites (Southworth, Fingeret, et al. 2000).

The rocks were then extensively folded and faulted. This faulting may have occurred during regional rifting that occurred about 200 Ma. Hot fluids moved upward through available fault conduits, depositing quartz veins containing small amounts of gold. This was the object of mining interest in the area intermittently from 1867 until 1941 (Reed et al. 1980).

From Early Cambrian through Early Ordovician time orogenic activity along the eastern margin of the continent began again. Known as the Taconic orogeny, this activity involved the closing of the ocean, subduction of oceanic crust, formation of volcanic arcs, and uplift of continental crust (fig. 14*B*). In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards creating a deep basin that filled with mud and sand eroded from the highlands to the east (Harris et al. 1997). This so-called Appalachian basin was centered on what is now West Virginia (fig. 14*C*). Infilling sediments covered the grand carbonate platform and are today recorded by the shale of the Ordovician (450 Ma) Martinsburg Formation (Southworth et al. 2001).

During the Late Ordovician, oceanic sediments of the shrinking Iapetus Ocean were thrust westward onto other deep-water sediments of the western Piedmont along the Pleasant Grove fault. Sediments that would later become sandstone, shale, siltstone, quartzite, and limestone were then deposited in the shallow marine to deltaic environment of the Appalachian basin. These rocks, now metamorphosed, currently underlie the Valley and Ridge province (Fisher 1976).

Piedmont metasediments record the transition from non-orogenic, passive margin sedimentation to extensive syn-orogenic clastic sedimentation from the southeast during Ordovician time (Fisher 1976). In the Manassas area, these metasediments include schist, metagraywacke, phyllonite, mélange, and metasiltstone. Oceanic crust caught up in the orogenic events now exists as the peridotite, gabbro, and pyroxenite (mantle rocks) of the Piney Branch Complex (Drake et al. 1994).

Shallow marine to fluvial sedimentation continued for about 200 million years during the Ordovician–Permian Periods, building thick layers of sediments. Their source was the highlands that were rising to the east during the Taconic orogeny (Ordovician) and the Acadian orogeny (Devonian). The Acadian orogeny continued the

mountain building of the Taconic orogeny as the African continent approached North America (Harris et al. 1997).

Following the Acadian orogeny, the proto-Atlantic Iapetus Ocean closed completely during the Late Paleozoic as the North American and African continents collided, forming the Appalachian mountain belt we see today. This mountain-building episode, known as the Alleghanian orogeny, is the last major orogeny that affected the Appalachians (fig. 15*A*). The rocks deformed along folds and faults producing 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 (Southworth et al. 2001).

During the Alleghanian orogeny, rocks of the Great Valley, Blue Ridge, and Piedmont provinces were transported along the North Mountain fault westward onto younger rocks of the Valley and Ridge. The amount of crustal shortening was very large, estimated at 20–50%, which would amount to 125–350 km (78–217 mi) of movement (Harris et al. 1997). Deformed rocks in the eastern Piedmont were also folded and faulted, and existing thrust faults were reactivated as both strike-slip and thrust faults during the Alleghanian orogeny (Southworth et al. 2001).

Following the Alleghanian orogeny, during the late Triassic, a period of rifting began as the deformed rocks of the joined continents began to break apart from about 230–200 Ma (fig. 15*B*). At this time the supercontinent Pangaea was segmented into roughly the same continents that persist today. This episode of rifting, or crustal fracturing, initiated the formation of the current Atlantic Ocean and caused many block-fault basins to develop with accompanying volcanism (Harris et al. 1997; Southworth et al. 2001).

The Newark Basin system is a large component of this tectonic setting. Large streams carried debris shed from the uplifted Blue Ridge and Piedmont provinces forming large alluvial fans. These were deposited as non-marine mud and sand in fault-created troughs, such as the Culpeper basin in the western Piedmont. Many of these rift openings became lacustrine basins and were filled with thick deposits of silts and sand. The Manassas Sandstone and the Balls Bluff Siltstone represent these deposits in the Manassas National Battlefield Park area.

The large faults that formed the western boundaries of the basins provided an escarpment that was quickly covered with eroded debris. Magma intruded into the new strata as sills and nearly vertical dikes that extend beyond the basins into adjacent rocks. After this magma was emplaced approximately 200 Ma, 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 and exposed it to erosion (fig. 15*C*). The igneous rocks (diabase) were harder than the surrounding sedimentary rocks and more resistant to erosion. Today they cap some of the highest ridges, hills, and slopes in the Manassas area.

Thick deposits of unconsolidated gravel, sand, and silt were shed from the eroded mountains. These were deposited at the base of the mountains as alluvial fans and spread eastward becoming part of the Atlantic Coastal Plain (Duffy and Whittecar 1991; Whittecar and Duffy 2000; Southworth et al. 2001). The amount of material that was deposited has been inferred from the now-exposed metamorphic rocks to have been immense. Many of the rocks exposed at the surface must have been at least 20 km (≈10 mi) below the surface prior to regional uplift and erosion. Today, the Potomac, Rappahannock, Rapidan, and Shenandoah Rivers and tributaries continue to erode the Coastal Plain sediments, lowering the mountains, and depositing alluvial terraces along the rivers, as they sculpt the present landscape (fig. 15*D*).

Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. Isostatic adjustments that uplifted the continent after the Alleghanian orogeny continued at a lesser rate throughout the Cenozoic Period (Harris et al. 1997).

The landscape and geomorphology of the greater Potomac and Rappahannock River valleys are the result of erosion and deposition from about the middle of the Cenozoic Period (≈5Ma) to the present. The distribution of flood plain alluvium and ancient fluvial terraces of the rivers and adjacent tributaries reflect the historical development of both drainage systems. There is little or no evidence that the rivers migrated laterally across a broad, relatively flat region. It seems the rivers have cut downward through very old, resistant rocks, overprinting their early courses (Southworth et al. 2001).

