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National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Richmond National Battlefield Park

GRI Ancillary Map Information Document

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

rich_geology.pdf

Version: 3/24/2014

Geologic Resources Inventory Map Document for Richmond National Battlefield Park

Table of Contents

Geologic Resources Inventory Map Document 1
About the NPS Geologic Resources Inventory Program 2
GRI Digital Map and Source Map Citations 4
Map Unit List 5
Map Unit Descriptions 7
Qml - Modified land (Holocene) 7
Qal - Alluvium (Pleistocene to Holocene) 7
Qcb - Carolina Bay (Pleistocene to Holocene) 8
Qts - Tabb Alloformation, Sedgefield Member (Pleistocene) 8
Qsh - Shirley Alloformation (Pleistocene) 8
Qc - Chuckatuck Alloformation (Pleistocene) 9
Qcc - Charles City Alloformation (Pleistocene) 9
Qw - Windsor Formation (Pleistocene) 10
QTg4 - Quaternary-Tertiary gravels (upper Pliocene to lower Pleistocene) 10
Tbc - Bacons Castle Formation (upper Pliocene) 11
Tg3 - Low-Level Tertiary gravels (upper Pliocene) 11
Ty - Yorktown Formation (Pliocene) 12
Tym - Yorktown Formation, Moore House Member (Pliocene) 12
Tcsg - Upper Chesapeake Group sand and gravel (Pliocene) 12
Tccl - Lower Chesapeake Group clayey silt (Miocene) 13
Te - Eastover Formation (Miocene) 14
Tc - Calvert Formation (Miocene) 14
Tl - Lower Tertiary Sediments, undivided (Oligocene, Eocene, and late Paleocene) 14
Toc - Old Church Formation (Oligocene) 15
Tpp - Piney Point Formation (Eocene) 15
TK - Tertiary and Cretaceous (?) sediments (Tertiary and Cretaceous) 15
Kp - Potomac Formation (Cretaceous) 15
Petersburg Granite 16
MPNpg - Petersburg Granite, subidiomorphic granite (Mississippian to Pennsylvanian) 16
MPNpp - Petersburg Granite, porphyritic granite (Mississippian to Pennsylvanian) 17
MPNpf - Petersburg Granite, foliated granite (Mississippian to Pennsylvanian) 17
MPNpl - Petersburg Granite, layered granite gneiss (Mississippian to Pennsylvanian) 17
MPNpm - Petersburg Granite, megacrystic granite (Mississippian to Pennsylvanian) 18
Geologic Cross Sections 19
Cross Section A-A' 19
Cross Section B-B' 19
Cross Section C-C' 19
Cross Section D-D' 20
Cross Section E-E' 20
Cross Section F-F' 20
Cross Section G-G' 21
Cross Section H-H' 21
Cross Section I-I' 21
Cross Section J-J' 22

Geologic Section and Photographic Localities **23**
Stratigraphic Section Locality 1 23
Geologic Photograph Locality 2 24
Geologic Photograph Locality 3 24
Geologic Photograph Locality 4 25
Geologic Photograph Locality 5 25
Geologic Photograph Locality 6 26
GRI Source Map Information **28**
Drew rys Bluff 7.5' Quadrangle 28
Drew rys Bluff Correlation of Map Units 28
Drew rys Bluff Index Map 29
Drew rys Bluff Map Symbols 29
Drew rys Bluff References 30
Dutch Gap 7.5' Quadrangle 31
Dutch Gap Correlation of Map Units 31
Dutch Gap Index Map 32
Dutch Gap Map Symbols 32
Dutch Gap References 32
Richmond 7.5' Quadrangle 33
Richmond Correlation of Map Units 34
Richmond Index Map 35
Richmond Map Symbols 35
Richmond References 36
Roxbury 7.5' Quadrangle 36
Roxbury Correlation of Map Units 37
Roxbury Index Map 38
Roxbury Map Symbols 38
Roxbury References 38
Seven Pines 7.5' Quadrangle 39
Seven Pines Correlation of Map Units 40
Seven Pines Index Map 40
Seven Pines Map Symbols 41
Seven Pines References 41
GRI Digital Data Credits **43**

Geologic Resources Inventory Map Document

Richmond National Battlefield Park, Virginia

Document to Accompany Digital Geologic-GIS Data

rich_geology.pdf

Version: 3/24/2014

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

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.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park 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://www.nature.nps.gov/geology/inventory/gre_publications.cfm

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: http://www.nature.nps.gov/geology/inventory, 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 Map and Source Map Citations

The GRI digital geologic-GIS map for Richmond National Battlefield Park, Virginia (RICH):

GRI Digital Geologic Map of Richmond National Battlefield Park and Vicinity, Virginia (*GRI MapCode RICH*)

The GRI digital data and map produced from the following, yet unpublished Virginia Division of Geology and Mineral Resources digital maps and datasets,

Bondurant, A.K., Berquist, C.R., Carter, M.W., and Bleick, H.A., 2011, Geologic Map of the Drewrys Bluff Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2011 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (Drewry's Bluff 7.5' Quadrangle). (*GRI Source Map ID 75764*).

Berquist, C.R., and Carter, M.W., 2009, Geologic Map of the Dutch Gap Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2008 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (Dutch Gap 7.5' Quadrangle). (*GRI Source Map ID 75763*).

Bleick, H.A., Carter, M.W., and Berquist, C.R., 2007, Geologic Map of the Richmond Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2006 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (Richmond 7.5' Quadrangle). (*GRI Source Map ID 75761*).

Gilmer, A.K., and Berquist, C.R., 2011, Geologic Map of the Roxbury Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2011 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (Roxbury 7.5' Quadrangle). (*GRI Source Map ID 75762*).

Bondurant, A.K., Bleick, H.A., Berquist, C.R., and Carter, M.W., 2011, Geologic Map of the Seven Pines Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, Open File Report 11-__, unpublished map and digital data, scale 1:24,000. (Seven Pines 7.5' Quadrangle) (*GRI Source Map ID 75760*).

Notes: All of the aforementioned maps are unpublished and have not been reviewed for conformity with the Virginia Division of Geology and Mineral Resources publication standards. Features in 1:24,000 scale data may be off up to 12.2 meters or 40 feet from their actual location based on National Map Accuracy standards. However, the GRI noticed that some shoreline and modified land (ml) features are even further off from imagery, sometimes up to 30 meters or 98 feet. Although few and far between, there are also some edge-matching problems between the Dutch Gap and Roxbury 7.5' quadrangles. These problems are a byproduct of the ever-changing naming and grouping of units in this area by the mapping geologists.

For a few geologic contacts on the Richmond 7.5' quadrangle the source map below was used to verify positional accuracy.

Daniels, P.A., Jr., 1974, Geologic Map of the Richmond quadrangle, Virginia, in Daniels, P.A. Jr., and Onuschak, E., 1974, Geology of the Studley, Yellow Tavern, Richmond and Seven Pines quadrangles, Virginia: Virginia Division of Mineral Resources, Report of Investigations 38, 75 p., 4 maps at 1:24,000-scale, 10 plates.

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

Map Unit List

The bedrock geologic units present in the digital geologic-GIS data produced for Richmond National Battlefield Park, Virginia (RICH) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). 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 (RICHUNIT) table included with the GRI geology-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
Qcb - Carolina Bay
Qts - Tabb Alloformation, Sedgefield Member
Qsh - Shirley Alloformation
Qc - Chuckatuck Alloformation
Qcc - Charles City Alloformation
Qw - Windsor Formation

Quaternary and Tertiary Periods

QTg4 - Quaternary-Tertiary gravels

Tertiary Period

Tbc - Bacons Castle Formation
Tg3 - Low-Level Tertiary gravels
Ty - Yorktown Formation
Tym - Yorktown Formation, Moore House Member
Tcsg - Upper Chesapeake Group sand and gravel
Tccl - Lower Chesapeake Group clayey silt
Te - Eastover Formation
Tc - Calvert Formation
Tl - Lower Tertiary Sediments, undivided
Toc - Old Church Formation
Tpp - Piney Point Formation

Cenozoic and Mesozoic Eras

Tertiary and Cretaceous Periods

TK - Tertiary and Cretaceous (?) sediments (*unit in cross-section only*)

Mesozoic Era

Cretaceous Period

Kp - Potomac Formation

Paleozoic Era

Mississippian and Pennsylvanian Period

MPNpg - Petersburg Granite, subidiomorphic granite
MPNpp - Petersburg Granite, porphyritic granite
MPNpf - Petersburg Granite, foliated granite
MPNpl - Petersburg Granite, layered granite gneiss
MPNpm - Petersburg Granite, megacrystic granite

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. Unit symbol, name and age are only listed with a unit description if the unit has multiple unit descriptions and/or if any these (the unit symbol, name and/or age) were changed on the GRI digital geologic map. If present and associated with a unit description these are as per the source map.

Qml - Modified land (Holocene)

ml - Modified Land (Holocene)
Extensive cut and/or fill related to grading and excavation. Widespread modified land in heavily urbanized areas is not shown. Variable thickness. (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

ml - Modified Land (Holocene)
Extensive cut and/or fill related to grading and excavation. Widespread modified land in heavily urbanized areas or roads is not shown. Holocene. Variable thickness. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

ml - Modified Land (Holocene)
Extensive cut and/or fill due to grading and excavation. Widespread modified land in heavily urbanized areas not shown. Holocene. Variable thickness. (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

ml - Modified Land (Holocene)
Extensive cut and/or fill related to grading, excavation, and mining-related activities. Widespread modified land in heavily urbanized areas and along roads is not shown. Variable thickness. (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

ml - Modified Land (Holocene)
Extensive cut and/or fill related to grading, excavation, and mining-related activities. Widespread modified land in heavily urbanized areas and along roads is not shown. Variable thickness. (*GRI Source Map ID 75760)* (Seven Pines 7.5' Quadrangle).

Qal - Alluvium (Pleistocene to Holocene)

Qal - Alluvium (Pleistocene to Holocene)
Floodplain deposits ranging from clay to gravel. Variable thickness. (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Qa - Alluvium (Pleistocene to Holocene)
Floodplain deposits ranging from clay to gravel. Holocene to Pleistocene. Variable thickness. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Qal - Alluvium (Pleistocene to Holocene)
Floodplain deposits ranging from clay to gravel. Pleistocene to Holocene. Variable thickness. (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Qal - Alluvium (Pleistocene to Holocene)
Floodplain deposits consisting of pebbly sand, sand, and silt, with interbeds of silt and fine sand. Organic matter is common. Variable thickness. (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Qal - Alluvium (Pleistocene to Holocene)
Floodplain deposits ranging from clay to gravel. Variable thickness. (*GRI Source Map ID 75760)* (Seven Pines 7.5' Quadrangle).

Qcb - Carolina Bay (Pleistocene to Holocene)

cb - Carolina Bay (Pleistocene to Holocene)
Carolina Bay – Elliptical depressions occurring on relatively flat upland surfaces underlain by Bacons Castle Formation (Tbc) and Tertiary upper Chesapeake Group (Tcu). Interpreted to be equivalent to Carolina Bays of the central and southern outer Atlantic Coastal Plain (Goodwin and Johnson, 1970). On the adjacent Bon Air quadrangle to the northwest, similar depressions are filled with 5- to 10-feet (1.5- to 3.0-meters) of massive, brownish-gray silty clay, with scattered rounded quartz pebbles, and surrounded by a low ridge or rim of fine sand1. Located and mapped using both remote sensing and soil survey data2 (Coxville and Rains Soil Series typically occur on Carolina Bays3). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Qts - Tabb Alloformation, Sedgefield Member (Pleistocene)

Clayey, fine-grained sand grading downward to pebbly sand with heavy minerals common; interbeds of peat and organic mud common. Thin deposits of the Tabb Alloformation might be found on broad land surfaces at elevations of less than 28 feet resulting from reworking of Shirley sediments. Allostratigraphic classification was proposed by Doar and Berquist (2009). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Qsh - Shirley Alloformation (Pleistocene)

Qsh - Shirley Alloformation (Pleistocene?)
Gray to brown gravel, sand, silt and clay; occurs above younger alluvial deposits on flats adjacent to the James River at elevations ranging up to 48 feet above present sea level. Quartzite clasts with the trace fossil Skolithos are common. Thickness is typically up to 50 feet, but could be greater in paleochannel thalwegs. The type section was defined by Johnson and Berquist (1989). Allostratigraphic classification was proposed by Doar and Berquist (2009). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Qsh - Shirley Alloformation (Pleistocene)
Gray to brown gravel, sand, silt and clay; occurs above younger alluvial deposits on flats adjacent to James River at elevations ranging up to 48 ft. above present sea level. Quartzite clasts with the trace fossil Skolithos are common. Maximum thickness about 50 feet but could be greater in paleochannels. The type section was defined by Johnson and Berquist (1989). Thin deposits of the Tabb Alloformation might be found on broad land surfaces at elevations of less than 30 feet resulting from reworking of Shirley sediments. Allostratigraphic classification was proposed by Doar and Berquist (2009). (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Qsh - Shirley Alloformation (Pleistocene)
Gray to brown gravel, sand, silt and clay; occurs above younger alluvial deposits on flats adjacent to Chickahominy River at elevations ranging up to 48 ft. above present sea level. Quartzite clasts with the trace fossil Skolithos are common. Thickness is typically up to 50 feet, but could be greater in paleochannel thalwegs. The type section was defined by Johnson and Berquist (1989). Allostratigraphic classification was proposed by Doar and Berquist (2009). (*GRI Source Map ID 75762)* (Roxbury 7.5'

Quadrangle).

