COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE MULBERRY ISLAND, NEWPORT NEWS NORTH, AND HAMPTON QUADRANGLES, VIRGINIA

GERALD H. JOHNSON

REPORT OF INVESTIGATIONS 41

VIRGINIA DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
1976

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GEOLOGY OF THE MULBERRY ISLAND, NEWPORT NEWS NORTH, AND HAMPTON QUADRANGLES, VIRGINIA

By

Gerald H. Johnson[1]

ABSTRACT

The Mulberry Island, Newport News North, and Hampton 7.5-minute quadrangles are located in the Outer Coastal Plain of southeastern Virginia. The quadrangles include portions of York and Isle of Wight counties and portions of the cities of Hampton, Newport News, and Poquoson. The area is characterized by a series of plains, which were created under subaqueous conditions, and scarps, which were former shorelines of the ancestral Chesapeake Bay or the James River during the Pleistocene Epoch. The margins of the plains have been deeply dissected by streams flowing into the Chesapeake Bay.

The exposed sediments are of Pliocene, Pleistocene, and Holocene age. They are assigned to the Yorktown, Windsor, Norfolk, Sand Bridge, and Tabb formations. Additionally, alluvium, marsh sediment, and beach and dune sand are present.

Construction materials for future use, principally sand, are found in the area between the Harpersville and Big Bethel scarps and along the course of the ancestral James River between Oyster Point and Kecoughtan. Marl for use as fill material is found at shallow depths beneath the Hampton flat. Peat and clay bodies in the Norfolk Formation, although discontinuous in distribution, may constitute a secondary economic mineral resource in the area south of the Big Bethel Reservoir. However, the spread of suburban and urban development threatens to preclude mining of these mineral resources.

In the last three centuries man has brought about extensive changes to the landscape of the lower York-James Peninsula. He has stabilized a major portion of the beaches along the Newport News and Hampton waterfronts, drained or filled salt marshes, diverted and dredged new courses for streams, urbanized the land, and helped to create a greater flood potential through these activities.

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INTRODUCTION

The Mulberry Island, Newport News North, and Hampton 7.5-minute quadrangles are located in the Outer Coastal Plain of southeastern Virginia (Figure 1). The quadrangles are bounded by parallels 37°00′ and 37°07′30″ north and meridians 76°15′ and 76°37′30″ west. The land area, including marshland, is approximately 90 square miles (233 sq km); the remainder is covered by Chesapeake Bay, the James and Back rivers, their tributaries, and man-made reservoirs (Plates 1, 2, 3). The quadrangles include portions of York and Isle of Wight counties and portions of the cities of Hampton, Newport News, and Poquoson. Second-growth, mixed deciduous and pine forests cover much of the area, but extensive salt marshes occur in the Plumtree and Mulberry Island areas, and along Back River, Long Creek, Warwick River, and Pagan River. Agricultural activity is limited to Isle of Wight County and to scattered localities in the remaining area. Urban development is spreading northward through Hampton and Newport News and into the lower part of York County. The principal roads in this area are Interstate Highway 64, U. S. Highways 17, 60, and 250, and State Highways 134 and 143. The Chesapeake and Ohio Railroad and Patrick Henry Airport serve the lower part

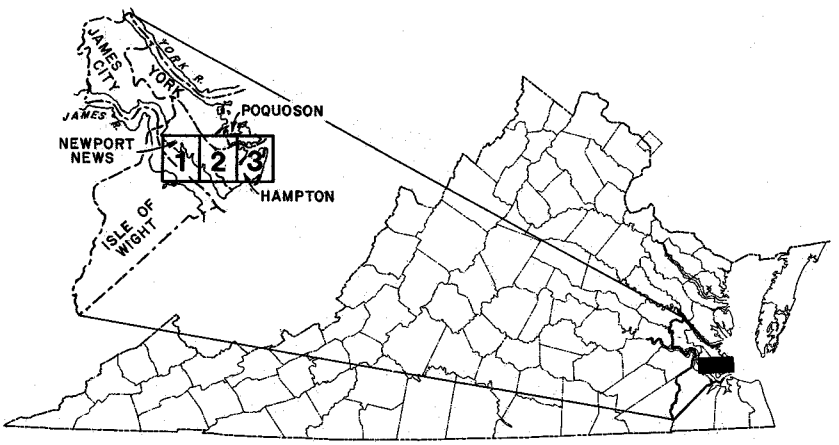


Figure 1. Index map showing location of the Mulberry Island (Plate 1), Newport News North (Plate 2), and Hampton (Plate 3) quadrangles.

of the York-James Peninsula. Shipbuilding, aeronautical research, light industrial activity, fisheries, tourism, and two large military installations are the principal sources of income in the Hampton and Newport News area.

Surface drainage flows eastward into Chesapeake Bay from the estuaries, principally the James River and Back River. Pagan River, Deep Creek, Warwick River, Hampton Creek, Mill Creek, and smaller tributaries drain directly into the James River. Newmarket Creek and Brick Kiln Creek reach Chesapeake Bay through branches of the Back River. Big Bethel Reservoir is the only major surface water supply in the area; most of the water used by man is imported to the area or is drawn from wells 150-550 feet (46-168 m) deep. Lake Maury, Lake Tormentor, and lesser impoundments serve as real estate lakes, wildlife centers, or for farm purposes. All of the major tributaries to the James River and Chesapeake Bay exhibit tidal fluctuation. Normal tidal variations within the map area range between 2.5 feet (0.8 m) in the Hampton quadrangle to about 2.8 feet (0.9 m) in the Mulberry Island area. Because of recent, extensive erosion of shorelines, much of the developed coastline has been protected by man-made shoreline structures.

Field work in the Mulberry Island, Newport News, and Hampton quadrangles was done intermittently from June 1968 through February 1975. Subsurface data were obtained from 11 test holes that were drilled under contract let by the Virginia Division of Mineral Resources (Table 1), from 307 engineering borings, and from 117 hand-auger holes. Examination of 139 surface outcrops provided additional data. Core samples were obtained from the test holes at intervals of 5.0 feet (1.5 m), using a standard split-spoon driven with a 140-pound (64 kg) hammer falling 30 inches (76 cm). Selected sediment samples were subjected to physical and/or chemical tests and, if fossiliferous, macrofauna or flora were identified.

Recent detailed mapping of 7.5-minute quadrangles in adjacent or other nearby areas of southeastern Virginia (Figure 2) was done by Coch (1968, 1971), Bick and Coch (1969), and Johnson (1972). These, as well as a report on the stratigraphy and morphology of the Coastal Plain in southeastern Virginia by Oaks and Coch (1973), established the stratigraphic nomenclature for the area. They have been drawn upon freely insofar as any information is applicable to the present report.

Table 1.—Summary of data from test holes; Holocene (alluvium, al; marsh sediments, m; sand, s); Tabb Formation (Poquoson Member, Qtp; Lynnhaven Member, Qtl; Sedgefield Member, Qts); Norfolk Formation, Qn (Clayey-sand facies, cs); Yorktown Formation, Ty (silty-sand facies, ss).

Drill Hole	Quadrangle Location	Top of Hole in Feet (m)	Top of Formation in feet (m)								Bottom of Hole in Feet (m)	Owner
			al	m	s	Qtp	Qtl	Qts	Qn cs	Ty ss		
W-3950	Mulberry Island	10 (3)				10 (3)			-2 (?) (-1) (?)	-37 (-11)	-60 (-18)	U. S. Army
W-3951	Mulberry Island	30 (9)							30 (9)	-32 (-10)	-40 (-12)	J. J. Layman
W-3952	Newport News North	21 (6)						21 (6)	15 (5)	-27 (-8)	-29 (-9)	J. S. Saunders
W-3953	Newport News North	25 (8)						25 (8)	13 (4)	-8 (-2)	-15 (-5)	State
W-3954	Newport News North	32 (10)						32 (10)		23 (7)	-28 (-9)	State
W-3955	Hampton	3 (1)				3 (1)				-5 (-2)	-47 (-15)	State
W-3956	Hampton	3 (1)	3 (1)			0 (0)				-2 (-1)	-47 (-15)	State
W-3957	Hampton	13 (4)					13 (4)			-1 (-1)	-27 (-8)	City of Hampton
W-3958	Hampton	3 (1)				3 (1)				-4 (-1)	-37 (-11)	Wallace Property
W-3959	Hampton	8 (2)					8 (2)			0 (0)	-32 (-10)	State
W-3960	Hampton	6 (2)	6 (2)	-2 (-1)	5 (-2)					-7 (-2)	-34 (-10)	State

N. K. Coch, Department of Earth and Environmental Sciences, Queens College, New York, Emil Onuschak, Jr., Virginia Division of Mineral Resources, Charlottesville, Robert Mixon, U. S. Geological Survey, Reston, Virginia, and R. Q. Oaks, Department of Geology, University of Utah, assisted the author in the field investigation or provided valuable insights into the stratigraphic or geomorphic problems encountered in this study. The Virginia Division of Mineral Resources, J. L. Calver, Commissioner of Mineral Resources and State Geologist, afforded financial and technical assistance. Page Herbert and Barry Sutphin, Herbert & Associates, Ltd., Virginia Beach, gave professional advice and engineering logs. Additional valuable

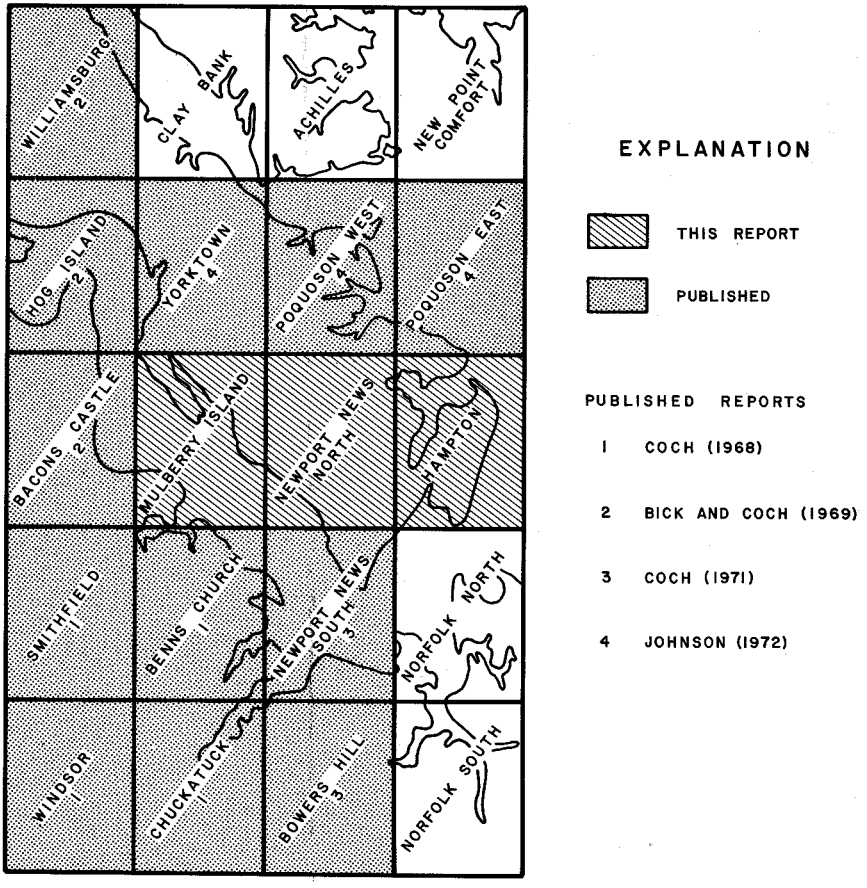


Figure 2. Index map showing location of published geologic maps of 7.5-minute quadrangles in areas adjacent to the present report.

logs, samples, and related data were provided by E. F. Caldwell, Carpenter Construction Co., Norfolk, T. E. Rodgers, Virginia Power and Electric Company, Richmond, W. E. Dvorak and R. L. Allwood, Virginia Department of Highways and Transportation, Richmond, E. B. Washington and G. M. Griggs, Newport News Shipbuilding and Dry Dock Co., Newport News, D. W. Bracken, Jr., Forest Coile and Associates, Newport News, and C. Rawles, National Space and Aeronautic Administration-Langley, Hampton. S. E. Jordan and Robert Briscoe, Williams Paving Co., Hampton, H. R. Dellinger, A. B. Southall, and W. N. Krause, W. N. Krause Company, W. M. Rice, J. S. D. Cumming, and many local citizens permitted the author access to their lands, quarries, and borrow pits. William Fyfe, Post Engineers, Fort Eustis, permitted drilling and geologic field work on federal lands. D. Rosenkrans, J. Brennan, S. M. Wallace, and many other students at the College of William and Mary assisted the author. M. A. Johnson and M. E. Magary assisted in the preparation of the manuscript.

MORPHOLOGY

The Coastal Plain of the lower York-James Peninsula and adjacent Southside Virginia is characterized by a succession of plains and intervening scarps (Figure 3) that imparts a stair-step appearance to the area (Clark and Miller, 1912; Wentworth, 1930; Roberts, 1932; and Oaks and Coch, 1973). The plains diminish in elevation to the east or slope gently toward the adjoining major estuaries. Nomenclatural and stratigraphic problems have arisen and correlation of surfaces and scarps between certain areas is difficult because the different areas have experienced slightly different geologic circumstances and no adequate means of temporal correlation has yet been devised. Coch (1965) and Johnson (1972) offer two dissimilar but not necessarily contradictory classifications of the scarps and plains in southeastern Virginia. Many of the higher plains and scarps recognized by these workers do not extend into the present study area.

A narrow tract of upland, named the Isle of Wight plain by Coch (1968), occurs in the southwestern corner of the Mulberry Island quadrangle (Figure 3). In the adjoining Bacons Castle quadrangle to the west, the Isle of Wight plain is a gently eastward-sloping plain with broad, poorly drained pocosins.

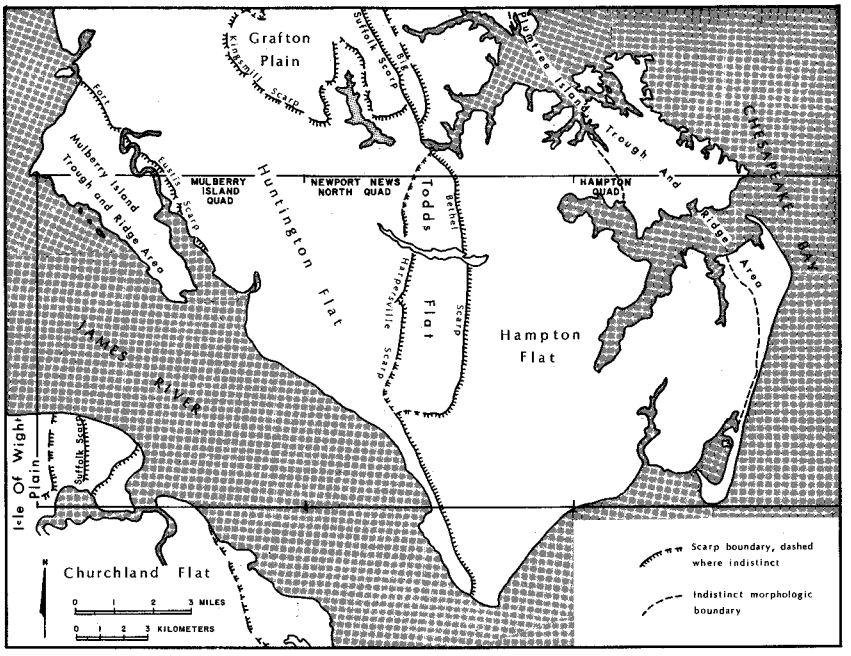


Figure 3. Map showing the principal geomorphic features in the Mulberry Island, Newport News North, and Hampton quadrangles and adjacent areas.

The eastern part of the plain has been dissected by the Pagan River and Tormentor Creek and their tributaries, producing a rolling topography. The elevation of the plain is slightly more than 75 feet (23 m) in the Mulberry Island quadrangle. The plain is bounded on the east by a low, unnamed scarp that lies about 0.5 mile (0.8 km) west of Tormentor Creek. This scarp may correlate with the Lee Hall scarp in the Yorktown quadrangle (Johnson, 1972) and the elevation and position of the eastern part of the Isle of Wight plain are evidence that it may be comparable to the Grove plain (Johnson, 1972) on the York-James Peninsula. Sediments of the Windsor Formation underlie the Isle of Wight and Grove plains.

The prominent Suffolk scarp (Wentworth, 1930, p. 63) has a north-south trend (Figure 3) on the York-James Peninsula and in Southside Virginia. It is approximately 32 feet (10 m) in elevation at its toe south of Mogarts Beach (Plate 1) and rises to over 50 feet (15 m) at its crest about 0.2 mile (0.3 km)

to the west. The scarp was created by wave and current erosion along a mainland beach during Norfolk time; clayey sands of the Sand Bridge Formation rest upon the toe of the scarp (Coch, 1968). The narrow tract of land between the Suffolk scarp and the unnamed scarp west of Tormentor Creek is characterized by a series of north-south trending ridges with relief of 7 to 12 feet (2 to 4 m). The ridges are composed of sand, presumably of the Norfolk Formation, and were formed by progradation of beach deposits seaward during the highest stand of sea level during Norfolk time. The sediments underlying this area rest upon the truncated edges of the Windsor Formation.

The gently sloping plain that lies to the east of the Suffolk scarp south of the James River in the Mulberry Island quadrangle is called the Churchland flat (Coch, 1968). In the study area the elevation of the flat east of the Suffolk scarp is about 32 feet (10 m) and slopes eastward at approximately 2 to 3 feet per mile (0.4 m/km). Although the Churchland flat is intricately dissected by Williams Creek in the Mogarts Beach area, most of the flat is only slightly etched into relief.

The Huntington flat, named by Coch (1971) covers the northeastern part of the Mulberry Island quadrangle and the western one-third of the Newport News North quadrangle (Figure 3). The southward-sloping flat ranges in elevation from about 42 feet (13 m) near the Kingsmill scarp (Figure 3) to about 28 feet (9 m) near the James River. The gradient ranges from 0 to 2.0 feet per mile (0 to 0.4 m/km). The plain is bordered on the north by the Kingsmill scarp, on the east by the Big Bethel and Harpersville scarps, and on the southwest by the Ft. Eustis scarp and the James River. With the exception of minor scarps parallel to the James River and the deeply incised drainage of the Warwick River and Deep and Lukas creeks, the surface is remarkedly flat and poorly drained. Swampy conditions prevail to the east and southeast of the Oyster Point area (Plates 1, 2). Soil erosion is locally severe on the steeply rolling lands adjacent to major streams because of the higher relief and clayey subsoil conditions. The plain is underlain by the clayey-sand and sand facies of the Norfolk Formation. The plain represents an aggradational surface formed by the ancestral James River during Norfolk time.

The Harpersville scarp (Johnson, 1969) trends north-south from the vicinity of Tabb to the community of Sedgefield. At

the north end, the scarp is very low and the adjoining Huntington and Todds flats appear to merge without significant change in elevation. Relief along the central and southern segments of the Harpersville scarp is about 12 feet (3 m). The southern extension of the Harpersville scarp curves southeastward from Sedgefield and merges with the Big Bethel scarp paralleling Warwick Boulevard in Newport News. Sand and clay of the Sedgefield Member of the Tabb Formation rests upon the truncated edge of the clayey-sand facies of the Norfolk Formation. Locally, medium to fine sands, deposited by storm water or wind, surmount the crest of the scarp. The scarp exhibits two offsets; these were created by currents and waves when the Harpersville scarp was the western shoreline of the lower Chesapeake Bay.

Todds flat, herein named for the major road that crosses it, is a distinctive geomorphic unit of limited areal extent and of major geologic importance (Figure 3). The flat extends southward from Tabb almost to Mercury Boulevard (Plate 2). its maximum width is about 1.8 miles (2.9 km) near Morrison. The Harpersville and Big Bethel scarps bound it on the west and east, respectively. Arcuate sandy ridges of low relief, usually less than 5.0 feet (1.5 m), trend northeast to southwest across the surface of the flat (Plate 2). At the southern end of the flat, the ridges are recurved sharply to the west. Elevations on the sand ridges decrease from over 35 feet (11 m) in the north to less than 20 feet (6 m) in the south. Swamps commonly occupy the swales between the ridges, where clayey soils impede infiltration and dense vegetation and a poorly integrated natural drainage network retards runoff. Channelization of Newmarket Creek and the construction of the Newmarket Creek diversion ditch have improved drainage and eliminated swamps that existed in this area as late as the 1950's on the middle reach of Newmarket Creek. Todds flat is underlain by the Sedgefield Member of the Tabb Formation and is comparable in elevation and geographic position to part of the Churchland flat in Southside Virginia.

