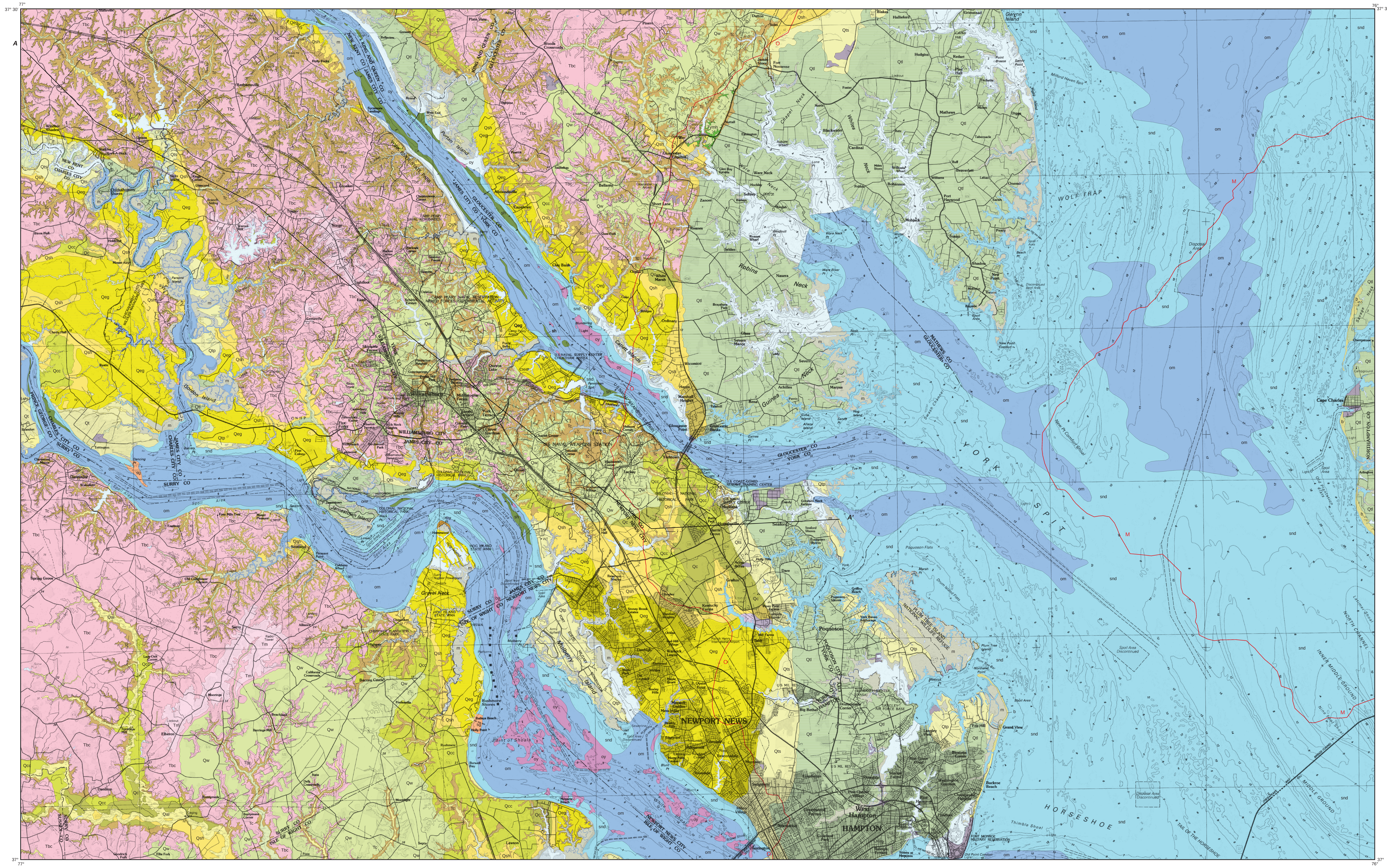
Virginia Department of Mines, Minerals and Energy

DRAFT - subject to revision

Open-File Report 2013-07
Geologic Map of the Williamsburg 30- x 60-minute quadrangle
Virginia Division of Geology and Mineral Resources

