

**COLONIAL NATIONAL HISTORICAL PARK  
GEOLOGIC RESOURCE MANAGEMENT ISSUES  
SCOPING SUMMARY**

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August 3, 2005



Shoreline preservation structures at Colonial National Historical Park.  
Photograph by Melanie Ransmeier, Geologic Resources Division, National Park Service.

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## ***Executive Summary***

A Geologic Resource Evaluation scoping meeting and field trip for Colonial National Historical Park took place at Yorktown, VA on August 1, 2005. The scoping meeting participants identified the following list of geologic resource management issues. These topics are discussed in detail on pages 14- 22.

1. Coastal and marine issues including sediment transport and erosion, storm damage and flooding, shoreline stabilization practices, and shoreline evolution
2. Connections between geology, and other disciplines including archaeology and history, pertaining to pre- settlement Native American sites, colonial areas, and battlefields
3. Paleontological resource potential especially along ravines cut into the Yorktown Formation
4. Karst features including sinkholes and ponds suspected to be of karst origin
5. Stratigraphic characteristics including shrink and swell clays, seeps and springs along impermeable layers, cliff formation, etc.
6. Seismicity
7. Land use evolution including the addition of glauconite and shell material to enrich the soil and iron ore extraction
8. Water issues including surficial water, storm water management, and groundwater hydrogeologic characterization
9. Slope processes
10. Disturbed lands
11. Unique geologic features including a type section for the Moorehouse Member of the Yorktown Formation at Moorehouse Cliff

## ***Introduction***

This report briefly describes the general geology of Colonial National Historical Park (COLO), including a geologic history of the park, geologic resource management issues in the park, and the status of Geologic Resource Evaluation (GRE) digital geologic mapping projects related to the park. The National Park Service held a Geologic Resource Evaluation scoping meeting for Colonial National Historical Park in Yorktown, Virginia on Monday, August 1, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. Products derived from the scoping meeting are: (1) digitized geologic maps covering the park; (2) an updated and validated bibliography; (3) a scoping summary (this report); and (4) a Geologic Resource Evaluation Report which brings together all of these products.

Colonial National Historical Park was established during Herbert Hoover's administration as a national monument on June 3, 1930. National Historic Park status was gained under Franklin D. Roosevelt's administration on June 5, 1936. The park preserves wild space between Jamestown and Yorktown, Virginia connected by the 37 km (23 miles) long and 165 m (~500 ft) wide Colonial Parkway. It commemorates the first permanent English settlement, early colonial efforts as well as the decisive battlefield of the Revolutionary War and remnants of Civil War use. Colonial National Historical Park covers 8,677 acres of eastern Atlantic Coastal Plain near Williamsburg, VA.

## Map Notes

The Inventory and Monitoring Program and Colonial National Historical Park identified 7 quadrangles of interest (Figure 1). These 7 quadrangles sit within the Williamsburg 30'x60' quadrangle, however, no known geologic maps are published for this quadrangle. The Virginia Division of Mineral Resources has published the following 1:24,000 scale 7.5' quadrangle maps covering all but the Clay Bank and Surry quadrangles:

- Bick, K.F. and Coch, N.K., 1969, Geology of the Williamsburg, Hog Island, and Bacons Castle quadrangles, Virginia: Geologic Map of the Williamsburg Quadrangle, Virginia (plate 1 / 3), Virginia Division of Mineral Resources, Report of Investigations 18, plate 1 / 3, 1:24,000 scale (GMAP\_ID 2462).
- Bick, K.F. and Coch, N.K., 1969, Geology of the Williamsburg, Hog Island, and Bacons Castle quadrangles, Virginia - Geologic Map of the Hog Island Quadrangle, Virginia (plate 2 / 3), Virginia Division of Mineral Resources, Report of Investigations 18, 1:24,000 scale (GMAP\_ID 5424).
- Johnson, G.H. and Berquist, C.R., Jr., 1988, Geology and Mineral Resources of the Brandon and Norge quadrangles, Virginia, Virginia Division of Mineral Resources, Publication 87, 1:24,000 scale (GMAP\_ID 2464).
- Johnson, G.H., 1972, Geology of the Yorktown, Poquoson West, and Poquoson East quadrangles, Virginia - Plate 1: Geologic Map of the Yorktown Quadrangle, Virginia, Virginia Division of Mineral Resources, Report of Investigations 30, 1:24,000 scale (GMAP\_ID 2463).
- Johnson, G.H., 1972, Geology of the Yorktown, Poquoson West, and Poquoson East quadrangles, Virginia - Plate 2: Geologic Map of the Poquoson West Quadrangle, Virginia, Virginia Division of Mineral Resources, Report of Investigations 30, 1:24,000 scale (GMAP\_ID 5426).

The Virginia Division of Mineral Resources has a geologic mapping project for the Williamsburg 30'x60' sheet in progress and updated geologic mapping exists for parts of the Surry quadrangle and several others of interest. Rick Berquist of Virginia Division of Mineral Resources at the College of William and Mary is in the process of completing these projects.