The Big Bethel scarp (Johnson, 1969) extends from the York River near Yorktown southeastward nearly to Huntington Park where it forms a reentrant (Plate 2) and then curves eastward parallel to Jefferson Boulevard in Newport News. It constitutes the boundary between the Todds and Huntington flats and the Hampton flat. The toe of the scarp lies at about 16.0 to 18.0

feet (4.9 to 5.5 m) elevation and the crest reaches a maximum elevation of 35 feet (11 m) in the study area. The prominence, slope, and elevation of the scarp decreases southeastward and northwestward toward the reentrant at Huntington Park. Along the northern segment of the Big Bethel scarp in the Newport News North quadrangle, the scarp was formed by the erosion of the Sedgefield Member of the Tabb Formation by waters of the ancestral Chesapeake Bay. The southeastern segment is carved into the sand facies of the Norfolk Formation. A thin veneer of sand and gravel of the Lynnhaven Member of the Tabb Formation is the surficial deposit at the toe of the scarp.

The Hampton flat, named by Coch (1971), is the principal geomorphic feature in the lower part of York County and the cities of Newport News and Hampton. The flat is bounded on the west and southwest sides by the Big Bethel and Harpersville scarps, on the north by the York River, on the east by Plumtree Island trough and ridge area, and by Hampton Roads on the south. The surface of the Hampton flat has a gentle eastward dip at about 1.0 foot per mile (0.2 m/km); northward the slope increases to about 5 feet per mile (1 m/km). With the exception of the transverse stream valleys of Newmarket, Brick Kiln, and other creeks, the flat is nearly featureless. Drainage on the interfluves is poor and swamps, such as Sawyers Swamp (Morrison 7.5-minute topographic quadrangle, 1955, edition published by the U. S. Geological Survey, now the Newport News North 7.5-minute quadrangle), were common in the western part of the area before streams were dredged. Salt- and fresh-water marshes are common along the major streams flowing into Chesapeake Bay. Dredging, filling, and mining have destroyed the fringing marshes along Merrimac Shores (Plate 3) and parts of Hampton and Back rivers. Although the Lynnhaven Member of the Tabb Formation underlies most of the Hampton flat, the weathered Yorktown Formation is locally the surficial deposit. The Hampton flat is equivalent to the western part of the Princess Anne terrace of Wentworth (1932).

The coastal salt marshes and linear ridges along the west edge of Chesapeake Bay form a distinctive geomorphic unit known as the Plumtree Island trough and ridge area (Johnson, 1972). Big Salt Marsh and the marshes north of Grand View and in Mill Creek have developed in the shallow trough between partially submerged linear ridges, such as Grunland Point and

the necks of land leading to Amorys Wharf and Messick Point. The ridges trend N. 20-40° W. and are best displayed in the Poquoson East and Poquoson West quadrangles (Johnson, 1972). Relief between the ridges and the adjoining marshes is about 1.0 to 6.0 feet (0.3 to 1.8 m). Depending upon the local soils and topographic conditions, the vegetative cover of the ridges varies from salt marsh cordgrass (*Spartina*) to large pine and deciduous trees. Holocene beach sand, dune sand, and tidal-flat mud form a discontinuous fringe around the Plumtree Island trough and ridge area. Sand beaches and dunes, such as at Northend Point and Grand View, are migrating westward over the salt marshes (Figure 4). Along some sections of the beach, older marsh and swamp sediments are exposed during low tide. The Poquoson Member of the Tabb Formation is the surficial sediment over much of this area. Locally sanitary landfills, housing, and commercial establishments have been constructed on the marshes.

Linear sand ridges and marsh-covered swales along the James River, such as Mulberry (Plate 1) and Jamestown (Hog Island 7.5-minute quadrangle) islands, constitute the Mulberry Island trough and ridge area as named by Johnson (1972). The ridges are short, straight to arcuate, and are usually subparallel to the course of the river. The ridges rise 2 to 10 feet (1 to 3 m) above the adjoining marshes and are covered by mixed deciduous and conifer forests. Beach development is usually limited along the coastline. The areas are commonly flooded during storm-induced high tides. The sediments forming the ridges are assigned to the Poquoson Member of the Tabb Formation. Although they bear similarities to the ridges of the Plumtree Island trough and ridge area and are believed to be the same age, the ridges of the Mulberry Island trough and ridge area were deposited as fluvial-estuarine sediments rather than through the activities of coastal processes.

STRUCTURE

The area investigated lies along the southeastern margin of the Chesapeake-Delaware embayment (Murray, 1961). The "basement" surface upon which late Mesozoic rocks have a regional easterly dip seaward at 40 to 50 feet per mile (8 to 10 m/km) in the study area (Teifke, 1973a) is penetrated at about 2,100 feet (640 m) at NASA-Langley and at 2,243 feet

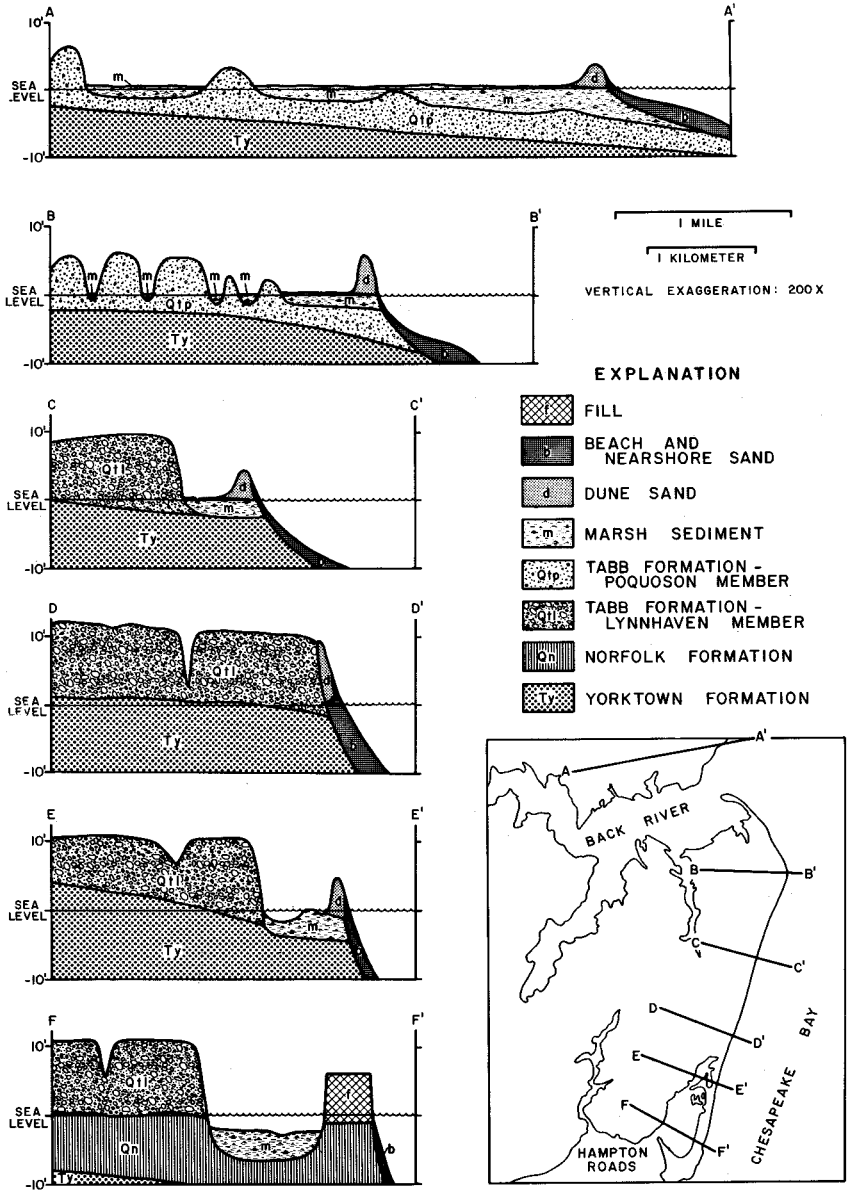


Figure 4. Schematic sections of the beach-marsh-mainland along the west side of Chesapeake Bay in the Hampton quadrangle.

(684 m) at Fort Monroe (Cederstrom, 1945). Based on magnetic and gravity surveys (Costain and Robinson, 1972), considerable topographic and structural relief may be present on the "basement" surface. A linear "basement" ridge, the Fort Monroe high, trends east-west across the southern part of the map area. The dip of the Cretaceous and younger sedimentary units decrease upward reflecting an increasingly stable tectonic condition during Cenozoic time. Dips measured in the Yorktown Formation vary from less than 1.0 foot per mile (0.2 m/km) to 55 feet per mile (10 m/km), with an average of approximately 5 feet per mile (2 m/km). Faulting has been postulated by Cederstrom (1945) and Spencer and Rogers (1969) to account for the variation in water quality, sedimentary pattern, and other subsurface anomalies. However, this issue has not been satisfactorily resolved for lack of adequate data. Structural deformation is observed along the south bank of the James River in the Mogarts Beach-Burwells Bay area. Beds in the silty-sand and shelly-sand facies of the Yorktown Formation form a shallow synclinal structure of which the east limb is exposed at Mogarts Beach. Stephenson, Cooke, and Mansfield (1933) observed this phenomenon and speculated that it was caused by tectonic warping. Johnson (1972) presents evidence from the Yorktown and Chuckatuck areas that the deformation was due to differential compaction of beds in response to the growth of a major bar complex during later Yorktown time. Although Oaks (1965) has suggested that tilting occurred in the area during the late Pleistocene time, the lack of tilted fluvial-estuarine and coastal terraces tends to diminish this possibility. Recent geodetic leveling on the Atlantic Coastal Plain indicates that differential movement is probably taking place in the Chesapeake Bay area but that long-range trends are unknown.

STRATIGRAPHY

The known sedimentary sequence in the Mulberry Island, Newport News North, and Hampton quadrangles consists of sediments ranging in age from Early Cretaceous to Holocene. Teifke (1973a) presents an excellent discussion of the subsurface stratigraphy and paleogeology of the Cretaceous through Miocene sediments in the Coastal Plain of Virginia. Only sediments of Pliocene through Holocene age crop out in the present study area (Table 2). Exposures of the Yorktown Formation

of Pliocene age (personal communication, Hazel, J. E.) are confined to man-made excavations on the York-James Peninsula but the formation crops out in the bluffs along the James River in Isle of Wight County. The Yorktown exposures on the peninsula are not shown on the geologic maps (Plates 1, 2, 3) because they are of limited areal extent such as at the bottom of drainage ditches. The Windsor Formation, restricted to a small area west of Tormentor Creek (Plate 1), unconformably overlies the Yorktown. Sediments of the Norfolk, Sand Bridge, and Tabb formations, all of late Pleistocene age, overlie the Yorktown Formation on the lower York-James Peninsula or in nearby Southside Virginia. Holocene deposits occur in Chesapeake Bay and along the James and Back rivers and their tributaries.

PLIOCENE SERIES

Yorktown Formation

Clark and Miller (1906) named the Yorktown Formation for the deposits of biofragmental and fossiliferous sands exposed in

Table 2.—Geologic formations in the Mulberry Island, Newport News North, and Hampton quadrangles.

Age	Name		Character	Thickness in feet (m)
Holocene	Alluvium		Fluvial and fluvial-estuarine sand, silt, and clay, locally organic-rich and gravelly.	0-125 (0-38)
	Marsh sediment		Organic-rich clay, silt, and sand; peat.	0-12 (0-4)
	Sand		Beach and dune sand.	0-10 (0-3)
Pleistocene	Tabb Formation	Poquoson Member	Beach and nearshore marine and fluvial estuarine fine to medium sand and sandy clay; basal gravelly sand.	0-9 (0-3)
		Lynnhaven Member	Nearshore marine clayey sand, sandy clay and gravel, beach sand, and cobbly gravel.	0-9 (0-3)
		Sedgefield Member	Brackish-bay sand and nearshore marine clayey sand; lagoonal marsh clay and clayey sand; basal fossiliferous gravelly and clayey sand.	0-11 (0-3)

Age	Name			Character	Thickness in feet (m)
Pleistocene	Sand Bridge Formation	Upper Member	Silty-sand facies	Fluvial and lagoonal silty sand.	0-8 (0-2)
			Clayey-sand facies	Fluvial-estuarine and nearshore marine clayey sand; silt.	0-25 (0-8)
			Silty-clay facies	Marsh and tidal-flat silty clay; tidal channel clayey sand.	0-7 (0-2)
	Norfolk Formation	Upper Member	Silty-sand facies	Brackish marine clayey medium sand, fine sandy silt, and clayey silt.	0-15 (0-5)
			Sand facies	Beach and nearshore marine fine to coarse sand; clayey silt.	0-35 (0-11)
			Clayey-sand facies	Fluvial and estuarine fossiliferous clayey sand, organic-rich clay, silt, and peat.	0-85 (0-26)
	Windsor Formation			Marine and lagoonal fine to coarse sand, silty and clayey sand, and silt.	0-15 (0-5)
Pliocene	Yorktown Formation			Marine sand, silt, and coquina.	0-125 (0-38)

the bluffs of the York River near Yorktown. Subdivision of the formation into faunal zones was accomplished by Mansfield (1943), based on mollusks, and Hazel (1971), based on ostracodes. The lithologic subdivision of Johnson (1972), based upon a combination of texture, composition, and bedding features, is followed in this report. Only two facies, the silty-sand and the coquina, were seen in exposures in this study area. The uppermost portion of the Yorktown Formation has been weathered and deeply eroded (Figures 5A, 5B). Deep valleys with more than 70 feet (21 m) of relief were cut into the Yorktown Formation by the ancestral James River and its tributaries.

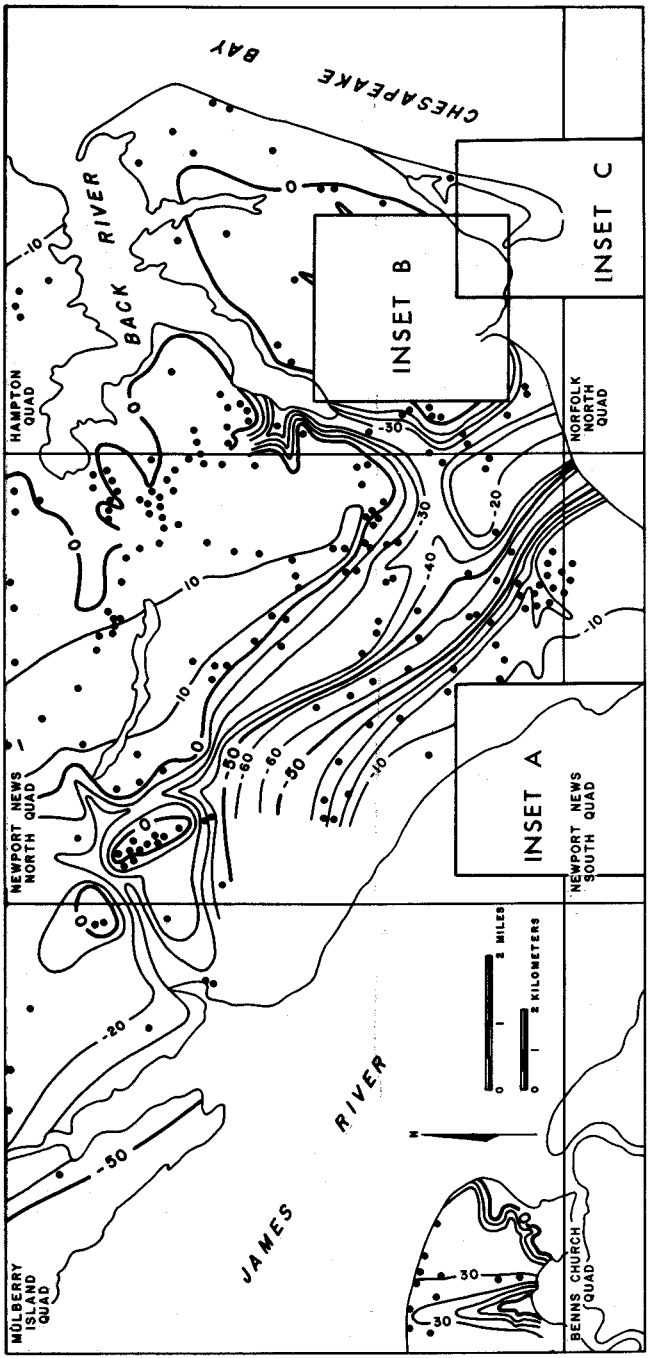


Figure 5A. Paleotopographic map on top of the Yorktown Formation in the Mulberry Island, Newport News North, and Hampton quadrangles and adjacent area to the south.

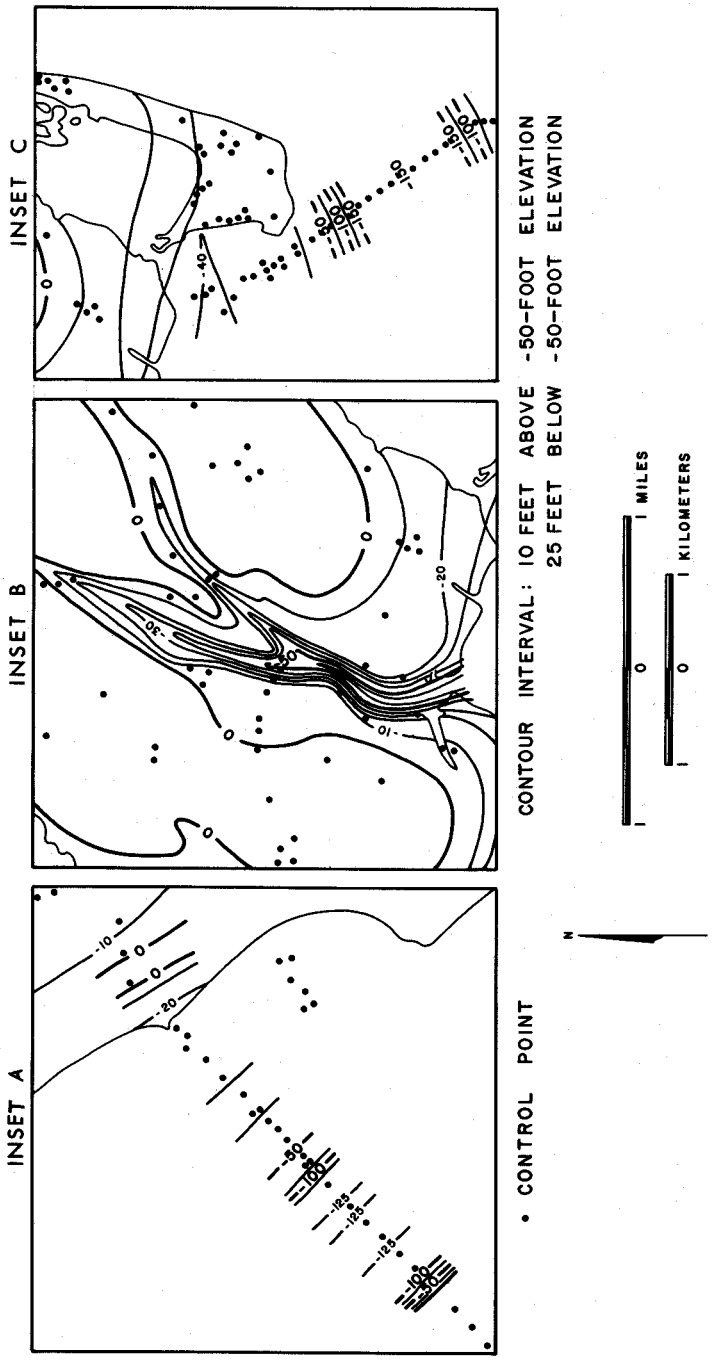


Figure 5B. Detailed maps of parts of Figure 5A.

The Yorktown Formation has been long considered Miocene in age (Lyell, 1845; MacNeil, 1938; Mansfield, 1943; Gibson, 1965; Johnson, 1972). Recent studies based upon foraminiferal and ostracode assemblages (personal communication, J. E. Hazel) suggest strongly that it is Pliocene in age. Deposits of the silty-sand facies at Rice pit (Plate 3, active quarry number 5) are assigned to the *Orianina vaughani* zone (Hazel, 1971) which is now considered to be an early Pliocene biozone. Further support for this conclusion is provided by the advanced evolutionary stage of development of whales recovered from the formation at Dellinger (Plate 2, active quarry number 2) and Rice pits.

Silty-sand facies: This facies has the widest known geographic distribution and greatest known thickness of the various Yorktown facies. It underlies the entire study area and it crops out along the south bank of the James River, in man-made drainage ditches on the Hampton flat, and in several active and abandoned pits on both sides of the river. (Appendix, Section 1). Zone "a" and "b" (Zone 2) of Mansfield (1943) and the clay of Roberts (1932) are in part comparable to this facies. The silty-sand facies grades upward into the coquina facies west of Mogarts Beach (Figure 9). The Yorktown Formation is overlain by the Windsor Formation west of the Suffolk scarp (Plate 1) and by Norfolk, Sand Bridge, Tabb, and Holocene sediments east of the scarp (Plates 2, 3).

