National Park Service
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Natural Resource Program Center

Prince William Forest Park
Geologic Resources Inventory Report

Natural Resource Report NPS/NRPC/GRD/NRR—2009/086

THIS PAGE:
South Fork Quantico Creek

ON THE COVER:
Bridge over South Fork Quantico Creek

NPS Photos

Prince William Forest Park Geologic Resources Inventory Report

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Executive Summary

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

Prince William Forest Park begins with the geology, that is, with the processes that formed the present-day environments and scenery. Understanding the geologic resources is relevant to resource-management decisions about geologic issues, future scientific research, interpretive needs, and economic resources.

Geologic processes formed a landscape composed of rock formations, ridge tops and valleys, waterfalls and wetlands. These processes develop a landscape that influences human use patterns. The geology attracted settlers to eastern Virginia to pursue hunting, mining, settlement, industry, and agriculture. The geology inspires wonder in visitors, and emphasis on geologic resources can enhance the visitor's experience.

The rocks in east-central Virginia reflect the tectonic forces that formed the Appalachian Mountains. Late Precambrian to early Paleozoic crystalline rocks, and younger sandstone, shale, siltstone, carbonate rocks, and quartzite underlie the landscape. The region was compressed during three separate tectonic events, the Taconic, Acadian, and Alleghanian orogenies (mountain building events). The faulted and folded metamorphic gneiss underlying Prince William Forest Park records this regional deformation.

Quantico Creek wanders through the largest piedmont forest ecosystem in the eastern United States. Nearly the entire Quantico Creek watershed is within the boundaries of Prince William Forest Park. This park is the third largest National Park Service unit in Virginia and a natural haven in the Washington, D.C., metropolitan area, some of the principal geologic issues and concerns pertain to protecting this environment. Humans have significantly modified the landscape surrounding Prince William Forest Park, and consequently modified its geologic system. This system is dynamic and capable of noticeable change within a human life span. Geologic processes also continue to change the landscape, making resource management a challenge.

In addition to natural causes of landscape change, dams, mines, roads, air and water pollution, and invasion by non-native species have had a significant impact on the natural resources of Prince William Forest Park. The further impacts of visitors are only just beginning to be measured and alleviated. Researchers are striving to better understand all these impacts on the environment.

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

- Mining-related issues.
  Prince William Forest Park has a long history of mineral extraction—principally pyrite from the Cabin Branch Mine. The abandoned shafts from gold operations at the Greenwood Mine were a safety hazard. Wastes from such mines may also degrade the environment by polluting water and soil through the weathering of mine tailings and other debris.
- Geology and biodiversity.
  The park is famous for its forest biodiversity, including the largest parcel of piedmont forest in Virginia. This diversity is a direct result of area geology, topography, and climate. Protecting ecosystems found in wetlands, hill slopes, and ridge tops, as well as understanding the relationships between geology and biology throughout the park, remains a key resource management issue.
- Erosion and slope processes.
  The relatively wet climate of the eastern United States, combined with severe storms, loose soils on steep slopes, and marshy wetlands along the streams in Prince William Forest Park, creates a setting that is especially susceptible to slumping, slope creep, and erosion of stream banks. This is commonly due to a local lack of stabilizing plant growth in the sandy, relatively infertile and easily disturbed soils. Substantial seasonal runoff and relatively frequent, intense rainstorms also contribute to high rates of erosion. Runoff can dramatically alter the landscape, creating new hazardous areas in the process. The runoff may also clog streams with excess sediment, affecting hydrologic systems and aquatic life.

Other geologic issues concerning ground water and surface water, recreational demands, and general geology, were also identified as management issues for Prince William Forest Park.

Introduction

The following section briefly describes the National Park Service Geologic Resources Inventory and the regional geologic setting of Prince William Forest Park.

Purpose of the Geologic Resources Inventory

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

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

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

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

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

History of Prince William Forest Park

Prince William Forest Park provides a respite in the rapidly growing Washington, D.C., metropolitan area. The park's 18,939 acres cover a major part of the forested Quantico Creek watershed (fig. 1). The park is one of the largest parcels of pristine piedmont forest land left in the area and is the third largest National Park Service unit solely in Virginia.

Prince William Forest Park is located in Prince William County, Virginia. The land was originally set aside in the 1930s by President Franklin D. Roosevelt's administration in order to preserve a piedmont forest landscape for the education and enjoyment of future generations. The park was formally established on June 22, 1948, by an act of Congress. The uses of the park have varied from an outdoor education center to an Office of Strategic Services training camp. The boundaries of the park have changed several times since its beginning as it has expanted to cover almost the entire Quantico Creek watershed. The park attracted 351,058 visitors in 2008.

Geologic Setting

The park is located within two physiographic provinces (fig. 2). The western two-thirds of the park are in the Piedmont province while the eastern third is located in the Atlantic Coastal Plain province. Marked differences in terrain combined with location in the transition zone between a northern and southern climate lead to ecosystem variations throughout the park and that supports a diversity of species.

The topography within the park consists of rolling hills and narrow ridge tops separated by steep-sloped valleys and ravines. The ridge tops are composed of resistant late Precambrian to early Paleozoic metamorphic rocks. Separating the ridge tops are valleys where less resistant material, such as unconsolidated deposits, was easily eroded. Relief in the park is fairly high: elevations range from lows of ≈3 m (≈10 ft) to heights of nearly 122 m (400 ft) above sea level.

The following is a general description of the various physiographic provinces of Virginia, including a regional province, the Culpeper Basin, located just to the west of Prince William Forest Park (fig. 2).

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 . The province was formed by sediments that were eroded from the Appalachian Highland areas to the west. These sediments were intermittently deposited over the past 100 million years in 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 extends north-south from New York to Florida and from the Fall Line east to the Chesapeake Bay and Atlantic Ocean. Coastal Plain surface soils are commonly sandy or sandy loams that are well drained. Large streams and rivers in the province, including the James, York, Rappahannock, 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 resistant 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 can be seen in the Potomac Gorge of the Chesapeake and Ohio Canal National Historic Park or, on a smaller scale, at Quantico Falls in Prince William Forest 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 Piedmont and Blue Ridge along the length of the Appalachian Mountains. The basin formed during the Mesozoic as an intermountain basin during an extensional 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 between the Culpeper Basin and 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 Great Smoky Mountains National Park in North Carolina and Tennessee. Precambrian and Paleozoic igneous and metamorphic rocks were uplifted during several orogenic events that formed the steep, rugged terrain. Erosion resistant Cambrian quartzite forms Blue Ridge, Bull Run Mountain, South Mountain, and Hogback Ridge in Virginia, whereas Precambrian metamorphic rocks underlie the valleys (Nickelsen 1956).

Eroding streams have narrowed the northern section of the Blue Ridge Mountains into a thin band of steep ridges, climbing to heights of approximately 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 and rivers dominating the landscape around Prince William Forest Park 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 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 landscapes dotted by sinkholes, caves, and caverns.

The eastern part of the Valley and Ridge 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.

