U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Petersburg National Battlefield

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Petersburg National Battlefield

pete_geology.pdf

Version: 6/12/2019

Geologic Resources Inventory Map Document for Petersburg National Battlefield

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Geologic Resources Inventory Map Document

Petersburg National Battlefield, Virginia

Document to Accompany Digital Geologic-GIS Data

pete_geology.pdf

Version: 6/12/2019

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Petersburg National Battlefield, Virginia (PETE).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

This document contains the following information:

1) **About the NPS Geologic Resources Inventory Program** – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.

2) **GRI Digital Maps and Source Map Citations** – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.

3) **Map Unit List** – A listing of all geologic map units present on maps for this project, generally listed from youngest to oldest.

4) **Map Unit Descriptions** – Descriptions for all geologic map units. If a unit is present on multiple source maps the unit is listed with its source geologic unit symbol, unit name and unit age followed by the unit's description for each source map.

5) **Geologic Cross Sections** – Geologic cross section graphics with source geologic cross section abbreviations.

6) **Ancillary Source Map Information** – Additional source map information (e.g., correlation of map units, map legend, report) presented by source map.

7) **GRI Digital Data Credits** – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage: http://go.nps.gov/gri_products

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park(s), enter "GRI" as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: https://www.nps.gov/subjects/geology/gri.htm, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS maps and their source maps for Petersburg National Battlefield, Virginia (PETE):

Digital Geologic-GIS Map of Petersburg National Battlefield and Vicinity, Virginia (*GRI MapCode PETE*)

> Occhi, M.E., Berquist, C.R., Latane, V.M., and Blanchette, J.M., 2018, Geologic Map of the Petersburg National Battlefield and Adjacent Areas, Virginia: Virginia Division of Geology and Mineral Resources, Publication Date: 2018, scale 1:24,000 (Petersburg National Battlefield). (*GRI Source Map ID 76287*).

The GRI used the full extent of the source digital GIS data, and incorporated prominent components of the provided source maps and reports (e.g., unit colors and unit descriptions) into the GRI digital geologic-GIS dataset and product.

Digital Geologic-GIS Map of Grant's Headquarters at City Point, Petersburg National Battlefield, Virginia (*GRI MapCode CIPO*)

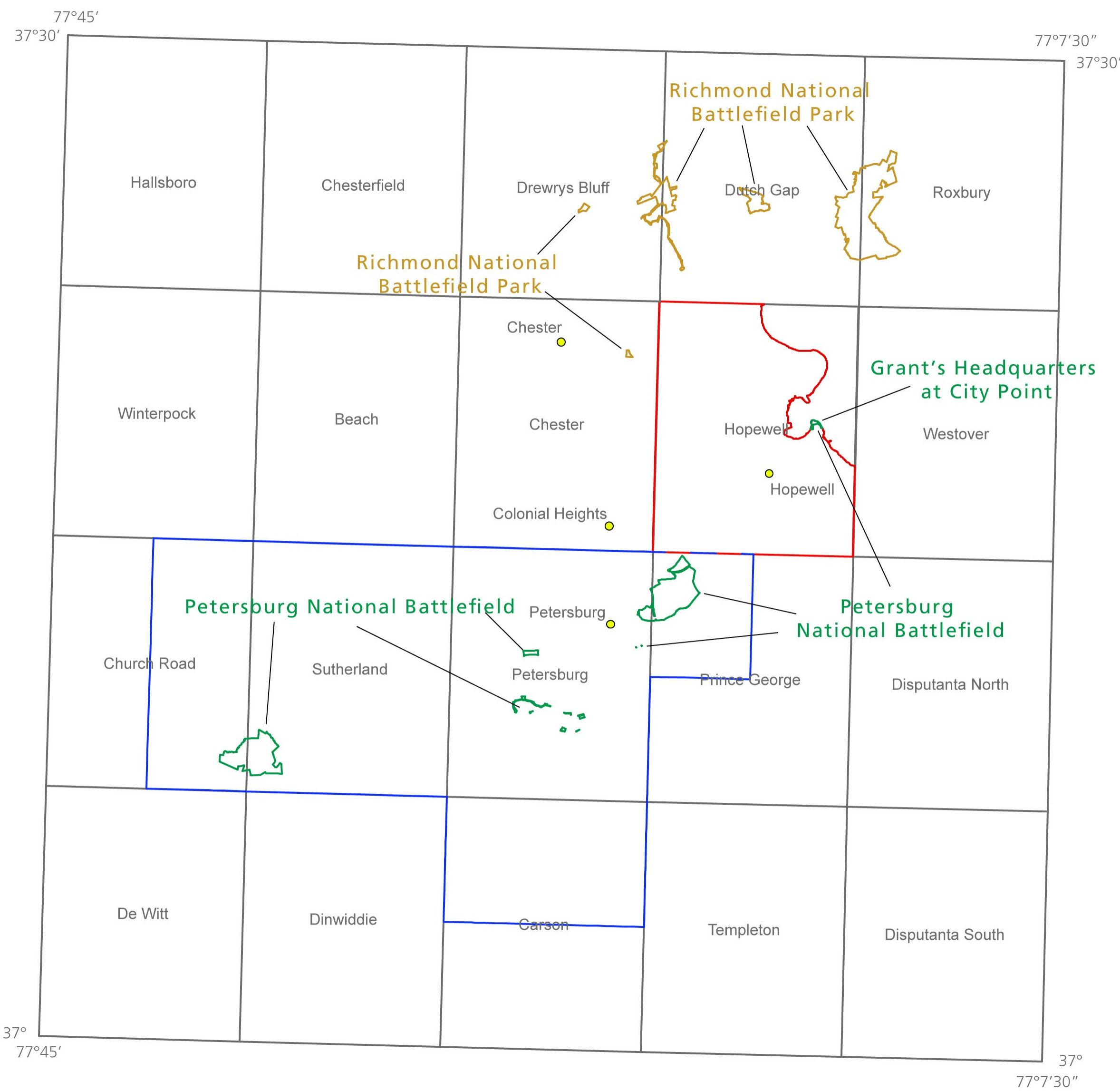
> Dischinger, J. B., 1987, Late Mesozoic and Cenozoic Statigraphic and Structural Framework near Hopewell, Virginia: U.S Geological Survey, Bulletin 1567, scale 1:24,000 (Grant's Headquarters at City Point). (*GRI Source Map ID 2430*).

The GRI digitized the extent of the source map within the Hopewell 7.5' quadrangle, and incorporated prominent components of the provided source map and report (e.g., unit colors and unit descriptions) into the GRI digital geologic-GIS dataset and product. Terrace units present on the source map were re-mapped and/or re-interpreted based on the uppermost surface and scarp toe elevations by C.R. Berquist (Virginia Division of Geology and Mineral Resources, personal communication, 2019). These changes are noted in several unit descriptions.

Additional information pertaining to each source map is also presented in the GRI Source Map Information (PETEMAP) table included with the GRI geologic-GIS data.

Index Map

The following index map displays the extent of the GRI Digital Geologic-GIS Map of Petersburg National Battlefield and Vicinity, Virginia (in blue), and the GRI Digital Geologic-GIS Map of Grant's Headquarters at City Point, Petersburg National Battlefield, Virginia (in red). The boundary for Petersburg National Battlefield (as of June, 2019) is displayed in dark green, whereas the boundary of nearby Richmond National Battlefield Park (also as of June, 2019) is displayed in brown. Relevant 7.5' quadrangle extents and their names are also displayed. GRI digital geologic-GIS data is also available for Richmond National Battlefield Park at the GRI publications webpage: http://go.nps.gov/gri_products . This data includes coverage of the Chester, Drewry's Bluff, Dutch Gap and Roxbury 7.5' quadrangles, as well as additional 7.5' quadrangles not shown that are related to Richmond National Battlefield Park.



Index map produced by James Winter (Colorado State University).

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Petersburg National Battlefield, Virginia (PETE) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qml - Modified land). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (PETEUNIT) table included with the GRI geologic-GIS data. Some source unit symbols, names and/or ages may have been changed in this document and in the GRI digital geologic-GIS data. This was done if a unit was considered to be the same unit as one or more units on other source maps used for this project, and these unit symbols, names and/or ages differed. In this case a single unit symbol and name, and the unit's now recognized age, was adopted. Unit symbols, names and/or ages in a unit descriptions, or on a correlation of map units or other source map figure were not edited. If a unit symbol, name or age was changed by the GRI the unit's source map symbol, name and/or age appears with the unit's source map description.

Cenozoic Era

Quaternary Period
Qml - Modified land
Qal - Alluvium
Qts - Tabb-Sedgefield Alloformation
Qeg - Elsing Green Alloformation
Qsh - Shirley Alloformation
Qc - Chuckatuck Alloformation
Qcc - Charles City Alloformation
Qw - Windsor Alloformation
Qtu - Quaternary terrace
Qbc - Bacons Castle Formation

Tertiary Period
Tch - Cold Harbor formation
Ty - Yorktown Formation
Tcl - Lower Chesapeake Group, undivided
Tsm - Virginia St. Marys Formation
Tg - Gravel terrace
Tn - Nanjemoy Formation
Ta - Aquia Formation

Mesozoic Era

Cretaceous Period
Kp - Potomac Formation

Paleozoic Era

Pennsylvanian and Mississippian Periods
PNMpg - Petersburg Granite
PNMa - Amphibolite

Protoerozoic Eon

Neoproterozoic Era

Zmsv - Metasedimentary and metavolcanic rocks, undifferentiated

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qml - Modified land (Holocene)

ml - Modified land (Holocene)
Extensive cut and fill related to grading, excavation, and mining-related activities; widespread modified land in urbanized area along roads not shown; variable thickness. Description from source map: Petersburg National Battlefield

Qal - Alluvium (Holocene)

Qal - Alluvium (Holocene)
Flood-plain and channel deposits consisting of pebbly sand, sand, silt, and clay, with interbedded silt and fine sand. Organic material common. Variable thickness. Description from source map: Petersburg National Battlefield

Qal - Alluvium (Holocene)
Holocene alluvial fill, composed of clays, sands, and gravels, constitutes the flood plains of minor streams and formed as extensive point-bar and channel-bar deposits of the James and Appomattox Rivers. Organic-rich silty clays and sands formed in swamps and tidal marshes border the fluvial-bar deposits and tidal tributaries to these rivers. Spoil from dredged shipping channels, sanitary landfills, and manmade lands are locally important contributors to these sediments. Holocene sediments range in thickness from less than 0.3 m onshore to 12m in some manmade lands. An unknown thickness of Holocene sediments floors the James and Appomattox Rivers. Swamp and marsh deposits are typically less than 3 m thick. From source map: Grant's Headquarters at City Point

Qts - Tabb-Sedgefield Alloformation (Pleistocene)

Gray to yellow, fine- to coarse-grained sand (slightly clayey in places) coarsening downward to pebbly sand with heavy minerals common; interbeds of clay, clayey sand, peat and organic mud common; may contain reworked glauconite and phosphate derived from adjacent Miocene and Eocene formations. Sediments are found below broad flats where the highest surface elevations range between 20 to 29 feet. Thickness ranges up to 25 feet (7.6 meters) but could be greater in paleochannels. Age is approximately 70 Ka (Scott and others, 2010). Description from source map: Petersburg National Battlefield

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of 28 feet to be the Tabb-Sedgefield Alloformation. No additional unit description was provided.