Many other maps exist for the region including coverage of the geology, structural geology, surficial geology, topography, aeromagnetic- gravity, mineral and mineral potential, etc. These maps are available from agencies such as the U.S. Geological Survey, the Virginia Division of Mineral Resources, and the Maryland Geological Survey.

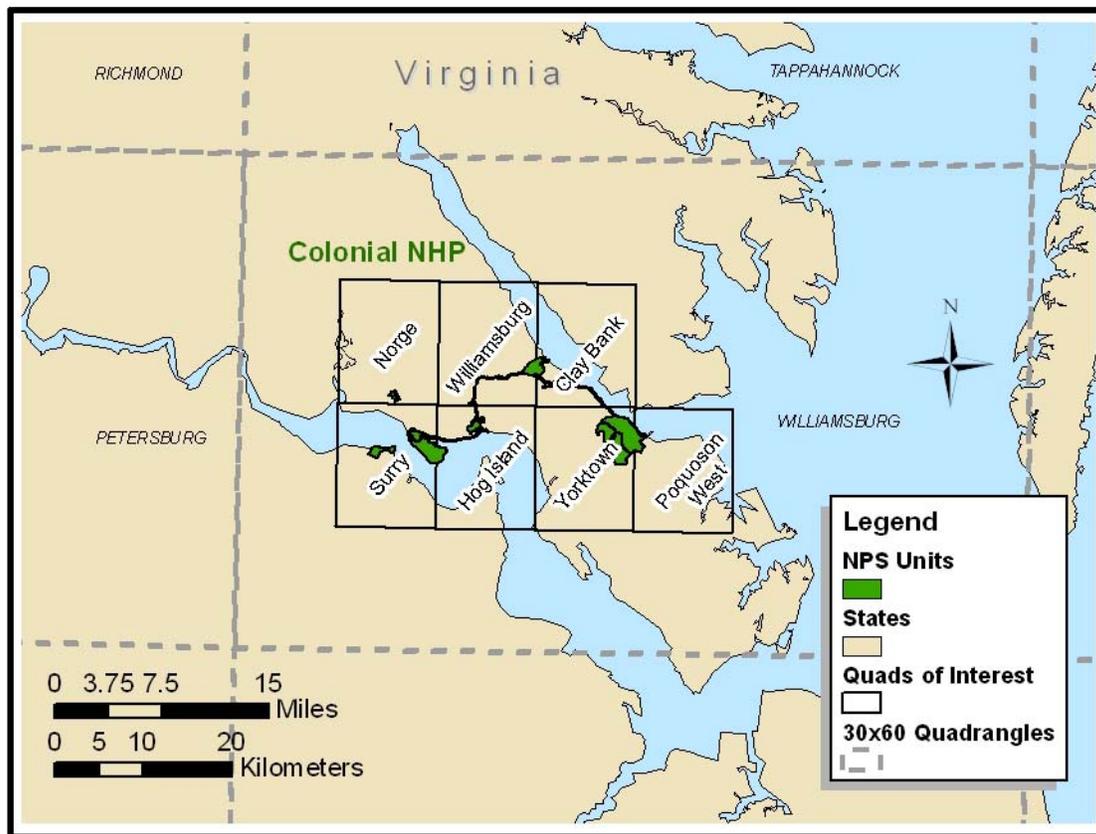


Figure 1. COLONIAL NATIONAL HISTORICAL PARK Quadrangles of Interest

### ***Mapping Deliverables***

Colonial National Historical Park has unpublished digital geologic data for much of the park and limited surrounding areas. This unpublished geologic data is part of the current Williamsburg 30'x60' mapping effort by the Virginia Division of Mineral Resources. The GRE team will obtain these data from the park and work with the Virginia Division of Mineral Resources to update this data, fill in gaps, and incorporate it into the GRE programs GIS data model.

A conference call including representatives from the Virginia Division of Mineral Resources and the GRE team is scheduled for Fall of 2005 to address mapping priorities and opportunities for collaboration with the NPS. During the conference call mapping projects pertinent to COLO, including mapping of the Clay Bank and Surry Quadrangles will be discussed.

## ***Physiography***

Colonial National Historical Park lies within the Atlantic Coastal Plain physiographic province near the interface between the upland and lowland subprovinces. Elevations in these subprovinces range from 20 to 80 m (60- 250 ft) and 0 to 20 m (0- 60 ft), respectively. Colonial National Historical Park straddles the peninsula between the James and York Rivers just north of the Tidewater area of Virginia. The landscape ranges from the tidally influenced marshy lowlands of Jamestown Island, to eroded rolling hills of the peninsula to the deeply scoured bluffs above the York River at Yorktown.

In the area of Colonial National Historical Park, the eastern United States is divided into 5 physiographic provinces with associated local subprovinces. These are, from east to west, the Atlantic Coastal Plain, the Piedmont Plateau, the Blue Ridge, the Valley and Ridge, and the Appalachian Plateaus provinces (Figure 2).