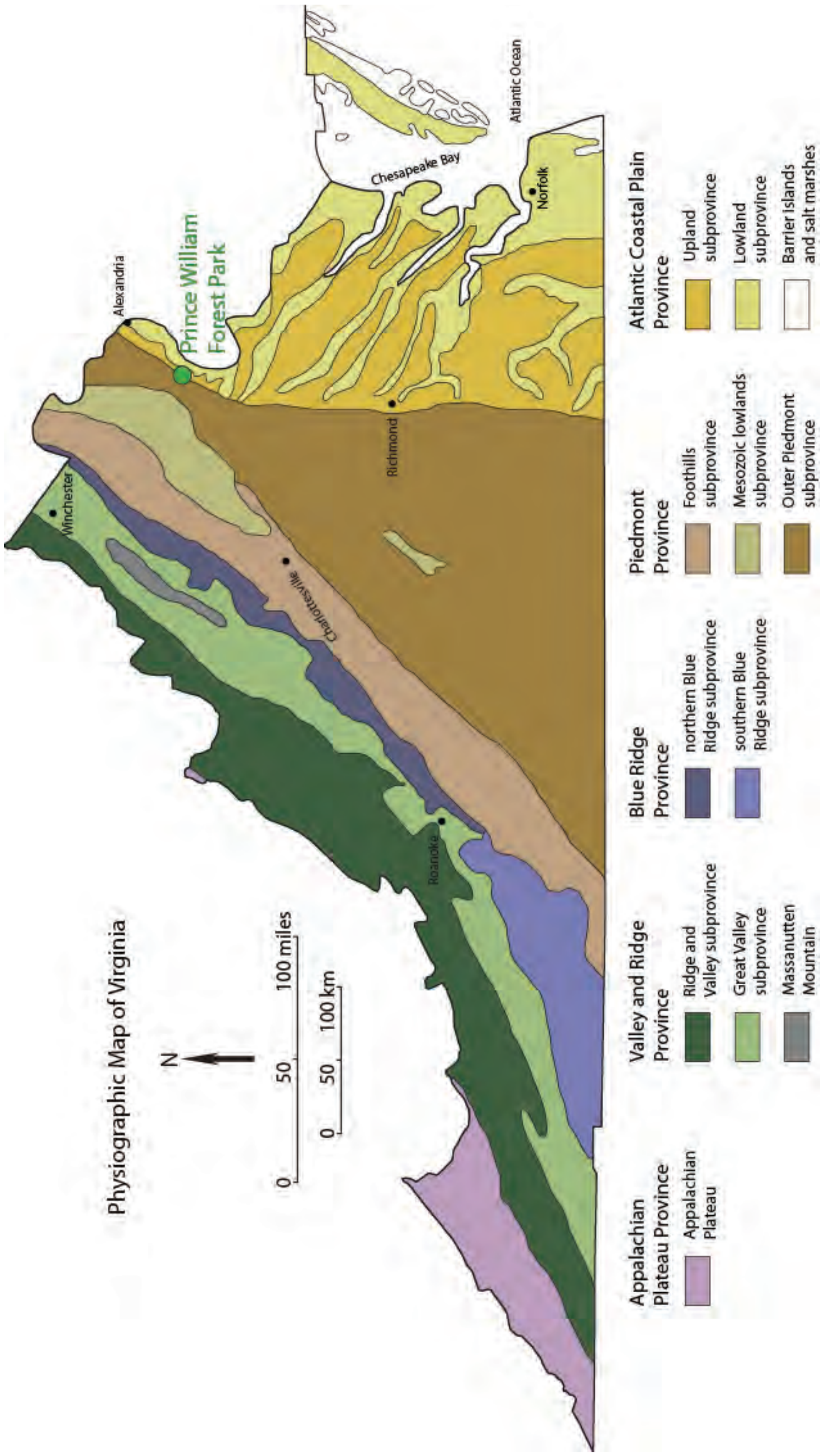

Figure 2: Location of Prince William Forest Park relative to the physiographic provinces of Virginia. Modified by Trista L. Thornberry-Ehrlich (Colorado State University) from Bailey (1999).

Geologic Issues

The National Park Service held a Geologic Resources Inventory scoping session for Prince William Forest 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.

Mining-Related Issues

Subsurface hazards are numerous on public lands in the United States. Many of these are sites of historic mining activity, which pose threats due to subsidence, contamination, and possible collapse. These threats make it difficult to maintain roads and trails through the mined areas. Failures of former mines can be catastrophic, and collapse would present a hazard to anyone visiting or working in the area including hikers, bicyclists, horseback riders, and recreational vehicle users.

Abandoned pyrite and gold mines are present at Prince William Forest Park. Speculation regarding the location and structural integrity of the main shafts of the abandoned mines necessitated electrical and magnetic geophysical surveys to locate the shafts and to assess shaft conditions. This was a project of the U.S. Bureau of Mines (Hauser and Jessop 1995). The volcanic-hosted Cabin Branch Mine is probably the most visited mine feature in the park. It was extracting a Cu-Zn-Pb massive sulfide deposit from 1889 to 1919. Mining at Cabin Branch ceased around 1920 and left several open shafts, historic remnants and foundations, and pyritic acid tailings that resulted in some acid drainage into Quantico Creek (Seal et al. 1999b). There is also an abandoned gold mine (Greenwood Mine) in the northwest part of the park, where there are partially collapsed mine shafts at Independence Hill.

Mines and abandoned mines create a strain on the ecosystem. At Prince William Forest Park, this strain is manifested as low biodiversity downstream from the Cabin Branch Pyrite Mine. In 1995, steps were taken to reclaim the site. This reclamation included the construction of storm-water diversion trenches around the tailings, grading the tailings away from the shorelines, the addition of topsoil and pulverized limestone (to reduce acidity), and revegetation of the surface. Although the chemistry of shallow ground water still remains affected—lower pH and higher concentrations of dissolved copper are found on the northeastern bank of the creek and higher concentrations of dissolved iron and sulfate are found on the southwestern side of the creek—stream waters are relatively neutral, having a pH of 6.4–7.1. Concentrations of dissolved sulfate, copper, and zinc in the stream are still higher downstream of the site (Seal et al. 1999a). Despite the disturbance, organisms that once fled the toxic metals and low pH (acidic) waters and soils are returning to the area.

Inventory, Monitoring, and Research Suggestions for Mining-Related Issues

- Accurately map mine features within the park.
- Use ground-penetrating radar, common offset seismic-reflection profiling, and magnetic-gradient surveying to identify any subsurface workings.
- Assess the risk of shaft failure in mapped mine workings.
- Assess environmental impact of abandoned pyrite mines on ground-water quality, the hydrogeologic system, and the biologic system within the park.
- Periodically sample and test water (surface and ground water) and soil to detect heavy metals, especially in drinking water.
- Contact the Abandoned Mineral Lands (AML) staff at the Geologic Resources Division office, Denver, CO, for resource management questions.

Geology and Biodiversity

Natural areas provide refuges for many species. They also serve as migration corridors for wildlife. For the public, they are living classrooms. Small national parks, such as Prince William Forest Park, add considerably to the biological diversity of an entire region, especially in areas of heavy development, such as the Washington, D.C., metropolitan area. The park is the largest protected green space in the area. It is also one of the largest protected Piedmont forest ecosystems in the National Park Service.

Prince William Forest Park provides a critical natural area in a dissected landscape. An understanding of the features that promote biodiversity, such as the geology, climate, topography, and hydrogeologic system, is important to understanding the distribution of unique habitats and ecosystems, as well as managing them effectively for preservation and restoration.

At least two distinct types of forest ecosystems are present in the upland areas of the park. These areas are controlled by the underlying geology. The ridges and slopes support a mixed oak forest, whereas the lower slopes support a mesic hardwood forest above the floodplain of the local waterways. Beeches, which are indicative of an undisturbed interior environment, are present in the park, as are a variety of rare species, including the butternut, bigtooth aspen, black walnut, swamp white oak, and cottonwood. The floodplain environments in the park support American beech, box elder, and sycamore trees.

The park is in a transition zone between northern and southern climates and between different physiographic provinces. This is reflected in the distribution of several species of trees in the park. For more information on the rare ecosystems in the park (a seepage swamp, remote stands of eastern hemlock, and populations of rare plants, including the small whorled pogonia orchid *Isotria medeoloides*), see the park's Web site (www.nps.gov/prwi).

Prince William Forest Park is also host to rare and diverse fauna. More than 38 species of mammals, 24 species of amphibians, more than 100 species of birds, 27 species of reptiles, 23 species of fish, and many invertebrates share the landscape and waterways of the park. Of these inventoried species, there are a few rare or threatened species listed by the State of Virginia, as well as species of special concern.

The geological features of the Culpeper Basin and the Piedmont province are major determining factors of the biodiversity of the flora and fauna protected within the park. The ecosystem can be dramatically different depending on the orientation of a particular, elevation, geologic substrate, soil type, and permeability, change in slope, and exposure to climate and wind. Therefore, correlation with geological features and resources should be part of any biological inventory and monitoring effort.

Inventory, Monitoring, and Research Suggestions for Geology and Biodiversity

- Determine and study geologic controls on habitat and species distribution.
- Create habitat maps and models that include geology and topography in a GIS to improve understanding of ecosystem processes and geographic distribution.
- Monitor changes in geologic controls on species distribution, including hydrologic systems, slopes, and human development.

Recreational Demands

The National Park Service has a dual mission, to protect park resources and to provide opportunities for visitors to enjoy those resources. Prince William Forest Park provides visitors numerous recreational opportunities, including hiking, fishing, bicycling, picnicking, photography, and almost any activity that does not damage the resources of the park or endanger other visitors.

The park receives many visitors, especially during the summer months. As many as 351,058 people entered the park in 2008, placing increasing demands on the resources of the park. Management concerns vary from trail erosion, waste treatment, and water quality to historic mine shaft stability.

Many trails wind through preserved biological, historical, and geological environments at the park. These environments can be especially fragile, and off-trail hiking leads to their degradation (fig. 3). The park designates trails and picnic areas to limit the negative impacts of recreation. Prohibited use in non-designated areas increases the area of impact and places delicate ecosystems at risk for contamination by waste.

Several streams, including Quantico Creek, enhance the natural beauty of the park. As with hiking, overuse of certain areas can lead to contamination by waste and degradation of the ecosystem and also increased stream-bank erosion. The park has attempted to buttress certain reaches of the creek where it approaches a visitor trail. These supports are intended to reduce stream bank erosion, but such measures are temporary (figs. 4 and 5).

Inventory, Monitoring, and Research Suggestions for Recreational Demands

- Identify and mitigate areas of trail erosion, social trails, and human impacts on park watersheds and wetlands.
- Design informative exhibits to encourage responsible use of park resources.

Water Issues

In the humid eastern climate of Virginia, water seems present everywhere—in streams, rivers, runoff, springs, and wells. Annual precipitation at Prince William Forest Park averages ≈100 cm (40 in) per year with most of the rain coming during short storms in the summer months. Because of the existing and future development of the surrounding populated areas, water resources are under constant threat of contamination and overuse.

Preserving the integrity of the Quantico Creek watershed is a major management objective at Prince William Forest Park, which contains approximately 70% of the entire watershed. The north branch of Quantico Creek and South Fork Quantico Creek join near the eastern boundary of the park. These streams receive more than 90% of the runoff from park lands. The park also contains several vernal pools that serve as vital breeding areas for many species. These pools are underlain by relatively impermeable geologic substrate, trapping seasonal precipitation.