Qc - Chuckatuck Alloformation (Pleistocene)

Qc - Chuckatuck Alloformation (Pleistocene?)
Medium light gray, silty fine sand, with scattered rounded quartz and quartzite pebbles, cobbles, and boulders; quartzite clasts with the trace fossil Skolithos are common. Underlying “The Slash” and Curles Neck, the Chuckatuck is composed of bluish-gray fine-grained sandy clay and clayey sand up to 40 feet thick; occurs on flats and low hills at elevations of up to 55 feet above present sea level. The type section was defined by Johnson and Berquist (1989). Maximum thickness about 40 feet but could be greater in paleochannels. Allostratigraphic classification was proposed by Doar and Berquist (2009). (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Qc - Chuckatuck Alloformation (Pleistocene)
Light- to medium-gray, yellowish-orange and reddish-brown sand, silt, and clay with minor amounts of dark-brown and brownish-black peat. Occurs on mid-level coast-parallel plains (elevations 55 to 58 feet) and equivalent riverine terraces. Fluvial-estuarine facies includes, from bottom to top: (1) channel-fill deposits of poorly sorted, cross-bedded, pebbly and cobbly sand interbedded, locally, with peat and sandy silt rich in organic matter; (2) moderately well-sorted, cross-bedded to planar bedded, fine- to medium-grained sand grading upward into; (3) clayey silt and sandy and silty clay. Thickness is up to 26 feet but could be greater in paleochannel thalwegs. The type section was defined by Johnson and Berquist (1989). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Qcc - Charles City Alloformation (Pleistocene)

Qcc - Charles City Alloformation (lower Pleistocene?)
Medium-to-light gray, silty fine sand, with scattered rounded quartz and quartzite pebbles, cobbles, and boulders. Quartzite clasts with the trace fossil Skolithos are common. Occurs on hills at elevations of about 35 to 70 feet above present sea level. Unit correlates with the lower Pleistocene (?) Charles City Formation (Johnson and Berquist, 1989). Maximum thickness about 30 feet (9 meters). Allostratigraphic classification was proposed by Doar and Berquist (2009). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Qcc - Charles City Formation (lower Pleistocene?)
Medium light gray, silty fine sand, with scattered rounded quartz and quartzite pebbles, cobbles, and boulders; quartzite clasts with the trace fossil skolithos are common; occurs on hills at elevations of about 35-70 ft above sea level. Most likely correlates with the lower Pleistocene (?) Charles City Formation (Mixon and others, 1989). Maximum thickness about 30 feet (9 meters). (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Qcc - Charles City Alloformation (Pleistocene)
Medium- to light-gray, silty fine sand with scattered rounded quartz and quartzite pebbles, cobbles, and boulders; quartzite clasts with the trace fossil Skolithos are common. Occurs on flats and low hills at elevations of 50 to 78 feet above present sea level. The type section was defined by Johnson and Berquist (1989). Thickness is up to 40 feet but could be greater in paleochannel thalwegs. Allostratigraphic classification was proposed by Doar and Berquist (2009). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Qw - Windsor Formation (Pleistocene)

Qw - Windsor Alloformation (lower Pleistocene)
Rounded quartz and quartzite pebbles, cobbles, and boulders. Quartzite clasts with the trace fossil Skolithos are common. Occurs on hills at elevations of about 70 to 100 feet above present sea level. Unit correlates with the lower Pleistocene Windsor Formation (Coch, 1968). Maximum thickness about 30 feet (9 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

QTw - Windsor Formation (Pliocene to Pleistocene)
Light gray to brown rounded quartz and quartzite pebbles, cobbles, and boulders; quartzite clasts with the trace fossil Skolithos are common; Underlying the Wallo Road area, the Windsor includes gray to brown, sandy clayey silt, up to 40 feet thick. Sediments occur on extensive flats and hills at elevations of about 40 to 95 feet above present sea level. Named by Coch (1968) and stratigraphically restricted by Johnson and Berquist (1989). Maximum thickness is about 55 feet. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

QTw - Windsor Formation (lower Pleistocene to upper Pliocene)
Rounded quartz and quartzite pebbles, cobbles, and boulders; quartzite clasts with the trace fossil skolithos are common; occurs on hills at elevations of about 70-100 ft above sea level along James and Chickahominy Rivers. Most likely correlates with the lower Pleistocene to upper Pliocene Windsor Formation (Mixon and others, 1989). Maximum thickness about 30 feet (9 meters). (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Qw - Windsor Alloformation (Pleistocene)
Gray and yellowish- to reddish-brown sand, gravel, silt, and clay. Occurs on flats at elevations of 60 to 95 feet above present sea level. Fluvial-estuarine deposits consist of muddy, coarse, trough cross-bedded sand and gravel grading upward to sandy silt and clay. Thickness is up to 48 feet, but could be greater in paleochannels. The type section was defined by Coch (1968) and later amended by Johnson and Berquist (1989). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

QTu - Gravel and Sand (lower Pleistocene to upper Pliocene)
Rounded quartz and quartzite pebbles, cobbles, and boulders; quartzite clasts with the trace fossil skolithos are common; occurs on hills at elevations of about 70-100 ft above sea level along Chickahominy River. May be correlative with at least part of the lower Pleistocene to upper Pliocene Windsor Formation along James River (Mixon and others, 1989). Maximum thickness about 30 feet (9 meters). (*GRI Source Map ID 75760)* (Seven Pines 7.5' Quadrangle).

QTg4 - Quaternary-Tertiary gravels (upper Pliocene to lower Pleistocene)

QTg4 - Quaternary-Tertiary Gravels (lower Pleistocene to upper Pliocene)
Deposits of gravel and sand that occur along Pocoshock Creek, at an elevation of 70 to 80 feet above present sea level in the central part of the quadrangle, and 130 to 150 feet above present sea level in the northwestern part of the quadrangle. These gravels consist of rounded quartz and quartzite pebbles and cobbles in a sandy matrix. Morphology and lithology of this fluvial-estuarine terrace unit is consistent with the upper Pliocene to lower Pleistocene Windsor Formation along James River. The maximum thickness of this unit is about 10 feet (3 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Tbc - Bacons Castle Formation (upper Pliocene)

Tbc - Bacons Castle Formation (upper Pliocene)
Grayish-yellow, containing quartzite cobbles with the trace fossil Skolithos. Grades upward into pebbly quartz sand and clayey sand or sandy clay; caps hills and upland surfaces between 105 to 170 feet above present sea level in the northern part of the quadrangle. In the southern part of the quadrangle, the base of the unit cuts down to about 50 feet above present sea level, and probably represents paleo-James River base level. Upper Pliocene. Maximum thickness about 70 feet (21 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Tbc - Bacons Castle Formation (upper Pliocene)
Gray, red and reddish-brown fine-grained sandy clay and clayey silt commonly exhibiting lenticular bedding typically found at highest elevations in the map area (Richmond International Airport area); ranges in thickness up to 20 feet; commonly overlies reddish-brown to brownish-yellow quartzo-feldspathic sands and pebble to cobble gravel, with and without clay. Rounded vein quartz and quartzite pebbles and cobbles comprise between 84 and 98% of the clast fraction (MacIntyre, 2009); the trace fossil Skolithos is common. Lower coarse material ranges in thickness from 20 to 40 feet, total thickness about 70 feet. The unit ranges in elevation from 95 to 170 feet above present sea level. Informally named by Coch (1965) and informally subdivided into the Barhamsville (tidal flat deposits) and Varina Grove (fluvial-estuarine sand and gravel) members by Ramsey (1987, 1988). These sediments overlie upper and lower Chesapeake Group sediments (Tcu, Tcl). (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Tbc - Bacons Castle Formation (upper Pliocene)
Grayish yellow to brownish yellow, massive to thick-bedded, skolithos-bearing quartzite pebble and cobble gravel, grading upward into pebbly quartz sand and clayey sand or sandy clay; caps hills and upland surfaces between 105-170 ft above sea level. Upper Pliocene. Maximum thickness about 70 feet (21 meters). (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Tbc - Bacons Castle Formation (Pliocene)
Gray, red and reddish-brown, fine grained sandy clay and clayey silt commonly exhibiting lenticular bedding; typically found at highest elevations in the map area; thickness is typically 20 to 40 feet, but can range up to 95 feet in places; commonly overlies reddish-brown to brownish-yellow quartzofeldspathic sands and pebble to cobble sized gravel, with and without clay. The unit ranges in elevation from 55 to 150 feet above present sea level. Named by Coch (1965, 1968) and informally subdivided into the Barhamsville (tidal flat deposits) and Varina Grove (fluvial-estuarine sand and gravel) members by Ramsey (1987, 1988). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Tbc - Bacons Castle Formation (upper Pliocene)
Brownish yellow, massive to thick bedded, skolithos-bearing quartzite pebble and cobble gravel grading upward into pebbly quartz sand and clayey sand or sandy clay. Upper Pliocene. Maximum thickness about 70 feet (21 meters). (*GRI Source Map ID 75760)* (Seven Pines 7.5' Quadrangle).

Tg3 - Low-Level Tertiary gravels (upper Pliocene)

Gravel and sand deposits that cap hills at elevations ranging from 150 to 190 feet above present sea level, along Pocoshock Creek, Reedy Creek (a tributary of Kingsland Creek), and rooked Branch (a tributary of Proctors Creek). Rounded quartz and quartzite pebbles, cobbles, and boulders, many with the trace fossil Skolithos, make up the gravel. Correlates with at least part of the upper Pliocene Bacons Castle Formation (Coch, 1965) to the east (Carter and others, 2007). Maximum thickness about 10 feet (3 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Ty - Yorktown Formation (Pliocene)

Yellowish-brown to bluish-gray clayey fine- to medium-grained sand; heavy mineral and glauconite concentrations range up to about 20% in places. Contains abundant shell hash, commonly as cemented masses. Abundant Chesapecten, Ostrea, and Mercenaria fragments were encountered during drilling. Maximum thickness in this map area exceeds 30 feet on the east side of the Malvern Hill Fault. (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Tym - Yorktown Formation, Moore House Member (Pliocene)

Ts - Sedley Formation (Pliocene)
Dark brown clayey silt with a fraction that coarsens downward from very fine grained sand to coarse-grained sand and granules; larger clasts are very well rounded; glauconite and manganese are common. Bioturbation has destroyed most sedimentary structures, but lenticular bedding is preserved in some places. Average thickness is 2 to 10 feet with a maximum thickness of 20 feet. The unit pinches out close to the eastern margin of the quadrangle. (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Note: Name changed to Moore House Member of the Yorktown based on communication with Rick Berquist, Geologist (VDMME).