Massively bedded, compact, bluish-gray to greenish-gray, fossiliferous, fine sand is the characteristic lithology of the silty-sand facies (Figure 6). Shelly beds up to 2 feet thick and thin, discontinuous pods and lenses of clayey silt occur locally in the facies. Quartz usually constitutes more than 75 percent of the sediment with calcite and clay being lesser components. The clay content decreases in abundance upward in the facies; calcite shows an inverse relationship to the clay. Structures left by sessile or migrant burrowers are prevalent in the finer sands (Figure 7) and many of the living burrows are filled by fine- to medium-grained quartz sand or fragmented shell. Beds with a higher proportion of shell are common within the upper part of the facies. These beds are usually discontinuous and are commonly dominated by one or two species of bivalve (Figure 8). The silty sand weathers to a gray to reddish-brown, clayey sand residue with greater permeability and less bearing strength than the unweathered material.

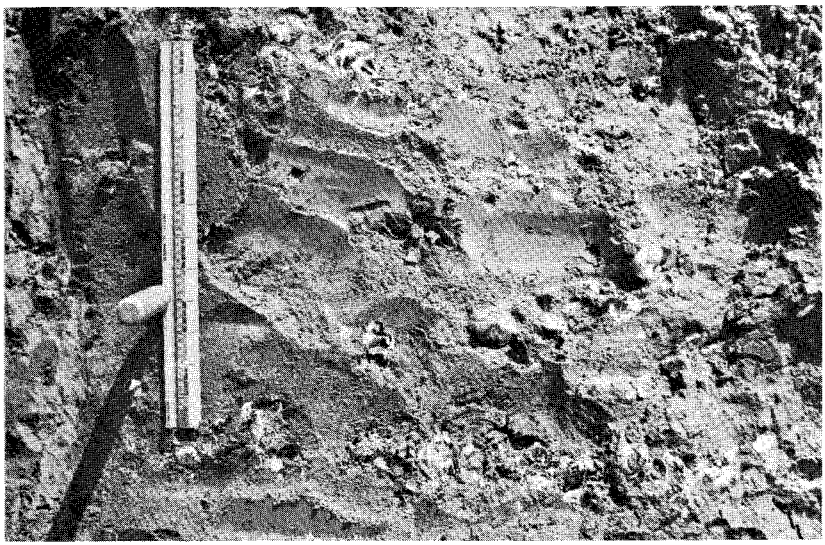


Figure 6. Silty-sand facies of the Yorktown Formation in H. R. Dellinger pit (Plate 2) east of Armistead Avenue about 1.0 mile (1.6 km) south of NASA-Langley. The shells are *Crepidula fornicata* encrusted with barnacles and bryozoans; little evidence of burrowing activity is present. (Scale is 1.0 foot or 0.3 m.)

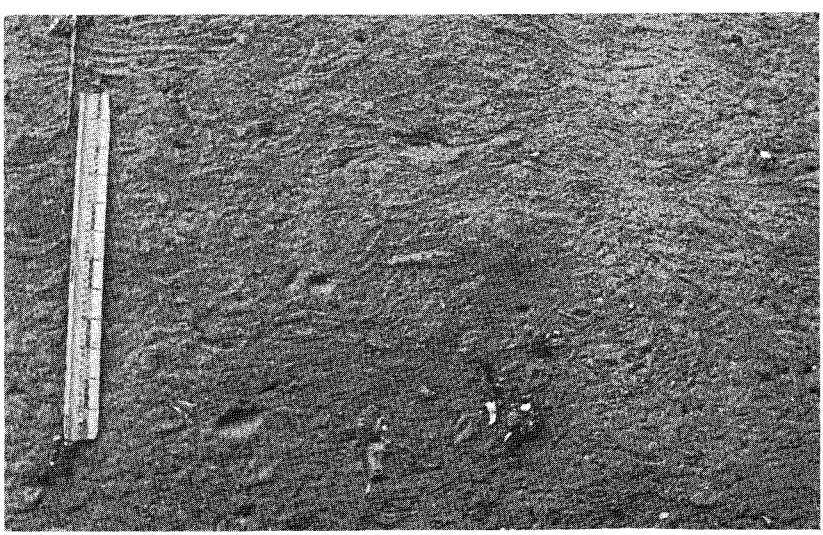
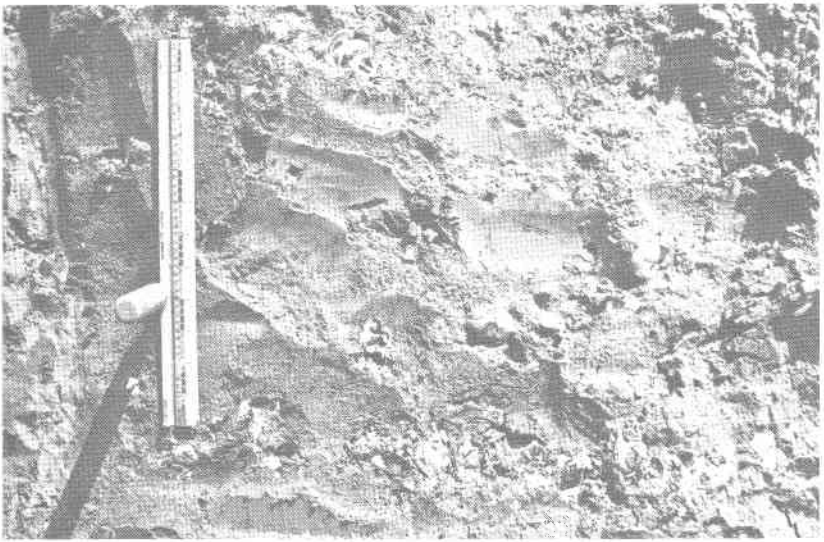


Figure 7. Silty-sand facies of the Yorktown Formation 1.25 miles (2.01 km) west of Mogarts Beach showing bioturbation. Burrows and randomly oriented articulated bivalves are common in this facies. (Scale is 1.0 foot or 0.3 m.)



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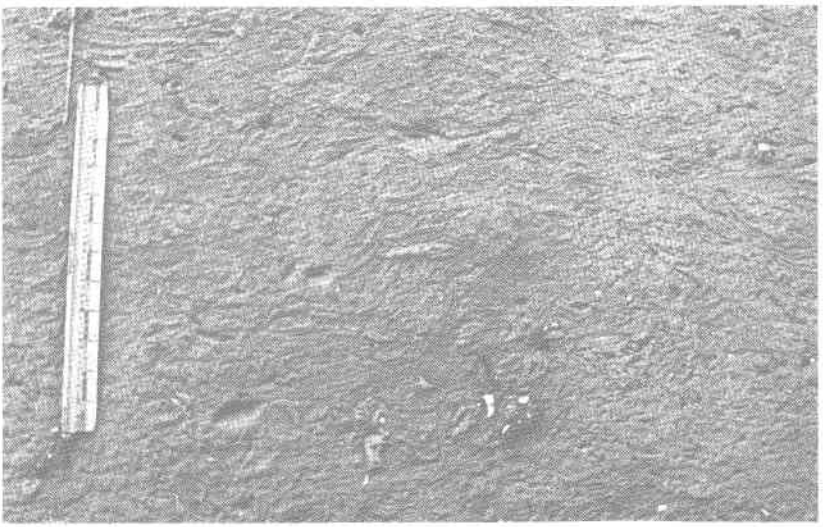

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Figure 8. Shelly beds within the silty-sand facies of the Yorktown Formation 1.25 miles (2.01 km) west of Morgarts Beach. (Scale is 1.0 foot or 0.3 m.)

The silty-sand facies contains a macrofauna dominated by mollusks; associated invertebrate groups include a diverse foraminiferal and ostracode assemblage, bryozoans, worms, barnacles, hydrozoans, echinoids, corals, and sponges. Fish and shark remains are found throughout the facies. Many localities have yielded whale remains, but large, relatively complete skeletons of *Balaena* and *Balanoptera* have been recovered only from Rice and Dellinger pits, respectively. Isolated sperm whale and porpoise remains have been found from scattered localities in this facies. Diatoms, pollen, and other plant microfossils are prevalent in this facies.

The macrofossil assemblage, containing over 400 species, is well preserved. Shells of varying strength and ornamentation show little sign of abrasion; but breakage of shells caused by compaction is common. Many colonies of *Crepidula fornicata* and *Ostrea* and individual specimens of the larger bivalves, such as *Panopea,* are found in an undisturbed state. *Dosinia, Nucula* and *Yoldia* are found intact but oriented randomly in the sediment. Large colonies of *Septastrea* occur up to 9 feet (3 m) long. *Crepidula fornicata* and attached *Balanus* and

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cheilstomatous bryozoans form thin beds or biostromes in the silty-sand facies. Thinner shelled, burrowing species are most common in the lower part of the facies but become less conspicuous in the upper part where a diverse mixed infaunal and vagrant benthonic assemblage dominates.

The silty-sand facies was deposited on the continental shelf in warm waters about 75 to 150 feet (23 to 46 m) deep. The

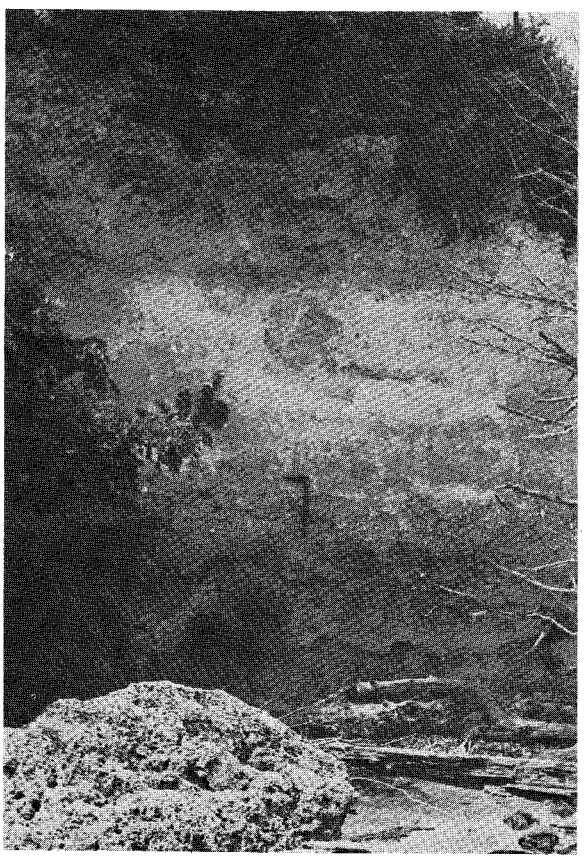

Figure 9. Silty-sand facies of the Yorktown Formation with shelly bed overlain by the coquinite of the coquina facies in bluffs of James River 1.25 miles (2.01 km) west of Morgarts Beach. A shelly bed occurs at horizon of shovel. Blocks of the coquinite form natural riprap along the shore. (Shovel is 1.75 feet or 0.53 m.)

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bottom was swept by gentle waves or currents and the bottom waters were well oxygenated and supplied with nutrients.

Coquina facies: The coquina facies crops out in the upper part of the bluff west of Mogarts Beach (Plate 1, Figure 9), where it projects from the cliff. Comparable beds occur in the Bacons Castle and Hog Island quadrangles (Figure 2); erosion of the upper part of the Yorktown east of the Suffolk scrap has removed all but about 6 feet (2 m) of the sediments of this facies. The coquina facies overlies the silty-sand facies with a gradational contact.

The facies is composed of whole and broken shell with a matrix of biofragmental sand and small quantities of quartz, clay, and glauconite. Shell fragments show signs of extensive abrasion. The beds of coquina in the Mogarts Beach area are commonly indurated; the low calcite-magnesium cement was deposited by ground water. Leaching of shell material has been selective and sporadic. Molds of *Chama congregata, Mercenaria,* and smaller bivalves are common in the middle and upper part of the facies; *Ostrea,* various pectens, and echinoids from the same bed are preserved without apparent morphologic alteration. An aggregate of randomly oriented heart urchins (Kier, 1972) came from the coquina facies.

The physical condition and orientation of the shells, the species composition and diversity of the fossils, and the textural characteristics of the sediments indicate that the coquina facies formed in shallower water than the underlying silty-sand facies. Wave and current activities were much stronger.

PLEISTOCENE SERIES

Windsor Formation

The Windsor Formation is the surficial deposit in a narrow belt west of Lake Tormentor (Plate 1). The Surry and Suffolk scarps constitute the western and eastern boundaries of the formation, respectively. In the Mulberry Island area sediments of the Windsor lie about 1.25 miles (2.01 km) west of the Suffolk scarp. In the study area, the maximum thickness of the formation is about 35 feet (11 m) (Coch, 1968); the elevation of the upper surface of the formation is about 70 feet (21 m).

The Windsor Formation is composed of silty and clayey sand that varies in color from light gray to reddish brown.

Oaks and Coch (1973) describe weathering characteristics and mineralogic properties of the formation. A cobble zone commonly occurs at the base of the formation. With the exception of burrows, no fossils are known from the Windsor and sedimentary structures other than planar bedding and small scale cross-bedding are lacking. Although Oaks and Coch (1973) and Johnson (1972) reported that the Windsor becomes increasingly more sandy to the east, this could not be ascertained in the study area.

The fine-grained, relatively featureless nature of the Windsor and its relatively flat upper surface suggests that the formation was deposited in a lagoon. The barrier of this lagoon presumably lay to the east of the Suffolk scarp and was subsequently eroded away (Coch, 1968). No definitely dateable fossils have been found in the Windsor; therefore it is assigned a middle Pleistocene age based upon its stratigraphic position and weathering profile.

Norfolk Formation

Clark and Miller (1906) named the Norfolk Formation from the beds and spoil along the Dismal Swamp Canal. Coch (1968) and Oaks (1965) subdivided the Norfolk Formation into eight facies, of which the clayey-sand, sand, and silty-sand facies crop out in the study area. The Norfolk Formation is the surficial formation on the Huntington flat and lies beneath a thin cover of younger sediments in both the southeastern part of the York-James Peninsula and on the Churchland flat. The formation is lithologically complex because it was deposited under fluvial-estuarine and nearshore marine conditions. Norfolk sediments rest unconformably upon Windsor clayey sands along the Kingsmill and Suffolk scarps and on Yorktown sediments in the channel of the ancestral James River. Sediments believed to be part of the Norfolk by Johnson (1972) are reassigned to the Tabb Formation in this report (Table 3).

Clayey-sand facies: The clayey-sand facies is the surficial deposit over the northwestern part of the Huntington flat (Plate 2). The deposits of this facies range in thickness from a feather edge against the Kingsmill scarp to over 85 feet (26 m) thick in the Oyster Point section of Newport News. These sediments fill a pre-Norfolk valley system (Figure 5). Along the Big Bethel and Harpersville scarps the upper part of the clayey-sand facies has been removed by erosion. The

Table 3.—Correlation of late Quaternary stratigraphic units shown on geologic maps of this report with those mapped on adjacent quadrangles (see Figure 2).

Coch (1968)	Coch (1971)	Johnson (1972)	This report
Holocene Series	Holocene Series	Holocene Series	Holocene Series
Alluvium	Alluvium	Alluvium	Alluvium
		Marsh sediment	Marsh sediment
		Sand	Sand
	Norfolk Formation	Norfolk Formation	Tabb Formation
	Clayey-sand facies	Silty-sand facies	Poquoson Member
			Lynnhaven Member
		Clayey-sand facies	Sedgefield Member
Sand Bridge Formation	Sand Bridge Formation		Sand Bridge Formation
Silty-sand facies	Silty-sand facies		Silty-sand facies
Clayey-sand facies	Clayey-sand facies		Clayey-sand facies
Silty-clay facies			Silty-clay facies
Norfolk Formation	Norfolk Formation	Norfolk Formation	Norfolk Formation
Silty-sand facies	Silty-sand facies		Silty-sand facies
Sand facies	Sand facies	Sand facies	Sand facies
Clayey-sand facies		Clayey-sand facies	Clayey-sand facies

facies consists of a complex of fluvial-estuarine, flood-plain and paludal sediments (Appendix, Section 2). Excellent exposures showing the complex interrelationship between the facies is found in the Williams and Cumming pits (Plate 2, active quarry numbers 2, 4).

The clayey-sand facies is composed of a discontinuous basal bouldery and cobbly sand (Figure 10) that is overlain by well-sorted, cross-bedded quartz channel sand with scattered cobbles. The cobbles and boulders from the basal part of the facies include epidotized and chloritized schist, quartzose gneiss, massive vein quartz, scolithid quartz sandstone, ferruginous sandstone, and other miscellaneous Paleozoic sedimentary rock clasts. Larger boulders, up to 38 inches (97 cm) in diameter, range from highly angular to very well rounded. The channel sands are cross-bedded with cross-bedding having a dip predominantly toward the east and southeast. The cross-beds are accentuated by heavy mineral concentrates and occur in

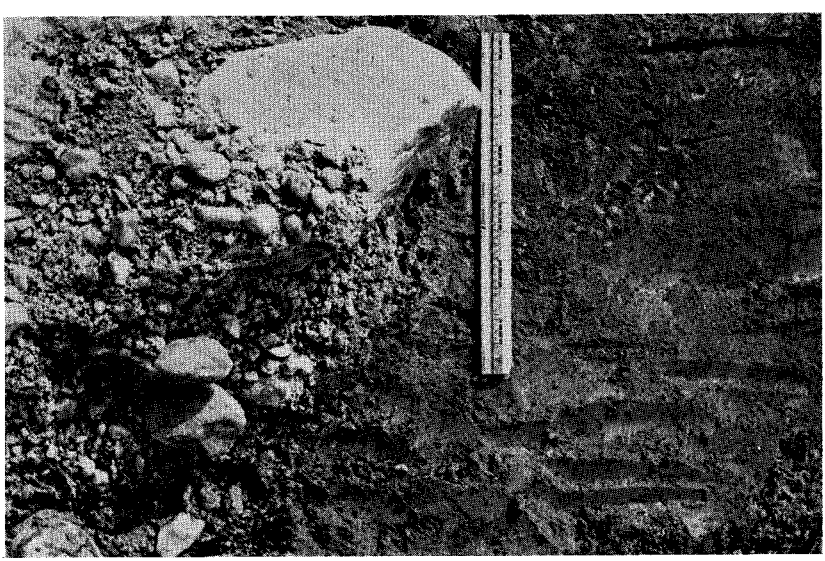

Figure 10. Bouldery gravel of the clayey-sand facies of the Norfolk Formation unconformably overlying the silty-sand facies of the Yorktown Formation in the J. S. D. Cumming pit (Plate 2) 0.6 mile (1.0 km) west of intersection of Interstate Highway 64 and Mercury Boulevard (vertical view). Boulders on the contact have a maximum diameter of 26 inches (66 cm). (Scale is 1.0 foot or 0.3 m.)

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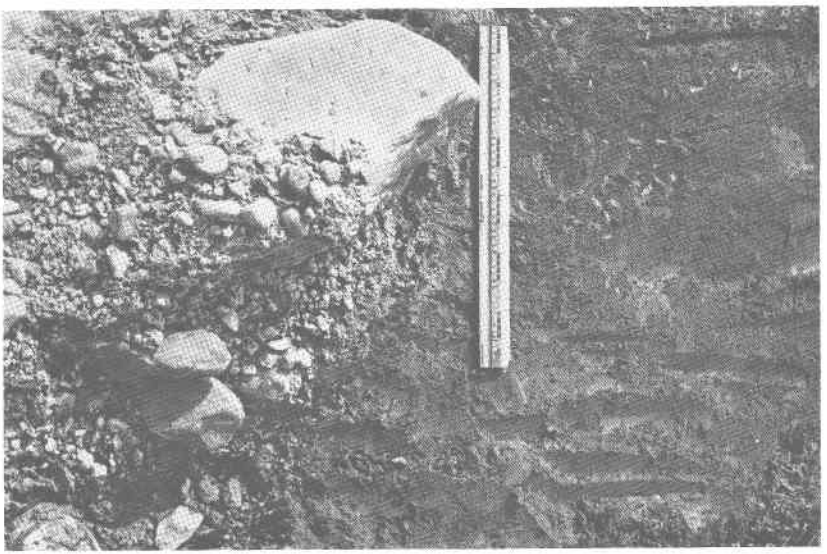

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sets 0.3 to 4.0 feet (0.1 to 1.2 m) thick. The quartz grains are well sorted and angular to subrounded and associated cobbles range in shape from spherical to discoid. Clay blebs and armored mudballs are found locally in these sediments. In places fine quartz sand occurs as laminae or thin beds between layers of plant debris (Figure 11) or as disseminated clasts in a mass of mascerated plant remains. In addition the cross-bedded sands contain abundant narrow pencil-like (Figure

Figure 11. Interbedded sand and black peaty material in the clayey-sand facies of the Norfolk Formation in Williams Paving Co. pit (Plate 2) 0.9 mile (1.4 km) northwest of Interstate Highway 64 and State Road 600. (Scale is 1.0 foot or 0.3 m.)

