VIRGINIA DIVISION OF MINERAL RESOURCES
PUBLICATION 87

GEOLOGY AND MINERAL RESOURCES OF THE BRANDON AND NORGE QUADRANGLES, VIRGINIA

Gerald H. Johnson and C. R. Berquist, Jr.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
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Robert C. Milici, Commissioner of Mineral Resources and State Geologists

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FRONT COVER: Intertidal sediments of the Barhamsville Member, Bacons Castle Formation exposed at the east side of the Little Creek Reservoir dam, Feburary 1989.

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DEPARTMENT OF MINES MINERALS AND ENERGY
RICHMOND, VIRGINIA
O. Gene Dishner, Director

DIVISION OF MINERAL RESOURCES
CHARLOTTESVILLE, VIRGINIA
Robert C. Milici, Commissioner of Mineral Resources and State Geologist

DEPARTMENT OF PURCHASES AND SUPPLY
RICHMOND, VIRGINIA

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GEOLOGY AND MINERAL RESOURCES OF THE BRANDON AND NORGE QUADRANGLES, VIRGINIA

Gerald H. Johnson[1] and C. R. Berquist, Jr.[2]

ABSTRACT

The Brandon and Norge 7.5-minute quadrangles are located on the lower Coastal Plain of southeastern Virginia in the counties of Charles City, James City, Prince George, and York. The area ranges in elevation from slightly over 140 feet in the Norge uplands to sea level along the James and Chickahominy rivers. Except for a portion of York County in the Norge quadrangle which drains into the York River, surface water flows into the James River and its tributaries. The Norge uplands represents the highly dissected remnants of a marine plain. The lower terrain is dominated by a succession of terraces that are separated from one another by river-parallel scarps.

Formations exposed in the Brandon and Norge quadrangles include the Eastover (Upper Miocene), Yorktown (Lower and Upper Pliocene), Bacons Castle (Upper Pliocene), Moorings (Upper Pliocene (?)), Windsor and Charles City (Lower Pleistocene), Chuckatuck (Lower or Middle Pleistocene), Shirley (Middle Pleistocene), Tabb (Upper Pleistocene), and Holocene deposits. The Tertiary formations were deposited under marine or marginal marine conditions whereas the Pleistocene and Holocene sediments formed in valleys that had been excavated during preceding glacial lowstands of sea level. The Quaternary deposits, each of which generally exhibits an upward-fining sequence, formed under fluvial-estuarine conditions during periods of relatively higher sea level.

Sand and gravel is the principal economic mineral resource mined from the Brandon and Norge areas. Large quantities of this material are extracted from the Shirley Formation in Charles City County, but less pure, more variable sand and gravel deposits with less utility are present in the lower portions of the Bacons Castle, Windsor, Charles City, and Tabb formations in this area. Clay from the Shirley Formation has numerous structural and utilitarian uses; none is being mined at the present time. Relatively thin, impure lime and glauconite deposits occur beneath a thick cover of Bacons Castle Formation in the Norge uplands.

Groundwater is extracted from aquifers in the Chesapeake, Pamunkey, and Potomac groups and Pleistocene deposits. Geologic hazards in the Brandon and Norge quadrangles include storm flooding in low-lying areas, shoreline recession from stream erosion and mass wastage, land subsidence caused by dissolution of carbonates and groundwater withdrawal (water mining), and groundwater contamination from the infiltration of sewage effluents and sanitary landfill leachate. Locally, peat at shallow depth, high surficial groundwater tables, and shrink-swell soils pose problems for construction of buildings and other structures.

INTRODUCTION

The Brandon and Norge 7.5-minute quadrangles (Figure 1) are located on the Middle Atlantic Coastal Plain of southeastern Virginia. With the exception of small portions in Prince George and York counties, the Brandon and Norge quadrangles lie within Charles City and James City counties. Longitudes 77°00' and 76°45' west and parallels 37°15' and 37°22'30" north bound the study area. Although tourism and retail sales are the leading sources of income, most of the areais rural with forestry, farming, fishing, and hunting as the principal industries. A second-growth, mixed hardwood-pine forest covers approximately 80 percent of the land area. Corn, soybeans, wheat, and barley are the principal crops grown on the moderately to well-drained soils along the James River and the adjoining interfluves. Only small settlements are present in the area. Interstate Highway 64, U. S. Highway 60, and State Highway 5 are the principal highways; numerous secondary roads cross the area. The Chesapeake and Ohio Railway services the area and coal is the principal freight. Except for Little Creek reservoir, no other major utility occurs in the area.

The surface runoff in the Brandon and Norge quad angles flows primarily into the Chickahominy River and then into the James River but a small portion drains northward into the York River. The James River crosses the Brandon quadrangle from northwest to southeast and the Chickahominy River flows from north to south along the common boundary of the two quadrangles. The Chickahominy River covers about 8.5 square miles of the quadrangles. Although the James and Chickahominy rivers in the study area have an average tidal range of 2.8 feet, neither have significant saltwater influx except in time of extreme drought. Marshes fringe the rivers and occupy the lower reaches of most smaller streams in the area; in addition to their aesthetic and ecologic value, the marshes reduce erosion and flooding (Moore,

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1980). Swamps and flood plains usually occur upstream from the marshes. The principal drainages in the Brandon and Norge quadrangles are Kennon, Barrows, Morris, Tomahund, Yarmouth, and Powhatan creeks. Little Creek Reservoir, completed in 1980 and owned by the City of Newport News, has a surface area of approximately 800 acres.

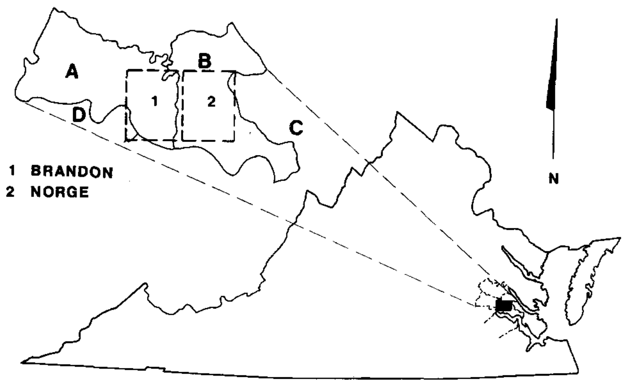

Figure 1. Map showing the location of the Brandon and Norge quadrangles in Charles City (A), James City (B), and Prince George (C) counties, Virginia.

Eugene K. Rader and D. A. Hubbard of the Virginia Division of Mineral Resources initiated the geologic investigation in the Norge quadrangle and assisted with later field work. Field work by the writers began in the fall of 1978 and continued intermittently through September, 1988. Natural and man-made exposures provided detailed sedimentologic and stratigraphic information. Subsurface data were acquired by several methods: over 500 hand-auger holes as deep as 37 feet; 60 power-auger holes, as deep as 24 feet; 18 split-spoon/hollow-stem auger holes, as deep as 127 feet; and 20 continuous-sample split-spoon holes, as deep as 65 feet. A summary of subsurface data is provided in Appendix II. During the construction of the Little Creek Reservoir, Berquist examined approximately 40 miles of continuous exposure along the shoreline of the reservoir. Berquist and Ramsey (1985) and Ramsey (1988) studied the stratigraphy of the Bacons Castle Formation on the York-James Peninsula and much of their work is reflected in the discussion of the formation in this report. Becky Darton, Michelle Dewey, Kathleen Farrell, Eileen Sullivan, and geology students at the College of William and Mary assisted the writers in field and laboratory work. Kelvin Ramsey provided a significant contribution in drilling, laboratory work, library research, soils analysis, and fossil identification in the Norge quadrangle.

Eugene Rader, Virginia Division of Mineral Resources, Wayne Newell and Lauck Ward, United States Geological Survey, Kenneth F. Bick, College of William and Mary, Pamela C. Peebles, Virginia Department of Transportation, and Nicholas K. Coch, Queens College, provided helpful discussion on the stratigraphy of the area. The writers would also like to thank Wayland Bass, Henry Stephens, Deward Martin and their staff of James City County for access to maps and engineering reports; Tony Izzo of Malcom Pirnie Engineers for engineering data at the Little Creek Reservoir; Harold Matthews and William E. Dvorak of Old Dominion Soil Consultants, Inc., and Art Russnow of Russnow-Kane and Associates, Inc., for boring samples at the James City County landfill. In addition, Tom Rodgers, Virginia Power Company, and N. L. Hofmeyer, farmer, provided boring data from their files. Larry Nester of Henry S. Branscombe, Inc., was particularly helpful in providing information on the operation of their pits in Charles City County. Robert L. Hodges, Soil Scientist, Department of Agronomy, Virginia Polytechnic Institute and State University, and Lester L. Seglin and John Mihalcoe, Jr., U.S. Department of Agriculture Soil Conservation Service, made soil surveys information available to the writers. Donald L. Brime of the Virginia Commission of Game and Inland Fisheries permitted access to the Chickahominy State Wildlife Management Area. Drew Meng, U.S. Geological Survey, provided water well data and helpful discussion on groundwater problems. The writers wish to express their grateful appreciation to the numerous farmers, hunt clubs, and landowners for access to their property. The quadrangles to the east and southeast (Figure 2) were mapped by Bick and Coch (1969) and others. Marilyn A. Johnson and Mary Ellen Magary typed the draft of the manuscript.

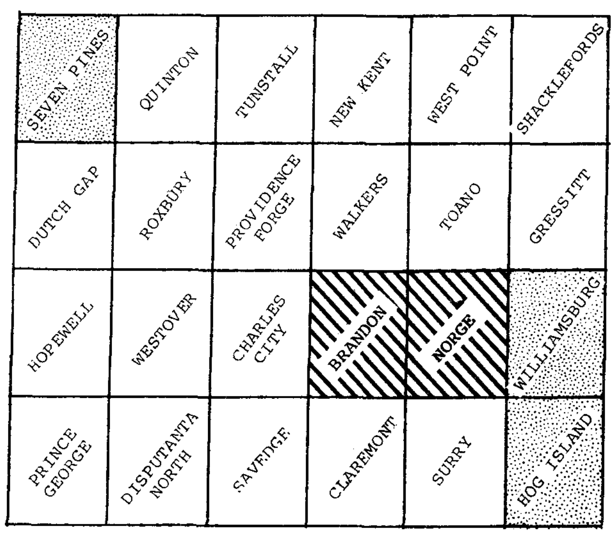

Figure 2. Diagram showing the quadrangles surrounding Brandon and Norge and the published geologic maps (shaded).

MORPHOLOGY

The topography of Brandon and Norge quadrangles is characterized by a succession of plains and intervening scarps (Figure 3). Previous workers (Clark and Miller, 1912;

Wentworth, 1930; Roberts, 1932; Bick and Coch, 1969; Johnson, 1969, 1972, 1976; Johnson and others, 1980) recognized the stair-stepped nature of the landscape on the York-James Peninsula (Table 1). The undissected portions of flats or plains represent the upper surface of aggradational sedimentary sequences and the scarps are the product of shoreline erosion. The flats decrease in elevation to the southeast and toward adjoining master streams. The highest flats occur in the northern portion of the Brandon and Norge quadrangles; adjacent flats generally decrease in elevation southward to the James River and toward the Chickahominy River. Subsequent to their formation, the scarps and plains have undergone erosion and colluviation.

erosion have created a rolling terrain of knobs and broad ridges with crests at 110 to 132 feet; local relief is 80 feet. Steep-sided V-shaped valleys occur in the upper reaches of streams; downstream these valleys are filled with Holocene floodplain, swamp, and marsh sediments forming flat-bottomed valleys.

Sediments of the Bacons Castle Formation and the Moorings unit underlie the Norge upland. The Norge uplands is separated from the Lackey plain by the Surry scarp (Bick and Coch, 1969; Johnson and others, 1980). The scarp, which was originally defined by Wentworth (1930) as a coast-wise scarp, is now recognized along the James River and major streams in southeastern Virginia. In the Norge and Brandon

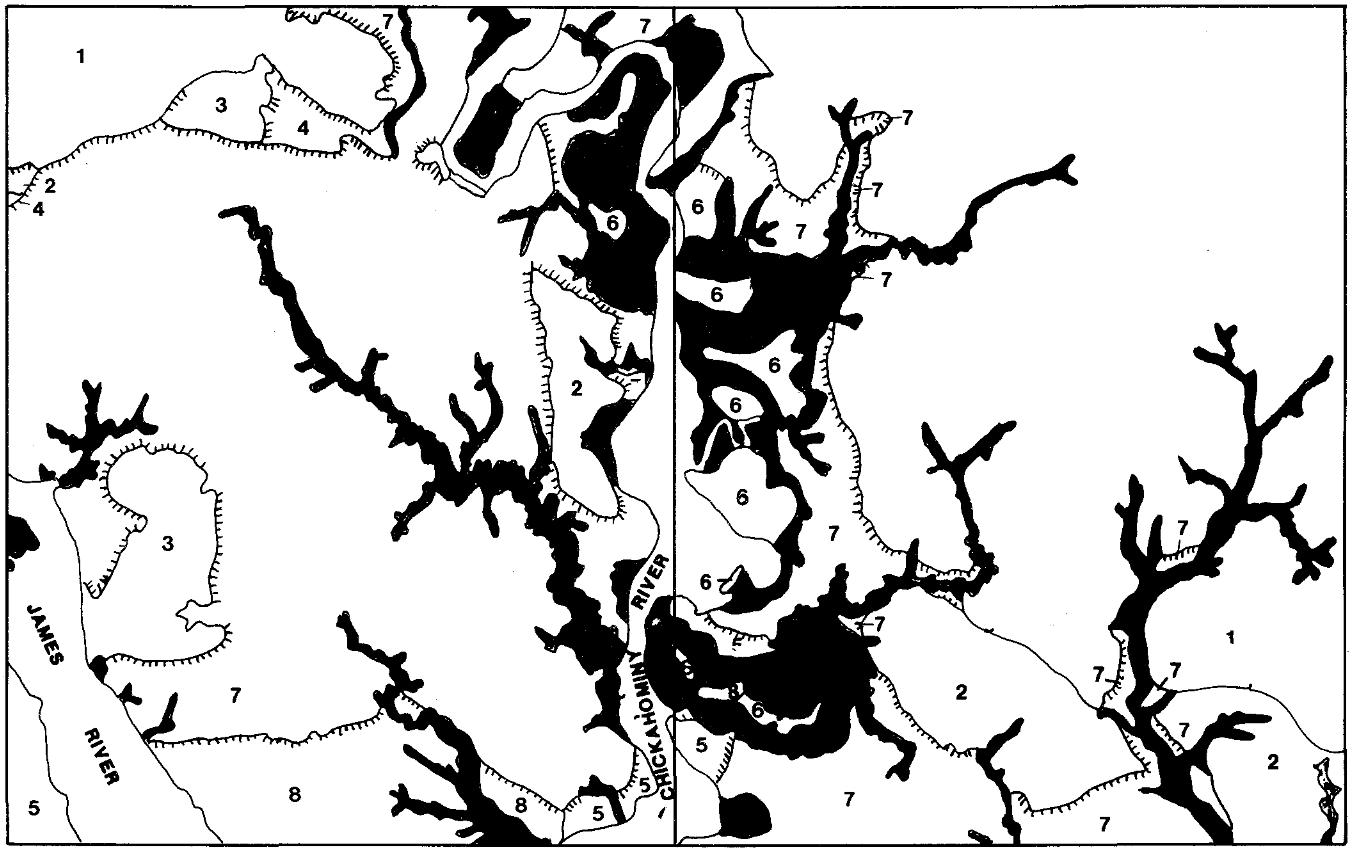

Figure 3. Map showing the principal geomorphic features in the Brandon and Norge quadrangles. Explanation: Scarps - hachured line, line on top of scarp; 1 - Norge uplands; 2 - Lackey plain; 3 - Grove plain; 4 - Grafton plain; 5 - Hampton flat (Dancing Point flat); 6 - Mulberry Island flat (Shield Point flat); 7 - Huntington flat; 8 - Todds flat; Black - marsh, swamp, and floodplain.