Tcsg - Upper Chesapeake Group sand and gravel (Pliocene)

Tcu - Upper Chesapeake Group Sand and Gravel (Pliocene)
Lower part consists of brownish-yellow silty quartz sand to gravel, 5 to 12 feet (1.5 to 3.6 meters) thick. Overlain by flaser and lenticular bedded sandy clay and clayey fine-grained sand, 16 to 17 feet (4.9 to 5.2 meters) thick. Overlain by upward fining clayey sand, 10 to 21 feet (3.0 to 6.4 meters) thick. This unit is interpreted to have been deposited in fluvial, nearshore, and strandline environments (Daniels and Onuschak, 1974; Goodwin, 1980). Most likely correlates with the Pliocene upper Chesapeake Group, as the nearshore equivalent of the down-dip marine Yorktown Formation (Newell and Rader, 1982). Maximum thickness about 30 feet (10 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Tcu - Upper Chesapeake Group Sand and Gravel (Pliocene)
Brownish-yellow clayey fine- to coarse-grained sand with pebbles grading upward and eastward into light brown to olive fine- to medium-grained sand; heavy minerals and glauconite concentration ranges up to about 20% in places. Rounded vein quartz and quartzite pebbles and cobbles comprise between 84 and 98% of the clast fraction and clast dimension is significantly smaller than in the Bacons Castle (MacIntyre, 2009). This unit is interpreted to have been deposited in fluvial, nearshore, and strandline environments (Daniels and Onuschak, 1974). These sediments are considered to be the nearshore equivalent of the down-dip marine Yorktown Formation (Newell and Rader, 1982). Maximum thickness in this map area is about 10 feet and overlies the lower Chesapeake Group (Tcl) clayey silt. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Tpsg - Sand and Gravel (Pliocene)
Lower part consists of brownish-yellow silty quartz sand to quartzite pebble gravel, 5 to 12 feet (1.5 to 3.6 meters) thick; overlain by flaser and lenticular bedded sandy clay and clayey fine-grained sand, 16 to 17 feet (4.9 to 5.2 meters) thick; overlain by upward fining clayey sand, 10 to 21 feet (3.0 to 6.4 meters) thick. Sediments of this unit are interpreted to have been deposited in fluvial, nearshore, and strandline

environments. Most likely correlates with part of the Pliocene upper Chesapeake Group, as the nearshore equivalent of the down-dip marine Yorktown Formation. Maximum thickness approximately 50 feet (15 meters). (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Tpsg - Sand and Gravel (Pliocene)
Lower part consists of brownish-yellow silty quartz sand to quartzite pebble gravel, 5 to 12 feet (1.5 to 3.6 meters) thick; overlain by flaser and lenticular bedded sandy clay and clayey fine-grained sand, 16 to 17 feet (4.9 to 5.2 meters) thick; overlain by upward fining clayey sand, 10 to 21 feet (3.0 to 6.4 meters) thick. Sediments of this unit are interpreted to have been deposited in fluvial, nearshore, and strandline environments. Most likely correlates with part of the Pliocene upper Chesapeake Group, as the nearshore equivalent of the down-dip marine Yorktown Formation. Maximum thickness approximately 50 feet (15 meters). (*GRI Source Map ID 75760)* (Seven Pines 7.5' Quadrangle).

Tccl - Lower Chesapeake Group clayey silt (Miocene)

Tcl - Lower Chesapeake Group Clayey Silt (Miocene)
Light-gray to dark bluish-gray sandy clay and silty to clayey fine-grained sand; locally fossiliferous; locally jointed. Subangular to subrounded quartz granules, abundant flakes of mica, iron oxide mottling, and staining from disseminated iron sulfide are common. Unit interpreted to be marine, most likely correlative with the Miocene lower Chesapeake Group which includes the Eastover, Choptank, and Calvert Formations. Maximum thickness about 75 feet (23 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Tcl - Lower Chesapeake Group Clayey Silt (Miocene)
Light-gray to dark bluish-gray sandy clay and silty to clayey fine-grained sand, muscovite very common; locally fossiliferous; locally jointed; typically contains subangular to subrounded quartz granules, and abundant flakes of mica. Iron oxide mottling and staining from disseminated iron sulfide are common. Unit interpreted to be marine, most likely correlative with the Miocene lower Chesapeake Group which includes the Eastover, Choptank, and Calvert Formations. Maximum thickness is about 50 feet and overlies the Potomac Formation and lower Tertiary sediments. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Tcl - Clayey Silt (Miocene)
Light gray to dark bluish gray sandy clay and silty to clayey fine-grained sand; locally fossiliferous; locally jointed; subangular to subrounded quartz granules, and abundant flakes of mica are common. Iron oxide mottling and staining from disseminated iron sulfide are common. Unit interpreted to be marine, most likely correlative with the Miocene lower Chesapeake Group which includes the Eastover, Choptank, and Calvert Formations. Maximum thickness about 75 feet (23 meters). (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Tcl - Clayey Silt (Miocene)
Light gray to dark bluish gray sandy clay and silty to clayey fine-grained sand; locally fossiliferous; locally jointed; subangular to subrounded quartz granules and abundant flakes of mica are common. Iron oxide mottling and staining from disseminated iron sulfide are common. Unit is interpreted to be marine, most likely correlative with the Miocene lower Chesapeake Group which includes the Eastover, Choptank, and Calvert Formations. Thickness greater than 100 feet (30.5 meters). Tertiary and Cretaceous(?) sediments (in cross sections)[2,3] – Grayish green, fossiliferous, glauconitic clayey silt and quartz sand, with a few thin limestone beds and basal conglomerate; pink to light gray clay, locally interlaminated with very fine-grained glauconite. (*GRI Source Map ID 75760)* (Seven Pines 7.5' Quadrangle).

Te - Eastover Formation (Miocene)

Light-gray to dark bluish-gray silty to clayey, very fine-grained sand (Cobham Bay member) and massive sandy clay (Claremont Manor member). The Cobham Bay member is locally fossiliferous; contains some shell hash and abundant Turritella. The mollusk Isognomon maxillata is a common species in the upper part of the Eastover. Most borings did not enounter shell material. The Cobham Bay member typically contains subangular to subrounded quartz granules and abundant flakes of mica. Iron oxide mottling and staining from the weathering of disseminated iron sulfide are common. In this quadrangle the boundary between the two units is gradational. The Claremont Manor member is sparsely fossiliferous, but does have abundant phosphate fragments and flakes of mica. Maximum thickness is about 50 feet. (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Tc - Calvert Formation (Miocene)

Dark blue to greenish-gray silty to clayey fine- to medium-grained sand with coarse sand common. Blue quartz granules are rare. Heavy mineral and phosphate concentrations range up to 10%. Chesapecten and Mercenaria fragments were encountered during drilling. Maximum thickness in this map area is 28 feet. Named by Shattuck (1902) and later revised by Ward (1985). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Tl - Lower Tertiary Sediments, undivided (Oligocene, Eocene, and late Paleocene)

Tl - Lower Tertiary Sediments (lower Eocene and/or upper Paleocene)
Light olive-green to grayish-olive green, fine to coarse glauconitic quartz sand and clayey silt; thick-bedded to massive. Locally fossiliferous and intensely burrowed. Most likely correlative with lower Eocene Nanjemoy Formation and/or upper Paleocene Aquia Formation (Mixon and others, 1989). Outcrops in cliffs and drainages east of James River. On the Drewrys Bluff quadrangle, maximum thickness about 20 feet (6 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Tl - Lower Tertiary Sediments (Pamunkey Group), undivided (Paleocene to Eocene?)
Light olive-green to grayish-olive green or black, fine to coarse glauconitic (up to 30%) quartz sand and clayey silt; locally fossiliferous and intensely burrowed. Includes the Eocene Nanjemoy (Clark and Martin, 1901), Paleocene-Eocene? Marlboro Clay (Formation) (Clark and Martin, 1901), and Late Paleocene Aquia formations (Clark, 1896). The basal Aquia gravel is distinctively stained dark green and composed of 97% to 100% vein quartz and quartzite (Reyher, 2009). Grouping follows Mixon and others (1989). Maximum encountered thickness is about 50 feet and overlies the Potomac Formation. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

KTl - Lower Tertiary Sediments (lower Eocene and/or upper Paleocene)
Light olive green to grayish olive green, fine to coarse glauconitic quartz sand and clayey silt, with few thin limestone beds and basal conglomerate; thickly to massively bedded; locally fossiliferous and intensely burrowed. Most likely correlative with lower Eocene Nanjemoy Formation and/or upper Paleocene Aquia Formation (Mixon and others, 1989). Outcrops in cliffs and drainages northeast of James River and the middle reaches of Upham Brook. Maximum thickness about 20 feet (6 meters). (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Note: Tl is lower Tertiary and consists of the Piney Point, Old Church, Nanjemoy, Marlboro Clay, and

Aquia formations which range in age from Oligocene to Paleocene. Information given by Rick Berquist, Geologist (VDMME).

Toc - Old Church Formation (Oligocene)

Light-gray clayey fine- to medium-grained shelly sand; heavy mineral and phosphate concentrations range up to 5%. The upper unit is locally fossiliferous with Ostrea fragments and spicules encountered during drilling; contains some zones of indurated calcium carbonate masses and concretions. Maximum thickness is about 10 feet. Named by Ward (1985); age modified by Powars and others (1992). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

Tpp - Piney Point Formation (Eocene)

Dark greenish-gray, fine- to coarse-grained, shelly glauconitic (20-40%) and quartz sand; abundant pyrite and rare quartz pebbles. Glauconite is greenish-black but some grains are bright green and stand out. Contains zones of calcite-cemented sand and moldic limestone. The upper unit is locally fossiliferous with Cubitostrea sellaeformis fragments encountered during drilling. Maximum thickness is about 30 feet. Named by Otten (1955) and later revised by Ward (1985). (*GRI Source Map ID 75762)* (Roxbury 7.5' Quadrangle).

TK - Tertiary and Cretaceous (?) sediments (Tertiary and Cretaceous)

KT - Tertiary and Cretaceous (?) sediments (Tertiary and Cretaceous)
Grayish green, fossiliferous, glauconitic clayey silt and quartz sand, with a few thin limestone beds and basal conglomerate; pink to light gray clay, locally interlaminated with very fine-grained glauconite. (*GRI Source Map ID 75760)* (Seven Pines 7.5' Quadrangle).

**unit *in cross-section only.*

Kp - Potomac Formation (Cretaceous)

Kp - Potomac Formation (Cretaceous)
Very light gray to grayish-pink, fine to coarse quartzofeldspathic sand; poorly sorted, locally pebbly; commonly thick-bedded and trough crossbedded. Sand is interbedded with thick, but locally discontinous beds of 1) polymictic conglomerate, consisting of rounded to well-rounded pebbles, cobbles, and boulders of quartz, metavolcaniclastic rocks, granite and carbonaceous clay clasts, 2) grayish-green, massive to thick-bedded sandy clay and silt, and 3) brownish-black, thin-bedded to laminated carbonaceous clay and silt, locally containing plant fragments. Unit is interpreted to have been deposited in fluvial-deltaic environments. Outcrops in cliffs and drainages along James River and major tributaries. Cretaceous. Unit thickens to the south and east to more than 450 feet (140 meters). (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Kp - Potomac Formation (Cretaceous)
Very light-gray to grayish-pink, fine to coarse quartzo-feldspathic sand; poorly sorted, locally pebbly; commonly thick-bedded and trough cross-bedded. Sand is interbedded throughout with thick, but locally discontinous beds of 1) polymictic conglomerate, consisting of rounded to well-rounded pebbles, cobbles, and boulders of quartz, metavolcaniclastic rocks, granite and carbonaceous clay clasts, 2) grayish-green, massive to thick-bedded sandy clay and silt, and 3) brownish-black, thin-bedded to laminated carbonaceous clay and silt, locally containing plant fragments. Gravel composition ranges

from 49% to 77% vein quartz and quartzite; 21% to 48% volcanics and mud clasts (Reyher, 2009). Clast dimensions range up to 6 feet. Unit is interpreted to have been deposited in fluvial-deltaic environments. Outcrops in cliffs and drainages along James River and major tributaries. Age is Early Cretaceous. Within the map area, the unit thickens to the east to about 300 feet and overlies the Petersburg Granite. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Kp - Potomac Formation (Lower Cretaceous)
Very light gray to grayish pink, fine to coarse quartzofeldspathic sand; poorly sorted, locally pebbly; commonly thick bedded and trough cross bedded. Sand is interbedded throughout with thick, but locally discontinous beds of 1) polymictic conglomerate, consisting of rounded to well-rounded pebbles, cobbles, and boulders of quartz, metavolcaniclastic rocks, granite and carbonaceous clay clasts, 2) grayish green, massive to thick bedded sandy clay and silt, and 3) brownish black, thin-bedded to laminated carbonaceous clay and silt, locally containing plant fragments. Unit interpreted to have been deposited in fluvial-deltaic environments. Outcrops in cliffs and drainages east of James River. Cretaceous. Unit thickens to the east and south to more than 75 feet (23 meters). (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

Petersburg Granite

The Petersburg Granite underlies a large region of east-central Virginia, from near Ashland in Hanover County to the north, to Dinwiddie in Dinwiddie County to the south. Its outcrop belt is bounded to the north and west by the Richmond-Taylorsville Mesozoic basins, and is covered by Coastal Plain sediments to the south and east. Dated at approximately 330 Ma (Mississippian) by Wright and others (1975), and approximately 315 Ma (Pennsylvanian) by Lee and Williams (1993). On the Drewrys Bluff quadrangle, the Petersburg Granite is subdivided into four phases, from youngest to oldest. It also outcrops in Richmond and Dutch Gap but there are less subdivisions. Drewry's Bluff uses the most current naming conventions for the Petersburg Granite. *Modified from:* (Drewry's Bluff 7.5' Quadrangle).

