GEOLOGY AND MINERAL RESOURCES OF THE NORGE QUADRANGLE, VIRGINIA

by

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ABSTRACT

The Norge 7.5 quadrangle is located on the York-James Peninsula in western James City and York counties and eastern Charles City County. The morphology of the area is characterized by a dissected upland and a series of planes and scarps at successively lower elevations.

Sediments of the Yorktown Formation (Miocene to Pliocene), Barhamsville Formation (Pliocene), the Moorings unit of Oaks and Coch (1973), and the Windsor, Charles City, Shirley and Tabb formations (Pleistocene) are exposed in the report area. The Yorktown is composed predominantly of shell and fine sand deposited in an open marine (shelf) environment. The Barhamsville, a new unit, is a mix of fine sand and clay, deposited in a tidal or restricted marine environment. The Windsor and younger units are fining upward sequences of fluvial-estuarine-bay origin. Two additional units are formally named; they are the Shirley and Charles City formations. The Shirley replaces the Norfolk Formation.

Sand and gravel production is small at present. The Windsor and Shirley formations appear to offer a potential for low tonnage production. Clay deposits are extensive in the Shirley Formation; testing has indicated potential use in structural products.

INTRODUCTION

The Norge 7.5-minute quadrangle (Figure 1) is located predominantly within James City County, Virginia; portions of the Chickahominy River are located in Charles City County. The quadrangle has an area of approximately 58.5 square miles (151.5 square kilometers) of which an estimated 2.3 square miles (6 square kilometers) is covered by water and 5.8 square miles (15 square kilometers) is salt- and fresh-water marsh. The quadrangle is bounded by parallels 37°15' and 37°22'30" north and meridians 76°45' and 76°52'30" west. Because of a great degree of dissection, nearly all urban development and agriculture is limited to interfluves. Forests consist of hardwoods, loblolly pines or mixed hardwoods and pines; all areas have been cut since about 1900 (Deborah Mills, Virginia Division of Forestry, personal communication). Major agricultural crops are wheat, barley, soybeans, and corn. The principal roads are Interstate Highway 64, U.S. Highway 60 and State Highway 5. The Chesapeake and Ohio Railway services the area; coal is the major freight. Major industries in the quadrangle include timbering, tourism, the Williamsburg Pottery Factory, Inc. and the Soap and Candle Factory.

Surface drainage is predominantly to the west into the Chickahominy River and to the south into the James River. The drainage divide for the York-James Peninsula follows U.S. Highway 60, northwest of which surface run-off is into the York River. Little Creek Reservoir, completed in 1980 and owned and operated by the City of Newport News, encompasses approximately 800 acres of water. Tidal range on the James and Chickahominy rivers averages 2.8 feet. Most of the shoreline in Norge quadrangle is composed of fresh-water tidal marsh; other than its

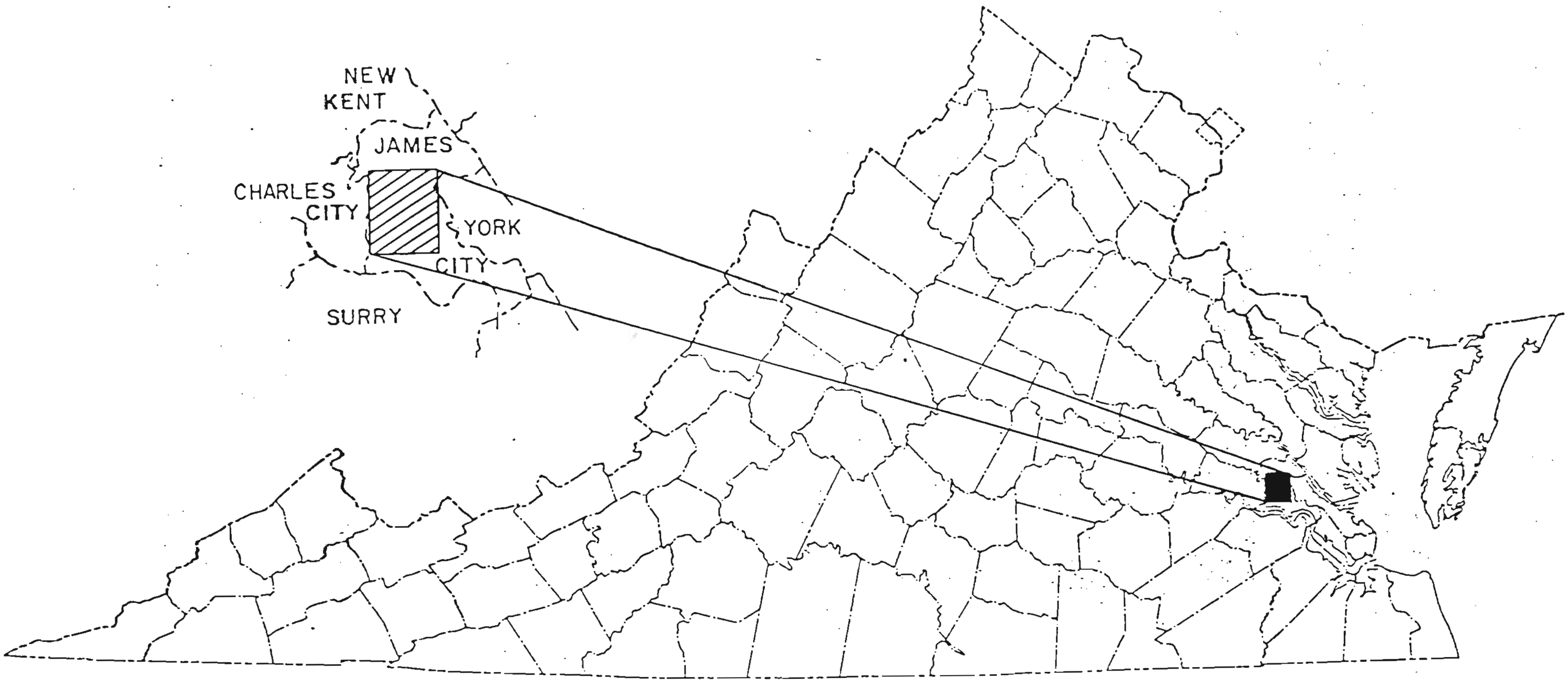

Figure 1. Index map showing the location of the Norge quadrangle, Virginia.

aesthetic and ecologic value, it is important as a control on erosion and flooding (Moore, 1980).

Field work began in the Fall of 1978 and continued intermittently through June, 1982. Subsurface data were acquired by several methods: over 400 hand auger holes up to 30 feet deep; 60 "post-hole" power-auger holes, up to 24 feet deep; 7 split-spoon/hollow-stem auger holes, up to 127 feet deep; and 20 continuous-sample split-spoon holes, up to 65 feet deep. A summary of subsurface data is provided in Appendix II. Very informative surface outcrops were found along the shoreline of the Little Creek Reservoir; during its construction, approximately 40 miles of continuous exposure was examined by the author.

Eugene K. Rader and D. A. Hubbard of the Virginia Division of Mineral Resources began the initial investigation and assisted with field work during the early stages. Becky Darton, Michelle Dewey, Kathleen Farrell and Eileen Sullivan assisted the author in field and laboratory work during their seasonal employment. Kelvin Ramsey provided a significant contribution in drilling, laboratory work, library research, soils analysis, and fossil identification. The author would also like to thank Tom Rodgers of VEPCO for subsurface data along power lines; Wayland Bass, Henry Stephens, Deward Martin and their staff of the James City County government for access to maps and engineering reports; Tony Izzo of Malcom Pirnie Engineers for engineering data at the Little Creek Reservoir; Harold Matthews and W. E. Dvorak of Old Dominion Soil Consultants, Inc., and Art Russnow of Russnow-Kane and Associates, Inc. for boring samples at the James City County landfill; and Bob Hodges of VPI&SU Department of Agronomy for soils information. Eugene Rader, VDMR, Wayne Newell, USGS, and Kenneth Bick and Gerald

Johnson, College of William and Mary provided helpful discussion and input throughout the project.

MORPHOLOGY

This area of Virginia has been described by earlier workers to consist of a succession of plains and intervening scarps (Clark and Miller, 1912; Wentworth 1930; Roberts, 1932; Oaks and Coch, 1973). Not all of the reported landforms appear within the boundaries of Norge quadrangle. Figure 2 shows the major geomorphic features of the report area.

The Shields Point flat is the terrace along the Chickahominy River lying between about 5 and 15' in elevation. This flat is underlain by the Poquoson Member of the Tabb Formation. The Dancing Point flat (Johnson, 1980) is located near the southwestern corner of Norge quadrangle, averages 15+ feet in elevation and is underlain by the Lynnhaven Member of the Tabb Formation (Plate 1). It is separated from the Huntington flat (Coch, 1971) by the Chickahominy scarp (Johnson, 1980). The Huntington flat (underlain by the Shirley Formation) ranges in altitude from 30 to 45 feet and is separated from highly dissected uplands by the Kingsmill scarp (Bick and Coch, 1969). This flat has been traced along the James River from Hampton to slightly west of Hopewell; it maintains the same altitude between these cities. The uplands are characterized by rolling hills and steep-sided drainages. The highest elevation in this area is slightly above 140 feet. Toward the mouths of larger streams, the steep valley walls abruptly end in a broad flat; these one V-shaped valleys have been filling with sediment during the rise in sea level over the approximately past 15,000 years.