The Norge uplands (Johnson and others, 1980) occurs in the northern portion of the study area and is extensively developed on the quadrangles to the northwest. This undissected plain in the Seven Pines and Dutch Gap areas to the west (Figure 2) is about 165 feet above sea level; its surface decreases in elevation eastward to approximately 148 feet in the eroded uplands in the Norge and Toano quadrangles. In the Norge uplands mass wastage and stream

quadrangles, the scarp is highly dissected and therefore commonly difficult to recognize in the field. The scarp is well preserved in the Providence Forge and Dutch Gap quadrangles to the west and northwest where the toe of the scarp lies at an elevation of approximately 95 feet. The James River cut the scarp during the time of deposition of the Windsor Formation.

The Lackey plain (Johnson, 1976) is represented by the upland at the Chickahominy State Wildlife Management Area and by broad flats in the southern portion of the Norge quadrangle (Figure 3). The plain slopes gently from 93 feet (near the Surry scarp) to less than 80 feet on its southern margin but exhibits no appreciable slope to the east. Deep stream valleys with more than 80 feet of relief have been cut into the Lackey plain. The surficial deposit over most of the plain is the Windsor Formation; locally the Yorktown Formation crops out along the valley walls.

The Ruthville scarp, herein named for the village of Ruthville in Charles City County, divides the Lackey plain from the subjacent Grove plain. The scarp trends subparallel to the course of the James River from James City County to Richmond. The elevation of the toe of the scarp varies from 75 to 80 feet. The crest of the scarp ranges from 90 feet to more than 150 feet. The slope on the scarp is gentle (6 feet per mile) to steep (120 feet per mile). Reentrants along the scarp have been cut by small transverse streams. Shoreline erosion at the time of deposition of the Charles City Formation formed the scarp.

Remnants of the Grove plain (Johnson, 1972) are found on the uplands to the south of Cherry Hall, at Mount Airy, southwest of Holdcroft (Figure 3) and as narrow terraces along Little Creek that are too small to illustrate; fragments also occur along small streams elsewhere but have not been mapped. In the Cherry Hall area, the Grove plain is rolling and slopes southward from 74 feet to less than 60 feet. Although weakly developed in the Brandon quadrangle, lin-

Table 1. Summary of geomorphic nomenclature in the Brandon and Norge area.

Wentworth, 1930 Roberts, 1932	Oaks and Coch, 1973, 1987	Johnson and others, 1981, 1987; this report
Sunderland terrace	Prince George upland Sussex plain	Norge uplands
	Surry scarp	Surry scarp
		Lackey plain
		Ruthville scarp
Wicomico terrace	Isle of Wight plain	Grove plain
		Lee Hall scarp
		Grafton plain
	Chippokes and Hazelton scarps	Kingsmill scarp
Chowan terrace	Hall Pocosin flat	Huntington flat
	Suffolk scarp	Suffolk scarp
Dismal Swamp terrace	Churchland flat and Fentress rise	Todds flat
	Hickory scarp	Big Bethel scarp
	Deep Creek swale and Mount Pleasant flat	Hampton flat
Princess Anne terrace	Sand-ridge and Mud-flat complex	Mulberry Island flat

ear ridges are prominent on the Grove plain in the Charles City quadrangle. The small terraces along Little Creek are aggradational flats with elevations of 67 to 74 feet. Although older sediments crop out locally, the Charles City Formation is the surficial formation under most of the Grove Plain.

A discontinuous, low scarp, the Lee Hall (Johnson, 1972), trends parallel to the middle reach of Barrow Creek and divides the Grove and higher plains from the Grafton Plain. No clearly defined scarp exists between the Grafton and Grove plains south of Cherry Hall (Brandon quadrangle). The toe of the scarp is at approximately 62 feet. The scarp was formed by shoreline erosion along the James River estuary during deposition of the Chuckatuck Formation.

A narrow tract of land along the middle reach of Barrow Creek and another on the southeastern half of the Cherry Hall upland at 55 to 60 feet are correlated to the Grafton Plain on the lower part of the York-James Peninsula. The plain is gently rolling to flat and is underlain by fine-grained estuarine sediments of the Chuckatuck Formation.

The Kingsmill scarp (Bick and Coch, 1969) separates the higher plains from the Huntington flat. This scarp trends subparallel to the James and Chickahominy rivers and encircles the uplands near Cherry Hall and the Chickahominy State Wildlife Management Area. The toe of the scarp ranges in elevation from 43 feet to 48 feet through much of its length. The crest is variable, ranging from 43 feet where the scarp is indistinct to more than 100 feet where prominent. The scarp was cut by shoreline erosion along the ancestral James River during the time of deposition of the Shirley Formation.

The Huntington flat, named by Coch (1971), occupies most of the central and southern portions of the Brandon quadrangle and the southern portion of the Norge quadrangle (Figure 3). The flat nearly surrounds the uplands near Cherry Hall, Mount Airy, and the Chickahominy State Wildlife Management Area, and extends north-northwestward along the Chickahominy River. The undissected flat ranges in elevation from approximately 48 feet near the Kingsmill scarp to approximately 33 feet in the central portion of the Huntington flat. The flat maintains a nearly constant elevation from east to west. Although the flat does not possess strongly developed ridge and swale topography typical of lower flats in the Brandon area or that typify the Huntington flat to the west (Charles City and Westover quadrangles), a shallow arcuate swale, along Morris Creek, occupies the central portion of the flat. Similarly, the rectangular drainage pattern of the tributaries to Morris Creek near Cherry Hall developed between short, low ridges and swales and the longer recurved drainage lines, such as Morris Creek and upper Parsons Creek. Small upland swamps, located 1 mile southwest of Mount Airy and elsewhere on the flat, developed in shallow depressions on the Huntington flat. Headward erosion by small streams and from man-made ditches has led to the partial or complete draining of these areas. A small spit projects into the flat approximately 1 mile southwest of Holdcroft. Much of the flat is poorly drained because of the low relief, broad flat, fine-grained soils, and dense vegetation. The Huntington flat slopes most steeply within 0.6 mile of the bounding scarps. The flat is dissected by Tomahund, Morris, Kennon, Barrows, Yarmouth, Gordon, and Powhatan creeks. Marshes, swamps, and flood plains occupy the lowlands. The surficial deposits of the Huntington flat are the clayey sand and locally gravelly sand of the Shirley Formation.

The Suffolk scarp (Flint, 1940) separates the higher plain, principally the Huntington flat, from the lower Dancing Point flat. This scarp has a toe elevation of approximately 25 feet and a crest that exceeds 35 feet. The scarp trends east-west in the southern part of the Brandon quadrangle and is found only as isolated remnants elsewhere in the study area. The scarp was cut by the ancestral James and Chickahominy rivers during the Late Pleistocene.

In the Brandon and Norge quadrangles, the boundary between the Hampton and Todds flats is not as clearly defined as on the lower part of the York-James Peninsula shown on Figure 3 (Johnson, 1976). The morphological distinction between these flats is not made in this report and they are collectively called the Dancing Point flat (Johnson and others, 1980). This flat is characterized by a ridge and swale topography with ridges that rise 5 to 15 feet above the adjacent swales. The ridges, which diminish in elevation downstream, range in elevation from 26 feet to less than 10 feet at their downstream extremity. They exhibit a curvilinear pattern that varies from subparallel to perpendicular to the present James River. The swales are poorly drained and are occupied by intermittent and perennial streams, marshes, and swamps. The ridges are composed of sand and are mantled with silts and clayey fine sand of the Sedgefield and Lynnhaven members of the Tabb Formation. The Dancing Point flat was created by fluvial-estuarine processes during the Late Pleistocene.

The Mulberry Island flat, formerly the Mulberry Island ridge and swale (Johnson, 1969), consists of areas with gently sloping, low-relief topography or with a series of curvilinear ridges and swales. The ridges decrease in elevation downstream; the swales near sea level are covered by marshes and swamps along the Chickahominy River and at Kennon Marsh. The flat ranges in elevation from near sea level to about 12 feet and is well developed along the Chickahominy River at Parsons Island, Shields Point, Wright Island, and Old Neck (Plate 1). The Mulberry Island flat is underlain by the Poquoson Member of the Tabb Formation and was deposited under fluvial-estuarine conditions.

Holocene landforms in the Brandon and Norge quadrangles include the lowlands occupied by stream floodplains, estuaries, marshes, and swamps.

STRUCTURE

The Brandon and Norge quadrangles lie on the southwestern flank of the Chesapeake-Delaware embayment (Murray, 1961). The embayment, which developed in Mesozoic time, is filled with later Mesozoic and Cenozoic sediments. Basement rocks beneath the coastal plain sequence are comprised of metamorphic and igneous rocks of Paleozoic and Precambrian (?) age and Triassic sedimentary rocks. The coastal plain deposits thicken from less than 30 feet west of Richmond to more than 2500 feet in the Virginia Beach area. The deposits are about 900 feet thick along the western border of the Brandon quadrangle, and increase to over 1100 feet in the eastern part of the Norge quadrangle (Meng and Harsh, 1984).

The coastal plain sediments rest on an eastward dipping basement surface cut by Cenozoic faults (Mixon and Newell, 1977). The dip of the formations within the coastal plain sequence decreases progressively with age; the Eastover-Yorktown contact has a regional dip of approximately 2.5 feet per mile in the study area. The regional dip to the southeast and the reduction in dip in younger deposits of the coastal plain indicate that the continental margin has been progressively downwarped through much of later Mesozoic and Cenozoic times.

The Brandon and Norge quadrangles lie between the York-James monocline (Ward and Blackwelder, 1980) and the zone of reverse faulting near Hopewell (Dischinger, 1987). Faulting and warping influenced the depositional pattern of sediments in the Yorktown and Chowan River Formations (Johnson and others, 1985) during Pliocene time. The gentle eastward dip of the Eastover-Yorktown contact, the apparent absence of structural faults and folds within the study area, and the lack of discernible warping of Quaternary aggradational surfaces suggest that the differential structural deformation of the coastal plain during the Late Tertiary did not effect this area during the Quaternary (Johnson and Peebles, 1984). The progressively higher elevations of older Quaternary deposits indicate regional uplift of the entire Coastal Plain during the Late Cenozoic Era.

Sinkhole collapse structures, as much as 10 feet in diameter, are found in the Yorktown, Bacons Castle, Windsor, and Tabb Formations on the York-James Peninsula. Differential dissolution of carbonates from the Yorktown has produced subsidence and collapse structures (Figure 4), including small slump folds, normal faults, and collapse breccia. Normal faults with displacements of 2 to 18 inches occur in the Bacons Castle, Windsor, and Shirley Formations in the Norge and Brandon quadrangles, and are probably related to penecontemporaneous compaction, slumpage, and dissolution in the underlying Yorktown Formation.

Figure 4. Photograph of exposure showing collapse of overlying material into Yorktown deposits; dark unit is brown clay residue of the weathered Yorktown; light unit is the Barhamsville Member of the Bacons Castle Formation.

STRATIGRAPHY

The Coastal Plain stratigraphic sequence in the Brandon and Norge quadrangles is comprised of the Potomac Group (Cretaceous), Pamunkey Group (Paleocene, Eocene and Oligocene), Chesapeake Group (Miocene and Pliocene), and Pleistocene and Holocene sediments, in ascending order. The formations of the Potomac and Pamunkey and the lower part of the Chesapeake groups are known only from deep borings in the study area and will not be discussed further. Definitions and usage of stratigraphic units in the Virginia Coastal Plain have changed over the past 60 years. Table 2 summarizes the upper Cenozoic stratigraphic units recognized by various workers since 1928. Lithologic and sedimentary characteristics of the stratigraphic units used in this report are presented in Table 3.

The stratigraphic units exposed at the surface in the Brandon and Norge quadrangles include the Eastover, Yorktown, and Bacons Castle Formations of the Chesapeake Group, the Moorings unit, and the Windsor, Charles City, Shirley, Chuckatuck, and Tabb Formations and Holocene deposits (Table 2). The Eastover, Yorktown, and Bacons Castle of Late Tertiary age are sheets of fossiliferous marine or tidal-flat sand and silt that crop out in deep valleys in the Norge uplands and on the flanks of the Lackey plain. The Eastover (Upper Miocene) and Yorktown (Pliocene) are mapped together because of the limited exposure and lithologic similarity of the weathered upper Eastover and lower Yorktown Formations.

The Moorings unit is sporadic in distribution and of problematic age. Each of the Quaternary formations consists of an upward-fining sequence and, with the exception of the bay deposits of the Windsor, consists of fluvial-estuarine gravel, sand, clayey silt, and organic-rich sediments. A brief summary of the lithologic characteristics of each unit is presented in Table 3.

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Table 2. Summary of stratigraphic nomenclature

SERIES	MANSFIELD (1928, 1943)	WENTWORTH (1930) ROBERTS (1932)	MOORE (1956)	COCH (1965)	BICK AND COCH (1969)	JOHNSON (1969)	JOHNSON (1972)	OAKS AND COCH (1973)
HOLOCENE	Undifferentiated Holocene and Pleistocene deposits	Unnamed Holocene deposits	Unnamed Holocene deposits	Unnamed Holocene deposits and Dismal Swamp peat	Unnamed Holocene deposits	Unnamed Holocene deposits	Unnamed Holocene deposits	Unnamed Holocene and Dismal Swamp peat
PLEISTOCENE		Princess Anne Formation Dismal Swamp Formation Chowan Formation	Nansemond Formation	Sandbridge Fm. Londonbridge Fm. Kempsville Fm. Norfolk Fm. Great Bridge Fm.	Norfolk Formation	Norfolk Formation	Norfolk Formation: Silty-clay facies Sandy-clay facies Sand facies Silty sand facies	Sandbridge Fm. Londonbridge Fm. Kempsville Fm. Norfolk Fm. Great Bridge Fm.
		Wicomico Formation	Kilby Formation	Windsor Formation	Windsor Formation	Windsor Formation	Windsor Formation	Windsor Formation
PLEISTOCENE AND/OR PLIOCENE		Sunderland Fm. Brandywine Fm.	Sedley Formation	"Moorings" unit Bacons Castle Fm. Sedley Formation	Bacons Castle Formation Sedley Formation	not reported Bacons Castle Formation	not reported	"Moorings" unit Bacons Castle Formation
MIOCENE	Yorktown Formation	Yorktown Formation	Yorktown Formation	Yorktown Formation	Yorktown Formation	Yorktown Formation	Yorktown Formation	Sedley Formation
	St. Marys Fm.	St. Marys Fm.	St. Marys Fm.	not reported	St. Marys Fm.	St. Marys Fm.	not reported	Yorktown Formation

SERIES	JOHNSON (1976)	WARD AND BLACKWELDER (1980)	JOHNSON AND OTHERS (1980–1982)	JOHNSON AND OTHERS (1985)	JOHNSON&PEEBLES (1976)	THIS REPORT
HOLOCENE	Unnamed Holocene deposits	Undifferentiated Holocene Pleistocene, and Pliocene deposits	Unnamed Holocene deposits	Kennon formation	Kennon formation	Unnamed Holocene deposits
PLEISTOCENE	Tabb Formation: Poquoson Mbr.		Tabb Formation: Poquoson Mbr.	Tabb Formation: Poquoson Mbr.	Tabb Formation: Poquoson Mbr.	Tabb Formation: Poquoson Mbr.
	Lynnhaven Mbr.		Lynnhaven Mbr.	Lynnhaven Mbr.	Lynnhaven Mbr.	Lynnhaven Mbr.
	Sedgefield Mbr.		Sedgefield Mbr.	Sedgefield Mbr.	Sedgefield Mbr.	Sedgefield Mbr.
	Norfolk Formation		Norfolk Formation	Shirley formation	Shirley formation	Shirley Formation
	Windsor Formation		not reported	Chuckatuck fm.	Chuckatuck fm.	Chuckatuck Fm.
				Charles City fm.	Charles City fm.	Charles City Fm.
				Windsor Formation (restricted)	Windsor Formation	Windsor Formation (restricted)
PLIOCENE	not reported		Upland deposits: Bacons Castle Formation	not reported	"Moorings" unit	"Moorings" unit
				Bacons Castle Formation	Residuum and colluvium on Pre-Quaternary deposits	Bacons Castle Formation
	Yorktown Formation	Yorktown Formation	"chocolate bed" Yorktown Fm.	Chowan River Fm. Yorktown Formation		Yorktown Formation
MIOCENE	not mapped	Eastover Formation	Eastover Formation	Eastover Formation		Eastover Formation

Table 3. Summary of geologic units and their characteristics in the Norge and Brandon area.