The “Fall Line” or “Fall Zone” marks a transitional zone where the softer, less consolidated sedimentary rock of the Atlantic Coastal Plain to the east intersects the harder, more resilient metamorphic rock of the Piedmont to the west to form an area of ridges, waterfalls, and rapids.

The Atlantic Coastal Plain province is primarily flat terrain with elevations ranging from sea level to a maximum of about 100 m (300 ft) in Maryland. Sediments eroding from the Appalachian Highland areas to the west formed the wedge- shaped sequence of soft sediments that were deposited intermittently on the Atlantic Coastal Plain during periods of higher sea level over the past 100 million years. These sediments are now more than 2,438 m (8,000 ft) thick at the Atlantic coast and are reworked by fluctuating sea levels and the continual erosive action of waves along the coastline. Large streams and rivers in the Coastal Plain province, including the James, York, Rappahannock, and Potomac, continue to transport sediment and to extend the coastal plain eastward. Beyond the province to the east the submerged Continental Shelf province extends another 121 km (75 miles).

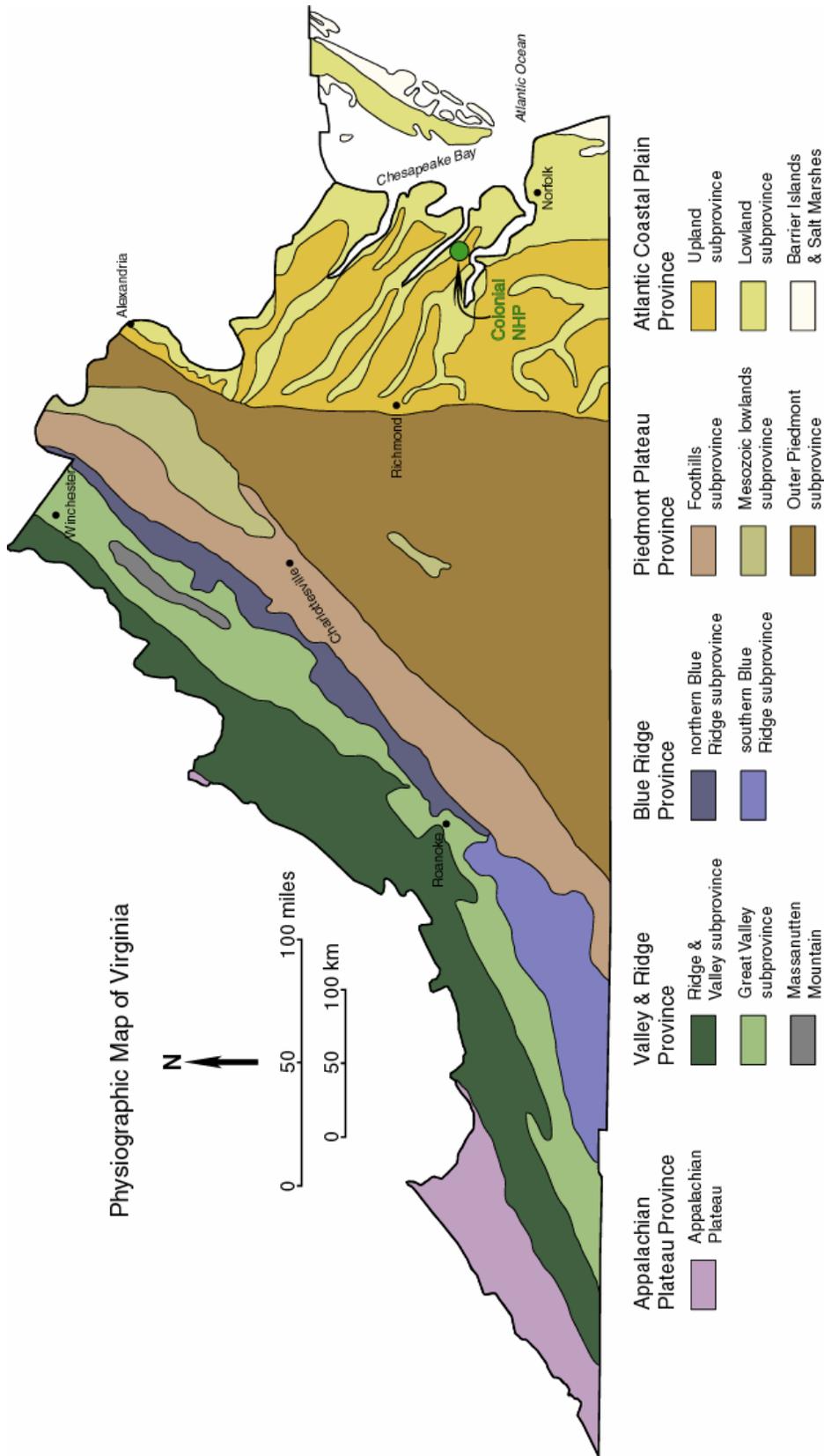


Figure 2: Location of Colonial National Historical Park relative to the physiographic provinces of Virginia. Graphic is adapted from Bailey (1999).