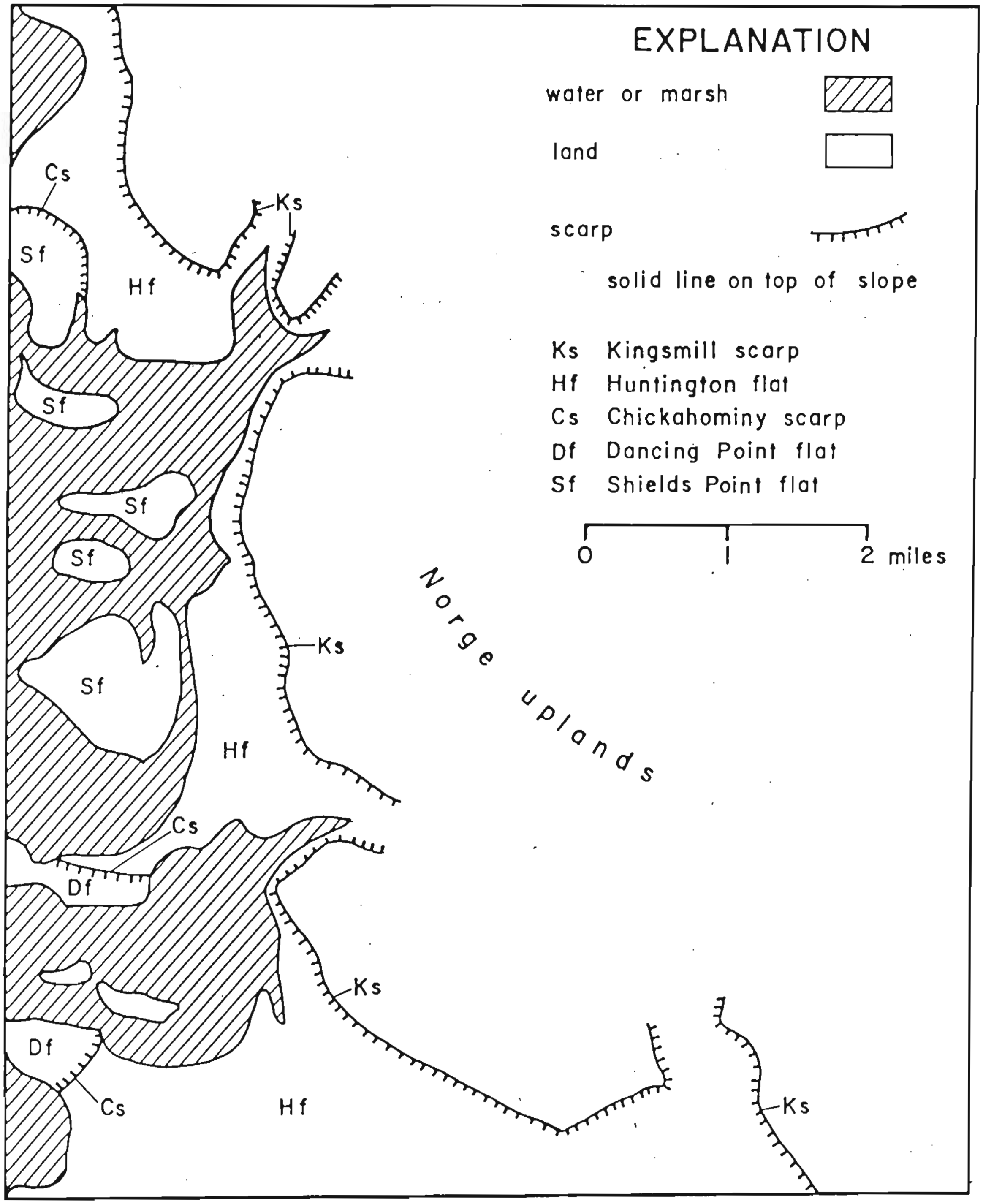

Figure 2. Major geomorphic features of the Norge quadrangle.

STRATIGRAPHY

Definitions and usage of stratigraphic units in the Virginia Coastal Plain have changed over the past few years. Table 1 summarizes the stratigraphic nomenclature proposed since 1969. Characteristics of stratigraphic units used in the report are presented in Table 2.

MIOCENE AND PLIOCENE SERIES

Yorktown Formation

The Yorktown Formation was named by Clark and Miller (1906) for the exposures of sand and shell along the York River near Yorktown, Virginia. Subsequent research was aptly summarized by Newell and Rader (1982) and Johnson and others (1981a). Considerable paleontologic work has been done by Mansfield (1943), Ward and Blackwelder (1975) and Campbell (in preparation). Johnson (1969) subdivided the Yorktown Formation into eight lithofacies, providing a useful basis when detailed analysis of the Yorktown is desired.

Bick and Coch (1969) mapped the Yorktown and St. Marys formations in the adjoining Williamsburg and Hog Island quadrangles. They reported no well-defined lithologic contact between these two units and therefore followed a faunal distinction as used by Mansfield (1943).

The Eastover Formation was named for sediments previously included in the Calvert, Choptank, St. Marys, and Yorktown formations (Ward and Blackwelder, 1980). They also subdivided the Yorktown and Eastover (Table 1) into several members, but in spite of lithologic descriptions their nomenclature remains dependent upon distribution of fauna. Ward and Blackwelder have not demonstrated mappability of their units; their contact between the Yorktown and Eastover in the region of this report

Table 1. Summary of recent stratigraphic nomenclature for the Virginia Coastal Plain and Correlation with units mapped the Norge Quadrangle.

Age	Bick & Coch, 1969	Oaks & Coch 1973 (in part)	Age Reassigned	Ward and Blackwelder 1980	Johnson & others 1981a	Newell & Rader, 1982	Johnson, 1983 (in review)	This report
Pleistocene	not present	Sandbridge Fm Londonbridge Kempsville	Pleistocene	not covered in report	Tabb Formation	not covered in report	Tabb Formation	Tabb Formation
Pleistocene	Norfolk Formation	Norfolk Formation	Pleistocene	not covered in report	Norfolk Formation	not covered in report	"Shirley" Formation	Shirley Formation
Pleistocene	Windsor Formation	Windsor Formation	Pleistocene	not covered in report	Not covered in report	not covered in report	"Chuckatuck" Formation	not present
Pleistocene	Windsor Formation	Windsor Formation	Pleistocene	not covered in report	Not covered in report	not covered in report	"Charles City" Fm	Charles City Formation
Pleistocene	Windsor Formation	Windsor Formation	Pleistocene	not covered in report	Uplands deposits	not covered in report	Windsor Formation	Windsor Formation
Pleistocene	Windsor Formation	"Moorings unit"	Pleistocene	not covered in report	Uplands deposits	not covered in report	"Moorings unit"	Moorings unit of Oaks and Coch (1973)
Miocene/Pliocene	Bacons Castle Formation	Bacons Castle Formation	Pliocene	"Yadkin Beds"	Uplands deposits; Bacons Castle Formation	Chesapeake Group, Upper Cycle	residuum on pre-Pleistocene deposits	Bacons Castle Formation (not present)
Miocene/Pliocene	Sedley Formation	Sedley Formation	Pliocene	Yorktown Fm: Moore House M., Morgarts Bch. M., Rushmere M.	Yorktown Formation	Chesapeake Group, Upper Cycle	residuum on pre-Pleistocene deposits	Barhamsville Formation
Miocene	Yorktown Formation	Yorktown Formation	Pliocene	Yorktown Fm: Sunken Meadow M.	Yorktown Formation	Chesapeake Group, Upper Cycle	residuum on pre-Pleistocene deposits	Chesapeake Group Upper Cycle: Yorktown Formation
Miocene	St. Marys Formation	Not covered in report	Miocene	Eastover Fm: Cobham Bay Member	Eastover Formation	Chesapeake Group, Upper Cycle	residuum on pre-Pleistocene deposits	Chesapeake Group Upper Cycle: Yorktown Formation
Miocene	St. Marys Formation	Not covered in report	Miocene	Eastover Fm: Claremont Manor Member	Eastover Formation	Chesapeake Group, Upper Cycle	residuum on pre-Pleistocene deposits	Chesapeake Group Upper Cycle: Yorktown Formation

Table 2. Summary of geologic units and their characteristics in the Norge area.

Unit		Morphologic Expression	General Characteristics	Origin	Age
Tabb Formation	Poquoson Member	flats 5' to 15' in elevation (Shields Point flat)	massive sands or sandy fining upward sequence	fluvial-estuarine	Pleistocent
	Lynnhaven Member	flats 15' to 25' in elevation (Dancing Point flat)	sandy fining upward sequence	fluvial - estuarine	
Shirley Formation		flats up to 45' in elevation (Huntington flat)	sand, cobbles grading upward to clay or clayey silt	fluvial-estuarine	
Charles City Formation		dissected flats up to 75' in elevation; underlies Norge uplands	sand grading upward to clay or clayey silt	fluvial-estuarine	
Windsor Formation		dissected flats between 80-100' in elevation; underlies Norge uplands	sand, cobbles grading upward upward to clay or clayey silt	fluvial-estuarine along James River; bay east of Surry scarp	
Moorings unit of Oaks and Coch (1973)		dissected dunes and flats generally between 90 and 125' in elevation; underlies Norge uplands	massive sand or silty clay	barrier/back bay/ lagoon complex	
Barhamsville Formation		underlies Norge uplands; generally very dissected	massive to interbedded sand, silt, and clay, flaser to lenticular bedded	various tidal environments	Pliocene
Upper part of Chesapeake Group (Yorktown Fm.)		subsurface and low on valley walls	sand or shelly sand; brown clay marker bed at top of Yorktown ("chocolate bed")	marine shelf	

is distinct only on fauna. Because there is no lithologic difference in sediments of the lower Yorktown and upper Eastover formations, and because extensive leaching of shell material has commonly removed or obscured biostratigraphic zones, the Eastover is regarded as an unmappable member of the Chesapeake Group in this report.

Newell and Rader (1982) accurately described the regional relationships of the Pliocene and Miocene marine units as shown in Figure 3. The area of this report is within a basin where sedimentation during the Upper Cycle of the Chesapeake Group was relatively continuous with only minor diastems. In the report area, the Yorktown Formation and the Chesapeake Group are equivalent.