MPNpg - Petersburg Granite, subidiomorphic granite (Mississippian to Pennsylvanian)

Pzpg - Petersburg Granite, Subidiomorphic Granite (Mississippian to Pennsylvanian)
Light bluish-gray; fine- to medium-grained, locally coarse-grained; homogenous, uniform subidiomorphic texture; locally foliated. Consists of quartz, plagioclase, potassium feldspar, muscovite, biotite, hornblende, zircon, epidote, carbonate, and traces of ilmenite/magnetite, apatite and garnet. Locally porphyritic, with pale-pink potassium feldspar phenocrysts less than 0.5-inch (1-centimeter) in length; locally contains pods, lenses, zones, and enclaves of foliated granite and layered granite gneiss; cross-cut by aplite and pegmatite dikes; well jointed. (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Pzpg - Petersburg Granite, Subidiomorphic Granite (Mississippian)
Light bluish gray; fine- to medium-grained, locally coarse-grained; homogenous, uniform subidiomorphic to idiomorphic texture; granitic composition; one sample from the adjacent Bon Air quadrangle consists of 37.5% quartz, 15% plagioclase, 24% potassium feldspar, 12% muscovite, 6% biotite, 1.5% hornblende, 0.5% zircon, 3% epidote, 0.5% carbonate, and traces of ilmenite/magnetite, apatite and garnet. Locally porphyritic, with pale pink potassium feldspar phenocrysts less than 0.5 inch (1 centimeter) in length; massive to very weakly foliated; locally contains pods, lenses, zones, and xenoliths of layered granite gneiss and foliated granite; cross-cut by aplite and pegmatite dikes; well jointed. (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

MPNpp - Petersburg Granite, porphyritic granite (Mississippian to Pennsylvanian)

Pzpp - Petersburg Granite, Porphyritic Granite (Mississippian to Pennsylvanian)
Grayish-blue, medium- to coarse-grained, porphyritic, with pale-pink potassium feldspar phenocrysts over 1-inch (2.5-centimeters) in length, commonly oriented and aligned subparallel to a weak to strong biotite foliation within the matrix. Consists of quartz, plagioclase, potassium feldspar, biotite, muscovite, zircon, epidote, carbonate, and traces of hornblende, hematite, and ilmenite/magnetite. Quartz and plagioclase dominate the matrix; quartz is typically medium-gray to light bluish-gray; locally, potassium feldspar phenocrysts deformed to porphyroclasts; commonly associated with coarse- to very coarse grained medium gray to light bluish-gray quartz and pale-pink potassium feldspar pegmatite, which also cross-cuts older phases. Also cross-cut by grayish-yellow aplite dikes; locally contains pods and lenses of subidiomorphic granite, and rarely, layered granite gneiss and foliated granite; well jointed. (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

MPNpf - Petersburg Granite, foliated granite (Mississippian to Pennsylvanian)

Pzpf - Petersburg Granite, Foliated Granite (Mississippian to Pennsylvanian)
Light bluish-gray granite; medium- to coarse-grained, locally fine-grained; weakly to strongly foliated. Phyllosilicate and quartz-feldspar alignment defines foliation. Locally contains pods, lenses, zones and enclaves of layered granite gneiss, subidiomorphic granite, and rarely porphyritic granite; cross-cut by aplite and pegmatite dikes; well jointed. (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Pzpf - Petersburg Granite, Foliated Granite (Mississippian)
Light bluish gray granite to granodiorite; medium- to coarse-grained, locally fine-grained; weakly to strongly foliated, with foliation defined by both phyllosilicate and quartz-feldspar alignment; unit locally contains pods, lenses and zones of layered granite gneiss subidiomorphic granite, and rarely porphyritic granite; cross-cut by aplite and pegmatite dikes; well jointed. (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

MPNpl - Petersburg Granite, layered granite gneiss (Mississippian to Pennsylvanian)

Pzpl - Petersburg Granite, Layered Granite Gneiss (Mississippian to Pennsylvanian)
Light bluish-gray to medium bluish-gray to medium-gray granite; compositionally layered; layers range from 0.5-inch- to several inches (1-centimeter- to 1-decimeter-) thick; composition ranges from quartz-feldspar- to biotite-quartz-feldspar-rich layers. Individual layers are fineto coarse-grained, subidiomorphic to locally porphyritic (potassium feldspar phenocrysts are less than 0.5-inch or 1-centimeter in length). Locally contains pods, lenses, zones and enclaves of subidiomorphic granite and foliated granite; cross-cut by aplite and pegmatite dikes; well jointed. (*GRI Source Map ID 75764)* (Drewrys Bluff 7.5' Quadrangle).

Pzpl - Petersburg Granite, Layered Granite Gneiss (Mississippian)
Light bluish gray to medium bluish gray to medium gray granite to granodiorite; distinctly compositionally layered into quartz-feldspar to biotite-quartz-feldspar rich layers; layering ranges from 0.5 inch to several inches (1 centimeter to 1 decimeter) thick; individual layers are fine- to coarse-grained, subidiomorphic to idiomorphic to locally porphyritic (potassium feldspar phenocrysts are less than 0.5 inch or 1 centimeter in length) textured; granitic composition; one sample consists of 48% quartz, 22.5% plagioclase, 18.5% potassium feldspar, 8.5% biotite, 2.5% muscovite, and a trace of

epidote; unit locally contains pods, lenses and zones of subidiomorphic granite, and xenoliths of foliated granite; cross-cut by aplite and pegmatite dikes; well jointed. (*GRI Source Map ID 75761)* (Richmond 7.5' Quadrangle).

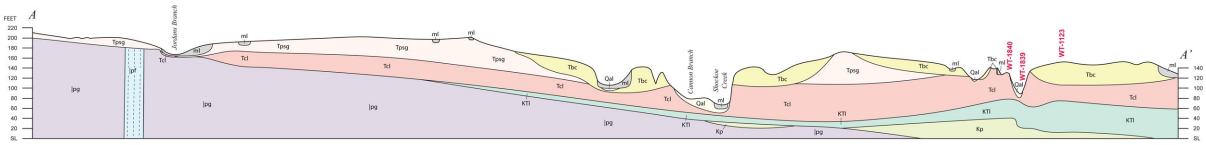
MPNpm - Petersburg Granite, megacrystic granite (Mississippian to Pennsylvanian)

Pzpm - Megacrystic Granite (Mississippian to Pennsylvanian)
In the southwest corner of the Dutch Gap quadrangle, Petersburg granite crops out on a rocky island in an abandoned channel of James River, in the hanging wall of the northern extension of the Dutch Gap fault zone (Dischinger, 1987). Here Petersburg granite consists of coarse- to very coarse-grained pale-pink potassium feldspar phenocrysts, up to several inches in length, within a light bluish-gray, medium- to coarse-grained, subidiomorphic matrix composed mostly of quartz, plagioclase, muscovite, and biotite. (*GRI Source Map ID 75763)* (Dutch Gap 7.5' Quadrangle).

Geologic Cross Sections

The geologic cross sections present in the GRI digital geologic-GIS data produced for Richmond National Battlefield Park, Virginia (RICH) are presented below. Note that some cross section abbreviations (e.g., A - A') may 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).

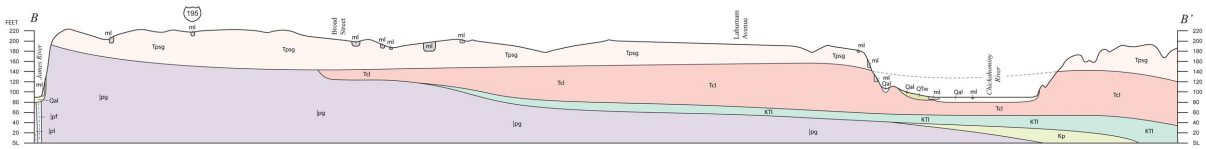
Cross Section A-A'



Note: Cross-section A-A' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Richmond 7.5' Quadrangle).

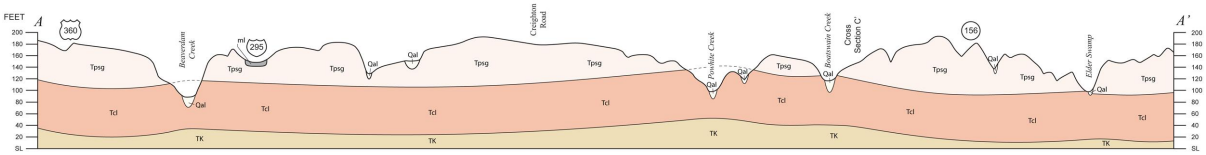
Cross Section B-B'



Note: Cross-section B-B' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Richmond 7.5' Quadrangle).

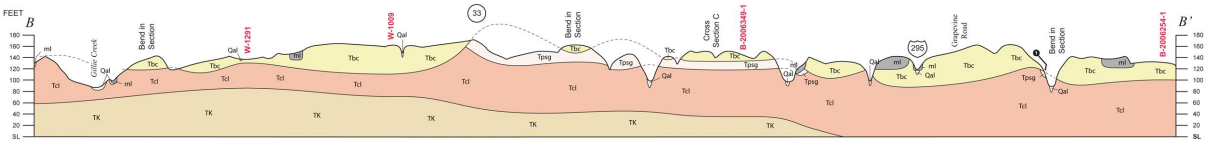
Cross Section C-C'



Note: Cross-section A-A' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Seven Pines 7.5' Quadrangle).

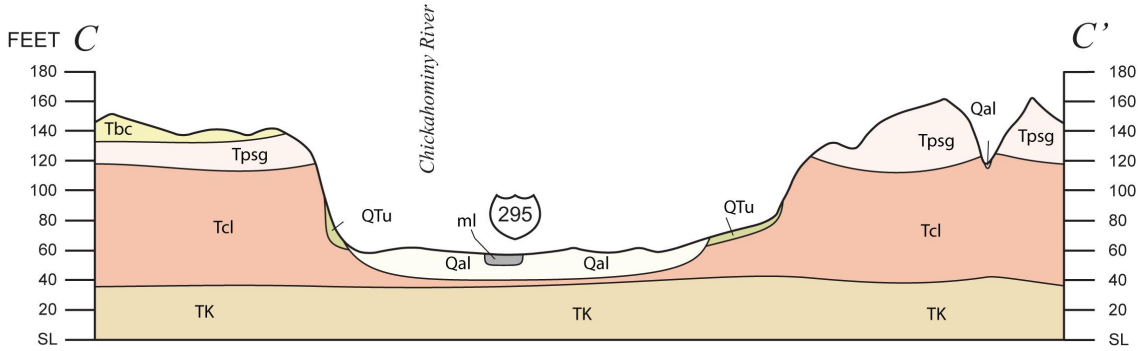
Cross Section D-D'



Note: Cross-section B-B' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Seven Pines 7.5' Quadrangle).