The natural course of Quantico Creek has been altered in the park to create recreational lakes. A series of small dams trap sediments from storm-water runoff, and these dams are periodically dredged. These constructed features provide additional breeding habitat for several fish and amphibian species. Normally, restoration of an original natural watershed would be a primary goal of the park. In this case, such a goal is tempered by the possibility of habitat degradation for the organisms living below the dams, as well as the increase in sediment load and the likelihood of intense flooding that would compromise park resources. Visitor expectations and access are also determining factors in remediation proposals.

Although its course has been altered, the creek is a "reference stream" regarded by various federal, state, and local entities as an example of a pristine, unspoiled watershed. Even so, issues related to the health of the streams and lakes in the park still exist. Suburban development surrounding Prince William Forest Park, part of the Washington, D.C., metropolitan area, affects the watershed in a variety of ways.

Where agricultural remnants, construction materials, and other wastes are present, nitrogen levels (and other contaminants) in the water may 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 development projects, and an understanding of the hydrogeologic system, including ground-water flow patterns, are essential to protect the watershed's ecosystem.

The movement of nutrients and contaminants through the ecosystem can be modeled by monitoring the composition of system inputs, such as rainfall, and outputs, such as streamflow. Other input sources include wind, surface runoff, ground water, sewage, landfills, and fill dirt. Streams in effect integrate the surface runoff and ground-water flow of their watersheds. Thus, they provide a cumulative measure of the status of the watershed's hydrologic system. Consistent measurement of these parameters is necessary to establish baselines for comparison.

The hydrogeologic system changes in response to increased surface runoff as well. This increase results from addition of impervious surfaces, such as parking lots, roads, and buildings. Sedimentation also increases due to clearing land for development. Water temperature increases because of the insulating nature of impervious surfaces. For example, runoff from a parking lot on a hot July day is much warmer than runoff from a grassy slope.

Inventory, Monitoring, and Research Suggestions for Water Issues

- Establish working relationships with the U.S. Geological Survey and the Virginia Geological Survey, as well as local to national conservation groups, to study and monitor the park's watershed and the hydrology of the area for applications in hydrogeology, slope creep, stream-bank erosion, and other geologic hazards.
- Measure and document changes in the hydrologic regime in impacted areas of the park, such as roadways, abandoned mines, trails, and visitor and administrative facilities.
- Survey species of fish and benthic organisms in the watershed. Relate species distribution to geologic controls, such as ripples, waterfalls, and vernal pools.
- Map and quantify subterranean recharge zones.

Erosion and Slope Processes

The topographic differences within and surrounding the park are large in some places, especially along the banks of Quantico Creek and its tributaries. The likelihood of landsliding increases with precipitation and undercutting of slopes by roads, trails, and other development in addition to natural erosion and weathering.

The walls of many of the river and tributary valleys within and around the park are steep and high (fig. 6). They are dangerous because of the likelihood of rock falls, landslides, slumps, and slope creep. This is a major concern in the areas of weaker rock units, such as fractured siltstone and unconsolidated alluvium. Slopes composed of unconsolidated deposits are especially vulnerable to failure. Heavy rainstorms, common in the eastern United States, can quickly saturate valley slopes. On slopes that lack stabilizing vegetation, rock and soil may mobilize and slide downhill as a massive slump or debris flow. Slides along streams and rivers lead to shoreline erosion, increased sediment load, and gullying, all of which threaten trails, bridges, and other features of interest in addition to visitor safety (figs. 7 and 8). Sediment load and distribution affect the location and health of aquatic and riparian ecosystems. Increased sediment load can cause turbidity which adversely affects aquatic plants and animals. Sediment loading can also result in changes to channel morphology and overbank flooding frequency affecting the riparian zones on either side of the stream. If the sediments entrain harmful substances, these can be deposited in overbank deposits, poisoning the plants within the riparian zone.

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

- Develop a landslide hazard model to identify vulnerable locations in the park using topographic, geologic, and rainfall data.
- Monitor erosion rates at key sites. Traditional profile measurements (repeated seasonally and, if possible, shortly after major storms) and repeat photography may be useful tools.
- Inventory areas that are susceptible to runoff flooding (paleoflood hydrology).
- Assess trails for stability and determine which trails are most at risk and in need of further stabilization.
- Study the morphology of stream channels with respect to intense seasonal runoff and monitor changes in channel morphology. Consult professional geomorphologists regarding erosional processes.
- Review changes in streamflow as they indicate basin dynamics, climate, and land use.
- Assess conditions such as channel morphology, seasonal flooding, and proximity to park facilities to identify actual and potential "problem reaches" for prioritized monitoring.
- Measure sediment load on Quantico Creek to establish baseline conditions for future comparative assessment. Data will provide information relevant to decisions regarding removal or maintenance of existing dams.

Paleontology

No formal paleontological inventories have been undertaken for Prince William Forest Park, and paleontological scoping sessions have not been completed for the park. However, the park has approximately 15 specimens of petrified wood accessioned into museum collections. One specimen is on display at the visitor center (Kenworthy and Santucci 2004). Fossils are non-renewable resources that require park protection and provide opportunities for visitor education about geology and past environments. Fortunately, fossil theft does not appear to be a problem for the park at this time.

The majority of rocks within Prince William Forest Park are igneous or metamorphic. Fossils are not typically found in igneous or metamorphic rocks, and as such fossils are not known from those units. However, the Ordovician Quantico Formation and the Potomac Group of Early Cretaceous age are located immediately adjacent to or within the park and are known to contain fossils.

The Quantico Formation, previously known as Quantico Slate, is a dark gray-black slate (lightly metamorphosed shale) originally named for exposures along Quantico Creek. Limited exposures of the Quantico Formation have been mapped within the southeastern corner of the park, near Quantico Creek and immediately adjacent to the park boundary. Numerous fossils of a well-preserved pelecypod bivalve, Pterinea, and poorly preserved brachiopod specimens, tentatively identified as Pholidops or Leptobolus were initially described in 1911 from a locality northeast of the park along Powell Creek (Kenworthy and Santucci 2004).

The Potomac Group is a well known, frequently fossiliferous group of formations found throughout Virginia, Maryland, and Washington, D.C. The Potomac Group has variable lithologies including light-gray to pink-gray medium to very coarse grained quartz sand, a green clay-sand, and a dark yellow-brown sandy soft clay. Found within these sands and clays are abundant, but generally poorly preserved, leaf and stem impressions of ferns, cycads, and gymnosperms along with rare silicified, or petrified, tree trunks. Upchurch et al. (1994) report on a different floral assemblage from Potomac Group sediments found in a gravel pit along Engineers Road, parallel to Chopawamsic Creek south of the U.S. Marine Corps Air Station. This assemblage contains 22 different species, including one species each of horsetail and cycadophyte, eight species of conifers and 12 species of angiosperms (Upchurch et al. 1994; Kenworthy and Santucci 2004).

The only paleontological resources cataloged within Prince William Forest Park collections include various pieces and chips of petrified wood collected from Potomac Group sediments. One shoe-box sized specimen is currently on display within the visitor center. Most of the petrified wood was discovered as a result of construction activities. All of the petrified wood samples have been classified as Taxodium distichum or bald cypress. This taxonomy has been updated and the material is most likely from the Cupressaceae family, in the fossil wood genus Cupressoxylon, closely related to modern sequoia and bald cypress. Cupressoxylon is the most common Early Cretaceous-aged fossil wood in the area. The largest pieces of petrified wood—2m (6 ft) in length—in addition to the piece already on display in the visitor center, have excellent interpretive potential due to their size and "recognizeablility" (Kenworthy and Santucci 2004).

Additional fossils from the Potomac Group are likely within the park. However, future discovery of fossils may be difficult. The heavily forested nature of the park precludes extensive rock exposures, therefore only stream valleys and construction projects are likely to provide exposures of the Potomac Group. Nevertheless awareness of the potential paleontological resource by resource managers may help to preserve any fossils unearthed during future excavation activities.

Geologic Education and Research

Along with a detailed geologic map and a road or trail log, a guidebook linking Prince William Forest Park to the other parks in the Central Appalachian region would enhance visitor appreciation of the geologic history and dynamic processes that created the natural landscape of the park. Strategically placed wayside exhibits can also help explain the geology to the visitor.

Inventory, Monitoring, and Research Suggestions for General Geology

- Promote geologic mapping within Prince William County, Virginia.
- 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 and Atlantic Coastal Plain.
- Map the geology within the park to determine the exact nature of the boundary between the Atlantic Coastal Plain and the Piedmont province.
- Develop interpretive exhibits discussing the geologic features (sedimentary deposits, igneous rocks, deformational structures, metamorphism) underlying the park, their origins, and their significance for the geomorphology of the area, especially with regards to the regional mining interest. Include exhibits about the tectonic history of the eastern United States.