## ***Geologic History of Southern Virginia***

Proterozoic Era – In the mid Proterozoic, during the Grenville orogeny, a supercontinent formed which included most of the continental crust in existence at that time. The sedimentation, deformation, plutonism (the intrusion of igneous rocks), and volcanism associated with this event are manifested in the metamorphic gneisses in the core of the modern Blue Ridge Mountains (Harris et al., 1997). These rocks were deposited over a period of 100 million years and are more than a billion years old, making them among the oldest rocks known from this region. They form a basement upon which all other rocks of the Appalachians were deposited (Southworth et al., 2001).

The late Proterozoic, roughly 600 million years ago, brought a tensional, rifting tectonic setting to the area. The supercontinent broke up and a sea basin formed that eventually became the Iapetus Ocean. In this tensional environment, flood basalts and other igneous rocks such as diabase and rhyolite added to the North American continent. These igneous rocks were intruded through cracks in the granitic gneisses of the Blue Ridge core and extruded onto the land surface during the break-up of the continental land mass (Southworth et al., 2001). The Iapetus basin collected many of the sediments that would eventually form the Appalachian Mountains and Piedmont Plateau.

Early Paleozoic Era – From Early Cambrian through Early Ordovician time there was another period of orogenic activity along the eastern margin of the continent. The Taconic orogeny (~440- 420 Ma in the central Appalachians) was a volcanic arc – continent convergence. Oceanic crust, basin sediments, and the volcanic arc from the Iapetus basin were thrust onto the eastern edge of the North American continent. The Taconic orogeny involved the closing of the ocean, subduction of oceanic crust, the creation of volcanic arcs and the uplift of continental crust (Means, 1995). In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards to the west creating a deep basin that filled with mud and sand eroded from the highlands to the east (Harris et al., 1997). This so-called Appalachian basin was centered on what is now West Virginia.

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, resulting in thick piles of sediments. The source of these sediments was from the highlands that were rising to the east during the Taconian orogeny (Ordovician), and the Acadian orogeny (Devonian). The Acadian orogeny (~360 Ma) continued the mountain building of the Taconic orogeny as the African continent approached North America (Harris et al., 1997). Similar to the preceding Taconic orogeny, the Acadian event involved land mass

collision, mountain building, and regional metamorphism (Means 1995). This event was focused further north than southern Virginia.

Late Paleozoic Era – Following the Acadian orogenic event, the proto- Atlantic Iapetus Ocean completely closed during the Late Paleozoic as the North American continent collided with the African continent. This formed the Appalachian mountain belt we see today and the Pangean supercontinent. This mountain building episode, called the Alleghenian orogeny (~325 – 265 Ma), and was the last major orogeny of the Appalachian evolution (Means, 1995). During this orogeny, rocks of the Great Valley, Blue Ridge, and Piedmont provinces were transported as a massive block westward onto younger rocks of the Valley and Ridge. The amount of compression was extreme. Estimates are of 20- 50 percent shortening which translates into 125–350 km (75- 125 miles) of lateral translation (Harris et al., 1997).

Mesozoic Era – Following the Alleghenian orogeny, during the late Triassic, a period of rifting began as the joined continents began to break apart from about 230- 200 Ma. The supercontinent Pangaea divided into roughly the continents that exist 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). Thick deposits of unconsolidated gravel, sand, and silt were shed from the eroding mountains. These were deposited at the base of the mountains as alluvial fans and spread eastward to be part of the Atlantic Coastal Plain (Duffy and Whittecar 1991; Whittecar and Duffy, 2000; Southworth et al., 2001).

The amount of material that has been eroded from the Appalachian Mountains, as inferred from the now- exposed metamorphic rocks, is immense. Many of the rocks exposed at the surface must have been at least 20 km (~10 miles) below the surface prior to regional uplift and erosion. The erosion continues today with the Potomac, Rappahannock, Rapidan, James, and Shenandoah Rivers stripping the Coastal Plain sediments, lowering the mountains, and depositing alluvial terraces along the rivers, creating the present landscape.

Cenozoic Era – Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. The isostatic adjustments that uplifted the continent after the Alleghenian orogeny continued at a subdued rate throughout the Cenozoic Period (Harris et al., 1997). These adjustments may be responsible for occasional seismic events felt throughout the region.

The landscape at Colonial National Historical Park is profoundly impacted by the deposition of Tertiary and younger sediments and the subsequent erosion of these units by evolving waterways. The James and York Rivers and their

associated wetlands, estuaries, and tributaries are among the major waterways in the Chesapeake Bay watershed. This natural riverine environment continues to cut terraces, entrench channels, shift bars and other sediments, and cut scarps and ravines as it responds to changes in climate, seasonal storms, and human influences.