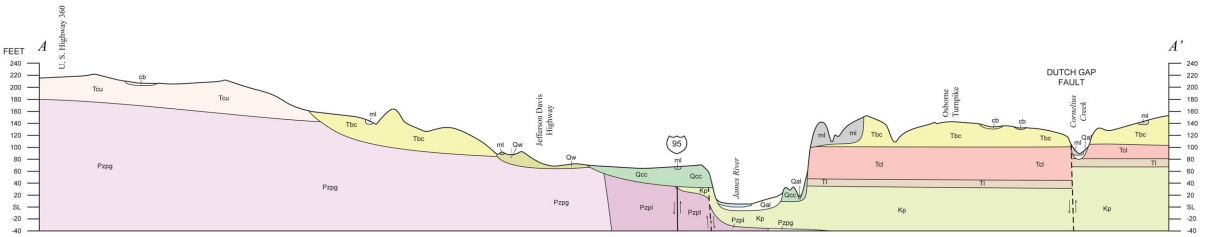
Cross Section E-E'



Note: Cross-section C-C' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Seven Pines 7.5' Quadrangle).

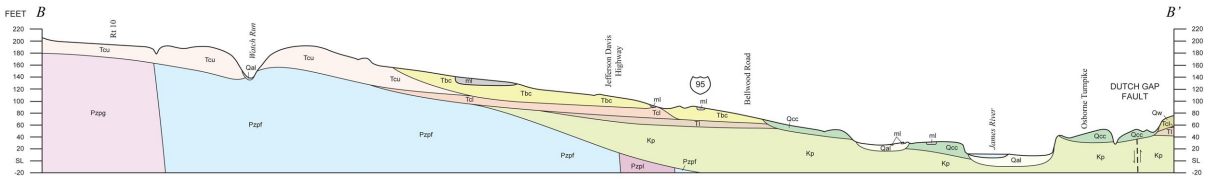
Cross Section F-F'



Note: Cross-section A-A' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Drewrys Bluff 7.5' Quadrangle).

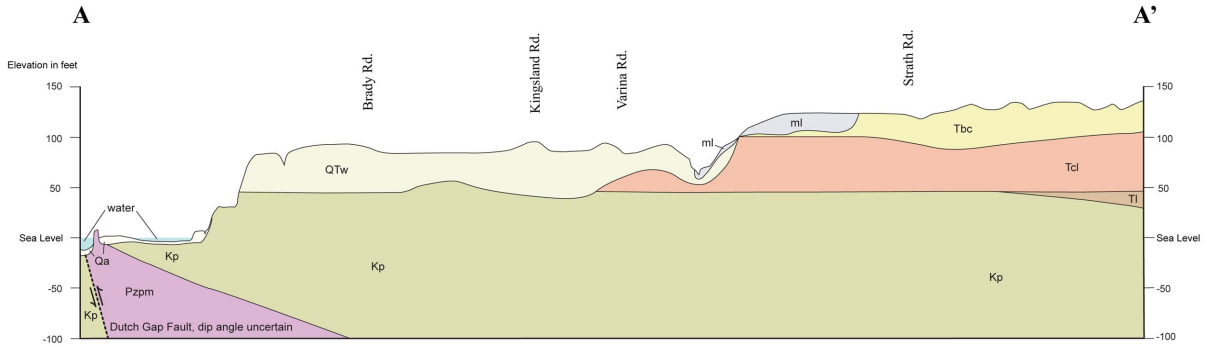
Cross Section G-G'



Note: Cross-section B-B' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Drewrys Bluff 7.5' Quadrangle).

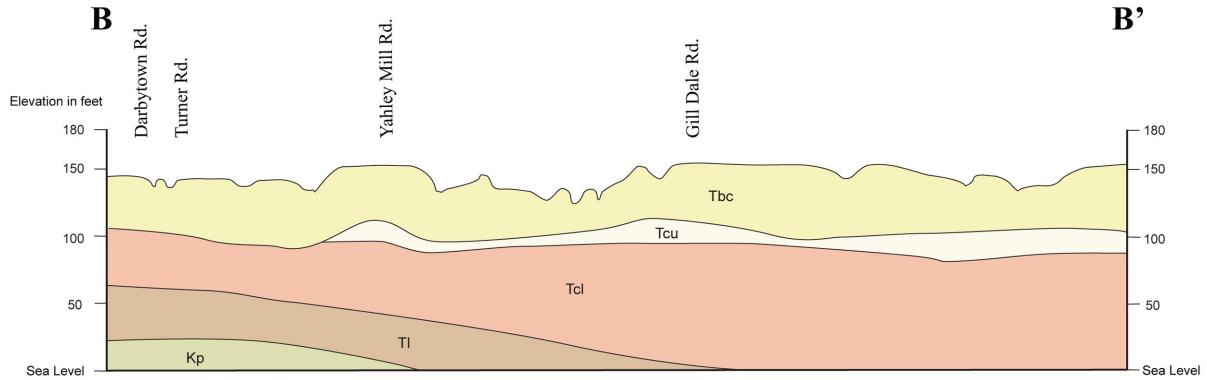
Cross Section H-H'



Note: Cross-section A-A' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Dutch Gap 7.5' Quadrangle).

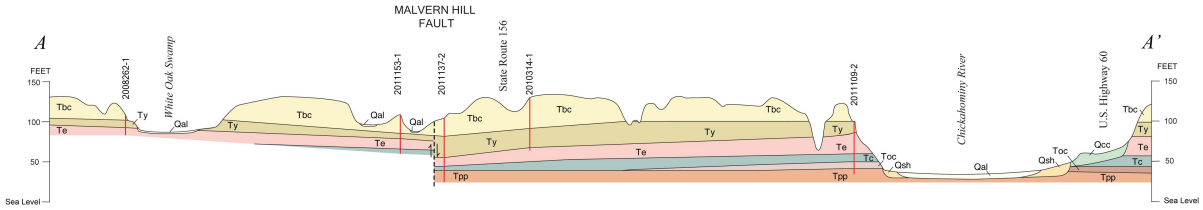
Cross Section I-I'



Note: Cross-section B-B' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

Extracted from: (Dutch Gap 7.5' Quadrangle).

Cross Section J-J'



Note: Cross-section A-A' in source data. 20X vertical exaggeration. Subsurface structures interpreted from surface measurements and geologic borings.

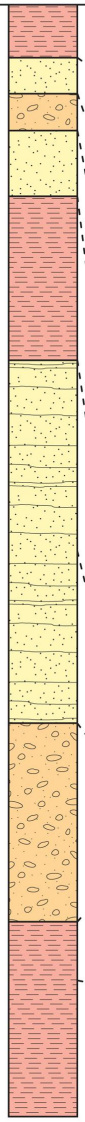
Extracted from: (Roxbury 7.5' Quadrangle).

Geologic Section and Photographic Localities

Geologic locality figures and photographs are presented below. The locations of these figures and photographs is included in the Geologic Observation Localities feature class (see the richgol feature class, Location ID field).

Stratigraphic Section Locality 1

GEOLOGIC REFERENCE LOCALITY 1:
Measured Section through Sand and Gravel unit (Tpsg) above Clayey Silt (Tcl)

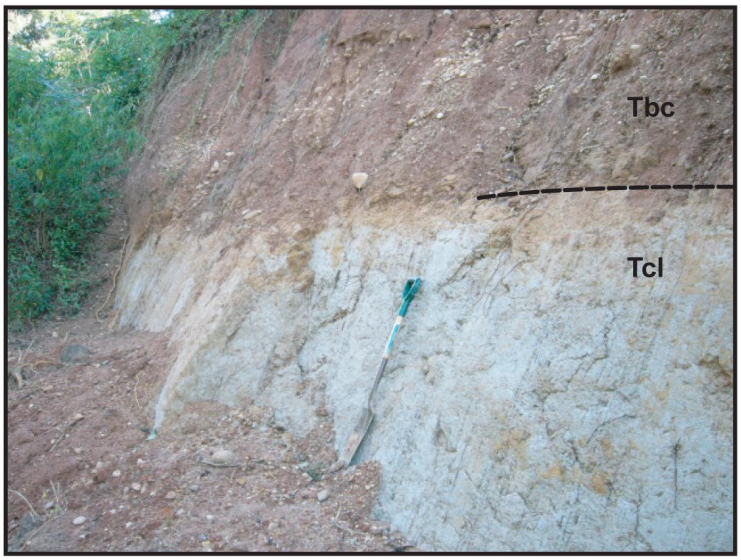


PHOTOGRAPH	STRATIGRAPHIC COLUMN	UNIT	TOP DEPTH (feet)	BASE DEPTH (feet)	DESCRIPTION
		Tpsg	0.0	3.8	light yellow/orange, very fine sand with medium sand common; sand grains are rounded; less than 1% heavy minerals; hard; moist.
			3.8	5.1	orange/brown, fine to medium sand; coarse sand and granules common, rare pebbles; grains are sub rounded; 8% chert, less than 1% heavy minerals; hard.
			5.1	6.6	orange/brown, coarse sand and gravel; clasts range in size from 1 mm to 60 mm in diameter; clasts rounded to sub angular; consists of blue quartz, chert, sandstone clasts and muscovite grains, less than 1% heavy minerals; hard.
			6.6	9.6	dark orange brown to light gray and light yellow, slightly clayey fine to coarse sand; granules and pebbles common; flaser bedded; grain size is variable; lenses contain up to 50% heavy minerals, average about 8% heavy minerals throughout unit.
			9.6	16.8	gray to yellow orange, thinly laminated silty clay and orange/brown, flaser bedded clayey fine to medium sand, containing 3% heavy minerals and 4-5% muscovite.
			16.8	23.3	orange/brown, flaser bedded, clayey fine to medium sand, coarser-grained sand in thin (less than 1mm) discontinuous to thicker (30 mm) continuous beds; clasts rounded to sub rounded; contains 4-5% heavy minerals and 2% muscovite.
			23.3	27.0	light yellowish orange to rusty orange, slightly clayey, fine to medium sand, with rare pebbles; contains chert and 2% muscovite; soft; wet.
			27.0	30.0	dark brown to rusty red, clast supported conglomerate; clasts range from 1mm to 30mm in diameter; sub rounded clay balls, 5 cm in diameter, are common; matrix consists of fine to coarse sand, with 5% heavy minerals; contact with underlying unit is irregular; firm; wet.
		Tcl	30.0	30.1	orange to light gray clay; sub rounded quartz pebbles are common; pebbly and clayey coarse sand near base; basal ferricrete layer, 2 cm thick.
			30.1	33.3	blue gray to dark brown silty clay; vertical burrows filled with fine sand, 1 to 1.5 cm in diameter; and ghost shells, 1 cm in diameter, are common; contains 15% muscovite; firm; wet.

Extracted from: (Richmond 7.5' Quadrangle).

Geologic Photograph Locality 2

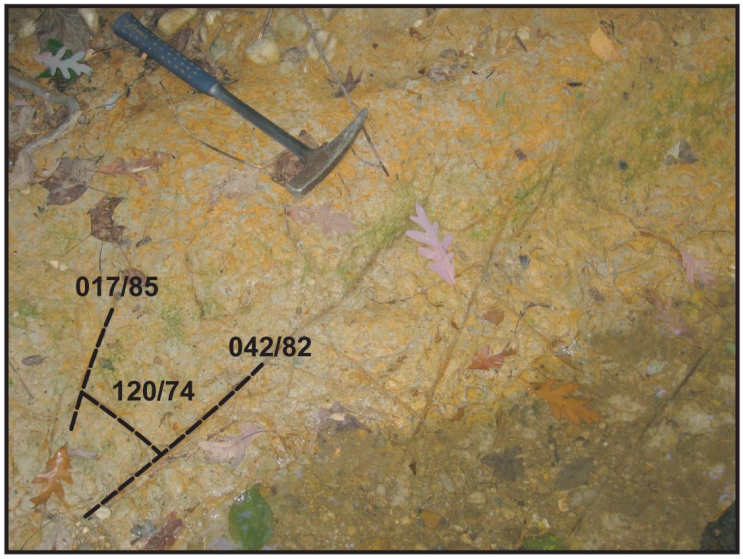
LOCALITY 2: Contact between sand and gravel of the Bacons Castle Formation (Tbc) overlying clayey silt of the lower Chesapeake Group (Tcl), marked by a dashed line at right of photograph. The Bacons Castle Formation here consists of massive to thick bedded pebble and cobble gravel grading upward into cross bedded pebbly sand and sandy silt; lower Chesapeake Group sediments consist of dark gray to bluish gray, micaceous sandy silt and clay. These units are exposed in the scarp of a landslide that occurred on August 30, 2004 during heavy rains from Tropical Depression Gaston. Shovel is Shovel is about 4 feet (1.2 meters) long.