The position, distribution, thickness, and elevation of terraces and the sediments deposited on them along the rivers vary by province and rock type. The elevations of terraces along the rivers show that the gradients of the ancient and modern river valleys are similar and suggest that the terraces formed as the result of either eustatic sea level drop or uplift (Zen 1997a and 1997b).

Though glaciers never reached the eastern Virginia area, the colder climates of the Ice Ages may have played a role in the river valley morphology. The periglacial conditions that must have existed at high altitudes intensified weathering and other erosional processes (Harris et al. 1997). The landforms and deposits are probably late Tertiary to Quaternary, when a wetter climate, sparse vegetation, and frozen ground caused increased precipitation to run into the ancestral river, enhancing downcutting and erosion (Zen 1997a and 1997b).

Eon	Era	Period	Epoch	Ma		Life Forms	N. American Tectonics
Phanerozoic (Phaneros = "evident"; zoic = "life")	Cenozoic	Quaternary	Holocene	0.01	Age of Mammals	Modern humans	Cascade volcanoes (W)
			Pleistocene	1.8		Extinction of large mammals and birds	Worldwide glaciation
		Tertiary	Pliocene	5.3		Large carnivores	Uplift of Sierra Nevada (W)
			Miocene	23.0		Whales and apes	Linking of N. and S. America
			Oligocene	33.9			Basin-and-Range extension (W)
			Eocene	55.8		Early primates	Laramide Orogeny ends (W)
			Paleocene	65.5			
	Mesozoic	Cretaceous		145.5	Age of Dinosaurs	**Mass extinction** Placental mammals Early flowering plants	Laramide Orogeny (W) Sevier Orogeny (W) Nevadan Orogeny (W)
		Jurassic		199.6		First mammals **Mass extinction** Flying reptiles	Elko Orogeny (W) Breakup of Pangaea begins
		Triassic		251		First dinosaurs	Sonoma Orogeny (W)
	Paleozoic	Permian		299	Age of Amphibians	**Mass extinction** Coal-forming forests diminish	Supercontinent Pangaea intact Ouachita Orogeny (S) Alleghenian (Appalachian) Orogeny (E)
		Pennsylvanian		318.1		Coal-forming swamps Sharks abundant Variety of insects	Ancestral Rocky Mts. (W)
		Mississippian		359.2		First amphibians First reptiles	Antler Orogeny (W)
		Devonian		416	Fishes	**Mass extinction** First forests (evergreens)	Acadian Orogeny (E-NE)
		Silurian		443.7		First land plants	
		Ordovician		488.3	Marine Invertebrates	**Mass extinction** First primitive fish Trilobite maximum Rise of corals	Taconic Orogeny (NE)
		Cambrian		542		Early shelled organisms	Avalonian Orogeny (NE) Extensive oceans cover most of N. America
Proterozoic ("Early life")		Precambrian		2500		First multicelled organisms Jellyfish fossil (670 Ma)	Formation of early supercontinent Grenville Orogeny (E) First iron deposits Abundant carbonate rocks
Archean ("Ancient")				≈4000		Early bacteria and algae	Oldest known Earth rocks (≈3.96 billion years ago)
Hadean ("Beneath the Earth")				4600		Origin of life?	Oldest moon rocks (4-4.6 billion years ago) Earth's crust being formed
						Formation of the Earth	

Figure 12. Geologic time scale; adapted from the U.S. Geological Survey and International Commission on Stratigraphy. Red lines indicate major unconformities between eras. Included are major events in the history of life on Earth and tectonic events occurring on the North American continent. Absolute ages shown are in millions of years (Ma, or mega-annum).