Though glaciers from the Pleistocene Ice Ages never reached the southern Virginia area (the southern terminus was in northeastern Pennsylvania), the intermittent colder climates of the ice ages played a role in the formation of the landscape at Colonial National Historical Park. Freeze and thaw cycles within unconsolidated terrace units homogenized bedding features. Cold climate subaerial deposits contain fossils such as woolly mammoth, mastodon teeth, etc. Sea level fluctuations during ice ages throughout the Pleistocene caused the baselevel of many of the area's rivers to change. During lowstands (sea level drops), the rivers would erode their channels exposing the deformed bedrock of the Piedmont Plateau to the west. During oceanic highstands, the river basins flooded and resulted in deposition of marine, nearshore marine and estuarine sediments in the park area.

## ***Stratigraphy***

Within the park and surrounding areas are younger deposits of Atlantic Coastal Plain rocks. At depth, the Cretaceous Potomac Formation underlies most of the coastal plain. Atop this unit lie the Aquia Formation, the Marlboro Clay, the Nanjemoy, Piney Point, Chickahominy, Old Church, Calvert, Choptank, St. Marys, and Eastover formations (Johnson et al., 2001). These units are only locally accessible in drill cores.

The deepest ravines in the area cut into the Yorktown Formation that was deposited on top of the Eastover Formation. The Yorktown Formation is a maximum of 25 m (82 ft) thick, contains quartz and feldspar sands mixed with lesser clays, and silts as well as crossbedded shelly layers. This unit is overlain by the clay- rich Windsor, Bacons Castle and Sedley formations. The upper Pliocene Bacons Castle Formation includes gravelly sand and sandy- silty- clayey upper layers. These are often found in high- level terrace areas. The fine to coarse sand, gravel, silt and clay of the Windsor Formation is of lower Pleistocene to upper Pliocene age. This unit locally contains fossil burrows (Kenworthy and Santucci, 2003).

The Shirley Formation contains coarse sands, gravels, pebbles and sporadic boulders from river terraces that are of the middle Pleistocene. This formation is rich in organic material including tree stumps and leaves and seeds of oak, cypress, and hickory trees (Kenworthy and Santucci, 2003). The upper Pleistocene Tabb Formation contains sands, gravels, silts and clays and underlies low terraces in the area. The Tabb Formation has three members: the Poquoson, the Lynnhaven, and the Sedgfield Members. The more recent deposits at the park include various Quaternary age units.

The youngest deposits at Colonial National Historical Park include thick alluvium deposits of sand, gravel, silt and clays as much as 15 m (49 ft) thick, beach and estuarine deposits, marsh and swamp deposits along waterways, shelly sands, and artificial fill from construction of roads, dams, bridges, landfills, and highways.

## ***Significant Geologic Resource Management Issues***

### I. Coastal and marine issues

Many of the cultural features present at Colonial National Historical Park are located within several meters of the James and York Rivers. The dynamic geomorphic processes associated with these waterways constantly threaten nearshore and onshore resources. In the park area, the James and York rivers are affected by tidal fluctuations that are on average <1 m (2.5 ft). As such, local sea level rise of 2.1 mm/year (0.1 inches/year) has significant implications for resource management at Colonial National Historical Park (Johnson et al., 2001). There is a great need at the park to understand the nature of sediment transport along the shorelines.

Storm events such as nor'easters and hurricanes have dramatic effects on the landscape at the park. In 1985 a nor'easter tore up the pier and docks of Yorktown's waterfront area. Following this storm, 10,000 yards of beach fill and one breakwater were added to the landscape. In 2003, Hurricane Isabel produced 2 m (6 ft) tall waves per 5 seconds in the York River. The 12-hour surge associated with this event started from the north and swung towards the south as the storm passed. This effect concentrated erosive waves in several different directions against the shorelines of the park. In Yorktown, along the commercial waterfront some nearshore breakwaters and other shoreline stabilization structures were damaged and the beach was washed away. At Jamestown, several archaeological sites were washed away in the vicinity of Blacks Point as the surge overwashed the island, destroying the Visitor Center and moving several wooden bridges off their support pilings.

Ongoing efforts to stabilize the shores at Colonial include instillation of breakwaters, riprap along reaches of the parkway, lines of rock, sand, marsh plants (creating a wetland area), stonewalls, beach replenishment, and vegetative interfaces. These measures have been met with mixed success. At Passmore Creek, the waterway bypassed a riprap structure and punctured a new channel into the James River, threatening cultural sites there. Rockwalls as high as 2 m (6 ft) were breached during Hurricane Isabel in 2003, carving a scarp only 1- 2 m (3- 6 ft) from the parkway in some places. The many breakwaters (installed in 1994, 2000, 2004- 2005, etc.) along the York River have been successful in preserving a scalloped shoreline, only major storms are capable of compromising these structures.

The York River continues to transgress southwards through time. The southern shore of the river near Yorktown is eroding 2- 3 times faster than the northern shore at Gloucester Point.