Unit	Morphologic Expression	General Characteristics	Origin	Age
Tabb Formation: Poquoson Member	flats 5' to 10' in elevation (Shields Point flat)	massive sands or sandy fining upward sequence	fluvial-estuarine	Pleistocene
Tabb Formation: Lynnhaven Member	flats 10' to 20' in elevation (Dancing Point flat)	sandy fining upward sequence	fluvial-estuarine	Pleistocene
Tabb Formation: Sedgefield Member	flats at 25-30 feet locally with ridge and swale topography (Todds flat)	basal pebbly sand grades upward into fine sandy silt	fluvial-estuarine	Pleistocene
Shirley Formation	flats up to 45' in elevation (Huntington flat)	sand, cobbles grading upward to clay or clayey silt	fluvial-estuarine	Pleistocene
Chuckatuck Formation	flats at elevation of 50-62 feet, restricted in extent (Grafton plain)	basal pebbly sand fining upward into fine sand and clayey silt	fluvial-estuarine	Pleistocene
Charles City Formation	dissected flats up to 75' in elevation; underlies Grove plain	sand grading upward to clay or clayey silt	fluvial-estuarine	Pleistocene
Windsor Formation	dissected flats between 80-100' in elevation; underlies Lackey plain	sand, cobbles grading upward to clay or clayey silt	fluvial-estuarine along James River; bay east of Surry scarp	Pleistocene
				?
Moorings unit of Oaks and Coch (1973)	dissected dunes and flats generally between 90 and 125' in elevation; underlies Norge uplands	massive sand or silty clay	barrier/back bay/ lagoon complex	Pliocene
Bacons Castle Formation Barhamsville Member	underlies Norge uplands; generally very dissected	massive to interbedded sand, silt, and clay; flaser to lenticular bedding common	various tidal environments	Pliocene
Upper part of Chesapeake Group (Yorktown and Eastover formations)	subsurface and low on valley walls	sand or shelly sand; brown clay marker bed at top of Yorktown ("chocolate bed")	marine shelf	Pliocene

MIOCENE SERIES

Eastover Formation

The Eastover Formation (Upper Miocene) was named by Ward and Blackwelder (1980) for beds formerly assigned to the St. Marys Formation in Virginia by Clark and Miller (1912). Within the study area, the formation is comprised of a lower clayey, fine sandy silt, the silty sand facies (Johnson, 1969) or the Claremont Manor Member (Ward and Blackwelder, 1980), and an upper interbedded fossiliferous fine sand and silty fine sand, the shelly sand facies (Johnson, 1969) and the Cobham Bay Member (Ward and Blackwelder, 1980). The members were considered isochronous by Ward and Blackwelder and diachronous by Johnson (1969). The formation crops out locally in deep valleys in the Norge upland.

The lower part of the Eastover Formation is composed of quartzose, clayey, and silty fine sand. Calcite and aragonite, mica, selenite, pyrite, glauconite, and heavy minerals are present in small amounts. These deposits are dark gray to medium greenish-gray on fresh surfaces but weather to a yellowish-brown upon exposure. A sulfurous odor is emitted by the beds. Where the sediments are jointed the fractures are stained yellowish- or reddish-brown by iron oxides. This unit is commonly leached, leaving internal and external molluscan molds. Bedding is mostly medium to thick but is laminated locally. Disrupted bedding caused by burrowing organisms and by the dissolution of shell material is common. Blow-counts from engineering borings indicate that the sediments are overconsolidated, except where weathered. The lower Eastover is sparsely fossiliferous and many of the body fossils are partially leached, yielding a chalky residue, or are represented by molds or ghosts when completely dissolved. *Ecphora, Mercenaria, Turritella, Glycymeris, Scapharca, Chesapecten*, and numerous other species have been identified from this unit. Burrows are common.

The lower Eastover is exposed in the deep valleys leading to the Chickahominy River from the Norge uplands and in the adjoining Claremont, Surry, and Williamsburg quadrangles. Samples from deep boreholes also indicate its presence in the study area and that it is at least 26 feet thick.

The upper fossiliferous Eastover is comprised of interbedded very shelly fine sand and less fossiliferous silty fine sand. The unit is light yellowish-brown to medium gray. Quartz, aragonite, and calcite are the dominant minerals; glauconite, phosphate, heavy minerals, and mica commonly constitute less than two percent of the sediment. The bedding is medium to thin and is accentuated by the alternation of very fossiliferous and sparsely fossiliferous beds. The relationship between the lower and upper Eastover is unclear in the study area. Quartzose and phosphatic pebbles occur at the top of this unit.

The macrofauna of the upper Eastover is dominated by *Isognomon*; *Glycymeris, Chesapecten, Scapharca, Septastrea, Discinisca, Turritella*, and *Ecphora* are common. Whale, porpoise, horse, and other vertebrate remains have been recovered from the upper part of this unit. *Isognomon* is commonly fragmented and abraded, whereas *Glycymeris* and *Scapharca* are very commonly articulated. Imbrication of planar shells is common. Although burrows are rare in the very shelly beds, they are abundant in the silty fine-sand beds. Diatoms are sparse.

The upper Eastover weathers to a light yellowish- to light-gray silty fine sand similar to the sand of the overlying Yorktown. Where the quartz, bone, and phosphate pebbles are absent and the fossils are leached, the Yorktown and Eastover are difficult to distinguish in outcrops and in the subsurface. Because the lithology of both formations is similar, the formations were not mapped separately in the Brandon and Norge quadrangles. The Eastover Formation is unconformably overlain by the Yorktown Formation.

PLIOCENE SERIES

Yorktown Formation

The Yorktown Formation was named by Clark and Miller (1906) for sand and shell beds along the York River near Yorktown, Virginia. Many stratigraphic studies (Mansfield, 1943; Johnson, 1969, 1972, 1976; Ward and Blackwelder, 1980; and Johnson and Peebles, 1983) and much paleontologic research (Gardiner, 1943, 1948; Ward and Blackwelder, 1975, 1980) have resulted in various lithostratigraphic and biostratigraphic subdivisions of the Yorktown Formation. Johnson (1969, 1972, 1976) subdivided the Yorktown into lithofacies based upon mineralogy and texture whereas Ward and Blackwelder (1980) used a combination of paleontologic and lithologic features to delineate members of the fossiliferous Yorktown. The members are superposed in extensive sheets in the Ward and Blackwelder hierarchy; the facies subdivision (Johnson, 1969) suggests their lateral intertonguing nature as well as the superposition of certain lithosomes.

The Yorktown Formation extends from Maryland to central North Carolina and from the Fall Zone to beneath the continental shelf. Within the study area the formation crops out in valleys in the Norge uplands and in borrow pits. Locally, it is also exposed in bluffs along the James River in the Claremont, Surry, and Hog Island quadrangles. The Yorktown unconformably overlies the Eastover and is in turn overlain disconformably by the Bacons Castle, Windsor, Charles City, and Shirley Formations in the Brandon and Norge quadrangles. The contact between the Yorktown and the Bacons Castle is a regional angular unconformity because the Bacons Castle rests on progressively older beds of the Yorktown and Eastover to the west (Johnson and Peebles, 1984; Berquist and Ramsey, 1985; Johnson and others, 1987a, 1987b). The Yorktown is Early and Late Pliocene in age (Akers, 1972; Ward and Blackwelder, 1980).

The Sedley Formation at its type and reference sections has been found to be composed primarily of weathered and leached Yorktown sediments. For this reason, the term Sedley will not be used in this report and it is recommended that the term be dropped from further usage.

A composite section of the Yorktown Formation based upon exposures at the Little Creek Reservoir and the closed Williamsburg Pottery landfill, and from borehole samples is summarized below. The composite thickness of the fossiliferous Yorktown is approximately 43 feet; the upper part is weathered and partially covered. Seven lithologic units are recognized within the formation: (1) a basal fossiliferous sand, (2) a very shelly sand, (3) a pebble-bearing shell bed, (4) a *Chama*-rich biofragmental sand, (5) a sparsely fossiliferous, silty, fine sand, (6) a biofragmental sand, and (7) a weathered unit. These units are progressively beveled to the west.

The basal fossiliferous sand is composed of sparsely fossiliferous fine sand. The sand, which ranges in color from a light gray to a light yellowish-brown, is predominately quartz (75 to 90 percent) and calcium carbonate (10 to almost 25 percent). Heavy minerals, glauconite, and mica constitute less than two percent of the sediment. Rudimentary bedding, defined by thin concentrations of shells, is present. *Chesapecten jeffersonius, Placopecten clintonius*, and *Carditamera granulata* are the most abundant species. *Ecphora, Turritella, Ostrea, Septastrea, Cliona*, and encrusting bryozoans are also relatively abundant. This unit grades upward into light gray to very yellowish-brown, shelly, fine to coarse sand. The carbonate content increases to nearly 60 percent locally and is in the form of whole shells and biofragmental sand. The shells are about equally matrix and clast supported. Planar shells, such as *Chesapecten* and *Ostrea*, occur in wave-form with amplitudes of almost three feet and wavelengths of four to ten feet in the Walkers, Surry, Williamsburg, and Hog Island quadrangles. *Chesapecten* is the dominate genus in this unit; *Ostrea, Glycymeris, Crassetella, Placopecten, Astarte*, ramose *Septastrea*, articulated *Phacoides*, and *Carditamera* are common to abundant. Locally, the aragonitic species have been differentially leached and the calcareous *Chesapecten* and *Ostrea* cemented with a calcite cement; these beds tend to be resistant and form ledges. The unit ranges in thickness from 3.3 feet to 5.6 feet thick and appears disconformable with the overlying beds. The lower two units comprise Zone 1, the *Placopecten clintonius* zone of Mansfield (1943) and the Sunken Meadow Member of Ward and Blackwelder (1980).

The pebble-bearing shell beds are comprised of quartz and biofragmental sand and disarticulated shells. Quartz and phosphate pebbles, ranging in diameter from 0.2 inch to almost 1.0 inch, and bone fragments are sparsely distributed at the base of this bed along the James River at Kingsmill, James City County, at Claremont, Surry County, and in York County north of Williamsburg. The shells are planar bedded and matrix supported. *Glycymeris* and *Crassetella* dominate the macrofauna. The unit is approximately 2 feet thick and grades upward into the overlying unit.

The *Chama*-bearing biofragmental sand is composed of whole and sand-size shell debris (45 to 80 percent calcium carbonate), quartz (10 to 35 percent), and varying amounts of glauconite and clay. This unit exhibits rudimentary bedding, which ranges from medium to thick. The macrofauna is dominated by *Chama, Noetia, Barbatia*, and cheilostomatous bryozoans. The bivalves are commonly articulated and the *Chama* occur in scattered colonies. Thin shell-beds with *Septastrea* and *Chesapecten* occur sporadically within the *Chama* bed. The upper part of the *Chama* bed is covered and the bed is estimated to be about 10 feet thick. This unit is equivalent to the lower part of Zone 2, *Turritella alticostata* zone, of Mansfield (1943) and the Rushmere Member of Ward and Blackwelder (1980).

A sparsely fossiliferous, medium gray, silty, fine sand overlies the *Chama* bed. This unit is thick-bedded and is composed of silt and fine-sand sized quartz, calcium carbonate, glauconite, and clay. Locally, thin beds of biofragmental sand and whole shells are interbedded with the silty sand. *Pseudochama, Mercenaria*, and *Panopea* are the most common genera in this unit. *Mulinia, Panopea, Dentalium, Diodora* and whole and broken echinoids occur in the thin shelly beds within this unit. The silt is extensively burrowed near the top and the burrows are filled with biofragmental sand from the overlying unit. The silty sand has a thickness of at least 9 feet and is equivalent to the upper part of Zone 2 of Mansfield (1943) and the Morgarts Beach Member of Ward and Blackwelder (1980).

A biofragmental sand, which disconformably overlies the silty fine sand, is composed almost entirely of calcium carbonate (85 to 90 percent); quartz, glauconite, and clay are minor components. The carbonate sand is fine to coarse and exhibits rudimentary bedding. Colonies of *Petaloconchus* are prevalent in this unit; *Plicatula, Marginella*, and *Amphistegina* are common to very abundant. The unweathered portion of this bed is approximately four feet thick and grades upward into reddish-brown to medium-brown clayey, fine, sandy silt. Ferricrete and small, disseminated iron oxide nodules and concretions occur above the biofragmental sand. Ward and Blackwelder (1980) assigned this unit to the Moorehouse Member of the Yorktown.

Weathering of the Yorktown Formation yields different residues depending upon the original mineralogic composition of the unit, the intensity of weathering, local groundwater conditions, and the texture of the sediments. The weathering of the Yorktown Formation is differential and produces a highly undulatory surface with more than 10 feet of relief on the fossiliferous Yorktown. Leaching of carbonate from the quartz-rich sand of the lower Yorktown produces a sand almost indistinguishable from the fine sand of the underlying Eastover. Weathering of calcareous beds, on the other hand, yields a clayey silt or clayey fine-sand residue. This residue is composed of iron and manganese oxides, silt- and fine-sand-sized quartz, and clay minerals. This unit grades downward into partially leached, chalky fossils or rests with sharp contact on unaltered shell beds. Locally, calcareous nodules, 5 to 20 inches in length, have formed in the partially weathered Yorktown. The dissolved carbonate is also precipitated as a cement in the shell beds. The latter produces a craggy, very porous limestone.

Where not removed prior to deposition of younger units, the top of the Yorktown is commonly marked by a sequence of dark-brown muddy sediments up to 10 feet thick. This conspicuous layer, informally known as the "chocolate bed", is composed of sand, silt, clay, ferricrete, glauconite, manganese oxide (wad), and weathered shells. The accumulation of iron- and manganese-oxide-cemented sediment (ferricrete) is caused by the reaction of groundwater with calcium carbonate from the shell beds. This brown, muddy, marker bed probably represents subaerial and subterranean dissolution of the Yorktown shell beds and marks the top of the Yorktown Formation. Rogers (1884) recognized that this zone "would furnish grounds if not confident anticipation of finding marl (Yorktown) beneath."

