# THOMAS STONE NATIONAL HISTORIC SITE

# GEOLOGIC RESOURCE MANAGEMENT ISSUES

# SCOPING SUMMARY

Trista L. Thornberry- Ehrlich
Colorado State University – Geologic Resource Evaluation
August 3, 2005

Haberdeventure plantation house at Thomas Stone Historic Site. Photograph by Melanie Ransmeier, Geologic Resources Division, National Park Service.

## *Table of Contents*

## *Executive Summary*

A Geologic Resource Evaluation scoping meeting and field trip for Thomas Stone National Historic Site took place in at the site in Maryland on July 26, 2005. The scoping meeting participants identified the following list of geologic resource management issues. These topics are discussed in detail on pages 15- 18.

1. Evolution of the landscape

2. Slope processes and erosion

3. Seismicity from nearby Stratford fault system and numerous other small- scale faults, as well as the continual downloading of the Chesapeake Bay impact structure

4. Hydrogeologic characterization to understand the flow of water beneath the site and be equipped to predict hydrologic response to contaminants

5. Surrounding development including urban encroachment at park boundaries, and potential pollution influx from neighboring areas

6. Potential fossil resources and unique geologic features

## *Introduction*

This report briefly describes the general geology of Thomas Stone National Historic Site (THST), including a geologic history of the site, geologic resource management issues in the site, and the status of Geologic Resource Evaluation (GRE) digital geologic mapping projects related to the site. The National Park Service held a Geologic Resource Evaluation scoping meeting for Thomas Stone National Historic Site near LaPlata, Maryland on Tuesday, July 26, 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 will include: (1) digitized geologic maps covering the park; (2) updated and verified bibliography; (3) scoping summary (this report); and (4) Geologic Resource Evaluation report which brings together all of these products.

Thomas Stone National Historic Site was established during President Jimmy Carter's administration on November 10, 1978. The National Park Service acquired the land in 1981. Thomas Stone National Historic Site covers 328 acres of western coastal plain south of Washington, D.C. It protects Haberdeventure, the colonial plantation of patriot Thomas Stone, signer of the Declaration of Independence. The home was constructed in 1770 and housed 5 generations of the Stone family until 1936. A fire partially destroyed the house in 1977. It protects some of the rapidly disappearing open space in the Atlantic Coastal Plain physiographic province, a variety of threatened habitats, not to mention the historical landscape.

## *Map Notes*

The Inventory and Monitoring Program and Thomas Stone National Historic Site identified 2 quadrangles of interest (Figure 1).

Both of the THST quadrangles of interest are contained within the Geologic map database of the Washington DC area (Figure 1):

Davis, A.M., Southworth, C.S., Reddy, J.E., and Schindler, J.S., 2001, Geologic map database of the Washington DC area featuring data from three 30 X 60 minute quadrangles: Frederick, Washington West, Fredericksburg, U.S. Geological Survey, Open- File Report OF- 01- 227, 1:100,000 scale (3136)

In addition the Maryland Geological Survey produced geologic maps for Charles and Prince George's Counties at 1:62,500 scale (Figure 2). However, none of these maps completely covers the THST quadrangles of interest.

Dryden, A.L., Jr., 1939, Map of Charles County showing the geological formations, Maryland Geological Survey, County Geologic Maps, 1:62,500 scale (GMAP_ID 3251)

Hack, J.T., 1977, Geologic map for land- use planning, Prince Georges County, Maryland, U.S. Geological Survey, I- 1004, 1:62,500 scale (GMAP_ID 1442)

McCarten, Lucy, 1989, Geologic map of Charles County, Maryland Geological Survey, County Geologic Maps, 1:62,500 scale (GMAP_ID 2943)

McCarten, Lucy, 1989, Geologic map of St. Mary's County, Maryland Geological Survey, County Geologic Maps, 1:62,500 scale (GMAP_ID 3353)

Many other maps exist for the region that include coverage of the geology, shoreline change, reconnaissance, surficial, glacial, land use, aeromagnetic-gravity, mineral and mineral potential, folio, geochemical and hydrogeology, and stratigraphy, etc. The maps are available from agencies such as the U.S. Geological Survey, the Maryland Geological Survey, the Virginia Division of Mineral Resources, and the Geological Society of America.