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

Where not removed prior to deposition of younger units, the top of the Yorktown is usually marked by a sequence of dark brown muddy sediments up to 10 feet thick. This layer, the "chocolate bed" of mappers, is composed of sand, silt, clay, ferricrete, glauconite, manganese (wad) and weathered shell debris. The accumulation of iron-cemented sediment (ferricrete) and wad is probably due to reactions of groundwater with calcium carbonate from the shell beds. This brown muddy marker bed probably represents subaerial or subterranean weathering and compaction of the Yorktown shell beds; although primary structures and trace fossils have been found in this zone, an accurate relationship to the Yorktown and overlying Barhamsville Formation has not yet been determined (Johnson and others, 1981). Despite its

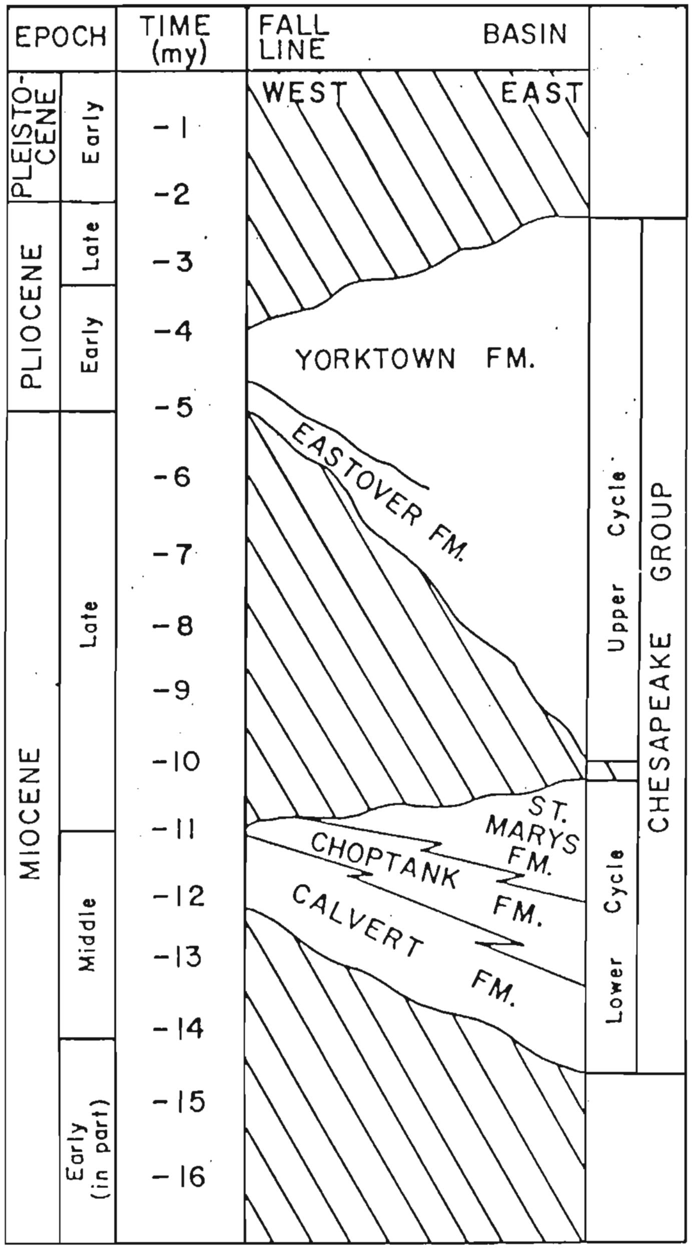

Figure 3. Stratigraphic relationships of formations within the Chesapeake Group, from Newell and Rader, 1982.

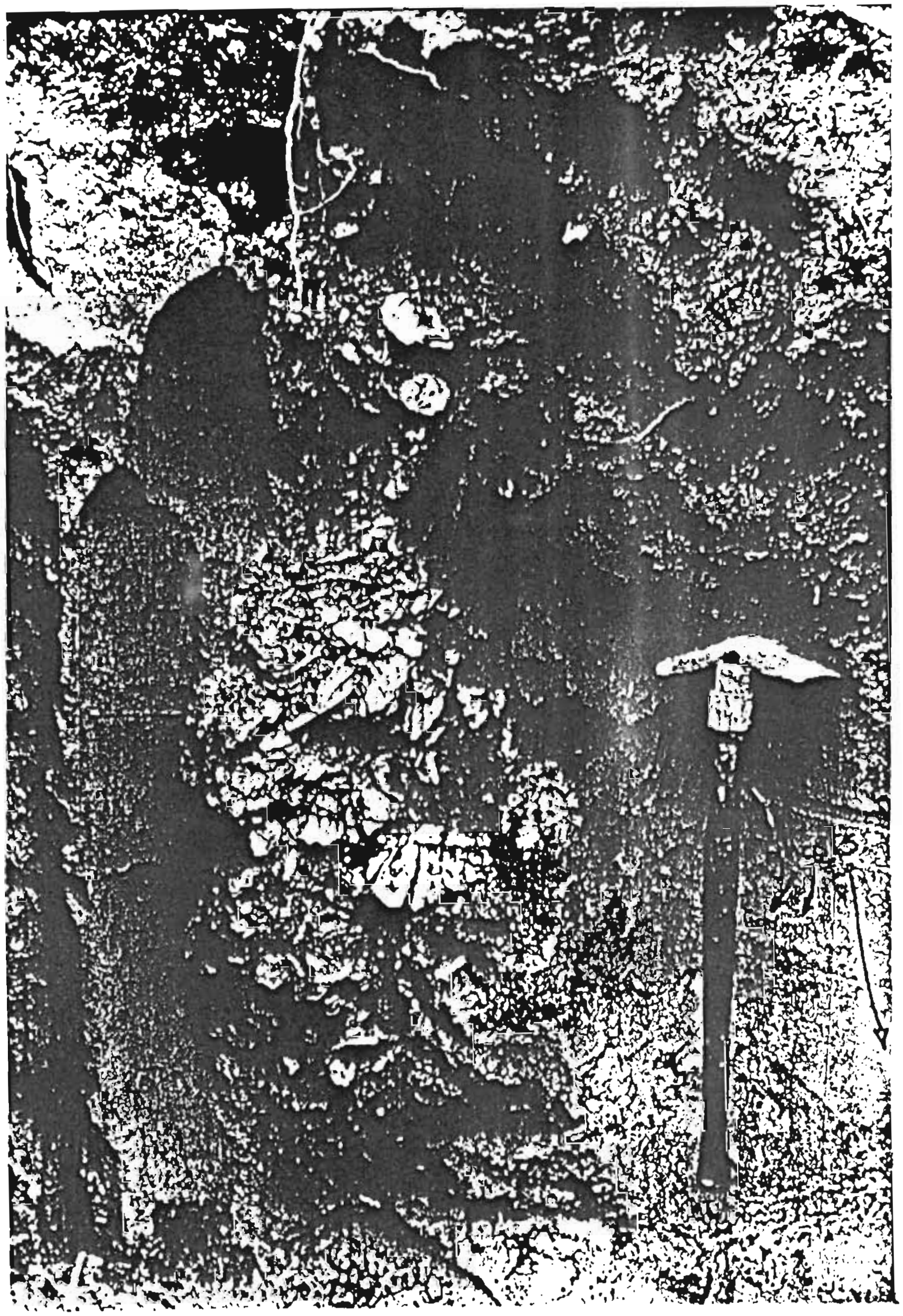

Figure 4. Exposure of the Yorktown shell bed and "ghost" sand at the Little Creek Reservoir.

unresolved origin, it unquestionably marks the top of the Yorktown Formation. Rodgers in 1884 (p. 126) recognized that this zone "would furnish grounds for the strong if not confident anticipation of finding marl beneath."

Directly below the marker bed is the classically defined marine Yorktown Formation. Although other facies are recognized (Johnson, 1969), the Yorktown in this report area is commonly composed of light yellow fine sand and shells; proportions of sand and shells vary greatly. The sand is well sorted and subrounded. Several percent of glauconite and heavy minerals are usually encountered. The Yorktown ordinarily grades downward to dark gray clayey to silty very fine sand and shells. These finer-grained sediments rarely crop out a few feet above sea level in the western part of Norge quadrangle. The only other facies is noted at Lightfoot where the upper part of the Yorktown is composed of glauconitic clayey silt (W-6556). In Appendix II, descriptions of "brown clay..." or "brown clayey silt..." opposite the Yorktown Formation reflect the composition of the "chocolate bed" and should not be interpreted as describing facies within the Yorktown. The base of the Yorktown is below sea level in this report area; total thickness is about 180 feet (Brown, Miller and Swain, 1972).

In many locations the shells have been totally dissolved leaving only a diffuse to detailed outline or "ghost" of the once present shell in a massive fine sand matrix (Figure 4). Misinterpretation of these leached sediments in earlier reports has resulted in the assignment of the material to units other than the Yorktown Formation. Dissolution is active today and most fossil rich outcrops are found at the heads of present drainages.

The Yorktown shelf sediments were deposited during a marine transgression-regession (Newell and Rader, 1982) which began during the late Miocene, 10 million years ago, Figure 3. The upper Yorktown sediments were deposited in a gradually shallowing sea, inferred from a general increase of carbonate content, grain size and abundance and diversity of organisms upward in the unit (Johnson and others 1981a). Deposition ended about two and one-half million years ago.

Barhamsville Formation

The sediments conformably(?) overlying the Yorktown through much of the central York-James peninsula have previously been included in the Bacons Castle and Sedley formations (Bick and Coch, 1969, Oakes and Coch, 1973). Detailed reconnaissance by the author indicates that the Kilby or sand facies of the Bacons Castle Formation unconformably overlies a mappable, distinctive group of tidally influenced sediments. Although the position in sequence of the tidal sediments is similar to that of the Sedley, reference and type sections of the Sedley are found to be composed of leached Yorktown sediments, the "chocolate bed", and possibly Bacons Castle sediments. Further use of the Sedley is not recommended. For these reasons the tidal deposits are here formally named the Barhamsville Formation for the exposure on State Road 621 east of Wahrani Swamp, Toano 7.5-minute quadrangle (Appendix I, Section 1). These sediments have been traced westward into New Kent County as well as south and north of the James and York rivers (Appendix I, Section 4). South of the James River the Barhamsville Formation is almost entirely removed by pre-Bacons Castle erosion.