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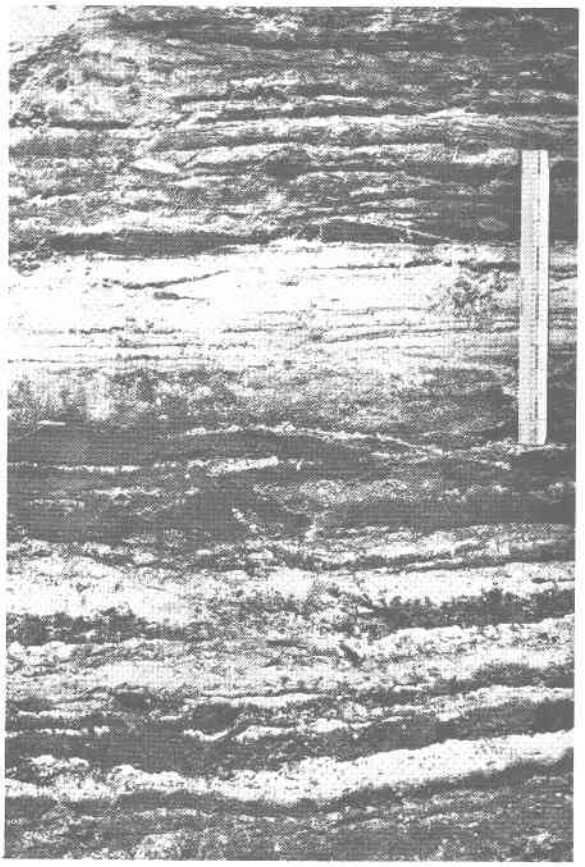

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12) and *Ophiomorpha* burrows. Locally, ferruginous siliceous nodules containing molds of brackish-water bivalves and Yorktown fossils occur near the top of the sequence.

Massive, light to dark, plastic clay bodies occur sporadically in the clayey-sand facies (Figure 13). Disseminated organic matter imparts a darker color to some of the clay. Indistinct bedding is observable on weathered slopes but is not readily apparent on fresh cuts. The clay bodies exhibit gradational

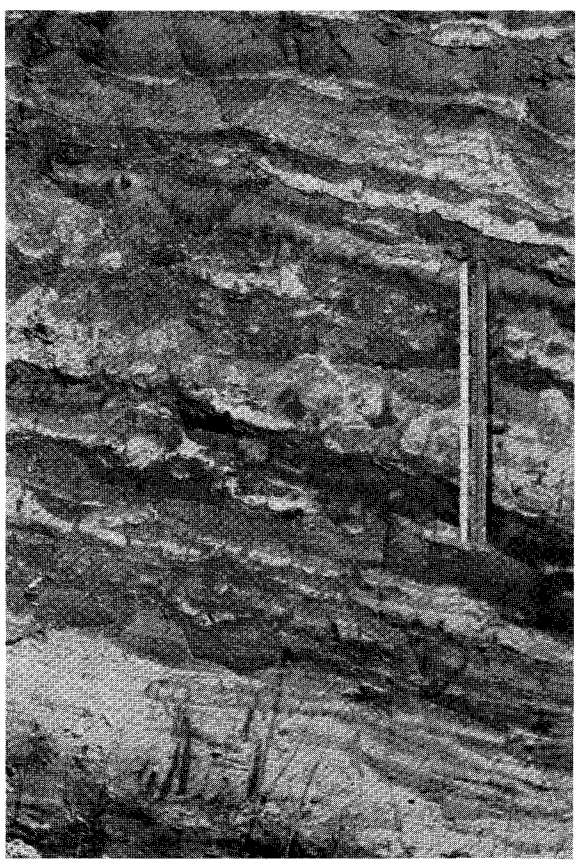

Figure 12. Burrowed cross-bedded fine sand and silt and medium sand of the clayey-sand facies of the Norfolk Formation in Williams Paving Co. pit (Plate 2) 0.9 mile (1.4 km) northwest of Interstate Highway 64 and State Road 600. (Scale is 1.0 foot or 0.3 m.)

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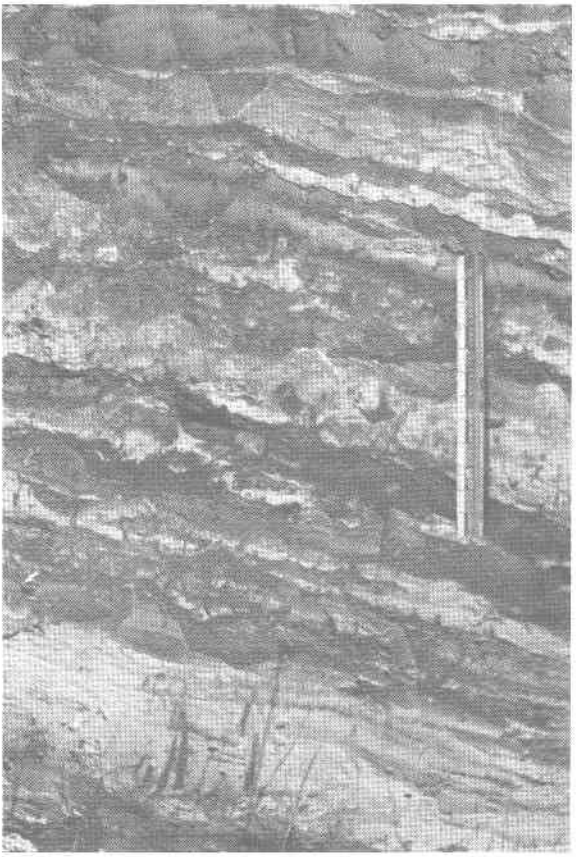

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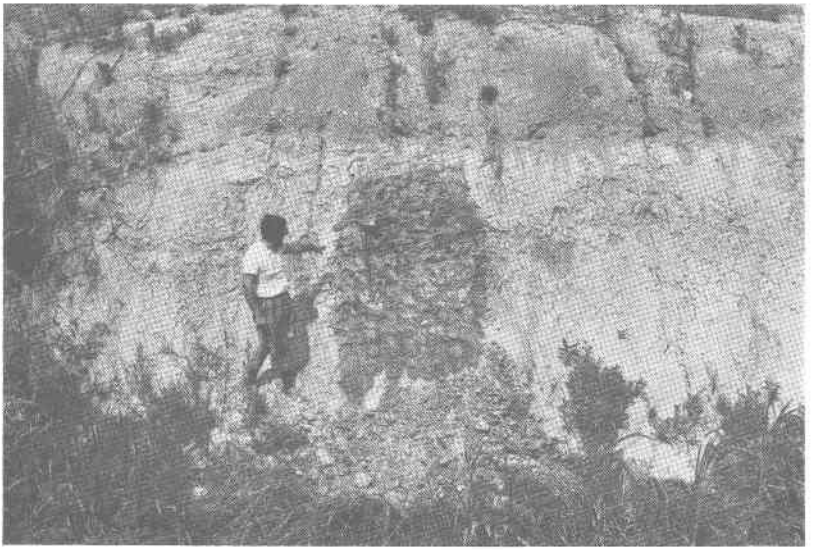
Figure 13. Massive clay beds of the clayey-sand facies of the Norfolk Formation overlain by the Sedgefield Member of the Tabb Formation in Williams Paving Co. pit (Plate 2) 0.9 mile (1.4 km) northwest of Interstate Highway 64 and State Road 600. The clay weathers to light gray and forms a blocky surface structure. The dark-gray band is rich in organic material. The unconformity is marked by a cobbly and pebbly sand and is above a light zone near top of this section.

and sharp lateral and vertical contacts with other lithologies in the clayey-sand facies. Commonly the clay bodies rest on a gray, gravelly, clayey sand that contains plant roots, stumps, and branches. Weathering of the clay produces a light-gray blocky surface.

Channel and flood-plain sediments of the clayey-sand facies grade into or truncate organic-rich silt, clay, and peat bodies (Figure 14). The organic deposits occur as lenses, thin sheets, and as irregular masses within sequences of sand and clay. The organic sediments are dark brown to black on fresh surfaces but develop a whitish coating and blocky structure when exposed to the atmosphere. Minute selenite crystals are abundant in these sediments. The peat and organic-rich clay, which are more than 8 feet (2 m) thick locally, are composed of mascerated and whole leaves, twigs, branches and bark, and contain tree stumps more than 7 feet (2 m) in diameter



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and sharp lateral and vertical contacts with other lithologies in the clayey-sand facies. Commonly the clay bodies rest on a gray, gravelly, clayey sand that contains plant roots, stumps, and branches. Weathering of the clay produces a light-gray blocky surface.

Channel and flood-plain sediments of the clayey-sand facies grade into or truncate organic-rich silt, clay, and peat bodies (Figure 14). The organic deposits occur as lenses, thin sheets, and as irregular masses within sequences of sand and clay. The organic sediments are dark brown to black on fresh surfaces but develop a whitish coating and blocky structure when exposed to the atmosphere. Minute selenite crystals are abundant in these sediments. The peat and organic-rich clay, which are more than 8 feet (2 m) thick locally, are composed of mascerated and whole leaves, twigs, branches and bark, and contain tree stumps more than 7 feet (2 m) in diameter

(Figure 15). More than 100 *in situ* tree stumps have been located in the upper part of this facies in Williams pit (Plate 2, active quarry number 2). Nuts, seeds, and other identifiable plant remains from hickory, oak, cypress, walnut, and sweet gum have been found in the Newport News area. All fossil material collected from the clayey-sand facies of the Norfolk was plant material except for several molds of indigenous brackish-water bivalves and reworked Yorktown mollusks and shark teeth. The organic-rich silt and clay, and peat, were mapped locally as a separate facies in the subsurface by Johnson (1972); the complex relationship between these deposits and the clayey-sand facies in the present study areas precludes mapping them separately.

The organic deposits accumulated in swamp, marsh, and flood-plain environments. The complex vertical and areal

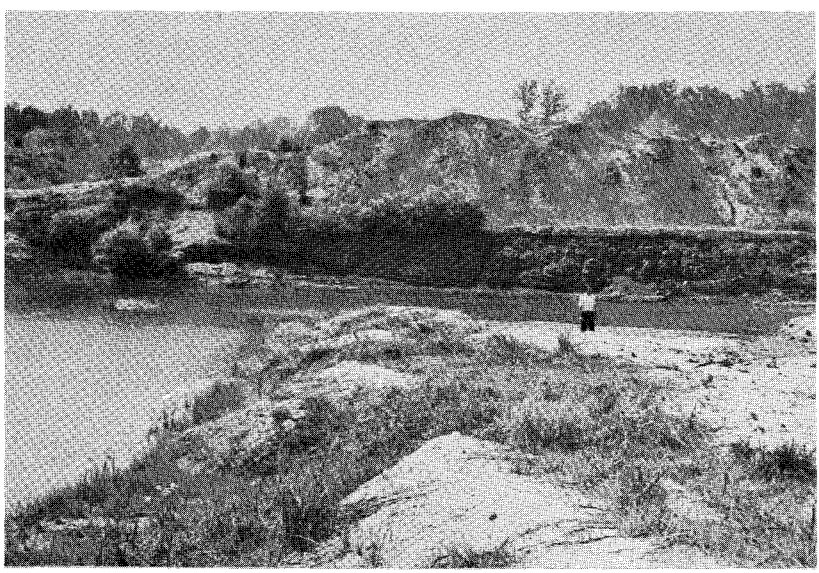

Figure 14. Lensoid-shaped peat body overlain by a channel sand of the clayey-sand facies of the Norfolk Formation in Williams Paving Co. pit (Plate 2) 0.9 mile (1.4 km) northwest of Interstate Highway 64 and State Road 600. A macrofossil assemblage of nuts, seeds, and macerated leaves were retrieved from the sand immediately below the peat. The upper surface of the peat was eroded and the Sedgefield Member of the Tabb Formation rests unconformably upon the peat and channel sand.

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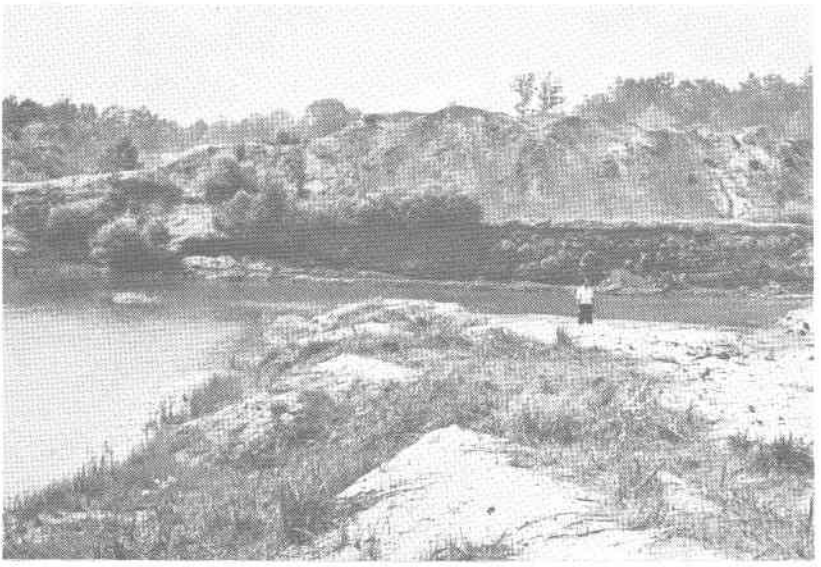

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distribution of sediments in the clayey-sand facies, its fossil assemblage, and the morphology of the sediment body indicate that the deposits of this facies were laid down under fluvial-estuarine conditions during the rise of sea level in Norfolk time.

Sand facies: The sand facies of the Norfolk Formation is coextensive with the Huntington flat in the lower part of Newport News (Plate 2) and also is exposed south of the James River in the area of Lake Tormentor. An excellent section of the facies in the study area is exposed in the bank of the James River at 70th Street in lower Newport News (Appendix, Section 3). The lower part of the section consists of interbedded fossiliferous, bluish-gray, clayey sand and clay. These beds contain fragments of *Spartina* and scattered branches and logs of trees up to 7 inches (18 cm) in diameter. Similar sediments have been reported from the Hampton flat (Coch, 1971) and were encountered in subsurface borings to the northwest. Presumably these sediments intertongue with the fluvial-estuarine deposits of the clayey-sand facies of the

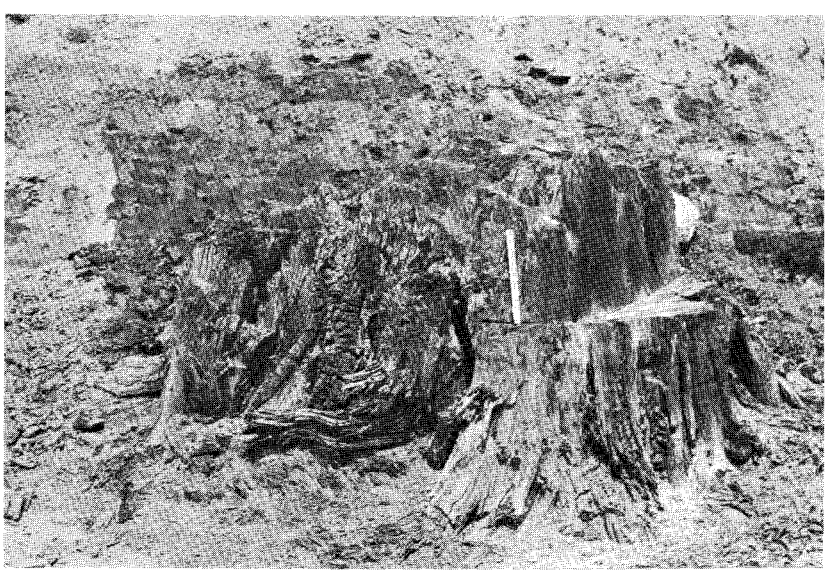

Figure 15. Fossil tree stump in the clayey-sand facies of the Norfolk Formation in Williams Paving Co. pit (Plate 2) 0.9 mile (1.4 km) northwest of Interstate Highway 64 and State Road 600. Tree has over 300 growth rings. (Scale is 1.0 foot or 0.3 m.)

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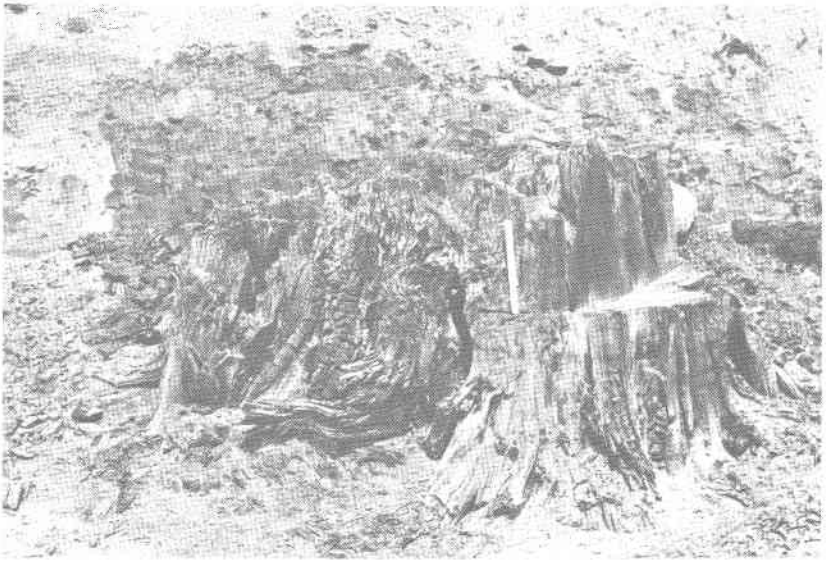

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Norfolk Formation. The upper 27 feet (8 m) of the exposure is composed of bedded, light-gray, tan, and reddish-brown, medium- to fine-grained quartz sands. Gravel is scattered through the section and cross-bedding in the finer sands has a dip to the southeast. No invertebrate fossils were observed except for small burrows and possibly yellowish-brown ghosts of bivalves in the planar and cross-bedded sand. These sediments become finer westward, becoming mostly silty sand and silts in the vicinity of the James River Bridge, and intertongue with the clayey-sand facies northwest of Mercury Boulevard (Plate 2).

The sand facies of the Norfolk Formation was deposited on a topographically high area underlain by the silty-sand facies of the Yorktown Formation. The linear high, approximately coextensive with the finger-like southeastern projection of the Huntington flat, lies between the deep valley of the ancestral James or one of its tributaries and the present James River. Although the sand facies is areally restricted, its sedimentary characteristics, morphology, and stratigraphic relationship indicate that it is contemporaneous with the clayey-sand facies and the Norfolk deposits along the Suffolk scarp and that it was deposited under shallow nearshore marine conditions.

Silty-sand facies: The silty-sand facies of the Norfolk Formation is exposed only in a small area south of the James River on Goodwin Point (Plate 1). It consists of brackish-marine, clayey medium sand, fine sandy silt, and clayey sand.

Sand Bridge Formation

The Sand Bridge Formation is the surficial stratigraphic unit on the Churchland flat in the Mulberry Island quadrangle. It was named by Oaks and Coch (1963) and the upper member was subdivided into four facies. Three of these were mapped in the Mulberry Island quadrangle, the silty-clay facies between the Suffolk scarp and Days Point, and the clayey-sand and silty-sand facies on Goodwin Point (Plate 1). Because of problems of correlation of the sediments of the Sand Bridge Formation with deposits on the York-James Peninsula, the useage of the Sand Bridge Formation will be restricted to sediments south of the James River. Beds assigned to the Sand Bridge by Oaks and Coch (1973) may be temporally

equivalent to the Lynnhaven and, possibly, the Sedgefield members of the Tabb Formation.

Deposits of the silty-clay facies of the Sand Bridge Formation in the Mogarts Beach area are light- to medium-gray, blocky, silty clay with yellowish- and reddish-brown mottling and streaks. Except for a slight increase in sand and scattered cobbles at the base, this facies exhibits no stratification. In this area the differentiation of the weathered silty-sand facies of the Yorktown and the silty-clay facies of the Sand Bridge is difficult in auger holes unless the cobble zone is encountered. The facies ranges in thickness from less than 2 feet (1 m) near the bluff at Mogarts Beach to over 5 feet (2 m) thick 0.5 mile (0.8 km) south. The facies is nonfossiliferous, and its surface ranges between 30 and 32 feet (9 and 10 m) elevation.

The silty-sand facies on Goodwin Point is composed of friable to loose, tan to yellowish-brown, silty, fine to medium quartz sand. The sediments as mapped appear conformable with the underlying Norfolk Formation, varying only slightly in texture and state of oxidation. Stratification is lacking in the upper part but is thin to medium bedded in the lower part. The elevation of the undissected upper surface of the facies is approximately 26 feet (8 m) and the facies is about 8 feet (2 m) thick in this area.

The clayey-sand facies is exposed only on Goodwin Point. It consists of fluvial-estuarine and nearshore marine clayey sand with some silt.

The silty-clay facies is believed by Oaks and Coch (1973) to have formed in a tidal flat-marsh environment and the silty-sand facies in a lagoon receiving sediment from the James River.