Mapping with lidar provides vital information for mapping Quaternary age deposits, which is traditionally difficult given the level of vegetative cover of the coastal plain. Lidar surveys are useful for landscape change comparisons. The use of aerial photographs, erosion rates, as well as historical surveys would also help the site monitor the changes in land surface expression and better manage geologic resources. Additional mapping at a smaller scale within park boundaries would be helpful for park resource management and interpretation.

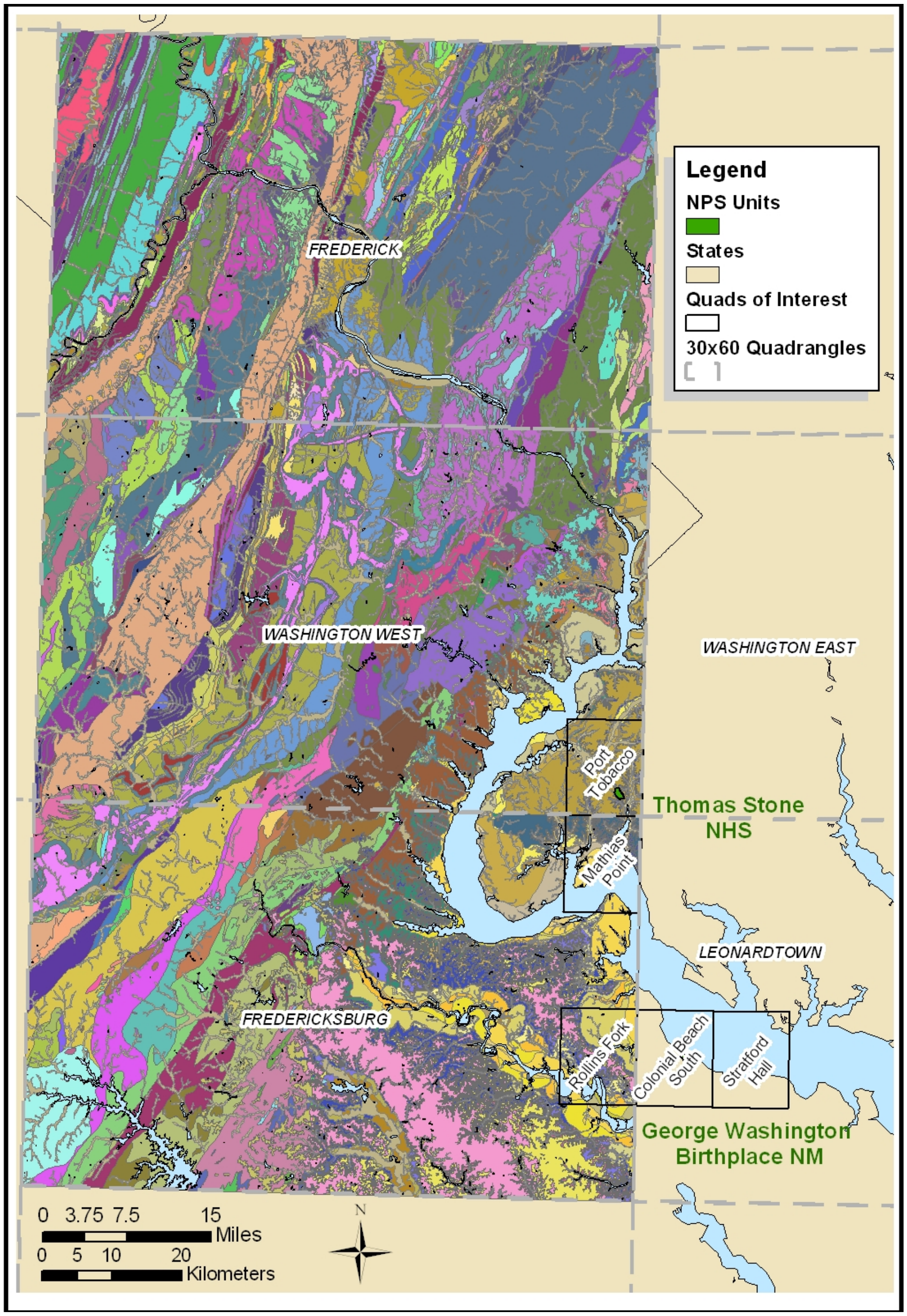


Figure 1: GEWA and THST Quadrangles of Interest and Proximity to USGS OF-01-227 Geologic map database of the Washington DC area

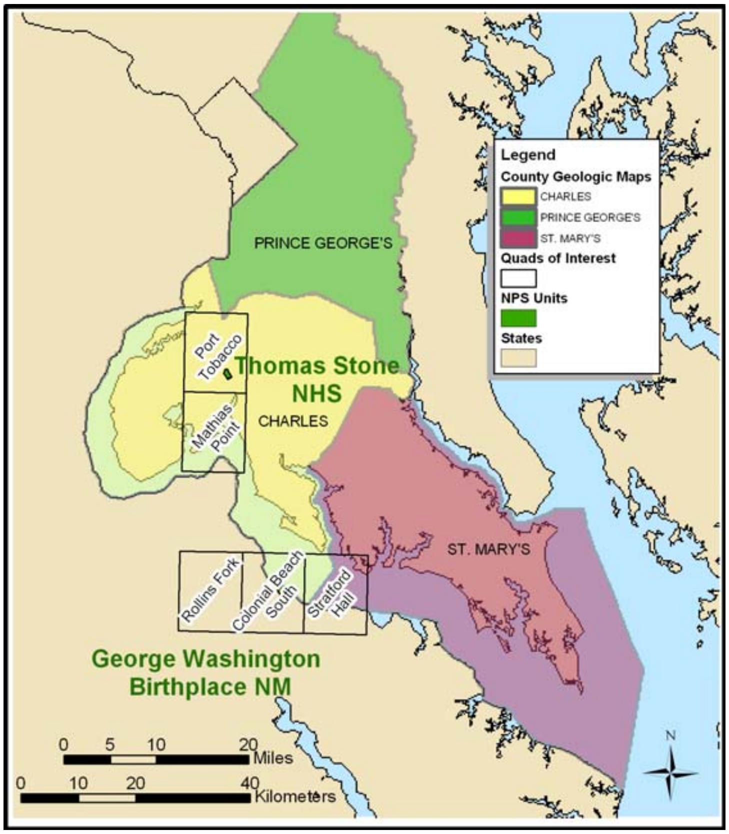


Figure 2: GEWA and THST Quadrangles of Interest and Proximity to MD County based geologic maps

### *Mapping Deliverables*

The GRE team plans to conduct quality control comparisons between the Port Tobacco portion of the *Geologic map database of the Washington DC area OF- 01- 227* and an earlier map of the Port Tobacco quadrangle (*Glaser, J.D., 1984, Geologic map of the Port Tobacco quadrangle, Prince Georges and Charles Counties, Maryland Geological Survey, Quadrangle Geologic Map, 1:24,000 scale*). If the *Geologic map database of the Washington DC area OF- 01- 227* is found to be of comparable quality to the older map then the GRE team will convert the Port Tobacco and Mathais Point portions of the *OF- 01- 227* into the NPS GRE Geology- GIS Data Model for delivery to the park. If the 1984 Glaser map is found to be superior in quality then it will be digitized for the Port Tobacco quadrangle and merged with the Mathais Point portion of *OF- 01- 227* according to the standards of the NPS GRE Geology- GIS Data Model. The combined digital map will then be provided to the park.

## *Physiography*

Thomas Stone National Historic Site lies within the Atlantic Coastal Plain physiographic province. In the area of the site, 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.

Thomas Stone National Historic Site lies on the eastern side of the Potomac River valley. Local streams and tributaries including Hoghole Run define the rolling landscape. The land around the site is primarily agricultural.