Figure 3. Erosion from foot traffic along the South Valley Trail. This stairway was intended to reduce erosion of the steep slope but its purpose has been undermined by off-trail hiking. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 4. A buttress along South Fork Quantico Creek is intended to prevent erosion of the South Valley Trail (foreground); however, slope creep from the undercut slope above has pushed the buttress out of alignment and is compromising visitor safety along trail. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 5. Top-down view of a gabion along the shoreline of South Fork Quantico Creek. This image shows the toe of the slope pushing the gabion into the stream and undermining the trail along the top of the gabion. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

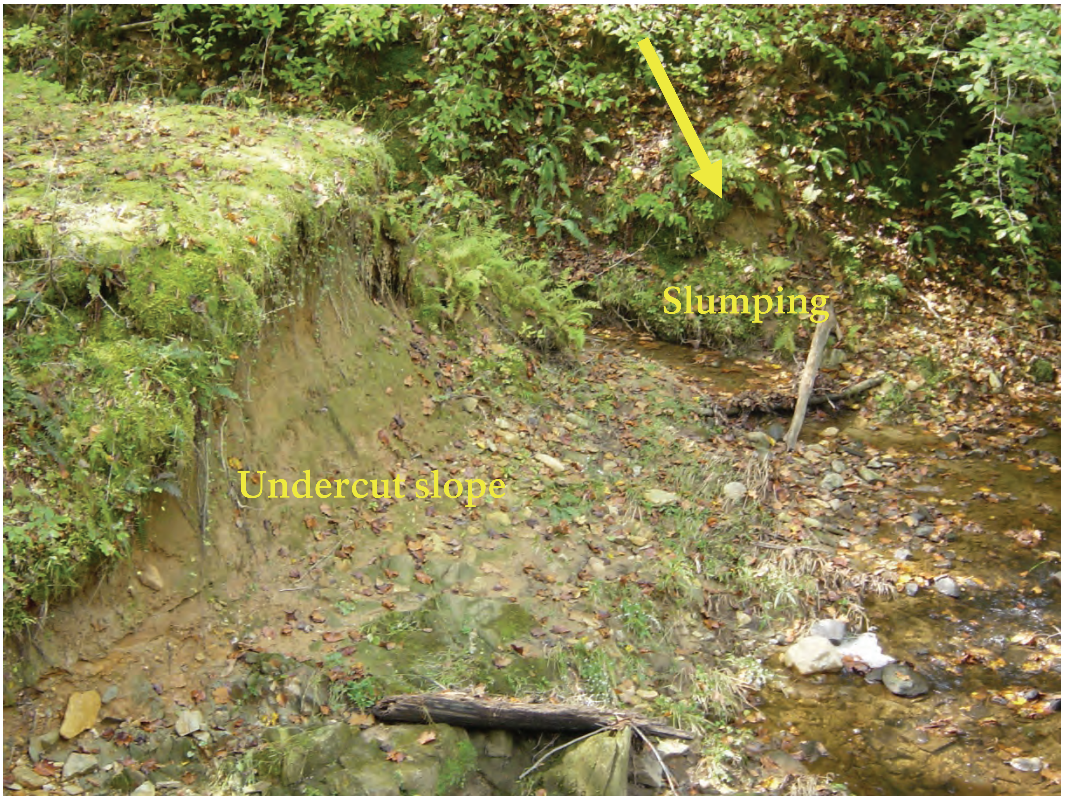

Figure 6. Undercut slope along the banks of South Fork Quantico Creek. Note the significant slumping on the steep slope of a minor tributary. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 7. Gullying along the South Valley Trail. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

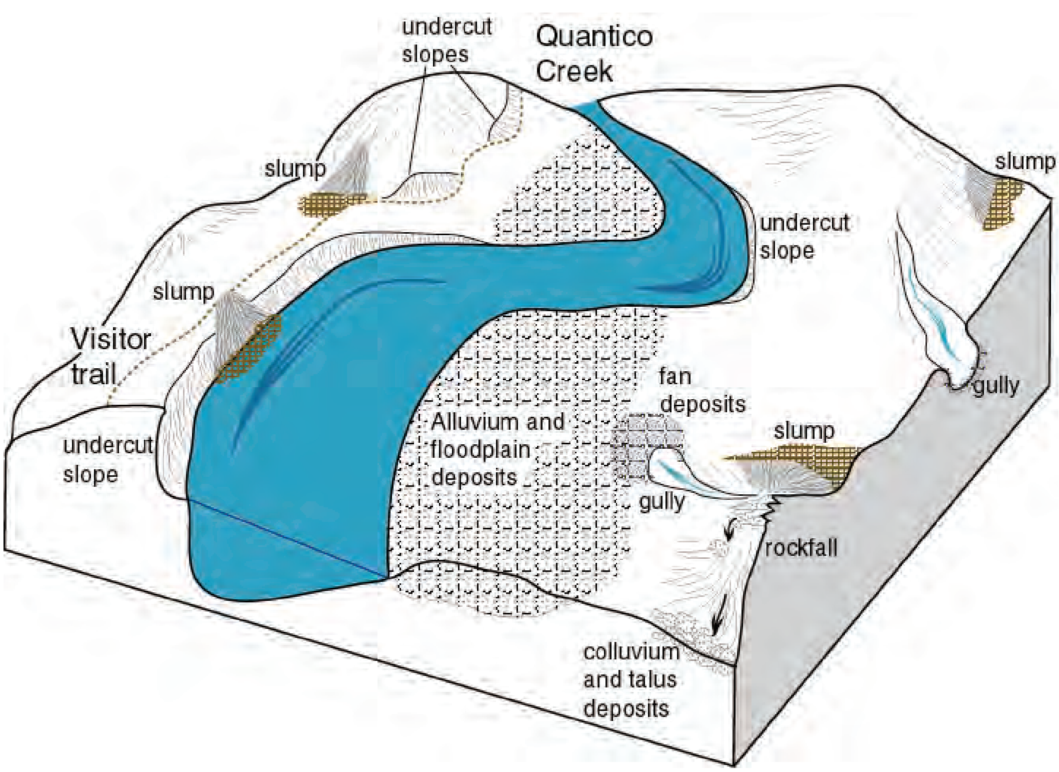

Figure 8. Diagram showing the effects of slope processes and erosion along Quantico Creek. Note typical deposits associated with slope processes and location of a visitor trail with respect to waterway, slopes, and hazards. Diagram not to scale and represents only those features present at Prince William Forest Park. Diagram 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 Prince William Forest Park.

Geology and the Landscape

Prince William Forest Park is on the fall line between the Piedmont and the Atlantic Coastal Plain physiographic provinces (figs. 9 and 10). The Piedmont is characterized by deformed metamorphic rocks (granitic and hornblende gneiss and mica schist) of late Precambrian to early Paleozoic age that were thrust upon the eastern margin of North America during the mountain building events (orogenies) that formed the Appalachian Mountains. The Coastal Plain is composed of mostly unconsolidated sediments shed from the highlands to the west and deposited in thick layers. These layers include sand, silt, and clay, as well as gravel.

In the two-thirds of the park that is within the Piedmont, the topography is characterized by narrow ridges capped by resistant rocks and separated by steep-sided valleys and ravines eroded through less resistant rocks. Some ridges and hilltops are covered with a mantle of coastal plain or other alluvial sediments. Relief throughout the park is fairly high. The elevation ranges from about 3 m (10 ft) above sea level to nearly 122 m (400 ft).

Intense erosion is common throughout the park and in places has exposed outcrops of folded and faulted bedrock. Where these beds are nearly vertical, steep ridges have been carved creating ripples, rapids, and falls along Quantico Creek. Some of these rocks represent the fall line, or the boundary between the Coastal Plain and the Piedmont. This line separates relatively hard, resistant rocks to the west from soft, easily eroded rocks to the east. In many river valleys along the eastern coast, this line is manifested as rapids and waterfalls. To the north, in the Potomac River, the fall line is as wide as 27 km (17 mi) and presented serious obstacles to upstream transportation before the railroads were built (Harris et al. 1997).

Substrate Types and Distribution

The substrates at Prince William Forest Park are generally sandy, poor in nutrients, and easily disturbed. The area sustained early tobacco farming that depleted the ground of nutrients. Poor farming practices may also have contributed to long-term depletion of nutrients. These soils have yet to recover. Their exposure on steep slopes makes them highly susceptible to erosion and to slumping and sliding. The types of rocks underlying the park play a role in determining the types and distribution of soils. Geologic processes also influence characteristics such as pH, permeability, and thickness.

The Soil Resources Inventory (SRI) Program of the NPS Geologic Resources Division worked with the Natural Resources Conservation Service (NRCS) to complete a soil survey for Prince William Forest Park in 2005. 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. The Soils map and data products for Prince William Forest Park are available through the NPS Data Store (http://science.nature.nps.gov/nrdata/).

Geologic Basis of Ecosystem Diversity

Climate and geology at Prince William Forest Park create a setting that favors biodiversity. This region in Virginia is composed of mixed deciduous/coniferous forests thriving 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 northern branch of Quantico Creek and South Fork Quantico Creek floodplains. Others require well-drained soils, such as those with a higher rock and sand content present on the higher slopes in the park, 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. Relatively flat topography and poorly drained nature of some of the soils in the park support unique oak species that are far less common in other areas of the Piedmont.

Primarily metamorphic rocks, such as gneiss and schist, underlie the park. Unconsolidated sediments and sandy soils overlie the metamorphic substrate. This geology in part determines the soil types and their distribution and thus influences forest types in the park. Thus, an understanding of the small-scale geologic differences at Prince William Forest Park and their interplay with the climate, topography, and soil types is important to managing both the recreational landscape and the vegetation that defines much of the natural setting.