Qeg - Elsing Green Alloformation

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of 38 feet to be the Elsing Green Alloformation. No additional unit description was provided.

Qsh - Shirley Alloformation (Pleistocene)

Gray to brown gravel, fine- to coarse-grained sand, silt, and clay. Typically consists of clayey sand that grades downward to coarse-grained sand, granules and pebbles. Quartzite clasts with the trace fossil Skolithos are common and rounded grains of phosphate and glauconite up to 5 millimeters are prevalent towards the base of the formation. Weathered, gold-colored, biotite grains are common with up to 5% heavy minerals. Occurs on broad flats adjacent to the Appomattox River where highest surface elevations range between 40 and 49 feet. Unit is interpreted as fluvial to estuarine/tidal. The type section of the Shirley was defined by Johnson and Berquist (1989). Age ranges from 195 Ka to 270 Ka (Parham, 2009). Thickness averages about 30 feet (9.1 meters), but could be greater in paleochannels. Description from source map: Petersburg National Battlefield

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of 48 feet to be the Shirley Alloformation. No additional unit description was provided.

Qc - Chuckatuck Alloformation (Pleistocene)

Brownish-yellow, fine- to coarse-grained, pebbly sand fining upward to clayey fine- to coarse-grained sand. Sand unit often contains thin (less than ½ inch thick, 1.3 centimeters) interbeds of clay-silt and trace amounts of heavy minerals (>1-2%). Occurs on broad flats adjacent to the Appomattox River where the highest surface elevations range between 50 to 58 feet. Unit is interpreted as fluvial to estuarine/tidal. The type section of the Chuckatuck was defined by Johnson and Berquist (1989), on the Brandon and Norge 7.5-minute quadrangles. Thickness of unit is up to 60 feet (18 meters), but could be greater in paleochannels. Description from source map: Petersburg National Battlefield

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of 58 feet to be the Chuckatuck Alloformation. No additional unit description was provided.

Qcc - Charles City Alloformation (Pleistocene)

Yellowish-red to brown, clayey fine- to medium-grained sand coarsening downward to sand and pebbles with interbeds of peat and organic and muddy sand of variable thickness. Occurs below broad flats adjacent to the Appomattox River where the highest surface elevations range from 60 to 75 feet. Unit is interpreted as fluvial to estuarine/tidal. The type section of the Charles City was defined by Johnson and Berquist (1989), on the Brandon and Norge 7.5-minute quadrangles. Thickness of unit is typically 15 feet (4.5 meters) but was observed to be 60 feet (18 meters) in paleochannels. Description from source map: Petersburg National Battlefield

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of 75 feet to be the Charles City Alloformation. No additional unit description was provided.

Qw - Windsor Alloformation (Pleistocene)

Red to yellow, yellowish brown, fine- to coarse-grained sand containing 1-2% heavy minerals. Occurs below flats where the highest surface elevations range between 100 to 125 feet. Thickness varies up to 10 feet (3 meters). May contain sporadic lenses of lenticular-bedded clay up to a few feet in thickness. Unit is interpreted as fluvial to estuarine/tidal. The type section of the Windsor was defined by Coch (1965) and later modified by Johnson and Berquist (1989). Description from source map: Petersburg National Battlefield

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of 98 feet to be the Windsor Alloformation. No additional unit description was provided.

Qtu - Quaternary terrace (Pleistocene)

Brownish-yellow, reddish-yellow, gray, clayey fine- to coarse-sand, granules, and cobbles common. Observed thickness ranges up to 10 feet (3 meters) but could be greater. Occurs below flats where the highest surface elevations are between 100 and 125 feet. These sediments may be time-equivalent with the Windsor Alloformation and represent the upstream and fluvial parts of the Windsor. Description from source map: Petersburg National Battlefield

Qbc - Bacons Castle Formation (Pleistocene)

Yellowish-brown, red, gray, fine- to medium-grained sand coarsening downward to sand with granules, pebbles, and cobbles. The lower part of the Bacons Castle was deposited in a fluvial environment and commonly contains clasts larger than those found in the Cold Harbor Formation, described below; a sandpit near boring 2016181-1 contains boulders, one measuring approximately 3 feet (0.9 meters) in diameter. Portions of the upper Bacons Castle sediments are difficult to discriminate from the older Cold Harbor Formation in places as the depositional environments were similar (marginal marine and tidal prism, possibly estuarine). At highest elevations, deposits are thin and likely resulted from minor erosion and reworking of Cold Harbor sediments. Occurs below somewhat dissected flats and rounded hills where the highest surface elevations vary up to 175 feet; observed thickness ranges up to 50 feet (15.2 meters). The Bacons Castle was established by Coch (1965) and later modified by Ramsey (1988). Description from source map: Petersburg National Battlefield

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of approximately 170 feet to be the Bacons Castle Formation. No additional unit description was provided.

Tch - Cold Harbor formation (Pliocene)

Commonly yellow but in some places red, slightly muddy fine- to coarse-grained sand with rare granules; commonly contains lenticular-bedded clay. The formation is characterized by interbedded mud and sand layers. Towards the base of the unit a gravelly angular to subrounded sand that contains some feldspar within a mud matrix is commonly present. The thickness of this sand layer ranges up to 10 feet (3 meters); this layer may correlate to the “feldspathic sand” unit mapped in the Richmond area (Carter and others, 2007). Commonly below this sand is a basal gravel that contains pebbles up to 1.5 inches (4 centimeters) in diameter. The Cold Harbor lies unconformably over the Petersburg Granite or sediments from the Lower Chesapeake Group (Tcl). The Cold Harbor thickens to the east and is up to 90 feet (27 meters) thick and its surface elevations range between 150 and 240 feet. The Cold Harbor correlates with the lower part of psg (Virginia Division of Minerals Resources, 1993) and Tpsg (Mixon and others, 1989). It was deposited in shallow marine, tidal channels and flats, and tidal marsh environments. In the Fredericksburg area (Mixon and others, 2000), correlative sediments are depicted to interfinger with the marine Yorktown, but within the Richmond area (Berquist and Gilmer, 2014) and this project area we did not find that relationship. Unit is named for borings in the Seven Pines quadrangle (Bondurant and others, in preparation) at Cold Harbor Battlefield, and the type section is described in VDGMR boring 2006313-1. Description from source map: Petersburg National Battlefield

C.R. Berquist (personal communication, 2019) differentiated terrace deposits based on the uppermost surface and scarp toe elevations and thus the terrace sequence (I-V) on the Dischinger, 1987 source map (Grant's Headquarters at City Point) were re-mapped and/or reinterpreted. See the terrace sequences section of this document for descriptions of the source map terraces sequence. Berquist interpreted terraces with an uppermost surface and scarp toe elevation of approximately 240 feet to be the Cold Harbor Formation. No additional unit description was provided.

Ty - Yorktown Formation (Pliocene)

Ty - Yorktown Formation (Pliocene)
Gray to bluish-gray where fresh, yellow, dark reddish brown or strong brown where weathered, fine- to coarse-grained sandy silty clay. The sand fraction typically coarsens downward, exhibiting very well rounded coarse sand and granules. Where present, granules are sub- to well-rounded and consist mostly of quartz. Unit fines upwards into a sequence of gray clayey silt commonly containing gray to orange laminated, sand-clay layers with iron oxide mottling, and massive blocky clayey silt. Unit contains 1-2% heavy minerals. Glauconite and shell fragments are rarely encountered. Locally, flaser to wavy bedding is manganese and iron-stained, likely caused by in-situ dissolution of shell material. Unit crops out in the eastern portion of the Petersburg quadrangle and unconformably overlies the marine Lower Chesapeake Group. Unit thickness is between 0 to 20 feet (0 and 6.1 meters), thickening to the east southeast where present. Description from source map: Petersburg National Battlefield

Ty - Yorktown Formation (Pliocene)
In the western part of the study area, the Yorktown Formation unconformably overlies the upper Miocene "Virginia St. Marys Formation."East of long 77°16', the transgressing Yorktown sea completely eroded the "Virginia St. Marys Formation," and the lower part of the Yorktown lies unconformably on the greensands of the Eocene Nanjemoy Formation (fig. 10). There the lowermost Yorktown sediments contain a mixed assemblage of late Miocene to early Pliocene fossils.

The Yorktown Formation· was named by Clark and Miller (1906) from the exposures of shelly sands and clays along the York River in the vicinity of Yorktown, Va. Clark and Miller (1912) extended the formation into North Carolina. Mansfield (1943) divided the Virginia Miocene units into four faunal zones. Stephenson and MacNeil (1954) designated unfossiliferous sands and gravels in Maryland as nearshore-marine equivalents of the marine Yorktown in Virginia. Ward and Blackwelder (1980) divided the Yorktown into four members. Gravels capping the uplands in the Fredericksburg area have been interpreted as a fluvial-deltaic facies of the Yorktown Formation (Newell, 1978).

Four major lithologies occur within the Yorktown in the study area. A representative section is exposed in a steep stream bank on the east side of Virginia Route 10, 0.4 km southeast of Chappell Creek. A basal lag of rounded phosphate and quartz pebbles and cobbles, shark teeth, vertebrate remains, corals, and shell debris marks the contact with the Nanjemoy. Relief on the contact is as much as 0.6-0.9 m.

The basal Yorktown is composed of a dark-greenish-gray, very fossiliferous, poorly sorted, very fine to medium sand constituting a shell hash. The macrofossil assemblage is predominantly molluscan. This basal unit is overlain by a light-greenish-gray bioclastic sand, which is very fine to fine, well sorted, and somewhat glauconitic. The bioclastic fraction consists of sand-size shell fragments, larger shell remains, and echinoderm or sponge spicules. This sand grades upward into a sequence of bluish- to greenish-gray clayey silts commonly containing gastropod and mollusk molds and (or) gray to reddish-orange, laminated, sand-clay layers and massive blocky clayey silts. In the western part of the study area, this fine-grained sequence is partly or completely missing, and the uppermost part of the Yorktown is represented by interbedded well-sorted sands having noded, clay-lined Ophiomorpha burrows and poorly sorted crossbedded sands containing pebble stringers. The total thickness at the representative section is approximately 18 m. The Yorktown Formation is missing over much of the central part of the study area, between Point of Rocks and Bailey Creek. For the most part, the areas west of Point of Rocks and east of Bailey Creek are underlain by a sequence of late Pliocene and Pleistocene terraces that unconformably overlie the Yorktown sediments.