Tabb Formation

The Tabb Formation, herein named after the village of Tabb in York County (Plate 2), crops out over the Todds and Hampton flats and over the Plumtree Island and Mulberry Island trough and ridge areas. The Tabb Formation is subdivided into three members, each of which is different lithologically. The members in order of decreasing age and surface elevation are the Sedgefield, the Lynnhaven, and the Poquoson. The Lynnhaven and Poquoson members were formerly mapped as the sandy-clay and silty-sand facies of the

Norfolk, respectively (Johnson, 1972) and the Lynnhaven as the clayey-sand facies of the Norfolk (Coch, 1971). The formation rarely exceeds 10 feet (3 m) in thickness and is restricted to the area east of the Suffolk scarp. Fossil mollusks, bryozoans, sponges, and arthropods occur in the Sedgefield Member of the Tabb, but no other indigenous fossils have been recovered. Its age is considered late Pleistocene.

Sedgefield Member: The Sedgefield Member, herein named after the settlement of Sedgefield (Plate 2) in Newport News, is areally coextensive with the Todds flat. The type section is in the northern part of the Williams Paving Company pit (Plate 2, active quarry number 2; Appendix, Section 2). The basal unit of the member is a fossiliferous gray, cobbly, clayey, medium to coarse sand, 4 to 19 inches (10 to 48 cm) thick (Figure 16). The cobbles are well rounded and represent rock types derived from the Piedmont, Blue Ridge, and Valley and Ridge. Cobbles include Antietam quartzite, Clinton sandstone, massive milky quartz, epidotized and chloritized schist and gneiss, iron-cemented burrow segments, and lesser lithologies. Most of the cobbles have been reworked out of older deposits such as the clayey sand of the Norfolk Formation. The sand is usually a moderately well-rounded, coarse to pebbly sediment with a bluish-gray clay which fills the interstices between the shells, cobbles, and sand. The dominating fossils are *Crassostrea virginica* and *Mercenaria mercenaria,* but *Noetia ponderosa, Urolsalpinx cinera,* crabs, and various cheilostomatous bryozoans are also present (Figure 17). In places the *Crassostrea* are in living position but in others the shells have been disarticulated and ground into a biofragmental sand. Where the fossiliferous bed rests on organic-rich silts or peats, the shells have usually been leached. Burrowing organisms living during the time of deposition of the Sedgefield Member burrowed into the underlying sediments (Figure 18). Burrows in the underlying Norfolk Formation are filled with sand of the Sedgefield Member.

The middle part of the member consists of fine to medium, tan to yellowish-brown quartz sands with thin discontinuous clay beds. In geographic locations where the formation is well drained, a ferricrete-manganese oxide zone forms at the water table; less well drained areas have a bluish-gray to light yellowish-brown sediment. Medium bedding and cross-bedding are present in the middle of the member. Small-scale faulting,

with clay coatings along the fault plane, are found locally. Large burrows filled by bluish-gray mud occur commonly in the lower part of the sand unit. The uppermost unit in the Sedgefield is a bluish-gray to reddish- or yellowish-brown clay

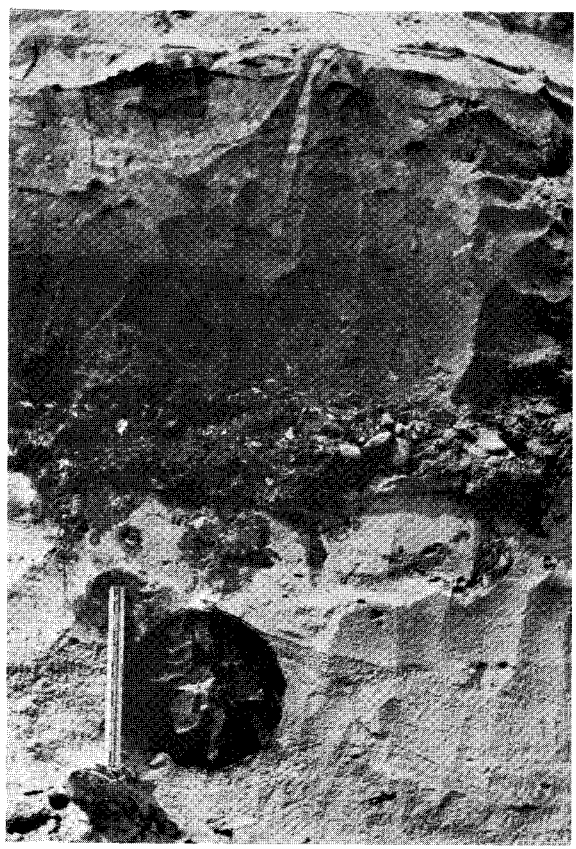

Figure 16. Fossiliferous Sedgefield Member of the Tabb Formation unconformably overlying channel sands of the clayey-sand facies of the Norfolk Formation in Williams Paving Co. pit (Plate 2) 0.9 mile (1.4 km) northwest of Interstate Highway 64 and State Road 600. The channel sands are cross-bedded, have a southeast dip, and contain scattered logs. The *Crassostrea virginica* and *Mercenaria mercenaria* in the lower part of the Sedgefield Member have been partially leached by ground water. (Scale is 1 foot or 0.3 m.)

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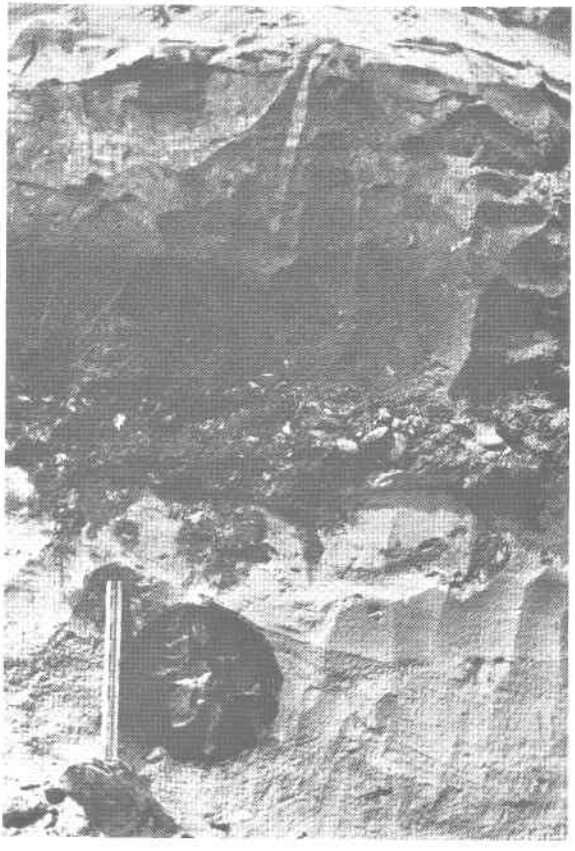

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Figure 17. Oyster bed at the base of the Sedgefield Member of the Tabb Formation overlying the Yorktown Formation in W. N. Krause Company pit (Plate 2) 0.25 mile (0.40 km) south of the junction of State Highway 134 and State Road 600. Many oysters, *Crassostrea virginica,* are in living position in the shelly and gravelly sand. (Scale is 1 foot or 0.3 m.)

or clayey sand that covers the area between the Big Bethel and Harpersville scarps.

The Sedgefield Member rests unconformably on the Yorktown and Norfolk formations and is overlain by the Lynnhaven Member of the Tabb along the Big Bethel scarp. The Sedgefield is 8 to 11 feet (2 to 3 m) thick in the northern part of the study area and thins southward to approximately 4 feet (1 m). The lower part of the member was formed under brackish-bay, the middle part under beach-nearshore marine, and the upper part under lagoonal-marsh conditions.

Lynnhaven Member: The Lynnhaven Member is named for the subdivision of Lynnhaven in the City of Hampton. The type section is exposed along Butler Farm ditch 0.5 mile (0.8 km) west of Magruder Boulevard (State Road 134A) in the City of Hampton (Plate 2; Appendix, Section 4). The member crops out over the Hampton flat and ranges in thick-

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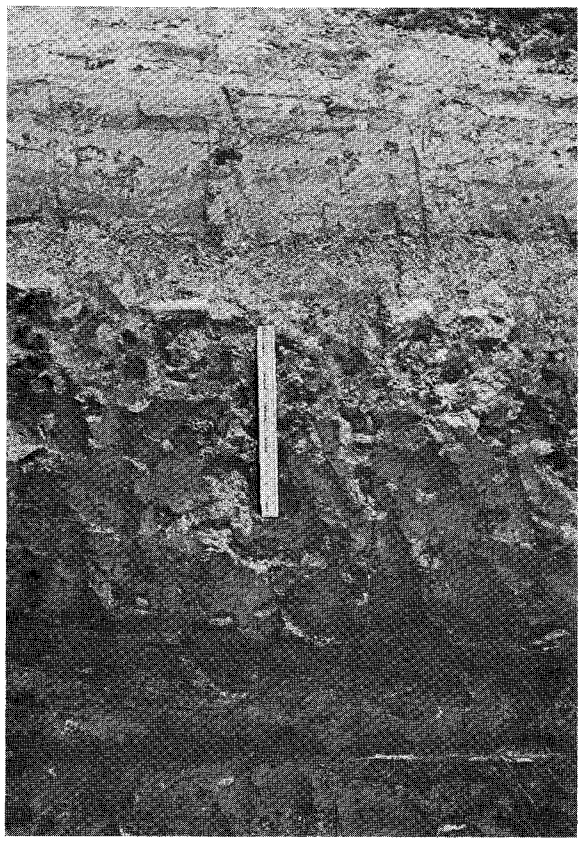

Figure 18. Lower gravelly sand of the Sedgefield Member of the Tabb Formation unconformably overlying burrowed organic-rich silt and peat of the clayey-sand facies of the Norfolk Formation in Williams Paving Co. pit (Plate 2) 0.9 miles (1.4 km) northwest of Interstate Highway 64 and State Road 600. Burrows are infilled by sand from the overlying bed and large cobbles mark the unconformity. (Scale is 1.0 foot or 0.3 m.)

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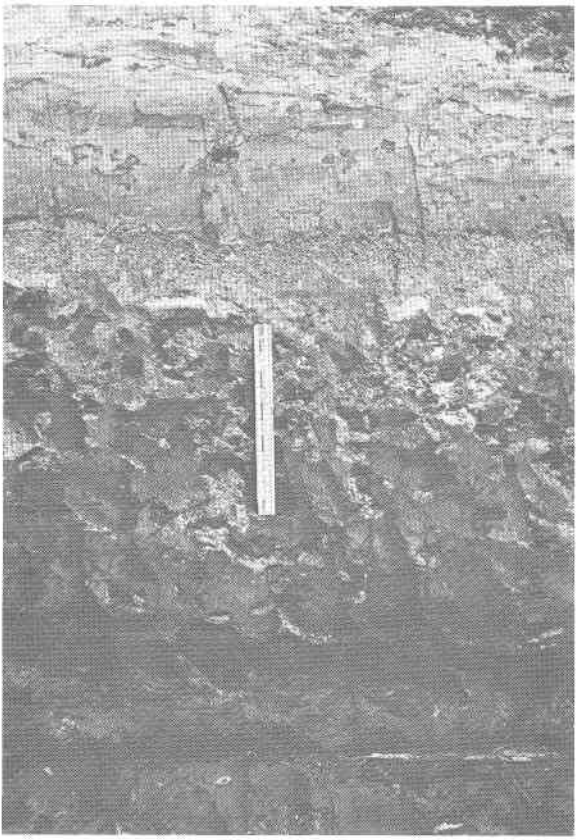

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The Lynnhaven is composed of a basal gravelly sand, and overlying clayey sand or sandy clay (Figure 19). A cobble layer marks the base of the member over much of its extent. The lower part of the member becomes coarser as the Big Bethel scarp is approached. Sediments of the Lynnhaven Member at the toe of the Big Bethel consist of an interbedded sand and cobbly gravel. Larger cobbles were reworked from older formations. A homogeneous bluish-gray sandy clay up to 5 feet (2 m) thick comprises the principal lithology of this member (Figure 20). The Lynnhaven was deposited as beach and nearshore-marine sediments.

Poquoson Member: The Poquoson Member of the Tabb Formation is named after the City of Poquoson. The member

Figure 19. Coarse bouldery and gravelly sand of the Lynnhaven Member of the Tabb Formation unconformably overlying the Yorktown Formation in W. N. Krause Company pit (Plate 2) 0.25 mile (0.40 km) south of the junction of State Highway 134 and State Road 600. Exposure is in the beach sediments at the toe of the Big Bethel scarp.

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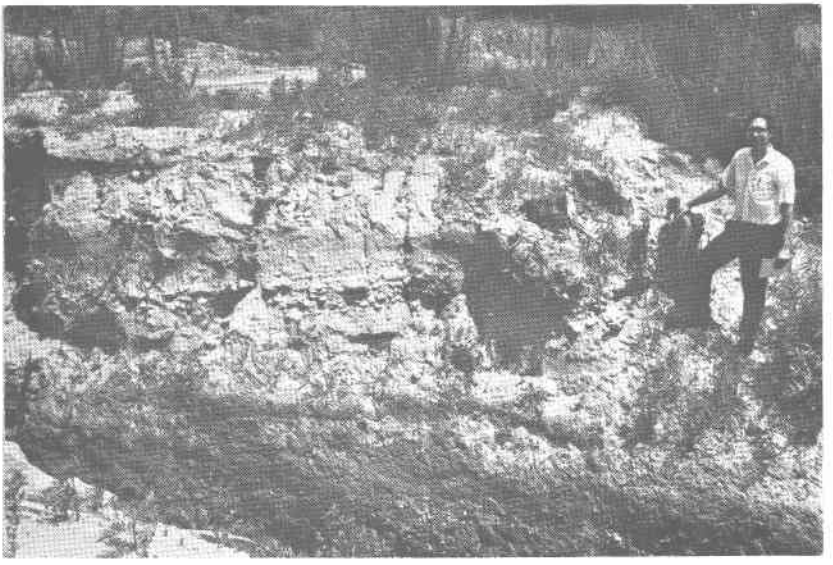

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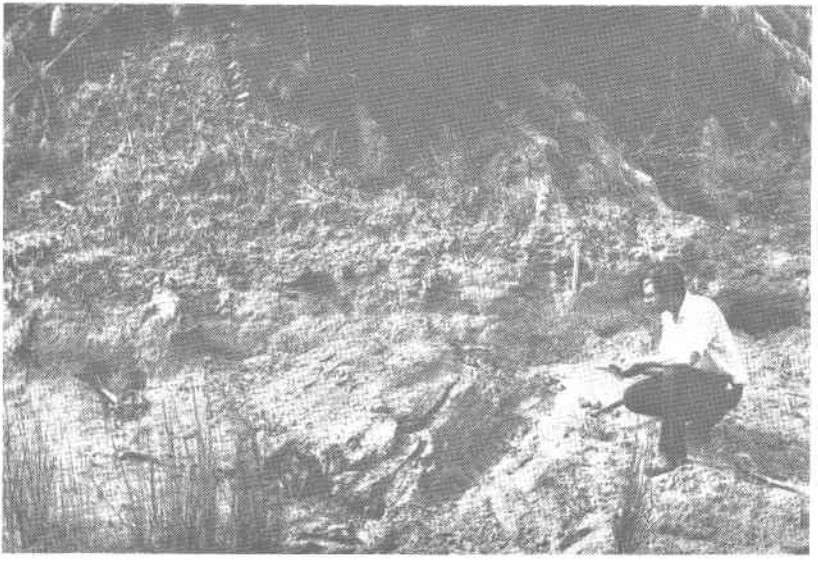
Figure 20. Clayey sand of the Lynnhaven Member of the Tabb Formation overlying the silty-sand facies of the Yorktown Formation in drainage ditch west of the intersection of State Highway 134A and Butler Farm Road. The contact is irregular and is typically marked by a basal cobble or gravelly zone of the Tabb Formation. (Scale is 1.0 foot or 0.3 m.)

crops out on the lower edge of the Hampton flat and in the ridges on Mulberry Island and Plumtree Island. The member is usually less than 9 feet (3 m) thick and rests unconformably on the Yorktown and Norfolk formations and on the Lynnhaven Member of the Tabb. The Poquoson Member was mapped as the silty-sand facies of the Norfolk Formation in the Poquoson West and Poquoson East quadrangles (Johnson, 1972). Relief on the surface of deposition was between 1.0 and 3.0 feet (0.3 and 0.9 m) locally. The type section is located on Poquoson Avenue 0.4 mile (0.6 km) northwest of Amorys Wharf (Plate 3, borehole; Appendix, Section 5).

A nonfossiliferous, medium-gray, silty and clayey sand constitutes the basal sediments of this member nearly everywhere. Gravelly sand and large cobbles and boulders are found locally at the base of the member. The upper part of the sequence is composed of gray to yellowish-brown, medium to



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fine sand with scattered thin gravelly sand lenses. Unfortunately, the sediments underlying the ridges lack distinctive primary structures. The Poquoson Member in the Plumtree Island area was deposited on a series of beaches as sea level fell during the late Sangamon.

In the Mulberry Island area the basal Poquoson Member consists of a gray, gravelly, fine sand overlain by yellowish-brown sand and a surficial silty fine sandy clay. In places the upper clay is plastic. The stratigraphic sequence and morphology of the deposit indicates that this part of the Poquoson was laid down as a point bar deposit (Onuschak, 1973). In general it was deposited as estuarine, nearshore, and beach sediment.

HOLOCENE SERIES

Holocene sediments in the study area include the geographically extensive salt-marsh deposits, tidal-flat muds, dune, beach, and bay sands along the major rivers and in Chesapeake Bay; flood-plain organic-rich silts and sands; and the thick interbedded fluvial-estuarine silty sands and clays of the James River. Spoil from dredging of ship channels, sanitary landfills, and man-made lands are locally important. Holocene sediments range in thickness from less than 1.0 foot (0.3 m) onshore to more than 125 feet (38 m) thick in the James River and disconformably overlie Tertiary and Pleistocene deposits.

Sediments beneath salt marshes in the Hampton area consist of a surficial dark-gray to black root mat overlying a dark-gray to bluish-gray sandy mud that increases in compactness downward. Scattered plant debris, including *Spartina* fragments, and voids left by decaying vegetation are common in these deposits. Locally stumps of large trees, up to 3 feet (1 m) in diameter, have been reported in the marsh sediments in the Grand View area. Marsh deposits along the bay are usually less than 6 feet (2 m) thick and rest on a gravelly sand substrate whereas similar deposits in tributary streams are usually much thicker and are interbedded with clay and sand. Many of the salt marshes shown on earlier maps of the Hampton-Newport News area have been eliminated by erosion and filling.

Fringing beach and spit sands occur along the natural coastline of the James River and Chesapeake Bay. The sands are composed mostly of quartz derived from the erosion of the bluffs and upland and some is transported from adjoining

areas. Heavy mineral laminae are prevalent within the beach sands. Locally, fossil and recent shell debris and ferricrete fragments are intermixed with the quartz sands; lesser amounts of bricks, glass, concrete, and other human artifacts are also present. Beach erosion is severe along segments of the James River and Chesapeake Bay where erosion rates vary from less than 12 inches (30 cm) to more than 10 feet (3 m) per year.

Holocene fluvial-estuarine deposits of the James River were studied by Moncure and Nichols (1968) and the sediments of the bay floor off Hampton were the subject of an investigation by Ryan (1953). The general sequence of Holocene deposits in the vicinity of the channel of the James River in Hampton Roads consists of a basal brown, fossiliferous, gravelly sand resting on the Yorktown or older formations overlain by a sparsely fossiliferous, gray, silty fine sand and clay. Discontinuous organic-rich silts and peat and plastic clays are found within the gray sand and clay. The surficial deposit over much of the James River is a dark-gray, organic-rich sandy silt with intercalated medium-sand layers. Similar deposits are found in the deep fills of Hampton River, and presumably in Back River. Alluvial sediments, mostly silt, clay and sand washed from the adjacent uplands and organic material entrapped on the flood plain, occur locally in stream areas above normal tidal flood range. These deposits were mapped in the upper reaches of Lukas and Tormentor creeks.

Sand dunes are restricted in distribution to the bay front between Fort Monroe and Northend Point and locally along the marshes of Plumtree Island. Dunes, which were formerly nearly 10 feet (3 m) high, have been extensively modified by man in the Fort Monroe, Buckroe Beach, and Grand View areas. Major breaches in the dune tracts were created by storms, such as the 1933 and 1962 hurricanes, that swept the Hampton area. In natural areas the dune line is migrating westward over the marsh deposits at a rate locally that exceeds 6 feet (2 m) per year (Hobbs and others, 1975). The configuration of the dune-marsh tract in the upper end of Mill Creek was extensively altered between 1965 and 1970 (Hampton 7.5-minute quadrangle, 1965, 1970 photorevised).