Regional Structure

The post-Early Cretaceous Stafford fault system crosses the area (Seiders and Mixon 1981). This system consists of a series of northeast-trending, high-angle reverse faults in the unconsolidated deposits. The system is more than 68 km (42 mi) long and contains the Dumfries, Fall Hill, Hazel Run, and Brooke faults. The individual segments are 16–40 km (10–25 mi) long. Separating the segments are 2–4 km (1.2–2.5 mi)-wide en echelon, leftstepping faults that suggest dextral (right) shear on the fault system (Dominion Nuclear North Anna 2004).

These faults were active from the Cretaceous to earliest Quaternary time and indicate tectonic activity along the eastern margin of North America, long considered to be a passive margin. Maximum vertical displacements along the faults are estimated at 30–60 m (100–200 ft). These faults commonly act as conduits to ground-water flow but can also offset and thereby seal pre-existing fractures and aquifers (Nelms and Brockman 1997).

In addition to these features, there are many large- to small-scale regional faults, including the Spotsylvania, Chopawamsic, and Long Branch thrusts, the Hylas shear zone, the Mountain Run fault zone, and the Sturgeon Creek fault (Dominion Nuclear North Anna 2004). These and other small faults are northeast-striking, east-dipping Paleozoic structures that have been reactivated intermittently during tectonic events since their formation.

In particular, the Mountain Run fault zone, which runs along the eastern margin of the Culpeper basin to the northwest of Prince William Forest Park, was reactivated during Mesozoic extension and again as recently as the Quaternary. The fault was initially accommodating thrust movement, followed by reactivation as strike-slip (dextral) and dip-slip (normal) movement.

The Chopawamsic and Spotsylvania thrusts bound the Chopawamsic belt on the west and east, respectively. This belt of rocks extends southwestward from Washington, D.C., through to North Carolina. Together with the Charlotte and Milton belts, the Chopawamsic belt makes up a broad part of the central Piedmont from Virginia to Georgia.

This series of belts is interpreted to be part of an island-arc complex accreted onto North America during the Taconic orogeny (Dominion Nuclear North Anna 2004). After accretion and subsequent erosion of the belt rocks, sediments such as those that became the Quantico Formation were deposited in successor basins and depositional troughs, such as the Quantico synclinorium.

The Quantico synclinorium is a northeast-southwest-trending structure that was compressed during the Ordovician Period. Within the synclinorium, the Quantico Formation is at garnet-staurolite metamorphic grade. The high temperatures and pressures indicated by this metamorphic grade indicate pervasive tectonic activity in the area (Dominion Nuclear North Anna 2004).

Quantico Falls

Several outcrops of folded and faulted metamorphic rocks are scattered throughout the park. These rocks dip nearly vertically in some areas. Where present along streambeds, these rocks form natural rapids. Many of the faulted rocks occur along the fall line: the geologic boundary between the harder, more resistant rocks of the Piedmont and the softer, unconsolidated deposits of the Atlantic Coastal Plain physiographic province.

Quantico Falls, along the northern branch of Quantico Creek, is a classic example of a fall-line feature (fig. 11). The falls cascade over nearly vertical beds of resistant gneissic rock (fig. 12). More easily eroded rocks downstream of the falls allow the lower reaches of the stream to cut more deeply, increasing the overhang of the ledge.

Figure 9. Map of Prince William County showing location of Prince William Forest Park in relation to the Culpeper Basin and the three physiographic provinces (Blue Ridge, Piedmont, and Atlantic Coastal Plain) in the county, the fall line between the Piedmont and Coastal Plain, and other regional features. Locations are approximate. Heavy red line indicates cross section of fig. 8, below. Diagram by Trista L. Thornberry-Ehrlich (Colorado State University).

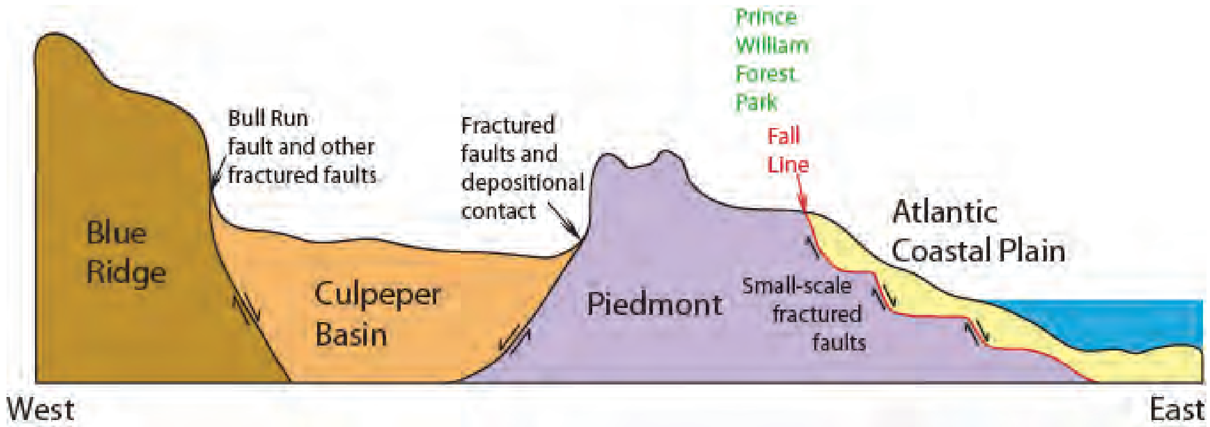

Figure 10. Generalized cross section through Prince William County showing location of Prince William Forest Park in relation to underlying structures. Drawing not to scale; vertical dimension is exaggerated. Diagram by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 11. Quantico Falls. Resistant gneissic rocks underlie this scenic setting. Less resistant rocks below are preferentially eroded away, increasing the overhang of the ledge. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Figure 12. Steeply dipping gneissic beds underlying Quantico Falls. The parallelogram represents a nearly vertical plane intersecting the rock along the yellow arrow (foliation trend). This resistant rock causes the rapids and falls along Quantico Creek. Photograph by Trista L. Thornberry-Ehrlich (Colorado State University).

Map Unit Properties

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

The map units in the Prince William Forest Park area can be divided into two groups on the basis of their age and the physiographic province where they occur. Piedmont rocks, including those of the Chopawamsic belt, are located on the western edges of the area. Cenozoic rocks, including unconsolidated marine sand, silt, and clay, are part of the Atlantic Coastal Plain to the east. Younger, Quaternary unconsolidated deposits, such as artificial fill, alluvium, colluvium, and terrace deposits, line river and stream beds and underlie developed areas.

The Piedmont rocks include deformed metasedimentary and metavolcanic rocks of late Precambrian and early Paleozoic age, such as the Cambrian Lunga Reservoir, Purcell Branch, Sykesville, and Chopawamsic formations, as well as the Ordovician Quantico ("Quantico slate") and Popes Head formations. The predominate rock types are metadiamictite, phyllite, amphibolite gneiss, metasiltstone, and slate (Nelms and Brockman 1997).

Some map units, such as the Wissahikon Formation, were formed as part of the ocean floor and were then smeared along the eastern edge of the continent during orogenic events (Pavlides et al. 1980). These were in turn intruded by premetamorphic granitic plutons of Cambrian and/or Ordovician age, such as the Dale City, Goldvein, and Lake Jackson plutons, and the Occoquan Granite (Nelms and Brockman 1997). These crystalline rocks underlie the unconsolidated sediments of Early Cretaceous age (Potomac Group), gravel deposits, and several sets of river terraces (Pavlides et al. 1980; Seiders and Mixon 1981).

Other unconsolidated map units overlying the crystalline rocks include the Paleocene Aquia Formation, the Pleistocene Tabb Formation, and Holocene alluvium and colluvium. Sediment types range from sand, silt, gravel, clay, and lignite, to soil and chemically weathered bedrock called saprolite (Nelms and Brockman 1997). Saprolite is an earthy material in which the major rock-forming minerals (except for quartz) have been altered to clays. The material retains many textural and structural characteristics of the original rock but has relatively little structural integrity (Dominion Nuclear North Anna 2004).

While the pre-Holocene deposits were collected in fluvial, estuarine, and marine settings, the recent sediments are fluvial deposits, marsh deposits, and soils (Nelms and Brockman 1997). These recent deposits drape hill slopes and fill valleys and other small depressions.

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

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

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

The geologic units listed in the following table correspond to the accompanying digital geologic data. Map units are listed in the table from youngest to oldest. Please refer to the geologic timescale (fig. 13) for the age associated with each time period. This table highlights characteristics of map units such as susceptibility to hazards; the occurrence of fossils, cultural resources, mineral resources, and caves; and the suitability as habitat or for recreational use.

The GRI digital geologic maps reproduce essential elements of the source maps including the unit descriptions, legend, map notes, graphics, and report. The following reference is source data for the GRI digital geologic map for Prince William Forest Park:

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.

The GRI team implements a geology-GIS data model that standardizes map deliverables. This data model dictates GIS data structure including data layer architecture, feature attribution, and data relationships within ESRI ArcGIS software, increasing the overall quality and utility of the data. GRI digital geologic map products include data in ESRI personal geodatabase and shapefile GIS formats, layer files with feature symbology, Federal Geographic Data Committee (FGDC)-compliant metadata, a Windows help file that contains all of the ancillary map information and graphics, and an ESRI ArcMap map document file that easily displays the map and connects the help file directly to the map document.