The Atlantic Coastal Plain province is primarily flat terrain with elevations ranging from sea level to 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 continually reworked by fluctuating sea levels and the erosive action of waves along the coastline. Large streams and rivers in the Coastal Plain province, including the James, York, Rappahannock, and Potomac, continue transporting sediment and extending the coastal plain eastward. Beyond the province to the east the submerged Continental Shelf province extends another 121 km (75 miles).

## *Geologic History of Southern Maryland*

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 an oceanic 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. These were derived from the eroding highlands that rose 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 to the north of present- day southern Maryland.

Late Paleozoic Era – Following the Acadian orogenic event, the proto- Atlantic Iapetus Ocean was completely destroyed during the Late Paleozoic as the North American continent collided with the African continent. This formed the Appalachian mountain belt we see today and a supercontinent named Pangaea. This mountain building episode is called the Alleghanian 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 was divided into roughly the 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). 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 of 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 Thomas Stone National Historic Site is profoundly impacted by the deposition of Tertiary and younger sediments and the subsequent erosion of these units by evolving waterways. Hoghole Run and its associated wetlands, and tributaries run through the site. This natural riverine environment continues to entrench channels, shift sediments, expose fossils within the Calvert Formation, and cut ravines as it responds to changes in climate, seasonal storms, and human influences.

Though glaciers from the Pleistocene Ice Ages never reached the southern Maryland 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 Thomas Stone National Historic Site. Freeze and thaw cycles within unconsolidated surficial units homogenized deposition features. 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 eroded their channels exposing the deformed bedrock of the Piedmont Plateau to the west. During oceanic highstands, the river basins flooded and deposition resulted in deposits of beach sediments in the park area.

### *Stratigraphy*

(from Geologic map of the Washington West quadrangle, District of Columbia, Montgomery and Prince George's Counties, Maryland, and Arlington and Fairfax Counties, Virginia, U.S. Geological Survey, Geologic Quadrangle Map GQ- 1748, 1:24,000 scale, 1994)

Beneath and within the site are the relatively young deposits of Atlantic Coastal Plain rocks. The Lower Cretaceous Potomac Formation underlies much of the area. This formation is comprised of feldspathic quartz sand and sandstone, silty channel- bar deposits, and lignitic sandy silt and clay layers. Atop the Potomac Formation is the upper Paleocene Aquia Formation of glauconitic sands, silts, clays, and containing some scant fossil layers. Between the Aquia and Nanjemoy Formations is the Marlboro Clay. This late Paleocene, 1 to 9 m (3- 30 ft) thick silty clay and clayey silt layer grades downward into the Aquia, but is unconformable with the overlying formation. Nanjemoy Formation deposits from the lower Eocene are glauconitic sands, clays, silts, and mixed layers. This unit is as much as 64 m (210 ft) thick. Miocene age deposits of the Chesapeake Group overlie the Aquia and Nanjemoy Formations in the park area. This includes the prominent Calvert Formation of marine sands, silts, and clays and upper Pliocene upland gravels.

The more recent deposits at the park include various late Tertiary - Quaternary age units. Gravels containing Piedmont and Blue Ridge cobbles grade into silty clay beds in the Ravens Crest Formation (analogous to the Windsor Formation in Virginia) of lower Pleistocene to upper Pliocene age. The gravelly Charles City Formation (locally called the Chicamuxen Church Formation), the sands and silts of the Chuckatuck Formation as well as the Shirley Formation (combined locally into the Omar Formation) of coarse sands, gravels, pebbles and occasional boulders are of the middle Pleistocene. Sands, gravels, silts, and clays of Pleistocene alluvial terraces sit parallel to the Potomac River. The youngest deposits at Thomas Stone National Historic Site include thick alluvium deposits of sand, gravel, silt and clays, marsh deposits along larger stream bottoms, shelly sands, and artificial fill from construction of roads, dams, bridges, landfills, and highways.