Research and monitoring questions and suggestions include:

- Is current southward movement of the York River related to a radial fault from the Chesapeake Bay Impact structure?
- Perform several shoreline surveys per year to detect seasonal variations. Supplement these surveys with lidar, GIS surveys, and aerial photographs.
- Cooperate with state and county agencies to study erosion rates and processes in surrounding areas and relate to the sediment budget of the different watersheds.
- Monitor loss of ridges within wetland areas near Jamestown.
- Monitor topographic changes due to surface and cliff erosion.
- Continue to promote coastal shoreline stability measures.
- Define the mappable shoreline in relation to tidal fluctuations. Where is the actual shoreline as recorded on maps?
- What are the effects of increased erosion on aquatic ecosystems at the park?
- Should storm effects be remediated by the park in lieu of natural processes?
- Update the aerial mosaics for shoreline evolution since 1937 including ongoing LIDAR surveys currently in progress.

## 2. Connections between geology and other disciplines

Archaeological sites and excavations are a major resource at Colonial National Historical Park. People were attracted to the area for settlement because of the unique geologic setting, which was rich in coastal resources and possessed a natural landing area, fresh water, timber, and waterways for navigation and trade. Changing water levels and brackish water encroachment may be among the reasons settlements were abandoned at Jamestown. Native American, as well as 17<sup>th</sup> and 18<sup>th</sup> century archaeological sites, are disappearing from the landscape due to shoreline erosion, wetland encroachment, storm events, and local development. Jamestown records almost 400 years of shoreline loss since the first landing in 1607. At that time, the shoreline probably lay more than 120 m (400 ft) to the west (Johnson et al., 2001). The isthmus that connected Jamestown Island to the mainland was breached in the late 18<sup>th</sup> century.

Blacks Point contained an early Native American site with a hearth. This area had to be excavated as a phase 3 excavation (salvage archaeology) to get whatever artifacts possible before the entire site was removed by erosion. In 2003 Hurricane Isabel removed meters of shoreline along the James and York rivers. Treefall associated with the storm's high winds has exposed graves from the pre-settlement era through the Civil War. Erosion of the areas ridgelines has put approximately 60 significant sites at risk (meeting discussion, 2005). A Confederate fort near Jamestown is eroding into the river. Areas especially

susceptible to future flooding include Black Point, the Pitch and Tar swamp, and the Passmore Creek lowlands (Johnson et al., 2001).

Geology also influenced the battles fought at Yorktown and the strategic movement of troops around the Peninsula. The area's waterways facilitated and hindered the movement of troops in both the Revolutionary and Civil wars. British general Cornwallis was trapped against the bluffs at Yorktown, unable to cross the river to Gloucester due to inclement conditions. Confederates chose not to defend the town based on their knowledge of the landscape and its historical reputation from the entrapment and defeat of Cornwallis during the Revolutionary War. At Colonial, the morphology of the landscape follows the underlying stratigraphic structures.

Geologic processes also affect how these cultural features are preserved. Often geologic forces must be managed to prevent loss of cultural resources. The park is charged with maintaining the historic context of the landscape. This often means resisting natural geologic changes. Many of the historical features at the park have been lost to coastline erosion (meeting discussion, 2005). The waterways are changing position constantly as part of natural meandering river flow. These shoreline changes threaten existing park facilities and the historical context of the landscape. Historic earthworks and structures are also threatened by erosion and weathering along with human impacts.

Research and monitoring questions and suggestions include:

- Create interpretive programs from interaction between geologists and interpretive staff concerning geologic features and processes and their effects on the settlement- battle history of the Colonial area.
- Create a general interest map handout with simple explanatory text on geologic influences for visitors to the area.
- How did the areas geomorphology and landscape affect the battles fought at Colonial?

### 3. Paleontological potential

Though no formal paleontological inventory has been completed for Colonial, some of the first fossils described from North America were found in the Yorktown Formation. The Yorktown Formation is famously rich in fossil remains and fossils from this unit grace a number of museums around the world. This unit contains the Virginia State Fossil (*Chesapecten jeffersonius*). Other fossils include 3 Ma sharks teeth, whale and walrus bones, gastropods, mollusks, ostracodes, foraminifera, bryozoans, brachiopods, echinoids, coral, sponge spicules, fish bones, and scallop shells (Kenworthy and Santucci, 1993). Incisement of the rivers and streams in the park area has created deep ravines into fossil- bearing beds of the Yorktown Formation. Remains of a woolly

mammoth were exhumed by stream downcutting (meeting discussion, 2005). These 20,000- year- old remains and other paleontological treasures need to be carefully catalogued and preserved.

Research and monitoring questions and suggestions include:

- Determine fossils resources obscured by riprap within Colonial National Historical Park, if possible during maintenance.
- Conduct a formal paleontological inventory for the park.
- Continue to use microfossils found near Jamestown to aid in the accurate determination of paleoclimatic conditions and paleovegetation patterns.