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

Geologic History

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

Prince William Forest Park is on the boundary between the Atlantic Coastal Plain and the Piedmont physiographic provinces. It therefore has features of both provinces and reflects the long geologic history of the Appalachian Mountains and the evolution of the eastern coast of North America. The regional perspective presented here connects the landscape and geology of the park with its surroundings.

The recorded history of the Appalachian Mountains begins in the Proterozoic (figs. 13 and 14*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 (the intrusion of igneous rocks), and volcanism are manifested in the metamorphic gneiss in the core of the modern Blue Ridge Mountains of Prince William Forest Park (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. 14*B*), roughly 600 million years ago, 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 would eventually form 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, all west of Prince William Forest Park. Also, in this extensional environment, flood basalt 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 break-up 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. 14*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 represent a grand platform, thickening to the east, that persisted during the Cambrian and Ordovician Periods (545–480 million years ago) (fig. 15*A*).

Somewhat later, 540, 470, and 360 million years ago, 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 migmatite (Southworth, Fingeret, et al. 2000).

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. 15*B*). In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards to create 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. 15*C*). These infilling sediments covered the grand carbonate platform and are today represented by the shale of the Ordovician (450 million years old) Martinsburg Formation (Southworth et al. 2001).

During the Late Ordovician, the oceanic sediments of the shrinking Iapetus Ocean were thrust westward onto other deep-water sediments of the western Piedmont along the Pleasant Grove fault. Sand, mud, silt, and carbonate sediments were then deposited in the shallow marine to deltaic environment of the Appalachian basin. The rocks that formed—sandstone, shale, siltstone, and limestone, all now metamorphosed—currently underlie the Valley and Ridge province far to the west of Prince William Forest Park (Fisher 1976).

The Piedmont metasediments, which cover approximately two-thirds of Prince William Forest Park, 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 Prince William Forest Park area, these metasediments include mica schist, granitic gneiss, and hornblende gneiss. Northwest of the park these also include phyllonite, mélange, and metasiltstone of the Mather Gorge, Yorkshire, Sykesville, and Popes Head formations. Oceanic crust caught up in the orogenic events now exists as the basic peridotite, gabbro, and pyroxenite (mantle rocks) of the Piney Branch Complex (Drake et al. 1994).

This shallow marine to fluvial sedimentation continued for a period of about 200 million years during the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and 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 Quantico synclinorium underlying Prince William Forest Park was compressed during the Taconic orogeny. Exotic terranes were added to the eastern margin of the continent, including the Chopawamsic belt. 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 continent collided with the African continent, 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. 16*A*). The rocks were deformed by folds and faults to produce the Sugarloaf Mountain anticlinorium and the Frederick Valley synclinorium in the western Piedmont, the Blue Ridge–South Mountain anticlinorium, and the numerous folds of the Valley and Ridge province (Southworth et al. 2001). Many of the faults and folds that resulted from orogenic stresses are exposed today in the landscape surrounding Prince William Forest Park.

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 translates into 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 million years ago (fig. 16*B*). 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, stream-fed alluvial fans collected debris shed from the uplifted Blue Ridge and Piedmont provinces. 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 silt and sand. The Manassas Sandstone and the Balls Bluff Siltstone represent these deposits in the area of Manassas National Battlefield Park, just northwest of Prince William Forest Park.

The large faults that formed the western boundaries of the basins provided an escarpment that was quickly covered with eroded debris. Magma was intruded into the new strata as sills (sub-horizontal sheets), and nearly vertical dikes that extend beyond the basins into adjacent rocks. After this magma was emplaced approximately 200 million years ago, the region underwent a period of slow uplift and erosion. The uplift was in response to isostatic adjustments within the crust, which forced the continental crust upwards and exposed it to erosion (fig. 16*C*). This erosion is evident in the landscape at Prince William Forest Park where deep ravines and ridges of metamorphic rock were carved by rapidly downcutting rivers.

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 to become part of the Atlantic Coastal Plain, which encompasses the eastern third of Prince William Forest Park (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. Erosion continues today with the Potomac, Rappahannock, Rapidan, and Shenandoah Rivers, as well as smaller branches such as the Quantico Creek watershed, and tributaries stripping the Coastal Plain sediments, lowering the mountains, and depositing alluvial terraces along the rivers, thus shaping the present landscape (fig. 16*D*).

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

The landscape and geomorphology of the greater Potomac River and Rappahannock River valleys (including the Quantico Creek watershed) in particular are the result of erosion and deposition from about the middle of the Cenozoic Period to the present, or at least the last 5 million years. 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 steep ridges and ravines in Prince William Forest Park are the result of this downward cutting and overprinting.

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 by waterways such as Quantico Creek (Zen 1997a and 1997b).

Given the susceptibility to erosion of the unconsolidated deposits throughout the area, dating of recent tectonic and climatic regimes is problematic. Most of the sediments have eroded away. However, loess deposits (wind-blown silt-sized particles, commonly associated with glaciation) found on stable landforms near Occoquan, Virginia, indicate that the local transition from a colluvial-dominated (rockfall and slope-failure processes) to a fluvial-dominated (river and other water action) geomorphic regime did not occur in the mid-Atlantic region until the end of the early Holocene (Feldman et al. 2000). Similarly, geologists measure the oxygen isotope ratios in pedogenic clays such as kaolinite (formed from the weathering of muscovite and microcline) to determine the climatic conditions during weathering. In the Piedmont province, a cooler climate persisted beyond the Pleistocene glacial stage in North America (Elliott et al. 1997).

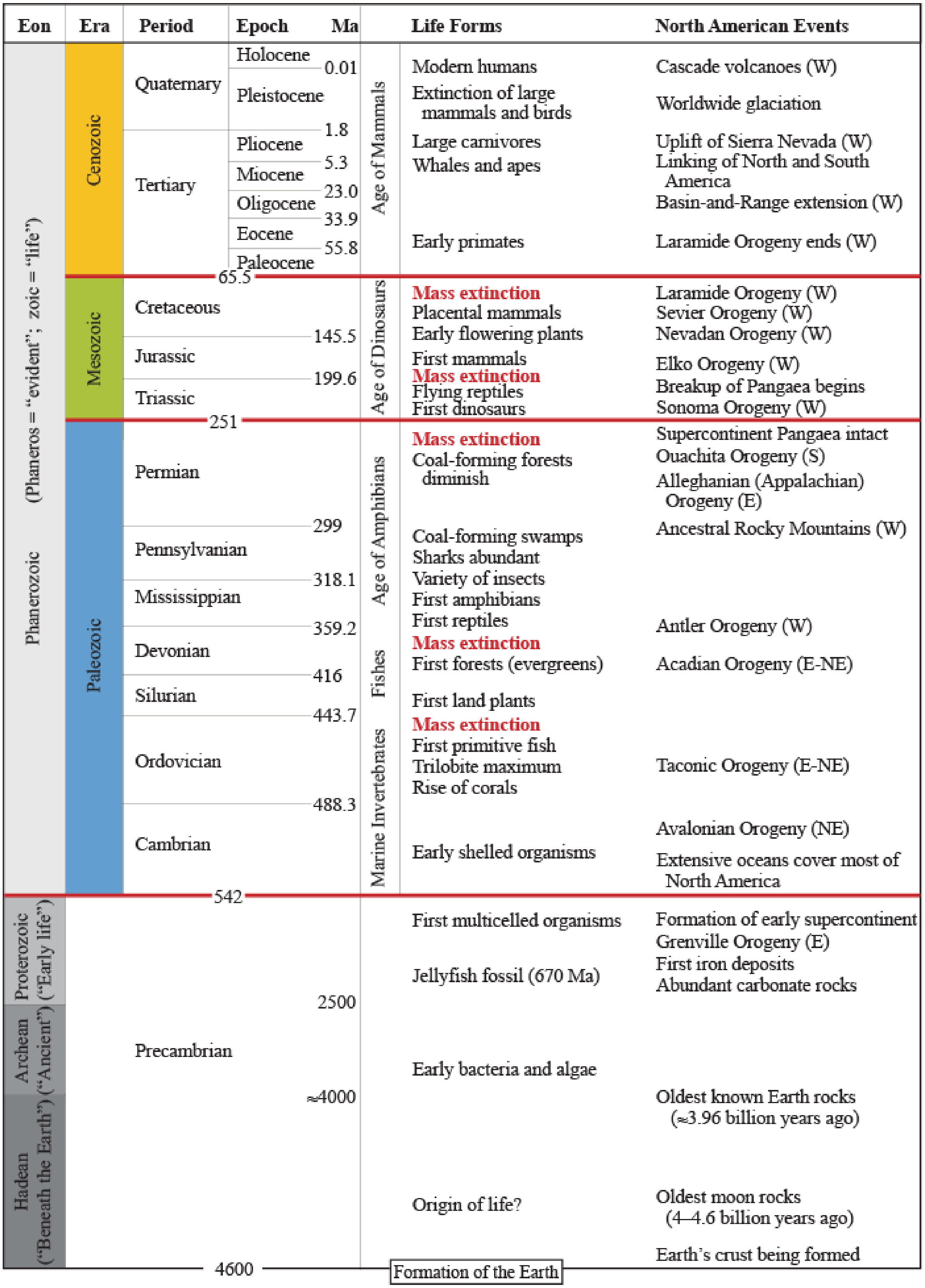

Figure 13: Geologic time scale; adapted from the U.S. Geological Survey (http://pubs.usgs.gov/fs/2007/3015/). Red lines indicate major unconformities between eras. Included are major events in life history and tectonic events occurring on the North American continent. Absolute ages shown are in millions of years.