## *Structure*

The Rappahannock anticlinorium dominates the structural features present to the west of Thomas Stone National Historic Site. The anticlinorium extends from the Stafford, Virginia area southwards beyond the James River. The anticlinorium trends roughly northeast and plunges to the northeast. The eastern portions of the anticlinorium are comprised of island- arc deposits and some felsic plutons. Associated with the anticlinorium is the parallel trending Quantico synclinorium within the Quantico Formation on the western side of the structure. The feature is bound on the east by the Spotsylvania thrust fault and on the west by the Long Branch fault. The northern end is truncated by the right- lateral Accockeek fault just northwest of Fredericksburg and contains the Salem Church allochthon (meaning its origin is elsewhere from its surrounding rocks), a relatively small fault- bounded area of granitic gneiss. (Mixon et al. 2000). Structures along the limbs of the anticlinorium suggest multiple phases of folding and at least two metamorphic events. (Onasch, 1986; Mixon et al., 2000).

Most of the regional structures are high- angle reverse faults present near the boundary between the western Atlantic Coastal Plain and the eastern side of the Piedmont. They are all part of the Stafford fault system within the inner Coastal Plain of Virginia. The Stafford Fault system extends along the Fall Line 68 km (42 miles) from Spotsylvania (west of the site) northeastward to southern Fairfax County. These features are en echelon, or step- like in map trend and all strike northeast. Vertical displacement along these features is minor, only 10- 60 m (33- 197 ft), but this amount of offset significantly affects the thickness and distribution of Coastal Plain sediments (Mixon et al., 2000). Sediments present on the western, upthrown blocks are thinner than their counterparts on the eastern downthrown blocks across the high- angle reverse faults. Small- scale faults within the site and adjacent areas have had a pronounced influence on landform development. Most of these are not well exposed.

## *Significant Geologic Resource Management Issues*

1. Natural and historical evolution of the landscape

Haberdeventure was constructed starting in 1770. The Stone family's farming and homestead activities created an unnatural landscape that persists today at Thomas Stone National Historic Site. Minor irrigation features, removal of soil and rocks, garden terraces, grazed pastures, extensive logging, and other settlement features dot the landscape.

Many open fields with streams existed during the time of the historic agricultural activities at Haberdeventure. These areas are now mostly forested and for cultural interpretation needs, plans may be proposed to expand upon the cleared areas. The resulting increase in soil erosion and subsequent sediment loading into local streams must be taken into account during resource management decision making.

Human impacts continue today as pipelines, power lines, roads, buildings, trails, visitor use areas, invasive species, acid rain, and air and water pollution take their toll on the landscape. Resource management of these impacts is an ongoing process.

Research and monitoring questions and suggestions include:

- Encourage further cooperative efforts with local universities, government agencies, and other groups to study the evolution of the landscape at Thomas Stone National Historic Site and the effects of change.
- Perform clay mineralogy and grain size studies on the soils in the park, relating these to past climatic patterns.
- How is the landscape rebounding from early agricultural effects?
- Should the unnatural landscapes created by early settlers be remediated?
- Are soils becoming more acidic due to acid rain?
- Should the historic pond (attracting mosquitoes) be removed?
- Identify and study a possible quarry for early brick construction suspected on the site.

2. Slope processes and erosion

One of the major goals of the site is to present the historical context of the area; this includes preserving and restoring any old buildings and the landscape around them. Maintaining this colonial landscape often means working against natural geologic changes, which presents several management challenges. Geologic processes such as landsliding, slumping, chemical weathering, and slope creep are constantly changing the landscape at the site. Runoff erodes sediments from any open areas and carries them down streams and gullies. Erosion naturally diminishes higher areas such as ridges and hills, undermines foundations, degrades bridge foundations, erodes streams back into restoration areas, and fills in the lower areas such as trenches, ditches, and stream ravines distorting the historical context of the landscape.

Erosion processes at Thomas Stone National Historic Site range from rain and surface flow and freeze/thaw cycles to small- scale mass wasting. Sedimentation has occurred over the years to the extent that Hoghole Run, as a former trade route for the area, has silted up. Incising, dendritic channels, in places, expose the Calvert Formation.