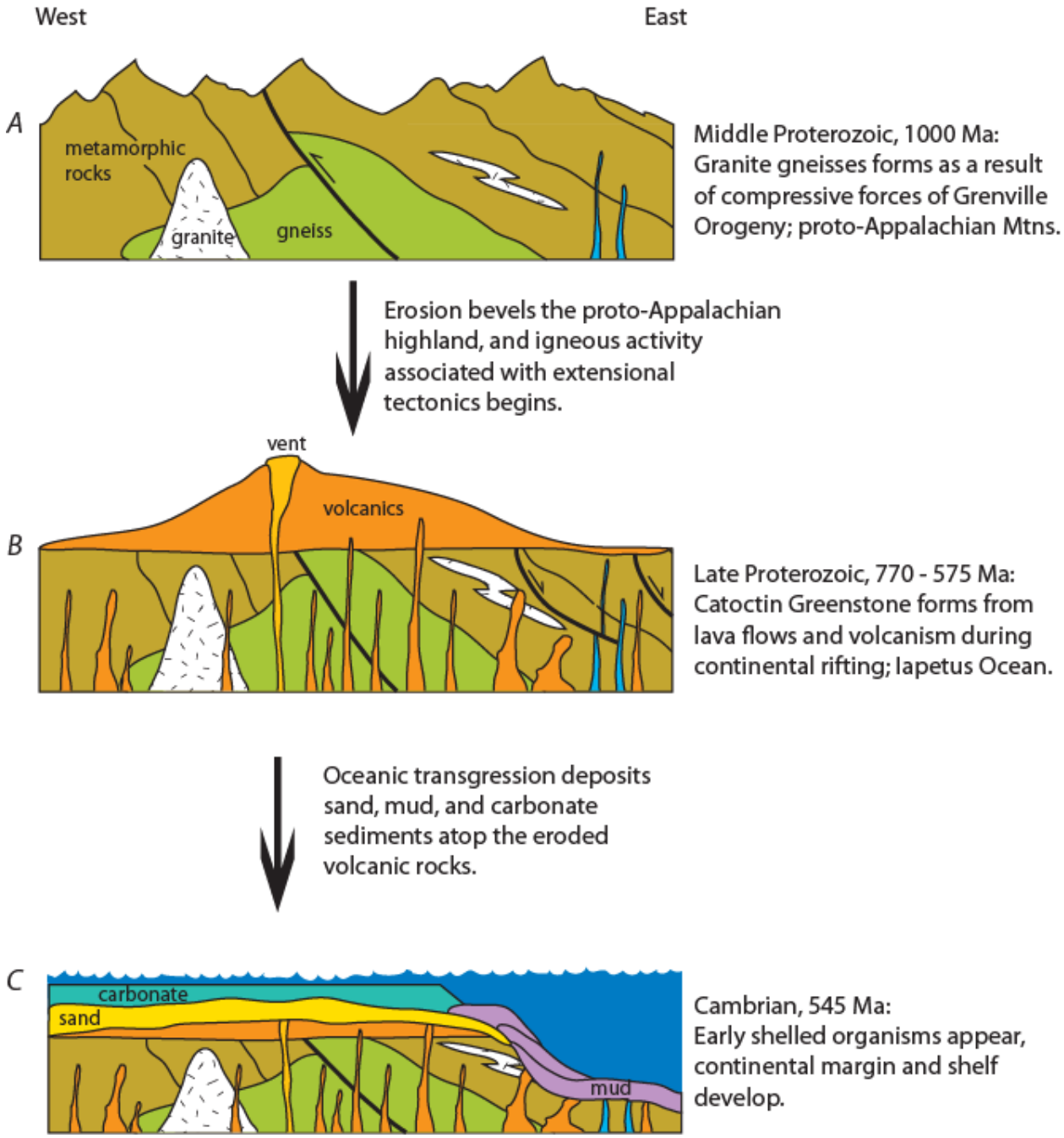

Figure 13. Geologic evolution of the Appalachian Mountains in the Manassas area. Cross section view is west to east. (*A*) First, intrusions of granitic gneiss, metamorphism, and deformation related to the Grenvillian orogeny lasted 60 million years, from 1.1 billion to 950 Ma. These rocks are found in the Blue Ridge province. (*B*) Then, continental rifting and volcanic activity in the Grenville terrane (current Blue Ridge province) and deposition of turbidites in deep water basin to the east (current Piedmont province) lasted about 200 million years, from about 770–575 Ma. (*C*) Next, the margin of the continent became stable with carbonate sediments being deposited in quiet water (rocks of the current Great Valley and Frederick Valley). Shelled organisms appeared about 545 Ma. Then, deep-water sediments were deposited into a basin east of the shelf margin for about 65 million years.

