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

GEOLOGY OF THE BENNS CHURCH, SMITHFIELD, WINDSOR, AND CHUCKATUCK QUADRANGLES, VIRGINIA

NICHOLAS K. COCH

REPORT OF INVESTIGATIONS 17

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

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ILLUSTRATIONS

GEOLOGY OF THE BENNS CHURCH, SMITHFIELD, WINDSOR, AND CHUCKATUCK QUADRANGLES, VIRGINIA[1]

By

NICHOLAS K. COCH[2]

ABSTRACT

The Benns Church, Smithfield, Windsor, and Chuckatuck quadrangles are located in the southeastern Virginia portion of the Coastal Plain. Stratigraphic units exposed in the quadrangles are unconsolidated sediments that range in age from late Miocene to Recent. The oldest unit is the fossiliferous Yorktown Formation that was deposited under marine conditions in warm shallow water during a period of relative tectonic stability. Overlying the Yorktown Formation are the Sedley and Bacons Castle formations that are transitional between the underlying and overlying units. The clastic sediments in the Sedley and Bacons Castle formations, and the unconformity separating them, indicate more tectonic activity in a western source area than there was before or after their deposition. Stratigraphically above the Bacons Castle formation are Pleistocene marine and estuarine units, the Windsor, Norfolk, and Sand Bridge formations. These units underlie the plains, flats, and scarps in the area, and provide stratigraphic evidence for determining the changes in sea level which occurred during the Pleistocene Epoch.

The Isle of Wight plain, at altitudes of 80 to 95 feet, slopes gently eastward from the Surry scarp to the Suffolk scarp. This plain is underlain by the Windsor Formation, a complex of nearshore marine and estuarine sediments deposited when sea level reached a maximum altitude of +95 to +100 feet. The Suffolk scarp is an eastward-facing escarpment that trends north-south across the Benns Church and Chuckatuck quadrangles. This scarp is a former shoreline capped by the sand facies of the Norfolk Formation; the formation was deposited when relative sea level reached a maximum altitude of +45 to +50 feet. The Churchland flat, east of the Suffolk scarp, is underlain by the Sand Bridge formation, a complex of lagoonal and estuarine sediments deposited when relative maximum sea level was at +17 feet. Stratigraphic relations at the Suffolk scarp indicate that the scarp was a

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[1]Manuscript completed September, 1967. The report was prepared during 1965-1967 while the writer was in the employ of the Virginia Division of Mineral Resources.

[2]Present address: Geology Department, Queens College of C.U.N.Y., Flushing, N. Y. 11367.

coastal shoreline in Norfolk time and an intracoastal shoreline in Sand Bridge time. The maximum sea levels associated with these relict marine features were determined from the altitudes of the highest occurrence of fluvial-estuarine sediments landward of the shoreline, and by the highest occurrence of beach sand along the former shorelines.

The morphologic features in the area studied are not underlain by simple marine "terrace-formations" that record only one sea-level position for each "terrace." Each of these morphologic features is underlain by several distinct stratigraphic units that can be subdivided into mappable facies; each of these stratigraphic units is evidence of a different Pleistocene sea level.

INTRODUCTION

The Benns Church, Smithfield, Windsor, and Chuckatuck quadrangles are located on the Coastal Plain of southeastern Virginia, south of the James River (Figure 1). The area is bounded by latitudes 36°45′ N. and 37°00′ N. and by longitudes 76°30′ W. and 76°45′ W. and is within Isle of Wight and Nansemond counties. Two major river systems, the James and the Blackwater, drain the area. The James River and its northward-flowing tributaries, Chuckatuck Creek, Brewers Creek, Jones Creek, and the Pagan and Nansemond rivers, drain into the Atlantic Ocean through Hampton Roads. Stallings Creek, a tributary to the Blackwater River, flows southward into the Atlantic Ocean by way of Albemarle Sound. The James River and Blackwater River drainage systems are separated by a narrow divide that trends north-south across the westernmost part of the Smithfield quadrangle (Plate 2).

In 1961, the writer and Robert Oaks began a regional study of the post-Miocene stratigraphy and morphology of the Coastal Plain in southeastern Virginia. The study was undertaken for the Geography Branch, U. S. Office of Naval Research (Contract NONR 609-40) under the supervision of R. F. Flint and J. E. Sanders. Reports on various aspects of the study have been published elsewhere (Sanders and others, 1962; Oaks, 1965; Coch, 1965; Flint, 1966). At the conclusion of this regional study in 1965, this four-quadrangle area was selected for detailed mapping under the sponsorship of the Virginia Division of Mineral Resources because it contained stratigraphic evidence to verify many of the new interpretations arising out of the earlier joint regional study by Flint, Sanders, Oaks, and Coch.

FIELD WORK

Field work was conducted for 27 weeks during the summers of 1965 and 1966. Stratigraphic relationships were studied by the examination of 132 exposures, 104 exposures with supplemental hand-auger

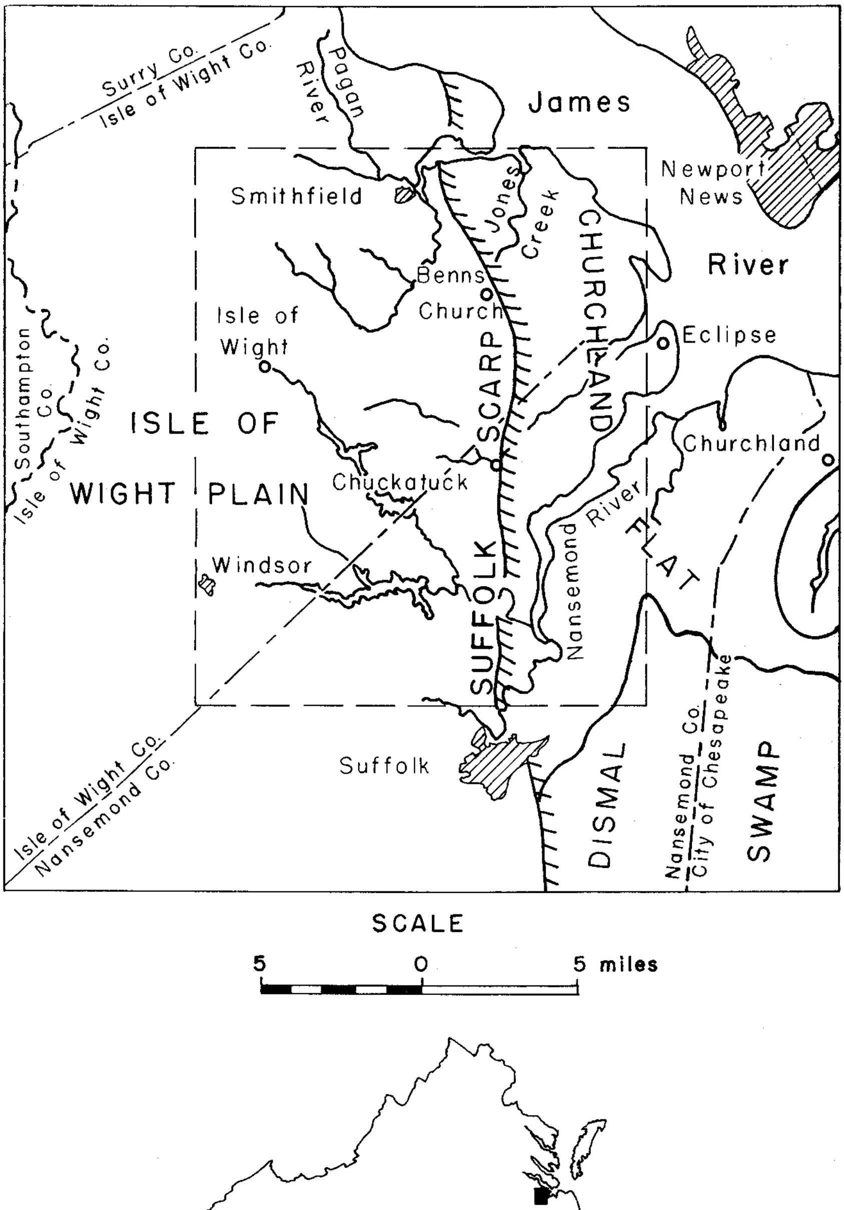


Figure 1. Index map showing location of area studied and morphologic subdivisions.

and plastic-tube borings, 104 hand-auger and plastic-tube borings (Shier and Oaks, 1966); and 30 deep core borings supervised by the writer. Stratigraphic control points were more closely spaced across critical areas such as the Suffolk scarp. The locations of all stratigraphic control points are shown on Plates 1-4. Altitudes of all stratigraphic contacts were determined in relationship to U. S. Geological Survey bench marks and surveyed intersections. The locations of core borings are given on Plates 1-4; the logs and samples for these core borings are in the repository of the Virginia Division of Mineral Resources. Samples for faunal, textural, and mineralogical analysis were taken at 5-foot intervals using a 2-foot Acker split-spoon sampler. Relative compaction for each interval was obtained from blows-per-foot data in accordance with standards proposed by the American Society for Testing Materials (1958). The unconfined compressive strength of each sample was determined in the field by use of a pocket penetrometer.

Each post-Yorktown stratigraphic unit that crops out has characteristic properties that include grain size, sorting, sedimentary structures, morphology, grain-surface texture, fossils, relative compaction, and degree of weathering. Stratigraphic subdivision was based on differences in these characteristics and on the presence of unconformities. Unconformities at the bases of units were recognized from weathering zones in the tops of underlying units (Sedley and Bacons Castle formations) and lag concentrates and channel fills (Sedley, Bacons Castle, Windsor, and Norfolk formations). Relative ages of stratigraphic units were determined from superposition and by comparing dissection and degrees of weathering, including development of iron oxides, enrichment in secondary clay, leaching of unstable heavy minerals, and etching of quartz-grain surfaces.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the financial and technical help given by the staff of the Virginia Division of Mineral Resources during the course of the study. Several of the concepts illustrated here were derived from joint discussions with Richard F. Flint, John E. Sanders, and Robert Q. Oaks during preparation of a doctoral dissertation at Yale University; the dissertation formed the base for a portion of this study. Robert Q. Oaks deserves special thanks for his many helpful suggestions during the course of the present study. Kenneth F. Bick and the writer had many useful discussions and exchanges of information on the stratigraphy west of the Suffolk scarp. The description of the Yorktown Formation was greatly improved by the additions and suggestions of Gerald H. Johnson, who graciously provided faunal lists and sieve analyses for the coquina facies of that formation. Horace G.

Richards and James D. McLean, Jr. supplied age and ecologic information on macrofossils and microfossils, respectively. David Krinsley provided information on quartz grain-surface textures. The writer was ably assisted by Edmund K. Stump in 1965 and Frank R. Smith in 1966; Steven R. Brennan aided in the drafting of many of the illustrations in this report. C. A. Staylor, of the Lone Star Cement Corporation, kindly allowed the writer and Gerald H. Johnson to collect from and study the coquina facies in the company's pit north of Chuckatuck. Mr. E. F. Caldwell and the Carpenter Construction Company graciously provided subsurface data and storage, laboratory, and shop facilities.