Storms such as Hurricane Isabel in 2003 can cause significant changes to the landscape of the site. Flooding and channel erosion are naturally occurring along small streams within the site. This flooding and erosion can threaten wetlands and visitor facilities.

Alterations to site vegetation along any steep, exposed slopes lead to changes in the hydrologic regime. Thomas Stone National Historic Site slopes are covered with loose, rounded, reworked channel sediments derived from piedmont rocks. These rocks are easily transported by surface runoff. The clearing of trees and their stabilizing roots for historical restoration or by fire can lead to increased sediment load in nearby streams and could potentially contribute to slumps and landslides. Hiking trails and other high use areas are also at risk of erosion.

Research and monitoring questions and suggestions include:

- Research planting new vegetation along any vulnerable reaches of park streams to prevent excess erosion and sediment loading.
- Monitor topographic changes due to surface erosion.
- What, if any, slope stability impacts exist?
- Can slope erosion be slowed or stopped?
- Identify areas prone to slope failure during intense storm events.
- Are slope processes destroying the historic features at the site?
- What are the effects of increased erosion on aquatic ecosystems at the site?
- Is runoff in the site increasing due to surrounding development? If so, are there any remedial efforts resource management can undertake to reduce this impact?
- Is soil loss occurring at the site?

3. Seismic potential

The Stratford fault system, a structure deep beneath the regolith west of the site, is considered low for seismic risk. Enigmatic small- scale tremors with a long recurrence interval may be due to isostatic rebound or sediment loading atop the coastal plain. The Chesapeake Bay impact structure to the southeast of the site is still downloading and causes frequent small magnitude earthquakes. A large earthquake could cause significant damage to slopes, and buildings, fences and other cultural features at Thomas Stone National Historic Site.

Research and monitoring questions and suggestions include:

- Promote the development of an active seismic network for the area.
- Evaluate cultural features at risk for damage during infrequent seismic events.

4. Hydrogeologic characterization

Resource management staff need to understand how water is moving through the hydrogeologic system into, under, and from the site. Management also needs to understand how the water table might change over time. The installation of several wells throughout the site could be useful for monitoring of ground water quality. It would be useful to perform tracer studies in these wells to see how quickly and in what direction water is moving through the system.

Understanding the hydrogeologic system is critical for understanding the impacts of human introduced contaminants on the ecosystem. The interaction between groundwater flow and the overall water quality should be quantitatively determined at the site. Visitor use and surrounding development are increasing the levels of certain substances in the water at the park.

There are several seasonal wetlands within the site boundaries. Though small in scale, wetlands are typically considered indicators of overall ecosystem health and should be researched and monitored periodically.

Research and monitoring questions and suggestions include:

- Inventory groundwater levels at the site.
- Test for and monitor phosphate and volatile hydrocarbon levels in the groundwater at the park, focusing on areas near facilities.
- Inventory and map any existing springs in the site, especially with regards to their potential historical importance.
- Test water quality at any existing springs in the site.
- Create hydrogeologic models for the site to better manage the groundwater resource and predict the system’s response to contamination.
- Comprehensively map and monitor water and soil quality at all wetlands within the site. This creates a baseline level of ecosystem health to use for understanding future changes.

5. Surrounding development concerns

The population of the area surrounding Thomas Stone National Historic is growing rapidly, especially with commuters to Washington, D.C. Increased development in the area makes conservation of existing forest, wetland, and meadow community types a critical concern. Understanding the geology beneath the biotic communities becomes vital to their management. Management of the landscape for historic preservation purposes compliments the preservation of these ecosystems.

A major issue with decreasing available land is an increase in property value making the lands around the site too expensive to consider acquiring for inclusion within the park.

Research and monitoring questions and suggestions include:

- Perform studies to define the impact of surrounding land use patterns on the geomorphology of the landscape at the site.
- Keep rigorous track of land use and development and create community profiles in surrounding areas. Possibly employ a GIS to monitor land use changes.
- Cooperate with local developers to minimize impact near site areas.
- Consult conservation groups regarding cooperative efforts to increase the areas of relevant parklands and protect more of the region from development.
- Promote environmentally sound methods of developing land parcels including partial clearing of trees and proper construction of stable slopes.