GEOLOGIC HISTORY

During late Mesozoic time the lower Chesapeake Bay area was actively subsiding and was simultaneously filled with

terrigenous detritus under predominantly nonmarine conditions (Teifke, 1973b). The basin of deposition shifted southward during Late Cretaceous(?) and Tertiary time and the rate of subsidence was greatly reduced. Under these tectonic conditions, oscillations of sea level (400 feet or 122 m) produced major transgressions and regressions in the study area. During Miocene and early Pliocene time the sea invaded the Tidewater area and extended to the Fall Line. Sand and clay, eroded from the Appalachian Mountains and the Piedmont, were carried eastward into the warm, shallow Yorktown sea. Fine sand and silt were transported across the shelf and deposited in the Newport News-Hampton area. A diverse marine fauna, dominated by mollusks, flourished on the sea floor and their shells contributed significantly to the quantity of sediment. Whale and other marine vertebrates inhabited the area. As sea level fell and/or the basin filled, a major submarine bar complex extending from Chuckatuck to Yorktown was constructed of broken shells under shoaling conditions by longshore currents and waves (Johnson and Coch, 1969). The coquina in the Mogarts Beach area records part of this event. Subsequently the upper Yorktown was weathered and eroded during a succeeding period of emergence.

Between the time of emergence of the Yorktown and the deposition of the overlying Windsor Formation, a thick fluvial sequence, the Bacons Castle Formation, was deposited over much of the Coastal Plain; subsequently most of it was eroded away in the study area. When sea level rose to approximately 100 feet (30 m) elevation during middle Pleistocene(?) time, the shoreline was at the Surry scarp and the Windsor Formation was deposited under nearshore and lagoonal conditions. As the sea retreated to below present sea level, deep valleys, including the buried valley that trends parallel to and lies north of the present James River, were cut into the Windsor and underlying formations.

Early in Norfolk time, sea level gradually rose and the deep valley of the ancestral James River began to aggrade. A complex of channel, flood-plain, swamp, and marsh sediments was deposited in the main valley of the James and along tributary stream valleys. Cypress, oak, hickory, sweet gum, and a variety of other water-loving plant species grew in the swamps and along the stream margins. As sea level approached 45 to 50 feet (13 to 15 m) elevation, the Kingsmill and Suffolk

scarps were cut (Figure 21, A). Clayey sand was deposited over the upper part of the Huntington flat and a blanket of nearshore marine and beach sand formed along the Suffolk scarp and on the lower part of the Huntington flat.

With the fall of sea level in late Sangamon time, the Norfolk Formation was exposed to erosion. On the York-James Peninsula no deep valleys are attributable to erosion during this period of emergence. Major shoreline erosion resulted in the removal of the sediments beneath the seaward extension of the Huntington flat and the formation of the Harpersville scarp (Figure 21, B). The northern and southern segments of this scarp were subsequently obliterated by erosion. During this period the Todds flat was covered by shallow brackish water in which *Crassostrea virginica, Mercenaria mercenaria,* and other species flourished. Sand being eroded from the northern segment of the Harpersville scarp was carried southward to form a spit complex in the reentrant along the coast line. A lagoon in which sandy clay accumulated formed between the spit and the Harpersville scarp. These sediments constitute the Sedgefield Member of the Tabb Formation. Spit development continued until sea level fell below 25 feet (8 m).

When sea level stood at about 20 feet (6 m) during the late Sangamon, the eastern edge of the spit and northern and southern segments of the Harpersville scarp were eroded further to form the Big Bethel scarp (Figure 21, C). Erosion of the older sediments along and to the east of the Big Bethel scarp yielded the gravel, sand, and clay of the Lynnhaven Member of the Tabb Formation. Gravelly sand was deposited along the toe of the Big Bethel scarp and finer-grained sediments were laid down in the shallow water to the east.

As sea level continued to fall in late Sangamon time, a series of linear beach ridges (Mulberry Island trough and ridge area) were built along the retreating shore line (Figure 21, D). At the same time migration of the James River produced a series of point-bar deposits in the Mulberry Island, Ragged Marsh, Hog Island, and Jamestown Island areas that are collectively called the Poquoson Member of the Tabb Formation.

During Wisconsin glacial time, streams in this area flowed into the Susquehanna River (Figure 21, E). As sea level was greatly depressed, the James River cut a deep valley (160 feet, 49 m) through Hampton Roads. Smaller tributaries, streams

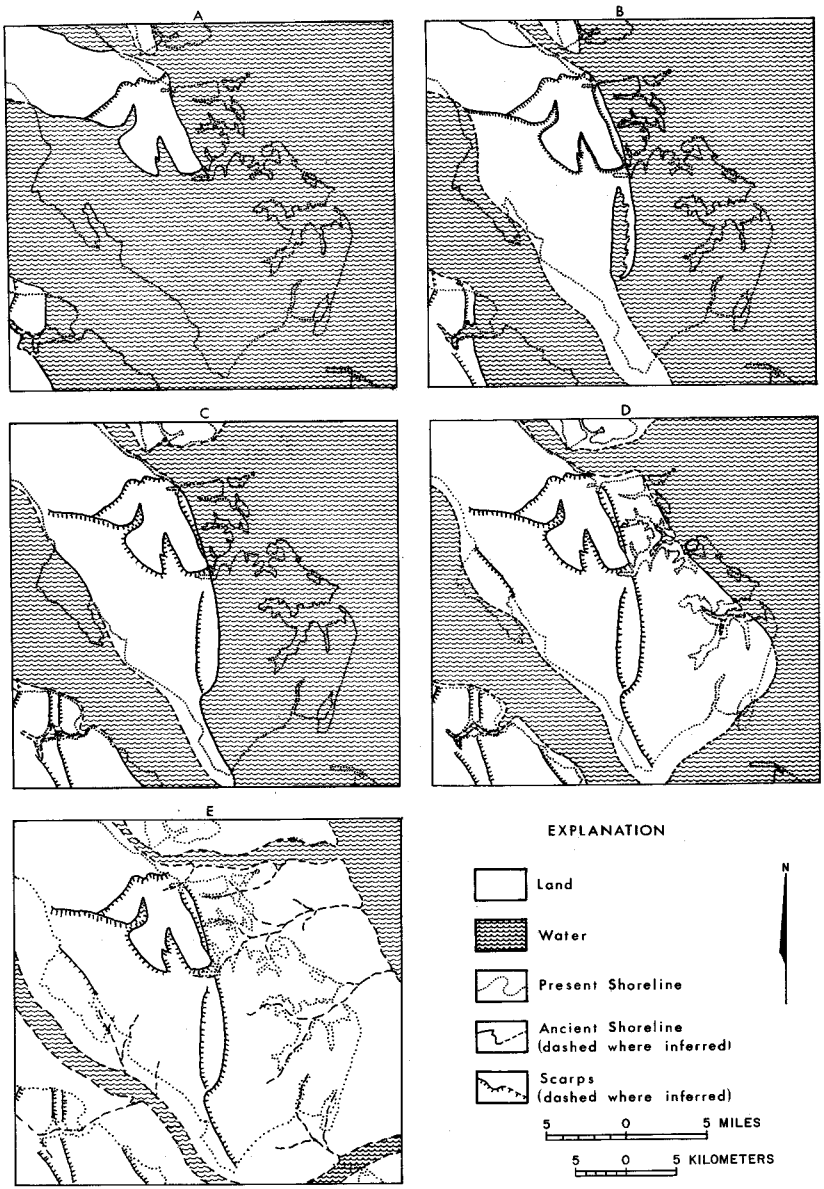

Figure 21. Paleogeography of the lower York-James Peninsula during late Pleistocene time:
A Middle Norfolk time, sea level at 45 to 50 feet (14 to 15 m);
B Sedgefield time, sea level at 25 to 30 feet (8 to 9 m);
C Lynnhaven time, sea level at approximately 20 feet (6 m);
D Poquoson time, sea level at approximately 5 feet (2 m);
E Late Wisconsin time, sea level below -150 feet (-46 m).

such as Deep Creek, Hampton River, and Back River, eroded headward into deposits of the Tabb and older formations.

As the Wisconsin glacier wasted, a major transgression took place. The deep channel of the James River was filled with fluvial-estuarine deposits with coarsest sediments at the base and becoming finer upward in the sequence. Marshes along the coastline and in tributary stream valleys were drowned by the Holocene rise of sea level. By 3,000 to 4,000 years ago the rate of sea level rise slowed and broad fringing salt marshes in the Poquoson-Hampton area became established. Subsequently, erosion along the beaches has diminished the areal extent of the marshes and has caused recession of the bluffs in the lower course of the James River. Tidal flooding has added a thin veneer of sediments on the lower part of the Hampton flat and the Mulberry and Plumtree Island trough and ridge areas. Man has attempted to stabilize much of the shoreline in the cities of Hampton and Newport News and has altered the landscape by filling and dredging.

ECONOMIC GEOLOGY

Economically mined minerals in the map area include sand and marl; potentially economic mineral deposits of clay and peat occur locally in the area. Sand is extracted from the Sedgefield Member of the Tabb Formation at the W. N. Krause pit ((Plate 2, active quarry number 1) and from the clayey-sand facies of the Norfolk Formation at the Williams Paving Company pit (Plate 2, active quarry number 2). Formerly sand was quarried from the J. S. D. Cumming pit and along Interstate Highway 64, Newmarket Creek, and near Big Bethel Reservoir. The sand is used extensively as subgrade for highway, housing, and commercial developments because of its stability, favorable compaction, and drainage properties. The sand deposits in the Sedgefield Member are relatively thin and are restricted to the Todds flat, whereas the Norfolk sand is thick, more than 60 feet (18 m) in places, and extends in a belt from the Kecoughtan area to the Oyster Point area. The clayey-sand facies contains sporadic peat, clay, and disseminated organic matter that makes economic extraction of these deposits more difficult and sometimes unprofitable.

Abandoned borrow pits along Interstate Highway 64 and elsewhere have been converted into small, ground-water-fed

lakes around which housing developments, and educational and recreational facilities, are commonly built. Unfortunately, much of the prime exploitable sand and fill resources have been covered or will be covered by housing and commercial developments. Furthermore, zoning regulations and current developmental practices preclude the utilization of additional tracts of potentially commercial sand deposits in this area. Unless current trends and practices are changed, the lower Peninsula will need to acquire sand resources from other areas to fulfill its needs.

The silty-sand facies of the Yorktown Formation is extracted at the Krause, Cumming, Dellinger, and Rice pits (Plates 2 and 3, active quarry numbers 1, 3-5). The principal use of this material is fill on road and building construction sites. Material from this facies tends to have a low permeability and must be stockpiled to allow drying before it is shipped to the site (Figure 22). Some of the silty sand contains higher concen-

Figure 22. Mining operations showing techniques for stockpiling and drying soil (left center), sand (far right), and fill (center) in the W. N. Krause Company pit (Plate 2) 0.25 mile (0.40 km) south of the junction State Highway 134 and State Road 600. Pit will become a real estate lake surrounded by housing after the mineral resources have been quarried.

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trations of clay that contribute not only to unfavorable drainage properties but also to undesirable compaction and stabilization characteristics and to difficulty of reworking the material. The silty sand is more than 125 feet (38 m) thick at the Krause pit. Locally in the Lake Tormentor area the coquina and silty-sand facies of the Yorktown Formation have been extracted for construction and agricultural purposes; no pits are active in this area.

ENVIRONMENTAL GEOLOGY

The wise use of land resources is dependent upon a knowledge of the distribution and character of sedimentary bodies, of the forces that shape them, and upon the capabilities of these materials. A lack of this information may lead to the burial of valuable mineral resources under a housing subdivision, the destruction of coastal property by storm action, or the obliteration of wetlands by landfilling. These actions limit the number of land-use options and contribute to the economic and environmental costs of future development. This section of the report discusses some of the geologic and engineering properties of the various stratigraphic units that limit or enhance their land-use capability.

ENGINEERING PROPERTIES

The engineering properties of soil, subsoil, and sediment are of fundamental importance in the construction of buildings, pipelines, sewers, electrical transmission towers, and other structures. The bearing and shear strengths, permeability, ground-water characteristics, chemical stability, and other properties determine primary use potential for a site or dictate what precautions or engineering techniques should be applied to correct for or adjust to natural limitations. Figure 23 shows areas underlain by certain sediments which may cause foundation problems. Although stratigraphic units may vary in their properties from place to place, the following engineering properties (Table 4) are summarized from well logs, engineering reports, and field observations on the lower York-James Peninsula and adjacent parts of Southside Virginia. The environmental, geologic, and engineering properties discussed in the succeeding part of this report are often interdependent.

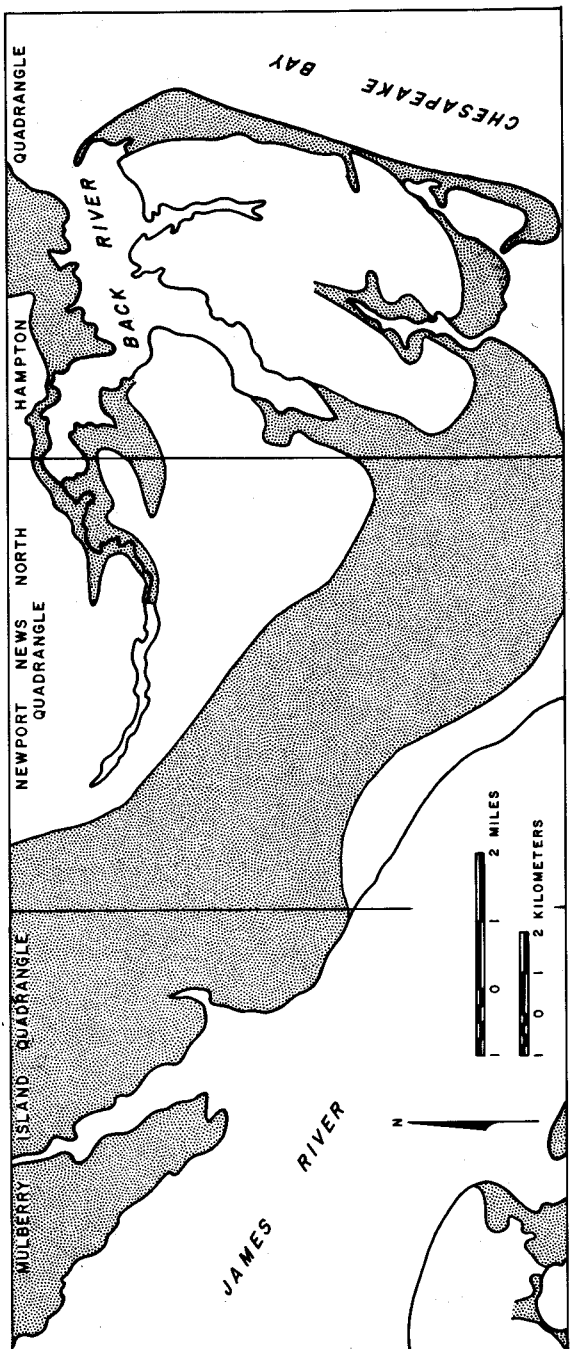

Figure 23. Map showing area underlain mostly by late Pleistocene and Holocene sporadic peat, organic silt, or plastic clay sediments (gray area) that may cause foundation problems unless proper precautions are taken.

Table 4.—Physical properties of stratigraphic units in the Mulberry Island, Newport News North, and Hampton quadrangles: Yorktown Formation. Ty; Windsor Formation, Qw; Norfolk Formation, Qn (clayey-sand facies, cs; sand facies, s; silty-sand facies, ss); Sand Bridge Formation, Qsb (silty-clay facies, sc; clayey-sand facies, cs; silty-sand facies, ss); Tabb Formation (Sedgefield Member, Qts; Lynnhaven Member, Qtl; Poquoson Member, Qtp); Holocene (marsh sediment, m; sand, s; alluvium, al).

Physical Characteristics	Yorktown Ty	Windsor Qw	Norfolk Qn			Sand Bridge Qsb		
			cs	s	ss	sc	cs	ss
Bearing capacity	high	moderate	low to moderate	moderate	moderate	poor to moderate	moderate	moderate
Plasticity	low	low to moderate	moderate to high	moderate	low to moderate	high to moderate	low	moderate
Slope stability	good	good to fair	fair	fair to poor	good	good to fair	good	fair
Permeability	low	moderate	low to moderate	moderate to high	low to moderate	low	moderate to low	moderate
Erosion resistance	high	moderate	moderate	moderate to low	low to moderate	moderate to high	moderate	low to moderate
Flooding potential	NA	low to moderate	moderate	low	NA	low to moderate	low	low
Sand or marl resource	good	poor	good to poor	good	poor	poor	poor	poor

Table 4.—Continued

Physical Characteristics	Tabb Qts	Tabb Qtl	Tabb Qtp	Holocene m	Holocene s	Holocene a
Bearing capacity	low to moderate	low	low to moderate	low	moderate to low	low to moderate
Plasticity	moderate to high	moderate	high	high	low	moderate to high
Slope stability	fair	fair	fair	poor to fair	poor	poor
Permeability	low to moderate	low to moderate	low to moderate	low	high	low
Erosion resistance	moderate	moderate	moderate to low	moderate	low	low
Flooding potential	moderate to high	high	high	high	high	high
Sand or marl resource	good to moderate	poor	poor	none	moderate	poor

NA Not applicable

The bearing capacity of a sediment is a measure of its ability to withstand loading without significant compaction. Geologically older deposits, such as the Yorktown Formation, were buried under younger sediments and are subsequently more compact than the overlying deposits. The weight of the younger deposits applied over long periods of time causes consolidation of the underlying sediments. Sand, composed mostly of quartz, tends to resist further compaction upon loading because the grains interlock and are resistant to breakage. Clays and organic-rich sediments saturated with water compress differentially; water is expelled during the consolidation process. Sediments with high-bearing capacity provide adequate support for moderate-sized structures, whereas low- to moderate-bearing capacity material requires structural modification to support the same structures.

Plastic materials tend to flow under stress and are permanently deformed by these stresses. Clays tend to exhibit a high degree of plasticity and constitute a severe engineering problem, if unconfined. Stabilization of clay or organic-rich silts is commonly difficult and may require lime treatment, excavation, or structural techniques to control or overcome their instabilities.

Slope stability describes the ability of a material in an undisturbed state to stand at a high angle without failing. This property is influenced by the degree of consolidation of the material, cohesiveness, permeability, angle of slope, and many other properties of the deposit. Failure on slopes is accomplished by slumping, creep, and landslide and is facilitated by erosion at the base of the slope by water. The Yorktown and Norfolk formations form natural high-angle slopes along the southside of the James River. Formations containing loose sand and water-saturated silt form lower angle slopes.

The ability of a sediment to transmit water is its permeability. Permeability varies with sediment mineralogy, particle size and arrangement, sorting and other factors. In sediments with higher clay content and smaller grain size, the permeability is generally lower. Surficial clayey beds, such as those in the upper part of the clayey-sand facies of the Norfolk and the silty-clay of the Sand Bridge, inhibit infiltration of water. Perched water tables occur where ground water is prevented from moving downward by an impermeable stratum below the surface.

Erosion resistance of a deposit is a measure of the rapidity of slope retreat under attack by an erosional agent. Water currents and waves are the principal agents of erosion in the study area. Erosional rates, measured in feet (m) per year, will vary from place to place in the same material because of differences in orientation of the shoreline, slope of the foreshore, height of the bluffs, presence of a beach or vegetation, and other factors. Differences in erosion resistance between deposits, such as between the clayey-sand and sand facies of the Norfolk Formation, may be related to the clay content and particle size. Clay tends to bind the deposits and contributes to the erosion resistance of the sediment.

Some deposits, because of their topographic setting and/or their textural or mineralogic characteristics, are subject to flooding. High flood-potential units usually have two or more of the following characteristics: relatively impermeable surficial deposits, high ground-water tables, or low topographic relief. Although the Poquoson Member of the Tabb Formation is moderately permeable, it has a low topographic expression and a high ground-water table; therefore it is subject to frequent flooding.

A stratigraphic unit constitutes a sand or marl resource if it contains potentially useable sand or marl deposits. Properties and distribution of these resources are discussed in the section on Economic Geology.

The silty-sand facies of the Yorktown Formation has the highest bearing capacity of the sediments on the York-James Peninsula. This condition can be attributed to its textural homogeneity, lack of distinctive bedding, and to its overconsolidated state (Harrison, 1962). Piling test records indicate that the Yorktown will bear a pile load of 50 to 60 tons. If pile driving into the Yorktown Formation is interrupted for a period of time, the piles tend to "set" and movement is difficult to reinitiate.

Bluffs cut into the silty-sand facies form nearly vertical slopes that erode relatively slowly. Bluff retreat caused by wave erosion varies from less than 12 inches (30 cm) to approximately 3 feet (1 m) per year. Erosion of the bluffs is inhibited by the shallow depths in the James River along the Mogarts Beach area, where the Yorktown Formation lies below a discontinuous, thin veneer of Holocene sand.

The weathered zone of the Yorktown in contrast to the unweathered Yorktown has lower bearing strength and greater permeability. Consequently, larger structures built in areas where the Yorktown is near the surface (northern Hampton flat) and where it is capped by a weathered zone must have their foundations or supports anchored or resting on the unweathered material. The clayey parts of the silty-sand facies absorb and hold water more readily than do the sandier units of the facies. Because of this they are more difficult to grade and stabilize after being wetted. The silty-sand facies is stable chemically and has a slightly alkaline pH. The facies has a low permeability and brackish ground water in the deep strata is corrosive to metals.