The Barhamsville sediments are characterized by their heterogeneity. Individual beds of massive sands, massive to laminated clay, and interbedded to laminated fine sandy silt and clay vary in thickness and extent. Further subdivision into mappable units is not practical at the present scale. However, a belt of predominantly sandy sediments follows the trend of upper Powhatan Creek and Long Hill Swamp.

The sediments are interpretated to have formed in a tidal environment (Johnson and others, 1981a) similar to the present Dutch Wadden Sea, North Sea, or the Wash (Johnson and others, 1981; Klein, 1977). The heterogeneity of the sediments reflects the various depositional environments (bay-lagoon, tidal channel, tidal flat, marsh, shoals). Sedimentary structures include flaser, wavy and lenticular bedding, clay drapes, polychaete (worm) and decapod burrows, flame structures, clay pebble cross beds, desiccation cracks and slump structures. Bedding is usually horizontal or dipping at less than 10°; however, within laminated sediments it may dip as much as 25° due to penecontemporaneous slumping. Secondary structures (ferricrete, liesegang rings) are also common. Colors of sandy sediments are usually yellow-brown to red; clay is gray to pink. Massively bedded or thick sections of sand may be gray in color, because of groundwater saturation. Soils are commonly pinkish-brown to dark red where the parent material is rich in clay. Light brown soils form over sandy sediments. Soil profiles over this unit are thicker than over the younger (Pleistocene) units. Weathered feldspar and heavy minerals compose a few percent of the sediments. No body fossils have been found but trace fossils are common. Coarse material is rare but a few cobbles have been found at the base of tidal channel deposits.

A tidally influenced origin for these sediments implies specific regional events. The intertidal part of the Barhamsville is at least 25 to 30 feet thick: either the tidal range was extremely high (25 to 30 feet) during deposition, or the tidal range was similar to that of today for this area (3 to 4 feet) with a sea level rising relative to the land (marine transgression). The second alternative seems more appropriate, coupled with a rate of sediment supply maintaining deposition within the tidal range and a progradation of the coastline seaward.

The relationship of the Barhamsville to the Yorktown is not absolutely clear in this area. Sea level must have been very close to the top of the Yorktown Formation at the time the Barhamsville sediments were initially deposited. During a change from marine regression to transgression, emergence of the Yorktown sediments to the west likely occurred. How long the Yorktown was exposed or how much (if any) was eroded is presently unknown. To the east of Norge (and more offshore) the Yorktown may never have been exposed during this erosional event, and the contact would have been conformable. The report area lies somewhere between these areas.

Total thickness of the unit ranges up to 70 feet. Good exposures in Norge quadrangle may be found at Little Creek Reservoir, Hughs sandpit and in roadcuts in Middle Planatation. Because of the stratigraphic placement of this unit and its degree of weathering, a relative age of middle to late Pliocene is suspected.

PLEISTOCENE SERIES

Moorings unit of Oaks and Coch (1973)

Coch (1965) named the Elberon Formation for sediments surrounding the Surry scarp. Three facies were defined: a silty clay facies (lagoonal) west of the scarp, a fine sand facies (barrier) along the scarp, and a silty sand facies (nearshore marine) east of the Surry scarp. The eastern, silty sand facies was redefined as the Windsor Formation (Coch, 1968) and the remainder of the Elberon was informally termed the Moorings unit (Oaks and Coch, 1973). Oaks and Coch (1973) also stated that the Windsor unconformably overlaid the Moorings unit. In the York-James Peninsula, the proximity to the confluence of the ancestral York and James rivers and subsequent dissection has obscured the simple morphologic relationships found around Surry. In the Norge quadrangle, massive, fine sand and sandy mud at elevations above 90 feet are similar to barrier and lagonal facies of the Moorings south of the James River. The relationship of the fluvial-estuarine and bay members of the Windsor Formation to these sediments in the Norge area is not as clear as the relationships are south of Surry where morphology is a helpful guide to geology.

Just as in the Surry area, the the Moorings unit is composed of two facies. The fine sand facies is massive, moderately well sorted and usually lacking sedimentary structures. Gray clay laminations and drapes and clay chip crossbeds have been observed and suggest a tidal channel/shoal origin. There is the possibility that these deposits could be confused with the Barhamsville. Color ranges from light gray to light yellow. A few percent of opaque minerals have been observed. The sand facies was formed in a barrier-beach environment with possible eolian reworking during subsequent glacial periods.

The fine-grained facies is composed of massively bedded sediments ranging from silty clay to muddy sand. Bioturbation is very common, but no diagnostic trace fossil has been observed. No other sedimentary structures have been found. The color is usually gray to grayish brown. A lagoon or back bay environment is inferred for several reasons. The sand (barrier) facies lies to the east of the fine-grained facies; the sands lie at slightly higher elevations and grade laterally into the muddier sediments at lesser elevations. Just as in modern back bay environments, the fine-grained facies is thoroughly bioturbated.

Both facies are commonly less than 10 feet thick. Erosion has removed much of the complex so that older units may be exposed in "windows" through the Moorings. Soil formation and massive colluviation of side slopes has obscured the contacts; therefore, contacts have been drawn to conform with contour lines and available field observations. Soils are generally light brown or gray in color.

The age of the Moorings unit is estimated to be early Pleistocene because of its relationship to other units and its "fresh" weathering aspect.

Windsor Formation

The Windsor Foramtion was named by Coch (1968) for the silty sand facies of the informal Elberon formation. Windsor sediments were believed to have formed in a lagoonal-estuarine complex. The sediments were found surficially from the Surry scarp to the Suffolk scarp, but were not identified west of the Surry scarp (Oaks and Coch, 1973). The Windsor Formation commonly underlies moderately dissected flats between

80 and 100 feet in elevation. Both flats and corresponding sediments have been traced up the James River basin toward Richmond. In the report area, the Windsor Formation is composed of two informal members, following the convention of Bick and Coch (1969). The lower member is fluvial-entuarine in origin and the upper member is of bay origin.

The fluvial-estuarine member of the Windsor Formation consists of muddy, coarse sand and gravel grading upward to sandy mud. The unit unconformably overlies the Yorktown or Barhamsville formations. Good exposures of this member may be found in the sandpits at Five Forks and the R. T. Armistead pit north of State Route 613. Some sediments presently mapped as the Windsor Formation previously were included in the Bacons Castle Formation (Bick and Coch, 1969). For this reason some contacts will not match between the Williamsburg (Bick and Coch, 1969) and Norge (this report) quadrangles.

The lower part of the lower unit is composed of muddy coarse sand, pebbles and cobbles. Rarely, boulders up to 2 feet in diameter have been found. The coarse clasts are composed of granite, phyllite, schist, gneiss, greenstone, quartzite, chert and other rock types common to the Piedmont, Blue Ridge and Valley and Ridge provinces of the state. Clay balls are also common. An abundance of Skolithos bearing quartzite indicates that the ancestral James River had certainly breached the Blue Ridge by this time. Coarse sediment was deposited during fluvial stages and may also have been reworked out of the Bacons Castle Formation (not present in this quadrangle). The sand fraction is dominantly quartz, but locally feldspar is very common. Sediment colors may range from light brown (rare) to pinkish-brown. Trough cross-bedding is very common, indicating transport generally to the east. The coarse deposits range up to 25 feet thick.

The lower coarse deposits grade upward into muddy sand and sandy mud. The upper sediments are massively bedded and devoid of any sedimentary structures. Colors are gray, brown and red; mottling of gray, red and tan is also common. Thickness ranges up to 25 feet.

The upper member of the Windsor Formation is ordinarily a gray massive clayey silt to silty clay or light gray massive silty fine sand. No primary sedimantary structures have been observed. Mottling of brown and red is common in these sediments and has been caused by root penetration and soil forming processes. This member ranges in thickness from an eroded feather-edge to about 12 feet.

The bay member correlates with the Windsor mapped by Bick and Coch (1969) but only south of the area around State Road 612 (Longhill Road). North of here the Windsor of Bick and Coch (1969) correlates with the Mooring unit in this report. Contacts between the bay member and other units are not easily discernable without numerous shallow borings. In areas of poor control, contacts have been generalized and drawn along contour lines.

Soils formed on the fluvial-estuarine member of the Windsor are comparable to those on the Barhamsville. Distinction between these two units is difficult with only shallow auger information. An accurate determination of which formation is present cannot normally be made without examination of at least the upper 15 feet of each unit.

No fossils have been found in the Windsor with the exception of rare enigmatic burrows. No absolute date has been reported, but in relation to other units, an early Pleistocene age is assigned.

Charles City Formation

A fining upward sequence underlying broad flats between 60 and 75 feet in elevation has been mapped along the James River (Johnson, and others, 1981b) and is herein formally named the Charles City Formation for exposures in Charles City County (Appendix I, Section 2). In prior reports these deposits were included in the Windsor Formation. However, small flats between 35 to 45 feet in elevation (Shirley Formation) and 60 to 75 feet in elevation were exposed along major drainages during construction of Little Creek Reservoir. Both of these terraces are characterized by a fining upward sequence having a basal unconformity. The terrace sediments are fluvial-estuarine in origin; those sediments at the higher elevation are correlated with the Charles City Foramtion.

Morphologic evidence of these flats is not obvious on the Norge 7.5-minute quadrangle and only barely so on the James City County (1" = 200') topographic maps. Not all flats between 60 and 70 feet in elevation contain such terrace deposits. Only those terraces observed in the reservoir have been mapped, but similar deposits adjacent to the larger drainages are predicted throughout Norge quadrangle. These deposits are wedge-shaped, thickening toward the drainage and thinning toward the interfluves. Dissection has removed the lateral continuity of the unit and thickness rarely exceeds 15 feet.

The sediments generally fine upward from a basal lag of coarse sand and pebbles to silty clay or clay. In the Little Creek Reservoir, the color of the Charles City ranges from light gray to light yellowish brown, contrasting with the yellow, brown or red Yorktown and Barhamsville sediments. Although bioturbation and the formation of soils have destroyed many primary features, current ripple cross bedding, clay drapes and interlayered sand and mud occurs in the lower parts of the unit. Deposits rarely contain more than a few percent heavy minerals. No fauna has been found, and no absolute age has been determined.