Environment of Deposition
As noted in the lithologic description of the Yorktown, at least four facies are distinguishable. The very fossiliferous basal part, which crops out only to the east of Bailey Creek, represents a transgressing, high-energy, nearshore zone in which underlying sediments were eroded and redeposited on the basal beds of the Yorktown Formation. In the study area, this facies is about 1.5 m thick. Conformably above the basal facies is a well-sorted bioclastic sand. As shown by the preservation of echinoderm spines and some larger shell remains, this facies probably developed below the wave base. The two sediment types that overlie the bioclastic facies, clayey silt containing abundant mollusk molds and laminated sand-clay layers and blocky clayey silts, were deposited in a much lower energy environment than the underlying sands and bioclastic sands. The sand-clay layers and clayey silts probably are the result of back-bay or protected-bay deposition. The uppermost facies of Ophiomorpha-burrowed sands and crossbedded sands represent alternating estuarine and fluvial parts of a regressive phase of the Yorktown Formation. When viewed as a whole, the suite of Yorktown sediments reflects a transgressive-regressive series of environments ranging from the offshore shell accumulations to the estuarine and even fluvial beds near the top of the section.

Age
Abundant macrofossils exist in outcrops of the Yorktown east of Bailey Creek (see table 3). Placopecten clintonius, Chesapecten septenarius, Astarte undulata, and other mollusks indicate an early Pliocene age (zone II of Mansfield, 1943) for part of this formation. In the lower transgressive part of the formation, reworked middle to late Miocene guide fossils have been retained in a basal lag and mixed with the younger transgressing sediments. Description from source map: Grant's Headquarters at City Point

Tcl - Lower Chesapeake Group, undivided (Miocene)

Light bluish gray to dark greenish gray clayey silt and fine- to very fine grained sand to sandy clay. The upper few feet may be oxidized to yellowish-brown. Lamellae and burrows are filled with dark gray fine-rained sand with common fine-grained mica and framboidal pyrite. The sand fraction is well rounded and well sorted, typically consisting of quartz and trace phosphate and glauconite (<1-2%). The lower portion becomes less clayey with increasing abundance of coarse- and granule-sized rounded quartz and phosphate grains ranging up to 2.5 inches in diameter (6.4 cm). Shark teeth, bone, and phosphate are common towards base of formation. Shell material is usually absent in borings but can range up to 20% locally; Mercenaria, Turritella, and Isognomon maxillata are common where shell material is present. Iron oxide mottling and staining from disseminated iron sulfide are common. Unit is massive to finely laminated and locally contains diatoms; minor joints are present where material exhibits sufficient cohesive strength.

The lower Chesapeake Group is interpreted to be marine and likely correlates with the Eastover and Calvert Formations of Ward and Blackwelder (1980). May include thin remnants of the Choptank Formation. Description from source map: Petersburg National Battlefield

Tsm - Virginia St. Marys Formation (Miocene)

The Miocene series is represented locally by a sparsely fossiliferous, fine-grained marine facies of the "Virginia St. Marys Formation" (see Gibson, 1982). The Calvert Formation (Shattuck, 1906) of Miocene age has been removed by erosion in the study area south of the James River (Blackwelder and Ward, 1976). Elsewhere in the Virginia Coastal Plain, the Calvert extends as far inland as Richmond and Washington, D.C.

In the updip areas west of Bailey Creek, discontinuous patches of fine-grained Miocene marine sand unconformably overlie the Eocene Nanjemoy Formation. The Pliocene Yorktown Formation unconformably overlies the marine sand. The Miocene unit was largely removed by late Pliocene to recent erosion over much of the study area.

"St. Marys Formation" is used properly as a stratigraphic term in Maryland, where it was established by Shattuck (1902) from the exposures in St. Marys County. Clark and Miller (1912) extended the formation into Virginia, and Mansfield (1943) subdivided the St. Marys Formation in Virginia into three faunal zones. Only zone 2 of Mansfield (Crassatellites meridonalis zone), which is younger than the St. Marys Formation in Maryland, crops out in southeastern Virginia. Beds of this age in Virginia have since been referred to as the Claremont Manor (lower unit) and Cobham Bay (upper unit) members of the Eastover Formation by Blackwelder and Ward (1976) and Ward and Blackwelder (1980). The author's tentative interpretation is that the unit exposed in the present study area is a Cobham Bay equivalent, and it is mapped as the "Virginia St. Marys Formation." The "Virginia St. Marys Formation" consists of light-greenish-gray to greenish-gray, fine to very fine, well-sorted sands that predominate in sections east of Bailey Creek. Updip from Bailey Creek, these sands are interbedded with layers of blocky clay in a suite of repeated fining-upward sequences. The sands often contain scattered small (3 mm) rounded quartz pebbles and shell ghosts of Turritella, Chesapecten, and small clams (probably Spisula rappahannockensis). These sands weather grayish- to yellowish-orange. Where exposed, the upper contact is marked by a lag deposit of small rounded quartz pebbles; molds of various pecten species and other mollusks occur. The shell-rich lag deposit is the base of the massive, blocky, clayey-silt facies of the overlying Yorktown Formation. The lower contact is marked by scattered, 'rounded, quartz and phosphate pebbles immediately overlying the glauconitic sands at the top of the Nanjemoy Formation. A representative section of the "Virginia St. Marys Formation" approximately 9 m thick is located behind the Harbor East trailer court on the south bank of the old James River channel around Farrar Island. The unit is approximately 6 m thick in a borrow pit near the intersection of Virginia Routes 646 and 156, about 0.6 km southeast of the confluence of Manchester Run and Bailey Creek. This formation was not found anywhere east of long 77° 16' in the study area

Environment of Deposition
In the eastern part of the study area, the "Virginia St. Marys Formation" was completely eroded by the trangressing sea into which the Yorktown Formation was later deposited. Miocene fossil remains, including the thick cardinal areas of I so gnomon, abraded Turritella plebeia (?), Chesapecten middlesexensis, and others, indicate a marine to nearshore-marine environment. The suite of interbedded sands and blocky clays occurring in repeated fining-upward sequences in the western part of the study area seems to indicate shallowing to the west and more offshore conditions to the east.

Age
The absence of identifiable, in-place fossils leaves room for speculation. Stratigraphic position and late Miocene shell remains found in the basal zone-I Yorktown sediments allow a tentative biostratigraphic

correlation of this unit with the upper Miocene Cobham Bay Member of the Eastover Formation as defined by Ward and Blackwelder (1975, 1980) and L. W. Ward (USGS, Reston, Va, oral commun., 1978). A complete fossil list for this unit is included in table 3. Description from source map: Grant's Headquarters at City Point

Tg - Gravel terrace (Miocene)

Yellowish brown, white and red, clayey fine- to coarse-sand, granules pebbles, and cobbles. Cobbles up to 5 inches (12.7 cm) are common in upper 10 feet. Larger clasts are often well-rounded, somewhat weathered, and commonly iron-stained. Non-quartzose clasts can be friable where weathered. Below the pebble rich zone, lenticular bedding is common with abundant muscovite near the base of the unit. Commonly occurs on tops of hills and ridges at elevations above 240 feet. Thickness ranges up to 32 feet (9.8 meters) based on auger holes on the Sutherland 7.5-minute quadrangle. This unit is possibly the landward equivalent of the marine Eastover Formation and is interpreted as such. Description from source map: Petersburg National Battlefield

Tn - Nanjemoy Formation (Eocene)

The Nanjemoy Formation unconformably overlies the Marlboro Clay and is unconformably overlain by the Miocene "Virginia St. Marys Formation" in the western part of the study area (west of long 77°16') and by the Pliocene Yorktown Formation east of this line. The Nanjemoy was first described by Clark and Martin (1901) along Nanjemoy Creek, a stream flowing into the Potomac River from southern Maryland. The Nanjemoy is the uppermost unit of the Pamunkey Group and consists of massive, olive-black to greenish-black, fine to very fine, moderately well-sorted, micaceous glauconitic sand. Zones of predominantly clayey silt tend to be lighter in color and contain less glauconite than the sandier zones. Glauconite-rich sands are concentrated in burrows. The unit weathers to a light-greenish-gray to reddish-brown. Molds of pelecypods are abundant in most of the section; however, very few are preserved well enough to distinguish species. The better preserved molds are concentrated in small lenses, which commonly contain shark teeth. A representative section is found 0.8 km east of Bailey Creek, along the south side of the James River, in a gully leading down from the end of Virginia Route 644 to the river. East of this representative section, and particularly in the subsurface, the upper limit of the Nanjemoy is marked by a calcite-cemented layer 0.3-0.6 m thick. This layer contains abundant Ostrea sellaeformis and other shells. Locally, this limestone layer contains small-scale solution cavities. The Nanjemoy Formation thickens eastward from the vicinity of Bailey Creek, where it is approximately 14 m thick.

Environment of Deposition
Both the Aquia and Nanjemoy greensands represent transgressive events of some similarity in the latest Paleocene and early and middle Eocene respectively (Reinhardt and others, 1980b). Fossils are generally better preserved in the Nanjemoy than in the Aquia Formation in the study area As with the Aquia, pelecypods and gastropods are dominant, but glauconite generally is not as abundant in the Nanjemoy as in the Aquia Teifke (1973) found that Aquia glauconite was predominantly formed in place, whereas glauconite in the basal Nanjemoy was reworked. He noted that glauconite in the Nanjemoy showed evidence of considerable abrasion as well as slight to intense chemical decomposition, indicating either a reworking of Aquia glauconite or genesis and deposition in a high-energy environment. Nanjemoy glauconite was also commonly found to be more lustrous and coarser than the accompanying quartz grains. Gibson and others (1980) have concluded, on the basis of changes in foraminiferal faunas in the Oak Grove core, that the basal Nanjemoy greensands represent the beginning of marine transgression with water depth increasing upward in the section. They conclude further that faunas in the upper part of the Nanjemoy indicate a gradual shallowing, representing the termination of the Nanjemoy transgression.

The presence of glauconite and of a diverse microfossil assemblage, and the generally mottled (bioturbated?) appearance of these sediments, suggest a relatively slow rate of deposition. The development of diverse macrofauna! assemblages, the scattered whole (and occasionally imbricated) shell material, and the concentration of mica flakes and abraded shell debris along bedding planes support an interpretation of weak to moderate current activity within a shallow marine realm.

Age

Bone fragments, shark and ray teeth, internal molds of gastropods and pelecypods, worm tubes, and pelecypod shell fragments occur within the Nanjemoy greensands. The better specimens are concentrated in lenses. Among the identified macrofossils are Cubitostrea sellaeformis (a middle Eocene guide fossil), Venericardia potapacoensis, Meretrix subimpressa, Corbula subengonata, and Nuculana improcera. Worsley (oral commun.) has identified calcareous nannofossils including Discoaster lodoensis and Chiasmolithus solitus. The presence of these species and the marked absence of several other indicative forms place the Nanjemoy Formation in the early-to-middle Eocene nannofossil zone NP-13 (Berggren, 1972).

Harris (oral commun.) determined a rubidium-strontium age for seven glauconitic concentrates collected from a single Nanjemoy outcrop. The average modal age for these samples is in excellent agreement with recent European glauconite ages, suggesting that the top of the NP-13 nannofossil zone (lower-middle Eocene boundary) is at 44 m.y. However, Harris apparently did not consider that Nanjemoy glauconites are reworked; thus the age of the glauconites may not represent the age of the formation. The fossils identified in the Nanjemoy Formation are listed in table 2.