The coquina facies is relatively thin in the Mogarts Beach area and does not constitute an important geologic environmental unit. Blocks of the cemented coquina have fallen to beach level and form a natural riprap. Cementation of the coquina appears to occur only on subaerial weathering surfaces.

Little engineering data exists on the Windsor Formation in the Mulberry Island quadrangle and adjacent area. Homesites constructed on adequate foundations show little evidence of settling. Although no industrial development has occurred in this area, comparison of development of this type elsewhere on the Windsor indicates that the formation will probably bear light to moderate industrial facilities without additional structural support. The Windsor Formation forms steep slopes along the James River where it rests upon the eroding Yorktown Formation; however, it is eroding more rapidly than the Yorktown because it lacks the same degree of consolidation. Agricultural activity is restricted to flat to gently sloping land; consequently soil erosion is limited. In two test borings made in May 1974, the ground water table was at depths of 7.8 feet (2.4 m) and 9.1 feet (2.8 m). The well-developed drainage network, extensive forest cover, and rolling topography of the land underlain by the Windsor Formation in the Mulberry Island quadrangle makes flooding a minor problem.

The clayey-sand facies of the Norfolk Formation exhibits great variation in bearing capacity because of the heterogeneity of the sediments within the facies. The thick sand units within it have good bearing capacity but the organic silts, plastic clays, and peat bodies have generally low-bearing capacity. These deposits are sporadically distributed in the study area

(Figure 22) and constitute potentially serious foundation problems. If deposits with low-bearing strengths are encountered at shallow depths, the deposits can be excavated and backfilled; otherwise construction techniques involving piling or floating on a mat will be necessary to obtain stable support. Nearly the entire section of the clayey-sand facies along the James River is now protected from erosion by revetments of various kinds (Hobbs and others, 1974). Prior to stabilization of the slopes with riprap, bulkheads, and other structures, erosion rates locally exceeded 5 feet (2 m) per year. Erosion was accomplished mainly by wave undercutting at the base of the slope, causing block slumping. The ground-water table in the area underlain by this facies is commonly high, less than 3 feet (1 m) below the surface but more than 8 feet (2 m) where sandy subsoils persist or where the deposits are adjacent to a major stream. The ground water that is drawn from this unit is usually of high quality, but may be sulfurous locally. The sulfurous odor is produced by the degradation of plant material in lenses within the clayey-sand facies.

The sand facies of the Norfolk Formation has been extensively developed for industrial, commercial, institutional, and domestic purposes. Although these deposits have excellent bearing capacity for smaller structures, multistory and heavier industrial buildings require piling or other measures to achieve structural stability. Part of this problem is aggravated by the presence of plastic organic silts and clays in the lower part of this facies (Appendix, Section 3). Surface infiltration in the sands is excellent, but the movement downward is inhibited by clay beds within the sediments. Saturation of the clayey silt and organic sediments with ground water contributes to slumping of the deposits in natural or man-made exposures, such as exist near 70th Street in Newport News. Consequently, erosion along unprotected reaches of the river is rapid. Because of the high permeability and topographically high position of these deposits, the ground-water table is usually below 8 feet (2 m).

Little development other than the construction of single-family dwellings has taken place in the area of Todds flat where the Sedgefield Member of the Tabb Formation crops out. The principal inhibiting factor in this area has been the high water table. With the exception of the area near the Big Bethel scarp, the water table is less than 3 feet (1 m) below

the surface; in many places it intersects the surface, creating swamps in these areas. The bearing capacity of the Sedgefield Member depends to a large extent upon the composition of the underlying formations. In areas where the Yorktown Formation is the underlying formation, the bearing capacity is good. If the clayey-sand facies of the Norfolk Formation is the subjacent unit, the bearing capacity required for larger structures will reflect the engineering properties of the underlying organic silts, peats, or clays within the facies. Steep slopes in the member, exceeding 3 feet (1 m), slump when disturbed and erode readily when left unprotected. Organic deposits on the surface and in the underlying deposits cause the water to have a lower pH. In the northern outcrop area of the Sedgefield, water seeping through the oyster bed at the base of the member and along the upper surface of the Yorktown Formation becomes slightly alkaline. Ground-water flow in the Sedgefield is toward the east north of Big Bethel.

The Lynnhaven Member of the Tabb Formation is the foundation material for most homes and single and two-story buildings on the Hampton flat. Larger structures require firmer foundation material and the Lynnhaven is commonly excavated or the foundations rest on piles driven through this member into the underlying Yorktown. Erosion of the Sedgefield along open shorelines is restricted to the Back and Hampton rivers. Rates of erosion are low and banks have gentle slopes and relief of less than 5 feet (2 m). The shoreline along the rivers is mostly protected by bulkheads and riprap (Hobbs and others, 1975).

Infiltration of surface water into the Lynnhaven is relatively rapid, but the ground-water storage capacity is limited by the high water table, usually less than 4 feet (1 m) deep, and by the relatively low porosity of the sediments. Flooding under normal conditions is limited to the broad, flat, poorly drained western part of the Hampton flat and urbanized areas where storm sewers become clogged or their capacity is exceeded.

The most intensive development of the land underlain by the Poquoson Member of the Tabb Formation north of Back River has occurred along the ridges. Many of the homes in Poquoson are constructed below the 5-foot (2-m) contour, many on fill material. Throughout the area underlain by the Poquoson, the member constitutes a firm foundation for housing,

small commercial buildings and light industrial buildings; larger structures will require piling or excavation into the underlying silty-sand facies of the Yorktown Formation. Nearly all of the sediments of the Poquoson Member are protected from shoreline erosion by fringing marshes and man-made erosion abatement structures. The ground-water table is less than 4 feet (1 m) below the surface over most of the area of outcrop and tidal flooding is common due to the low topographic relief.

Holocene marsh, beach and dune, and stream deposits are geologically hazardous to develop. The sediments are unconsolidated, most are subject to excessive compaction and flow plastically upon being stressed, and all are subject to flooding. Beach erosion is severe along unprotected coastlines, such as Northend Point in Hampton, and structures built upon beaches and dunes are frequently damaged by storms or require costly beach erosion abatement structures to preserve them. Construction of roadways, dams, and landfills on marsh or organic-rich alluvial sediments commonly leads to the formation of mud waves, bulges in the surface of the marsh, or flood plains caused by plastic flowage of sediments from beneath the dam fill.

FLOODING

The lower York-James Peninsula experiences flooding that results from excessive storm runoff in areas of low relief and from storm generated high tides along Chesapeake Bay and the streams leading into it. Flooding causes not only economic loss and social hardships, but is accompanied by extensive erosion of beaches and localized sedimentation. In order to reduce the severity of flooding and concomitant erosion, shoreline protection devices have been installed along much of the coastline (Hobbs and others, 1974, 1975) and dredging, ditching, and storm water diversion channels have been completed. Futhermore, assessment of the past and probable future tidal flooding frequency (U. S. Corps of Engineers, 1968; Weeks, 1971) and of shoreline erosion rates and current status of coastal areas (Hobbs and others, 1974, 1975) have been obtained; these reports provide a basis on which to plan future uses of the coastal zones.

Floods created by storm runoff are a threat to property and life in parts of the Todds, Huntington, and Hampton flats

where natural drainage is poorly developed. In parts of the Oyster Point area and Todds flat, little natural runoff occurs; as a consequence swamp and marsh conditions persist on the flat upland tracts. Most surface water infiltrates slowly into the ground or is lost to the atmosphere through evapotranspiration. Suburban development has aggravated the flooding situation in the higher altitude areas by increasing the amount and rapidity of storm runoff.

In order to accommodate additional surface runoff and to drain swampy areas, drainage and diversion ditches have been constructed and streams have been channelized. As development occurs in the Oyster Point tract and the area around Thomas Nelson Community College, new storm-water problems will arise unless adequate measures are taken to handle the runoff and/or intensity of development is limited. Flood abatement measures that would reduce the flood potential downstream include retention ponds, lakes, or other structures for the temporary holding of storm waters.

Tidal flooding is a serious problem in the Mulberry Island and Plumtree Island trough and ridge areas and on the lower part of the Hampton flat. This area has been repeatedly flooded by storm-generated high tides (U. S. Army Corps of Engineers, 1968; Weeks, 1971). A major hurricane in 1933 created tides to heights of 8.6 feet (2.6 m) elevation in the Hampton-Poquoson area; a second major flood occurred in 1962 when a northeaster raised tides nearly 7 feet (2 m) above normal in the Hampton area. During tidal floods beach erosion is severe and sediments entrained in the flood waters may be deposited inland.

Based upon previous tidal-flooding records it is possible to predict the probable frequency of storms of a given magnitude in an area. In the Hampton-Poquoson area, a 7-foot (2 m) tide can be expected once in 25 years (Weeks, 1971). The Intermediate Regional Tidal Flood, predicted to occur once a century, will probably reach about 8.0 to 9.0 feet (2.4 to 2.7 m) elevation and the Standard Project Tidal Flood, a catastrophic tidal flood, is projected to reach 13 feet (4 m). The area on the lower York-James Peninsula that would be inundated by the Intermediate Regional and Standard Project Tidal Floods constitutes the greater part of Hampton and Poquoson and lesser areas of Newport News and York County (Figure 24). With the reduction in forest cover in the tidal flood-prone areas

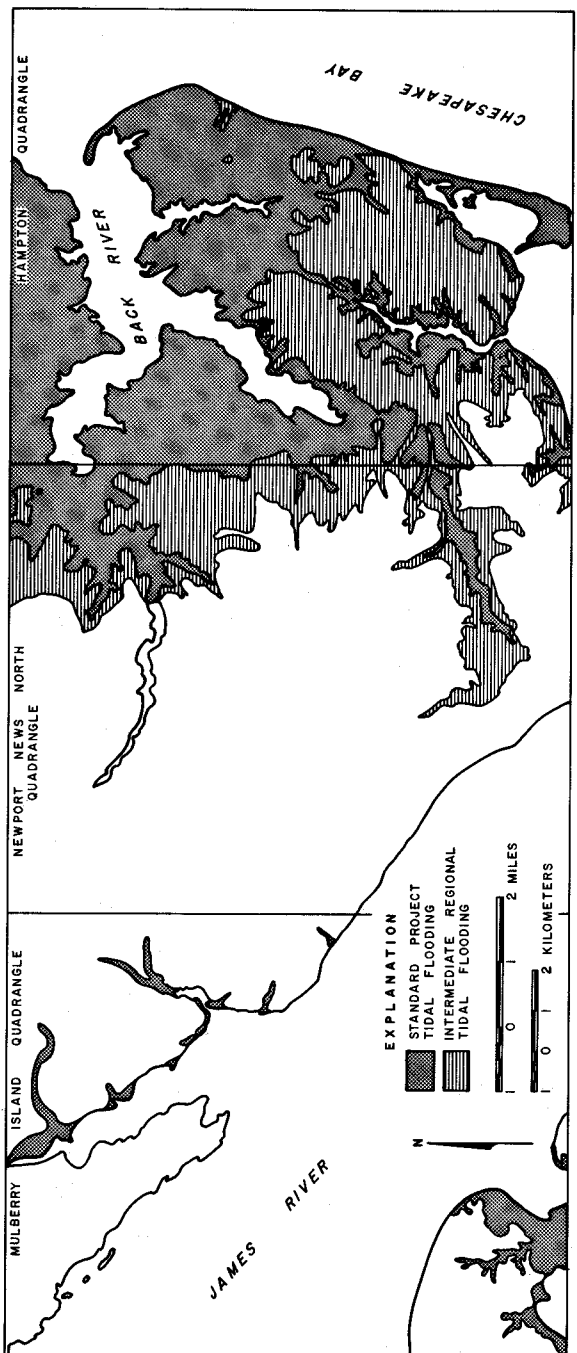

Figure 24. Map showing the probable extent of Standard Project and Intermediate Regional Tidal Floods.

and the gradual rise of sea level in the lower Chesapeake Bay region, the severity of storm-generated tidal flooding can be expected to increase. Combined with the more intensive development of the low-lying areas, major economic loss and social dislocations seem likely. Reduction of these problems can be accomplished in part by structural modification, such as filling sites to predetermined elevations and diking, but restrictions on the intensity and type of development in these flood-prone areas constitute the long-term solution to these problems.

WASTE DISPOSAL

Waste disposal by the landfill method may create ground- and surface-water problems and, if constructed in marshlands, may lead to the destruction of the marsh and associated aquatic biota. Water quality may be impaired by the leaching of materials from the solid waste by ground water and the introduction of the leachates into the surface water through seeps. Landfill sites located on Holocene valley fill are subject to compaction and frequently create mud waves that cause the elevation and destruction of adjoining marshes and the constriction of nearby stream channels. In addition, access roads on fill must frequently be constructed across marshland and, in most cases, the marsh does not supply appropriate covering material for the solid wastes and it must be imported to the site. In order to protect the working area from tidal flooding an earthen dike is usually constructed around the site. Erosion of the dike by normal and storm high tides generate sediment that is distributed across the marsh and into adjacent water bodies causing further damage. Because of the openness of marshland, wind may distribute litter across the marsh and onto nearby lands and waters. The cities of Newport News and Poquoson currently operate landfills in marshland.

The City of Hampton disposes of its solid waste in trenches on the Hampton flat. Large cells are excavated in the silty-sand facies of the Yorktown Formation and the trenches are backfilled with waste and calcareous silty sand. Although the water table is high in this area, the low permeability of the silty-sand facies greatly reduces the amount of water that enters the cells. Furthermore, the movement of leachates generated in the disposal cells by existing ground water and surface

runoff is retarded. Locally abandoned borrow pits serve as disposal sites for industrial and construction wastes. Environmentally sound landfill sites exist to the northwest (Johnson, 1972).

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APPENDIX

TYPE AND REFERENCE SECTIONS

All type and reference sections were measured in outcrop with the exception of Section 5. Representative samples of all sediments are in the repository of the Virginia Division of Mineral Resources where they are available for examination.

Section 1: Yorktown Formation (Silty-sand Facies) and Tabb Formation, Lynnhaven Member

Exposure in the east wall of marl pit at 29 Harris Creek Road, Hampton 7.5-minute quadrangle (Plate 3), latitude 37°03′41″N., longitude 76°19′36″W. Elevation at top of section is approximately 12 feet (4 m). The pit is owned by W. M. Rice and is known as the Kenneth M. Rice, Jr. Memorial Fossil Pit. Section measured by G. H. Johnson and J. Rivero, October 1974.

	Thickness *Feet*	*(m)*
Tabb Formation		
Lynnhaven Member		
Silt, dark-gray to black, fine sandy, friable, humus and rootlets abundant, gradational basal contact	0.6	(0.2)
Silt, light-gray, pebbly, fine sandy, cohesive, quartzose pebbles, scattered roots, gradational basal contact	0.7	(0.2)
Silt, medium to dark-gray, mottled medium reddish-brown, fine sandy, clayey, irregular dessication fractures, grades downward into fine sand	1.5	(0.5)
Sand, medium-gray to drab greenish brown, fine with scattered pebbles, thin discontinuous gravel zone about 6 inches (15 cm) above base, quartzose pebbles, gradational basal contact	1.1	(0.3)
Sand, medium-gray, coarse, pebbly, well-sorted, planar bedding; quartzose pebbles of metamorphic, sedimentary, and igneous origin, become more abundant near base, pebble supported; scattered rootlets, sharp basal contact	0.9	(0.3)
Sand, light-gray to yellowish-gray, fine, pebbly, noncalcareous, rounded small quartzose pebbles of varied lithology, nonfossiliferous, gradational basal contact	0.3	(0.1)
Sand, medium-gray, mottled reddish-brown, pebbly, clayey, calcareous (6 percent), pebbles up to 0.3 feet (9 cm), discoidal to equidimensional, rounded, concentrated near base; one fragment of *Crassostrea* (?) recovered; base irregular	0.5	(0.2)

Yorktown Formation

Silty-sand facies

Sand, medium reddish-brown, fine, silty, quartzose, calcareous (40 percent), very fossiliferous, much shell material chalky, fragmented; bivalves disarticulated and oriented convex side up; rootlet canals filled with clay; gradational basal contact	0.9	(0.3)
Sand, medium-brown, very fine, silty, quartzose, calcareous (34 percent), moderately fossiliferous, macrofossils mostly mollusks, some *Ensis* and other burrowers in living position, most bivalves oriented convex side up, abundant microfossil assemblage of foraminifers, gradational basal contact	5.6	(1.7)
Sand, brownish-gray, fine, silty, quartzose, calcareous (31 percent), micaceous, glauconitic; moderately fossiliferous, diverse microfossil assemblage of foraminifers, ostracods, echinoid spines, and micromollusks; macrofossils scattered and in various orientations, stages of disarticulation, and fragmentation; *Ensis, Dosinia, Ostrea,* pectens are numerous; gastropods common; gradational basal contact	4.4	(1.3)
Sand, greenish-gray, fine to very fine, silty, quartzose, calcareous (17 percent), micaceous, glauconitic, quartz grains subangular to subrounded; compact; scattered macrofossils, less fossiliferous than overlying unit, shells commonly articulated but randomly oriented among thin shelled bivalves which are present and fewer gastropods, numerous burrows; foraminifers, ostracods, echinoid fragments, and mollusk fragments common; base gradational	5.8	(1.8)
Sand, greenish-gray, very fine, silty, quartzose, calcareous (10 percent), micaceous, glauconitic, quartz grains subangular to subrounded, compact, sparsely fossiliferous, dominated by bivalves, principally *Dosinia, Yoldia,* and other thin-shelled forms, usually whole shells or broken by compaction, various orientations; abundant burrows; microfossils abundant (exposed)	21.2	(6.5)

Section 2: Norfolk Formation
(Reference Section, Upper Member, Clayey-sand facies) and
Tabb Formation (Type Section, Sedgefield Member)

Exposure in sand pit about 0.4 mile (0.6 km) west of Big Bethel Road (State Road 600), 0.6 mile (1.1 km) north of Interstate Highway 64, Hampton, Newport News North 7.5-minute quadrangle (Plate 2), latitude 37°04′33″N., longitude 76°25′59″W. Elevation of top of section is approximately 27 feet (8 m). Pit owned by Williams Paving Company. Section measured by S. M. Kidwell and G. H. Johnson, April 1974.

Tabb Formation

Sedgefield Member

Sand, dark-gray, clayey, slightly gravelly, humus and rootlets present, hard when dessicated, gradational basal contact	0.7	(0.2)
Sand, light-tan mottled to yellowish-brown, fine to medium, quartzose, 1-4 percent heavy mineral; with thin lenses (< 1.6 inches, 4.1 cm) of light-gray silty clay, gravelly near base, quartzose clasts of igneous, metamorphic, and sedimentary origin; horizontally bedded, nonfossiliferous, basal contact gradational	1.5	(0.5)
Sand, light-gray to tan, locally yellowish-brown, clayey, gravelly, quartzose, blocky when dry, nonfossiliferous, lower contact sharp	0.7	(0.2)
Sand, bright-gray, locally mottled gray, reddish and yellowish brown, fine to medium, thin gravelly zones and clay lenses locally, quartzose, slightly micaceous, 1-4 percent heavy minerals, thick to massively bedded, planar cross-bedding, accentuated by heavy mineral concentrates; burrowed with burrows filled with fine sand and gray sandy clay and with hematitic or limonitic lining, ghosts near base, basal contact gradational	7.2	(2.2)
Sand, bluish-gray, mottled yellowish and reddish-brown where well drained, clayey, gravelly, quartzose, calcareous; clasts up to 3.1 inches (7.9 cm) in diameter, discoidal to subspherical planar orientation, well-rounded, locally normal faults with displacements of 2.4 inches (6.1 cm); fossiliferous, fauna dominated by *Mercenaria mercenaria* and *Crassostrea virginica,* other forms include *Noetia,* bryozoans, crabs, and barnacles(?), fossils leached, fragmented, or *in situ* locally; basal contact sharp	1.2	(0.4)

Norfolk Formation

Clayey-sand facies

Sand, light-gray to tan, medium to fine, pebbly locally, 1-4 percent heavy mineral, thin to thick-bedded, with lenses of clay (up to 8.2 feet or 2.5 m thick) and peat and organic-rich clay (up to 7.6 feet or 2.3 m thick) locally; fossils include burrows of decapods, and bivalves, tree trunks, roots, leaves, nuts and seeds, burrows in upper part of unit filled with sediment from overlying formation	9.2	(2.8)
(exposed)		

Section 3: Norfolk Formation
(Reference Section, Upper Member, Sand Facies)

Exposure in north bank of James River 475 feet (145 m) northwest of the intersection of 70th Street and River Road, Newport News, Newport

News North 7.5-minute quadrangle (Plate 2), latitude 37°00′27″N., longitude 76°26′40″W. Elevation of top of section is approximately 28 feet (9 m). Section measured by G. H. Johnson.