#### 4. Karst activity

Karstic landforms result from the unique juxtaposition of the clay rich Windsor Formation (~ 20- 25 m, 60- 85 ft above sea level) atop the relatively fossil shell rich carbonate Yorktown Formation (15 m, 50 ft above sea level). Acidic groundwater causes the dissolution of the carbonate layers. The overlying layers sink into the cavities left after dissolution. Karst landforms locally include sinkholes (present as seasonal ponds), and wetlands. Ponds include the Grafton Pond complex and Brackens Pond. Sinkhole formation may threaten homes and buildings throughout the area (Rick Berquist, personal communication, 2005). A karstic wetland developed in the yard of a home in the Queens Lake subdivision near Williamsburg.

Cornwallis' Cave, a feature along the bluffs in Yorktown is man- made and not related to karst formation in the area. This feature is a cultural resource that contains holes carved in the stone cave walls for wooden beams (inhabited at some point?) and merits preservation.

Research and monitoring questions and suggestions include:

- Are current karst processes endangering areas, structures, buildings, and/or roads within Colonial National Historic Site?
- Identify and monitor known karst areas to determine rates of change.

#### 5. Stratigraphic characteristics

Atop the cliff- forming Yorktown Formation is a linear bed referred to as the Sedley Formation. This bed is typically 2- 3 m (7- 10 ft) thick and as much as 8 m (25 ft) thick in Suffolk, Virginia. This bed contains clayey silt and has high shrink- and- swell potential. This unit caused significant problems in recent road and building developments near Williamsburg including the Queens Lake subdivision.

The lower parts of the Windsor and Bacons Castle formations commonly contain sand, pebbles and cobbles. These coarse- grained sediments are highly permeable. These sediments commonly sit atop the clay rich Sedley Formation or clay- rich Yorktown material and acts as an aquitard, blocking vertical groundwater flow. The groundwater flows laterally along the top of the Sedley to a cliff face or ravine and emerges as a spring or seep. These features are prominent in higher elevations of the peninsula.

Research and monitoring questions and suggestions include:

- Does the Sedley Formation represent prodelta clays during marine transgression atop the Yorktown Formation?
- Is spring flow concentrated along the top of the Yorktown Formation?
- Inventory and monitor all springs and seeps for flow and water quality.
- Identify potential shrink- and- swell clay problem areas to avoid for future development of administrative and visitor facilities.

## 6. Seismicity

The Chesapeake Bay impact structure to the southeast of the park is still downloading and causes frequent small magnitude (~2) earthquakes. These earthquakes are occurring during the shift of blocks along concentric, listric faults. Much of Colonial National Historic Park is located on a subsiding side of a rotating fault- bounded block (Johnson et al., 2001). Earthquakes may cause significant damage to buildings, fences and other cultural features at Colonial National Historical Park. Seismic waves may also undermine slope stability and increase local spalling along the cliffs.

Research and monitoring questions and suggestions include:

- Cooperate with state and local agencies to promote the development of an active seismic network for the area.
- Evaluate if risk of damage exists for any cultural features during infrequent seismic events.

## 7. Land use evolution

Early settlement uses of the landscape included tobacco plantations and other agriculture. After a few years of overuse, most plantations suffered widespread depletion of soil nutrients. Glaucinite and shell material were extracted from the Yorktown Formation for use as soil additives to boost tobacco production.

Iron rich cemented sediments in the local deposits sparked local interest in iron ore extraction through the Civil War. Iron minerals such as limonite and goethite are part of the ledge forming units at the top of the Yorktown and overlying units.

These minerals form cements as iron and magnesium precipitate during carbonate dissolution. It is believed that Colonials and slaves removed large chunks of these iron rich rocks to transport to furnaces.

Historic manipulation of the hydrogeologic system of the area has also left remnants on the colonial landscape. Several of the areas waterways were dammed for hydroelectric power, such as the Jones Mill pond. The Wormley Pond area was damaged during Hurricane Floyd in 1999. The earthen dams associated with the Augustus Moore mill were present during the signing of the treaty at the end of the Revolutionary War.

Land use evolution continues today as increasing developments threaten the colonial viewshed of the parks and parkway. Human impacts include pipelines, power lines, roads, buildings, trails, visitor use areas, invasive species, acid rain, and air and water pollution. Effects from these developments also include groundwater level changes, an increase in impermeable roadways, the interruption and contamination of spring flows. The Greenspring Plantation Development may threaten the colonial Greenspring spring: an early water source.

Research and monitoring questions and suggestions include:

- Will the Greenspring spring continue to flow?
- Promote studies by academics, other agencies, etc. correlating land use changes with movement of Native Americans and early settlers.
- Continue to cooperate with local developers to minimize impact near park areas.
- Is runoff in the park increasing due to surrounding development? If so, are there any remedial efforts resource management can undertake to reduce this impact?
- Promote environmentally sound methods of developing land parcels including partial clearing of trees and proper construction of stable slopes.
- Create programs interpreting geologic features and processes and their effects on the settlement history of the area.