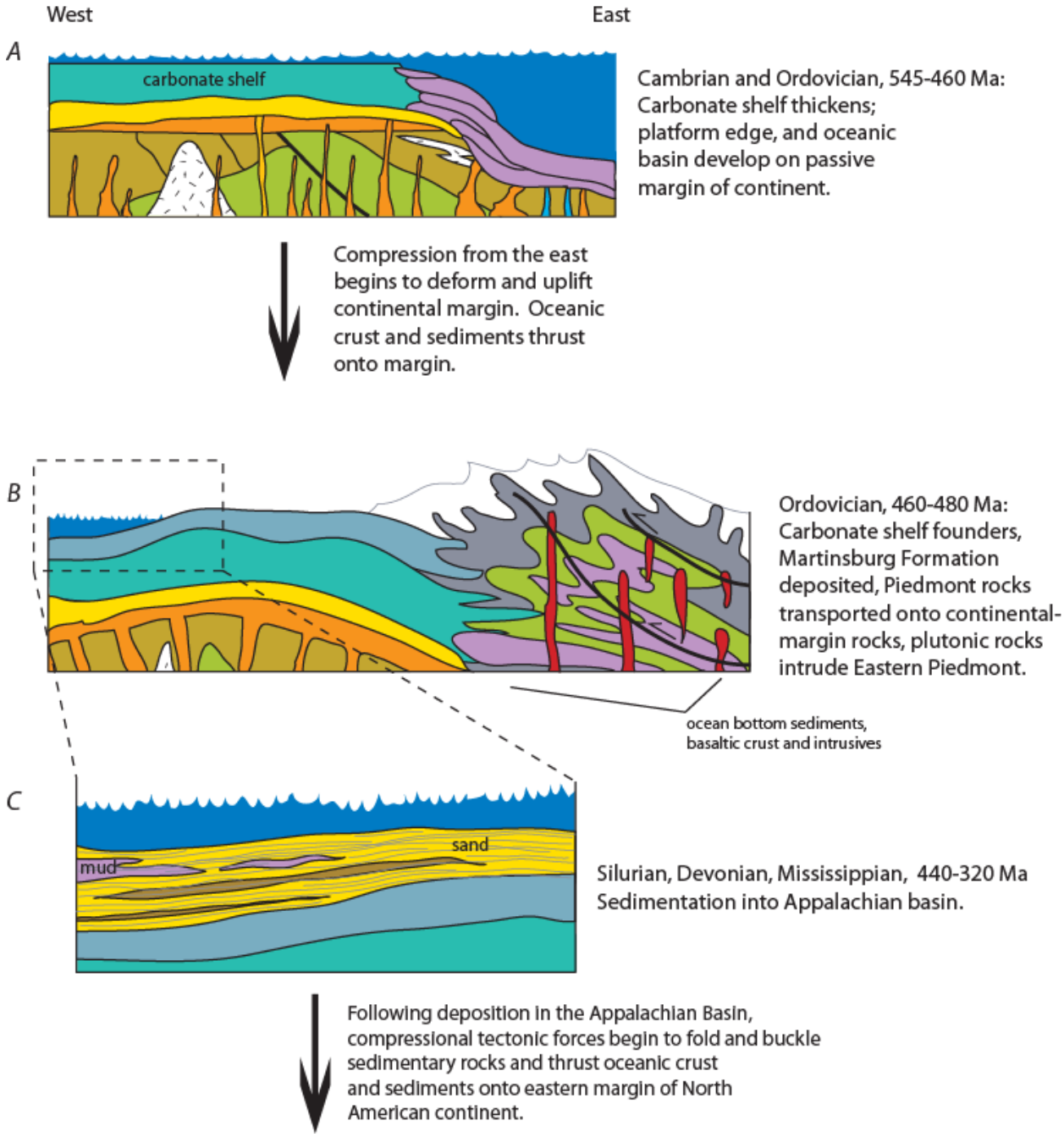

Figure 14. (*A*) Following deposition, the stable shelf foundered as the Taconic orogeny (*B*) (480-460 Ma) elevated the rocks to the east and provided a source for the clastic materials that make up the shale of the Martinsburg Formation. Rocks in the Piedmont province were intruded by plutonic rocks. (*C*) Then, a thick sequence of sediments was deposited in a deepening Appalachian basin over a span of 120 million years. Most of these rocks are now found in the Valley and Ridge province. About 370 Ma magma forming igneous rocks was intruded into rocks near Great Falls.

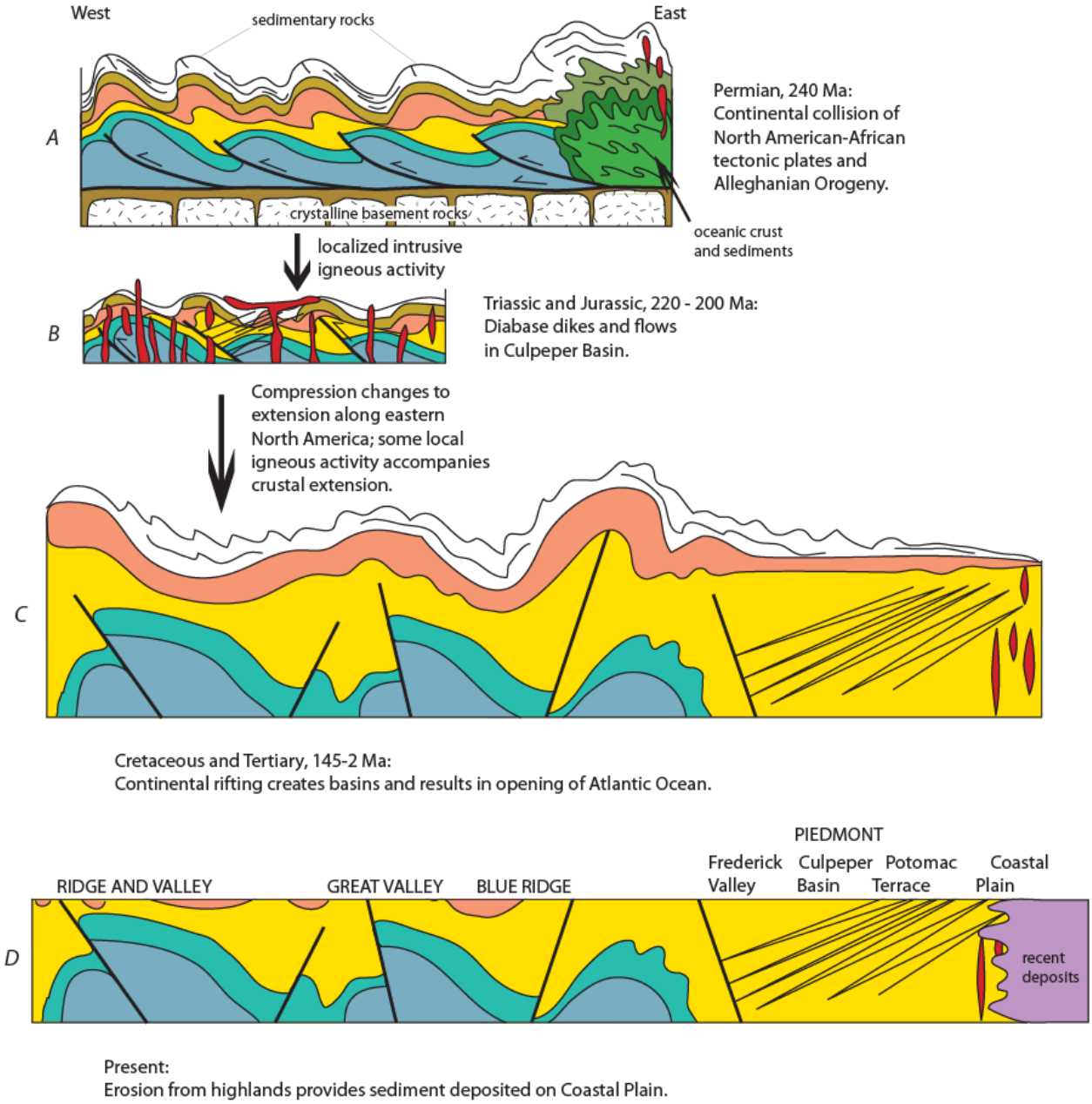

Figure 15. (*A*) About 240 Ma, the continental tectonic plates of North America and Africa collided, resulting in the Alleghanian orogeny. Many of the folds and faults in rocks west of the Piedmont province are related to this event. (*B*) About 20 million years later, continental rifting began and lasted for about 20 million years (220–200 Ma). (*C*) Thick sequences of sediments were deposited in fault-bounded basins, there was volcanic activity, and continental rifting resulted in the creation of the Atlantic Ocean. The Culpeper and Gettysburg basins in the western Piedmont are also the result of this event. (*D*) For the last 200 million years, the landscape has eroded and rivers have carried the sediment eastward deposit the thick strata of the Atlantic Coastal Plain. Diagrams are not to scale and are broadly representative of the tectonic settings. Adapted from Southworth et al. (2001).