MORPHOLOGY

The topography of the Coastal Plain consists of plains that slope eastward at an average of 1.5 feet per mile from west to east in a series of steps. These plains are separated by eastward-facing scarps with slopes of 50 to 450 feet per mile. The morphologic features in southeastern Virginia (Figure 1) have been described and named by Oaks (1965) and Coch (1965); only those morphologic features occurring in the area studied are reviewed.

The Isle of Wight plain, named for Isle of Wight County, lies south of the James River, between the Suffolk and Surry scarps and north of the Virginia-North Carolina boundary (Figure 1). This plain slopes eastward at an average of 2 feet per mile from an altitude of 95 to 100 feet at the toe of the Surry scarp to about 80 feet at the Suffolk scarp. Although the Isle of Wight plain is more dissected near the James and Blackwater rivers, large undissected areas occur along the divide between these river systems. The plain is also deeply dissected near the Suffolk scarp where streams such as the Pagan River, Chuckatuck Creek, and Nansemond River have cut through the scarp. The Isle of Wight plain coincides with the Wicomico "terrace" of Wentworth (1930); it is underlain by lagoonal-estuarine sediments of the upper member of the Windsor Formation.

The Suffolk scarp, first recognized by Rogers (1884), was named by Wentworth (1930, p. 63) for the town of Suffolk (Figure 1). It is a distinct feature with a slope of 2 to 4 degrees, trending almost north-south. The scarp is indistinct where it is cut through by present drainage systems; at these places it trends slightly eastward. The scarp represents a former shoreline which is capped by the beach and dune sediments of the sand facies of the Norfolk Formation.

The Churchland flat is named for Churchland in the city of Chesapeake (Figure 1). It is south of the James River, east of the Suffolk scarp, west of the Elizabeth River, and north of the Dismal Swamp.

The flat ranges in width from about 7 miles near Smithfield to about 10 miles near Churchland and is about 18 miles long. Altitudes range from 25 feet in the east to 30 feet in the west. The flat is well drained by tributaries of the James River, but is considerably less dissected than the higher Isle of Wight plain to the west. The Churchland flat coincides with the eastern one-third of the Dismal Swamp "terrace" of Wentworth (1930). It is underlain by lagoonal and estuarine sediments of the upper member of the Sand Bridge formation.

REVIEW OF STUDIES

The stratigraphy of the Coastal Plain formations in southeastern Virginia was first studied by Rogers (1884), and later by Shaler (1890) and Darton (1902). Beginning with the work of Shattuck (1901) the "terrace-formation" concept was developed, and was later expanded by Clark and Miller (1906, 1912), Wentworth (1930) (Figure 2), and Cooke (1930). In this concept each "terrace" represents a surface underlain by marine sediments deposited during successively lower stands of sea level. Each "terrace" is terminated on the east by a scarp cut when the sea stood at the next lower level. Flint (1940) prepared an excellent critical review of earlier stratigraphic and morphologic interpretations of the Atlantic Coastal Plain to which the reader is referred. Moore (1956), in a reconnaissance study of southeastern Virginia, recognized that sediments cannot universally be given the same name of the terrace they underlie because the same formation may underlie two different terraces (Figure 3). The concept has been shown to be invalid also in Virginia (Oaks and Coch, 1963), Maryland (Hack, 1955; Rassmussen and Slaughter, 1955), Delaware (Rassmussen and others, 1960), and North Carolina (DuBar and Solliday, 1963).

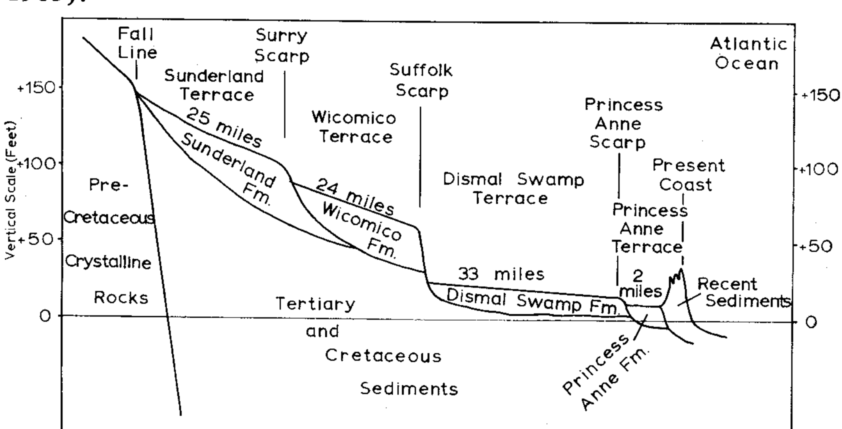


Figure 2. Stratigraphic interpretations of Wentworth (1930).

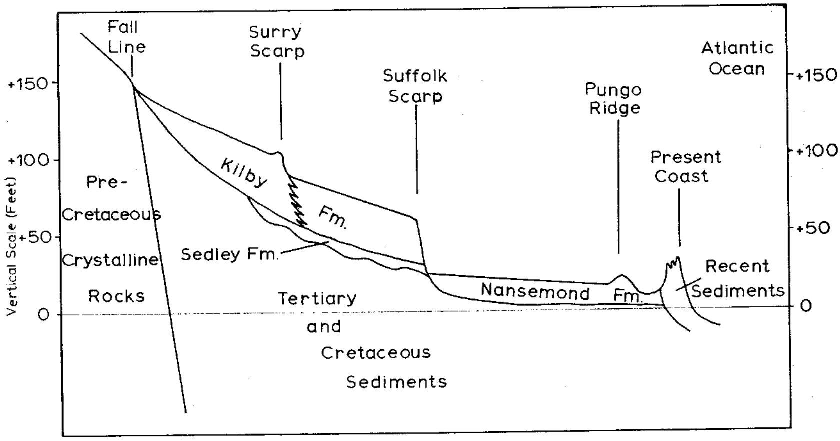


Figure 3. Stratigraphic interpretations of Moore (1956).

Pleistocene stratigraphy of the Atlantic Coastal Plain is considerably more complex than has been previously thought. A distinction must be made between stratigraphic units and morphologic features, and different names should be used for each.

STRATIGRAPHY

YORKTOWN FORMATION

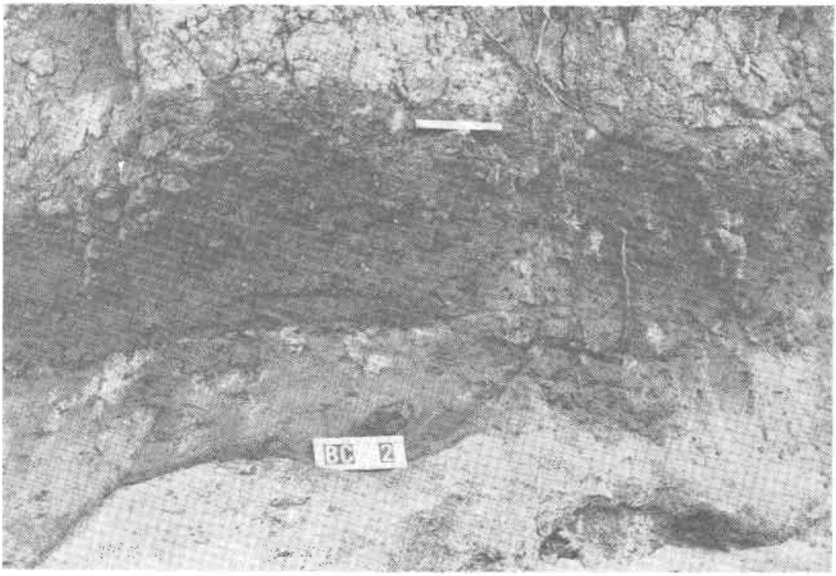
The Yorktown Formation was named by Clark and Miller (1906) for the marine sand, clay, and broken shell material that make up the uppermost unit of the Miocene Chesapeake Group at Yorktown, Virginia. The present study is concerned only with the uppermost part of the Yorktown Formation. West of the Nansemond River the top of the Yorktown Formation is characterized by a yellowish-orange saprolite, 5 to 10 feet thick (Figure 4). Where this conspicuous saprolite zone has been removed by erosion, the formation is medium blue and is difficult to distinguish from younger units of similar color. In core borings, the top of the Yorktown is recognized by abrupt changes in compaction, degree of oxidation, and type and abundance of fossils. It is considerably more compact than the overlying stratigraphic units (Harrison, 1962), and the top is readily distinguished in the subsurface by its variegated fauna (McLean, 1966, p. 34). In contrast, post-Yorktown stratigraphic units are characterized by sparse fossil assemblages where one or two brackish-water or nearshore species such as *Elphidium florentinae* are dominant (McLean, 1966, p. 32).

West of the Suffolk scarp, the Yorktown Formation is unconformably overlain by the Sedley formation; east of the scarp, the Yorktown may be unconformably overlain by the Sand Bridge formation,

Figure 4. Saprolite and ferricrete overlying Yorktown Formation along the Nansemond River (Appendix, section I). The clayey-sand facies of the upper member of the Sand Bridge formation overlies the saprolite.

the Norfolk Formation, or by remnants of the Sedley formation (Figure 5). In general, the upper surface of the Yorktown slopes gently eastward, but locally this surface is irregular, having more than 60 feet of relief. The altitude of the upper surface of the Yorktown decreases markedly in the vicinity of present streams; the same relationship exists on the upper surface of the overlying unit, the Sedley formation. These relations suggest that stream valleys west of the Nansemond River are controlled by topographic lows on the top of the underlying Yorktown Formation.

The upper part of the Yorktown Formation ranges from fossiliferous clayey sand and clay beneath the Isle of Wight plain and Churchland flat (Figure 1) to coquina that occurs in discontinuous belts east of and parallel to the Suffolk scarp from Chuckatuck northward to the James River. The coquina facies ranges in thickness from a few feet to more than 40 feet, being thicker just north of Chuckatuck Creek and just north of the Pagan River (Figure 1). It is best exposed in the extraction site of the Lone Star Cement Corporation at Chuckatuck where about 20 feet of coquina is present above water level (Figure 6). A measured section (Plate 1, location 7) is given in Appendix, section A.



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The upper part of the Yorktown Formation ranges from fossiliferous clayey sand and clay beneath the Isle of Wight plain and Churchland flat (Figure 1) to coquina that occurs in discontinuous belts east of and parallel to the Suffolk scarp from Chuckatuck northward to the James River. The coquina facies ranges in thickness from a few feet to more than 40 feet, being thicker just north of Chuckatuck Creek and just north of the Pagan River (Figure 1). It is best exposed in the extraction site of the Lone Star Cement Corporation at Chuckatuck where about 20 feet of coquina is present above water level (Figure 6). A measured section (Plate 1, location 7) is given in Appendix, section A.