GEOLOGIC MAP OF THE WILLIAMSBURG 30- x 60-MINUTE QUADRANGLE, VIRGINIA

C.R. BERQUIST, JR.
2013

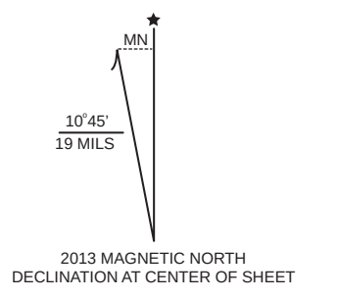


Basemap, Modified Plate Carree

lon: -76.5000000; lat: 37.2500000
k1=0.0174533; k2=0.0138929

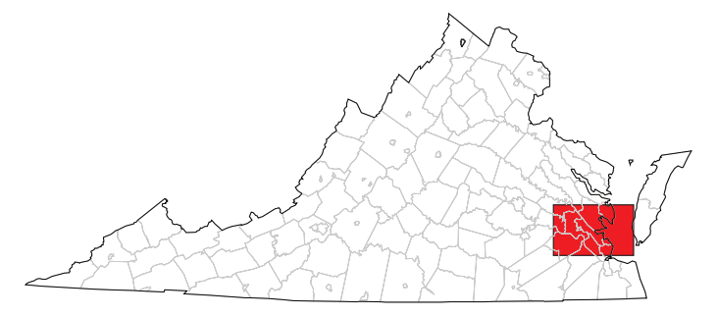
Williamsburg, Virginia 1:100,000 scale

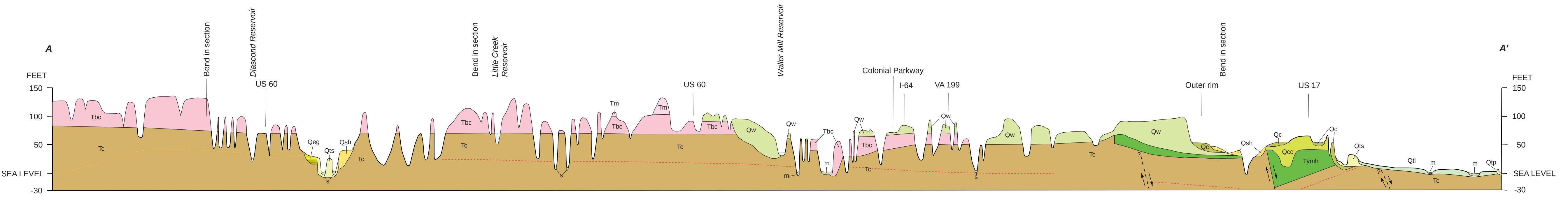
Digital Cartography by Rick Berquist



SCALE 1:100,000
3 MILES
5 KILOMETER

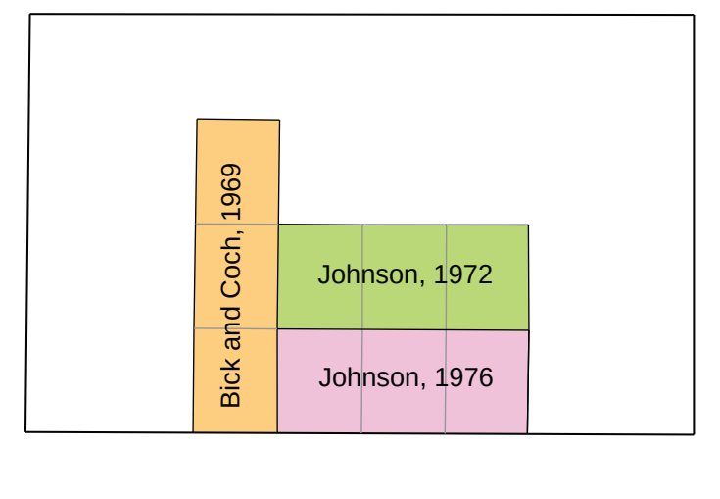
NATIONAL GEODETIC VERTICAL DATUM OF 1929
CONTOUR INTERVAL 5 FEET
Geology mapped from June 1999 to June 2013



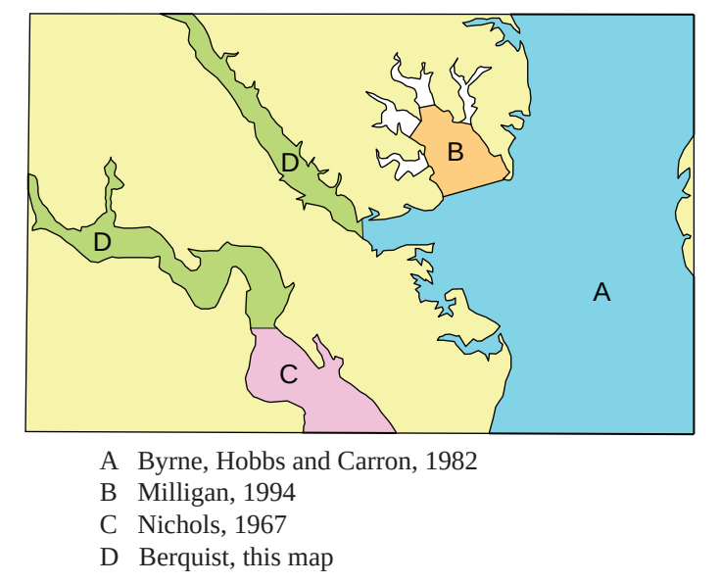


Interpretive cross-section
1. Vertical exaggeration = 83
2. ------- Yorktown - Eastover contact
3. Borings available as separate document

Index to previous geologic mapping



Index map for sources of bottom sediment data



- A Byrne, Hobbs and Carron, 1982
- B Milligan, 1994
- C Nichols, 1967
- D Berquist, this map

DESCRIPTION OF MAP UNITS

fill	**Fill** – Undifferentiated material used for fill; modified or disturbed material.
m	**Marsh sediment** – Organic-rich silt with fine sand and clay interbeds.
s	**Swamp sediment** – Peat and organic-rich sand, silt, and clay.
Qal	**Alluvium** – Pebbly sand and sand; silt; interbeds of silt and fine sand with organic matter common.
b	**Beach and dune** – Fine- to coarse-grained quartz sand, poorly to well-sorted; may include rip-rap adjacent to water.
sh	**Shelly organic mud** – Organic mud with abundant shell material; individual shells or massers of oyster, fossil *Rangia*, and other shells in contact with one another surrounded by mud; may contain areas of mostly unidentified shell in places.
oy	**Oysters** – Live oysters and oyster shell; substrate may be mud or sand, shells are typically in contact with one another and forming mounds or reefs; may include some fossil shell.
peat	**Peat** – Decomposed plant remains commonly mixed with sand or mud; dark brown; may include roots of inundated marsh and swamp plants.
om	**Organic mud** – Organic-rich clay and silt; black, dark gray, or dark brown; consistency ranges from fluid or soupy to somewhat firm.
snd	**Sand** – Fine- to coarse-grained sand, may include granules, small pebbles, and organic material; gray in channel bottoms or brown adjacent to cliffs, beaches, and active erosion; along shorelines, it transitions to adjacent muddy channels over tens of feet by becoming gradually more muddy and less sandy; contacts that shift with time are shown with a zig-zag pattern.
sg	**Sand and gravel** – Fine- to coarse-grained sand, granules, pebbles, and cobbles; commonly brown; typically found adjacent to cliffs or exhumed Pleistocene-age deposits.
Qt	**Tabb Alloformation, undivided** – Clayey fine- to coarse-grained sand.
Qts	**Tabb Alloformation, Sedgefield Member** – Pebbly sand, sand and clayey silt.
Qtl	**Tabb Alloformation, Lynnhaven Member** – Silt, fine sand, and clay.
Qtlp	**Tabb Alloformation, Lynnhaven and Poquoson Members, undivided** – Fine to coarse sand, clayey sand, and silt.
Qtp	**Tabb Alloformation, Poquoson Member** – Sand, silt, and clay.
Qeg	**Elsing Green Alloformation** – Slightly muddy fine- to medium-grained sand that grades downward to coarse-grained sand, granules and pebbles.
Qsh	**Shirley Alloformation** – Pebble to boulder sand, sand, silt, and clay; scattered peat and organic silt beds.
Qc	**Chuckatuck Alloformation** – Pebbly sand, sand, silt, and clay.
Qcc	**Charles City Alloformation** – Pebble to boulder sand, interbedded cross-bedded sand and silt, and silt and clay.
Qw	**Windsor Alloformation** – Clayey, fine- to coarse-grained sand overlying fine- to coarse-grained sand with pebbles.
Tm	**Moorings Unit of Oaks and Coch (1973)** – Massively bedded sand or clay.
Tbc	**Bacons Castle Formation** – Interbedded sand, silt, and clay, massively bedded and lenticular to flaser bedded; basal pebbly to coarse sand common.
Tc	**Chesapeake Group, Yorktown and Eastover Formations, undivided** – Interbedded shelly fine-grained sand, clayey fine-grained sand and silty fine- to very fine-grained sand. Moore House member**:** Clayey silt with very fine grained sand grading downward to muddy fine- to coarse-grained sand with granules; glauconite common.

MAP SYMBOLS

Stratigraphic Contact- approximately located

U
D
Normal Fault Contact- not exposed at surface; U = upthrown block, D = downthrown block

O
M
Chesapeake Bay Imapact Structure
O - Outer Rim, M - Margin of central crater
(Horton, Powars, and Gohn, 2005)

INTRODUCTION

Mapping of the Williamsburg 30- by 60-minute quadrangle began in 1999, in response to rapid growth along the I-64 corridor of the York-James Peninsula. This effort incorporated the early detailed mapping by Bick and Coch (1969) and Johnson (1972, 1976), with some modification of their work. The regional stratigraphy has been simplified into a consistent nomenclature, particularly within the Pleistocene map units. This work is not complete. Mapping in the Quinton quadrangle, east of Richmond, in early 2013 confirmed that nearshore sediments of late Yorktown age (Cold Harbor Member) are traceable into the western part of this map area; here they comprise the lower part of the Bacons Castle Formation.