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.

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

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

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

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

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

basin (structural). A doubly-plunging syncline in which rocks dip inward from all sides (also see "dome").

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

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

bedding. Depositional layering or stratification of sediments.

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

calcareous. A rock or sediment containing calcium carbonate.

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

chemical weathering. The dissolution or chemical breakdown of minerals at Earth's surface via reaction with water, air, or dissolved substances.

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

clay. Clay minerals or sedimentary fragments the size of clay minerals (>1/256 mm).

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

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

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

craton. The relatively old and geologically stable interior of a continent.

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

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

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

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

debris flow. A rapid and often sudden flow or slide of rock and soil material involving a wide range of types and sizes.

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 at a stream's mouth where it 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 an angle to the orientation of adjacent rocks.

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

eustatic. Relates to simultaneous worldwide rise or fall of sea level in Earth's oceans.

extrusion. The emission of relatively viscous lava onto the Earth's surface; also, the rock so formed.

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

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

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

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

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

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

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

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

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.

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

karst topography. Topography characterized by abundant sinkholes and caverns formed by the dissolution of calcareous rocks.

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

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

lava. Magma that has been extruded out onto Earth's surface, both molten and solidified.

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

lithosphere. The relatively rigid outmost shell of Earth's structure, 50–100 km (31–62 mi) thick, that encompasses the crust and uppermost mantle.

mafic. A rock, magma, or mineral rich in magnesium and iron.

magma. Molten rock generated within the Earth that is the parent of igneous rocks.

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

matrix. The fine-grained interstitial material between coarse grains in porphyritic igneous rocks and poorly sorted clastic sediments or rocks.

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

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

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

mid-ocean ridge. The continuous, generally submarine, seismic, median mountain range that marks the divergent tectonic margin(s) in the world's oceans.

mud cracks. Cracks formed in clay, silt, or mud by shrinkage during subaerial dehydration.

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

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

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

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

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

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

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

parent (rock). The original rock from which a metamorphic rock or soil was formed.

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

pebble. Generally, small, rounded rock particles from 4 to 64 mm in diameter.

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

plateau. A broad, flat-topped topographic high of great extent and elevation above the surrounding plains, canyons, or valleys (both land and marine landforms).

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 (cracks, interstices) in a volume of a rock or sediment.

recharge. Infiltration processes that replenish groundwater.

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

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

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

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

roundness. The relative amount of curvature of the "corners" of a sediment grain, especially with respect to the maximum radius of curvature of the particle.

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

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

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

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

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

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

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

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

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

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

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

spring. A site where water flows out at the surface due to the water table intersecting the ground surface.

strata. Tabular or sheetlike masses or distinct layers (e.g., of rock).

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

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.

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

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

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.

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

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

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

thrust fault. A contractional, dip-slip fault with a shallowly dipping fault surface ($<45^{o}$) 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 (fault). The exposed intersection of a fault with Earth's surface.

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

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

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

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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References

This section lists references cited in this report as well as a general bibliography that may be of use to resource managers. A more complete geologic bibliography is available from the National Park Service Geologic Resources Division.

Clapp, F.G. 1911. *Underground waters near Manassas, Virginia*. Water-Supply Paper 94-97. Reston, VA: U.S. Geological Survey. .

Drake, A. A., Jr., A. J. Froelich, R. E. Weems, and K. Y. Lee. 1994. *Geologic map of the Manassas Quadrangle, Fairfax and Prince William counties, Virginia*. Scale 1:24,000. Geologic Quadrangle Map GQ-1732. Reston, VA: U.S. Geological Survey.

Duffy, D. F., and G. R. Whittecar. 1991. Geomorphic development of segmented alluvial fans in the Shenandoah Valley, Stuarts Draft, Virginia. *Geological Society of America Abstracts with Programs* 23 (1): 24.

Fisher, G. W. 1976. The geologic evolution of the northeastern Piedmont of the Appalachians. *Geological Society of America Abstracts with Programs* 8 (2): 172–173.

Froelich, A. J., R. E. Weems, R. J. Litwin, and J. P. Smoot. 2000. Triassic and Jurassic sedimentary and intrusive rocks of the Culpeper Basin. In *Geologic map of the Fredericksburg 30' × 60' quadrangle, Virginia and Maryland,* eds. R. B. Mixon, L. Pavlides, D. S. Powars, A. J. Froelich, R. E. Weems, J. S. Schindler, W. L. Newell, L. E. Edwards, and L. W. Ward, 13–15. Geologic Investigations Series I-2607. Reston, VA: U. S. Geological Survey.

Gore, P. J. W. 1985. Triassic floodplain lake in the Chatham Group (Newark Supergroup) of the Durham sub-basin of the Deep River Basin, N.C.; comparison of the Culpeper basin, VA. *Geological Society of America Abstracts with Programs* 17 (2): 94.

Gore, P. J. W. 1988. Lacustrine sequences in an early Mesozoic rift basin; Culpeper Basin, Virginia, USA. In *Lacustrine petroleum source rocks*, eds. A. J. Fleet, K. Kelts, and M. R. Talbot. Geological Society of America Special Publication 40:247–278.