Biostratigraphic data from Gibson and others (1980) indicate that no large unconformities are present within the Pamunkey Group; however, several minor unconformities might exist. If they do exist, they are certainly not of the magnitude of the unconformity between the Early Cretaceous Potomac Formation and the late Paleocene Aquia Formation along the James and Appomattox Rivers.
Description from source map: Grant's Headquarters at City Point

Ta - Aquia Formation (Paleocene)

The Aquia Formation rests unconformably upon the irregularly eroded surface of the Potomac Formation sediments. The Aquia is unconformably overlain by the Nanjemoy Formation (Eocene). Locally, the Aquia Formation is overlain unconformably by unconsolidated Pleistocene deposits where the Nanjemoy and (or) younger Tertiary sediments have been removed by erosion. The Aquia Formation was named from Aquia Creek, a tributary of the Potomac River in Stafford County, Va (Clark, 1895, 1896). The best exposures of this unit occur along lower Aquia Creek and along the south bank of the Potomac River in Stafford and King George Counties, Va.

The Aquia Formation consists of massive, greenish-gray to greenishblack, fine to very fine, well-sorted sand. It is glauconitic and typically micaceous. Pods of glauconite-rich sand occur as concentrations in burrows. Molds of pelecypods and gastropods occur abundantly in some beds, but shell material is commonly poorly preserved, except for some calcitic forms. The unit weathers to a light-greenish-gray to reddishbrown. A representative section is exposed on the south bank of the James River, just east of Bailey Creek (pl. 1). A characteristic basal gravel in the Aquia consists of a bed containing rounded quartz pebbles and glauconitic sand from 0.5 to 3 m thick. The thickest section of the gravel occurs in the Sadler Materials borrow pits on the east bank of the Appomattox River. Typically along the James River, this basal gravel is 0.6-1.0 m thick. The upper contact of the Aquia is marked by a gradual increase in the silt and clay fraction, grading to the Marlboro Clay. This contact dips beneath the ground surface in the vicinity of Jordan Point. Elsewhere down dip, indurated shell and limestone lenses occur within the unit in the subsurface. In outcrop, the Aquia Formation is about 6 m thick on the James River south of Farrar Island. Along Ashton Creek it is 9-11 m thick. Thickness increases eastward from the representative section at Bailey Creek where at least 9 m is exposed.

The Aquia Formation is the lowermost of three units included in the Pamunkey Group (Paleocene and Eocene), the uppermost unit being the Nanjemoy Formation. These two greensands are separated locally by a middle unit of thin, massive, gray to red clay, known as the Marlboro Clay.

The Marlboro Clay is an excellent marker bed in the study area A representative section exists above the Aquia Formation just east of the mouth of Bailey Creek (pl. 1). At Bailey Creek, the clay is 3.4 m thick and varies from gray to pink. The lower contact is gradational from the glauconitic sand of the Aquia, to clay containing thin sand laminae, to the pure clay of the Marlboro over a 1-m interval. The upper contact is marked by numerous burrows filled with glauconitic sand and quartz and phosphate pebbles of the overlying Nanjemoy Formation. The relationships at the lower and upper contacts of the Marlboro Clay with the Aquia and Nanjemoy Formations respectively are observable throughout the study area Similar occurrences are noted in northern Virginia (R. B. Mixon, USGS, Reston, Va, oral commun., 1978) and in the Oak Grove core (Reinhardt and others, 1980b). These observations indicate that the Marlboro Clay is genetically related to the underlying Aquia Formation and, more realistically, that it should be treated as a separate unit rather than be included with the Nanjemoy Formation, as had been previously accepted (Darton, 1948). Glaser (1971) and Reinhardt and others (1980b) recommended that the Marlboro be defined as a separate unit because of its lithologic continuity and mappability over a considerable area of southern Maryland and Virginia.

Environment of Deposition
The Aquia Formation has yielded numerous and diverse marine fossils including invertebrates, fishes, and reptiles (Clark and Miller, 1912); molluscan assemblages predominate. At some localities glauconite may represent as much as 60 percent of the sand-sized fraction of the Aquia Teifke (1973) stated that the shape of glauconite grains in the Aquia suggests relatively slow accumulation. Clark and Miller (1912) believed that most of the Aquia was deposited in quiet and probably relatively deep water. Gibson and others (1980) found a very low diversity of only 16 foraminifera species, indicative of a shallow-marine environment, in the part of the Oak Grove core that is correlative to the Aquia in the Hopewell area However, the grain size, sorting, and bedforms of most of the Aquia in the Oak Grove core (Reinhardt and others, 1980b) tend to support Clark and Miller's conclusions.

Gastropod and pelecypod molds and a high percentage of glauconite characterize the Aquia Formation at Hopewell. Nearshore deposition along the western part of the study area is indicated by a 3.0- to 3. 7-m-thick layer of basal gravel in the vicinity of the Appomattox River and by an increase in quartz-pebble and cobble size within the greensands westward. The thick basal gravel along the Appomattox may represent the sediments of a paleo-river flowing into the shallow Aquia sea.

Nogan (1964) and Gibson and others (1980) interpreted foraminiferal data to indicate brackish water to less than normally saline water conditions at the time of deposition of the Marlboro; low dinoflagellate diversity and the abundance of two specific forms suggest an estuarine environment for the Marlboro. The presence of freshwater algae, reported by Gibson and others (1980), lends additional support for a brackish-water environment of deposition for the Marlboro Clay. These authors further suggest that the presence of a large number of fern spores in Marlboro samples indicates moist climatic conditions during deposition.

Stratigraphy
Reinhardt and others (1980b) observed that the Marlboro represents a considerable divergence in texture and mineralogy from the overlying and underlying greensands. They noted that key differences are abundant stable heavy minerals in the Marlboro, a high kaolinite content compared to the illite-and-smectite compositions characterizing the greensands, and the occurrence of reworked Paleozoic and Late Cretaceous palynomorphs in the Marlboro. They stated that these features suggest a strong extrabasinal influence. High rainfall could have produced increased runoff from low-lying and deeply weathered Piedmont and inner Coastal Plain terrain immediately to the west. This interpretation is compatible with Gibson and others' (1980) conception of a moist climate. Such an erosional event could have been responsible for a series of mudflows that blanketed the area Deposition would have been rapid, especially in comparison to that of the greensands, and would have preserved the color and mineralogy of much of the pink Marlboro Clay (Reinhardt, USGS, Reston, V a, oral commun., 1978).

Age
Within the coarser sands of the Aquia Formation are fragments of bone, shark and ray teeth, poorly preserved internal molds of gastropods (including Turritella mortoni) and pelecypods, and pelecypod

shell fragments. Worm tubes and echinoderm spines were also noted in places. L. W. Ward (USGS, Reston, V a, written commun., 1978) placed the Bailey Creek Aquia section in the upper Paleocene (Paspotansa Member of the Aquia Formation) on the basis of the occurrences of Ostrea sinuosa and Turritella mortoni. Calcareous nannofossils contained within the sediments were examined by T. R. Worsley (written commun., 1979). He found a low-diversity but wellpreserved assemblage of coccoliths indicating placement in zone NP 9 (Berggren, 1972) (uppermost Paleocene). The results of his findings are shown in table 1.

Sporomorph assemblages are found throughout the Marlboro Clay, and they provide the basis for dating the unit by correlation with assemblages from the Gulf Coast and southern Atlantic Coastal Plain (Frederiksen, 1979). The data suggest that the age of the uppermost part of the Marlboro is either latest Paleocene or earliest Eocene, perhaps representing slightly younger rocks than those previously studied in the southeastern United States (Gibson and others, 1980). Description from source map: Grant's Headquarters at City Point

Kp - Potomac Formation (Cretaceous)

Kp - Potomac Formation (Cretaceous)
Very light gray to grayish-pink, fine- to coarse-grained, poorly sorted, angular to subrounded quartzofeldspathic sand, partially indurated, which locally contains granules, pebbles, and cobbles. Sand is interbedded with thick, but locally discontinuous stringers of gravel and beds of polymictic conglomerate, containing rounded to well-rounded pebbles, cobbles, and boulders of quartz, metavolcanic rocks, granite and carbonaceous clay clasts in a grayish-green, massive to thick-bedded sandy clay and silt. Commonly thick-bedded and trough cross-bedded. Unit is interpreted to have been deposited in a proximal, fluvial-deltaic environment and outcrops in cliffs and drainages along the Appomattox River and its tributaries. The Potomac Formation lies unconformably on top of the Petersburg Granite and unconformably beneath younger Coastal Plain sediments. Formation thickness varies between 6 and 100 feet (1.8 and 30 meters) and thickens considerably to the east and southeast of the map area. Skolithos-bearing quartzite clasts are absent. Description from source map: Petersburg National Battlefield

Kp - Potomac Formation (Cretaceous)
The Potomac Formation is the basal unit of the Coastal Plain of Virginia, Maryland, Delaware, and southern New Jersey. Throughout the greater part of the Salisbury embayment, the Potomac nonconformably overlies a basement of Precambrian and Lower Paleozoic metamorphic and igneous rocks that are highly eroded and weathered to thick saprolite. The Potomac overlies Triassic and Jurassic rocks (of the Newark Group) near Doswell, V a. (Fontaine, 1896), and possibly in the subsurface of Caroline County, Va. (Cederstrom, 1945b). Several other possible occurrences of subsurface Triassic and Jurassic rocks have been noted underlying Charles, Prince George's, Wicomico, and Worcester Counties, Md. Sediments overlying the Potomac Formation vary widely in age. Overlying units include Upper Cretaceous sedimentary rocks of the Magothy and Severn Formations in northern Maryland and Paleocene, Eocene, Miocene, Pliocene, and Quaternary deposits in southern Maryland and Virginia.

The "Potomac Group," as originally defined by McGee (1885), occupied the interval between the Newark Group and the Cretaceous greensands of New Jersey and was separated from each by a hiatus. Darton (1891, 1893) and Ward (1895) retained the "Potomac Group." Clark and Bibbins (1897), introducing a terminology that has survived to the present in Maryland, divided the "Potomac Group" into four formations: the Patuxent, Arundel, Patapsco, and Raritan. These formations are not recognized in Virginia, where the entire Cretaceous section is referred to as the Potomac Formation.

In the James-Appomattox River region of Virginia, the Potomac Formation consists of alternating sequences of very light gray to white, medium to very coarse grained feldspathic sand, gravel, and silty to sandy clay. These sediments show lithologic variations over short distances, both laterally and vertically. The gravels are commonly very coarse, and the sands are often trough crossbedded and contain a considerable clayey-silt fraction. Individual sand-sized grains are mostly angular quartz, although feldspar may constitute as much as 40 percent or more of the sand grains in some outcrops.