A few miles to the west, the Providence Forge Fault, a high-angle normal fault, is mapped roughly south to north from the James River to the Pamunkey River. This fault is likely syndepositional with the Rushmere Member of the Yorktown Formation with a throw of about 130 feet (down to the east). The effect of faulting on the Yorktown-Eastover contact is evident in the cross-section. Drilling in August 2013 verified westward dipping contacts earlier observed by Johnson (2007), and delineated a rotated fault-block (see cross-section) related to deformation in the vicinity of the Chesapeake Bay Impact Crater. This deformational event is likely syndepositional to the Moore House Member. Similar faulting was found in eastern Gloucester County. Additional radial and listric normal faults are likely to be found in this highly urbanized part of the lower York-James Peninsula.

Environmental hazards within the map area include acid forming soils, sinkholes, shoreline erosion, and inundation caused by rising sea level. Acid forming soils result from excavation and exposure of the Eastover Formation. This formation has been mapped in some detail from the Chesapeake Bay to Richmond. Numerous areas show the deleterious effects of low pH runoff, such as rusted-out highway signs, drain grates, and guardrails, dissolution and staining of concrete, and the inability for re-vegetation without mitigation. Shoreline erosion is common within the map area. Global sea level rise coupled with local subsidence will exacerbate this problem.

Mapping bottom sediments in rivers is a recent addition to the Williamsburg quadrangle project. This effort has increased the value of the geologic map in that aquatic habitats have been defined and submerged economic resources have been delineated. Rehabilitation of the American sturgeon relies on identification and protection of hard bottom areas with sparse sedimentation that serve as spawning grounds. Bottom areas mapped as shelly organic-rich mud are being dredged in the James River as a source for oyster shell to be used in rebuilding depleted oyster reefs downriver. These artificial reefs in higher salinity water will provide a new habitat for oyster spat to recolonize and rebuild productive oyster reefs.

EXPANDED EXPLANATION

CENOZOIC TO PLEISTOCENE FORMATIONS

Lower Chesapeake Group, Eastover Formation

The Chesapeake Group was defined by Dall and Harris (1892) to include all formations of Miocene age from the Chesapeake Bay to Florida. Ward and Blackwelder (1980) defined the Eastover Formation and its two members, the Claremont and Cobham Bay, from exposures on the James River in Surry County, Virginia, and placed them in the Lower Chesapeake Group. Prior to 1980, the Saint Marys Formation was mapped locally to unconformably underlie the Yorktown Formation (Bick and Coch, 1969); the Saint Marys sediments are now recognized to be Eastover. For this map, both Lower and Upper Chesapeake Group sediments have been consolidated into the Chesapeake Group (Tc). We chose not to map the Eastover for the following reasons: 1) at 1:100,000-scale, it was not feasible to show the thin outcrop; 2) Lower Yorktown (Rushmere and Sunken Meadow members) shelly sands are lithologically similar to Upper Eastover (Cobham Bay) shelly sands; and 3) dissolution of shell material is very common in outcrop and borings; this removal of guide fossils (*Isognomon*) makes interpretation and assignment to a formation most difficult.

Consistent lithologic characteristics have been observed in Chespeake Group sediments through recent detailed mapping in the York-James Peninsula from Richmond to the Chesapeake Bay. This work includes almost 1,000 auger borings and supports the existing nomenclature with the following lithologic observations: 1) the Cobham Bay sediments, in the absence of fossil material, are composed of slightly muddy to muddy, dark-bluish-gray, very fine- to fine-grained sand that commonly contains fine-grained sand-filled burrows, pyrite, muscovite, and 1-3% heavy minerals. This sediment contrasts with subtle difference to the overlying fine- to medium-grained Yorktown sands; 2) the Claremont Manor sediments are somewhat shelly, dark greenish-gray, very fine grained mud (compact and sticky), that commonly contains dark gray fine-grained sand-filled burrows, and some pyrite. Acid-forming soils commonly form on exposure of the Eastover sediments to the atmosphere. The age of the Eastover is Late Miocene. The thickness of this formation above sea level ranges from absent to about 50 feet in the western parts of the map area.

Upper Chesapeake Group, Yorktown Formation

The Yorktown Formation was named by Clark and Miller (1906) for exposures on the York River cliffs at Yorktown, York County, Virginia. After numerous modifications and age determinations, Ward and Blackwelder (1980) assigned the Yorktown to the Upper Chesapeake Group and defined four members. Many outcrops and most borings encounter little if any shell material. In the absence of fossil evidence to the contrary, keeping the current nomenclature seems appropriate. The following lithologic characteristics were observed while mapping between Richmond and the Chesapeake Bay: 1) the Sunken Meadow and Rushmere Members are shelly, olive to bluish-gray, fine- to medium-grained sands with 1-2% heavy minerals and glauconite; 2) the overlying Morgarts Beach Member is a bluish gray, very fine grained sandy clayey silt that commonly contains thin beds of disarticulated *Mulinea*. In the Yorktown area, 1-inch- to 1-foot-thick beds of shell hash occur sporadically.

The Moore House Member was named for exposures on the York River at Moore House, Colonial National Historical Park. Much of the upper part is covered, but borings have found that this member is quite extensive across the map area. Some sediments formerly mapped as "amended" Sedley Formation have been assigned to the Moore House. The Sedley Formation was informally named by Moore (1956) for sediments that overlie the Yorktown Formation and underlie the Bacons Castle Formation. Coch (1965) formalized the name; its use was retained in subsequent mapping (Coch, 1968; Bick and Coch, 1969; Oaks and Coch, 1973). Johnson and Berquist (1989) first suggested that the Sedley be abandoned. Recent borings at the type and reference sections confirmed that sandy muds assigned to the Sedley are Morgarts Beach sediments and as such, abandonment of the name is required.

A thin (less than 10-foot-thick) but widespread interval of sandy clay-silt below the Bacons Castle Formation and above the Yorktown Formation can be traced from Roxbury (west of Providence Forge) to Yorktown and from Gloucester to Dendron. It is distinct and not to be confused with weathered and non-fossiliferous Sunken Meadow and Rushmere sediments, the Morgarts Beach Member of the Yorktown, or the Claremont Manor Member of the Eastover Formation. This layer was traced via borings eastward to the Moore House type section. The shell hash or coquina at Cornwallis Cave is laterally equivalent and when deeply weathered is the source for much of the clay found locally.