In many places the shells have been totally dissolved leaving only a diffuse to detailed outline or "ghost" of the once present shell in a massive fine-sand matrix (Figure 5). Misinterpretation of these leached sediments in earlier reports has resulted in the assignment of the material to units other than the Yorktown Formation. Dissolution is active today and most shell-rich outcrops are found at the heads of present drainages.

The Yorktown was deposited during a succession of marine advances during the Early and Late Pliocene Epoch. The lower Yorktown accumulated under cool temperate conditions and the upper parts under subtropical or tropical climatic conditions (Ward and Blackwelder, 1980).

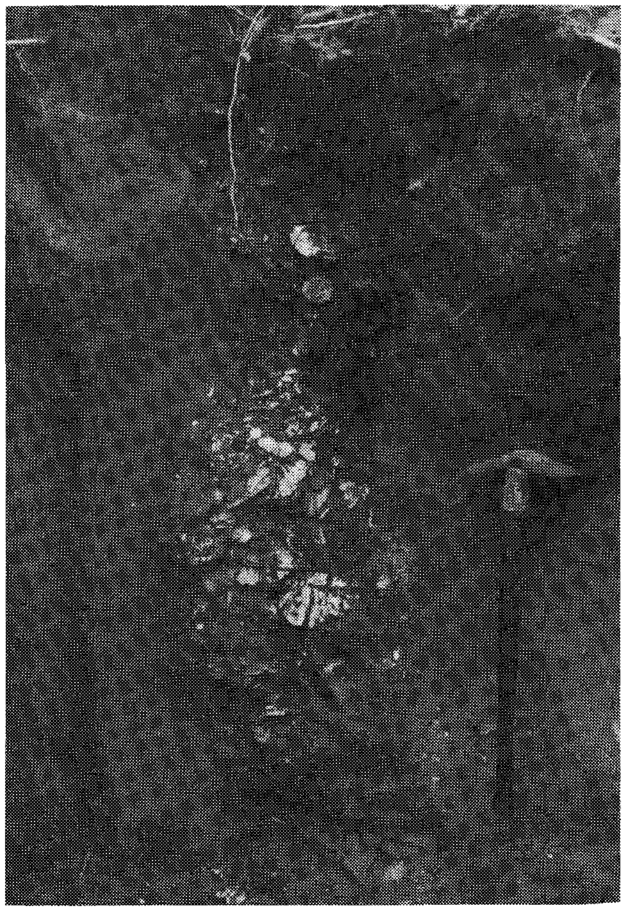

Figure 5. Photograph of exposure of Yorktown shell-bed and leached shell-bed at Little Creek Reservoir; note pinnacle of shell-bed surrounded by fine sand residue with traces of fossils ("ghosts") behind shovel.

Bacons Castle Formation

The Bacons Castle Formation, informally named by Coch (1965), is comprised of interbedded, intertidal- and marine-silt, -sand, and -clay that overlie a thin, pebbly or coarse sand. These deposits grade westward into a lower coarse, gravelly, fluvial sand (Berquist and Ramsey, 1985) and an upper marine-sand, -silt, and -clay sequence (Johnson and Peebles, 1985). In western James City and Charles City counties, the Bacons Castle rests disconformably on the Yorktown. There is a regional angular unconformity over much of the Yorktown and Eastover Formations in the Middle Coastal Plain (Johnson and Peebles, 1985; Ramsey, 1987). The Bacons Castle Formation is the principal surficial deposit beneath the Norge uplands between the Broad Rock (Johnson and Peebles, 1981) and Surry scarps; it is mappable over much of the Middle Coastal Plain in Virginia and North Carolina (Colquhoun and others, in preparation). Part or all of the formation has been called the Columbia Group, the Sedley (Oaks and Coch, 1973), and Upland deposits (Johnson and others, 1980). Ramsey (1987, 1988) proposed that the Bacons Castle be subdivided into the Barhamsville member (tidal flat deposits) and the Varina Grove member (fluvial and estuarine gravel and sand). All of the Bacons Castle sediments within the study area are of the Barhamsville Member (Appendix I, Section 2). The formation is assigned to the Chesapeake Group in this report.

The Bacons Castle sediments exhibit great textural variability. Locally, paleochannels cut into the older Tertiary deposits in the Norge area are filled with sand and gravel, organic-rich silt and sand, and peat. The base of the formation contains a sporadic, pebbly or coarse sand in western James City and Charles City counties. This unit is overlain by beds of massive sand, massive to laminated clay, and interbedded and laminated fine sand, silt and clay, which are variable in thickness and extent. The basal sand is composed principally of quartz, with lesser amounts of clay, heavy minerals, feldspar, some of which is kaolinized, and lithic fragments, including chert and phosphate, and reworked glauconite.

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This unit is commonly iron-stained and locally cemented by iron and manganese oxides. A belt of dominantly sandy sediments follows the trend of upper Powhatan Creek and Long Hill Swamp.

Sedimentary structures include flaser, wavy and lenticular bedding, clay drapes, flame structures, clay-pebble cross beds, desiccation cracks, and slump structures. Bedding is horizontal or dipping at less than 10°; however, within laminated sediments it may dip as much as 25° due to penecontemporaneous slumping. Secondary features (ferricrete and Liesegang bands) are also common. Sandy sediments are commonly yellow-brown to red whereas clay tends to be gray to pink. Massively bedded or thick sections of unweathered sand are gray. Soils are commonly pinkish-brown to dark red where the parent material is rich in clay and light brown over sandy sediments. Soil profiles on the relatively undissected Bacons Castle are thicker than over the younger Pleistocene units. No shell fossils have been found but burrows of polycheates and decapods are common. Plant fossils have been recovered from the Bacons Castle near Richmond.

Total thickness of the unit is about 70 feet. Exposures of the Bacons Castle Formation are found at Little Creek Reservoir and in roadcuts in the uplands near Binns Hall and Middle Plantation (now Fords Colony).

The Bacons Castle Formation was deposited during a relative rise of sea level to about 170 feet inundating a dissected coastal plain (Ramsey, 1987, 1988). Initially intertidal conditions similar to those along the present Wadden Sea, North Sea, or the Wash (Klein, 1977) predominated in the eastern part of the Middle Coastal Plain, but with the passage of time these were supplanted by marine or lagoonal environments.

The age of the Bacons Castle is uncertain because no in situ shell fossils or radiometrically dateable material have been found. Based upon its stratigraphic position above the Late Pliocene Yorktown Formation and below the Windsor, its relatively advanced soil development, and the presence of plant fossils of Pliocene age near Richmond, the Bacons Castle is considered Late Pliocene in age.

Moorings unit

The Moorings unit was an informal stratigraphic unit proposed by Oaks and Coch (1973), to describe sand and silty clay of problematic stratigraphic relationship and age west of the Surry scarp. This unit has been called the Sunderland (Wentworth, 1930) and the Elberon (Coch, 1965). Coch (1965) proposed the Elberon formation and defined three facies: a silty clay facies (lagoonal) west of the scarp, a fine sand facies (barrier) along the scarp, and a silty sand facies (nearshore marine) east of the Surry scarp. The eastern, silty sand facies was later redefined as the Windsor Formation (Coch, 1968) and the remainder of the Elberon was informally designated the Moorings unit (Oaks and Coch, 1973). Oaks and Coch (1973) also stated that the Windsor rests unconformably on the Moorings unit. The stratigraphic and morphologic relationships commonly observed near Surry have been obscured on the York-James Peninsula; this was caused by the area's proximity to the confluence of the ancestral York and James rivers and the subsequent dissection during the Pleistocene Epoch. In the Norge quadrangle, certain massive, fine sand and sandy mud at elevations above 90 feet are similar to barrier and lagoonal facies of the Moorings unit south of the James River. The relationship of the fluvial-estuarine and bay members of the Windsor Formation to these sediments in the Norge quadrangle area is not as clear as the relationships are south of Surry where dissection is less severe and morphology is a useful guide to the geology.

The Moorings unit in the Norge quadrangle is subdivided into an eastern sand facies and a western clay facies. The sand facies is a massive, moderately well sorted, fine sand and commonly lacks sedimentary structures. Locally, gray clay laminations and drapes and clay-chip crossbeds have been observed. Color ranges from light gray to light yellow. The sand is quartzose with a few percent of opaque minerals.

The clay facies is composed of massively bedded sediments ranging from silty clay to muddy sand. Bioturbation is very common, but no diagnostic trace fossil has been observed. No other sedimentary structures have been found. Sediments are commonly gray to grayish-brown and soils are generally light brown or gray.

The Moorings unit formed as a barrier-beach (sand facies) and backbarrier lagoon or bay (clay facies) couplet. The sand (barrier-beach) facies, which lies to the east of the clay facies, is at slightly higher elevations and grades laterally into the fine-grained sediments at lower elevations. Just as in modern back-bay environments, the fine-grained sediments are thoroughly bioturbated.

The age of the Moorings unit is considered Late Pliocene or Early Pleistocene because the unit overlies the Late Pliocene Bacons Castle and is, in turn, overlain by the Windsor Formation of probable Early Pleistocene age.

Both facies are each commonly less than 10 feet thick. Erosion has removed much of the complex; this produces a map pattern where older units are exposed on hilltops and are surrounded by the Moorings on hillsides. Soil formation and massive colluviation of side slopes has obscured the contacts; therefore, the locations of contacts are approximate and have been drawn to conform with contour lines and available field observations.

PLEISTOCENE SERIES

Windsor Formation

The Windsor Formation was named by Coch (1968) for a sand, silt, and clay sequence which he considered to be lagoonal-estuarine in origin and had been assigned earlier to the silty sand facies of the Elberon (Coch, 1965). Although the Windsor was originally mapped as the surficial formation between the Surry and Suffolk scarps, it is now known to crop out on the Lackey plain along major rivers west of the Surry scarp (Johnson and Peebles, 1984, and this report). The formation was mapped as the Wicomico formation by Clark and Miller (1906, 1912) and Wentworth (1930), and the Kilby formation by Moore (1956). The Windsor Formation as mapped by Bick and Coch (1969), contains both the Windsor and the Charles City Formations of this report, as well as part of the Moorings unit. Some sediments presently mapped as the Windsor Formation previously were included in the Bacons Castle Formation (Bick and Coch, 1969). The Windsor Formation is therefore amended in this report and is more restricted in definition than previously reported. For this reason some contacts will not match between the Williamsburg (Bick and Coch, 1969) and Norge (this report) quadrangles.

Along the James and Chickahominy rivers the Windsor Formation consists of muddy, coarse sand and gravel grading upward into sandy mud. Exposures may be found in the sandpits at Five Forks and the R. T. Armistead pit north of State Road 613 (Plate 1). The lower part of this unit is composed of muddy coarse-sand, pebbles, and cobbles. Rarely, boulders up to 2 feet in diameter have been found. The larger clasts are composed of quartzite and chert along with lesser amounts of granite, phyllite, schist, gneiss, greenstone, and other rock types common to the Piedmont, Blue Ridge, and Valley and Ridge provinces of the State. Some chert clasts contain fossils of Middle Ordovician and Lower Devonian age (E.K. Rader, personal communication). Clay balls are also common. The sand fraction is dominantly quartz, but locally feldspar is very common. Sediment colors range from light brown (rare) to pinkish-brown. Trough cross-bedding is very common, with eastward dipping cross stratification. The coarse deposits attain a thickness up to 25 feet. The lower part of this unit is of fluvial origin and unconformably overlies the Yorktown and Bacons Castle Formations.

The lower coarse deposits grade upward into muddy sand and sandy mud. The upper sediments are massively bedded and, because of bioturbation, are devoid of any sedimentary structures. Colors are gray, brown, and red; gray, red, and tan mottling are also common. Thickness ranges from less than 1 foot to about 25 feet. These sediments are interpreted to be estuarine in origin and commonly overlie the fluvial coarse-grained material. The fluvial-estuarine Windsor is common along the James River west of the Surry scarp and has been mapped as "Qwf" in the study area.

East of the Surry scarp, or east of areas underlain by the Moorings unit in the Williamsburg area, the Windsor Formation is commonly massively bedded and is composed of gray, clayey silt to silty clay or light-gray, silty fine-sand. Because of bioturbation, no primary sedimentary structures have been observed in these muddy sediments. Brown and red mottling is common and has been caused by root penetration and soil-forming processes. The Windsor in this area ranges in thickness from less than 1 foot to about 12 feet. These sediments were probably deposited in a bay environment and have been mapped as "Qwb" in the Norge quadrangle.

The Windsor of this report correlates with that mapped by Bick and Coch (1969) south of the area around State Road 612 (Longhill Road) in the Norge quadrangle. North of State Road 612 the Windsor of Bick and Coch (1969) correlates with the Moorings unit in this report. Contacts between the Windsor and other units are not easily discernible without numerous shallow borings. In areas of limited control, contacts have been generalized and drawn along contour lines.

Soils formed on the Windsor are comparable to soils formed on the Bacons Castle Formation. Distinction between these two units is difficult with only shallow auger information. An accurate determination of which formation is present cannot normally be made without examination of at least the upper 15 feet of each unit. The degree of weathering as indicated by iron-oxide formation is greater in the Windsor than in the younger Chuckatuck and Shirley Formations. Where the Charles City is well-drained, the weathering profile is similar to the Windsor.

With the exception of rare enigmatic burrows, no fossils have been found in the Windsor. The age of the Windsor Formation is uncertain because no definitive fossils or dateable material have been found. It is assigned an Early Pleistocene age because it overlies unconformably the Late Pliocene Bacons Castle and older formations and is separated from younger formations of Middle or Late Pleistocene age by a disconformity.

Charles City Formation

The Charles City Formation, herein named, is comprised of an upward-fining sequence of gravelly sand and silty to clayey sand. The type section is a gravel pit at the Copeland triangulation station on the left bank of the James River in Charles City County, Virginia (Appendix I, Section 2). The formation has been previously described as the Wicomico Formation (Wentworth, 1930). The Wicomico, which was originally defined as a terrace and later as a morphostratigraphic unit, is not appropriately used as a lithostratigraphic unit (Oaks and Coch, 1973). The Charles City, the surficial formation under the Grove plain, is mappable along the streams of the Middle Coastal Plain. The formation has been extensively eroded; it is preserved as discontinuous remnants along the James and York rivers and their major tributaries. In the study area, the Charles City crops out along stream terraces in the Norge uplands and on the upland south of Cherry Hall.

The formation is comprised of a lower interbedded pebbly-sand and coarse- and medium-grained sand, about 30 feet thick, that grades upward into a fine sandy or clayey silt. Pebbles, cobbles, and boulders mark the basal contact or occur sporadically in the lower part of the formation. These coarse deposits are graded, lenticular in cross-section or form thick planar beds, and are clast and matrix supported. The interstices in the clast-supported beds are filled with sand, silt, and clay. The larger clasts are covered with a clay coating and are commonly stained or cemented by iron and manganese oxides. The coarser units are interbedded with planar-bedded or crossbedded very-fine to coarse sand. Quartz is the dominant mineral in these beds; feldspar (commonly kaolinized), heavy minerals, clay, and iron oxides are also present. The beds are varied in color, being medium gray, light brown, and yellowish- and reddish-brown. Except for clay-lined burrows in the lower part, the formation is devoid of fossils. The lower beds grade upward into, or have a sharp contact with, the overlying beds.

The upper part of the formation ranges from a silty fine-sand to a clayey silt. Bedding is commonly massive and the silt or sand is commonly light gray or brown. The uneroded upper surface of this formation exhibits a ridge and swale topography with a relief of about 5 feet.