6. Unique geologic features and potential paleontological resources

Interpreters make the landscape come alive for visitors and give the scenery a deeper meaning. The rolling hills and gentle landscape and topography at Thomas Stone National Historic Site are defined by the geology. Because geology forms the basis of the entire ecosystem and is directly responsible for the unique history at Thomas Stone National Historic Site, geologic features and processes should be emphasized to improve the visitor's experience. The website for the site needs to be updated for geologic content and connections with other scientific and cultural disciplines.

Within Thomas Stone National Historic Site are Tertiary age rocks of the Calvert Formation. These rocks have the potential to contain fossils, which would be exposed and removed from the formation during fluvial erosion and deposited in sediment- choked streams. A fossil bone fragment was discovered during a 2003 paleontological survey. Paleontological resources, if discovered, would be an important resource at the site adding to the geologic history of the area. Fossils are also attractive targets for visitors. Fossil theft would be a concern to any paleontologic resources at the site.

Research and monitoring questions and suggestions include:

- Are there potential fossil and mineral resources that might be subject to theft?
- Create interpretive programs concerning geologic features and processes and their effects on the settlement history of the site.
- Encourage the interaction between geologists and the interpretive staff to come up with a list of features and programs to execute.
- Create a general interest map with simple explanatory text on geological-historical connections for visitors to the site.
- Update the site website relating geology with other resources.

## *Scoping Meeting Participants*

| NAME | AFFILIATION | PHONE | EMAIL |
|---|---|---|---|
| Rijk Morawe | NPS, GEWA, THST | 804- 224- 1732, ext. 237 | Rijk_Morawe@nps.gov |
| Bruce Heise | NPS, GRD | 303- 969- 2017 | Bruce_Heise@nps.gov |
| Melanie Ransmeier | NPS, GRD | 303- 969- 2315 | Melanie_Ramsmeier@nps.gov |
| Mark Duffy | NPS, NCBN | 410- 641- 1443, ext. 219 | Mark_Duffy@nps.gov |
| Lindsay McClelland | NPS, GRD | 202- 208- 4958 | Lindsay_McClelland@nps.gov |
| Trista Thornberry-Ehrlich | Colorado State University | 757- 222- 7639 | tthorn@cnr.colostate.edu |

## *References*

Duffy, D.F., Whittecar, G.R., 1991, Geomorphic development of segmented alluvial fans in the Shenandoah Valley, Stuarts Draft, Virginia. Abstracts with Programs - Geological Society of America, vol.23, no.1, p.24.

Harris, A.G., Tuttle, E., Tuttle, S.D., 1997, Geology of National Parks. Kendall/Hunt Publishing Company, 759 p.

Means, J., 1995, Maryland's Catoctin Mountain parks; an interpretive guide to Catoctin Mountain Park and Cunningham Falls State Park. McDonald & Woodward Publishing Company : Blacksburg, VA, United States, 168 p.

Mixon, R.B., Pavlides, L., Powars, D.S., Froelich, A.J., Weems, R.E., Schindler, J.S., Newell, W.L., Edwards, L.E., Ward, L.W., 2000, Geologic Map of the Fredericksburg 30’x60’ Quadrangle, Virginia and Maryland. U.S. Geological Survey, Geologic Investigations Series Map I- 2607, 1:100,000 scale.

Onasch, C.M., 1986, Structural and metamorphic evolution of a portion of the Blue Ridge in Maryland. Southeastern Geology, Vol. 26, Issue 4, pp. 229- 238.

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

Whittecar, G. R., Duffy, D.F., 2000, Geomorphology and stratigraphy of late Cenozoic alluvial fans, Augusta County, Virginia, U.S.A. In: Regolith in the Central and Southern Appalachians, Clark, G.M., Mills, H.H., Kite, J.S., eds., Southeastern Geology, vol.39, no.3- 4, p.259- 279.

***Map of Thomas Stone National Historic Site***