In addition to faunal content, the Moore House is composed of a sandy clayey-silt (mud that is yellowish brown to strong brown in color. The sand fraction coarsens downward from very fine-grained sand to granules. This sequence is typically 7 to 10 feet thick. Coarse sand and granules are commonly very well-rounded. Glauconite is common in the lower part of the sandy mud. Wavy bedding is rarely preserved as extensive bioturbation has homogenized the sediment. In three places, drilling has encountered a sequence of white to yellowish gray, fine- to coarse-grained sand with gray clay flasers below the typical sandy mud (and above shelly Rushmere/Sunken Meadow sediments). Some weathered and cemented shell fragments are rarely found.

The thickness of the Yorktown ranges from absent (where removed during sea level lowstands and subsequent deposition of estuarine terraces) to approximately 130 feet. This abnormal thickness occurs east of the north-south trending Providence Forge Fault, a few miles west of the map area. The age of the Yorktown was previously estimated to be Early Pliocene. Recently, however, *Chesapecten* and *Ostrea* from an exposure at Tutters Neck Pond (Rushmere?) yield preliminary strontium ages of 2.5 ± 0.6 Ma (Paul Hearty, personal communication).

Bacons Castle Formation

The Bacons Castle Formation is perhaps the most widespread surficial map unit in the Virginia Coastal Plain. It was informally named by Coch (1965, 1968) where he derived the name for the community of Bacons Castle in Surry County. His type sections for two facies are exposures in road cuts in Claremont and Surry quadrangles, also in Surry County. More recently, Ramsey (1988) provided a comprehensive study of the Bacons Castle and defined two members, the Varina Grove and Barhamsville. Although this map does not discriminate between these two members, Ramsey's nomenclature redefinition is most reasonable. The Varina Grove member is composed of reddish brown, cross-bedded sand and gravel that grade upward into mud or muddy sand. Lenticular to flaser bedding is common and basal clasts usually contain cobbles. The Barhamsville member is composed of variable amounts of sand and mud. Colors range from reds and browns to light gray. Lenticular to flaser bedding is also common. Within the map area, thickness ranges upward to about 80 feet. The Bacons Castle is thought to be Late Pliocene in age.

Moorings Unit

The informal "Moorings unit" was defined by Oaks and Coch (1973) and carried forward in the mapping of Mixon and others (1989) and the most recent geologic map of Virginia (1993). It originally represented the central and western facies of the Elberon formation (Coch, 1965) (and thus equivalent to the currently used Windsor Formation), but further work indicated that Moorings is older. Oaks and Coch (1973) provide a description of a core in Runnymede quadrangle that they use to define the Moorings (Section E, Appendix I). It is described as 24 feet of fine-grained sand with some silt. The contact with the underlying Bacons Castle is sharp. Mapping for this project supports their definition and adds two additional borings as reference sections, 2008273-1 in Surry and 2010028-3 at Elberon, Dendron quadrangle. Similar contacts were found at about 105 feet in these borings. The westward extent of thin Moorings sediment is very difficult to discern from underlying Bacons Castle sediments; both are muds or muddy sands. Note, however the distinct difference in the degree of dissection above and below 115 feet westward of the Surry Scarp on 7.5-minute topographic maps. Land surface above 115 feet is more dissected than land (flats) below 115 feet. Possibly there are very thin, eroded, and relict Moorings marsh muds and muddy sands underlying these flats.

Windsor Formation

The Windsor was named by Coch (1968) for a sand, silt, and clay sequence in a boring near the town of Windsor, Isle of Wight County. It has commonly been mapped as a sandy mud grading downward to muddy coarse sand and gravel. This was noted years ago: "The Elberon [Windsor] is a massive unit 10 feet to 20 feet thick that exhibits no sedimentary structures. It is basically sand, but contains much silt and clay locally. On the whole, the Elberon [Windsor] resembles a completely homogenized mixture of the various facies of the Bacons Castle. In some places the basal contact is distinct, in others somewhat gradational (Department of Geology, 1967). A more accurate description of Windsor sediments has proven to be problematic in the map area. For example, the Berryman Sand Pit (Surry Quadrangle) shows massive (bioturbated) gray and light pink mottled muddy sand grading downward to fine- to coarse-grained sand over a 15-foot interval. These basal sands continue westward and correlate with sand in the lower part of the Bacons Castle Formation. In the map area, the Windsor appears to be mostly reworked Bacons Castle sediment that underlies a prominent morphologic setting. The Windsor lies below the Surry Scarp on flats between about 75 and 90 feet in elevation and below a scarp toe of 95 feet. Given the problematic lower sands that are likely Bacons Castle sediments, thickness ranges upward to about 15 feet in the map area.

Charles City Alloformation

The Charles City was named for a thick sequence of gray to light brown clayey silt, sands, pebbles and cobbles exposed adjacent to the James River in Charles City County, Virginia (Johnson and Berquist, 1989). These sediments typically lay below flats that range from 60 to 75 feet in elevation and below scarps where the toe is between 75 and 80 feet. Thickness ranges from 65+ feet to a feather edge. In the Yorktown area, gray, slightly muddy fine- to medium-grained sands with flaser and lenticular bedding are common. Sediments of the Charles City follow the typical marine transgressive sequence in estuaries by grading upwards from coarse pebbly sand to lenticular-bedded clay-silt. In conjunction with morphologic setting, Izagora loam soils are somewhat correlative to the Charles City; Slagle fine sandy loam soils are also commonly found (USDA 2010c and d). The age of the Charles City is uncertain, but older than the Chuckatuck.

Chuckatuck Alloformation

The Chuckatuck was named for an upward-fining sequence of sediments in Isle of Wight County, Virginia by Johnson and Berquist (1989). Pebbly or coarse-grained sand typically grades upward to clayey sand or sandy clay. Organic-rich mud and muddy sand may also be encountered having been deposited in marsh and swamp environments. Sediments are found below flats ranging from 50 to 55 feet in elevation and below scarps where the toe is approximately 58 feet. The age is uncertain, but older than the Shirley (~400,000y). It is possible that these sediments relate to a sea level highstand around 950,000 years ago, marine oxygen isotope stage 25.

Shirley Alloformation

The Shirley was named for deposits exposed in borrow pits at Shirley Plantation, Charles City County, Virginia (Johnson and Berquist, 1989). There it is composed of a basal gravelly sand grading upward into a fine- to coarse-grained sand that is overlain by clayey-silt (mud) or muddy sand. In the Yorktown quad area at boring location 94298-1, the Shirley is light gray silty clay grading downward to pebbly muddy sand, 8 feet thick, that represents estuarine fill adjacent to Beaverdam Creek. Correlative soils, in part, include Bethera and Chickahominy silty loams. Shirley sediments were deposited during a marine transgression about 400,000 years ago (marine oxygen isotope stage 11). In estuaries it conforms to the typical upward-fining sequence, but in more coastal areas such as Gloucester Point it is mostly composed of sand. Shirley sediments underlie flats between about 35 to 40 feet in elevation and below a scarp toe of about 48 feet. Its thickness ranges from a feather edge to over 60 feet.