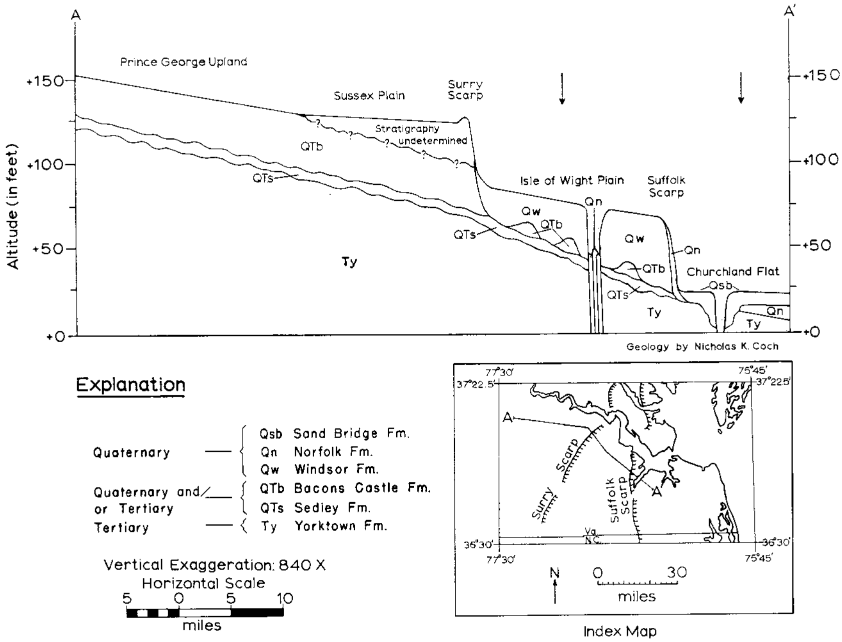


Figure 5. Generalized geologic section across inner Coastal Plain in southeastern Virginia. Vertical arrows indicate boundaries of area studied.

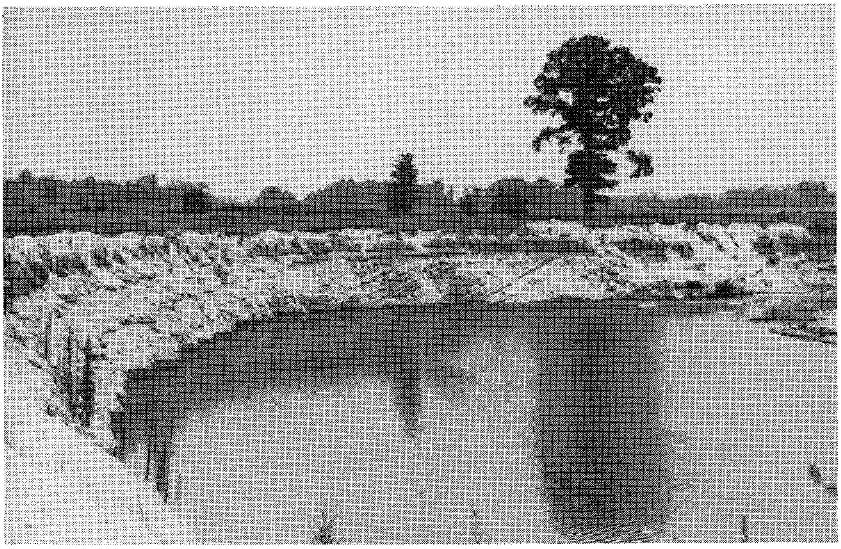
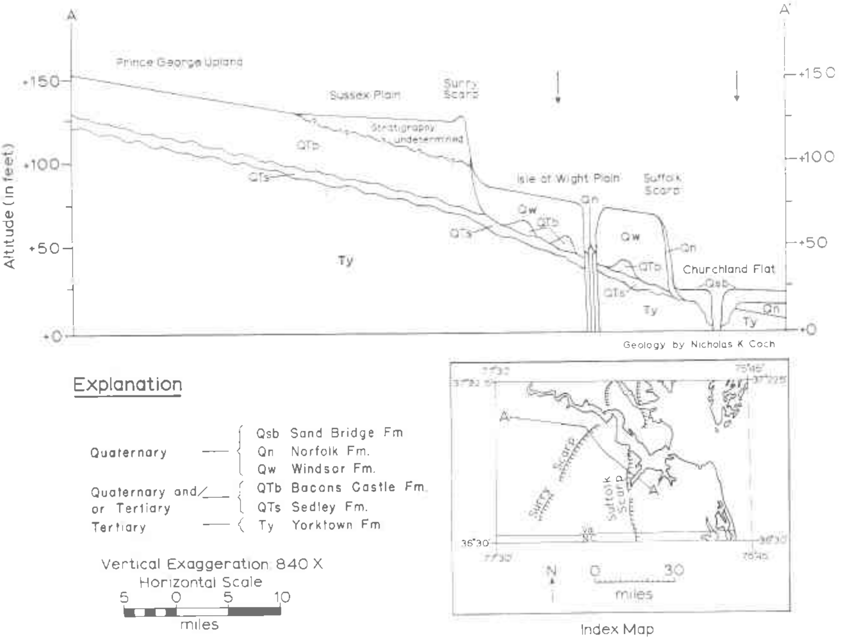


Figure 6. Coquina facies of the Yorktown Formation at Chuckatuck (Appendix, section A). View looking northward shows horizontal bedding in upper member and steep dip of beds in middle member. Dip on beds decreases towards east side of cut.



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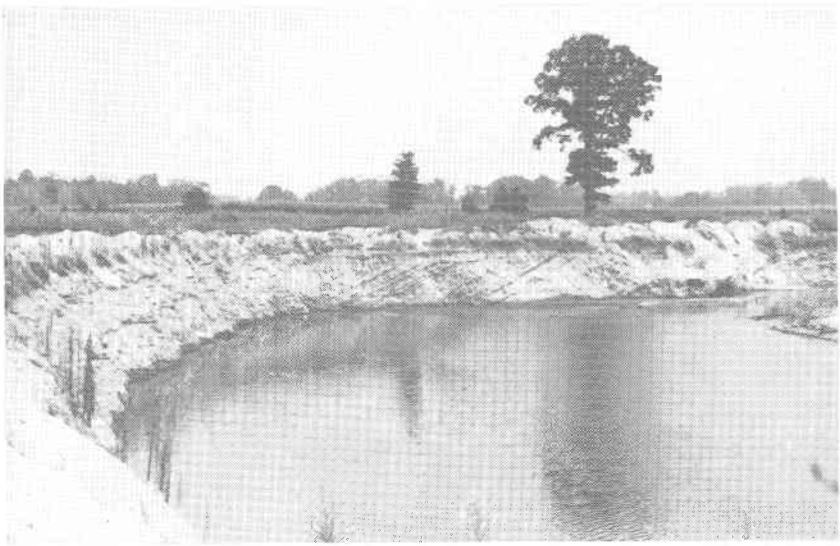


Figure 6. Coquina facies of the Yorktown Formation at Chuckatuck (Appendix, section A). View looking northward shows horizontal bedding in upper member and steep dip of beds in middle member. Dip on beds decreases towards east side of cut.

The coquina facies is distinctive because of its unusually low percentage of terrigenous detritus (less than 10 percent), the lack of fine matrix between the shell fragments, extensive high-angle cross beds (Figure 6), and diverse shallow-water fauna. The coquina consists of friable to indurated, well-sorted (Figure 7), well-rounded, and bluish-gray to reddish-brown shells and shell fragments. In the northwestern part of the Lone Star Cement Corporation extraction site at Chuckatuck, the coquina facies can be subdivided into a lower gently dipping series of beds (exposed only in the eastern part of the north wall), a middle steeply dipping series of beds (exposed only in the western part of the north wall), and an upper finer grained (Figure 7), nearly horizontal series. Steeply dipping planar cross beds characterize the middle member (Figure 6). Farther eastward along the north face, the dip of the middle series decreases and the beds become parallel to the beds above and below (Figure 6).

In the area covered by this report, beds that are considered Yorktown by the writer are identified on the bases of compaction, abundant

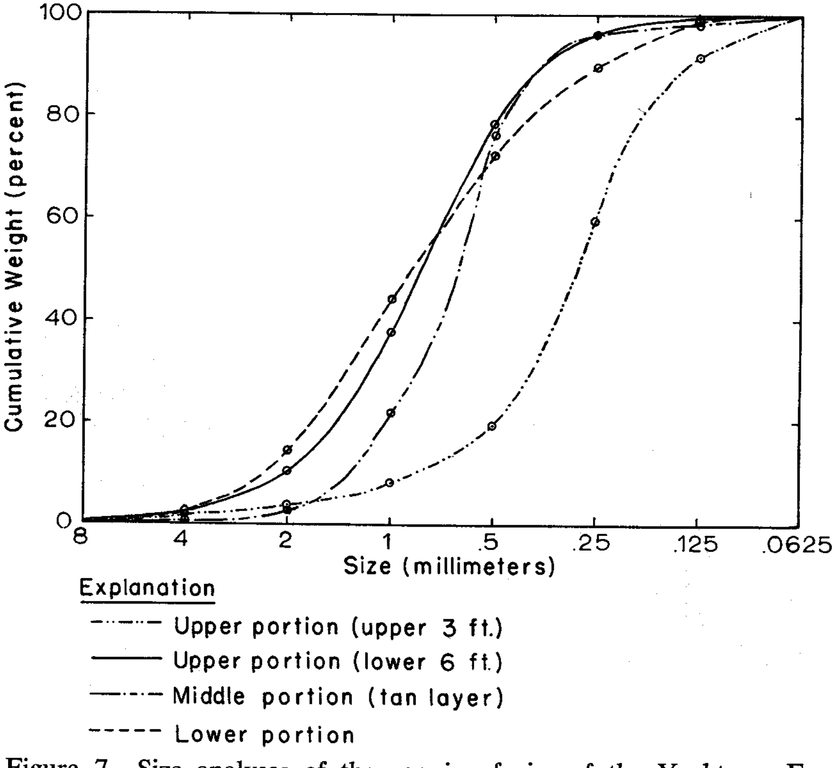


Figure 7. Size analyses of the coquina facies of the Yorktown Formation.

macrofossil content, and lateral continuity with the recognized Yorktown Formation along the James River. This formation has generally been considered Miocene in age since the first description of it by Clark and Miller (1906). However, the U. S. Geological Survey (1965, p. A71) reported discoveries of vertebrate fossils in the Yorktown Formation in southeastern Virginia as follows:

> "A single lower horse molar, collected from the Yorktown Formation (upper Miocene) at Cobham Wharf, Va., has been identified by F. C. Whitmore, Jr., of the U. S. Geological Survey and M. F. Skinner, of the Frick Laboratory, American Museum of Natural History, as *Hipparion* cf. *H. eurystyle* Cope, of Clarendonian or early Hemphillian (early or early middle Pliocene) age. The possibility that part of the Yorktown may be of Pliocene age is further supported by the finding in 1960, at Hampton, Va., of a baleen whale of a type that seems too advanced for the Miocene."

From microfaunal studies in southeastern Virginia, G. H. Johnson (personal communication) suggested that the upper Yorktown sediments may possibly be early Pliocene in age. McLean (1966, p. 28) noted the upper part of the formation contains a fauna that is younger than Miocene.