The origin of the Charles City is related to Pleistocene fluctuations in sea level. During a low stand, erosion cut valleys into older units. With a subsequent rising sea level, fluvial deposits filled the new drainages. With a continued rise in sea level the drainages were eventually flooded and affected by tides (similar to the lower reaches of Little Creek today); fine- grained esturaine-marsh-swamp sediments were then deposited.

Shirley Formation

The fluvial-estuarine terrace deposits underlying the 45-foot plain have previously been included in the Norfolk Formation. At its type section, the Norfolk of Clark and Miller (1906) has been found to be composed of Holocene deposits, the Sedgefield member of the Tabb Formation, and the Yorktown Formation in descending order (Johnson and others, 1981b). Therefore, the sediments underlying the 45-foot plain are here formally named the Shirley Formation for exposures in the Lone Star pits at the Shirley Plantation, Westover 7.5-minute quadrangle (Appendix I, Section 3).

The Shirley is an overall fining upward sequence of sediments. Light-brown, coarse-grained quartz sand and cobbles grade upward to interbedded light brown to light gray sand and clay, which in turn grades upward to gray, massively bedded clayey silt or clay. The lowest part of the unit is characterized by repetitive fining upward sequences and contains wood fragments and lenses of gray clay (channel fill). Pebbles and cobbles are composed of quartzites, and to a lesser degree, igneous and metamorphic rocks. Toward the top of the unit, clay drapes, flaser to lenticular bedding and finely disseminated organic material become common; the uppermost beds are bioturbated and altogether reflect estuarine conditions. Variation to this fining upward sequence may be found near the prominent Kingsmill scarp; erosion of the Charles City or or older units by the ancestral James River estuary incorporated coarse material into the otherwise fine sediments. Colluviation of the scarp has further obscured the landward contact of the Shirley.

In the Norge quadrangle, the Shirley ranges in thickness from a feather edge at the Kingsmill scarp to greater than 48 feet near the intersection of State Highway 5 and State Route 613 (W-6548). The unit thickens toward adjacent major drainages but anomalous thicknesses may occur in paleochannels. Small terraces are found in minor drainages, for example, in Little Creek Reservoir (Figure 5).

No fauna has been found in the Shirley Formation in the study area. A uranium-series date of 184,000 ± 20,000 years B. P. has been reported from correlative deposits by Mixon and others, 1982. The relationship between the Shirley (Norfolk) sediments and those which have been dated is presently being examined. The origin of the Shirley deposits is similar to that of the Charles City Formation.

Tabb Formation

The Tabb Formation was named for exposures in the Newport News North and Hampton quadrangles by Johnson (1976). He also named three lithologically distinct members; in decreasing age and surface elevation they are the Sedgefield, Lynnhaven and Poquosin. Correlation of

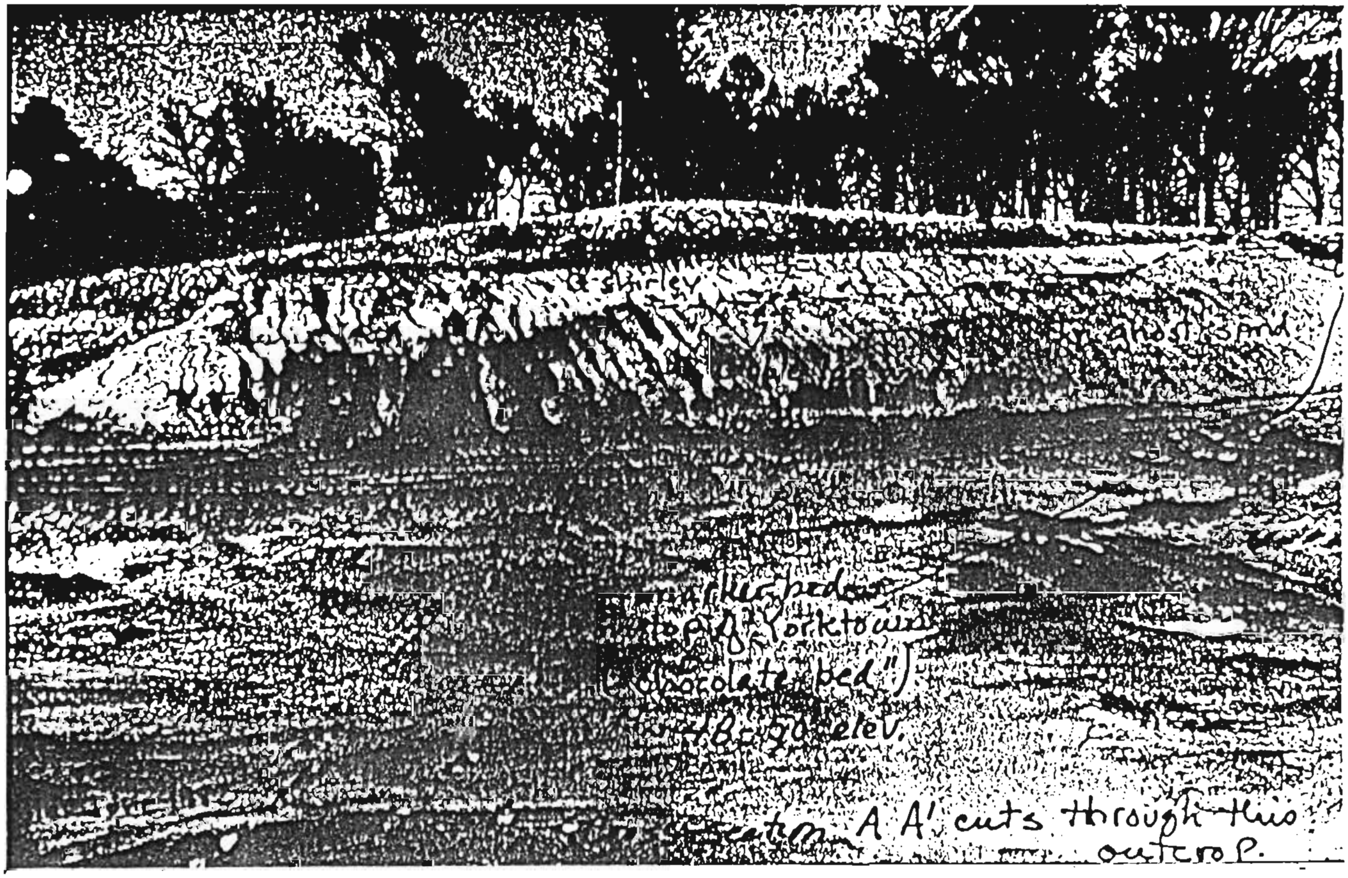

Figure 5. Exposure of the Shirley Formation in the Little Creek Reservoir.

deposits in Norge quadrangle with the Tabb can only be made on the basis of morphology (scarps and surface elevations) as no absolute age or biostratigraphic or lithologic continuity to the type sections can be proven. However, position in sequence, similar morphology and corresponding lithologic relationships between the Tabb and older units is regarded as evidence enough for correlation.

The Lynnhaven and Poquoson members are exposed along the Chickahominy River, forming flats at about 18 and 10 feet in altitude respectively. The Lynnhaven commonly fines upward from light brown coarse sand and pebbles to clay or silt. Its maximum thickness in the area is unknown but is estimated to be on the order of tens of feet. It is about 25 feet thick at the campground between Gordon Creek and State Highway 5 (W-6551, Table 1).

The Poquoson Member is exposed on some of the low-lying islands in the Chickahominy River. There it is composed of light brown fine to coarse sand averaging between 5 to 10 feet thick. Discrimination between this unit and alluvium is difficult. Broad areas of similar sediments above 5 feet elevation are likely underlain by the Poquoson.

No fauna has been found in the study area. Correlative deposits have uranium-series ages between 62,000 and 125,000 years B. P., suggesting a late Pleistocene age (Mixon and others, 1982).

The Lynnhaven member of the Tabb Formation has an origin similar to that of the Shirley and Charles City. However, the Poquoson formed during the marine regression following the Lynnhaven high stand (Johnson, 1976). Differences between units may be due to the sediment supply rate and duration of low and high stands of sea level.

<u>HOLOCENE SERIES</u>

Marsh Deposits

Marsh deposits consist of organic material, silt and clay. Areas containing these deposits support fresh-water or salt-tolerant plants such as <u>Spartina</u> and are generally restricted to zones affected by tidal water. Lenses of sand or coarser material may be included in these deposits in the vicinity of fastland (land which is near water but remains dry). Thicknesses of up to 35 feet are reported in borings along the Chickahominy River (B-58A, Table 1); this suggests that a similar environment has existed in this area throughout the latter part of the Holocene. Some areas mapped as marsh were compiled directly from Moore (1980).

Swamp Deposits

Swamp deposits may be found in poorly drained areas at any elevation above sea level and are composed of organic material and clay, sand and/or gravel. The significant constituent of these deposits is the accumulation of wet organic material, generally over an impervious or clay-rich zone. Some swamps may exist because of man's intervention (abandoned mill ponds and heads of man-made ponds) or may be related to natural clay-rich units, as the upper Shirley Formation. Swamps may also form in areas where the land surface intersects clay or other impervious zones in the underlying strata. Swamp deposits commonly support cypress trees.

Alluvium

Alluvium consists of a mixture of clay, sand, gravel and organic debris. Areas underlain by alluvium are subject to periodic flooding and lie above an elevation normally affected by tides. Hence, alluvium would not necessarily be saturated except during times of high rainfall or exceptional storms. Deposits are generally very thin (less than 10 feet) but thicken toward the center of drainages. Thickest deposits would be found toward the mouths of larger drainages and are caused by infilling during the post-Wisconsin rise of sea level. Relationships with adjacent marsh and swamp deposits are complex at depth.