Elsing Green Alloformation

The Elsing Green Alloformation was named for sediments that lay beneath a flat at 30 feet elevation and are bounded by a prominent scarp toe at approximately 38 feet, adjacent to the Pamunkey River, Tunstall 7.5-minute quadrangle west of this map area (Gilmer and Berquist, in progress). There, slightly muddy fine- to medium-grained sand grades downward to coarse-grained sand, granules and pebbles with about 2% heavy minerals including phosphate locally. The Elsing Green sediments are typically sandy throughout the map area. Thickness ranges up to 15 feet but can be much thicker in filled paleochannels in the York and James Rivers.

Rowan Lockwood (personal communication) calculated an age of about 125,000 y based on amino acid work on *Mercenaria* and *Ostrea* in correlative deposits adjacent to the Piankatank River. Hancock, Gilmer, and Berquist (in preparation) found a similar cosmogenic age on sand at Elsing Green. This age correlates to marine oxygen isotope stage 5e.

A local sea level high-stand at just below 40 feet in elevation may not everywhere have a prominent shoreline (scarp) to guide the delineation of sediment (formation) contacts. This is a particularly acute problem to resolve in urbanized settings such as in the City of Newport News. However, soil maps do show somewhat consistent changes in soil types above and below 35-40 feet elevation. In addition, arcuate ridges defined by the 30-foot contour are found east of Tabb, on the Newport News North 7.5-minute quadrangle (Slagle fine sandy loam, USDA, 2010c) and are likely older than Tabb Sedgefield sediments. Mapping for this project considered the distribution of Slagle, Bethera, Craven and Altavista soils (USDA 2010 c and d) in conjunction with the morphologic setting to support mapping the Elsing Green in the Newport News area.

On the Hog Island peninsula, there is a clear demarcation of the Elsing Green based on morphology and soils. In Surry County, Newflat silt loam and Ackwater silt loam commonly form on Qeg sediments (USDA 2007); in Isle of Wight, Peawick silt loam commonly forms on Qeg sediments (USDA 2010b); In James City County, Peawick and Chickahominy silt loam are common on Qeg sediments (USDA 2010c).

Tabb Alloformation

The Tabb Formation was named by Johnson (1976) and was subdivided into three members. They are the Sedgefield, Lynnhaven and Poquoson Members in decreasing age and surface elevations. The members are thought to correlate with marine oxygen isotope stages 5c, 5a, and 3 respectively.

In its type section in Newport News, the Sedgefield is a fossiliferous, gray to yellowish-brown, cobbly clayey, medium- to coarse-grained sand grading upward to clay or clayey sand, and is about 11 feet thick. Fossils include *Mercenaria mercenaria* and *Crassostrea virginica*. In the Chickahominy River, the Sedgefield is commonly sandy and typically contains up to 2 % heavy minerals. The Sedgefield is found on flats between 20 to 25 feet in elevation and below a scarp toe of about 28 feet.

The Lynnhaven was named for exposures in a drainage ditch at Butler Farm in Hampton. It is composed of a basal gravelly sand grading upward to bluish-gray sandy clay or clayey sand. In the Chickahominy River, the Lynnhaven is commonly sandy, and typically contains up to 2 % heavy minerals. On the Eastern Shore, the Lynnhaven is slightly muddy fine- to medium-grained sand grading downward to medium- to coarse-grained sand, with granules and pebbles. There, it correlates with the Nassawadox Formation, Occohannock Member of Mixon (1985). The Lynnhaven sediments underlie flats between about 6 to 15 feet in elevation and below a scarp toe of about 18 feet.

The Poquoson is defined by a hand-auger boring in the city of Poquoson, Hampton 7.5-minute quadrangle (Johnson, 1976). On this map, it is restricted to areas with ridge and swale morphology at elevations below 10 feet and to some low-lying nearby areas. On Plum Tree Island, it is dark gray silt grading downward to a light gray to reddish brown medium- to coarse grained sand with pebbles and cobbles and is about 15 feet thick. Heavy minerals compose about 3 % of the formation. On Mulberry Island, the ridges are capped with fine sandy clay. On Jamestown Island, the Poquoson appears to be a sandy clay or clayey sand, grading into the underlying Lynnhaven sediments.

BOTTOM SEDIMENT SAMPLING

Bottom sediment mapping for this project began in 2007 in the Chickahominy River and expanded to the James River within the Surry 7.5-minute quadrangle. This new mapping, shown on the January 2013 version of the Williamsburg sheet covered the York River upstream from the Coleman Bridge, the James River upstream of Mulberry Point, the Chickahominy River downstream from Walkers dam, and the navigable part of Diascund Creek. A map from Nichols (1978) was used for the lower James River; a map adapted from Milligan (1994) was used for Mobjack Bay. Sediment distribution for the rest of the Bay was adapted from Byrne, Hobbs and Carron (1982); the 4-phi contour line separating mud from sand was taken from their Figure 29. Areas of no data are represented by "water". Data from Haven, Whitcomb, and Kendall (1981) were not included in this version of the map, but might be incorporated in the future along with additional sidescan and sampling.

The survey involved making multiple transects across the rivers, stopping at various intervals and recording the station location with GPS. At each station, a grab sample of the bottom sediment was collected with small "clamshell" or PVC pipe devices. Penetration of the bottom ranged up to about 6 inches. Map units evolved naturally over time with multiple encounters of similar bottom sediments. Contacts between observed materials were sketched on 7.5-minute topographic maps in the field and later modified in a GIS setting aided by plotted station locations. In 2009 we began using a Humminbird 1197c side-imaging sonar on loan from VMRC/VIMS and later replaced with our own 1198c. The sonar imagery was used in combination with sediment samples to make an interpreted map. In addition to samples, bottom material was interpreted by dragging samplers (or a chain) in conjunction with observing different imagery patterns. At each station, a "snapshot" of the imagery was taken; water depth, lat/long, course direction, time were also recorded by the Humminbird. Our tracklines evolved to a zigzag pattern of approaching shorelines (typically sandy bottoms), then heading to deeper water where black muds typically would be encountered. Linear trends of sediment types were extrapolated between traverses. As confidence of interpretation of the imagery grew, fewer grab samples were collected.

Because this geologic map is regional in scope, some bottom sediment details have been omitted and some areas were not traversed in our survey. A more detailed survey might include additional map units such as brown sand, gray sand, sand and shell, significant man-made objects, and discriminate between different shell types (live oyster, oyster shell, *Rangia* both live and shell only).

The bottom sediments are continuously moving. For example, a brown sandy shoal was found at the south side of the mouth of Queen Creek several years ago. Recent sampling found mud covering this sand in most places. Elongate bodies of sand marginal to channels gradually grade into mud at up- and down-stream ends; contacts with central channel mud are typically abrupt. Sand waves up to 1 meter in height are common between Hog Island and Jamestown Island and indicate active sand transport, some of which appears to fill in the dredged Goose Hill Channel. This regional map is a snapshot in time of generalized bottom sediment type; contacts will change with time.