SEDLEY FORMATION

The Sedley formation was informally named by Moore (1956) for the "sand, sandy clays, and clays" (Figure 3) that overlie the Yorktown Formation; this name is retained in the present study. The formation has been traced in exposures and in the subsurface from the Suffolk scarp westward to beyond Windsor. East of the Suffolk scarp, this formation is present only as very thin isolated remnants encountered in borings near the scarp itself.

West of the Suffolk scarp, the Sedley formation overlies the Yorktown Formation and is overlain by the Bacons Castle formation, or by the Windsor Formation where the Bacons Castle formation is absent (Figure 5). Along the tributaries of the James River, remnants of the Sedley are overlain by the fluvial and estuarine clayey sand of the Norfolk Formation (Plates 2, 5). The Sedley is well exposed just northeast of Woodland Church (Plate 3, location 9) where it is composed of fine sand and sandy silt with thin laminae of silty clay (Appendix, section B; Figure 8). The formation thickens (Plate 5) and contains coarser material in the vicinities of present streams, where it is characteristically a clayey, fine to medium sand. It ranges in thickness from less than 1 foot, just east of the Suffolk scarp, to more than 30 feet; average thickness is 10 feet. The contact between the Sedley and the underlying Yorktown is irregular; relief of up to 25 feet has been observed in exposures along the James and Pagan rivers.

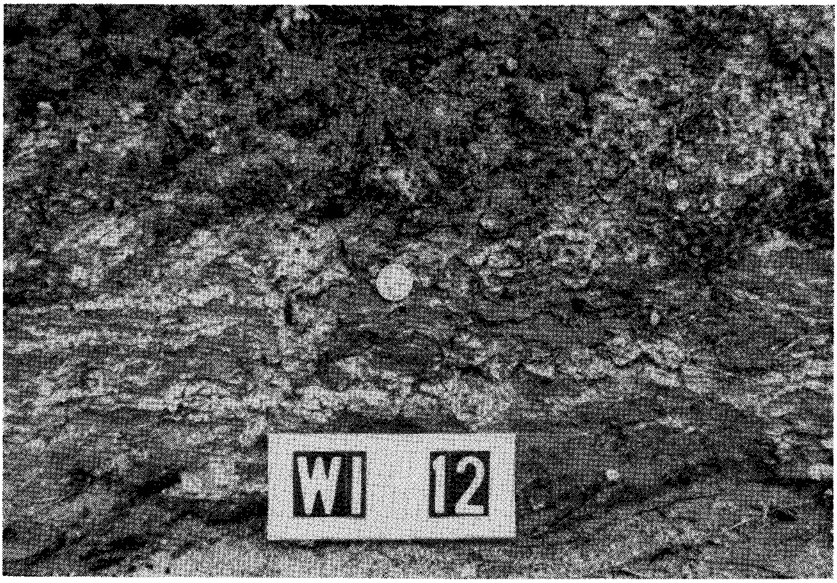
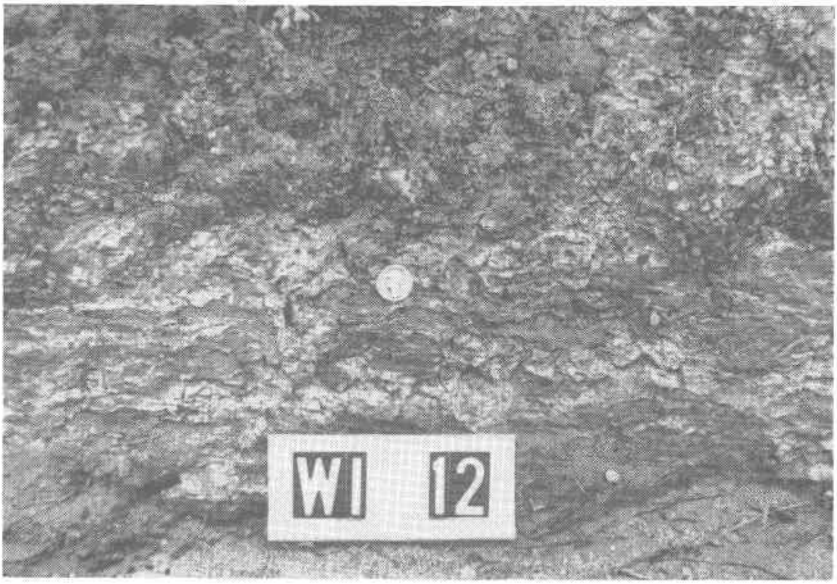


Figure 8. Upper portion of Sedley formation northeast of Windsor showing disturbed laminae (Appendix, section B).

The heavy-mineral fraction of the Sedley formation is largely opaque minerals, zircon, kyanite, epidote, sillimanite, tourmaline, rutile, and hornblende. The minerals in the clay-size fraction consist of chlorite, montmorillonite, illite, goethite, siderite, and hematite. The presence of spongy red and yellow iron oxide coatings on most grains makes identification difficult, even after chemical and ultrasonic cleaning. Several highly etched grains of brown hornblende had perfect cocks-comb terminations that are indicative of intrastratal solution (Bradley, 1957). Siliceous overgrowths are present on several quartz grains and on a few of the heavy minerals, particularly kyanite.

The Sedley formation near the James and Pagan rivers is more deeply weathered than the part under the Isle of Wight plain. Near these rivers, the formation has been oxidized light brown to medium red to a depth of 15 feet and contains Liesegang structures and ferricrete nodules. In contrast, the Sedley beneath the Isle of Wight plain is oxidized medium reddish orange to a depth of 3 feet. These weathering differences may be explained by the differences in the thickness and permeability of the overlying sediments, and by variations in the grain size of the formation in these two areas. The Sedley near the James and Pagan rivers is coarser than that under the Isle of Wight plain, and is overlain only by remnants of the relatively permeable lower member of the Windsor Formation. In contrast, the relatively unoxidized Sedley



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The age of the Sedley formation is uncertain. It contains shell imprints, but few shells; the fauna is a mixture of Yorktown and post-Yorktown forms. Imprints of *Pecten* near the James River were identified as Miocene, and a Miocene form, *Pecten madisonius* Say, was collected beneath the Isle of Wight plain (H. G. Richards, written communication). Microfossils from a core boring at a nearby locality at the same altitude as the occurrence of *Pecten madisonius* are believed by J. D. McLean, Jr. (written communication) to be post-Yorktown in age.

BACONS CASTLE FORMATION

The Bacons Castle formation (Coch, 1965) is composed of clayey sand, silty sand, pebble gravel, and cobble gravel that overlie the Sedley formation and are overlain by the Windsor Formation. The Bacons Castle is present only as isolated remnants east of the Surry scarp. There are several exposures of the formation in the area of study, but they are too small to be illustrated at the map scale of 1:24,000.

The Bacons Castle formation is subdivided into a coarse-grained sand facies and a fine-grained silt facies. In most exposures, the silt facies overlies the sand facies, but in many places the two facies are complexly interbedded. A remnant of the formation is exposed about 2.5 miles southwest of Kings Fork (Plate 3, location 10). The sand facies is composed of clayey sand, pebble gravel, and cobble gravel; coarser fragments are more abundant near the base of the facies. A measured section of this facies is given in Appendix, section C. Sedimentary structures include channels, planar cross beds, and trough-type cross laminae (Figure 9). The sand facies is coarser near major rivers and also becomes coarser from east to west across the area; it grades upward and laterally into the silt facies. Only a few remnants of the silt facies are preserved in the area studied because of the deep erosion of the formation. The silt facies is composed of sandy silt and sand with partings of clay less than 1 inch thick. Sedimentary structures consist of cross laminae with dips of less than 5 degrees; thin platelets of gray clay occur on the laminae.

The heavy-mineral suite of the Bacons Castle formation consists mainly of opaque minerals, zircon, staurolite, kyanite, epidote, sillimanite, tourmaline, and rutile, and is characterized by the absence of unstable minerals such as pyroxenes and amphiboles. Several of the heavy-mineral grains, particularly sillimanite, have jagged terminations

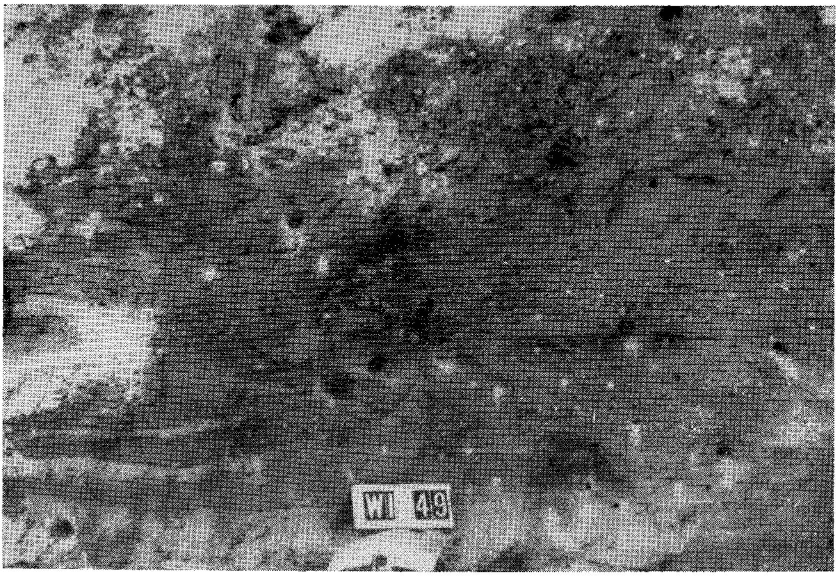

Figure 9. Remnant of Bacons Castle formation (sand facies) at Lake Cahoon (Appendix, section C). Note trough-type laminae and coarse grain size.

indicative of intrastratal solution (Bradley, 1957); quartz grains are deeply etched (D. H. Krinsley, written communication). The clay-size fraction is largely composed of illite with a minor amount of chlorite and feldspar.

The Bacons Castle formation is less deeply weathered than the Sedley formation, but considerably more weathered than any of the post-Bacons Castle stratigraphic units. The formation is oxidized reddish brown, moderate red, or yellowish orange to a depth of about 15 feet. The iron oxide in the Bacons Castle and Sedley formations is hematite, rather than the limonite which is characteristic of the weathered zones of younger stratigraphic units. The age of the Bacons Castle is uncertain at the present time. The absence of unstable minerals, etching of mineral grains, deep oxidation, and weathering indicate that a long period elapsed before the beginning of deposition of the overlying Windsor Formation.