Extracted from: (Richmond 7.5' Quadrangle).

Geologic Photograph Locality 3

LOCALITY 3: Joint sets in Miocene clayey silt (Tcl), marked by dashed lines in photograph. Joints strike 017/85SE, 042/82SE and 120/74SW. Hammer is approximately 15 inches (38 centimeters) long.



Extracted from: (Richmond 7.5' Quadrangle).

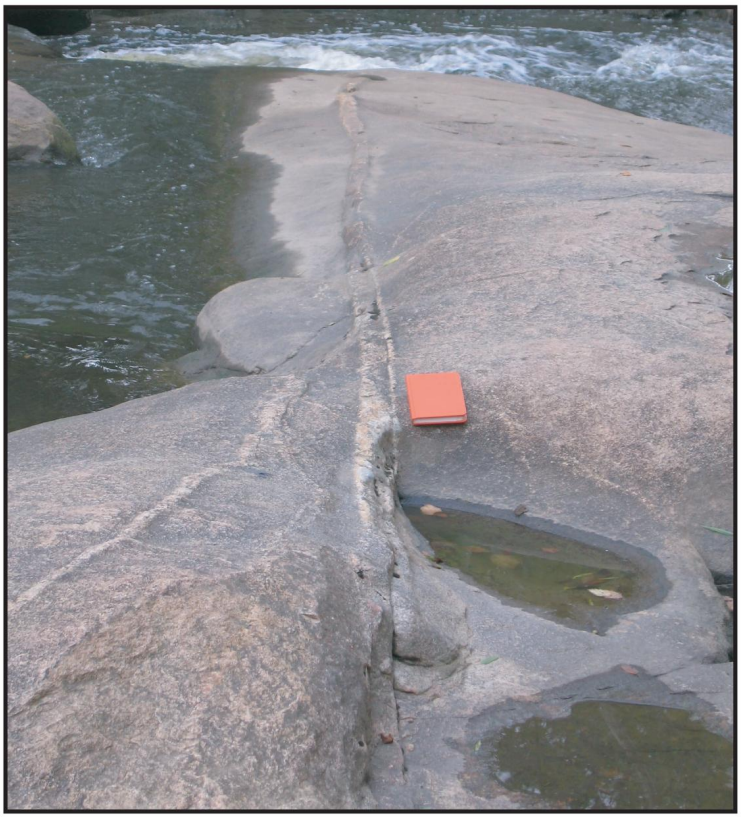
Geologic Photograph Locality 4

LOCALITY 4: Compositionally layered granite gneiss phase of the Petersburg Granite (Pzpl). Layering, marked by a dashed line at left of photograph, consists of alternating bands of coarse-grained quartz and feldspar and finer-grained biotite-quartz-feldspar rich layers. Here, layering is broadly folded in a steeply southwest plunging synform. Hammer is approximately 15 inches (38 centimeters) long.

Extracted from: (Richmond 7.5' Quadrangle).

Geologic Photograph Locality 5

LOCALITY 5: Pegmatite and aplite dikes cross cutting subidiomorphic granite of the Petersburg Granite (Pzpg). Edge of fieldbook is about 7.5 inches (19 centimeters) long.



Extracted from: (Richmond 7.5' Quadrangle).

Geologic Photograph Locality 6

LOCALITY 6 (Locality 1 on source map): Stratigraphic section from the upper Pliocene Bacons Castle Formation (Tbc) to the Miocene lower Chesapeake Group (Tcl), located at the spillway of a dam south of the Chickahominy River near Savage Station. Bacons Castle Formation sediments, consisting of rounded skolithos-bearing quartzite pebbles and cobbles, unconformably overly and channelize into the Pliocene upper Chesapeake Group sediments of the Yorktown Formation (Tpsg). At least three feet of Yorktown sediments are exposed and consist of pebbly silty sand in a fining upward sequence. The Yorktown Formation unconformably overlies lower Chesapeake Group sediments along a sharp, undulatory contact. In this section, the lower Chesapeake Group (Eastover Formation?) is represented by a locally fossiliferous, heavily burrowed, muscovite-bearing clayey fine sand containing scattered pebbles. Note the numerous diastems (marked by an arrow and “D” in photograph) in the lower Chesapeake Group. Tape is approximately 5 feet (1.5 meters) long. Locality is on private property - please contact landowner before visiting site.

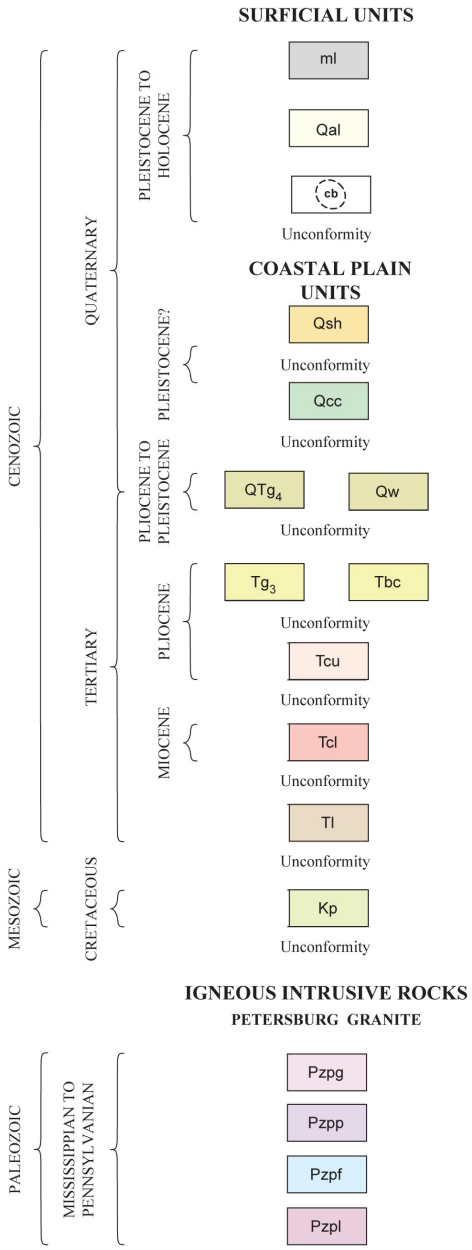
Extracted from: (Seven Pines 7.5' Quadrangle).

GRI Source Map Information

Drewrys Bluff 7.5' Quadrangle

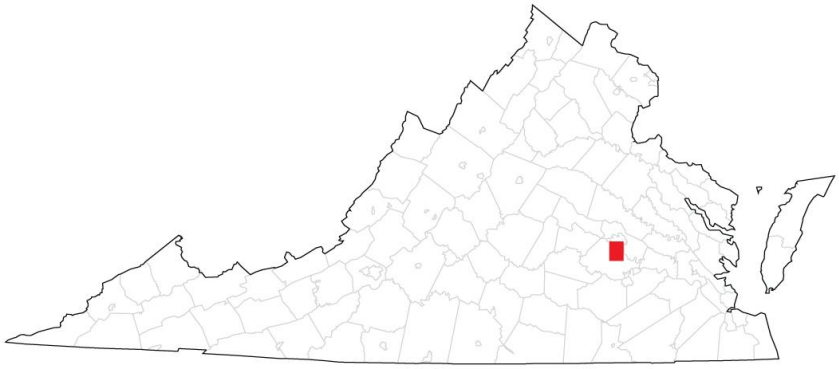
Bondurant, A.K., Berquist, C.R., Carter, M.W., and Bleick, H.A., 2011, Geologic Map of the Drewrys Bluff Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2011 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (*GRI Source Map ID 75764*).

Drewrys Bluff Correlation of Map Units



Extracted from: (Drewry's Bluff 7.5' Quadrangle).

Drewrys Bluff Index Map



Extracted from: (Drewry's Bluff 7.5' Quadrangle).

Drewrys Bluff Map Symbols

For all line symbols: lines are solid where the location is exact (located in field to within 50 feet or 15 meters), long-dashed where the location is approximate (located to within 200 feet or 60 meters); short-dashed where the location is inferred. For geologic observation symbols, observation sites are centered on the strike bar, or are at the intersection point of multiple symbols.

Line Symbols

Contacts

Fault Contacts

Reverse - Ornaments show dip direction (arrows in cross sections show relative displacement)

U D Dip-slip - option)—U, upthrown block; D, downthrown block

Line Symbols in Cross Sections

Contact

Fault

? **Possible fault** (suggested by offset in Coastal Plain sediments, from borehole and cross section analysis; arrows show relative movement

Geologic Observations

59 Strike and dip of inclined foliation in Petersburg Granite

56 Strike and dip of inclined aplite or pegmatite dike

87 Strike and dip of inclined joint

Geologic References

R-9947 Rock repository sample

2009050-1 Geologic borehole

Mineral Resources

Commodity letter symbol precedes identifcation number (identification numbers are preceded by "99B-" in Mineral Resources of Virginia database). Commodity letter symbols: bs - building and dimension stone; cs - crushed stone; sg - sand and gravel.

sg-303 Abandoned or reclaimed borrow pit

bs-206 Abandoned or reclaimed mine or quarry

cs-204 Active mine or quarry

Extracted from: (Drewry's Bluff 7.5' Quadrangle).

Drewrys Bluff References

Carter, M.W., Berquist, C.R., Jr., Bleick, H.A., and Bondurant, A.K., 2007, Geology of the Richmond area, in Bailey, C.M., and Lamoreaux, M.H., Geology of Jamestown and the lower James River basin: Guidebook for the 37th Annual Virginia Geological Field Conference, Williamsburg, Virginia, p. 31-56.

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Doar, W. R., III., and Berquist, C. R., Jr,. 2009, The Late Pliocene and Pleistocene marine stratigraphies of South Carolina and Southeastern Virginia (abs.): Geological Society of America Abstracts with Programs, v. 41, No. 1, p. 53.

Goodwin, B. K., 1980, Geology of the Bon Air Quadrangle, Virginia: Virginia Division of Mineral Resources Publication 18, 1:24,000-scale geologic map.

Goodwin, B.K., and Johnson, G.H., 1970, Geology of upland gravels near Midlothian, Virginia: Eleventh Annual Field Conference of the Atlantic Coastal Plain Geological Association Guidebook, Part 2, 30 p.

Johnson, G.H., and Berquist, C.R., Jr., 1989, Geology and mineral resources of the Brandon and Norge quadrangles, Virginia: Virginia Division of Mineral Resources Publication 87, 28 p., 1:24,000-scale geologic map.

Lee, J.K.W., and Williams, I.S., 1993, Microstructural controls on U-Pb mobility in zircons: EOS, Transactions of the American Geophysical Union, v. 74, Supplement, p. 650-651.

Mixon, R.B., Berquist, C.R., Jr., Newell, W.L., Johnson, G.H., Powars, D.S., Schindler, J.S., and Rader, E.K., 1989, Geologic map and generalized cross sections of the Coastal Plain and adjacent parts of the Piedmont, Virginia: U.S. Geological Survey Miscellaneous Investigations Map I-2033, scale 1:250,000.

Newell, W.L., and Rader, E.K., 1982, Tectonic control of cyclic sedimentation in the Chesapeake Group of Virginia and Maryland, in Lyttle, P.T., Central Appalachian Geology: Northeast-Southeast Geological Society of America 1982 Field Trip Guidebooks, p. 1-28.

Wright, J.E., Sinha, A.K., and Glover, L., III, 1975, Age of zircons from the Petersburg Granite, Virginia, with comments on belts of plutons in the Piedmont: American Journal of Science, v. 275, no. 7, p. 848-856.

Footnotes

[1]Description of map unit modified from Goodwin (1980).