ACKNOWLEDGEMENTS

This map was prepared in cooperation with the United States Geological Survey under the National Cooperative Geologic Mapping Program - STATEMAP Component 20122013 Agreement G11AC20236. Appreciation is extended to Jack Travelstead of the Virginia Marine Resources Commission for providing a Humminbird side-scan sonar to use for bottom sediment mapping; David Stanhope and Kory Angstadt of Virginia Institute of Marine Science provided technical assistance on use of the sidescan sonar. Amy Gilmer, Aaron Cross, Pete Berquist, Lee Bristow, Curt Romanchok, Dennis Feeney, and Hannah Shepherd provided assistance in the field.

The fault identified as "PP1731" was taken from McFarland, F.R. and Bruce, T.S., 2006, The Virginia Coastal Plain Hydrogeologic Framework, U.S. Geological Survey Professional Paper 1731. The top of the Exmore clast confining unit drops in elevation (feet below MSL) from -545 to -634 between 2 wells separated horizontally by about 2000 feet.

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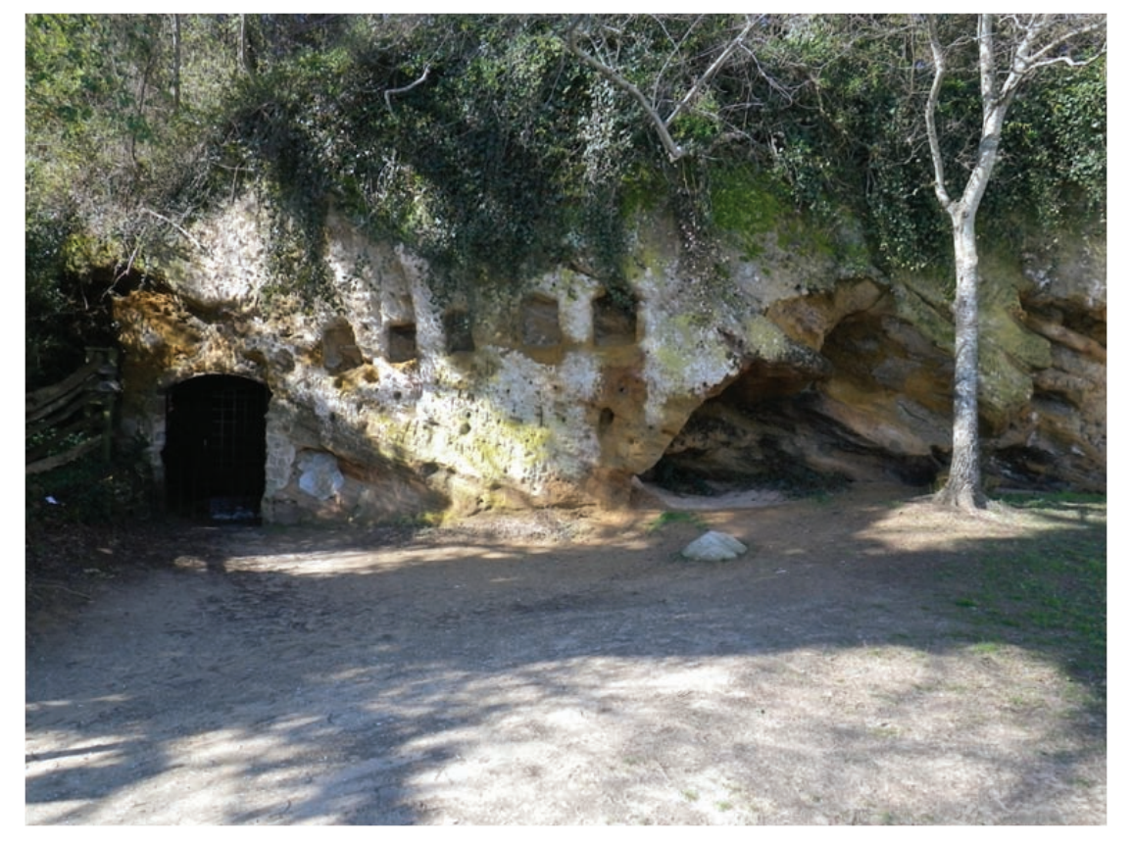

Figure 1. Shell hash – coquina, Moore House Member of the Yorktown Formation, forming "Cornwallis Cave" at Yorktown.

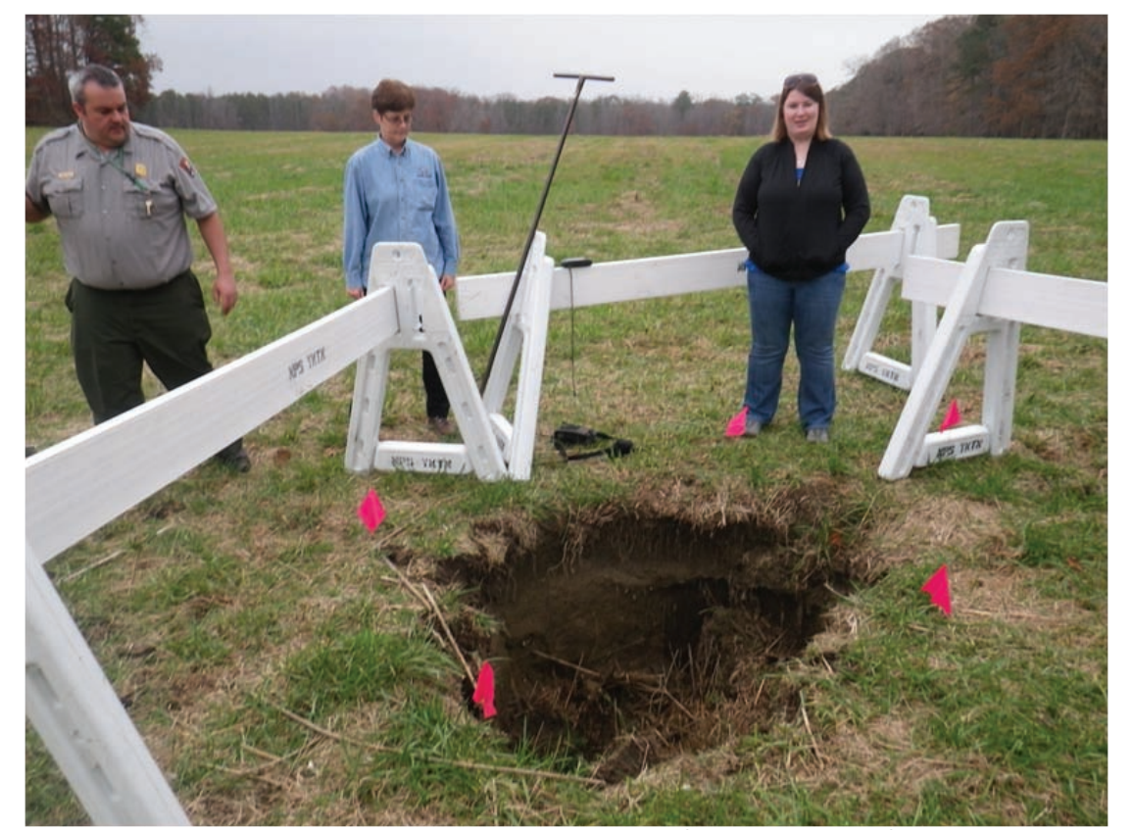

Figure 2. Sinkhole in Colonial National Historical Park battlefield. Dissolution of underlying shells in the Yorktown Formation forms a void over time, eventually overlying sediments collapse into the void. This is a common occurrence within the map area and in other places in the southern part of the Virginia coastal plain.