WINDSOR FORMATION

Coch (1965) named the Elberon formation for the community of Elberon, Virginia. He defined the formation as composed of three facies: a silty-clay facies (lagoon) west of the Surry scarp, a fine-sand facies (barrier) along the Surry scarp, and a silty-sand facies (nearshore marine) east of the Surry scarp. This study and reconnaissance work

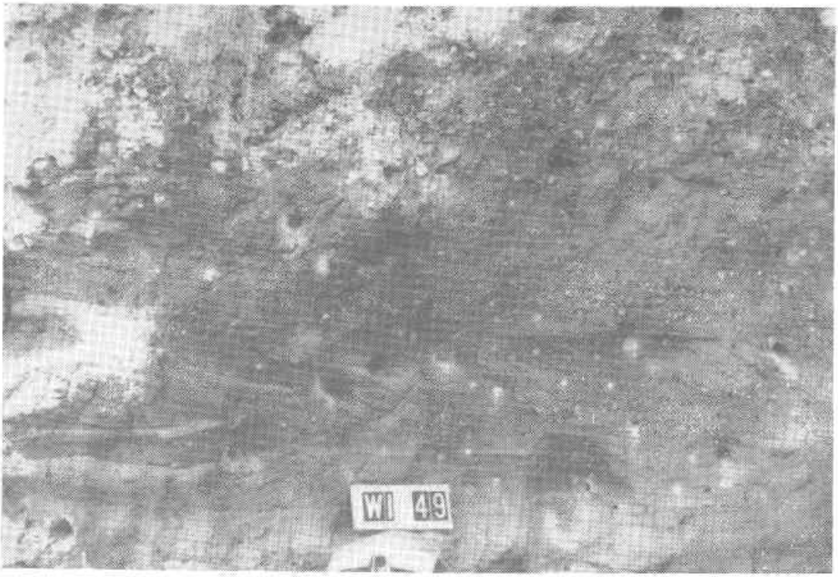

Figure 9. Remnant of Bacons Castle formation (sand facies) at Lake Cahoon (Appendix, section C). Note trough-type laminae and coarse grain size.

indicative of intrastratal solution (Bradley, 1957); quartz grains are deeply etched (D. H. Krinsley, written communication). The clay-size fraction is largely composed of illite with a minor amount of chlorite and feldspar.

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Coch (1965) named the Elberon formation for the community of Elberon, Virginia. He defined the formation as composed of three facies: a silty-clay facies (lagoon) west of the Surry scarp, a fine-sand facies (barrier) along the Surry scarp, and a silty-sand facies (nearshore marine) east of the Surry scarp. This study and reconnaissance work in the area to the west have indicated the need for redefinition of the informally proposed Elberon formation of Coch (1965). The name Windsor Formation is herein given to the silty-sand facies of the Elberon formation which is now known to be a lagoonal-estuarine complex rather than a nearshore facies. The type section of the Windsor Formation is herein designated at core boring W-1211 (Plate 4), located southeast of the town of Windsor in Isle of Wight County. The remaining facies included in the Elberon appear to be older than the Windsor Formation, but the exact relationships are uncertain at the present time (Figure 5). The Windsor Formation has been traced from the James River southward through Suffolk, and from the Suffolk scarp to the west of Windsor (Figure 10).

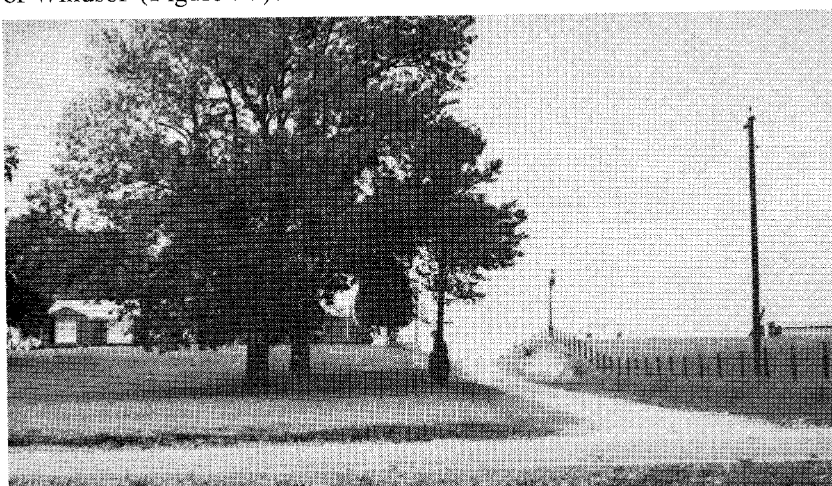

Figure 10. Lower member of Windsor Formation truncated by Suffolk scarp at Wills Corner. The sand facies (beach) of the Norfolk Formation has been removed from the scarp at this locality by post-Norfolk erosion.

The Windsor Formation is the chief surficial unit exposed in the Isle of Wight plain in the area of study (Plates 2, 3). The maximum thickness of the formation is about 35 feet; it is thickest near the Suffolk scarp in the eastern part of the quadrangle and thins westward to less than 5 feet at the Surry scarp. Under the Isle of Wight plain, the Windsor Formation unconformably overlies erosional remnants of the Bacons Castle formation, the Sedley formation, and in local areas where the underlying formations have been removed by erosion, the Windsor overlies the Yorktown Formation. The lower member is coarse grained and the upper member is fine grained; the contact between the two members is gradational (Appendix, section D). At the Surry scarp, the upper and lower members are indistinguishable.

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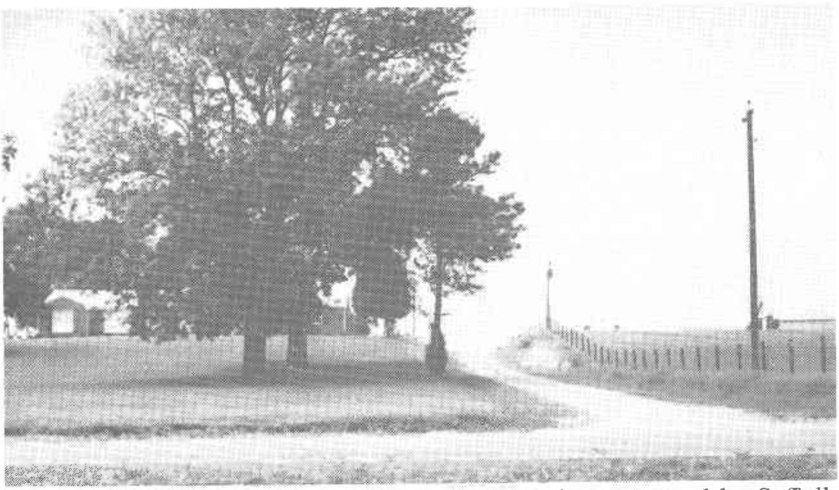

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The lower member is composed of grayish-white, unfossiliferous, medium to coarse sand and fine pebble gravel. In the lower portion of the member, the sand is well sorted and contains some laminae with abundant dark minerals; the pebble gravel at the base of the member is well rounded. Silt content increases gradually upward in the member, and at the top, chunks and platelets of gray clay are common. The lower member ranges in thickness from less than 5 to about 17 feet; it is thicker in the eastern portion of the area studied.

The upper member of the Windsor is composed of unfossiliferous silty clay, silty sand, and clayey sand. At altitudes above 85 feet, the lithology is a stiff purplish-gray, silty clay with about 15 percent fine to medium sand. Below 80 feet, the lithology is a massive gray clayey medium sand with minor brick-red mottling. The upper member ranges in thickness from less than 10 to about 25 feet, and is thicker in the eastern part of the area of study.

In areas near present streams, major grain-size changes occur within a few feet, both laterally and vertically, and the upper and lower members grade laterally into thick sections of gray clayey sand, medium well-sorted sand with rounded clay chunks, and beds of laminated silty clay and fine to medium sand. This lithology appears to fill channels cut into the underlying Bacons Castle, Sedley, and, in some cases, Yorktown.

The heavy-mineral suite of the Windsor Formation consists mainly of opaque minerals, zircon, staurolite, kyanite, sillimanite, sphene, rutile, hornblende, and traces of orthopyroxene. The heavy-mineral grains are considerably less etched and pitted than in pre-Windsor stratigraphic units. Hornblende occurs in amounts of 1 to 2 percent; this is more than in pre-Windsor stratigraphic units, but considerably less than in post-Windsor units. High undissected remnants of silty clay in the upper member of the Windsor Formation at altitudes above 85 feet are oxidized to a depth of only 2 feet. Where the uppermost part of the formation has been stripped away by erosion, the material is oxidized dark yellowish orange with dusky-red streaks to a depth of 8 feet.

The lithology, sedimentary structures, facies relations, and morphology of the Windsor Formation are indicative of a nearshore marine-lagoonal environment of deposition. The good sorting and opaque-mineral laminae of the lower member are characteristic of nearshore marine sands. The lithology and facies relations of the upper member are similar to those of present lagoonal and estuarine sediments. The thick sections of clayey sand, medium sand mixed with clay chunks, and laminated clay filling channels cut into the underlying formations are suggestive of fluvial and tidal-channel deposits. The evidence suggests that during deposition of the lower member the shoreline was at the Surry scarp, and that the area of study was covered by nearshore marine sand. Shoaling of the water and development of tidal channels are indicated by the increase in clay content and by the sedimentary structures present at the top of the lower member. A possible cause for this shoaling could have been the development of a barrier east of the Suffolk scarp. The clayey sands and silty clays in the upper member could have accumulated in an area of tidal flats, shallow bay, and tidal marsh behind the postulated barrier. At the same time, clayey sand, silt, and fine to medium sand were deposited in tidal channels that cut across the lagoonal environment. Sea level during Windsor time reached a maximum relative value of +95 to +100 feet; this is the highest occurrence of the upper member of the Windsor Formation along the Surry scarp.

Such a hypothesis of origin for the Windsor Formation requires the original presence of a barrier that was subsequently eroded away. The stratigraphic relations in the Windsor in the area of study suggest that a barrier existed to the east. Stratigraphic relations at the Suffolk scarp, where the Windsor Formation is overlain unconformably by the sand (beach) facies of the Norfolk Formation, indicate that this barrier must have been located east of the Suffolk scarp. The writer believes that this barrier may have been partially eroded during the emergence and subaerial erosion that followed the deposition of the Windsor Formation. Any remnants of this former shoreline that were not removed during this period of subaerial erosion could have been eroded away by headland retreat during the transgression of the Norfolk sea to the Suffolk scarp. The absence of fossils in the Windsor Formation prevents a definite age assignment. However, pre-Windsor sediments exposed in the Surry scarp (Figure 5) have quartz-grain surface features (Coch, 1965, Plate 7) characteristic of "glacial" action (D. H. Krinsley, written communication). Based on this evidence, a tentative Pleistocene age is assigned to the Windsor Formation.

NORFOLK FORMATION

The Norfolk Formation, named for Norfolk County by Clark and Miller (1906), was assigned to the Pliocene by them on the basis of shells from the Dismal Swamp Canal and from spoil heaps alongside it. Clark and Miller did not establish a type section; Oaks (1965, Appendix A-10) established Boring RO-9 as a reference section for the Norfolk Formation. Reference sections for those facies of the Norfolk Formation which crop out in the area of study are given in Appendix, sections E-G. The formation has been traced in outcrop and in the subsurface from west of the Suffolk scarp along Lawnes Creek eastward beneath the Churchland flat to Bowers Hill (Figure 1).

The Norfolk Formation consists of a coarse lower member and a finer grained upper member that is subdivided into eight mappable facies (Oaks, 1965; Coch, 1965). The lower member can be traced, as a distinct unit, eastward from the Suffolk scarp for about 1 mile under the Churchland flat; east of this area it is indistinguishable from the sand facies of the upper member. The lower member is about 5 feet thick and consists of medium to coarse sand with 10 to 15 percent of fine pebble gravel.