Bedding was observed in virtually all fresh exposures of these sediments. Curved bedding planes defining lenticular sedimentation units were commonly found in gravels and crossbedded sands. Undulatory bedding is generally associated with finer grained deposits and may reflect sediment accumulation on irregular surfaces. However, the common occurrence of contorted and disrupted bedding suggests that penecontemporaneous slumping and compaction are responsible for some irregularities. The occurrence of large-scale inclined bedding in thick gravels and in interstratified coarse sands and gravels (fig. 7) is typical of sedimentation in braided river channel deposits (and in point and channel bars) (Glaser, 1969).

Clay clasts are quite common in the coarse clastic beds and may be rounded, angular, or flattened. They occur in virtually all of the gravel beds and in most of the sand units as scattered chips and are concentrated along bedding planes and the basal parts of beds. The clasts usually contain no internal structure, although some exhibit secondary Liesegang banding. Uncommonly, smaller clay balls are armored with pebbles.

Scoured and filled troughs are prevalent in the sands, and the filled channels commonly contain coarse-grained to pebbly sand, typically having concentrations of pebbles, cobbles, or clay clasts at the base. Figure 8 shows an excellent example of this type of channel fill, as exposed near Point of Rocks.

Lignitized coniferous wood and a well-preserved microflora are abundant in the gray to black clays and clayey silts of the Potomac Formation. Fragments of lignite and petrified wood pseudomorphs range in size from splinters to small logs. The wood is replaced by hematite, limonite, pyrite, marcasite, or quartz. Cellular structure is commonly preserved.

Liesegang banding is a common secondary structure in the Potomac sediments, both in the sands and the clays. Patterns of parallel, closely spaced bands of yellow, brown, or purple limonite-cemented or -coated sediment may be mistaken in the field for cross bedding in the absence of well-defined textural stratification.

Potomac gravels are composed mostly of subrounded pebbles and cobbles of vein quartz, quartzite, or quartz sandstone. A small percentage of other rocks, such as chert, thoroughly weathered pebbles of quartzo-feldspathic, gneissic, or granitic rocks, and several metavolcanic and low-grade metamorphic rock types are also found. These gravel deposits are typically interbedded with arkosic sands and at some localities contain boulders nearly 0.5 m in diameter, indicating transport and abrasion over relatively short distances. The nonresistant boulders have been weathered to saprolite.

Indurated ledges produced by clay cementation in the arkoses and subarkoses are found on well-drained slopes along the major rivers. These rocks crop out at Point of Rocks on the Appomattox River, along the south bank of the abandoned James River channel around Farrar Island, and near Halls Island on the east bank of the Appomattox River (pl. 1).

The Potomac Formation thickens southeastward across the study area from approximately 30 m along the western margin to nearly 107m at the eastern edge. A major disruption in the altitude of the upper contact with the overlying Aquia Formation occurs along a line generally paralleling the north-trending reach of the Appomattox River, as shown by the structure contours (fig. 9). The upper contact dips beneath the ground surface in the vicinity of the crossing of the Appomattox River by Virginia Route 10 at Hopewell.

<u>Environment of Deposition</u>
Depositional environments within the Potomac Formation have been studied by a number of workers including Fontaine (1896), Clark and Bibbins (1897), Berry (1906, 1911), Hansen (1968), Glaser (1969), and Reinhardt and others (1980a). Clark and Bibbins (1897) concluded that the coarse basal parts of the unit indicated rapid deposition in shallow water. They envisioned the existence of an extensive sound, embayment, or estuarine environment, or combinations of these environments, along the mid-Atlantic coast. Glaser (1969) demonstrated that the Potomac sediments were deposited in a

complex fluvial and deltaic environment. The petrographic and palynologic study of Reinhardt and others (1980a) suggests the migration of major fluvialdeltaic lobes progressively northward in Aptian through Cenomanian time.

A coarse biomodal sorting of the sediments, abundant plant fragments, scour-and-fill structures, clay-clast conglomerates, and lenticular bedding all compare with the modem alluvial valley-fill of the Mississippi River, as described by Fisk (1944). The general lack of siltclay strata in the lower part of the Potomac Formation may result from the dominance of bedload deposition and limited flood-plain sedimentation. The large-scale inclined bedding, particularly in the gravels and coarse pebbly sands, is similar to the bedding in the channel bars of braided rivers described by Doeglas (1962). Intraformational clay clasts in Potomac sands and gravels indicate rapid channel-shifts and erosion of cohesive clay banks. Perhaps rapid channel-shifting accounted for the paucity of overbank fine-grained sediment. Fining-upward point-bar and channel-bar sequences are typically truncated, further indicating rapidly shifting channels.

Age
Analyses of pollen samples from carbonaceous clayey silts within the Potomac Formation in the study area have yielded Early Cretaceous ages equivalent to pollen zone I (Barremian to Aptian) and zone II-B (lower to middle Albian), as defined by Doyle and Robbins (1977) and Brenner (1963) (R.A. Christopher, USGS, Reston, Va, written commun., 1979). Most of the samples contained a moderately abundant and diverse terrestrially derived microflora No dinoflagellate cysts or acritarchs were observed, indicating a lack of marine influence. One assemblage was dominated by Classopollis torosus, which, with the presence of monocolpate angiosperm pollen and the absence of tricolpate and tricolporate angiosperm pollen, is the primary basis for assignment to zone I (Barremian to Aptian). The tricolpate angiosperm pollen first appeared at the very top of zone I, and they dominate this and younger assemblages. The repeated absence of these species in the samples, coupled with the presence of several other guide fossils such as Kuylisporites lunaris and Equisetosporites uirginiaensis, provided Christopher sufficient data for assignment to zone I.

One sample from the Sadler Materials quarry contained a low frequency of tricolpate angiosperm pollen species, including Tricolpites albiensis, T. crassimurus, "Retitricolpites" uermimurus, and Tricolpopollenites paruulus. All of these species first occur in pollen subzone II-A, and all extend into subzone II-B (lower Albian).

A sample from the Lone Star quarry yielded tricolpate grains having wider variety and greater frequency than those of the Sadler Materials quarry sample, and one species not previously recorded from below subzone II-B (Ajatipollis sp. A). Tricolpate grains also included Tricolpites micromunus, T. albiensis, T. sagax, T. crassimurus, "Retitricolpites" uennimurus, and "R." magnificus (?). Based on the presence of Ajatipollis sp. A and the higher relative frequency and greater diversity of tricolpates, Christopher placed this sample in the basal part of subzone II-B (lower to middle Albian). Description from source map: Grant's Headquarters at City Point

PNMpg - Petersburg Granite (Pennsylvanian and Mississippian)

PNMpg - Petersburg Granite (Pennsylvanian and Mississippian)
Light bluish-gray, fine- to coarse-grained, subidiomorphic to locally porphyritic granite with coarse to very coarse pale pink potassium feldspar phenocrysts up to 12 inches (30 cm) in length, within a light-bluish gray subidomorphic matrix composed of quartz, plagioclase, potassium feldspar, muscovite, biotite, hornblende, zircon, epidote, carbonate, and traces of ilmenite/magnetite, apatite, and garnet. Unit locally contains pods and lenses of foliated, texturally and compositionally layered granite; layering ranges from 0.4 to 12 inches (1 to 30 cm) in thickness. Quartz exhibits undulatory extinction in thin section but with no apparent foliation. Weathers to smooth, rounded boulders and bedrock pavement. Description from source map: Petersburg National Battlefield

PNMa - Amphibolite (Pennsylvanian and Mississippian)

PZa - Amphibolite (Pennsylvanian and Mississippian)
Dark gray, fine- to medium-grained amphibolite. In thin section rocks contain amphibole, plagioclase, microcline, titanite, epidote, quartz and opaque minerals. Opaque minerals are found mostly within the amphibole grains in thin section and represent ~3% of the modal mineralogy. Interpreted as a metamorphosed basalt xenolith within the Petersburg Granite. Description from source map: Petersburg National Battlefield

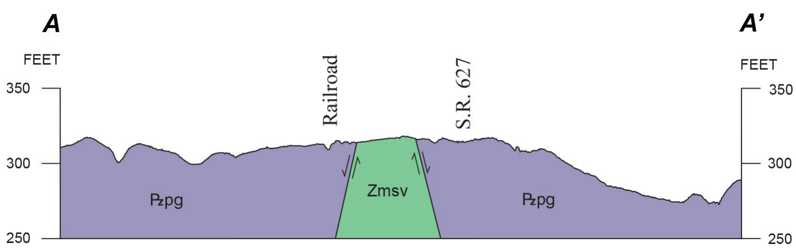
Zmsv - Metasedimentary and metavolcanic rocks, undifferentiated (Neoproterozoic)

Light greenish-gray to dark brown phyllite; fine-grained quartz matrix with fine-grained mica and chlorite grains showing a weak to moderate foliation in hand sample. Thin section reveals quartz, chlorite, and muscovite, which shows a weak to strong foliation defined by chlorite and muscovite. Cordierite was found in abundance in one thin section. Zircon is present as an accessory mineral within muscovite and chlorite, has a characteristic metamict appearance. Description from source map: Petersburg National Battlefield

Geologic Cross Sections

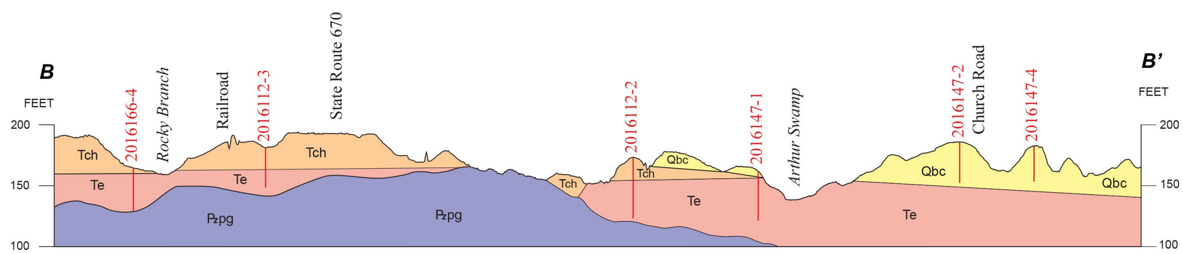
The geologic cross sections present in the GRI digital geologic-GIS data produced for Petersburg National Battlefield, Virginia (PETE) are presented below. Note that some cross section abbreviations (e.g., A - A') have been changed from their source map abbreviation in the GRI data so that each cross section abbreviation in the GRI data is unique. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).