#### 8. Water issues including surficial water, storm water management, and groundwater hydrogeologic characterization

Streams cut through the Coastal Plain deposits creating the rolling hills, ravines, and bluffs that are characteristic of the landscape at Colonial National Historical Park. These streams include Yorktown, Mill, Powhatan, Kingsmill, Passmore, and Ballard Creeks, and the Back River. In the Jamestown area, these streams are removing cultural resources; sea-level rise continues to inundate the landscape.

Streams and stormwater are piped under the Colonial Parkway. Culverts in place to facilitate water movement in many cases are ~75 years old and are often inadequate to handle peak flows. Erosion and sedimentation from stormwater remains a problem along the length of the parkway (meeting discussion, 2005). This erosion is threatening cultural features including unexcavated archaeological sites. Long-term changes and repairs are proposed in conjunction with an assessment regarding federal highways (I- 64 corridor).

Research and monitoring questions and suggestions include:

- Are the sewer lines connecting Gloucester with the Hampton Roads system affecting local water quality?
- What remediation is necessary for old culverts along the Parkway?
- Promote revegetation in areas of significant gulying and erosion.

#### 9. Slope processes

Slope processes and erosion are continuously changing the landscape at Colonial National Historical Park. Shoreline erosion is of utmost concern for resource management because many historic features and cultural resources have been lost and/or remain at risk along the park's shorelines. Storm events cause extreme erosion along the park's slopes. Falling trees releasing pulses of material to streams as well as removing stabilizing roots facilitate much of this erosion. Lack of stabilizing vegetation leads to increased erodability of most slopes in the area. Park mowing caused bare soil exposure and increased erosion.

Research and monitoring questions and suggestions include:

- What if any slope stability impacts exist?
- Can cliff erosion be slowed for specific identified priority areas?
- Identify problem reaches for immediate remediation.
- Develop a slope monitoring plan for the park.
- Change mowing regimes and vegetation management to reduce erosion problems within the park.

#### 10. Disturbed land sites

Disturbed lands include several Superfund sites along the parkway. The Naval Weapons Station, Yorktown Pier acts as a jetty of sorts, changing fluvial sediment transport in the York River. Associated with the Naval Weapons Station in the York River was a pre- WWII mine center. This feature currently leaks pollution into the local ecosystem. A mercury leak poses a problem along Ballard Creek. Restoration efforts for these sites includes stabilization of sites with caps, warm season sea grasses and improved storm water management.

The Virginia Division of Mineral Resources knows of an abandoned borrow pit near parklands along the Colonial Parkway at I- 64. This has caused significant erosion problems as it drains through the park, under the parkway into the York River. An expert from the Geologic Resources Division (Pranger) recently visited the site to provide initial input on how to approach reclamation and stabilization of this area. Ownership of this feature is unknown at this time.

This site is associated with the construction of I- 64 and is threatening a riparian ecosystem through park property near the Colonial Parkway. This feature is a deep 3- 4 m (10 to 12 ft) gully and contributes excess sediment to the York River and Chesapeake Bay. Erosion is facilitated by heavy rains and a lack of stabilizing vegetation in the adjacent borrow area. The interstate blocks natural water flow and its impermeable surface greatly adds to storm runoff. Stormwater culverts along the highway concentrate erosive flow (NPS, 2005).

Impacted areas and features within the park such as clogged drains, undersized culverts, and insufficient outflow protection measures are adding to the sedimentation and stormwater issues facing park resource management. The park is currently in the process of making improvements to the design of parkway culverts and other stormwater management features.

Research and monitoring questions and suggestions include:

- Define goals for the desired future conditions of the gully associated with I- 64. This may or may not include stabilizing the gully and developing a watershed restoration plan with adjacent landowners and managers for upstream reaches of the park's waterways.
- Promote revegetation of affected areas within and adjacent to parklands to curtail excessive erosion.
- Cooperate with local, state, and federal agencies to remediate disturbed lands within and surrounding the park.

## ii. Unique geologic features including a type section for the Moorehouse Member of the Yorktown Formation at Moorehouse Cliff

The upper layers of the Yorktown Formation include a shelly hash unit known as the Moorehouse Member. This unit contains abundant fossils including the Virginia State Fossil (*Chesapecten jeffersonius*). Other fossils include 3 Ma shark teeth, whale and walrus bones, and scallop shells. Fossils weather out of the Yorktown and are found along the shorelines of the local waterways. The type section for this member is along the cliffs below Moorehouse at Yorktown. A type section is generally the first place a particular geologic unit is described, though this location may change to describe the best field example of the unit. In other words, the geologic definition of a particular unit is recorded at its type section.

Research and monitoring questions and suggestions include:

- Perform a geologic survey of the Parkway.
- Identify all reaches of exposed shelly layers within the Yorktown Formation and slumps and washes below it to target for fossil protection.

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***Map of Colonial National Historical Park***