Only three of the eight facies of the upper member of the Norfolk Formation are exposed in the area. A lithologic name, based on the dominant lithology, is here assigned to each facies.

The sand facies crops out in a belt less than 1 mile wide trending north-south along the Suffolk scarp from the Pagan River to just south of Wills Corner (Plate 1). The sand facies ranges in thickness from a thin veneer, where it has been almost entirely stripped away by post-Norfolk erosion, to more than 50 feet in undissected portions of the Suffolk scarp. Three lithologic subdivisions are recognized in a vertical direction in this facies. The lower portion, composed of very coarse sand and fine pebble gravel 3 to 5 feet thick, occurs up to an altitude of 36 feet. The middle portion is composed of medium to coarse sand and very fine pebble gravel and has a maximum altitude of 45 feet. The upper portion (Figure 11) is composed of fine to medium, well-sorted sand with brown bands rich in organic material (J. F. Conley, personal communication) and has a maximum altitude of 70 feet. Quartz grains from the upper portion have grain-surface features (Coch, 1965, Plate 7) characteristic of eolian deposits (D. H. Krinsley, written communication). A section of the sand facies is described in Appendix, section E.

The heavy-mineral suite of the sand facies consists of zircon, staurolite, opaque minerals, kyanite, sillimanite, hornblende, sphene, tourmaline, epidote, and trace amounts of orthopyroxene, rutile, and garnet. The minerals of this suite occur throughout the Norfolk Formation. The Norfolk can be readily distinguished from older and younger stratigraphic units on the basis of relative percentages of staurolite, rutile, and, especially, hornblende. For example, average percentage of hornblende (8 percent) is about 4 to 8 times that in the Windsor Formation. The sand facies has been oxidized pale yellowish orange to dark yellowish orange and is also enriched in clay to an average depth of 5 feet.

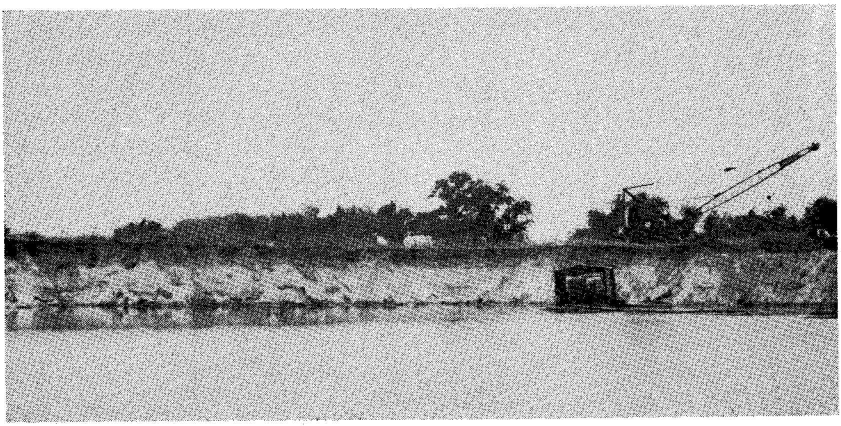


Figure 11. Norfolk Formation (sand facies) at Benns Church. Note dark humite bands below soil zone.

The clayey-sand facies crops out west of the Suffolk scarp as flat-topped remnants in the valley of the Pagan River (Plates 1, 2). Undissected portions of this facies are preserved as a flat surface with altitudes of 45 to 50 feet. Near Smithfield, the facies is composed of horizontal strata of silt, clayey fine sand, and clay with some thin beds of well-sorted fine sand (Figure 12). The facies is coarser upstream where abrupt lithologic changes are also more common. The upstream portions of this facies are composed of clayey medium sand, cross-stratified medium to coarse sand, and thin beds of pebble gravel. A

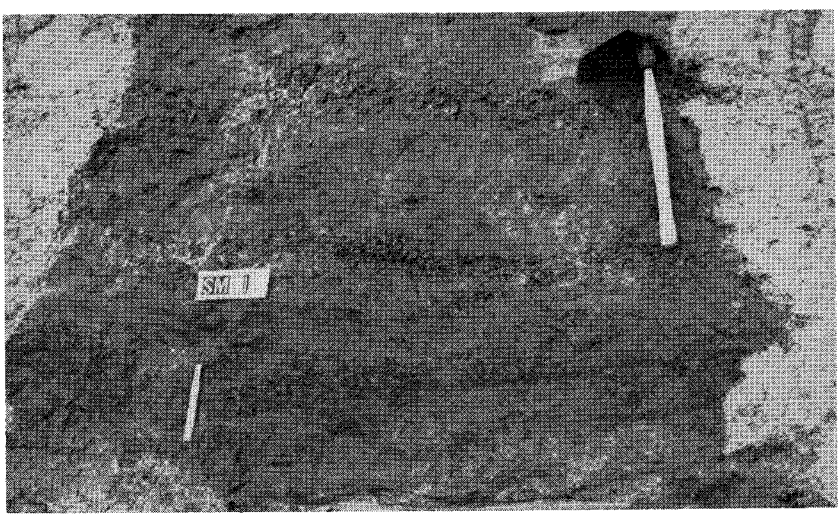
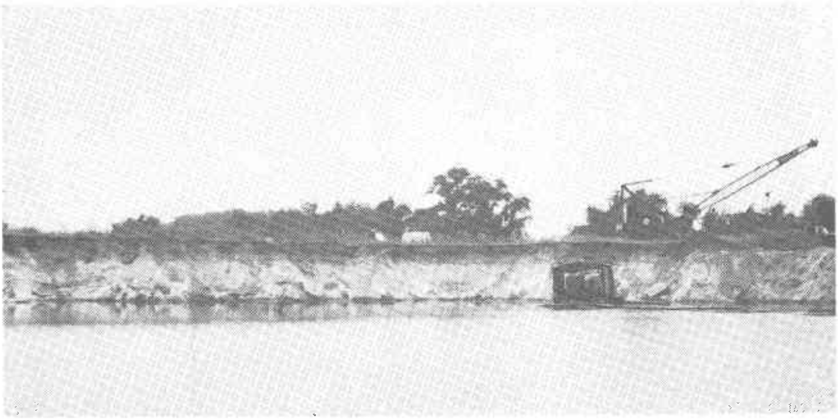


Figure 12. Norfolk Formation (clayey-sand facies) at Smithfield (Appendix, section F). Note sharp changes in grain size in this section.



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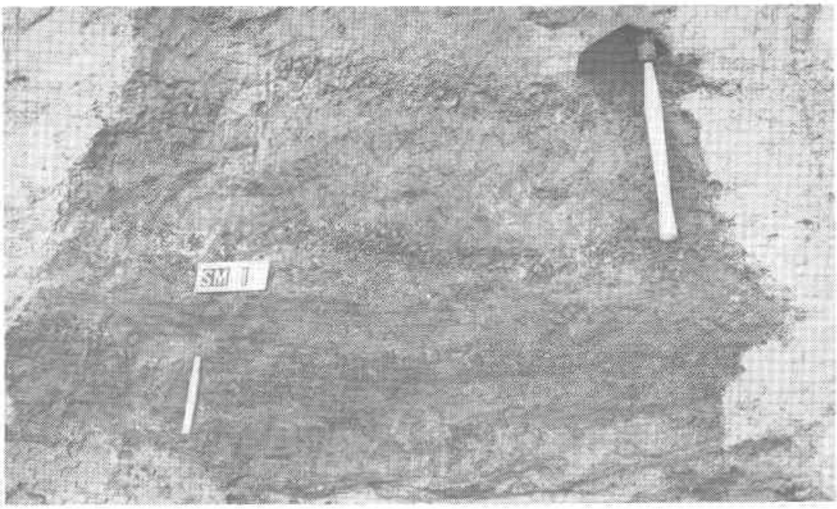

Figure 12. Norfolk Formation (clayey-sand facies) at Smithfield (Appendix, section F). Note sharp changes in grain size in this section.

section of the clayey-sand facies is described in Appendix, section F. The facies has been oxidized orange-yellow to a depth of 4 feet. The clay-size fraction of this facies consists of quartz, illite, vermiculite, and goethite with lesser quantities of montmorillonite, chlorite, and feldspar.

The silty-sand facies occurs beneath the Churchland flat northeast of a line extending from Carrollton Branch to Ballard Marsh (Plate 1). The facies ranges in thickness from 5 to 20 feet and has an average thickness of 10 feet; it is composed of well-stratified fine sandy silt, slightly clayey medium sand, and clayey silt with a trace of sand. A section of the silty-sand facies is described in Appendix, section G. The clay-size fraction of this facies consists largely of quartz, illite, chlorite, montmorillonite, and minor amounts of feldspar. The fauna of the silty-sand facies of the Norfolk Formation in the area of study is a warm-water fauna of Pleistocene age (H. G. Richards, written communication).

SAND BRIDGE FORMATION

The Sand Bridge formation, informally named by Oaks and Coch (1963), is divided into a homogeneous lower member and an upper member composed of several different mappable facies. The lower member unconformably overlies the Norfolk Formation and is exposed in deep drainage ditches in the easternmost portion of the area studied. This member is present in the subsurface beneath the Churchland flat, except near major streams where it was removed during deposition of the clayey-sand facies of the upper member (Plate 5). Reference sections of the lower member and the upper member (clayey-sand facies, silty-sand facies, and silty-clay facies) are described in Appendix, sections H-J).

The lower member of the Sand Bridge formation is 3 to 6 feet thick and consists of unstratified, well-sorted, fine to medium sand with a trace of silt. The top of the lower member has little relief, and occurs at altitudes from 15 to 18 feet beneath the Churchland flat. The contact between the lower member of the Sand Bridge formation and the underlying Norfolk Formation is generally sharp, but the contact between the lower member and the overlying silty-sand facies of the upper member is a gradational zone about 1 foot thick. The lower member has been slightly oxidized; the upper part is light olive gray, and it grades downward into a very light gray in the lower part. Near the contact with the underlying Norfolk Formation, the lower member has been oxidized light brown. The heavy minerals in the lower member are fresh and unaltered, and contain a relatively high percentage of hornblende (10 to 16 percent). The clay-size fraction of the lower member consists largely of quartz, illite, chlorite, and lesser amounts of montmorillonite and feldspar.

The upper member covers most of the area east of the Suffolk scarp and is much more variable in texture than is the lower member. The upper member was subdivided into six major facies by Oaks (1965) and Coch (1965); only three of these facies (clayey-sand, silty-clay, and silty-sand) occur in the area of study.