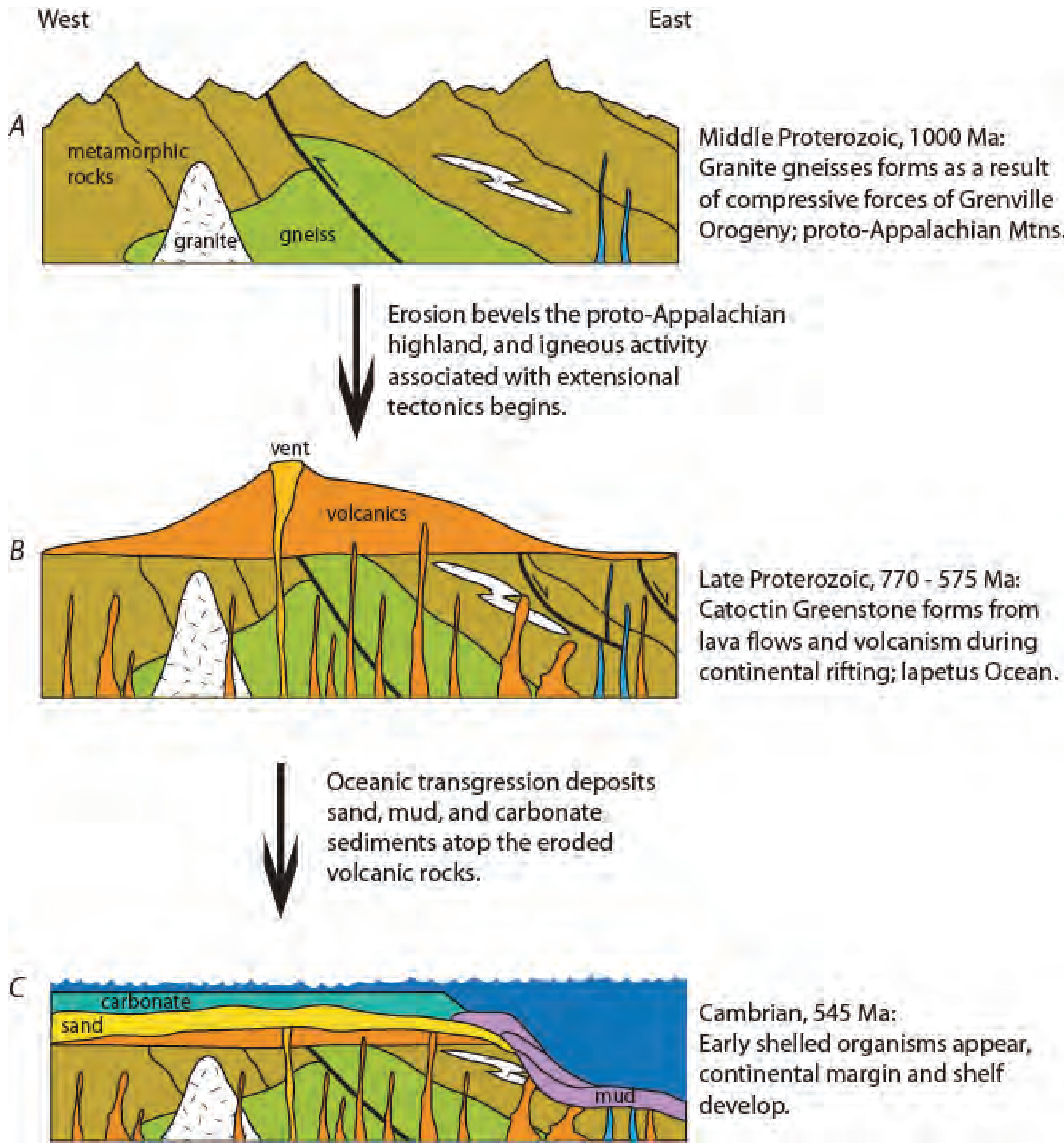

Figure 14. Geologic evolution of the Appalachian Mountains in the Prince William Forest Park area. Cross-section view is west to east. (*A*) First, intrusions of granitic gneiss, metamorphism, and deformation related to the Grenvillian orogeny lasted 60 million years, from 1.1 billion to 950 million years ago. 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 million years ago. (*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 million years ago. Then, deep-water sediments were deposited in a basin east of the shelf margin for about 65 million years. Ma, mega-annum (millions of years).

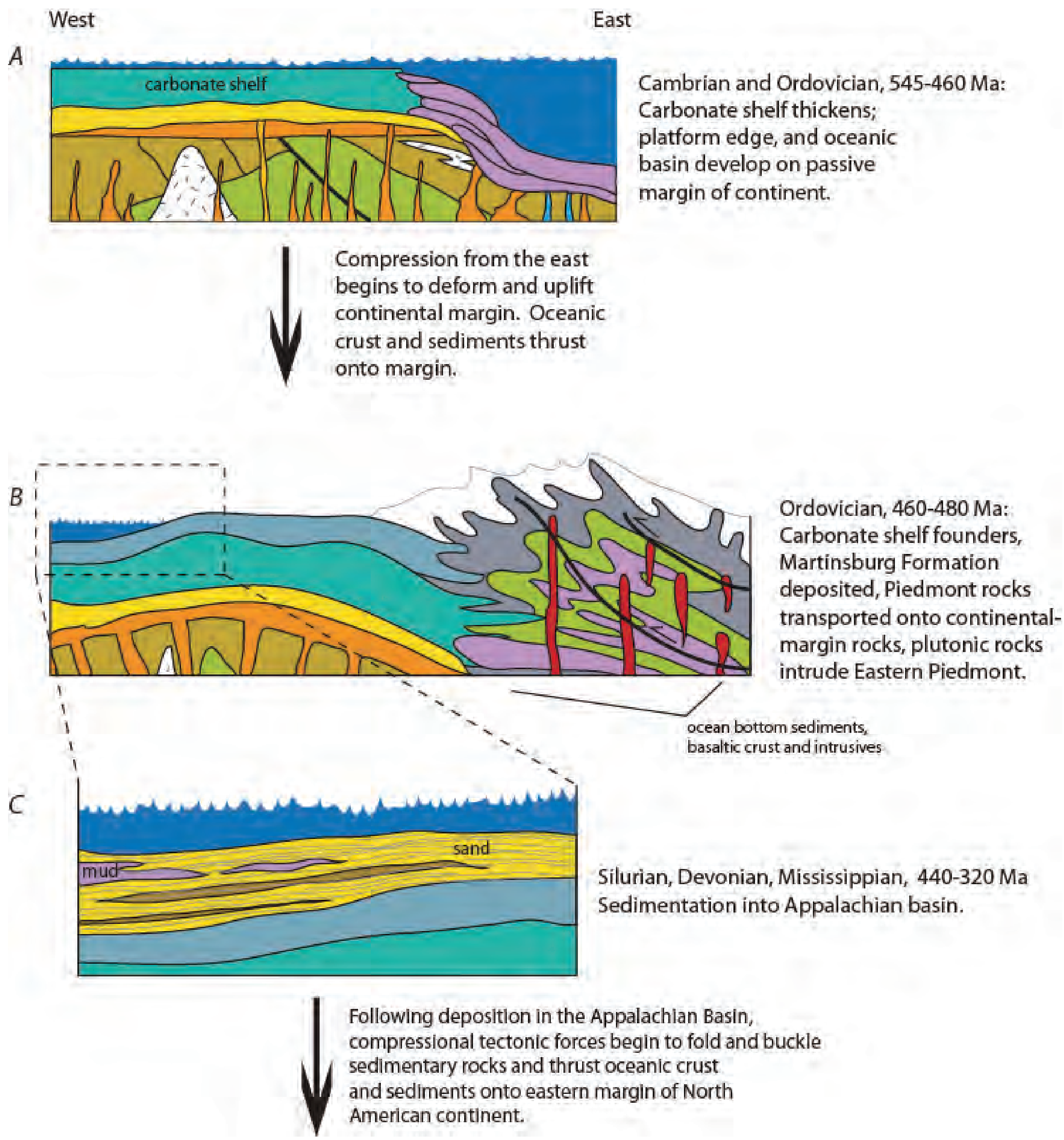

Figure 15. (*A*) Following deposition, the stable shelf was destroyed (?) as the Taconic orogeny (*B*) (480–460 million years ago) elevated the rocks to the east and provided a source for the clastic material that makes up the shale of the Martinsburg Formation. Rocks in the Piedmont province were intruded 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 million years ago magma forming igneous rocks was intruded into rocks near Great Falls. Ma, mega-annum (millions of years).