Harris, A. G., E. Tuttle, and S. D. Tuttle. 1997. *Geology of National Parks*. Dubuque, IA: Kendall/Hunt Publishing Company.

Junium, C. K., J. W. Niemitz, and J. M. Elick. 2000. Hydrothermal alteration of the Balls Bluff Siltstone, Culpeper Basin, Virginia. *Geological Society of America Abstracts with Programs* 32 (1): 26–27.

Kane, W. J., J. L. Klosky, and C. J. Martel. 2001. Portable wastewater treatment. *Water Environment and Technology* 13 (3): 44–48.

Kauffman, M. E., and E. P. Frey. 1979. Antietam sandstone ridges; exhumed barrier islands or fault-bounded blocks? *Geological Society of America Abstracts with Programs* 11 (1): 18.

Kenworthy, J.P. and V. L. Santucci. 2004. *Paleontological Resource Inventory and Monitoring, National Capital Region*. National Park Service TIC# D-289.

Leavy, B. D. 1980. Tectonic and sedimentary structures along the eastern margin of the Culpepper Basin, Virginia. *Geological Society of America Abstracts with Programs* 12 (4): 182.

Lee, K. Y. 1978. Upper Triassic stratigraphy in the Culpeper Basin of Virginia and Maryland. Professional Paper 1100. Reston, VA: U.S. Geological Survey.

Litwin, R. J., and R. E. Weems. 1992. Re-evaluation of the age of Triassic strata (Doswell Formation) of the Taylorsville Basin, Va. *Virginia Journal of Science* 43 (2): 265.

Nickelsen, R. P. 1956. Geology of the Blue Ridge near Harpers Ferry, West Virginia. *Geological Society of America Bulletin* 67 (3): 239–269.

Nutter, L. J. 1974. Hydrogeology of Antietam Creek Basin. *Journal of Research of the U. S. Geological Survey* 2 (2): 249–252.

Olson, C. G. 1983. *Soils and land use tour*. Madison, WI: Soil Sciences Society, American Division.

Reed, J. C., Jr., R. S. Sigafoos, and G. W. Fisher. 1980. *The river and the rocks—The Geologic story of Great Falls and the Potomac River Gorge*. Bulletin 1471. Reston, VA: U.S. Geological Survey.

Ridky, R. W., and J. V. O'Connor. 1979. The Culpeper Basin of the Triassic lowlands of northern Virginia. In *Guidebook for field trips in Virginia*, ed. J. D. Exline, 49–59.

Schwab, F. L. 1970. Origin of the Antietam Formation (late Precambrian?, lower Cambrian), central Virginia. *Journal of Sedimentary Petrology* 40 (1): 354–366.

Silliman, B., Jr. 1853. Report on the Manassas [Fauquier County, Virginia] mining property. *Mining Magazine*. 228–231.

Simpson, E. L. 1991. An exhumed Lower Cambrian tidal-flat; the Antietam Formation, central Virginia, U.S.A. In *Clastic tidal sedimentology*. eds. D. G. Smith, B. A. Zaitlin, G. E. Reinson, and R. A. Rahmani. Canadian Society of Petroleum Geologists Memoir 16:123–133.

Smoot, J. P. 1989. Fluvial and lacustrine facies of the early Mesozoic Culpeper Basin, Virginia and Maryland. In *Collection field trips for the 28th International Geological Congress*, ed. P. M. Hanshaw. Washington, D.C.: American Geophysical Union.

Southworth, S., and D. K. Brezinski. 1996. *Geology of the Harpers Ferry Quadrangle, Virginia, Maryland, and West Virginia*. Bulletin B-2123. Reston, VA: U.S. Geological Survey.

Southworth, S., D. K. Brezinski, R. C. Orndorff, P. G. Chirico, and K. M Lagueux. 2001. *Geology of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor, District of Columbia, Maryland, West Virginia, and Virginia*. CD-ROM (Disc 1: A, geologic map and GIS files; Disc 2: B, geologic report and figures). Open-File Report OF 01-0188. U.S. Geological Survey.

Southworth, S., D. K. Brezinski, R. C. Orndorff, K. M. Lagueux, and P. G. Chirico. 2000. *Digital geologic map of the Harpers Ferry National Historical Park*. 1 CD-ROM. Open-File Report OF 00-0297. Reston, VA: U.S. Geological Survey.

Southworth, S., C. Fingeret, and T. Weik. 2000. *Geologic Map of the Potomac River Gorge: Great Falls Park, Virginia, and Part of the C & O Canal National Historical Park, Maryland*. Open-File Report OF 00-264. Reston, VA: U.S. Geological Survey.

Scott, S., and D. Denenny. 2006. Geologic Map of the National Parks in the National Capital Region, Washington D.C., Virginia, Maryland and West Virginia. Open-File Report OF 2005-1331. Reston, VA: U.S. Geological Survey.

Weems, R. E., and C. R. Wiggs. 1991. Parasuchian occurrences in Upper Triassic rocks of the Culpeper Basin of Virginia and Maryland. *Virginia Journal of Science* 42 (2): 222.

Whittecar, G. R., and D. F. Duffy. 2000. Geomorphology and stratigraphy of late Cenozoic alluvial fans, Augusta County, Virginia, U.S.A. In *Regolith in the Central and Southern Appalachians*, eds. G. M Clark, H. H. Mills, and J. S. Kite. *Southeastern Geology* 39 (3–4): 259–279.

Zen, E-an. 1997a, *The seven-storey river: Geomorphology of the Potomac River channel between Blockhouse Point, Maryland, and Georgetown, District of Columbia*, with emphasis on *The Gorge complex below Great Falls*. Open-File Report OF 97-60. Reston: VA: U.S. Geological Survey.