The clayey-sand facies of the upper member overlies the Yorktown Formation (Figure 4), the Norfolk Formation (Figure 13), and the lower member of the Sand Bridge formation. The clayey-sand facies crops out in broad linear areas on both sides of major streams north of the Dismal Swamp and east of the Suffolk scarp (Plates 1, 4). A zone of ferricrete and cobble gravel, 1 to 4 feet thick, underlies the facies along creeks east of the scarp. The ferricrete contains imprints of *Pecten* and other fossils common in the underlying Yorktown Formation and well-rounded cobbles of sandstone and quartzite up to 18 inches in diameter. The ferricrete is dark red and well indurated; it is an excellent marker horizon for the base of the clayey-sand facies. The

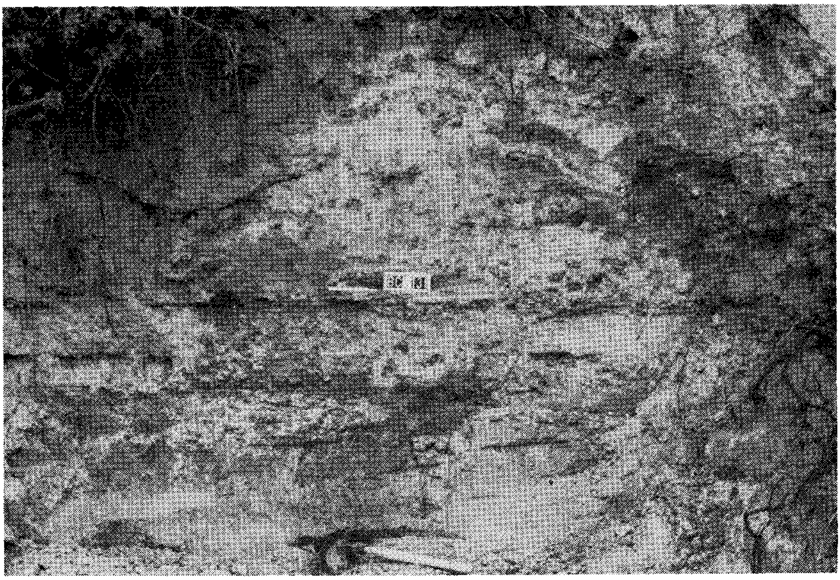

Figure 13. Sand Bridge formation (clayey-sand facies) overlying Norfolk Formation (silty-sand facies) east of Rescue (Appendix, section G). The Norfolk Formation is composed of laminated silt and clay; the Sand Bridge formation is composed of homogeneous clayey sand.

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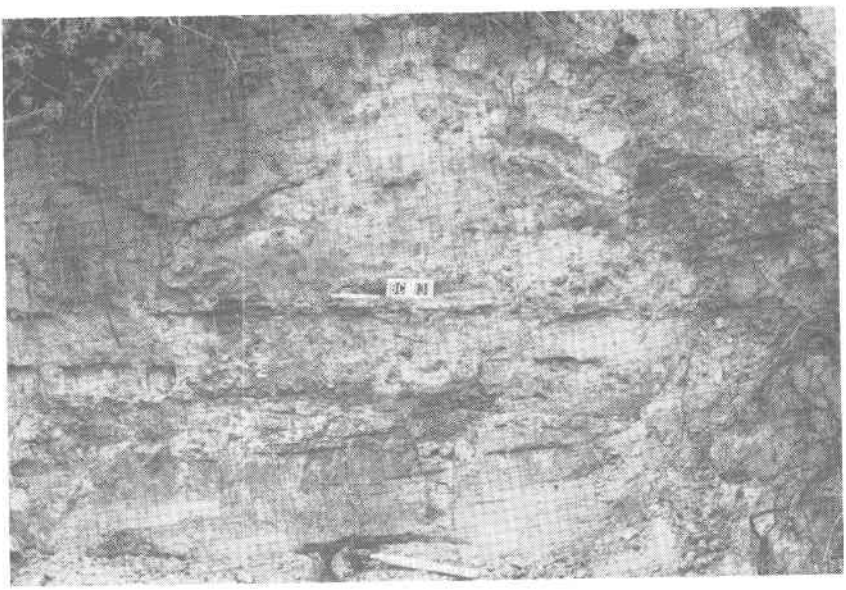

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base of the facies is an irregular surface, cut into older stratigraphic units, which decreases in altitude toward present streams (Plate 5). A section of the clayey-sand facies is described in Appendix, section I.

The lithology of the clayey-sand facies ranges from thick-bedded clayey sand, silt, and clay to well-sorted fine to medium sand; grain-size changes occur over short distances. Low-angle (5 to 15 degrees) planar cross-laminae and plates and chunks of clay are present in the sandier parts of the facies. The texture generally becomes coarser near the upstream portions of creeks and estuaries where the facies is characterized by abrupt changes in grain size, both laterally and vertically. The facies is up to 25 feet thick near present streams; away from them it thins and grades laterally into the other facies of the upper member. Along many streams east of the Suffolk scarp, the clayey-sand facies is overlain at the surface by a discontinuous layer of silty sand, 1 to 2 feet thick, which contains disarticulated oyster shells at altitudes of 20 to 23 feet. Oyster shells (*Crassostrea*) from a shell layer at Newmans Point have a radiocarbon date of 3160 ±160 years B. P. (Stuiver and Deevey, 1961). An excavation by Virginia State Archeologist, Col. W. McCord, and the writer at Wilkerson Landing (Appendix, section I) yielded pottery, burned shell, and broken and fire-cracked stones. McCord stated that the shells are related to activities of human culture.

The facies has been moderately weathered and is oxidized to a depth of 5 feet. In exposures, the clayey-sand facies is yellow-green, light gray, or bluish white below the oxidation zone, and pale yellowish orange to dark yellowish orange in the zone of oxidation. Surface textures of quartz grains are slightly more etched than in Recent sands (D. H. Krinsley, written communication). The heavy-mineral suite of the clayey-sand facies consists of opaque minerals, zircon, staurolite, kyanite, sillimanite, hornblende, and sphene; lesser quantities of epidote, orthopyroxene, and monazite; and trace amounts of rutile, garnet, and biotite. The minerals of this suite occur throughout the Sand Bridge formation. The average amount of hornblende in the heavy-mineral suite is 16 percent; this is twice the amount of hornblende in the sand facies of the Norfolk Formation, and greater than 15 times the amount of hornblende in the older stratigraphic units.

The silty-clay facies crops out in a narrow strip adjacent to and east of the Suffolk scarp (Plates 1, 4). Along the scarp it unconformably overlies the sand facies of the Norfolk Formation (Plate 5; Figure 14). The silty-clay facies is composed of approximately equal amounts of silt and clay with about 10 to 15 percent of medium sand. In some places, the facies lacks stratification and consists of clay and silt with minor sand. In others it is composed of fairly continuous wavy beds, 1 to more than 3 inches thick, which have silty clay and very clayey sand; the bedding is irregular and seems disarranged (Figure 15). Decayed vegetation (E. S. Gaffney, personal communication), isolated pebble gravel, and small cobble gravel occur locally in this facies near the Suffolk scarp (Figure 15). The silty-clay facies is dark yellowish brown to grayish brown in the 1-foot-thick oxidized zone, and beneath that it is pale yellowish brown to pale olive. The clay-size fraction is composed of quartz, illite, montmorillonite, chlorite, vermiculite, and feldspar. A section of the silty-clay facies is described in Appendix, section H.

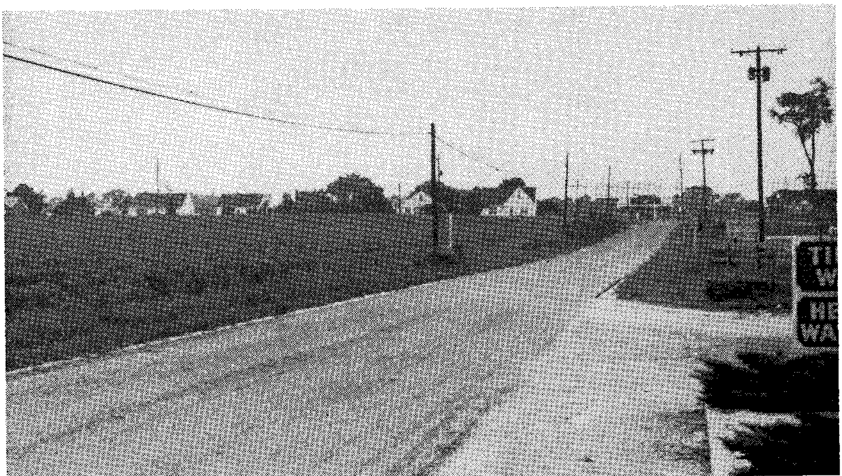

Figure 14. Suffolk scarp at Smithfield. View looking westward showing Churchland flat in foreground and Suffolk scarp in distance. Core boring (Appendix, section K), at base of power pole on right, shows unconformable overlap of silty-clay facies of Sand Bridge formation onto sand facies of Norfolk Formation; the Suffolk scarp represents a compound shoreline.

The silty-sand facies underlies the Churchland flat northeast of a line from Rescue to Smith Neck (Plate 1). The facies is 5 to 8 feet thick and occurs at altitudes higher than 18 feet beneath the Churchland flat. It consists of fine to medium sand with approximately 20 to 30 percent silt. The facies is gradational into the sands of the underlying lower member, and grades laterally into the silty-clay and clayey-sand facies (Plate 5). A section of the facies is described in Appendix, section J. The weathering characteristics of the facies are the same as for the silty-clay facies, but the oxidized zone is 2 to 3 feet thick. The clay-size fraction consists of quartz, illite, vermiculite, and feldspar.

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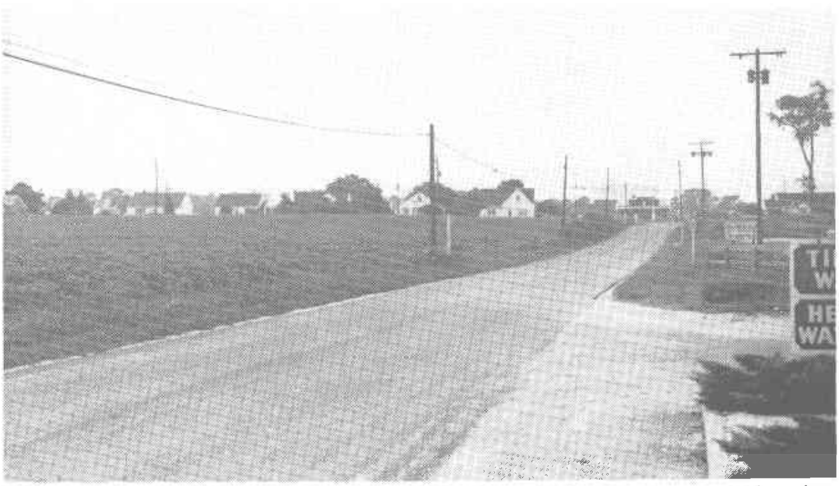

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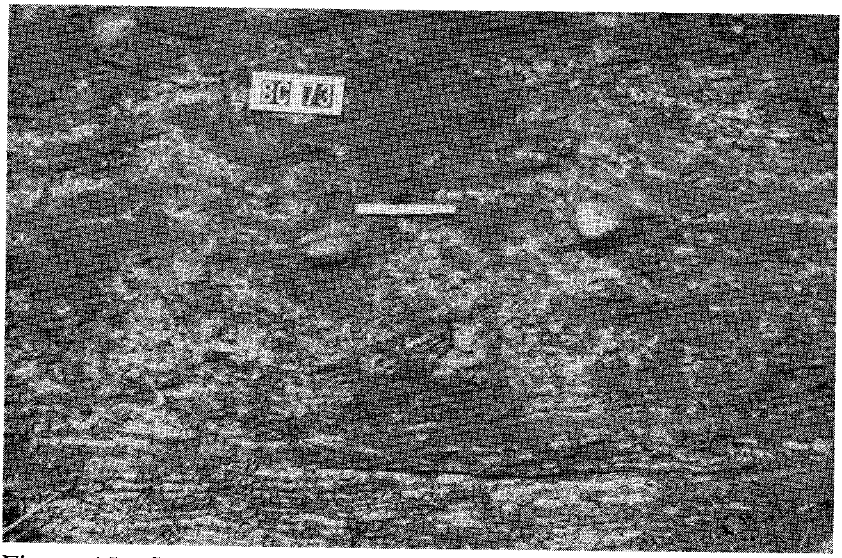

Figure 15. Sand Bridge formation (silty-clay facies) exposed on north side of State Road 600, about 1 mile east of State Highway 10 and 32, Nansemond County. Note isolated pebble gravel and disturbed laminae in upper part of exposure.