The age of the Charles City is unknown but is probably Early Pleistocene because it rests disconformably on the Windsor of presumed Early Pleistocene age and older formations and is overlain by the Chuckatuck and Shirley Formations of Middle Pleistocene age. The presence of clay coatings on larger clasts, the higher degree of oxidation, and extensive ferricrete development within the formation indicate that the Charles City is older than the Shirley.

Chuckatuck Formation

The Chuckatuck Formation is formally named for sediments exposed in the Smith pit, Isle of Wight County, Virginia (Appendix I, Section 4). The Chuckatuck in the vicinity of the type section has been mapped as the Wicomico (Wentworth, 1930), Windsor Formation (Coch, 1968; Oaks and Coch, 1973) and the Chuckatuck Formation (Johnson and Peebles, 1986, 1987). This formation typically exhibits an upward-fining sequence with a basal cobbly- to pebbly-sand, overlying medium- to fine-sand, and a capping clayey sand or silt. Fluvial and marsh deposits occur locally in channels at the base of the formation; the overlying beds are bay or lagoonal sediments along the coast and estuarine along the rivers. The Chuckatuck is the principal surficial unit under the Grafton flat (Johnson and Peebles, 1986, 1987). The formation exhibits marked vertical and lateral lithologic variations.

The lowermost beds of the Chuckatuck occupy channels cut at least 25 feet deep into older Pleistocene and Tertiary sediments. The channel deposits commonly contain poorly sorted, basal pebbly- to cobbly-sand that is less that 6 inches thick. Unlike the younger Shirley Formation, the clasts in the Chuckatuck are predominantly quartzose metamorphic and igneous rocks. The basal gravelly-sand grades upward into either a quartzose sand or into organic-rich sediments. Where the sand is the overlying unit, it is moderately to well sorted, crossbedded to planar bedded with heavy-mineral laminae accentuating the bedding, and lenticular in cross section. This unit ranges in thickness from less than 1 foot to more than 11 feet in the deepest part of the paleochannels. A thin, gray clay is interbedded within the sand in places. Locally the sand grades laterally into a poorly sorted clay-sand or into organic-rich sediments.

The organic-rich silt is highly variable in thickness and ranges from less than 1 foot to more than 8 feet. Grain size and composition are also variable. The organic material occurs as disseminated lenticular accumulations of woody material, and dark brown to black peat beds up to several feet thick. The peat grades laterally into organic-rich sand or clay, thin beds of fine sand, or may rest with sharp contact on older deposits. The flora includes pines and a variety of deciduous trees and shrubs including hickory, sweet gum, and myrtle.

On interfluves and parallel to the paleocoastline, the basal Chuckatuck contains a thin, discontinuous pebbly- or cobbly-sand that grades upward into a gray, medium to fine, planar-bedded sand with heavy-mineral laminae. Locally the sand contains *Ophiomorpha* burrows. The sand grades upward into a silty fine-sand with an increasing amount of silt and clay; this sandy unit is the most persistent lithology within the formation. Bedding is absent or rudimentary in the upper 10 feet of the unit. The maximum measured thickness of the Chuckatuck on the ancient interfluves is 26 feet.In the Brandon area and near Shirley Plantation, the Chuckatuck is comprised of a basal, thin, gravelly sand, a light to medium gray, medium- to fine-sand, and an upper nonbedded silty clay or fine, sandy, clayey silt.

The Chuckatuck can be distinguished from the Charles City Formation by its overall finer grain size, lack of feldspathic grains, shallower weathering profile, and its lower topographic position. In comparison to the Shirley, the Chuckatuck is generally finer-grained, lacks the lithologically immature clasts, and crops out at higher elevations. In addition, channel-fill sequences have not been found to be as thick in the Chuckatuck as documented in the Charles City or Shirley Formations.

The age of the Chuckatuck is uncertain. It is unconformably overlain by the Shirley of Late Middle Pleistocene age and in turn rests with an erosional disconformity on the Charles City and Windsor Formations of presumed Early Pleistocene age. No definitive paleontologic material has been found in the formation. The flora from the Chuckatuck is indicative of temperate conditions at least as warm as the present. Shallow channels filled with coarse clasts and organic-rich sediments at the base of the Chuckatuck indicate that the sediments were deposited on a dissected coastal plain under fluvial and paludal regimes. When sea level rose and water covered the interfluves, the upper Chuckatuck was deposited in tidally influenced bay and estuarine environments.

Shirley Formation

The Shirley Formation is named herein for deposits exposed in borrow pits of the Tarmac-LoneStar, Inc. plant at Shirley Plantation in Charles City, Virginia (Appendix I, Section 3). This formation was formerly mapped as the clayey sand, sand and peat, and gravelly sand facies of the Norfolk Formation (Coch, 1965, 1968, 1971; Oaks and Coch, 1973; Johnson, 1972, 1976; and Johnson and others, 1980) and as the Norfolk Formation west of the Suffolk scarp (Mixon and others, 1982). The Norfolk Formation (Clark and Miller, 1906) as redefined by Oaks and Coch (1973) has been shown by Peebles and others (1984) to consist of two formations, the Tabb and an older unit, separated by a disconformity. The Shirley Formation is established in order to eliminate this stratigraphic problem, The Shirley Formation is an upward-fining sequence, comprised of a basal, gravelly sand that grades upward into a fine to coarse sand and is overlain by clayey silt or clayey, silty fine-sand. Coarse material is also found along the Shirley shoreline (the Kingsmill scarp) where pebbles and cobbles were eroded from adjacent older deposits and along spits. The Shirley was deposited under fluvial, estuarine, and marsh conditions in the Brandon and Norge area but also includes barrier, bay, nearshore marine, and aeolian deposits on the lower York-James Peninsula and in southeastern Virginia south of the James River (Peebles and others, 1984).

The Shirley Formation exhibits lateral and vertical lithologic and paleontologic variability. The basal Shirley deposits consist of a lower pebbly- to bouldery-sand. The coarse clastics, which reach a maximum thickness of 4.3 feet, are of variable lithology: quartz, sandstone, granite, gneiss, schist, chert, greenstone, diabase, and amphibolite. The cobbles and boulders are subangular to well rounded; the surfaces of the clasts are commonly faceted, reflecting joints, and bedding in the source rock.

Above the basal gravelly sand are interbedded and intertonguing sand, clay, and peat bodies. The sands are medium gray to reddish-brown, thin to thick bedded, graded, planar or crossbedded, and commonly lenticular in shape. Southeasterly dipping crossbeds prevail. The gravelly sands are locally cemented with iron and manganese oxides.

Lenticular masses of clay and peat are interbedded with the sand in the lower part of the Shirley. The clay lenses, which range in thickness from 1 foot to more than 4.6 feet, are plastic, light gray to dark gray depending upon the amount of organic matter, and are thin- to medium-bedded. Finely divided, disseminated plant detritus, and locally pyrite, impart a black color to the clays. In the Brandon quadrangle and at the type locality plant fragments, branches, small tree trunks, leaves, and seeds were recovered from organic-rich lenses in the clays. Peat layers are sparse and occur as thin (1 to 10 in) beds within sands and clays and as lenticular masses more than 3.9 feet thick. The peat is composed of recognizable woody plant tissue and partially decayed organic material.

The sand fines upward in the Shirley and occurs in thin to medium beds with multidirectional cross bedding or cross laminations. Heavy-mineral laminae and clay drapes accentuate the cross stratification. The quartzose sand is commonly graded, contains ripple marks, and is interbedded with thin, discontinuous sandy silt and clayey silt. The interbedded silt and sand contains pencil-like, near vertical burrows but no other recognizable fossils. Although not observed in the study area, *Crassostrea virginica* biostromes occur in quartzose and calcareous silty sands at the base of the formation in the Fort Eustis area.

The upper part of the Shirley Formation in the Brandon and Norge area is comprised of thin to thick bedded, clayey fine sand, clayey silt and less commonly silty clay. The bedding thickens upward and is obscured or destroyed by weathering in the upper part of the formation. The clay and silt-rich beds are light to medium gray and are commonly mottled reddish- or yellowish-brown. Thin sand beds within the lower part of this unit are cross-laminated. Pebbles are scattered sparingly through the fine gravel deposits and nodules and near-vertical ferruginous tubes occur locally. The tubular structures may represent plant root and stem casts. The clay is principally composed of kaolinite, but also contains expandable minerals. When wet, the clays are plastic. Perched water tables commonly form above the clay beds.

The Shirley ranges in thickness from less than 1 foot near the Kingsmill scarp to more than 55 feet in the paleochannels beneath the Huntington flat. Small terraces are found in minor drainages, for example, in Little Creek Reservoir (Figure 6).

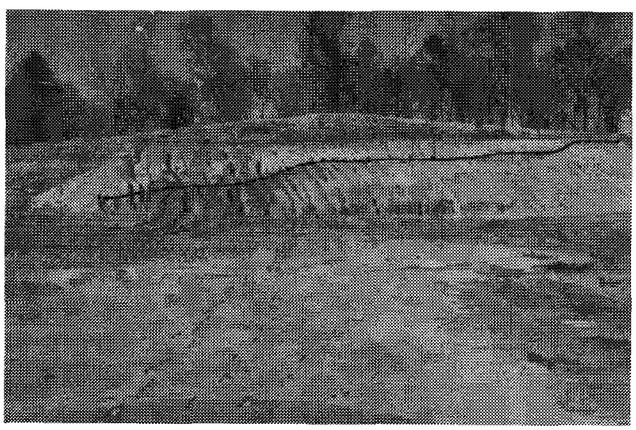

Figure 6. Photograph of exposure of the unconformable contact of the Shirley Formation overlying the Yorktown Formation; cross section B - B'.

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Above the basal gravelly sand are interbedded and intertonguing sand, clay, and peat bodies. The sands are medium gray to reddish-brown, thin to thick bedded, graded, planar or crossbedded, and commonly lenticular in shape. Southeasterly dipping crossbeds prevail. The gravelly sands are locally cemented with iron and manganese oxides.

Lenticular masses of clay and peat are interbedded with the sand in the lower part of the Shirley. The clay lenses, which range in thickness from 1 foot to more than 4.6 feet, are plastic, light gray to dark gray depending upon the amount of organic matter, and are thin- to medium-bedded. Finely divided, disseminated plant detritus, and locally pyrite, impart a black color to the clays. In the Brandon quadrangle and at the type locality plant fragments, branches, small tree trunks, leaves, and seeds were recovered from organic-rich lenses in the clays. Peat layers are sparse and occur as thin (1 to 10 in) beds within sands and clays and as lenticular masses more than 3.9 feet thick. The peat is composed of recognizable woody plant tissue and partially decayed organic material.

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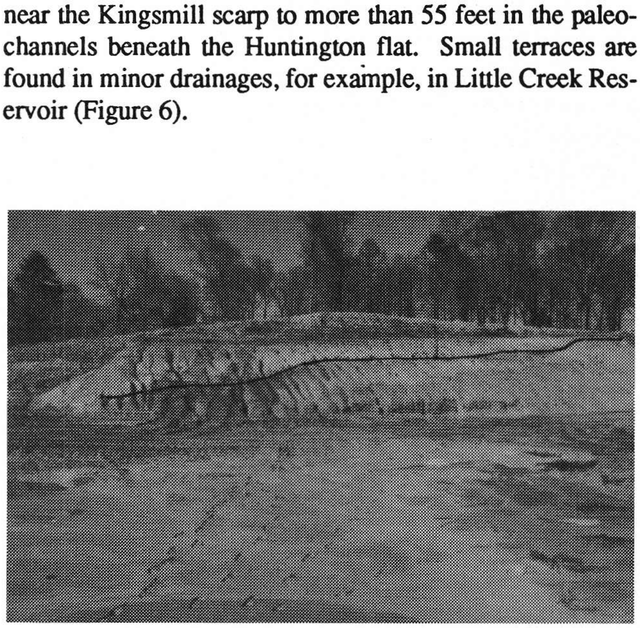

Figure 6. Photograph of exposure of the unconformable contact of the Shirley Formation overlying the Yorktown Formation; cross section B - B'.

Initially the Shirley in the Brandon and Norge area was deposited under fluvial conditions in channels cut into the underlying Aquia, Eastover, Yorktown, Windsor, and Charles City Formations. The upper portion is estuarine in origin. It is in turn overlain by the Tabb Formation and Holocene sediments. Uranium-series ages of 184,000 years (Mixon and others, 1982) and 187,000 years (Cronin and others, 1981) on corals from apparently correlative deposits along the Rappahannock River place the age of the Shirley Formation as Late Middle Pleistocene.

Tabb Formation

The Tabb Formation (Johnson, 1976) crops out along the James and Chickahominy rivers and their tributaries within the study area and on the Lower Coastal Plain of southeastern Virginia. The formation is subdivided into three members: the Sedgefield, Lynnhaven, and Poquoson. Although bay, barrier, and nearshore marine facies of these members have been mapped in the Hampton, Virginia Beach, and Suffolk areas (Johnson, 1976; Peebles, 1984), only the fluvial-estuarine facies occur within the Brandon and Norge quadrangles. The Tabb has been mapped as the Talbot formation (Wentworth, 1930) and as the Norfolk Formation (Bick and Coch, 1969; Coch, 1971; and Johnson, 1972). Because the boundary between the Sedgefield and Lynnhaven members cannot be recognized in Brandon quadrangle, these members are mapped together. The Sedgefield is not exposed in Norge quadrangle.

Sedgefield and Lynnhaven Members

The Sedgefield and Lynnhaven Members exhibit an upward-fining sequence of sediments interpreted to be fluvial-estuarine in origin. The lowermost part of this unit consists of a light gray to light brown, cross-bedded pebbly sand. Well-rounded cobbles are found locally at the unconformity between the Tabb and older formations. The clasts are dominantly massive quartz, quartzite, and chert, but pebbles and small cobbles of granite, schist, and greenstone (?) are also known. The pebbly gravel has been partially cemented by iron and manganese oxides. The cross-stratification is accentuated by the heavy-mineral laminae and exhibits a prevalent southeasterly dip. Units comprised of organic-rich silty clay and peat up to 14 feet thick occur in the lower part of this unit.

The pebbly sand grades upward into interbedded light brown, fine to medium sand and light brown to medium gray, very-fine sandy silt. The sand and silt beds tend to decrease in thickness upward; they range in thickness from 2 feet to less than 0.4 inches. These beds are planar or cross-stratified; the cross-stratification is multidirectional. Ripple and small-scale trough cross-stratification are found locally. Scattered burrows about 0.2 to 0.4 inches in diameter disrupt the bedding; the biologic affinity of these structures is unknown. The upper part of the Sedgefield and Lynnhaven is comprised of thick beds of silty fine-sand and clayey silt. These deposits are typically oxidized to a yellowish-brown color and mottled reddish-brown. The Sedgefield and Lynnhaven together range in thickness from less than 1 foot near the Suffolk scarp to more than 40 feet in borings in the Dancing Point flat.

A disconformity separates the Sedgefield and Lynnhaven Members from the underlying Shirley and older formations. The members are overlain by the Poquoson Member of the Tabb and Holocene-age marsh, swamp, estuarine, and alluvial deposits. Sediments correlated with the Sedgefield Member on the York-James Peninsula and in southeastern Virginia have been dated at 75,000 to 120,000 years old (Mixon and others, 1982). The Sedgefield and Lynnhaven Members were deposited by the ancestral James River under fluvial-estuarine conditions.