GEOLOGIC HISTORY

Throughout the Tertiary, this area remained below sea level as a part of the continental shelf. During a major marine transgression beginning about 10 million years ago, marine shelf sediments of the lower part of the Chesapeake Group, upper cycle (Figure 3) were deposited. A marine regression began about 4.5 million years ago, the shoreline moved eastward. Sedimentation was continuous in the report area throughout both episodes. Following the regression an increased supply of sediments was coupled with a rising (relative) sea level, creating the tidal sediments of the Barhamsville Formation; the low-lying coast prograded seaward.

A continued high rate of sediment supply to the area caused a shift from a tidal to a fluvial-deltaic environment. After this time (Late Pliocene) sea level may have fallen to about 40 feet above the present, providing a base level and gradient for the Bacons Castle deposits to form. By this time the Blue Ridge mountains had been breached by the ancestral James River.

In the early Pleistocene, a shoreline existed in the vicinity of the Surry scarp, sea level being at about 125 feet. Barrier and lagoon sediments of the Moorings complex were deposited. An oscillation in sea level followed, creating the fluvial-estuarine and then bay deposits of the Windsor Formation.

Due to Pleistocene glaciation, major sea level oscillations created the Charles City, Shirley, and Tabb formations. In each case erosion cut valleys during the lowering of sea level, and deposition of fluvial deposits occurred during the rising phase. As sea level continued to rise fluvial environments because estuarine; once the drainages were flooded, estuarine sedimentation continued throughout the high stand of sea level. Subsequent oscillations in sea level created the next younger terraces.

After the peak of the Wisconsinan glaciation (about 18,000 years ago) melting of the glaciers caused sea level to rise from about -300 feet creating the recent sediments of today. Sea level continues to rise at an average rate of 10 cm (3.9 in.) per century since 3500 yrs. B.P. (Newman and Rusnack, 1965).

ECONOMIC GEOLOGY

Sand and gravel for general construction, fill, embankments and road base is being obtained intermittently from the R. T. Armistead (Active borrow pit 2) and Beamer (Active borrow pit 3) pits. Areas underlain by the fluvial-estuarine facies of the Windsor Formation may contain significant amounts of sand and gravel. Material from this unit is particularly well suited for road fill because there is usually enough mud and sand to bind the coarser clasts. Sand and clay for general fill material is being obtained intermittently from the F. Hughs pit (Active borrow pit 1).

Sand and gravel is common in the lower part of the Shirley Formation. The Chickahominy Sand and Gravel Company is extracting material from this unit just west of the Chickahominy River. In the Norge area thick gravel deposits lie below 15 to 20 feet of fines, thus limiting the economic potential.

Clay was used locally in the making of bricks during colonial times. Often this resource came from the house site or within six miles of the kiln (Paul Buchanan, Colonial Williamsburg Foundation, personal communication). Clay samples from the upper part of the Shirley Formation have been tested and reported potentially suitable for structural clay products. Samples were also tested for Al_2O_3 (Alumina) content; the highest percentage present was 17.6 (Sweet, 1982). In this report, sample R-7542 was also found potentially useful for floor brick and R-7543 for roofing tile. The upper part of the Shirley is nearly everywhere composed of clay-rich sediment and represents a potential source of economic material. After the fines have been removed, the underlying sand and gravel might also be available for exploitation.

Of minor economic importance are the shell and glauconite deposits in the Yorktown. A mixture of shells and sand has been used locally for walks and driveways; the shells were burned for making cement in earlier times. The mixture of weathered shells and glauconite at the top of the Yorktown was commonly used to enrich the soil. The economic potential of the glauconite zone is in part limited by the units' thickness.

GEOLOGIC HAZARDS

Although surficial evidence is rare, sinkholes are a potential environmental hazard in the report area. The upper part of a small cavern was found during excavation of a sewer line near the intersection of State Route 614 and Settlers Lane. A hole 6 feet in diameter formed overnight in the front yard of a York County home north of Williamsburg because of the collapse of material into a void. Smaller-scale collapse structures less than a few feet in diameter were observed during construction of Little Creek Reservoir. Dissolution of Yorktown shells by circulating groundwater created a void with subsequent collapse of overlying material into the void (Figure 6). Although these features are less extensive than sinkholes in limestone terrain, they may contribute to local foundation failures.

In conjunction with the sinkholes is the reaction of Yorktown shell beds with groundwater made acidic because of man's intervention (landfill leachate or storm effluent). Any acidic contamination of the groundwater would enhance local shell dissolution and void formation with possible surficial collapse.

The Yorktown Formation is a shallow aquifer for many of the more remote homes and developments in the York-James Peninsula. Bacterial pollution has occurred where septic effluent contaminated shallow wells in the Yorktown (Sand Hills Subdivision, Toano quadrangle; Lake Powell area, Hog Island quadrangle). Although the top of the Yorktown is commonly capped with up to several feet of brown clay-rich sediments ("chocolate" bed), the cap is not an aquiclude because of collapse structures or irregularities in thickness and texture. With increased public utility service or properly constructed or deeper wells, the

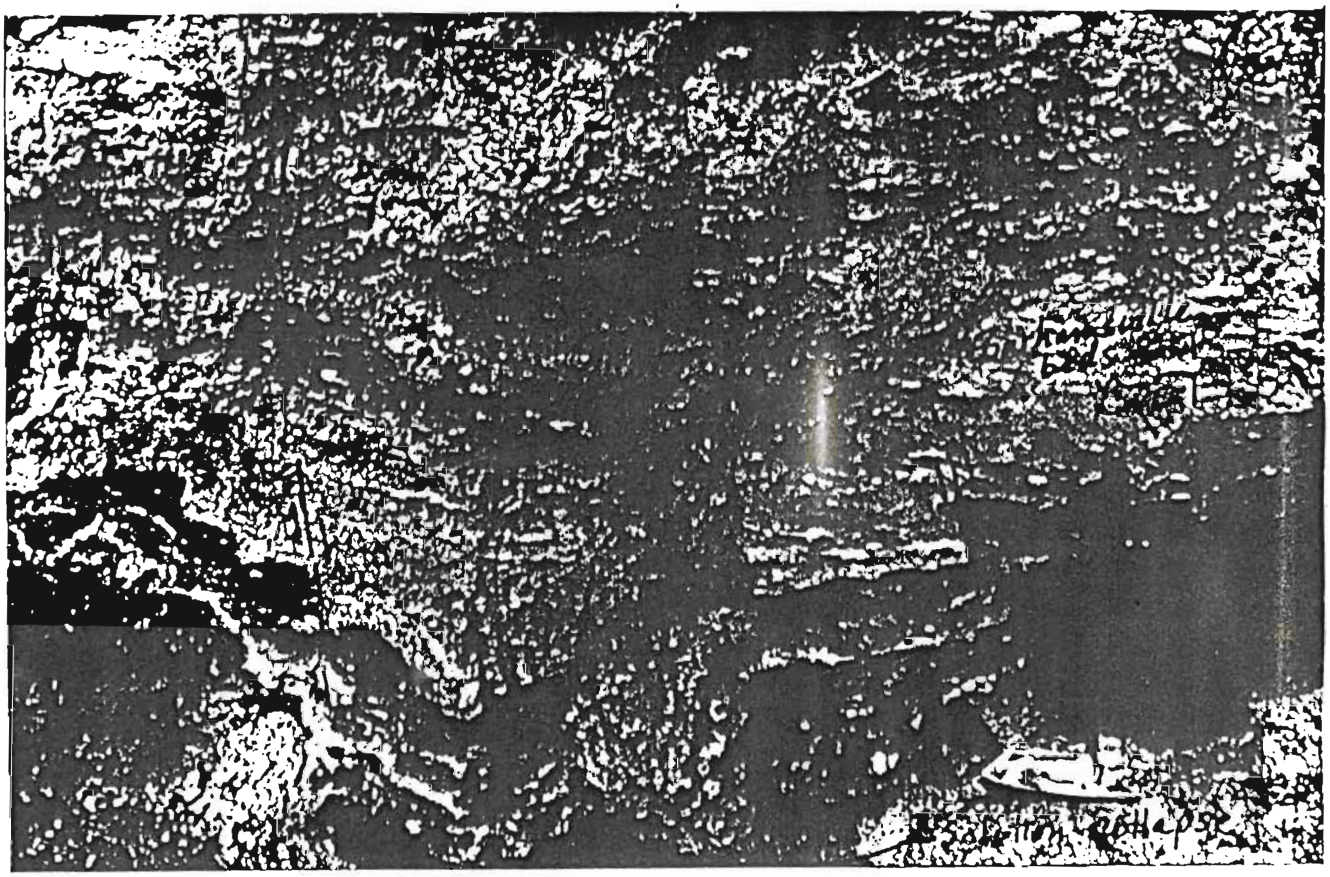

Figure 6. Exposure showing collapse of the overlying Barhamsville beds into the underlying Yorktown Formation at the Little Creek Reservoir. Dissolution of shells in the Yorktown created the voids.

domestic water supply problem may be mitigated, but there is continued localized degradation of water quality in the Yorktown Formation.

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APPENDIX I

STRATIGRAPHIC SECTIONS

Section 1: Wahrani Swamp

Type section of the Barhamsville Formation was measured along the north side of State Road 632 beginning approximately 1200 feet (366 m) east of the intersection with Wahrani Swamp, New Kent County, Toano quadrangle. Additional discussion of this exposure may be found in Johnson and others (1981). The elevation at the top of the section is approximately 105 feet (32 m). The section was measured from the top of the hill downslope over a horizontal distance of 280 feet (85.3 m).