Cross Section A-A'



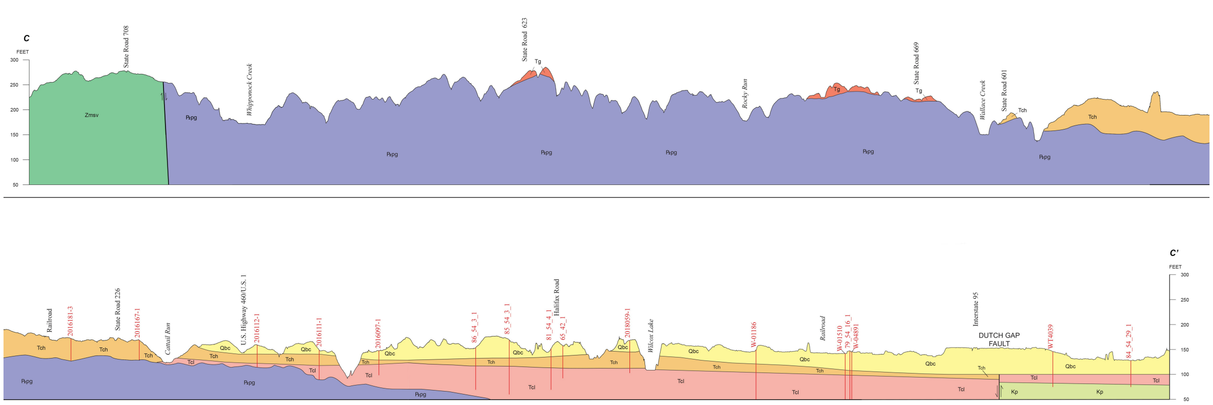
20X vertical exaggeration. *Graphic from source map:* Petersburg National Battlefield

Cross Section B-B'



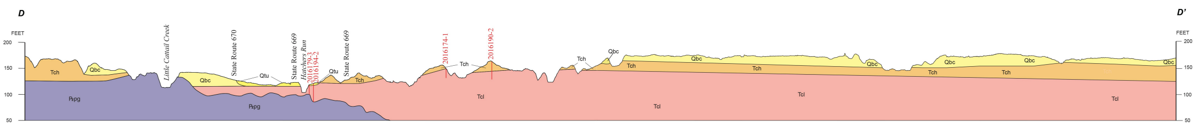
20X vertical exaggeration. *Graphic from source map:* Petersburg National Battlefield

Cross Section C-C'



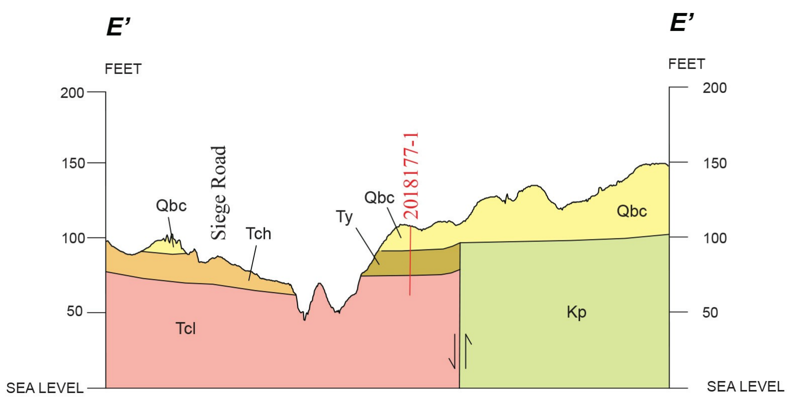
20X vertical exaggeration. For display purposes the cross section graphic is split into two graphics because of its length. *Graphic from source map:* [Petersburg National Battlefield]

Cross Section D-D'



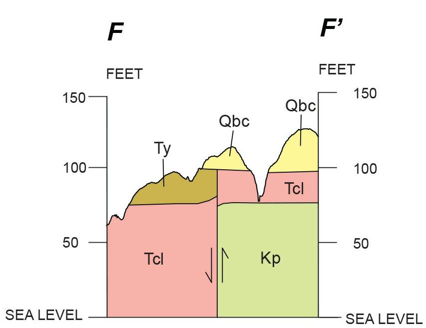
20X vertical exaggeration. *Graphic from source map:* [Petersburg National Battlefield]

Cross Section E-E'



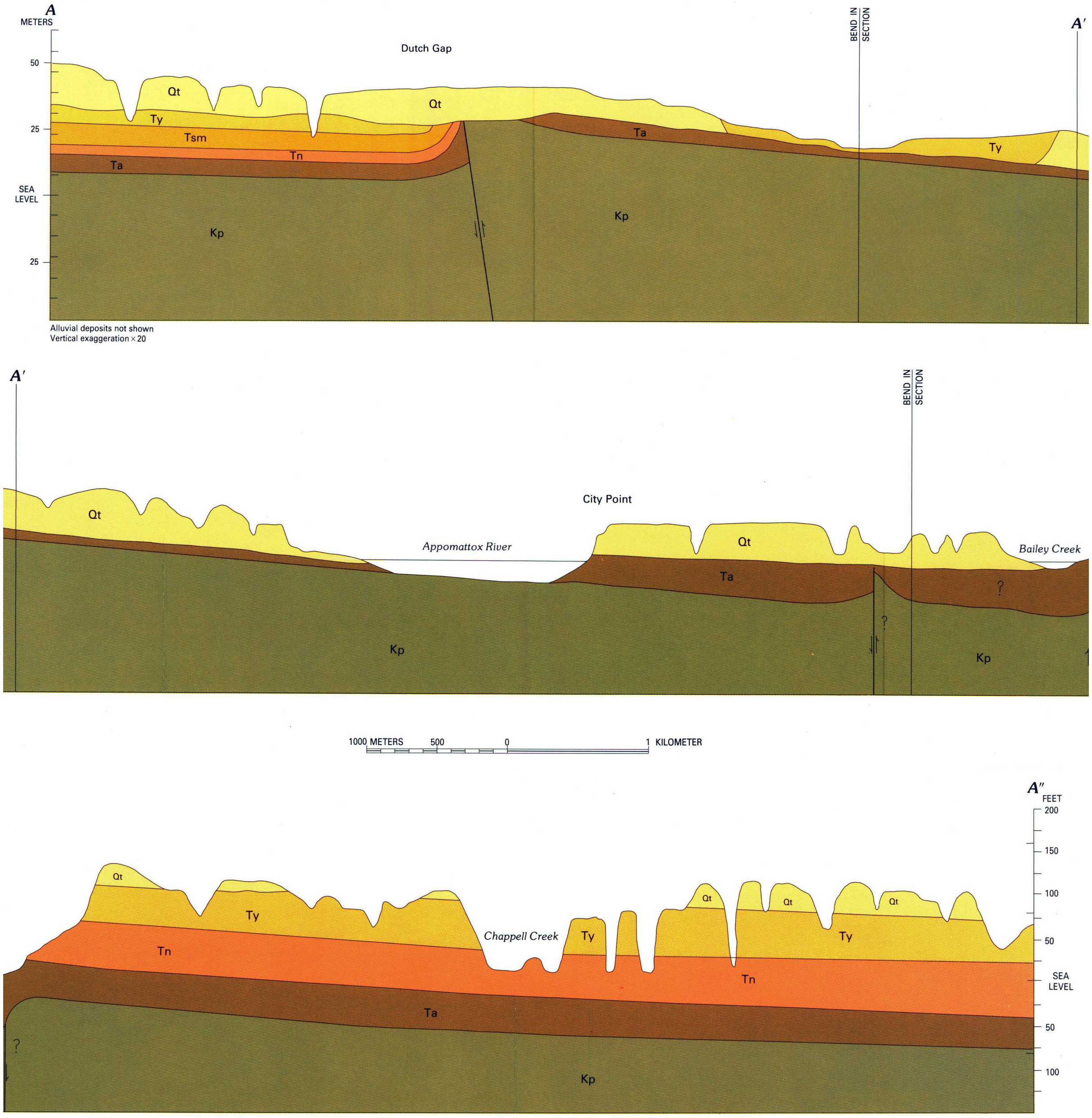
20X vertical exaggeration. *Graphic from source map:* [Petersburg National Battlefield]

Cross Section F-F'



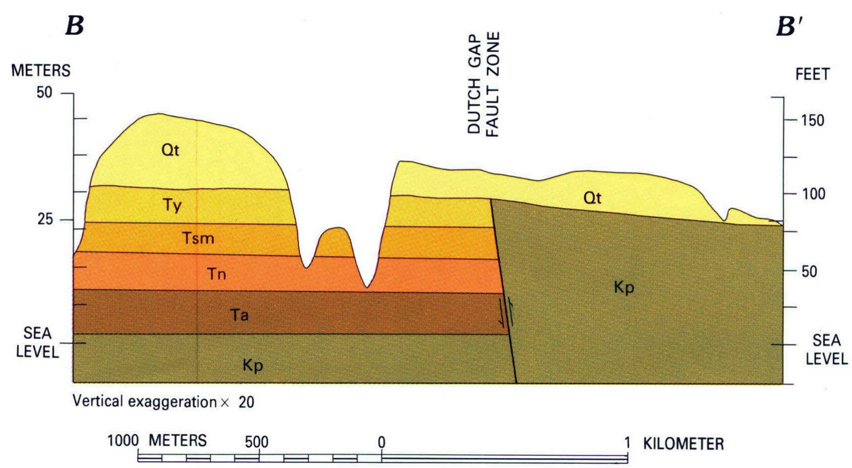
20X vertical exaggeration. *Graphic from source map:* [Petersburg National Battlefield]

Cross Section G-G'-G"



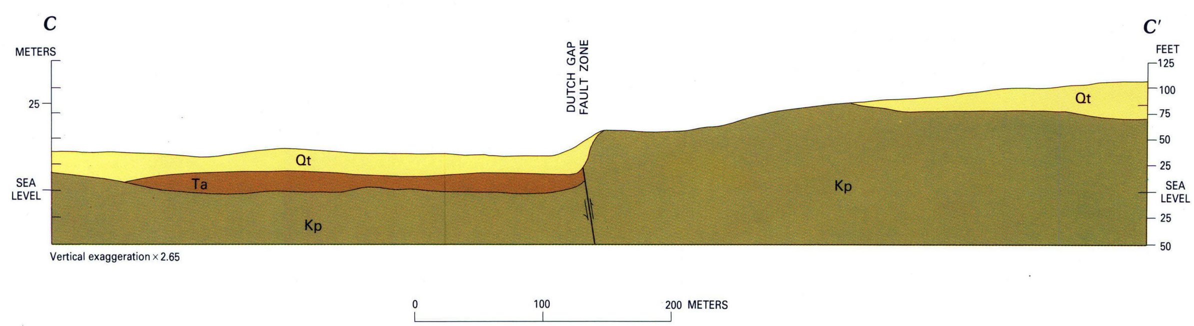
Cross section A-A'-A" on source map. 20X vertical exaggeration. For display purposes the cross section graphic is split into three graphics because of its length. *Graphic from source map:* [Grant's Headquarters at City Point](). Of note, only a portion of the above cross section are within the extent of the GRI digital geologic-GIS data.