Poquoson Member

The Poquoson Member of the Tabb Formation crops out on the Mulberry Island flat along the James and Chickahominy rivers. This member is composed of fine- to coarse-sand and silt and is commonly upward-fining in grain size. The sediments are light gray under saturated conditions and light brown where oxidized. Bedding is rudimentary or lacking. This member is unfossiliferous and commonly less than 9 feet thick. Holocene-age paludal and estuarine deposits overlie the Poquoson. Sediments of the Poquoson were deposited during the Late Pleistocene by the ancestral James and Chickahominy estuaries.

HOLOCENE SERIES

Holocene deposits consist of estuarine, marsh, swamp, and alluvial and colluvial sediments. These deposits comprise a complex of estuarine sandy silts; paludal organic-rich sand, silt, and peat, and fluvial gravelly sand, sand, and silt. The sediments are mutually intergradational and can be traced downstream to lagoonal, bay, and nearshore marine deposits. The Holocene deposits disconformably overlay older formations. They are generally unconsolidated, and in the case of paludal deposits, highly compressive. The Holocene deposits are subdivided into four lithofacies: 1) swamp peat (swamp sediments), 2) marsh silt (marsh sediments), and 3) fluvial and beach gravelly sand (alluvium). A fourth lithofacies (subaqueous estuarine sandy silt), present under water and periodically exposed at low tide was not mapped. Colluvial deposits, which are commonly thin or crop out in belts too narrow to map, are not shown on the geologic map.

The sandy-silt facies is subaerially exposed along the shore of the James River and is encountered in numerous submarine borings along the James and Chickahominy rivers. This facies ranges in texture from a fine sand near beaches to a silty clay, but is typically a fine sandy silt. Quartz is the dominant mineral in the sand- and silt-sized fraction; heavy minerals constitute less than 1 percent of the sediment. Clay minerals, organic matter, and iron sulfides are common in this facies. The deposits are thick bedded to laminated. The sediments are water-saturated, compressive, unconsolidated, and at least 45 feet thick along the Chickahominy River and more than 100 feet thick beneath the James River. The facies grades downward into fluvial sand and laterally into the paludal facies. This facies was deposited by the estuarine James River and its tributaries during the Holocene rise in sea level. Because of their subaqueous extent beneath the James and Chickahominy rivers, they are not shown on the geologic maps.

Swamp sediments, or the peat facies, underlies most of the well-established swamps along the James and Chickahominy rivers and their tributaries and is characterized by peat or organic-rich silt and clay. Wood, woody plant detritus, and seeds and leafs are a dominant constituent of the facies. Varying amounts of silt, clay, and fine sand are found disseminated or interbedded with the unit. Although organic matter is dominant, small quantities of quartz, iron sulfide, and gypsum are found in the peat facies; locally, clay and silt constitute more than 50 percent of the sediment. Bedding is lacking to indistinct in the peat except where clay or silt laminae occur. Recognizable plant remains include cypress, black and sweet gum, and other hygrophilous species of trees. The deposit is commonly medium brown to black. The peat facies is more than 13 feet thick in the Brandon and Norge area and intergrades with the other Holocene lithofacies. The peat facies
was deposited in swamps along streams and in the uplands during the very Late Pleistocene and Holocene epochs.

Marsh sediments, or the silt facies, is found beneath brackish and freshwater marshes along streams in the Brandon and Norge quadrangles. Near the surface the organic content of this facies is high (greater than 20 percent) and decreases downward to a mineral-dominated sediment. Sand and silt-sized quartz is the principal constituents in the mineral portion of the facies; clay minerals are the other major component of the sediment. Although the texture varies, the sediments range between a fine sandy silt and a silty clay. Bedding is not well developed. Plant remains in the organic-rich portion of the facies include detritus of fresh and brackish water plants, such as arrow arum (Peltandra *virginica*) and salt cordgrass (*Spartina*). The deposits are compactible, water saturated, and commonly plastic. The deposits are at least 34 feet thick in places along the Chickahominy River. The sediments accumulated in fresh and brackish water marshes during the Holocene.

Alluvium, or the fluvial sand facies, crops out along upland streams and is encountered in the subsurface beneath estuarine silts in the James and Chickahominy rivers and their tributaries. Gravelly sand and sand are the principal sediments in this facies. Pebbles, cobbles, and small boulders derived from older formations are common in the basal part of these deposits; sediments tend to fine upward and downstream. In the upper reaches of modern streams, this facies is composed of silt and fine sand and rarely clay. Quartz is the dominant mineral although heavy minerals are locally abundant in laminae. Disseminated organic-matter is prevalent on flood plains and in the shallow soils developed on this facies. The sand facies is commonly medium to thin bedded and commonly exhibits cross-stratification in the lower part. The facies ranges in thickness from less than 1 foot to more than 20 feet; in upland valleys, the sediments may occur as terraces along the major stream. The gravelly sand was deposited in the channel of streams or along beaches during the Holocene and Late Pleistocene.

Colluvial deposits occur as a veneer (less than 2.5 feet) on most slopes or as thicker deposits (greater than 11 feet) along steep slopes or bluffs in the Brandon and Norge quadrangles. The deposits are derived from older formations and obscure formational contacts. Mass wastage sediments vary widely in texture. They range from pebbly and cobbly sand, if they are derived from gravelly deposits of the Charles City, Shirley, and Tabb Formations, to sand and clayey silt if they are derived from the weathered, fine-grained sediments of other formationsthe. Bedding is commonly absent but locally stone lines and contorted bedding are found in these deposits. The color, which varies from medium gray to reddish brown, reflects the parent material from which the colluvium was derived and the local drainage conditions. The deposits were created by sheetwash, slumpage, and landsliding and are probably Holocene and Late Pleistocene in age.

GEOLOGIC HISTORY

The Coastal Plain stratigraphic sequence in the Brandon and Norge area records the opening of the Atlantic Ocean during the Mesozoic era, the formation of the Salisbury embayment and its partial filling with deltaic and associated sediments (Potomac Group) during the Late Mesozoic era, and a succession of marine invasions during the Late Mesozoic and Cenozoic eras.

Through the Tertiary, the Virginia Coastal Plain was gently downwarped and faulted; the center of deposition shifted southward from Maryland into Virginia (Newell and Rader, 1982; Ward, 1984). Consequently, the shoreline changed position and was reoriented (Johnson and others, 1985). Because only Upper Tertiary and Quaternary formations are exposed at the surface in the study area, only the Late Cenozoic history will be discussed in this report. Assuming that the dates and correlations are correct, the following geologic history is postulated.

The Late Cenozoic history of the Brandon and Norge quadrangles was punctuated by a series of marine transgressions that spread across the entire Middle Coastal

Plain during the Late Tertiary, and then by alternating stages of valley cutting and filling along the ancestral James and Chickahominy rivers through the Quaternary. During the Late Miocene, a sea advanced across the study area to the vicinity of Richmond, leaving a thin basal gravel as a result of shoreline erosion of older sediments and depositing the overlying fossiliferous sand of the upper Eastover Formation. Withdrawal of the sea following deposition of the Eastover left the Middle Coastal Plain emergent and subject to stream erosion.

A rise of sea level during the Early Pliocene caused flooding of at least the Lower and Middle Coastal Plain. As the shoreline moved westward across the older marine and fluvial deposits, a pebbly sand and overlying fossiliferous sand (Sunken Meadow Member) was deposited in relatively warm temperate seas. A regression of the sea in Late Early Pliocene time was accompanied by erosion of the newly formed beds and a major extinction of marine bivalves (including *Chesapecten jeffersonius* and *Placopecten clintonius*). During the succeeding marine transgression in the Early Late Pliocene, the Coastal Plain was faulted and warped. This caused the formation of a partially restricted marine environment between a barrier to the east and the fastland to the west; *Chama* and other marine organisms flourished in the shallow, warm temperate to subtropical, marine environment of the study area. In the Late Pliocene the Middle Yorktown beds (Rushmere - Morgarts Beach Members) were exposed briefly. Subsequently, the biofragmental and shelly sands of the Upper Yorktown (Moore House Member) were deposited on the slowly deforming Coastal Plain during a Late Pliocene marine transgression across the area (Johnson and others, 1985). The seas withdrew from the area following deposition of the Yorktown strata.

Between the cessation of Yorktown deposition and the completion of the deposition of the lower Bacons Castle Formation, more than 100 feet of the Yorktown and upper Eastover Formations were stripped away in western Charles City and eastern Henrico counties. This was accomplished primarily through marine shoreline erosion of a pre-existing stream-dissected coastal plain. As the Bacons Castle shoreline migrated westward, a thin basal transgressive sand was deposited. The large supply of fine-grained sediments derived from erosion of the fastland and from the ancestral James River contributed to the formation of tidal-flat conditions over much of the study area. Tidal-flat deposits accreted as sea level rose, but in the Late Pliocene a shallow restricted sea or lagoon covered the Middle Coastal Plain to the Broad Rock scarp in the Richmond area. As the Middle and Lower Coastal Plain became emergent following deposition of the Bacons Castle Formation, the James and Chickahominy rivers extended their courses seaward.

The Moorings unit was laid down in Late Pliocene time as part of a backbarrier, barrier, and marine triplet; the latter has subsequently been removed by erosion.

Prior to deposition of the Windsor Formation the lower Coastal Plain was exposed to subaerial erosion. The valley of the ancestral James and Chickahominy rivers was cut downward, the former to below an elevation of 40 feet. Tributary streams extended their courses headward into the Norge uplands. Local relief along the major rivers was approximately 100 feet.

With the relative rise of sea level to about 95 feet in the Early Pleistocene, fluvial and marsh deposits (Windsor Formation) were trapped in the valley of the James River and its tributaries. When the interfluves were flooded by the rising sea, a broad, open bay formed to the east of the study area. Shoreline erosion caused the strandline to retreat to the position of the Surry scarp. Concurrently, the James River became tidal. At this stage the Windsor lagoon or bay extended northeastward onto the Middle Peninsula and southwestward into North Carolina, and the James River estuary reached westward to the Fall Zone.

An Early Pleistocene retreat of the sea left the Middle and Lower Coastal Plain above water and subject to erosion. The paleovalley of the James River was cut to near present sea level in Charles City County during this episode of lower sea level. With the wastage of Early Pleistocene ice sheets, sea level rose. Stream gradients were reduced and fluvial sediments were trapped in the paleochannel. Gradually the tidal conditions replaced the unidirectional flow of the earlier streams. Beach erosion along the ancestral James and Chickahominy rivers and their tributaries cut the Ruthville scarp. The aggradational surface of this transgression is the Grove flat.

Following the deposition of the Charles City Formation, sea level fell, then rose to a relative elevation of approximately 62 feet when the Chuckatuck strata were deposited, and then fell again during the early part of the Middle (?) Pleistocene. The floors of valleys were cut into the Chuckatuck and older formations to below present sea level. The course of the pre-Shirley paleochannel passed north of the uplands near Cherry Hall; the Chickahominy River held a parallel course to the James River on the east side of the Chickahominy State Wildlife Management Area.

With the melting of glaciers in the Late Middle Pleistocene, sea level began to rise, causing the paleovalley to fill with fluvial and paludal sediments. When sea level reached its present level, the James changed from a fluvial to an estuarine system with noticeable tidal effects. A small spit developed along the north bank, southeast of Holdcroft; erosion by the Chickahominy and James rivers removed the divide between the rivers. During the relative highstand at 48 feet, the James and Chickahominy rivers were confluent in the vicinity of Mt. Airy and southeast of the Chickahominy State Wildlife Management Area. At this stage the estuarine silt and clay of the upper Shirley Formation were deposited on the Huntington flat and gravelly, coarse sand was laid down locally along the shoreline. Growth of Illinoian Stage glaciers caused sea level to fall, exposing the Shirley Formation and subjecting these and older deposits to erosion.

The wastage of Illinoian glaciers resulted in the inundation of the ancestral James River valley and its tributaries, and the deposition of the Tabb Formation. Subsequently, reduced gradients caused by the rise of sea level during the Early Sangamonian Stage decreased the competency of the major streams in the Brandon and Norge areas and the lowermost beds of the Tabb Formations were deposited under fluvial conditions. With the continued increase in elevation of the sea, the James and Chickahominy rivers became tidal and the upper estuarine silt, fine sand and clay of the Tabb Formation were deposited.

During the Wisconsinan Stage, sea level fell to approximately 330 feet below present sea level and both the James and Chickahominy rivers cut deeply into the older Pleistocene deposits, especially the Tabb Formation. The melting of the Wisconsinan glaciers caused flooding of the Chesapeake Bay lowland and its principal tributaries. With this inundation the James and the Chickahominy rivers changed from a fluvial system to an estuarine depositional mode. Locally fringing marshes developed on flats and along stream margins and migrated upward as sea level rose. Shoreline erosion along the estuaries caused widening of the rivers and contributed to aggradation of the river bottoms. At present, sea level is rising at about 1 foot per century.

ECONOMIC GEOLOGY

The principal economic resources exploited in the Brandon and Norge quadrangles are sand and gravel and clay; potentially recoverable resources include peat and lime. Sand and gravel are mined from the lower part of the Shirley Formation at the Chickahominy Sand and Gravel Company and previously at the American Materials pits, and from small pits in the Windsor Formation. Contiguous deposits of the Tabb Formation are being mined in the Claremont quadrangle by the Chisman Company. The overburden of clayey silt and fine sand is stripped and the sand and gravel are mined by dragline and front-end loader. The material is sold either without beneficiation or is sorted. The principal uses of the sand are as general fill material, cement and mortar sand, and as subgrade material for highway construction.

Numerous small, intermittently active or abandoned sand and gravel pits are present in the fluvial-estuarine facies of the Windsor Formation on the Lackey plain, Bacons Castle Formation in the Norge uplands, and the Tabb Formation on the Dancing Point flat. These deposits are not exploited extensively because the overburden is relatively thick, the deposits are sporadic in occurrence, or the sand and gravel contain undesirable impurities. They are used locally for roadconstruction and general fill. The Windsor and some Bacons Castle deposits are well suited for road fill because there is commonly enough clay and silt to bind the coarser clasts.

Clay-rich sediments are found in all formations except the Yorktown and Eastover within the area of the Brandon and Norge quadrangles. The first human utilization of clays in this area was by the Indians who used the clay for pottery (McCroy, personal communication). During the Colonial period, the clays were probably used for brick, tile, and pottery. In most places the clays are very thin, contain excessive amounts of coarse material, or have deleterious impurities, such as organic material. The most abundant and widely used clay resources in the Brandon and Norge quadrangles have been extracted from the upper part of the Shirley Formation on the Huntington flat northwest of Bachelor Point, off State Road 614 near Morris Creek, and south of State Highway 5 in southwestern James City County. The alumina-rich (Al_2O_3) clays from the Shirley Formation are potentially suitable for roofing tile, building brick, and related structural uses (Johnson and Tyrell, 1967; Sweet, 1982). No active commercial pits exist in the area today.

Peat occurs sporadically in the Shirley Formation and Holocene deposits. These deposits are uneconomical to exploit because they are either too thin and impure, not geographically widespread, or are covered by thick overburden. The fossiliferous Yorktown is locally near the surface and is potentially a source of lime and glauconite. Locally the mixture of lime and sand has been used for driveway fill; and the shell was burned for making mortar in the Colonial period. The mixture of weathered shell and glauconite wasused to enrich the soil for agricultural purposes. The economic potential for the extraction of both lime and glauconite is limited by the low concentration of glauconite and the relatively deep burial of the resource.