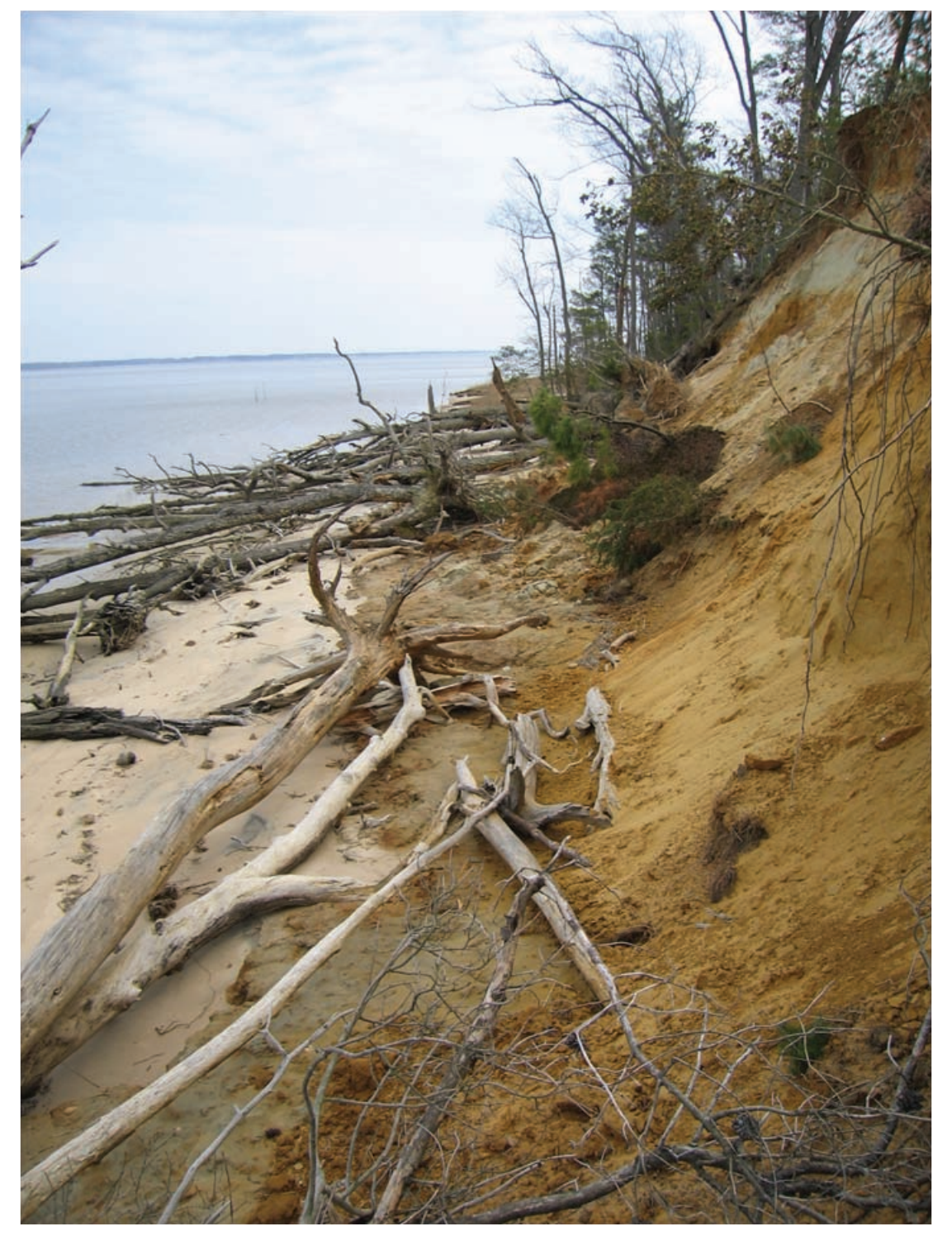

Figure 3. Continuous shoreline erosion at York River State Park.

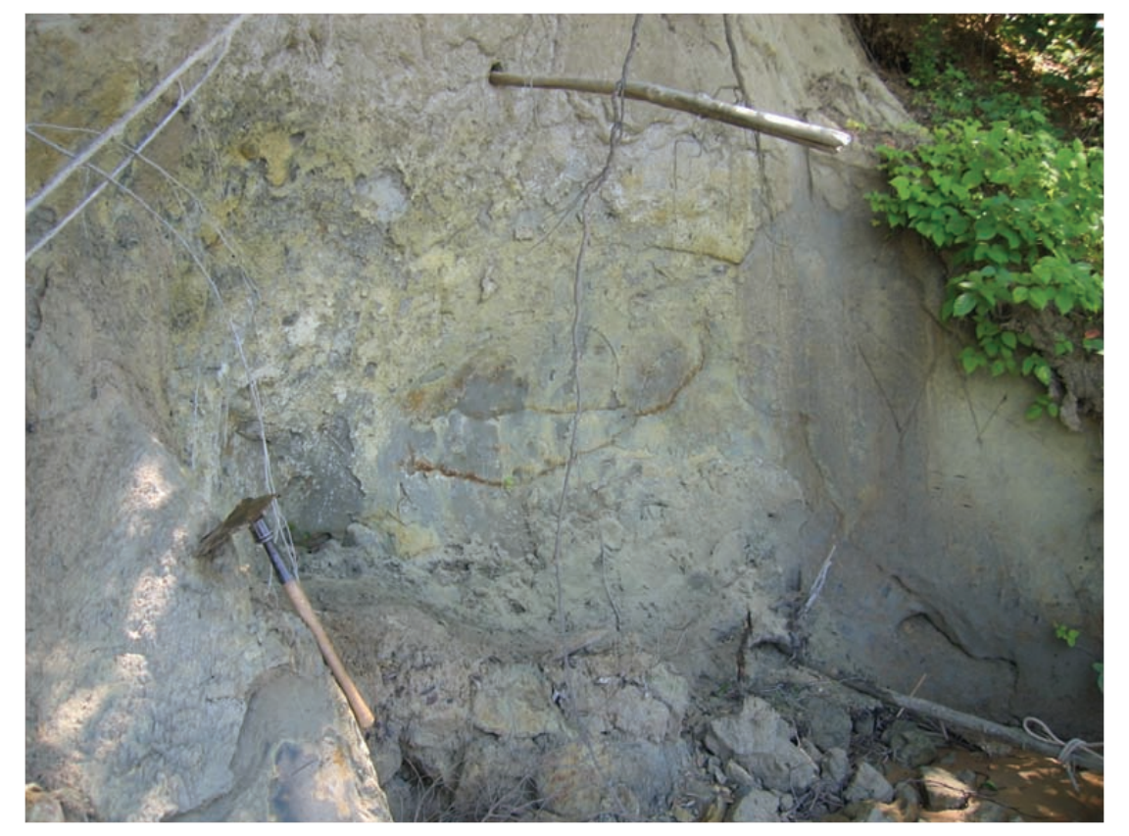

Figure 4. Yellow (sulphur) coating on outcrop of Eastover Formation, Claremont Manor Member from weathering of pyrite results in acid runoff with low pH; Fishhole Landing, Chickahominy River.