Cross Section H-H'



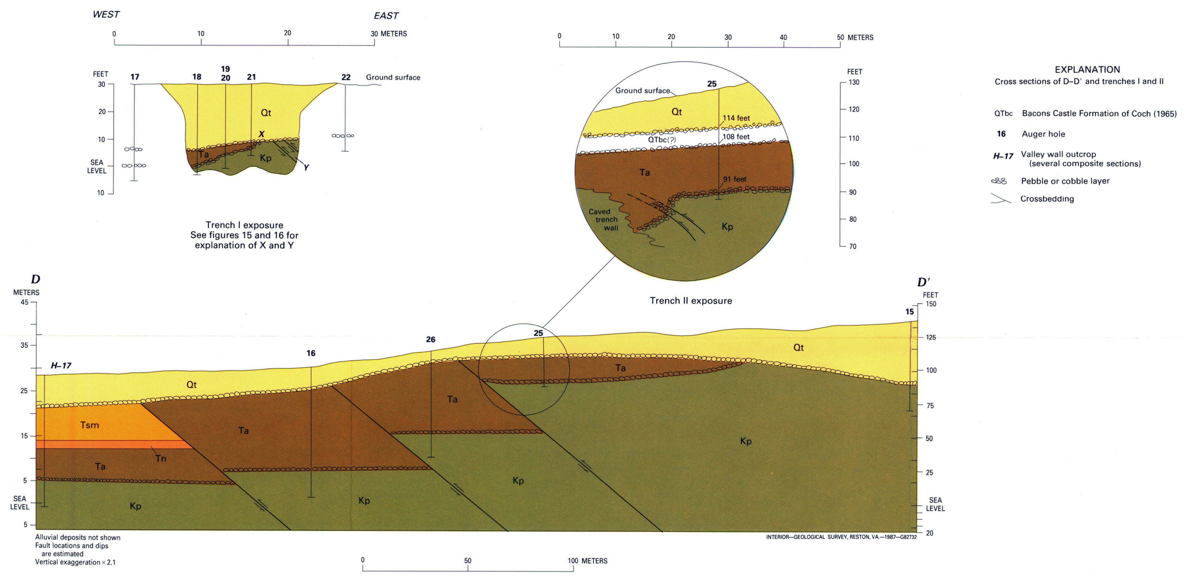
Cross section B-B' on source map. 20X vertical exaggeration. *Graphic from source map:* [Grant's Headquarters at City Point]

Cross Section I-I'



Cross section C-C' on source map. 2.65X vertical exaggeration. *Graphic from source map:* [Grant's Headquarters at City Point]

Cross Section J-J'



Cross section D-D' on source map. 2.1X vertical exaggeration. *Graphic from source map:* Grant's Headquarters at City Point

Auger Holes

All auger holes present on the source map were captured in the GRI digital geologic-GIS data. Auger holes 15, 16, 18-22, 25, and 26 are only present on Cross Section J-J' and trench 1 (see the Geologic Observation Localities (CIPOGOL) data layer in the GRI digital geologic-GIS data for the location of trench 1).

GRI Ancillary Source Map Information

The following sections present ancillary source map information associated with source maps used for this project.

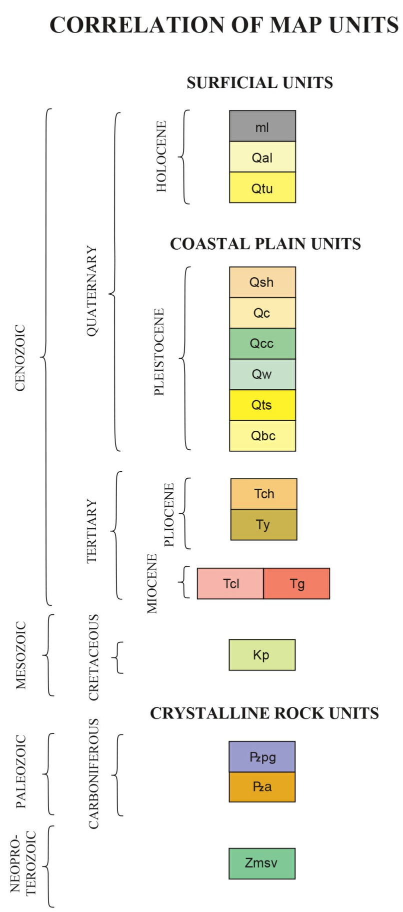
Petersburg National Battlefield

The formal citation for this source.

Occhi, M.E., Berquist, C.R., Latane, V.M., and Blanchette, J.M., 2018, Geologic Map of the Petersburg National Battlefield and Adjacent Areas, Virginia: Virginia Division of Geology and Mineral Resources, Publication Date: 2018, scale 1:24,000 (*GRI Source Map ID 76287*).

Prominent graphics and text associated with this source.

Correlation of Map Units



Graphic from source map: Petersburg National Battlefield

Map Legend

MAP SYMBOLS

For all contact symbols: lines are solid where the location is exact, long-dashed where the location is approximate, short-dashed where the location is inferred; dotted where the location is concealed.

Stratigraphic Contacts

Normal Fault Contact- ball and bar on downthrown block

U D Fault Contact - U on upthrown block and D on downthrown block

Landslide feature - bar indicates headscarp location and arrows indicate direction of motion

Geologic Observations

59 Strike and dip of inclined metamorphic foliation

35 Strike and dip of inclined igneous foliation

80 Strike and dip of inclined joint

Strike of vertical joint

Mineral Resources - commodity letter symbol precedes identification number (s - sand, sg - sand and gravel, cs - crushed stone)

070B-301 Active sand and gravel pit

069B-604 Abandoned sand and gravel pit

069B-208 Active quarry or open pit

069B-205 Abandoned quarry or open pit

Geologic References

R-11112 R number Identification number - cataloged sample

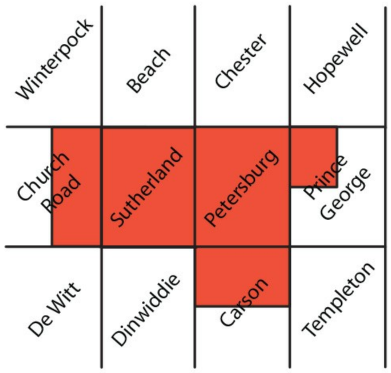
2018166-1 Geologic borehole in the VDGMR borehole database completed during the mapping for this quadrangle (ID always formatted as 201XXXX-X)

83_54_8_1 Geologic log from Virginia Department of Transportation record

W-05141 Geologic log from VDGMR borehole database which predates the mapping period (location identifier can begin with “W”, “WT”, “B” or “G” or a number).

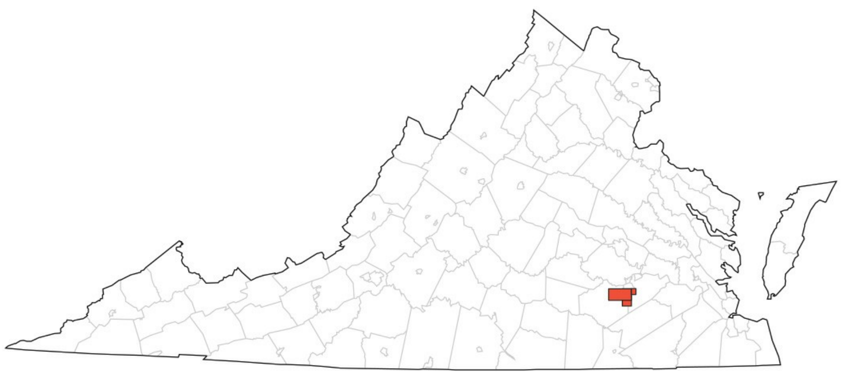
Graphic from source map: Petersburg National Battlefield

Index Map



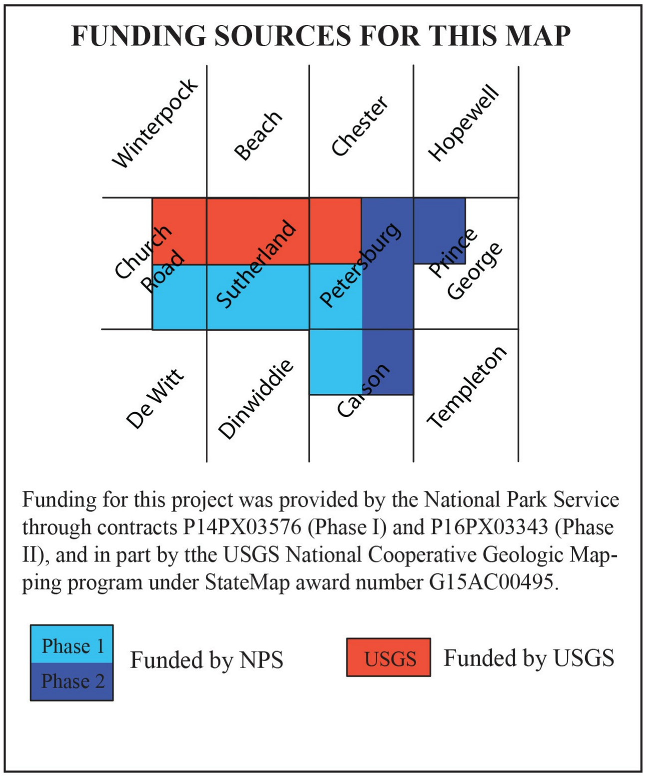
Graphic from source map: [Petersburg National Battlefield]

Location Map



Graphic from source map: [Petersburg National Battlefield]

Funding Sources



Graphic from source map: Petersburg National Battlefield Of note, NPS funding was from the Geologic Resources Inventory (GRI) program.

Report

The major sections of the report associated with the source map is presented below.

List of Figures
Introduction
Project Deliverables
Location and Geologic Setting
Data Collection Methods
Geologic Discussion
Acknowledgments
References

An embedded PDF document of the report can be accessed by double-clicking the following document link.

Geology of the Petersburg National Battlefield and Adjacent Areas

Geochemical Analysis of Repository Samples

Locations of geochemical repository samples are present in the Geologic Sample Localities (petegsl) data layer in the GRI Digital Geologic-GIS Map of Petersburg National Battlefield and Vicinity, Virginia. Geochemical analysis of the samples, identified by their sample number (e.g., R-11093), is presented in the report associated with this source map.

The analysis consists of major element composition of 18 sediment samples from the Church Road, Petersburg, and Sutherland quadrangles.

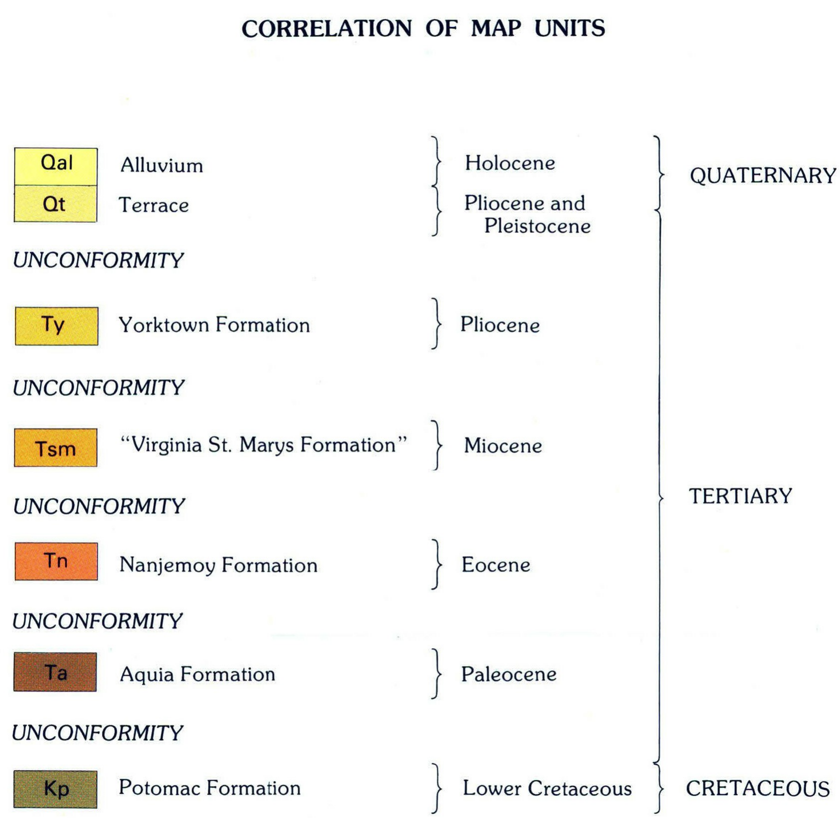
Grant's Headquarters at City Point

The formal citation for this source.