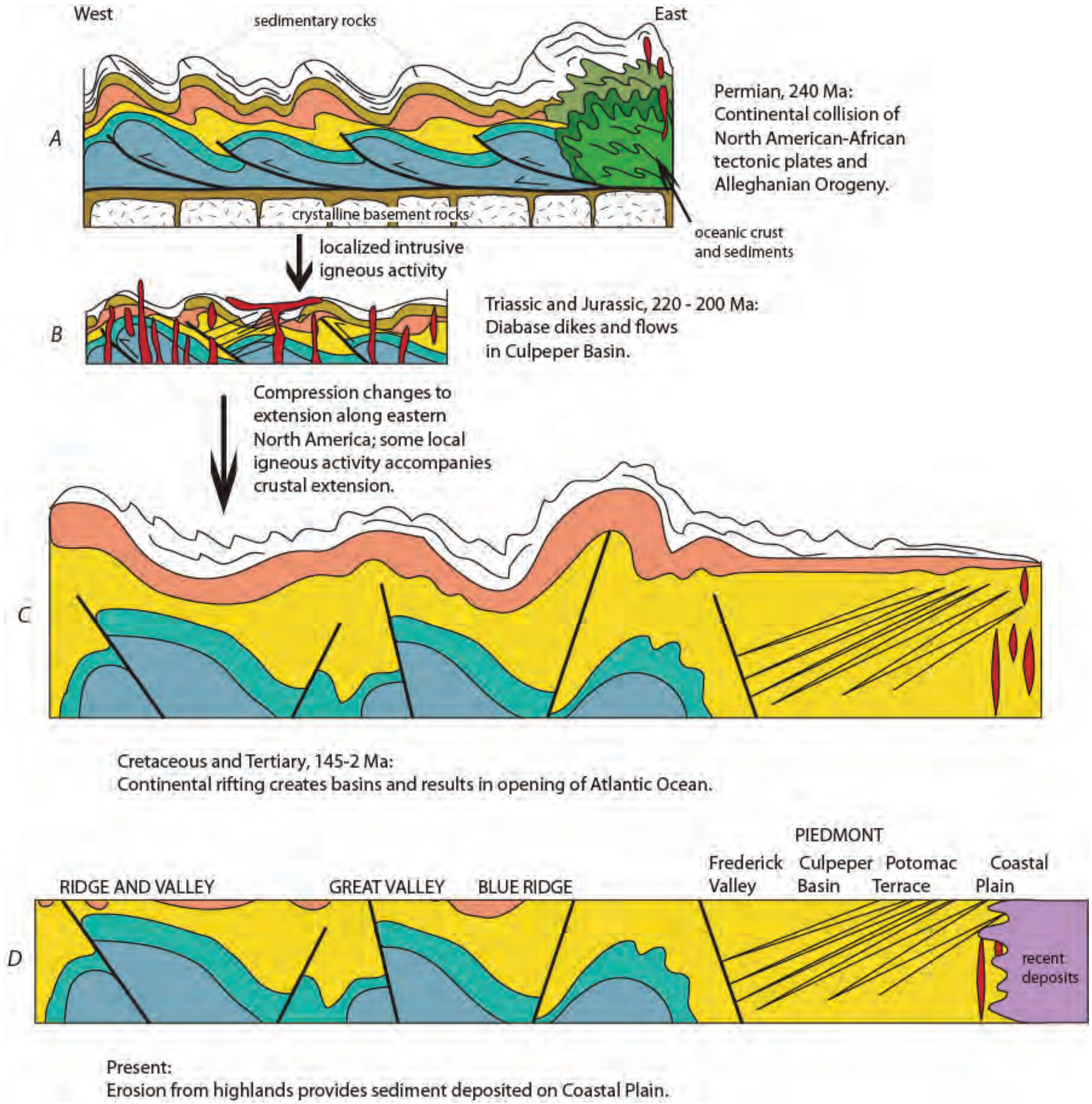

Figure 16. (*A*) About 240 million years ago, the continental tectonic plates of North America and Africa collided, resulting in the Alleghanian orogeny. Many of the folds and faults in rocks west of the Piedmont province are related to this event. (*B*) About 20 million years later, continental rifting began and lasted for about 20 million years (220–200 million years ago). (*C*) Thick sequences of sediments were deposited in fault-bounded basins, there was volcanic activity, and the end result was the creation of the Atlantic Ocean. The Culpeper and Gettysburg basins in the western Piedmont are the result of this event. (*D*) For the last 200 million years, the landscape has eroded and rivers have carried the sediment eastward to 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. Ma, mega-annum (millions of years).

Glossary

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

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

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

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

angular unconformity. An unconformity where the strata above and below are oriented differently; generally caused by structural deformation and erosion prior to deposition of the upper bed.

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.

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

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

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.

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

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

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

calcareous. A rock or sediment containing calcium carbonate.

carbonaceous. A rock or sediment with considerable carbon, especially organics, hydrocarbons, or coal.

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

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

chemical weathering. 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).

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

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

conglomerate. A coarse-grained sedimentary rock with clasts 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.

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

continental rise. Gently sloping region from the foot of the continental slope to the abyssal plain.

continental shelf. The shallowly submerged part of a continental margin extending from the shoreline to the continental slope with water depths of less than 200 m (656 ft).

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

continental slope. The relatively steep slope from the outer edge of the continental shelf down to the more gently sloping ocean depths of the continental rise or abyssal plain.

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 (also see "continental shield").

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.

disconformity. An unconformity at which the bedding of the strata above and below are parallel.

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

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

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

en echelon. Describing parallel or subparallel, closely-spaced, overlapping or step-like minor structural features in rock, such as faults and tension fractures, that are oblique to the overall structural trend.

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

evaporite. Chemically precipitated mineral(s) formed by the evaporation of solute-rich water under restricted conditions.

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

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.

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

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

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

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

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.

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

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.

limbs. The two sides of a structural fold on either side of its hingeline.

lineament. Any relatively straight surface feature that can be identified via observation, mapping, or remote sensing, commonly representing tectonic features.

lithification. The conversion of sediment into solid rock.

lithology. The description of a rock or rock unit, especially the texture, composition, and structure of sedimentary rocks.

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

loess. Silt-sized sediment deposited by wind, generally of glacial origin.

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.

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

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

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

mesic. Requiring moderate water.

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

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.

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

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

nonconformity. An erosional surface preserved in strata in which crystalline igneous or metamorphic rocks underlie sedimentary rocks.

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.

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

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

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

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.

Principal of Original Horizontality. The concept that sediments are originally deposited in horizontal layers and that deviations from the horizontal indicate post-depositional deformation.

Principle of Superposition. The concept that sediments are deposited in layers, one atop another, i.e., the rocks on the bottom are oldest with the overlying rocks progressively younger toward the top.

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

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

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

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

recharge. Infiltration processes that replenish groundwater.

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

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.

ripple marks. The undulating, subparallel, usually small-scale ridge pattern formed on sediment by the flow of wind or water.

rock. A solid, cohesive aggregate of one or more minerals or mineraloids.

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.

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

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

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

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.

slickenside. A smoothly polished and commonly striated surface representing deformation of a fault plane.

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.

stream. Any body of water moving under gravity flow and confined within a channel.

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.

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

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

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

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

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

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

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

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

theory. A hypothesis that has been rigorously tested against further observations or experiments to become a generally accepted tenet of science.

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.

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

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

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

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

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

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

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Appendix A: Geologic Map Graphic

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

Appendix B: Scoping Summary

The following excerpts are from the GRI scoping summary for Prince William Forest 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 coverages 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 is a useful reference for the NCR. However, some of these maps are dated and are in need of refinement and in other places there are no existing large-scale coverages available. The USGS began a project to map the Baltimore-Washington, D.C., 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 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, D.C., proper has 1-meter topographic coverage, and Prince George's County has 1:24,000 coverage.

Notes on Prince William Forest Park

Prince William Forest (PRWI) has the Quantico quadrangle in paper format; however USGS Geologist Wright Horton has been out to the park and found some issues with miscorrelated volcanic units on the map along South Fork (they shouldn't be volcanics). There was a major reclamation project of the Cabin Branch Pyrite Mine back in 1995, and the rehabilitation of the area is continuing still; there are a few Web sites on the subject (EPA Web site at http://www.epa.gov/reg3wapd/nps/pdf/cabinbranch.pdf and NPS Web site at http://www2.nature.nps.gov/grd/distland/prwi_restoration). The park is preparing "The Geology Trail and Related Sites" as an interpretive trail to showcase some of the park's geology. There is also an abandoned gold mine in the northwest part of the park with partially collapsed mine shafts at Independence Hill. Bob Mixon has worked on the geology of the Joplin quadrangle; Scott and Pete Chirico will check on the status of the open-file report as well as bringing Wright Horton in on this project.

Digital Geologic Map Coverage

The USGS will supply digital geology in ArcInfo format for all of the NCR parks. GRI staff will take these data and add the Windows help file and NPS theme manager capability to the digital geology and will supply it to the region to distribute to each park in NCR.

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 parts of three 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 hoped that after the individual reports are finished a regional physiographic report will be completed for the entire NCR.

List of Attendees for NPS National Capital Region Workshop

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Prince William Forest Park
Geologic Resources Inventory Report

Natural Resource Report NPS/NRPC/GRD/NRR—2009/086

National Park Service

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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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