	Thickness Feet (Meters)
Barhamsville Formation (31.5 feet) (9.6 m)	
Clay, light gray; silt and sand, yellow-brown to pinkish red, very fine-grained; flaser-bedded; bedding dips up to 25° toward the north; burrows-rare, bioturbation-common, solution-collapse features present- 10 inch diameter vertical tube-shaped zone of disrupted and rotated blocks of sediment; faults, subvertical, intersecting, up to 6 feet exposed with offsets up to 1 inch. At approximately 150 feet downhill the base of this section contains a penecontemporaneous slump block with 4- to 6-inch interbeds of tan to tannish-pink bioturbated silt and gray clay. The clay displays convolute bedding and flame structures. The base of the slump is composed of rip-up clasts and clay pebbles. Small subvertical faults with offsets up to 1 inch are associated with the slumping	26. 0 (7.9)
Clay, gray to red, flaser to lenticular bedded; sand, yellow-brown to pink, very fine-grained; burrows-rare	5. 5 (1.7)
Yorktown Formation (upper 13.5 feet) (4.1 m)	
Sand, dark brown, medium- to coarse-grained, muddy; grades downward to silty clay, dark brown, massive to disrupted bedding, manganese or ferricrete layer to 0.5 inch thick common; grades downward to sandy clay, olive gray with 1/8 inch thick sand or clay laminations	4. 5 (1.4)
Sand, light yellow, fine-grained, leached fossils (ghosts) marked by white sand or manganese stained (black) sand; liesegang rings, ferricrete laminations, and bioturbated gray clay flasers common in upper 5 feet (1.5 m)	9. 0 (2.7)

Section 2: Copeland Triangulation Station

The type section of the Charles City Formation is exposed in a sand and gravel pit on the north bank of the James River, at the Copeland triangulation station, due east of Windmill Point, Charles City County, Charles City quadrangle. Elevation at the top of the section is approximately 65 feet (19.8 m).

	Thickness Feet (Meters)
Charles City Formation (54+ feet) (16.8 m)	
Silt, clayey, light gray, weathers light brown, massively bedded; grades downward to a medium- to coarse-grained, sandy mud, rare pebbles in lower 1 foot; sharp basal contact commonly marked by thin (1/4 inch) ferricrete	11.0 (3.3)
Sand, muddy light brown, coarse-grained, quartz and feldspar with larger pebbles; clast supported; horizontally bedded; somewhat indurated by fines and iron oxide (limonite); sharp basal contact marked by 1 inch thick ferricrete	1. 5 (0.5)
Sand, silty, brown and light tan, very fine-grained; long, low angle trough cross beds defined by 1 inch thick beds of clayey silt (mud drapes) and massively bedded; small burrows common; grades to a basal 6 inch thick quartz pebble bed; some manganese staining	3. 5 (1.1)
Sand, quartz, silty, light brown to tan, fine- to medium-grained with interbeds of quartz pebbles defining trough crossbeds; small burrows common; ripple cross beds defined by opaque minerals or manganese staining; lower 1 foot very coarse-grained, feldspar rich sand with low angle trough cross beds; sharp basal contact ..	2. 5 (0.8)
Sand, pebbles, and cobbles, quartz, light brown, minor feldspar; horizontally bedded; clast supported; boulders to 11 inches at base; sharp basal contact	6. 5 (2.0)
Sand, pebbly, quartz, yellowish brown, coarse-grained; becomes coarser downward; trough cross beds; sharp basal contact	2. 5 (0.8)
Sand, silty, quartz, light tan; low angle trough cross beds; gray mud-lined vertical burrows, 1/8 to 1/4 inch in diameter and up to 4 inches long; ripple cross bedding at base defined by opaque minerals; sharp basal contact	3. 5 (1.1)

Sand and pebbles, quartz, light tan; horizontally bedded; gray clay balls and clay drapes up to 2 inches thick	6. 0 (1.8)
Sand, quartz, tan to light brown, medium- to coarse-grained; low angle trough cross bedding; dark brown liesegang stains	7. 0 (2.1)
Covered by slumped material to pit floor	11. 0 (3.3)

Section 3: Lone Star Pit, Shirley Plantation

The type section of the Shirley Formation is taken from the east-west face of the Lone Star borrow pit, 0.2 mile southwest of the intersection of State Highways 5 and 156, Charles City County, Westover quadrangle. The elevation at the top of the section is approximately 33 feet (10.1 m).

	Thickness Feet (Meters)
Shirley Formation (38 feet, average) (11.6 m)	
Mud, sandy, light brown; interbeds of light brown, fine- to medium-grained sand, up to 3 inches thick	10-18 (3.0-5.5)
Clay, gray; with some sand interbeds up to 3 inches thick; upper part of this unit cut out by channel sands to east	8 (2.4)
Sand and cobbles, tan to brown; unit thickness ranges from 0.5 to 25 feet	0.5-25 (0-76)
Aquia Formation (not measured)	
Sand, glauconitic, medium- to coarse-grained	

Section 4: Carvers Creek

A reference section of the Barkamsville Formation was measured on the east side of State Road 637 approximately 500 feet (152.4 m) north of the intersection with Carners Creek, Gloucester County, Saluda quadrangle. The elevation at the top of this section is approximately 75 feet (22.9 m). The measured exposure consisted of a 1 foot wide trench scraped through colluvium.

	Thickness Feet	(Meters)
Barhamsville Formation (25.5 feet) (7.8 m)		
Sand, muddy, pinkish brown and light brown mottling, very fine-grained; massively bedded	10.0	(3.0)
Clay, gray and pink; silt and sand, yellow-brown to red, very fine-grained; flaser to lenticular bedded; no burrows noted	4.5	(1.4)
Sand, yellow-brown to brownish gray, fine- to coarse-grained; medium-bedded; olive-brown clay pebbles are common; ½ inch thick gray clay beds or drapes and horizontal manganese stains up to 1 inch thick are rare	11	(3.4)
Yorktown Formation (upper 6.5 feet) (2.0 m)		
Clay, fine sandy, olive brown, massive; several percent glauconite, manganese stains lower 4 feet covered by allunium	6	(1.8)
Shell fragments, light gray; clay, sandy, light grayish-green, glaucomtic	0.5	(0.2)

APPENDIX II

GEOLOGIC SUMMARIES OF SUBSURFACE DATA

Explanation

W-1754	Numbers preceded by the letter "W" refer to those wells or borings whose samples are on file in the Division's repository.
B-58A	Numbers preceded by the letter "B" refer to those borings furnished by the Virginia Electric and Power Company.
m	Top of marsh deposits
Qtp	Top of Tabb Formation, Poquoson Member
Qtl	Top of Tabb Formation, Lynnhaven Member
Qs	Top of Shirley Formation
Qwb	Top of Windsor Formation (bay member)
Qwf	Top of Windsor Formation (fluvial-estuarine member)

Qm	Top of Moorings Unit
Tb	Top of Barhamsville Formation
Ty	Top of Yorktown Formation
Tc	Top of "Calvert" Formation
Tn	Top of Nanjemoy Formation
Tm	Top of Marlboro Clay
Ta	Top of Aquia Formation
Kp	Top of Patuxent Formation
TD	Total depth of well or boring in feet

All elevations are relative to a sea level datum.

W-1754	Elevation of top (in feet)	Thickness (in feet)	Remarks
Qm	103	30	
Ty	73	120	
Tc	-47	100	
Tn	-147	50 drilled	
TD 300			
W-2192			
Tb	65	20	
Ty	45	100	
Tc	-55	100	
Tn	-155	70 drilled	
TD 290			
W-3259			
Tb	88	60	
Ty	28	120	
Tc	-92	70	
Tn	-162	51 drilled	
TD 301			
W-3639			
Tb	120	60	
Ty	60	110	
Tc	-50	90	
Tn	-140	80	
Tm	-220	20	
Ta	-240	40	
Kp	-280	28 drilled	
TD 428			
W-3753			
Qm	103	30	
Ty	73	120	
Tc	-47	100	
Tn	-147	30 drilled	
TD 280			
W-3799			
Tb	115	70	
Ty	45	110	

Tc	-65	60	
Tn	-125	80	
Tm	-205	20	
Ta	-225	13 drilled	
TD 353			
W-3877			
Tb	88	40	
Ty	48	110	
Tc	-62	80	
Tn	-142	70	
Tm	-212	20	
Ta	-232	78 drilled	
TD 398			
W-3977			
Tb	123	60	
Ty	63	130	
Tc	-67	80	
Tn	-147	70	
Tm	-217	30	
Ta	-247	32 drilled	
TD 402			
W-6539			
Tb	89	45	interbedded, laminated sand and clay
Ty	44	17 drilled	brown-clay, sand and shell
TD 61			
W-6540			
Tb	100	55	laminated sand and clay
Ty	45	12 drilled	brown clay, sand and shell
TD 67			
W-6541			
Tb	124	63	dark red fine sand, clay flasers
Ty	61	64 drilled	brown clay, sand and shell grading down to dark gray clayey fine sand
TD 127			
W-6542			
Qtp	11	12 drilled	medium to fine sand
TD 12			
W-6543			
Qs	32	20	laminated clay, organics
Ty	12	7 drilled	sand and shell
TD 27			
W-6544			
Qwb	95	6	yellow-brown fine sand

Qwf	89	11	clay and sand
Tb	78	14	laminated sand and clay
Ty	64	16 drilled	brown clay, sand and shell
TD 47			
W-6545			
Qwf	81	24	clay grading down to sand and gravel
Ty	57	13 drilled	brown clay, sand and shell
TD 37			
W-6546			
Tb	85	38 drilled	laminated sand and clay
TD 38			
W-6547			
Tb	70	26 drilled	brown sand, clay laminations
TD 26			
W-6548			
Qs	33	48 drilled	laminated sand, clay, organics grading to muddy pebbly sand
TD 48			
W-6549			
Tb	100	39 drilled	laminated clay and fine sand
TD 39			
W-6550			
Tb	80	27	red brown sand, clay laminations
Ty	53	8 drilled	brown sandy clay
TD 35			
W-6551			
Qtl	16	24	silty sand grading down to sand and gravel
Qs	-8	3 drilled	clay
TD 27			
W-6552			
Qwf	68	16	clay grading down to coarse sand and gravel
Ty	52	24 drilled	brown clay, sand and shell
TD 40			
W-6553			
Qwb	97	12	gray sandy clay
Tb	85	19	dark red sand, clay flasers
Ty	66	2 drilled	dark brown clay