[2]United States Department of Agriculture, Natural Resources Conservation Service, 2006, Soil Survey Geographic (SSURGO) database for Chesterfield and Henrico counties, Virginia: U.S. Department of Agriculture, Natural Resources Conservation Service, Fort Worth, Texas (Available at http://SoilDataMart.nrcs.usda.gov).

[3]Soil Survey Staff, 2004, Official Soil Series Descriptions: U. S. Department of Agriculture, Natural Resources Conservation Service (Available at http://soils.usda.gov/technical/classification/osd/index.html).

[4]Description of map unit modified from Daniels and Onuschak (1974).

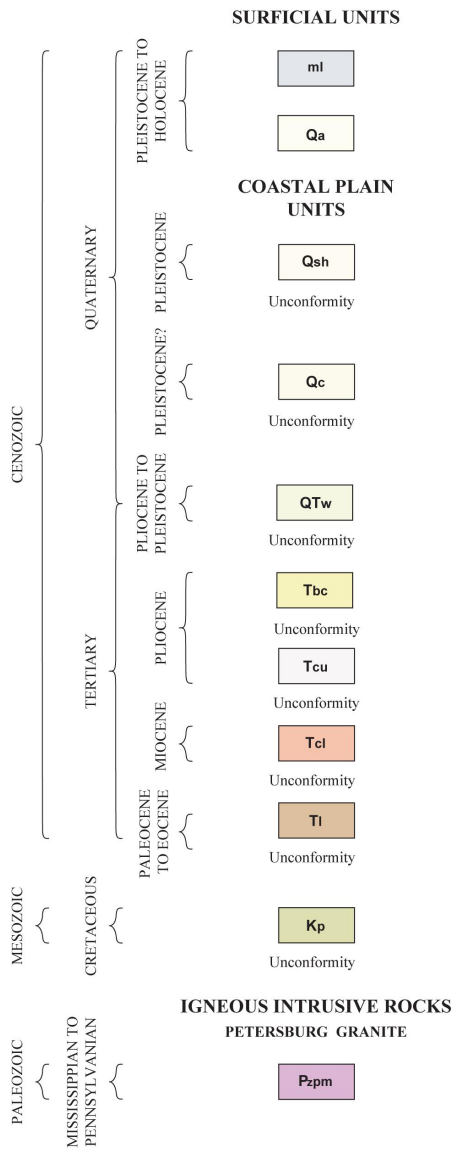
[5]Description of map unit modified from Mixon and others (1989).

Extracted from: (Drewry's Bluff 7.5' Quadrangle).

Dutch Gap 7.5' Quadrangle

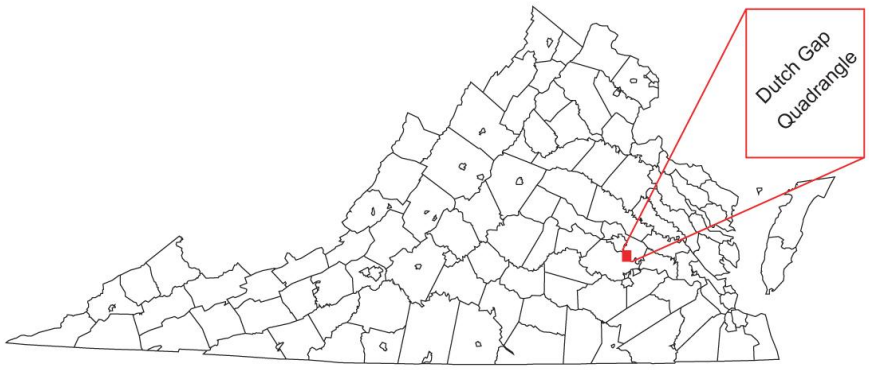
Berquist, C.R., and Carter, M.W., 2009, Geologic Map of the Dutch Gap Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2008 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (*GRI Source Map ID 75763*).

Dutch Gap Correlation of Map Units



Extracted from: (Dutch Gap 7.5' Quadrangle).

Dutch Gap Index Map



Extracted from: (Dutch Gap 7.5' Quadrangle).

Dutch Gap Map Symbols

For all contact symbols: lines are solid where the location is exact (located in the field to within 50 feet or 15 meters), long-dashed where the location is approximate (located to within 200 feet or 60 meters); short-dashed where the location is inferred; for faults, dotted where the location is concealed beneath surficial and Coastal Plain cover.

Line Symbols on Map

Stratigraphic Contacts

Fault Contacts
high-angle reverse or normal faults;
"U" on upthrown block, "D" on downthrown block

Line Symbols in Cross Section

Stratigraphic Contacts

Eroded Contacts

Mineral Resources
Commodity letter symbol precedes identifcation number (identification numbers are preceded by "99A-" in Mineral Resources of Virginia database). Commodity letter symbols: sg - sand and gravel.

sg-708 Active borrow pit

sg-701 Abandoned or reclaimed borrow pit

Geologic References

R-10132 Rock repository sample

W-4041 Water well drill cuttings

B-2008182-1 VDGMR Borehole

Other boreholes used to construct map and cross sections

Extracted from: (Dutch Gap 7.5' Quadrangle).

Dutch Gap References

Clark, W. B. 1896, The Potomac River section of the middle Atlantic Coast Eocene: American Journal of Science, 4th series, v. 1, no. 5, p. 363-374.

Clark, W. B., and Martin, G. C., 1901, The Eocene deposits of Maryland: in Clark, W.B., and others, Eocene: Maryland Geological Survey Systematic Report, 331 p.

Coch, N. K., 1968, Geology of the Benns Church, Smithfield, Windsor and Chuckatuck quadrangles, Virginia: Virginia Divsion of Mineral Resources, Report of Investigations 17, 39 p.

Daniels, P. A. Jr., 1974, Geologic map of the Seven Pines Quadrangle, Virginia, in

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Dischinger, J. B., 1987, Late Mesozoic and Cenozoic stratigraphic and structural framework near Hopewell, Virginia: U. S. Geological Survey Bulletin 1567, 48 p.

Doar, W. R.,III., and Berquist, C. R., Jr,. 2009, The Late Pliocene and Pleistocene marine stratigraphies of South Carolina and Southeastern Virginia (abs.): Geological Society of America Southeastern Section Meeting, 12-13 March.

Johnson, G. H., and Berquist, C. R., Jr., 1989, Geology and mineral resources of the Brandon and Norge quadrangles: Virginia Divsion of Mineral Resources, Publication 87, 28 p.

Johnson, G. H., and Peebles, P. C., 1983, Geology of the Capitol area, Richmond, Virginia in Exline, J. D., Earth Science Field Guide, Region 1: Virginia Department of Education, Commonwealth of Virginia, p. 9-90.

Lee, J. K.W., and Williams, I. S., 1993, Microstructural controls on U-Pb mobility in zircons: EOS, Transactions of the American Geophysical Union, v. 74, Supplement, p. 650-651.

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McGee, W.J., 1886, Geologic formations of Washington, D.C., and vicinity: District of Columbia, Health Officer Report, 1885, p. 19-20, 23-25.

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Ramsey, K., 1988, Stratigraphy and sedimentology of a Late Pliocene intertidal to fluvial transgressive deposit: Bacons Castle Formation, Upper York-James Peninsula, Virginia [PhD dissert.]: University of Delaware, Newark, Delaware, 399 p.

Reyher, T., 2009, A Comparison of Clast Composition and Size Between Sediments of the Aquia Formation and Potomac Formation: Unpublished Senior Thesis, Department of Geology, College of William and Mary, 43 p.

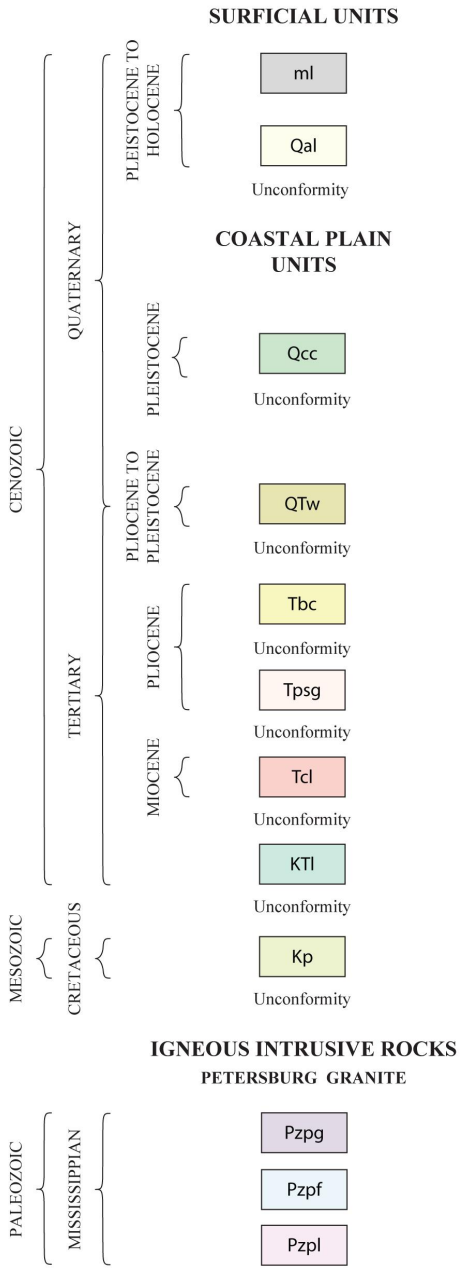
Wright, J. E., Sinha, A. K., and Glover, L., III., 1975, Age of zircons from the Petersburg Granite; with comments on belts of plutons in the Piedmont: American Journal of Science, v. 275, p. 848-856.

Extracted from: (Dutch Gap 7.5' Quadrangle).

Richmond 7.5' Quadrangle

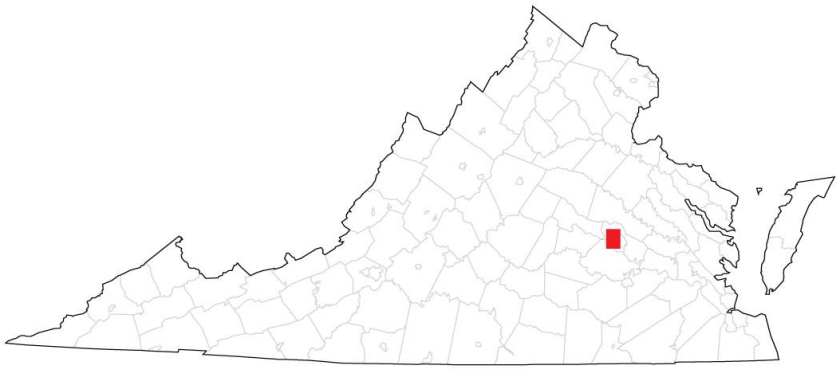
Bleick, H.A., Carter, M.W., and Berquist, C.R., 2007, Geologic Map of the Richmond Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2006 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (*GRI Source Map ID 75761*).

Richmond Correlation of Map Units



Extracted from: (Richmond 7.5' Quadrangle).

Richmond Index Map



Extracted from: (Richmond 7.5' Quadrangle).

Richmond Map Symbols

For all contact symbols: lines are solid where the location is exact (located in field to within 50 feet or 15 meters), long-dashed where the location is approximate (located to within 200 feet or 60 meters) ; short-dashed where the location is inferred. For geologic observation symbols, observation sites are centered on the strike bar, or are at the intersection point of multiple symbols.

Contacts

Form Line or Eroded Contact (in cross sections)

Geologic Observations

11 — Strike and dip of inclined beds in Coastal Plain sediments

81 — Strike and dip of inclined foliations in Petersburg Granite

68 — Compostional layering in Petersburg Granite

65 — Strike and dip of inclined quartz veins, aplite and pegmatite dikes

43 — Strike and dip of inclined joints

40 — Strike and dip of inclined chalcedony-filled fractures or joints

3 — Bearing and plunge of slickenlines

29 — Bearing and plunge of crenulation axes

Mineral Resources

Commodity letter symbol precedes identifcation number (identification numbers are preceded by "126C-" in Mineral Resources of Virginia database). Commodity letter symbols: bs - building and dimension stone; cs - crushed stone; sg - sand and gravel.