Zen, E-an. 1997b. *Channel geometry and strath levels of the Potomac River between Great Falls, Maryland, and Hampshire, West Virginia*. Open-File Report OF 97-480. Reston, VA: U.S. Geological Survey.

Zen, E-an, and A. Walker. 2000. *Rocks and war; geology and the campaign of second Manassas*. Shippensburg, PA: White Mane Books.

Zenzen, J. M. 1998. *Battling for Manassas: The fifty-year preservation struggle at Manassas National Battlefield Park*. University Park, PA: Pennsylvania State University Press.

Appendix A: Geologic Map Graphic

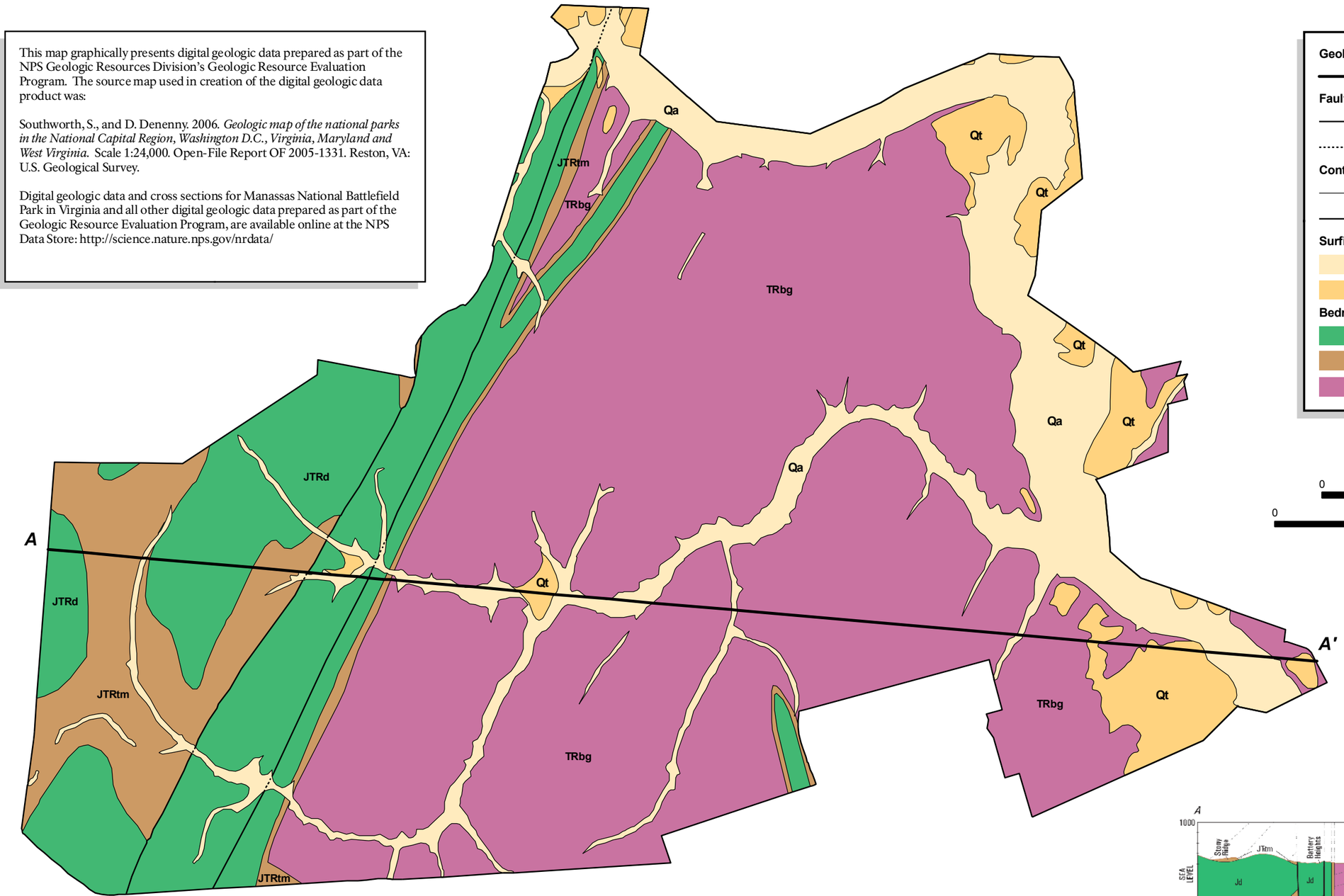
The following page is a snapshot of the geologic map for Manassas National Battlefield Park. For a poster-size PDF of this map or for digital geologic map data, please see the included CD or visit the Geologic Resource Evaluation publications Web page (http://www.nature.nps.gov/geology/inventory/gre_publications).

Geologic Map of Manassas National Battlefield Park

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

Southworth, S., and D. Denenny. 2006. *Geologic map of the national parks in the National Capital Region, Washington D.C., Virginia, Maryland and West Virginia.* Scale 1:24,000. Open-File Report OF 2005-1331. Reston, VA: U.S. Geological Survey.