Dischinger, J. B., 1987, Late Mesozoic and Cenozoic Statigraphic and Structural Framework near Hopewell, Virginia: U.S Geological Survey, Bulletin 1567, scale 1:24,000 (*GRI Source Map ID 2430*).

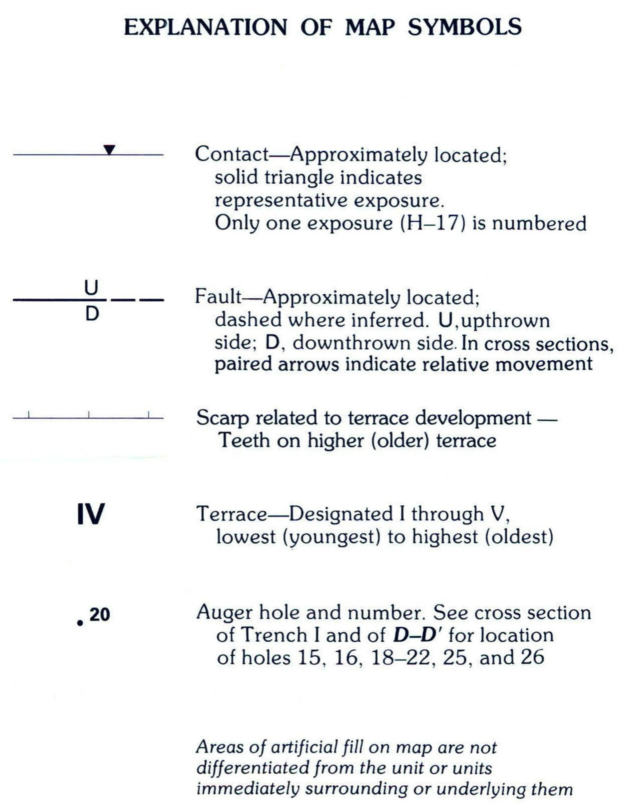
Prominent graphics and text associated with this source.

Correlation of Map Units



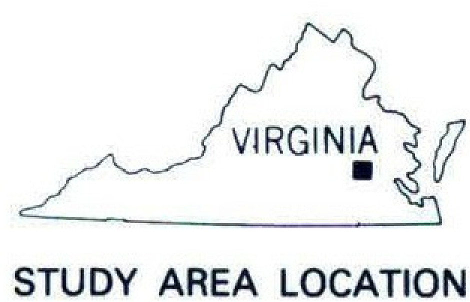
Graphic from source map: Grant's Headquarters at City Point

Map Legend



Graphic from source map: Grant's Headquarters at City Point

Study Area



Graphic from source map: Grant's Headquarters at City Point

Report

The sections of the report associated with the source map is presented below.

Abstract
Introduction
Deformation of Coastal Plain Sediments
Physiography
Stratigraphy
Structural Geology
Summary
References Cited

An embedded PDF document of the report can be accessed by double-clicking the following document link.

Bulletin 1567

Accuracy of Mapping

In 2016, Berquist and Cross completed a report on the accuracy and relevance of geologic mapping that covers the National Park Service properties at City Point and Parker's Battery found in U.S. Geological Survey Bulletin 1567 (Dischinger, 1987). An embedded PDF document of that report can be accessed by double-clicking the following document link.

Report on the Accuracy and Relevance of legacy mapping (covering the City Point and Parker's Battery Units).

Note: Parker's Battery is not included in the Digital Geologic-GIS Map of Petersburg National Battlefield and Vicinity or the Digital Geologic-GIS Map of Grant's Headquarters at City Point, Petersburg National Battlefield.

Pliocene and Pleistocene Terrace Sequences

At least five terrace surfaces are recognized in the study area These surfaces border the major drainages of the James and Appomattox Rivers. The terrace surfaces range in altitude from 3 to 55 m. Four scarps, which identify the surfaces, are also recognized. Terrace materials beneath the surfaces unconformably overlie all of the Cretaceous and Tertiary units found in the area (fig. 11). These sediments constitute the youngest rocks at any given locality.

The terrace surfaces have been numbered from I to V (lowest to highest in altitude) for purposes of this report. These surfaces rise between scarps and increase in altitude westward toward the Fall Zone.

The terrace materials underlying these surfaces are primarily combinations of sandy clays, laminated clayey silts and sands, crossbedded sands, and pebble to cobble gravels, which are all typically highly oxidized to various hues of yellow and orange. These deposits are thought to represent nearshore, fluvial-estuarine depositional systems associated with the various sea-level changes that occurred during the Pliocene and Pleistocene Epochs. Some of the terrace IV sediments may represent the regressive phase of the Pliocene Yorktown Formation.

The highest terrace in the study area is terrace V. Its surface altitude ranges from 43 to 55 m (fig. 5). Slightly higher surfaces west of the study area may be remnants of this surface. The sediments underlying the terrace V surface are at least 12 m thick. They are characterized by abundant trough crossbeds, cut-and-fill structures, repeated fining-upward sequences, and truncated sequences, indicating fluvial deposition.

The terrace-V surface encompasses the area upon which Fort Lee (south of the study area) has been built. A small part of this terrace extends northward from the south edge of the map area near long 77° 14' (pl. 1). The western part of "peninsular" Chesterfield County, roughly between the old James River channel south of Farrar Island and the Appomattox River at Ashton Creek (pl. 1) is also covered by the terrace V surface. The material underlying this surface was called marine sand and gravel by Shaler (1890). It was also referred to by Darton (1891) as the fluvial "Lafayette Formation." Wentworth (1930) revived Clark and Miller's (1906) terminology, designating the terrace plain as the "Sunderland terrace" and the underlying materials as the Sunderland Formation. Moore (1956) returned to Rogers' (1884) earlier concepts of terrace formation in designating these deposits as the fluvial part of the fluvial-marine "Kilby Formation." More recently, Oaks and others (1974) abandoned all previous terminology, believing that the terrace and the underlying materials were not necessarily related. As a result, they named the surface the Prince George upland and the sediment underlying this surface the fluvial Bacons Castle Formation of Coch (1965).

The second-highest terrace surface (terrace IV) ranges in altitude from 27 to 43 m. Terrace IV is cut into the higher and older terrace V. This surface can be subdivided into two benches (IV a and IVb) along the east bank of the Appomattox River. Sediments underlying the surface are approximately 15 m thick and show fluvial characteristics similar to terrace V materials (fig. 12). Unlike terrace V sediments, terrace IV sediments are commonly quite feldspathic. The terrace materials are best exposed in several borrow pits along the old James River channel around the south margin of Farrar Island.

Terrace IV sediments underlie the terrain along the Norfolk and Western Railway from Kenwood subdivision to Petersburg. The headwaters of Bailey Creek cut the terrace south of Hopewell. Although the sediments underlying this plain commonly reflect a fluvial depositional environment, at several localities these deposits have marine, or at least estuarine, affinities. Generally, these deposits can be mapped as a fluvial part (regressive phase) of the Pliocene Yorktown Formation. Various earlier names for terrace IV sediments include the Columbia Group of Darton (1891), the marine part of the "Kilby Formation" of Moore (1956), the "Wicomico terrace sediments" of Clark and Miller (1906) and Wentworth (1930), and the Isle of Wight Plain underlain by the lagoonal Windsor Formation of Coch (1968; and Oaks and others, 1974).

Terrace III has surface altitudes ranging from 14 to 27m. Sediments underlying this surface are approximately 14 m thick and are characterized mostly by fluvial sedimentary structures. The terrace extends from the Appomattox River Bridge to near Cabin Creek in Hopewell and is dissected by Johnson Creek in Chesterfield County between the James and Appomattox Rivers.

Terrace II exists as an arcuate middle land between the lower terrace of Bermuda Hundred and terrace III near the mouth of Shand Creek (pl. 1). The terrace II surface ranges in altitude from 9 to 14m. Several smaller patches of terrace II occur near the mouth of Johnson Creek. The most extensive occurrences of terrace II are just above water level from Bailey Creek to City Point in Hopewell, and along the west bank of the Appomattox River south of Point of Rocks. The sediments underlying this surface have exclusively fluvial characteristics and occur in older dissected channel and point-bar deposits. The deposits define early courses of the James and Appomattox Rivers.

The lowest terrace (terrace I) ranges in surface altitude from 3 to 9 m. Terrace I generally abuts Holocene alluvial fill or a cut bank along the James and Appomattox Rivers. Terrace I sediments completely underlie Jordan Point on the James and Bermuda Hundred near the Turkey Island Cutoff, compose a major part of Curies Neck, and occupy both banks of the Appomattox south of Point of Rocks. These materials, like those underlying terrace II, are exclusively fluvial.

Text from source map: Grant's Headquarters at City Point

Scarp Toe Elevations

As previously mentioned, terrace units present on this source map were re-mapped and/or re-interpreted by C.R. Berquist (Virginia Division of Geology and Mineral Resources, personal communication, 2019) based on the uppermost surface and scarp toe elevations. The table below lists elevations (in feet) used to re-map and/or re-interpret such terrace units.

Name and symbol	Uppermost surface and scarp toe, feet
Cold Harbor Nch	~240
Bacons Castle Qbc	~170
?Moorings? Qm	~115
Windsor Qw	98
Charles City Qcc	75
Chuckatuck Qc	58
Shirley Qsh	48
Elsing Green Qeg	38
Tabb, Sedgefield Qts	28
Tabb, Lynnhaven Qtl	18
Tabb, Poquoson Qtp	6-11

Provided by C.R. Berquist, 2019.

GRI Digital Data Credits

This document was developed and completed by James Winter (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Quality control of this document by Stephanie O'Meara (Colorado State University).

The information in this document was compiled from GRI source maps, and is intended to accompany the digital geologic-GIS maps and other digital data for Petersburg National Battlefield, Virginia (PETE) developed by James Winter, Sarah Lowe, Stephanie O'Meara, and Jake Suri (Colorado State University) (see the GRI Digital Maps and Source Map Citations section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps).

GRI finalization by Stephanie O'Meara.

GRI program coordination and scoping provided by Jason Kenworthy and Tim Connors (NPS GRD, Lakewood, Colorado).