TD 33			
W-6554			
Qm	95	4	light brown sand
Tb	91	25	orange sandy clay, laminated
Ty	66	1 drilled	brown clay and shell
TD 30			
W-6555			
Tb	123	53 drilled	red-orange sand, clay laminations
TD 53			
W-6556			
Qm	115	8	gray clay
Tb	107	37	orange sand, clay laminations
Ty	70	3 drilled	green clayey silt and shell
TD 48			
W-6557			
Tb	95	35	interbedded red-brown sand and clay
Ty	60	3 drilled	brown clay, sand and shell
TD 38			
W-6558			
Qs	34	37	silt grading down to sand and gravel
Ty	-3	1 drilled	shell and sand
TD 38			
W-6559			
Tb	104	42 drilled	red sand and clay
TD 42			
W-6560			
Tb	102	45	red sand and clay
Ty	57	2 drilled	brown clay and shell
TD 47			
W-6561			
Tb	75	28	brown silty sand, clay laminations
Ty	47	2 drilled	clayey sand, shell
TD 30			
W-6562			
Tb	80	35	red clayey sand, clay laminations

Ty	45	12 drilled	brown clay, sand and shell
TD 47			
W-6563			
Qwb	84	6	gray silty clay
Tb	78	22	red sand, clay laminations
Ty	56	2 drilled	brown clay and sand
TD 30			
W-6564			
Tb	123	40 drilled	interbedded gray and brown clayey silt and sand
TD 40			
W-6565			
Qwb	90	10	gray clay over tan sand
Tb	80	17	red brown sand, clay laminations
Ty	63	4 drilled	brown clay
TD 31			
W-6566			
Qwb	97	7	brown silt grading down to sand
Tb	90	30 drilled	red sand, clay laminations
TD 37			
B-58A			
m	2	35	black organic silt
Qs?	-33	2 drilled	sand and silty clay
TD 37			
B-60			
m	2	5	organic sandy silt
Qtp	-3	6	fine to coarse sand and gravel
Qs	-9	41 drilled	clay grading down to sand and gravel
TD 52			
B-70			
Tb	95	51	red sand, clay laminations
Ty	44	32 drilled	brown clay, sand and shell
TD 83			
B-80			
Tb	118	73	interbedded sand and clay

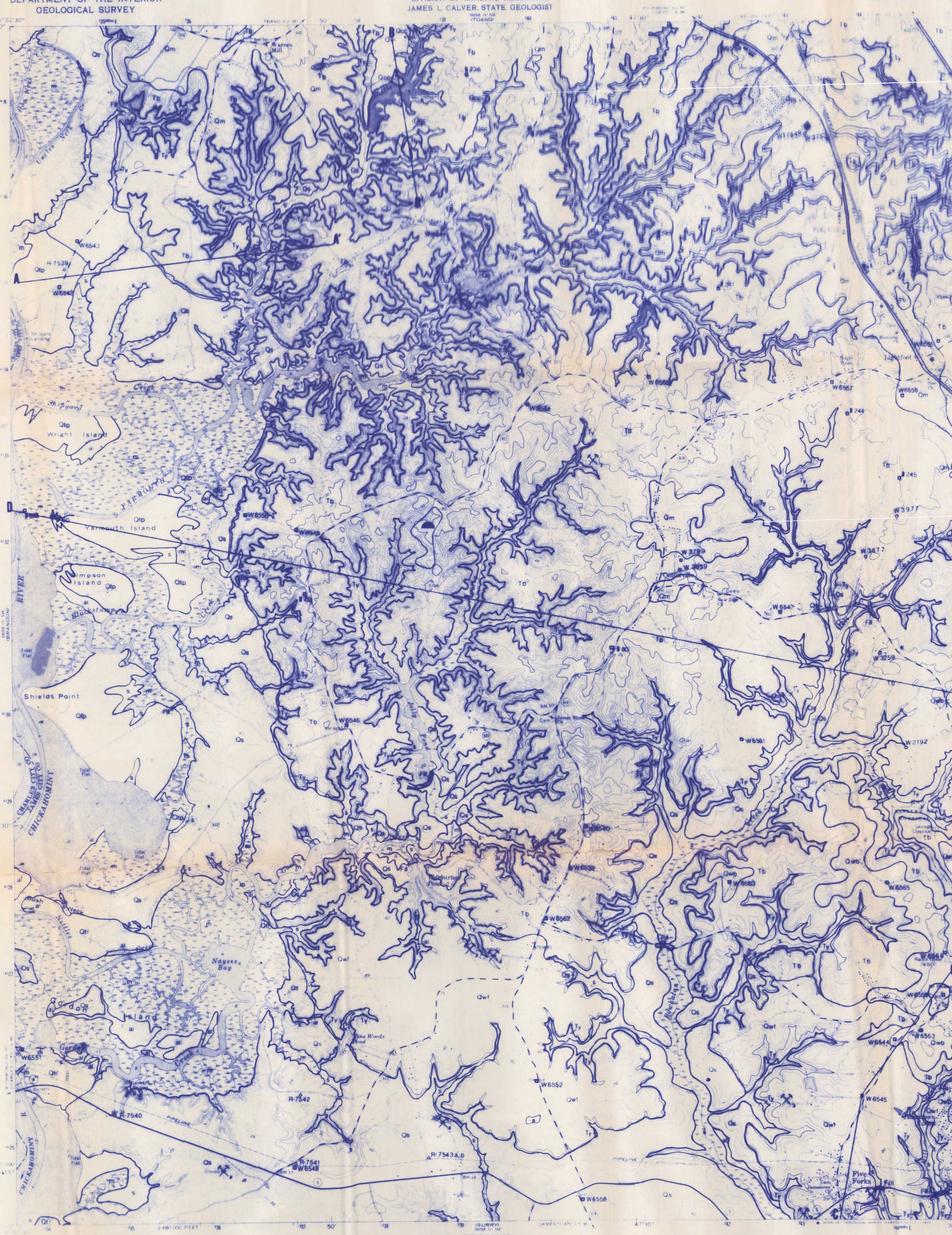
Ty	45	9 drilled	brown sand, clay, and shell
TD 82			
B-236			
Tb	100	32 drilled	red fine sand, clay laminations
TD 32			
B-237			
Tb	102	34	brown fine sand, gray clay
Ty	68	10 drilled	brown clayey sand
TD 44			
B-240			
Qm	105	23	light gray fine sand and clay
Tb	82	11	red fine sand, clay laminations
Ty	71	3 drilled	brown clayey silt
TD 37			
B-241			
Tb	106	33 drilled	red fine sand, clay laminations
TD 33			
B-244			
Tb	86	18	silt and clay
Ty	68	55 drilled	clay, shell and sand
TD 73			
B-245			
Tb	97	43	silt and clay
Ty	54	29 drilled	brown clayey silt, sand and shell
TD 72			

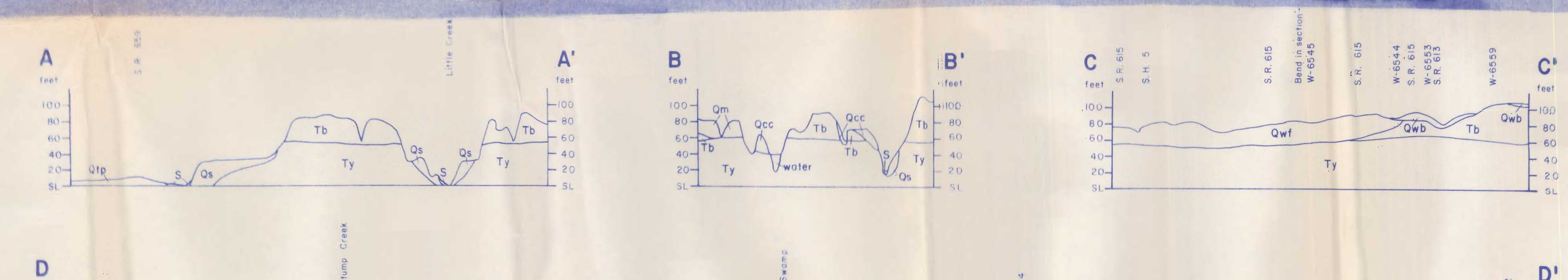
MUSRPT / R.B. 6/13/[illegible]

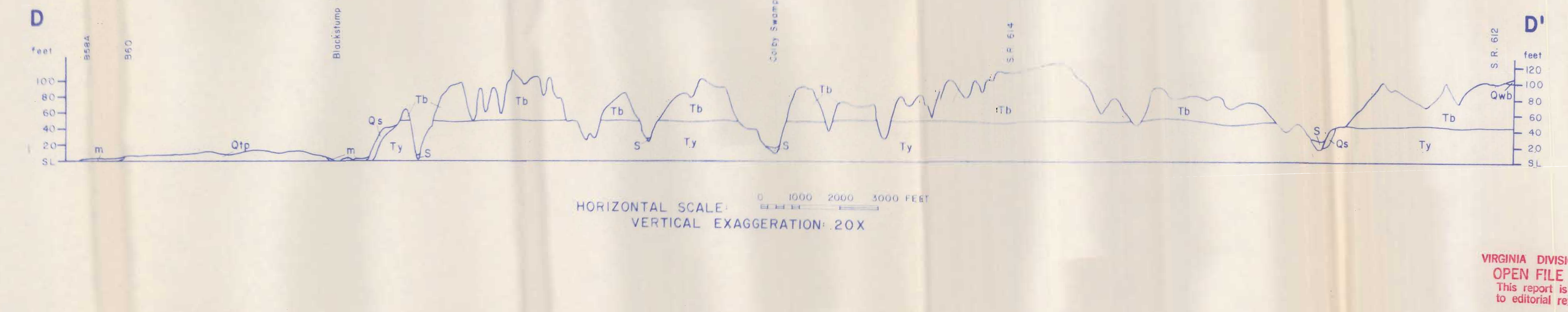
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST

NORGE QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)







HORIZONTAL SCALE 0 1000 2000 3000 FEET
VERTICAL EXAGGERATION 20X