13064AE — Active Mine or quarry

bs-403 — Abandoned or reclaimed mine or quarry

sg-105 — Abandoned or reclaimed sand and gravel borrow pit

Geologic References

W1123 — Water Well drill cuttings

2010006-1 — Borehole

2 — Locality photographed and described, below and at right (location at tip of arrow)

Extracted from: (Richmond 7.5' Quadrangle).

Richmond References

[1]Daniels, P.A., Jr., 1974, Geologic map of the Richmond quadrangle, Virginia, in Daniels, P.A. Jr., and Onuschak, E., 1974, Geology of the Studley, Yellow Tavern, Richmond and Seven Pines quadrangles, Virginia: Virginia Division of Mineral Resources, Report of Investigations 38, 75 p., 4 maps at 1:24,000-scale, 10 plates.

[2]Description of map unit modified from: Daniels, P.A. Jr., and Onuschak, E., 1974, Geology of the Studley, Yellow Tavern, Richmond and Seven Pines quadrangles, Virginia: Virginia Division of Mineral Resources, Report of Investigations 38, 75 p., 4 maps at 1:24,000-scale, 10 plates.

[3]Description of map unit modified from: Mixon, R.B., Berquist, C.R., Jr., Newell, W.L., Johnson, G.H., Powars, D.S., Schindler, J.S., and Rader, E.K., 1989, Geologic map and generalized cross sections of the Coastal Plain and adjacent parts of the Piedmont, Virginia: U.S. Geological Survey Miscellaneous Investigations Map I-2033, scale 1:250,000.

Additional reference cited in text:

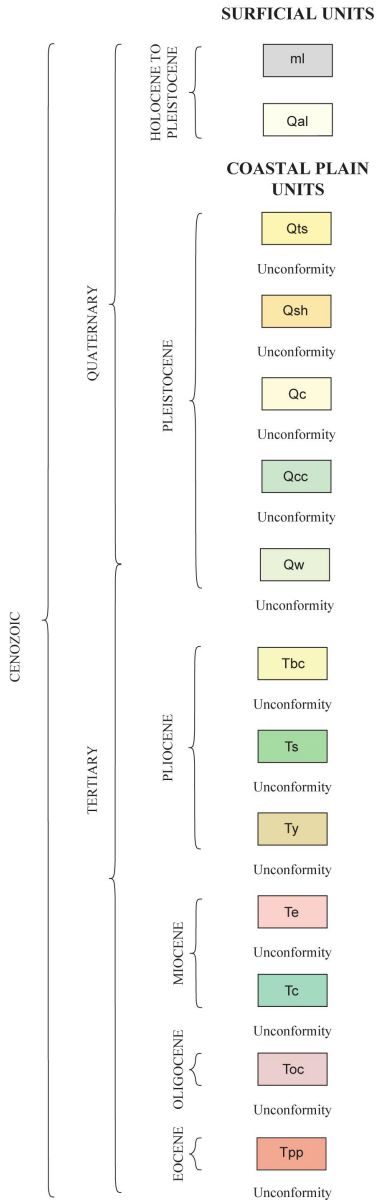
Wright, J.E., Sinha, A.K., and Glover, L., III, 1975, Age of zircons from the Petersburg Granite, Virginia, with comments on belts of plutons in the Piedmont: American Journal of Science, v. 275, n. 7, p. 848-856.

Extracted from: (Richmond 7.5' Quadrangle).

Roxbury 7.5' Quadrangle

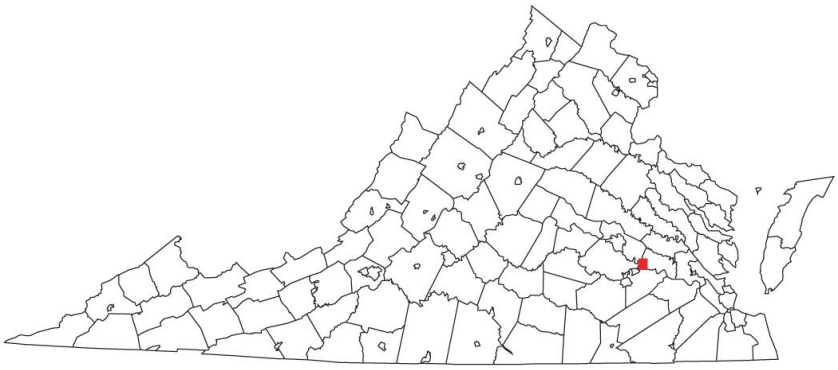
Gilmer, A.K., and Berquist, C.R., 2011, Geologic Map of the Roxbury Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, 2011 STATEMAP Deliverable, unpublished map and digital data, scale 1:24,000. (*GRI Source Map ID 75762*).

Roxbury Correlation of Map Units



Extracted from: (Roxbury 7.5' Quadrangle).

Roxbury Index Map



Extracted from: (Roxbury 7.5' Quadrangle).

Roxbury Map Symbols

Stratigraphic Contacts

Approximate

Inferred

Concealed

Fault Contacts
high-angle fault;
"U" on upthrown block, "D" on downthrown block

U
D
Concealed

Mineral Resources

Commodity letter symbol precedes identifcation number (identification numbers for inactive sites are preceded by "98B-" in Mineral Resources of Virginia database). Identification number for active sites is the Division of Mineral Mining permit number.

90436AA Active sand and gravel borrow pit

sg-105 Abandoned or reclaimed sand and gravel borrow pit

Geologic References

2010006-1 Geologic Borehole

Extracted from: (Roxbury 7.5' Quadrangle).

Roxbury References

Coch, N. K., 1965, Post-Miocene stratigraphy and morphology, inner coastal plain, southeastern Virginia: Office of Naval Research, Geography Branch Technical Report, no. 6, 97 p.

Coch, N. K., 1968, Geology of the Benns Church, Smithfield, Windsor and Chuckatuck quadrangles, Virginia: Virginia Divsion of Mineral Resources Report of Investigations 17, 39 p.

Costain, J. K., L. Glover, III, and A. K. Sinha, eds.,1979, Evaluation and targeting of geothermal energy resources in the southeastern United States: Series of Progress Reports VPI&SU-5103 and VPI&SU-5648.

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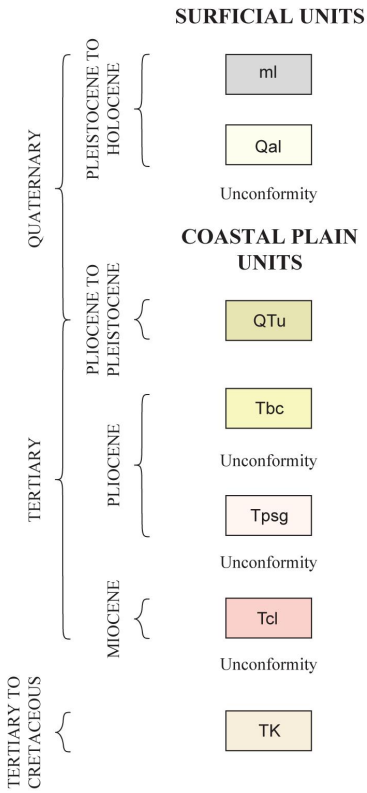
Extracted from: (Roxbury 7.5' Quadrangle).

Seven Pines 7.5' Quadrangle

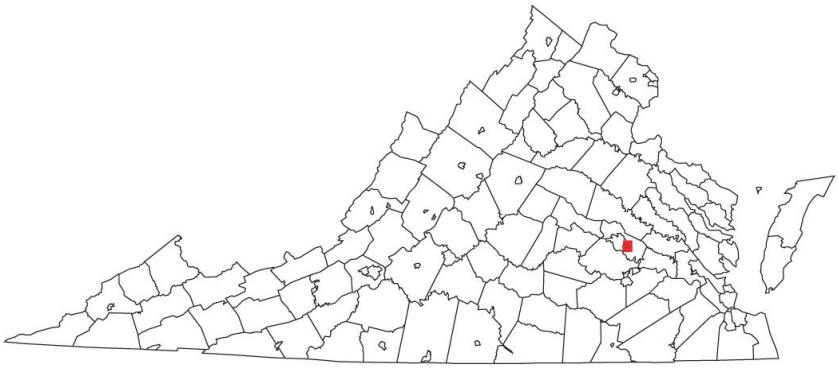
Bondurant, A.K., Bleick, H.A., Berquist, C.R., and Carter, M.W., 2011, Geologic Map of the Seven Pines Quadrangle, Virginia: Virginia Division of Geology and Mineral Resources, Open File Report 11-__, unpublished map and digital data, scale 1:24,000. (*GRI Source Map ID 75760*).

Seven Pines Correlation of Map Units



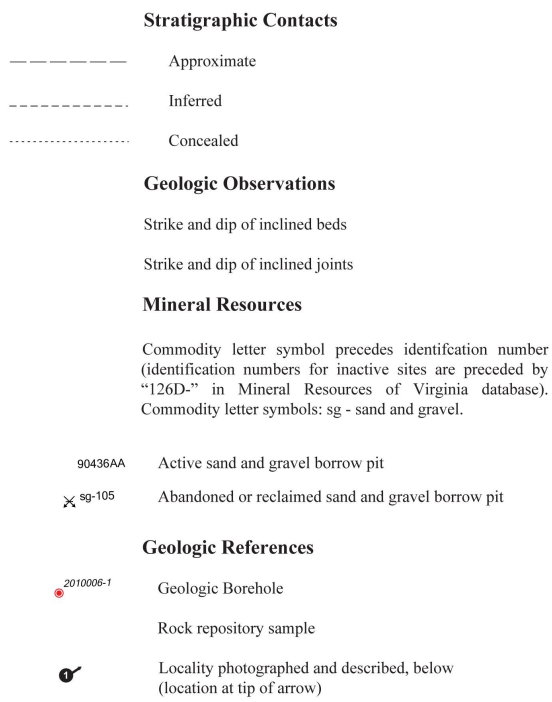
Extracted from: (Seven Pines 7.5' Quadrangle).

Seven Pines Index Map



Extracted from: (Seven Pines 7.5' Quadrangle).

Seven Pines Map Symbols



Extracted from: (Seven Pines 7.5' Quadrangle).

Seven Pines References

[1]Daniels, P. A. Jr., 1974, Geologic map of the Seven Pines Quadrangle, Virginia, in Daniels, P. A. Jr. and Onuschak, E. Jr., 1974, Geology of the Studley, Yellow Tavern, Richmond and Seven Pines Quadrangles, Virginia: Virginia Divsion of Mineral Resources, Report of Investigations 38, 75 p., 4 maps at 1:24,000-scale, 10 plates.

[2]Description of map unit modified from:

Daniels, P. A. Jr., 1974, Geologic map of the Seven Pines Quadrangle, Virginia, in Daniels, P. A. Jr. and Onuschak, E. Jr., 1974, Geology of the Studley, Yellow Tavern, Richmond and Seven Pines Quadrangles, Virginia: Virginia Divsion of Mineral Resources, Report of Investigations 38, 75 p., 4 maps at 1:24,000-scale, 10 plates.

[3]Description of map unit modified from:

Daniels, P. A. Jr., 1974, Geologic map of the Richmond Quadrangle, Virginia, in Daniels, P. A. Jr. and Onuschak, E. Jr., 1974, Geology of the Studley, Yellow Tavern, Richmond, and Seven Pines Quadrangles, Virginia: Virginia Division of Mineral Resources, Report of Investigations 38, scale 1:24,000.

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Footnotes

[1]Description of map unit modified from Goodwin (1980).

[2]United States Department of Agriculture, Natural Resources Conservation Service, 2006, Soil Survey Geographic (SSURGO) database for Chesterfield and Henrico counties, Virginia: U.S. Department of Agriculture, Natural Resources Conservation Service, Fort Worth, Texas (Available at http://SoilDataMart.nrcs.usda.gov).

[3]Soil Survey Staff, 2004, Official Soil Series Descriptions: U. S. Department of Agriculture, Natural Resources Conservation Service (Available at http://soils.usda.gov/technical/classification/osd/index.html).

[4]Description of map unit modified from Daniels and Onuschak (1974).

[5]Description of map unit modified from Mixon and others (1989).

Extracted from: (Seven Pines 7.5' Quadrangle).

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GRI finalization by Stephanie O'Meara.

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