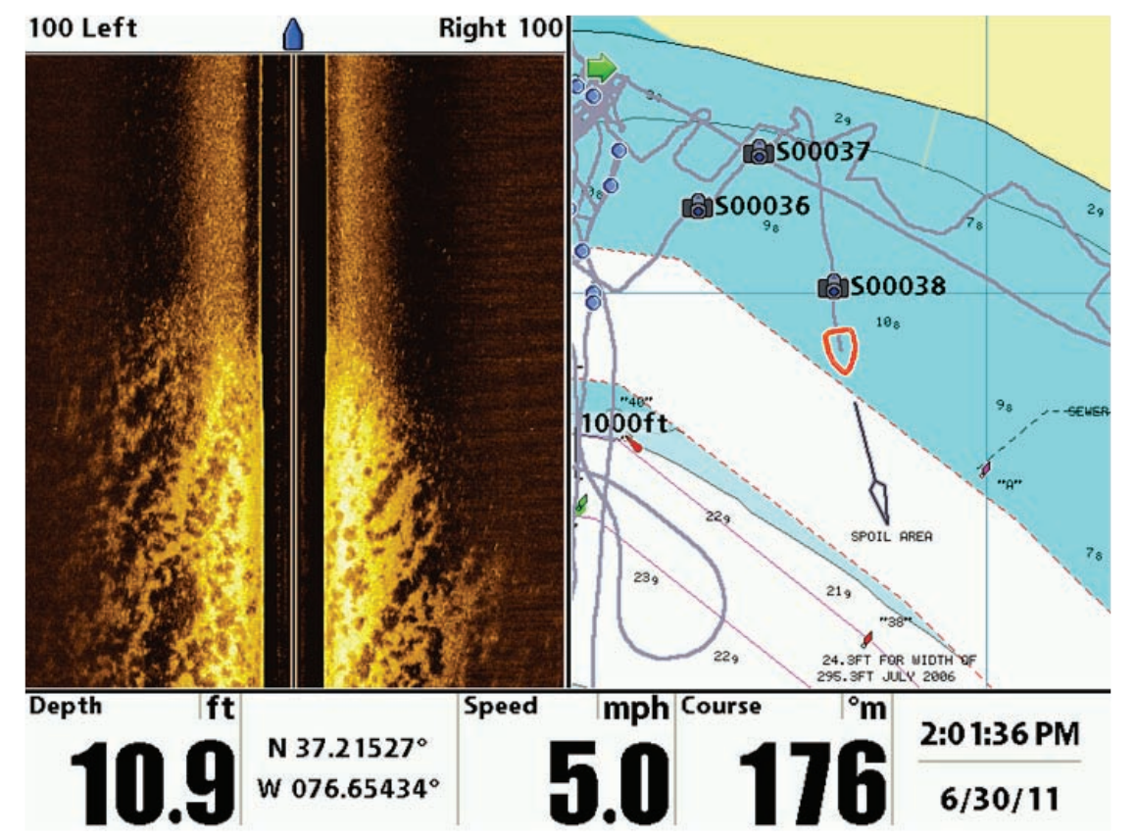

Figure 5. Sidescan sonar image and chart showing transition from shelly organic mud to firm mud, James River offshore of Kingsmill.

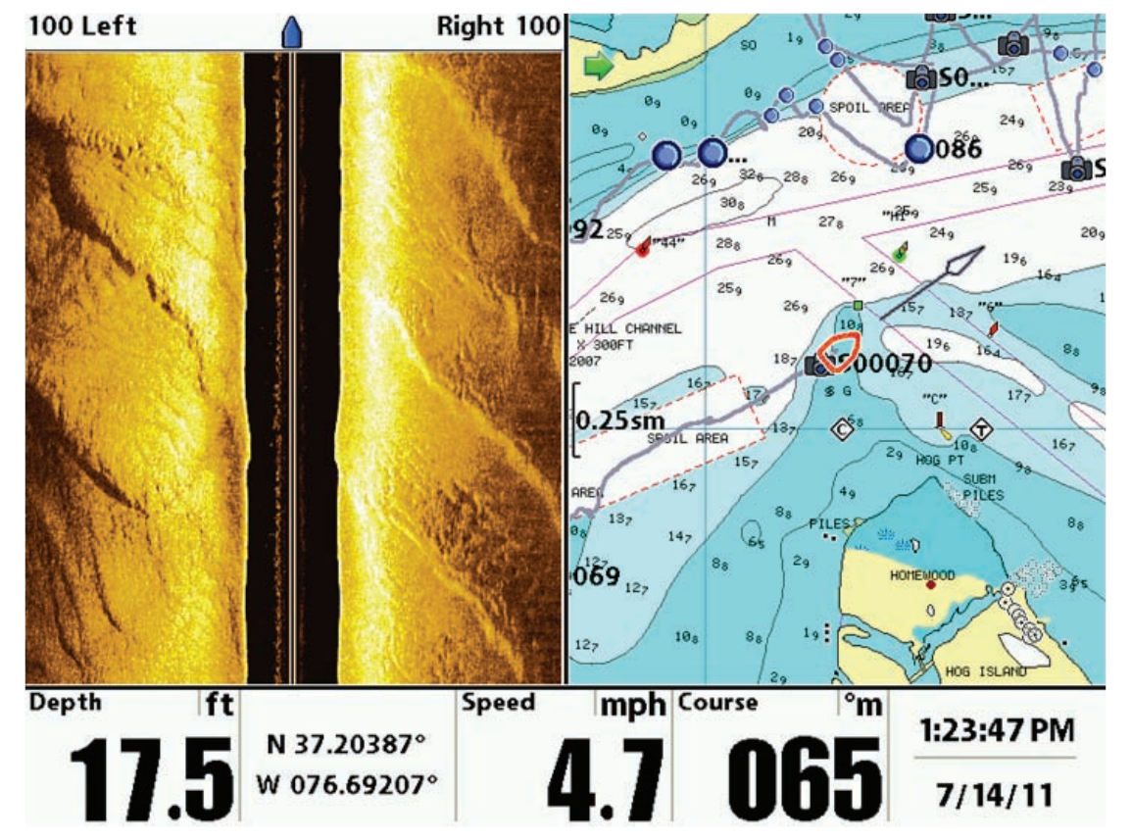

Figure 6. Sidescan image and chart showing upriver-facing sand waves offshore of Hog Island, James River.