ENVIRONMENTAL GEOLOGY

Geologic hazards in the Brandon and Norge quadrangles include storm flooding, shoreline erosion, mass wastage, land subsidence, and groundwater depletion and contamination. Storm flooding is caused by intense short-term rainfall and by storm-generated high tides. Rain-produced flooding occurs most commonly on the Huntington flat because infiltration is impeded by the relatively thick and impermeable clayey soils; runoff is inhibited by the exceptionally low relief, widely spaced natural drainageways, and dense vegetative cover. Much of the upland area subject to flooding has been left in a forested state and the impact of flooding on humans has been minimized. Where farming and other activities are practiced in the flood-prone areas, drainage ditches have been constructed or field tile installed to remove the surface water.

Tidal flooding is limited to low-lying areas, principally marshes (Moore, 1980), swamps, and narrow streambottoms less than 6.7 feet above sea level. For the most part these areas are uninhabited, and roads, bridges, and other structures have been built above flood stage; consequently the damage caused by tidal flooding in this area is minimal.

Tidal flooding associated with major storms is a contributing factor in shoreline erosion.

Shoreline erosion (Hobbs and others, 1975; Owen and others, 1976) causes severe problems only locally. Bank recession is most rapid where fetch is greatest (more than 2 miles), the coastline is underlain with noncohesive sand (lower part of the Shirley and Tabb Formations), beaches are narrow or lacking, and where the bluffs are low. Moderate rates of erosion (1.1 to 2.4 feet per year) are reported along the Chickahominy River near Ferry Point and Morris Creek. The Old Neck Creek area, which is surrounded by marshes, has been eroding about 4.5 feet per year in historic times (Owen and others, 1976) whereas accretion is occurring in the Oldfield area (Plate 1). The high bluffs (greater than 66 feet) north of Trees Point are slumping because unconsolidated gravelly sand of the Charles City Formation is being undercut by waves and sapped by groundwater. Shoreline protection devices, such as rip-rap, groins, and bulkheads, have been installed and have reduced or halted the recession of the shoreline caused by erosion and slumpage.

The dissolution of shell material in the upper Yorktown Formation by groundwater has caused subsidence of the land surface. Small caverns and sinkholes, less than 8 feet in diameter, are known from sewer excavations near the intersection of State Road 614 and Settlers Lane (Berquist) and in yards north of Williamsburg and in Norge (Johnson). Sinkholes, or dolines, some of which are seasonally flooded, occur in open fields northeast of Lightfoot. In addition, small-scale collapse structures were exposed during the excavation along the banks of the Little Creek Reservoir and in roadcuts along State Road 637 in James City County (Plate 1). Although these features are less prevalent than in limestone terrain, they pose a hazard to road foundations, wells, and personal safety, result in decreased agricultural productivity because of flooding, and increase the cost of construction. Subsidence related to intensive groundwater withdrawals may also occur.

The withdrawal of large quantities of groundwater at West Point, Williamsburg, and Franklin from the Yorktown, Pamunkey, and Potomac aquifers (Meng and Harsh, 1984) and production from the groundwater table aquifer have depleted groundwater supplies locally, necessitating the drilling of deeper wells. A concern of this water mining is the possibility of depressurization of the deeper aquifers, the encroachment of brackish water westward in the Norge quadrangle, and possible subsidence. Other problems relating to groundwater in this area are the infiltration of leachate from landfills and septic system filter fields. The contamination of water supplies by leaking sanitary wastes from filter fields inJames City County has been reduced by improvements in water-well construction and by the installation of central sewage treatment and water supply systems.

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APPENDIX I

STRATIGRAPHIC SECTIONS

Section 1: Wahrani Swamp

The type section of the Barhamsville Member of the Bacons Castle Formation is located along the north side of State Road 632 beginning approximately 1200 feet east of the intersection with Wahrani Swamp, New Kent County, Toano quadrangle, Additional discussion of this exposure may be found in Johnson and others (1981). The elevation at the top of the section is approximately 105 feet. The section was measured from the top of the hill downslope over a horizontal distance of 280 feet. Location, UTM coordinates: Zone 18, 335,335 m.E., 4,147,200 m.N.

Thickness Feet

Bacons Castle Formation
Barhamsville Member (31.5 feet)

Clay, silt, and sand. Clay, light-gray; silt and sand, yellow-brown to pinkish red, very fine-grained; flaser-bedded;bedding dips up to 25° to the north; burrows rare, bioturbation common, solution-collapse features present - 10-inch diameter vertical tube-shaped zone of disrupted and rotated blocks of sediment; faults, subvertical, intersecting, up to 6 feet exposed with offsets up to 1 inch. At approximately 150 feet downhill the base of this section contains a penecontemporaneous slump block with 4- to 6-inch interbeds of light-brown to brownish-pink silt and gray clay; clay displays convolute bedding and flame structures; base of the slump is composed of rip-up clasts and clay pebbles; small subvertical faults with offsets up to 1 inch are associated with the slumping...26.0

Clay and sand. Clay, gray to red, flaser to lenticular bedded; sand, yellow-brown to pink, very fine-grained; burrows rare...5.5

Yorktown Formation (upper 13.5 feet)

Sand, dark-brown, medium- to coarse-grained, muddy; grades downward to silty clay, dark brown, massive to disrupted bedding, manganese or ferricrete layer to 0.5 inch thick common; grades downward to sandy clay, olive-gray with 1/8 inch thick sand or clay laminations..4.5

Sand, light yellow, fine-grained, light-gray or black manganese stained sand marks the location of leached fossils (ghosts); liesegang rings, ferricrete laminations, bioturbated gray, clay flasers common in upper 5 feet............9.0

Section 2: Copeland Triangulation Station

The **type section** of the Charles City Formation is exposed in an inactive sand and gravel pit on the north bank of the James River, at the Copeland triangulation station, east of Windmill Point, Charles City County, Charles City quadrangle. Elevation at the top of the section is approximately 65 feet. Location, UTM coordinates: Zone 18, 316,350 m.E., 4,131,300 m.N.

Thickness Feet

Charles City Formation (65.1+ feet)

Silt, clayey, light gray, weathers light brown, massively bedded; grades downward to a medium- to coarse-grained, sandy mud, pebbles rare in lower 1 foot; sharp basal contact commonly marked by thin (1/4 inch) ferricrete.. 11.0

Sand, muddy, light-brown, coarse-grained, quartz and feldspar with larger pebbles; clast supported; horizontally bedded; somewhat indurated by silt, clay, and iron oxide (limonite); sharp basal contact marked by 1 inch thick ferricrete... 1.5

Sand, silty, brown to light brown, very fine-grained; long, low-angle trough crossbeds defined by 1-inch thick beds of clayey silt (mud drapes) and massively bedded; small burrows common; grades to a basal 6-inch-thick quartz pebble bed; some manganese staining... 3.5

Sand, quartz, silty, light brown fine- to medium-grained with interbeds of quartz pebbles defining trough crossbeds; small burrows common; ripple crossbeds defined by opaque minerals or manganese staining; lower 1 foot very coarse-grained, feldspar-rich sand with low-angle trough crossbeds; sharp basal contact........................... 2.5

Sand, pebbles, and cobbles, quartz, light-brown, minor feldspar; horizontally bedded; clast supported; boulders to 11 inches in maximum diameter at base; sharp basal contact.. 6.5

Sand, pebbly, quartz, yellowish-brown, coarse-grained; becomes coarser downward; trough crossbeds; sharp basal contact... 2.5

Sand, silty, quartz, light-brown; low-angle trough crossbeds; gray mud-lined vertical burrows, 1/8 to 1/4 inch in diameter, up to 4 inches long; ripple crossbedding at base defined by opaque minerals; sharp basal contact... 3.5

Sand and pebbles, quartz, light-brown; horizontally bedded; gray clay balls and clay drapes up to 2 inches thick.. 6.0

Sand, quartz, light-brown, medium- to coarse-grained; low angle trough crossbedding; pebbly sand interbeds; dark brown liesegang stains; lower 5 feet of unit augered...13.5

Sand, quartz, slightly feldspathic (kaolinite), fine- to coarse-grained, light-brown to dark-gray; pebbly and cobbly, crossbedded, cross bedding accentuated by heavy mineral laminae; cobble and boulder layer at base, basal contact sharp... 6.8

Sand, fine, silty, quartz, light-yellowish-brown, grades downward to light gray; no apparent bedding, scattered heavy minerals, non-cohesive; base not reached by auger... 7.8

Section 3: Tarmac-LoneStar Pit, Shirley Plantation

The **type section** of the Shirley Formation is described from the north-south face of the Tarmac-LoneStar borrow pit, 0.8 mile southwest of the intersection of State Highways 5 and 156, Charles City County, Westover quadrangle. The elevation at the top of the section is approximately 36 feet. Units in the pit exhibit lateral variation in thickness and lithology. Location, UTM coordinates: Zone 18, 302,760 m.E., 4,133,870 m.N.

Thickness Feet

Shirley Formation (25.7 ft)

Silt, fine-grained sand, slightly clayey, few scattered, rounded pebbles, medium-brown, with roots and disseminated organic matter, friable; grades downward to underlying unit..4.5

Sand, fine-grained, clayey, silty; brown; quartzose, little mica...2.4

Sand, fine, silty, brown, interbedded with medium- to coarse-grained, light-brown sand and clayey, silty, fine-grained sand, interbeds are 0.2 to 0.9feet thick; coarser sand beds, lenticular, pebbly and cobbly at base and fining upward, quartzose with noticeable heavy minerals and mica; finer beds clayey, silty, with scattered pebbles up to 0.1 inch in diameter; clasts, predominately quartzose; chert, schist, and granite clasts present;ferricrete sporadic in lower part of this and subjacent units............9.4

Sand, fine-grained, very clayey, silty, medium-gray, weakly cohesive, fines downward to cohesive clay, scattered fossil plant detritus consisting of seeds and leaves of oak, beech, hickory, and pine, locally cut by gravel filled channels, lower contact sharp................6.3

Sand and gravel, interbedded with pebbles and cobbles, and boulders up to 6 feet in maximum diameter, coarse clasts common near base of beds and in channel-fills, predominately quartzose clasts (sandstone, quartzite, vein and foliated quartz, flint and chert), some granite, schist and greenstone; maximum thickness observed in pit is 8.6 feet; sharp basal contact..................................3.1

Aquia Formation (6.8 ft)

Sand, silty, dark greenish-gray, quartzose and glauconitic with some mica; compact; nonfossiliferous except for indistinct molds; base not exposed............................6.8

Section 4: Floyd Smith Sand and Gravel Pit

The type section of the Chuckatuck Formation is exposed in the Floyd Smith Sand and Gravel Pit, 0.6 miles west of State Highway 10 and 1.1 miles north of the City of Suffolk-Isle of Wight County line, in Isle of Wight County, Benns Church quadrangle. The Cat Ponds are immediately south of the pit. Elevation of the undisturbed land surface varies from 55 to 60 feet. Units in the pit exhibit lateral variations in thickness and lithology. Location, UTM coordinates: Zone 18, 358,000 m.E., 4,084,450 m.N.

Thickness Feet

Holocene deposits (2.4 ft)

Clay, silty and sandy, organic-rich, dark-gray to black, abundant organic detritus and roots, plastic, water saturated, lenticular, sharp basal contact.............................. 2.4

Chuckatuck Formation (28.8 ft)

Sand, fine, clayey, brownish-gray grading downward to medium-brown, massive, non-bedded, roots common, grades into underlying unit.................................. 4.2

Silt, clayey, medium-gray to light-gray, lower part medium-brown, blocky, rudimentary bedding, contains more sand in lower 6 inches; grades into underlying unit.. 3.3

Sand, fine-grained with silt interbeds, coarsens downward, irregularly banded, light-gray, orange, and medium-brown, quartzose, micaceous, scattered clay lenses and very thin beds, soft, burrowed, grades through several inches into underlying unit............................... 4.4

Sand, fine-grained, generally coarsens downward, yellowish-brown to orange, medium-brown and light-gray, quartzose, abundant heavy mineral; thin lenses and layers of pebbles, cross laminated and cross bedded, cross stratification varies but commonly dips westward, disrupted bedding, clay balls, near vertical and nodose clay-lined burrows, contact with underlying unit sharp.......... 8.8

Peat and organic-rich silt and sand, black to dark gray, interbedded white sand, abundant woody material, plant detritus, seeds and cones of pine, cypress, hickory, and other deciduous trees, compacted, fetid odor, scattered pebbles in basal part of unit; unit fills channels cut into underlying formation.. 6.2

Sand, pebbly and cobbly, small boulders sparse, quartzose, clasts of quartzite, sandstone, chert, and granite, scattered clay clasts derived from underlying unit, planar-shaped clasts parallel to bedding, cross bedded; deposit occupies base of channel or interfluves......................... 1.9

Charles City or Windsor Formation (11.4 ft)

Clay, silty, silt, and fine-grained sand interbedded, sand, light-gray, orange, and reddish-brown, flaser bedded, lower part of unit medium bedded with sand predominant and upper part thin to medium bedded with clay dominant, convoluted bedding, base of unit not exposed... 11.4

APPENDIX II

GEOLOGIC SUMMARIES OF SUBSURFACE DAT

Explanation

W-1754	Numbers preceded by the letter "W" refer to those wells or borings whose samples are on file in the Division's repository.
B-58A	Numbers preceded by the letter "B" refer to those borings furnished by the Virginia Electric and Power Company.
m	Top of marsh deposits
Qtp	Top of Tabb Formation, Poquoson Member

Qtl	Top of Tabb Formation, Lynnhaven Member
Qs	Top of Shirley Formation
Qwb	Top of Windsor Formation (bay deposits)
Qwf	Top of Windsor Formation (fluvial-estuarine deposits)
Qm	Top of Moorings unit
Tbc	Top of Bacons Castle Formation
Ty	Top of Yorktown Formation
Tc	Top of Calvert Formation
Tn	Top of Nanjemoy Formation
Tm	Top of Marlboro Clay
Ta	Top of Aquia Formation
Kp	Top of Potomac Group
TD	Total depth of well or boring in feet

All elevations are relative to a sea level datum.