Norfolk Formation

Sand facies

Spoil, oyster shells mixed with organic-rich sand	1.3 (0.4)
Silt, medium-tan, very fine sand, slightly cohesive, rootlet channels abundant, gradational basal contact	2.2 (0.7 m)
Silt, medium-brown to reddish-brown, slightly cohesive, scattered coarse sand, quartzose, root channels common, some filled with flakes of organic material, gradational lower contact	1.5 (0.5 m)
Sand, tan to reddish-brown, loose, fine to medium with scattered granules and pebbles, quartzose, rounded, larger clasts, subspherical to tabular, diverse rock types; cross-bedded, cross-beds have a dip to southeast and east, gradational lower contact	1.3 (0.4 m)
Sand, light-tan to gray, fine, quartzose, micaceous, heavy minerals (4 percent), cross-bedded locally, basal contact gradational	4.6 (1.5 m)
Sand, light-tan, fine to pebbly, coarser in upper part, quartzose, scattered mica and heavy mineral grains, larger grains moderately to well-rounded, subspherical to tabular, gradational lower contact	3.5 (1.1 m)
Sand, light-tan to reddish-brown, fine, gravelly, quartzose, heavy minerals (5 percent)	0.4 (0.1 m)
Sand, gray to reddish-brown, fine, quartzose; with thin, discontinuous, laminated to thin-bedded clay; heavy minerals (4 percent), planar bedding, burrowed, basal contact gradational	5.1 (1.6 m)
Silt, light bluish-gray, upper part yellowish-brown, very fine sandy, micaceous, slightly cohesive, thin- to medium-bedded, scattered vertically oriented bladed plant remains, basal contact gradational	1.8 (0.5 m)
Clay, light-gray, silty, micaceous, cohesive, slightly plastic, indistinctly bedded, plant remains abundant, vertically oriented blades, basal contact indistinct	0.9 (0.3 m)
Silt, light bluish-gray, very fine sandy, micaceous, moderately cohesive, indistinctly bedded, vertical blade plant remains abundant, basal contact gradational	1.4 (0.4 m)
Clay, light bluish-gray, slightly silty, micaceous, plastic, cohesive; few plant fragments, basal contact gradational	0.4 (0.1 m)
Clay, dark-gray, fine sandy, silty, very cohesive, micaceous, disseminated organic matter, branches and other tree remains, basal contact gradational	0.9 (0.3 m)

Silt, dark-gray to black, clayey, scattered sand and gravel clasts; clasts well-rounded, quartzose, indistinctly bedded; abundant bladed plant remains, tree trunks, branches, and other plant debris, base not exposed ..... 1.3 (0.4 m)

Section 4: Norfolk Formation (Reference Section, Upper Member, Clayey-sand Facies) and Tabb Formation (Type Section, Lynnhaven Member)

Exposure in north bank of drainage ditch between Interstate Highway 64 and Magruder Boulevard (State Highway A134), 0.67 mile (1.08 km) west of the intersection of Magruder Boulevard and Butler Farm Road, Hampton, Newport News North 7.5-minute quadrangle (Plate 2), latitude 37°03′38″N., longitude 76°24′47″W. Elevation of top of section is approximately 17 feet (5 m). Section was measured by G. H. Johnson and D. Rosenkrans, October 1973.

Tabb Formation

Lynnhaven Member

Sand, brownish-black to dark-gray, clayey, silty; micaceous, upper part organic-rich scattered modern roots, gradational basal contact 1.30 (0.39)

Sand, medium-gray to brownish-black, fine, very clayey, silty quartzose, micaceous; nonfossiliferous, gradational into underlying unit 1.50 (0.45)

Sand, light-gray to tan, mottled reddish-brown, fine to very fine, well-sorted, subangular to subrounded, slightly cohesive, quartzose, micaceous (<1 percent), heavy minerals (1-2 percent), nonfossiliferous, gradational basal contact 2.30 (0.70)

Sand, gray to reddish-brown, fine to very fine, silty, clayey, quartzose; micaceous, heavy minerals (1-3 percent); gravelly near base, well sorted near top; nonfossiliferous; basal contact sharp 0.75 (0.23)

Norfolk Formation

Clayey-sand facies

Gravel, grayish-brown, sandy, slightly clayey, quartz pebbles up to 2.4 inches (6.1 cm) in diameter, quartz of metamorphic, sedimentary, and igneous origins, scattered plant fragments including logs, twigs and leaves, burrowed (?), base inclined and sharp 1.50-1.90 (0.45-0.58)

Peat, dark-gray to black, fibrous, scattered rounded quartz grains and thin lenses of gray quartz sand; plant remains include leaves, twigs, nuts, and seeds of hickory, walnut, beech, oak, and sycamore; base inclined and gradational to sharp 0-0.60 (0-0.18)

Sand, bluish-gray to tan, fine to coarse, quartzose, micaceous, 1-2 percent heavy minerals, quartz clasts rounded to subangular; burrowed with burrow filling of clay to medium sand 0.50-1.40 (0.15-0.42)
(exposed)

Section 5: Yorktown Formation and Tabb Formation
(Type Section, Poquoson Member)

Hand auger boring on south side of lane 0.10 mile (0.16 km) southwest of Poquoson Avenue and 0.47 mile (0.75 km) northwest of Amorys Wharf, City of Poquoson, Hampton 7.5-minute quadrangle (Plate 3), latitude 37°06′38″N., longitude 76°20′36″W. Elevation of ground surface is approximately 5.0 feet (1.5 m). Section measured by G. H. and M. S. Johnson and H. F. Bulifant, February 1975.

Tabb Formation

Poquoson Member

Silt, dark-gray to black, very fine sandy, scattered pebbles, soft, organic-rich, sharp basal contact (base of plow zone) 0.75 (0.23)

Sand, light tan-gray, very fine, silty, crumbly; slightly micaceous, gradational basal contact .....

Sand, light-gray, slightly mottled yellowish-brown, very fine, quartzose, micaceous, heavy mineral trace, gradational basal contact 0.50 (0.15)

Sand, light-tan, fine to very fine, massive, loose quartzose, micaceous, heavy minerals (1 percent), gradational basal contact 4.00 (0.12)

Sand, reddish-brown, medium to coarse, pebbly and cobbly, quartzose, heavy minerals (3 percent), clasts well rounded to subrounded and of diverse rock types; basal contact irregular 9.25 (2.81)

Yorktown Formation

Silty-sand facies

Silt, reddish-brown, streaked with greenish-gray and dark-gray, fine sandy, clayey, very soft 2.40 (0.73)
(base of boring)

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COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

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Base map from U.S. Geological Survey, 1965-(70 PR)-(73PR)
Mulberry Island Quadrangle, 7½-Minute Series

Williams & Heintz Map Corporation
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EXPLANATION

QUATERNARY — HOLOCENE

al | m | s

Alluvium, Marsh Sediment, and Sand

al, *silt, sand, and clay with organic material;* m, *peat, silt, sand, and clay with organic material;* s, *beach and dune sand, locally tidal-flat mud.*

QUATERNARY — PLEISTOCENE

Qtp

Tabb Formation

Poquoson Member: estuarine clay and sand.

Qsb: sc | cs | ss

Sand Bridge Formation

Facies—sc, *tidal-flat and marsh silty clay;* cs, *fluvial and estuarine clayey sand;* ss, *lagoonal silty sand.*

Qn: cs | s | ss

Norfolk Formation

Facies—cs, *fluvial and estuarine clayey sand, organic silt, peat, and clay;* s, *beach and near-shore marine sand;* ss, *brackish marine silty sand.*

Qw

Windsor Formation

Marine and lagoonal sand and silt.

TERTIARY — PLIOCENE

Ty

Yorktown Formation

Marine sand, silt, and coquina.

CONTACTS

Solid where exposed, dashed where approximate, dotted where covered or inferred

STRATIGRAPHIC CONTROL

○ W-3950 Borehole; w, repository number; o, test boring

X Representative stratigraphic section that was examined

△F Fossil locality

QUARRIES

⚒ Abandoned quarry (marl)

GEOLOGIC MAP OF THE MULBERRY ISLAND QUADRANGLE, VIRGINIA

Geology by G. H. Johnson

MN GN
7½° 133 MILS
0°57' 17 MILS
UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL

1975

VIRGINIA
QUADRANGLE LOCATION

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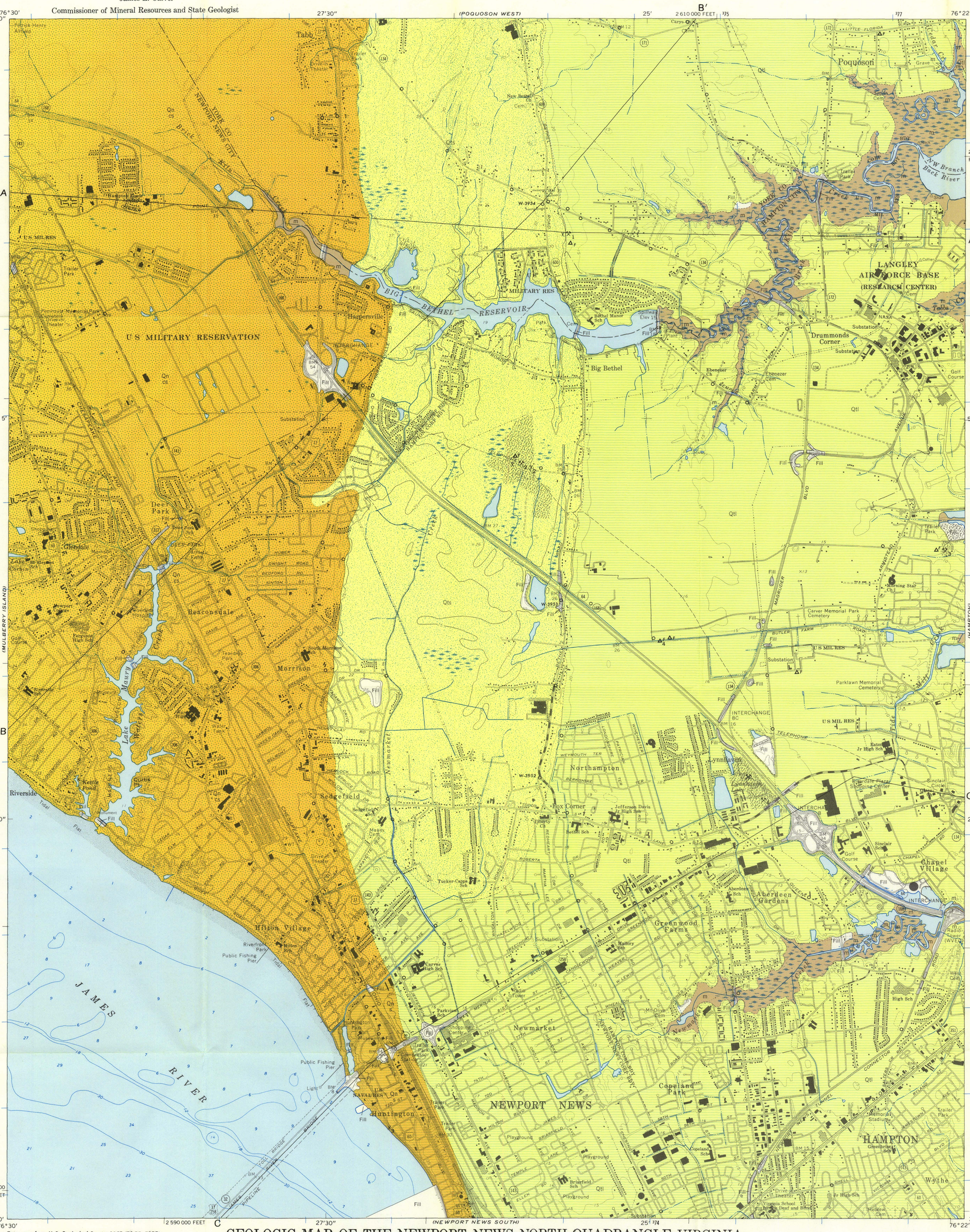
C.5



Base map from U.S. Geological Survey, 1965-(70 PR, 73PR)
Newport News North Quadrangle, 7½-Minute Series

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GEOLOGIC MAP OF THE NEWPORT NEWS NORTH QUADRANGLE, VIRGINIA

Geology by G. H. Johnson

1975

EXPLANATION

QUATERNARY — HOLOCENE

al | m

Alluvium and Marsh Sediment

al *(in section C-C′ only), silt, sand, and clay with organic material;* m, *peat, silt, sand, and clay with organic material.*

QUATERNARY — PLEISTOCENE

Qtl | Qts

Tabb Formation

Qtl, *Lynnhaven Member: beach and nearshore-marine sand and clay.* Qts, *Sedgefield Member: fossiliferous brackish-bay sand, beach and near-shore marine clayey sand, and lagoonal and marsh clay and clayey sand.*

Qn | cs | s

Norfolk Formation

Facies—cs, *fluvial and estuarine clayey sand, organic silt, peat, and clay;* s, *beach and near-shore marine sand.*

TERTIARY — PLIOCENE

Ty

Yorktown Formation
(In sections A-A′, B-B′, and C-C′ only)
Marine sand and silt.

CONTACTS

Solid where exposed, dashed where approximate, dotted where covered or inferred

STRATIGRAPHIC CONTROL

○ W-3950 Borehole; w, repository number; ○, test boring

X3 Representative stratigraphic section that was examined; number indicates measured section described in Appendix

Δ4F Fossil locality; number indicates measured section described in Appendix

QUARRIES

⚒1 Active quarry

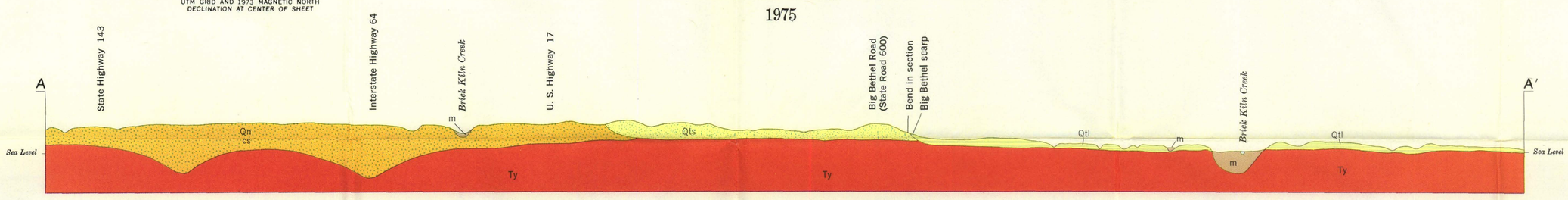
1. W. N. Krause Company (sand and marl)
2. Williams Paving Company (sand)
3. H. R. Dellinger (marl)
4. J. S. D. Cumming (marl)

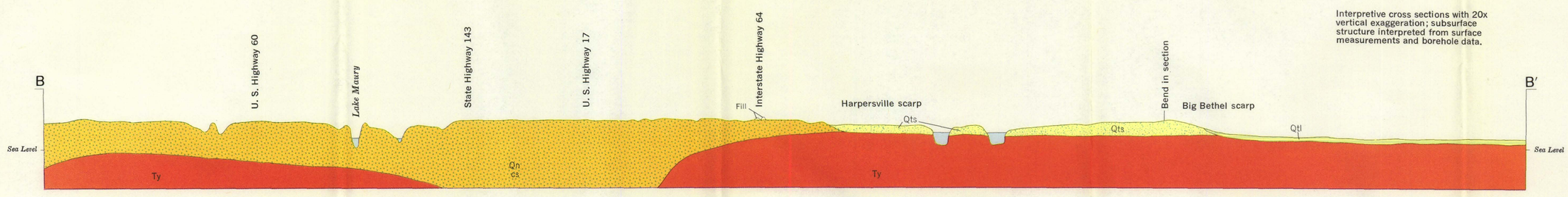
⚒ Abandoned quarry (sand and marl)

MN GN
7½° 133 MILS
0°52′ 15 MILS
UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

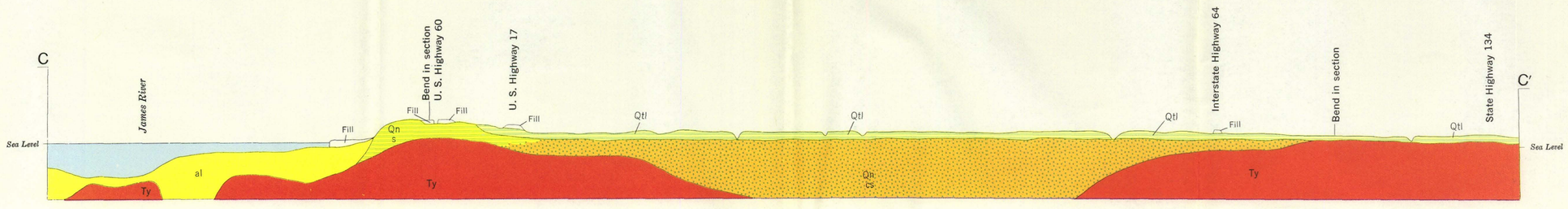
SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL

VIRGINIA
QUADRANGLE LOCATION





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



COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

VIRGINIA DIVISION OF MINERAL RESOURCES
LIBRARY

EXPLANATION

QUATERNARY	HOLOCENE	al, m, s — Alluvium, Marsh Sediment, and Sand. al (*in sections A-A′ and B-B′ only*), *silt, sand, and clay;* m, *peat, silt, sand, and clay with organic material;* s, *beach and dune sand, locally tidal-flat mud.*
QUATERNARY	PLEISTOCENE	Qtp, Qtl — Tabb Formation. Qtp, *Poquoson Member: Beach and nearshore sand;* Qtl, *Lynnhaven Member, nearshore marine sand and clay.*
QUATERNARY	PLEISTOCENE	Qn, cs — Norfolk Formation (In section B-B′ only). *Facies*— cs, *fluvial and estaurine clayey sand, organic silt, peat, and clay.*
TERTIARY	PLIOCENE	Ty — Yorktown Formation (In sections A-A′ and B-B′ only). *Marine sand and silt.*

CONTACTS

Solid where exposed, dashed where approximate, dotted where inferred

STRATIGRAPHIC CONTROL

- ○W-3955 — Borehole; *w*, repository number; ○, test boring, number 5 is location of section described in Appendix
- X_1 — Representative stratigraphic section that was examined; number indicates measured section described in Appendix
- △F — Fossil locality

QUARRY

Active quarry

⚒5 — 5. W. M. Rice (marl)

Base map from U.S. Geological Survey, 1965-(70 PR)
Hampton Quadrangle, 7½-Minute Series

Williams & Heintz Map Corporation
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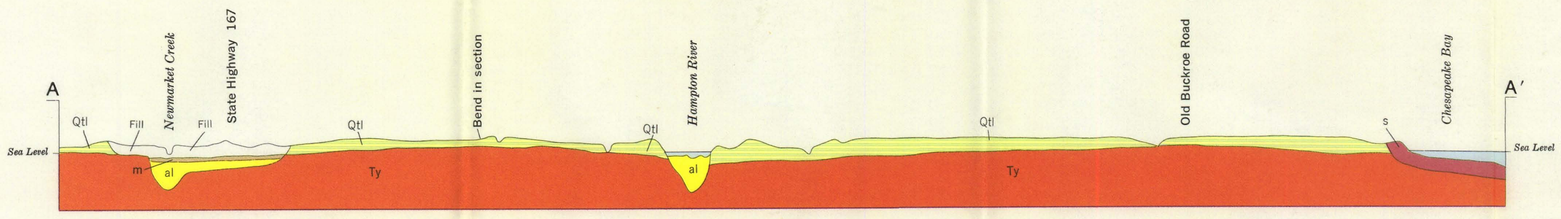
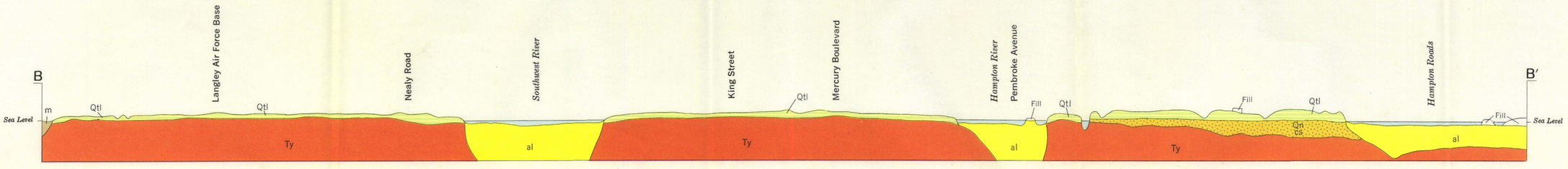
GEOLOGIC MAP OF THE HAMPTON QUADRANGLE, VIRGINIA

Geology by G. H. Johnson

MN GN
7° 124 MILS
0°47′ 14 MILS
UTM GRID AND 1970 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
1975

VIRGINIA
QUADRANGLE LOCATION



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