Digital geologic data and cross sections for Manassas National Battlefield Park in Virginia and all other digital geologic data prepared as part of the Geologic Resource Evaluation Program, are available online at the NPS Data Store: http://science.nature.nps.gov/nrdata/



Geologic Cross Section Lines

Geologic Cross Section Lines

Faults

unknown offset/displacement fault, known or certain

unknown offset/displacement fault, concealed

Contacts

known or certain

map boundary

Surficial Units

Qa - Alluvium

Qt - Terrace deposit, low level

Bedrock Units

JTRd - Diabase dikes and sills

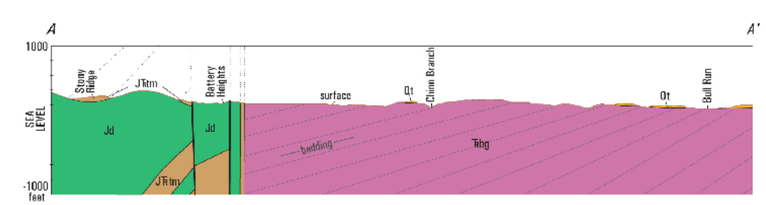
JTRtm - Thermally metamorphosed rocks

TRbg - Groveton Member of the Bull Run Formation

0 0.25 0.5 1 Miles

0 0.5 1 2 Kilometers

N W E S



Appendix B: Scoping Summary

The following excerpts are from the GRE scoping summary for Manassas National Battlefield Park. The scoping meeting was on April 30–May 2, 2001; therefore, the contact information and Web addresses referred to in this appendix may be outdated. Please contact the Geologic Resources Division for current information.

Executive Summary

Geologic Resources Inventory (GRI) workshops were held for National Park Service (NPS) Units in the National Capital Region (NCR) over April 30-May 2, 2001. The purpose was to view and discuss the park's geologic resources, to address the status of geologic mapping for compiling both paper and digital maps, and to assess resource management issues and needs. Cooperators from the NPS Geologic Resources Division (GRD), Natural Resources Information Division (NRID), individual NPS units in the region, and the United States Geological Survey (USGS) were present for the workshop.

This involved half-day field trips to view the geology of Catoctin Mountain Park, Harpers Ferry NHP, Prince William Forest Park and Great Falls Park, as well as another full-day scoping session to present overviews of the NPS Inventory and Monitoring (I&M) program, the GRD, and the on-going GRI. Round table discussions involving geologic issues for all parks in the National Capital Region included the status of geologic mapping efforts, interpretation, paleontologic resources, sources of available data, and action items generated from this meeting.

Geologic Mapping

Existing Geologic Maps and Publications

After the bibliographies were assembled, a separate search was made for any existing surficial and bedrock geologic maps for the National Capital Region parks. The bounding coordinates for each map were noted and entered into a GIS to assemble an index geologic map. Separate coverage's were developed based on scales (1:24,000, 1:100,000, etc.) available for the specific park. Numerous geologic maps at varying scales and vintages cover the area. Index maps were distributed to each workshop participant during the scoping session.

Status

The index of published geologic maps are a useful reference for the NCR. However, some of these maps are dated and are in need of refinement and in other places, there is no existing large-scale coverage available. The USGS began a project to map the Baltimore-Washington DC area at 1:100,000 scale and as a result it was brought to their attention that modern, large-scale geologic mapping for the NCR NPS areas would be beneficial to NPS resource management.

Because of this, the USGS developed a proposal to re-map the NCR at large scale (1:24,000 or greater) and to supply digital geologic databases to accompany this mapping. Scott Southworth (USGS-Reston, VA) is the project leader and main contact. The original PMIS (Project Management Information Systems) statement is available in Appendix C and on the NPS intranet (PMIS number 60900); of note is that portions of it need to be changed to reflect that the source of funding will be Inventory and Monitoring funds and NOT NRPP.

Desired Enhancements in the geologic maps for NCR parks

To better facilitate the geologic mapping, Scott Southworth would like to obtain better topographic coverage for each of the NCR units. Tammy Stidham knows that some of these coverages are already available and will supply them to Scott and the USGS. In general, anything in Washington DC proper has 1 meter topographic coverage and Prince George's county has 1:24,000 coverage.

Notes on Manassas National Battlefield Park

Manassas (MANA) was unrepresented at the scoping session, but Bruce says they're doing exotic weed mapping based on geology. We have high resolution topographic data for Prince William County. It's geologically covered in Scott's 100,000 scale map.

Other Desired Data Sets for NCR

Soils

Pete Biggam (GRD Soil Scientist) supplied the following information in reference to soils for parks:

National Capitol Parks - Central is covered by the "District of Columbia" Soil Survey (State Soil Survey Area ID MD099). It has been mapped, and is currently being refined to match new imagery. An interim digital product is available to us via NRCS, but the "final certified" dataset most likely will not be available until FY03.

National Capitol Parks - Eastern is covered by portions of 3 soil survey areas; "District of Columbia" (MD099), "Charles County, Maryland" (MD017), and "Prince George's County, Maryland" (MD033). Both Charles County and Prince George's County are currently being updated, with Charles County scheduled to be available sometime in calendar year 2002, and Prince George's County sometime within calendar year 2003.

Paleontology

Greg McDonald (GRD Paleontologist) would like to see an encompassing, systematic Paleontological inventory for the NCR describing the known resources in all parks with suggestions on how to best manage these resources.

In addition to the parks containing paleo resources in NACE, according to his current database, the following are considered "paleo parks" in the NCR:

- Chesapeake & Ohio Canal NHP
- George Washington Memorial Parkway
- Manassas NBP
- Prince William Forest Park
- Harpers Ferry NHP

Geologic Report

A "stand-alone" encompassing report on each park's geology is a major focus of the GRI. As part of the USGS proposal to map the NCR, they will be summarizing the major geologic features of each park in a report to accompany their database. It was suggested hoped that after the individual reports are finished that a regional physiographic report will be completed for the entire NCR.

List of Attendees for NPS National Capital Region Workshop

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Manassas National Battlefield Park

Geologic Resource Evaluation Report

Natural Resource Report NPS/NRPC/GRD/NRR—2008/050
NPS D-89, September 2008

National Park Service

Director • Mary A. Bomar

Natural Resource Stewardship and Science

Associate Director • Bert Frost

Natural Resource Program Center

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

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