	Elevation of top (in feet)	Thickness (in feet)	Remarks
W-1754			
Qm	103	30	
Ty	73	120	
Tc	-47	100	
Tn	-147	50 drilled	
TD 300			
W-2192			
Tbc	65	20	
Ty	45	100	
Tc	-55	100	
Tn	-155	70 drilled	
TD 290			
W-3259			
Tbc	88	60	
Ty	28	120	
Tc	-92	70	
Tn	-162	51 drilled	
TD 301			
W-3639			
Tbc	120	60	
Ty	60	110	
Tc	-50	90	
Tn	-140	80	
Tm	-220	20	
Ta	-240	40	
Kp	-280	28 drilled	
TD 428			

	Elevation of top (in feet)	Thickness (in feet)	Remarks
W-3753			
Qm	103	30	
Ty	73	120	
Tc	-47	100	
Tn	-147	30 drilled	
TD 280			
W-3799			
Tbc	115	70	
Ty	45	110	
Tc	-65	60	
Tn	-125	80	
Tm	-205	20	
Ta	-225	13 drilled	
TD 353			
W-3877			
Tbc	88	40	
Ty	48	110	
Tc	-62	80	
Tn	-142	70	
Tm	-212	20	
Ta	-232	78 drilled	
TD 398			
W-3977			
Tbc	123	60	
Ty	63	130	
Tc	-67	80	
Tn	-147	70	
Tm	-217	30	
Ta	-247	32 drilled	
TD 402			
W-6539			
Tbc	89	45	interbedded, laminated sand and clay
Ty	44	17 drilled	brown-clay, sand and shell
TD 61			
W-6540			
Tbc	100	55	laminated sand and clay
Ty	45	12 drilled	brown clay, sand and shell
TD 67			
W-6541			
Tbc	124	63	dark red fine sand,clay flasers

	Elevation of top (in feet)	Thickness (in feet)	Remarks
Ty	61	64 drilled	brown clay, sand and shell grading down to dark gray clayey fine sand
TD 127			
W-6542			
Qtp	11	12 drilled	medium to fine sand
TD 12			
W-6543			
Qs	32	20	laminated clay, organics
Ty	12	7 drilled	sand and shell
TD 27			
W-6544			
Qwb	95	6	yellow-brown fine sand
Qwf	89	11	clay and sand
Tbc	78	14	laminated sand and clay
Ty	64	16 drilled	brown clay, sand and shell
TD 47			
W-6545			
Qwf	81	24	clay grading down to sand and gravel
Ty	57	13 drilled	brown clay, sand and shell
TD 37			
W-6546			
Tbc	85	38 drilled	laminated sand and clay
TD 38			
W-6547			
Tbc	70	26 drilled	brown sand, clay laminations
TD 26			
W-6548			
Qs	33	48 drilled	laminated sand, clay, organics grading to muddy pebbly sand
TD 48			

	Elevation of top (in feet)	Thickness (in feet)	Remarks
W-6549			
Tbc	100	39 drilled	laminated clay and fine sand
TD 39			
W-6550			
Tbc	80	27	red brown sand, clay laminations
Ty	53	8 drilled	brown sandy clay
TD 35			
W-6551			
Qtl	16	24	silty sand grading down to sand and gravel
Qs	-8	3 drilled	clay
TD 27			
W-6552			
Qwf	68	16	clay grading down to coarse sand and gravel
Ty	52	24 drilled	brown clay, sand and shell
TD 40			
W-6553			
Qwb	97	12	gray sandy clay
Tbc	85	19	dark red sand, clay flasers
Ty	66	2 drilled	dark brown clay
TD 33			
W-6554			
Qm	95	4	light brown sand
Tbc	91	25	orange sandy clay, laminated
Ty	66	1 drilled	brown clay and shell
TD 30			
W-6555			
Tbc	123	53 drilled	red-orange sand, clay laminations
TD 53			
W-6556			
Qm	115	8	gray clay
Tbc	107	37	orange sand, clay laminations
Ty	70	3 drilled	green clayey silt and shell
TD 48			

	Elevation of top (in feet)	Thickness (in feet)	Remarks
W-6557			
Tbc	95	35	interbedded red-brown sand and clay
Ty	60	3 drilled	brown clay, sand and shell
TD 38			
W-6558			
Qs	34	37	silt grading down to sand and gravel
Ty	-3	1 drilled	shell and sand
TD 38			
W-6559			
Tbc	104	42 drilled	red sand and clay
TD 42			
W-6560			
Tbc	102	45	red sand and clay
Ty	57	2 drilled	brown clay and shell
TD 47			
W-6561			
Tbc	75	28	brown silty sand, clay laminations
Ty	47	2 drilled	clayey sand, shell
TD 30			
W-6562			
Tbc	80	35	red clayey sand, clay laminations
Ty	45	12 drilled	brown clay, sand and shell
TD 47			
W-6563			
Qwb	84	6	gray silty clay
Tbc	78	22	red sand, clay laminations
Ty	56	2 drilled	brown clay and sand
TD 30			
W-6564			
Tbc	123	40 drilled	interbedded gray and brown clayey silt and sand
TD 40			

	Elevation of top (in feet)	Thickness (in feet)	Remarks
W-6565			
Qwb	90	10	gray clay over tan sand
Tbc	80	17	red brown sand, clay laminations
Ty	63	4 drilled	brown clay
TD 31			
W-6566			
Qwb	97	7	brown silt grading down to sand
Tbc	90	30 drilled	red sand, clay laminations
TD 37			
B-58A			
m	2	35	black organic silt
Qs?	-33	2 drilled	sand and silty clay
TD 37			
B-60			
m	2	5	organic sandy silt
Qtp	-3	6	fine to coarse sand and gravel

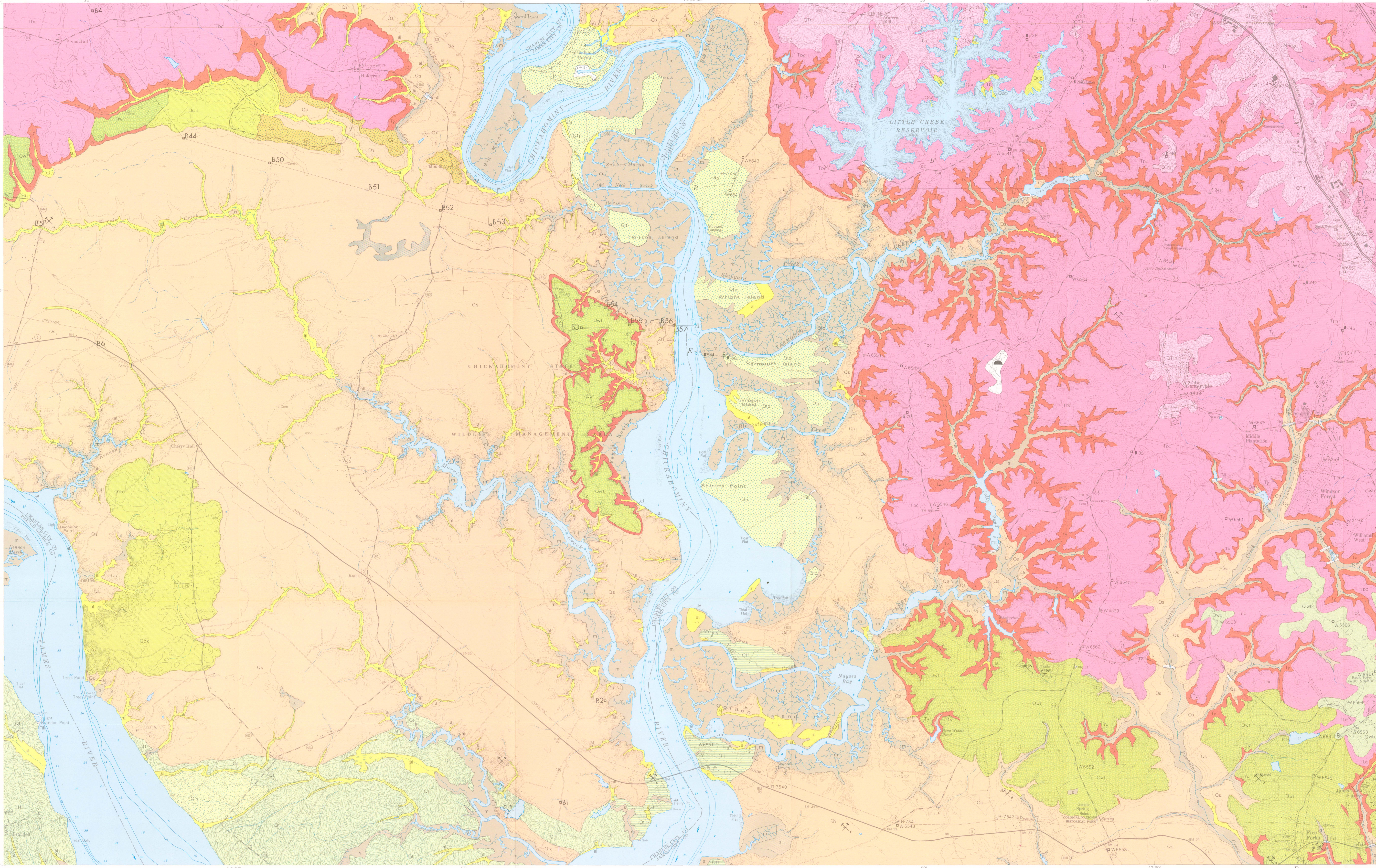
	Elevation of top (in feet)	Thickness (in feet)	Remarks
Qs	-9	41 drilled	clay grading down to sand and gravel
TD 52			
B-70			
Tbc	95	51	red sand, clay laminations
Ty	44	32 drilled	brown clay, sand and shell
TD 83			
B-80			
Tbc	118	73	interbedded sand and clay
Ty	45	9 drilled	brown sand, clay, and shell
TD 82			
B-236			
Tbc	100	32 drilled	red fine sand, clay laminations
TD 32			

	Elevation of top (in feet)	Thickness (in feet)	Remarks
B-237			
Tbc	102	34	brown fine sand, gray clay
Ty	68	10 drilled	brown clayey sand
TD 44			
B-240			
Qm	105	23	light gray fine sand and clay
Tbc	82	11	red fine sand, clay laminations
Ty	71	3 drilled	brown clayey silt
TD 37			
B-241			
Tbc	106	33 drilled	red fine sand, clay laminations
TD 33			
B-244			
Tbc	86	18	silt and clay
Ty	68	55 drilled	clay, shell and sand
	Elevation of top (in feet)	Thickness (in feet)	Remarks
TD 73			
B-245			
Tbc	97	43	silt and clay
Ty	54	29 drilled	brown clayey silt, sand and shell
TD 72			
B-1			
Qs	36	48	interbedded sand and gravel with upper part clayey silt
Te	-12	9 drilled	silty fine sand
B-2			
Qs	32	55	interbedded sand and gravel with upper clayey silty fine sand
Te	-23	2 drilled	silty fine sand
B-3			
Qwf	86	31	lower gravelly sand grades upward into sand and clayey silt
Te?	55	47 drilled	fossiliferous silty fine sand
B-4			
Tbc	124	50	interbedded sand and silty clay
Ty	74	22	fossiliferous fine sand
Te	52	5 drilled	greenish-gray glauconitic fine sand
B-5			
Qs	33	36	basal coarse sand grades upward into fine sand and clayey silt
Ty	-3	14 drilled	micaceous clayey silty fine sand
B-6			
Qs	42	56	upper clayey silt grades downward into sand and gravelly sand
Te	-14	10 drilled	micaceous clayey silty fine sand
B-7			
Qtp	4	11	basal pebbly sand grades up into sandy silt
Te	-7	17 drilled	micaceous clayey silty fine sand

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES

PUBLICATION 87, PLATE 1
GEOLOGY OF THE BRANDON
AND NORGE QUADRANGLES, VIRGINIA

INSET MAP A



EXPLANATION

QUATERNARY — HOLOCENE

al | m | s

Alluvium, Marsh Sediment, and Swamp Sediment

al, *pebbly sand and sand; silt; interbeds of silt and fine sand with organic matter common.* m, *organic rich silt with fine sand and clay interbeds.* s, *peat and organic-rich sand, silt, and clay.*

QUATERNARY — PLEISTOCENE

Qt | Qtp | Qtl | Qts

Tabb Formation

Qt, *Tabb Formation undivided.* Qtp, *Poquoson Member, silt, fine sand, and clay.* Qtl, *Lynnhaven Member, sand, silt, and clay.* Qts, *Sedgefield Member, pebbly sand, sand, and clayey silt.*

Qs

Shirley Formation

Pebble to boulder sand, sand, silt, and clay; scattered peat and organic-silt beds.

Qc

Chuckatuck Formation

Pebbly sand, sand, silt, and clay.

Qcc

Charles City Formation

Pebble to boulder sand, interbedded cross-bedded sand and silt, and silt and clay.

Qwb | Qwf

Windsor Formation

Qwb, *sand and mud.* Qwf, *gravel, sand, and mud.*

TERTIARY — PLIOCENE

QTm

Moorings unit of Oaks and Coch (1973)

Massively bedded sand or clay.

Tbc

Bacons Castle Formation

Interbedded sand, silt, and clay, massively bedded and lenticular to flaser bedded; basal pebbly to coarse sand common.

TERTIARY — PLIOCENE/MIOCENE

Ty

Yorktown Formation
(may locally include upper Eastover Formation)

Interbedded shelly sand and fine sand; dark brown clayey sand and clay at top of unit.

Fill

Undifferentiated material used for fill.

Active Landfill

KEY

CONTACTS

Exposed, approximate, or inferred.

STRATIGRAPHIC CONTROL

- △ R-7542 — Repository number of sample on file at the Division of Mineral Resources.
- □ W-3877 — Repository number of well or boring on file at the Division of Mineral Resources and referenced in Appendix II.
- □ B 60 — Test boring referenced in Appendix II.

SAND, GRAVEL, AND CLAY PITS

Active Pits

1. F. Hughs — sand
2. R.T. Armistead — sand and gravel
3. Karl et. als. Beamer — sand
4. Chickahominy Sand and Gravel — sand and gravel

Inactive Pits

5. Green Springs Land Trust — sand and gravel
6. Art Stone Investors, Inc. — clay
7. Green Springs Land Trust — sand and gravel
8. C.C. Casey — sand and gravel
9. Dudley S. Waltrip — sand and gravel
10. Americal Materials Co. — sand and gravel
11. Sand and gravel
12. Clay

(Brandon Quadrangle) (Norge Quadrangle)

Base map from U.S. Geological Survey, 1965
Brandon and Norge Quadrangles.
7½ Minute Series

GEOLOGIC MAP OF THE BRANDON AND NORGE QUADRANGLES, VIRGINIA

Gerald H. Johnson (Brandon Quadrangle)
C.R. Berquist, Jr. (Norge Quadrangle)

1988

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
SUPPLEMENTARY CONTOUR INTERVAL 5 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 2.5 FEET

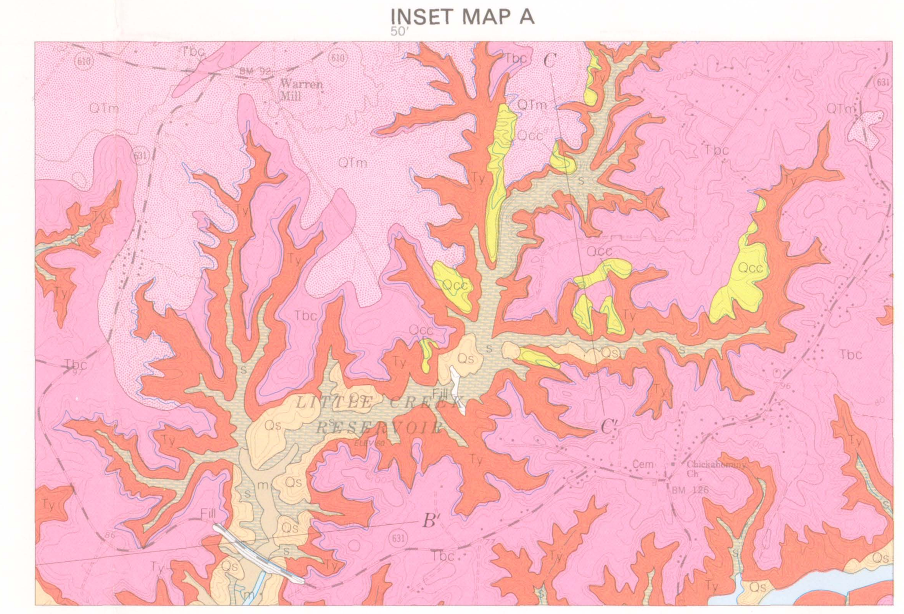
Map printed as part of the Division of Mineral Resources and the U.S. Geological Survey cooperative COGEOMAP project Agreement No. 14-08-0001-A0627.

UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

Williams & Heintz Map Corporation, Capitol Heights, Md. 20743

INSET MAP A



Interpretive cross sections with 20x vertical exaggeration; subsurface structure interpreted from surface measurements and borehole data.