RECENT SEDIMENTS

In the upper portion of streams, clayey fine to medium sand, well-sorted fine to medium sand, and sandy silt are being deposited. The sediments covering the beaches along the James River are composed largely of fine to medium sand with some shell fragments and fine pebble gravel. Thick fluvial-estuarine valley fills underlie all major rivers and creeks in the area of study. These sediments were deposited in channels cut into the clayey-sand facies of the upper member of the Sand Bridge formation and other units. The tops of the valley fills reach an altitude of +1 to +2 feet, and in some cases, their bases extend down to at least −125 feet. The fill in Jones Creek at Fulgham Bridge (Plate 1) is typical of the post-Sand Bridge valley fills; it is composed of more than 125 feet of soft, organic, homogeneous silt (E. F. Caldwell, personal communication). The channels underlying these fills were cut during a low stand of sea level during the Wisconsin glacial age; they were filled with fluvial and estuarine sediments during the post-Wisconsin rise in sea level.

GEOLOGIC HISTORY

During late Miocene time, southeastern Virginia was covered by a warm, shallow sea as indicated by the characteristics of abundant and varied marine fauna in the Yorktown Formation. The shoreline lay

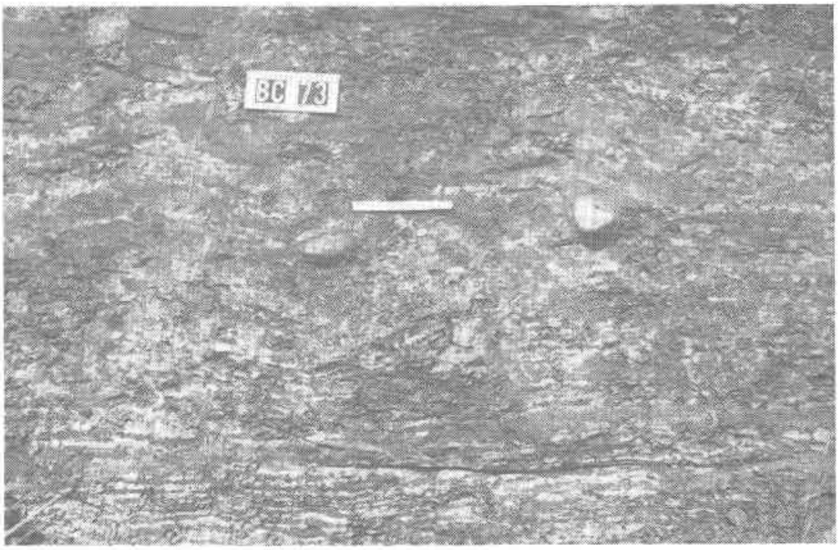

Figure 15. Sand Bridge formation (silty-clay facies) exposed on north side of State Road 600, about 1 mile east of State Highway 10 and 32, Nansemond County. Note isolated pebble gravel and disturbed laminae in upper part of exposure.

RECENT SEDIMENTS

In the upper portion of streams, clayey fine to medium sand, well-sorted fine to medium sand, and sandy silt are being deposited. The sediments covering the beaches along the James River are composed largely of fine to medium sand with some shell fragments and fine pebble gravel. Thick fluvial-estuarine valley fills underlie all major rivers and creeks in the area of study. These sediments were deposited in channels cut into the clayey-sand facies of the upper member of the Sand Bridge formation and other units. The tops of the valley fills reach an altitude of +1 to +2 feet, and in some cases, their bases extend down to at least −125 feet. The fill in Jones Creek at Fulgham Bridge (Plate 1) is typical of the post-Sand Bridge valley fills; it is composed of more than 125 feet of soft, organic, homogeneous silt (E. F. Caldwell, personal communication). The channels underlying these fills were cut during a low stand of sea level during the Wisconsin glacial age; they were filled with fluvial and estuarine sediments during the post-Wisconsin rise in sea level.

GEOLOGIC HISTORY

During late Miocene time, southeastern Virginia was covered by a warm, shallow sea as indicated by the characteristics of abundant and varied marine fauna in the Yorktown Formation. The shoreline lay somewhere west of the area studied, and in this shallow sea only shells, shell fragments, and silts and sands were deposited. Later the shoreline migrated to a position east of Chuckatuck, and a drainage system developed on the newly emerged sea floor to the west of Chuckatuck. Contours on the top of the Yorktown Formation indicate that this dissected surface coincides with present-day stream patterns. The streams deposited both sediments and reworked shells along the coast, and some of this land-derived material was mixed with greater quantities of shell material from the sea floor to form longshore bars. By the process of longshore drift, under conditions of high wave energy and shallow water, these bars grew northward and the coquina facies was deposited. Eventually the shoreline migrated eastward beyond the position of the present coast, exposing more of the Yorktown Formation to weathering and subaerial erosion. This period of emergence was of long duration as indicated by the presence of deep channels that were cut into the formation, and development of a thick saprolite.

During Sedley time the sea transgressed over the land, and the shoreline again lay somewhere west of the area. As sea level rose, stream valleys were filled with estuarine sediments that gradually covered the interfluves. Fine sand, silt, and clay were deposited on the interfluves, but the grain size is somewhat coarser in the pre-existing stream valleys because of incorporation of older fluvial sediments. Eventually the Sedley shoreline migrated to a position somewhere east of the area, and streams cut deep channels into the exposed surface.

The next recorded event in the area was the deposition of the Bacons Castle formation by aggrading streams. Channel and floodplain deposits filled the stream valleys and spread out over the interfluves. Pebble and cobble gravels composed mostly of quartzite and sandstone with some gneisses, granites, and schists are representative of materials from a western source area that was subjected to uplift and erosion. The deep weathering profile developed on the Bacons Castle formation, the deep etching of quartz-grain surfaces and the absence of unstable minerals suggest a long period of emergence following the deposition of this formation.

The stratigraphic relationships of the Windsor Formation show that sea level rose to a relative maximum altitude of +90 to +100 feet in early Windsor time. The lower member of the formation was deposited under nearshore marine conditions when the shoreline was located west of the area; after a relatively short period of time, the upper member of the Windsor Formation was deposited in a lagoonal complex that developed on the west side of a barrier bar located east of the Suffolk scarp. This bar is thought to have been destroyed by a later marine transgression. A period of emergence and deep dissection followed the retreat of the sea from the Windsor barrier. Sea level descended to a minimum altitude of at least −80 feet (Oaks, 1965, p. 211). Deep valleys were cut through the Windsor and underlying units into the Yorktown Formation, and large portions of these units were removed by erosion.

Early in Norfolk time, sea level rose to +20 feet or higher and inundated river valleys. The coarse sand and pebble gravel of the lower member of the Norfolk Formation were deposited in a rapidly transgressing beach zone. This westward-migrating shoreline removed erosional remnants of post-Yorktown units in the area of study and formed a wave-cut slope at the westernmost limit of marine transgression. This slope, the Suffolk scarp, was capped by the beach and dune sand of the sand facies deposited as the Norfolk sea rose to a maximum altitude of +45 to +50 feet. Maximum sea level during Norfolk time is determined from: (1) the altitude of the highest occurrence of Norfolk beach sand (sand facies), (2) the maximum altitude of the depositional upper surfaces of estuarine fills (clayey-sand facies) of Norfolk age in the area of study, and (3) the highest occurrence of the lagoonal facies of the Norfolk Formation near the Virginia-North Carolina boundary (Oaks, 1965, p. 125). The southward offset of the Suffolk scarp at the James River and the presence of constructional beaches south of the two major rivers that cut through the Suffolk scarp indicate that the longshore drift direction in Norfolk time was from north to south.

The sand, clayey-sand, and silty-sand facies of the Norfolk Formation were deposited in different environments. The sand facies, a complex of beach and dune sediments, was deposited on and along the Suffolk scarp. West of the scarp, the clayey-sand facies was deposited as fluvial-estuarine fills in major stream valleys. East of the scarp the silty-sand facies was deposited in an open-marine nearshore environment at Bowers Hill, and in a brackish-marine nearshore environment near the James River.

After the sea retreated from the Suffolk scarp to a line east of the present coast, the area was subjected to subaerial weathering and dissection. Between the end of Norfolk time and the beginning of Sand Bridge time, several units were deposited during marine transgressions (Oaks, 1965), but none of these occur in the area studied. The lower member of the Sand Bridge formation was deposited as the sea rose to a maximum position between +13 feet and +15 feet (Oaks, 1965, p. 216). A barrier beach then formed at Pungo Ridge (Figure 1), as a result of littoral drifting of sand from south to north. Bays, tidal channels, tidal flats, and marshes developed behind Pungo Ridge, and the sediments deposited in these environments are represented by the various facies of the upper member of the Sand Bridge formation. The silty-clay facies was deposited in bay, tidal-flat, and marsh environments; the silty-sand facies was deposited in the shallow, river-influenced parts of the lagoon; and the clayey-sand facies was deposited in the broad tidal channels that cut across this lagoonal complex. Sea level reached a maximum relative altitude of +17 feet during Sand Bridge time; this is inferred from the highest known altitude of the silty-clay facies on the west side of Pungo Ridge (Oaks, 1965).

A time of subaerial exposure that resulted from lowering of sea level followed the deposition of the Sand Bridge formation. This period is believed to have been of long duration (Oaks, 1965, p. 220) as suggested by the development of indistinctly zoned soils in ridges of Sand Bridge age and the presence of deep channels cut into the formation. Following the weathering and erosion, sea level rose to its present altitude as evidenced by the deep fills of unoxidized silt and fine sand that occur in all the present-day major creeks and rivers.

ECONOMIC GEOLOGY

Sand for general construction and road fill is being obtained from several formations. West of the Suffolk scarp, there are numerous borrow pits in the lower member of the Windsor Formation (R-2660). (Numbers preceded by "R" correspond to sample localities shown on Plates 1, 2, 4; samples from these localities are on file in the rock and mineral repository of the Division of Mineral Resources at Charlottesville where they are available for examination.) East of the scarp, sand for construction purposes is obtained from the clayey-sand facies (R-2670) of the upper member of the Sand Bridge formation; the general distribution of this facies is given on Plates 1 and 4. The sand facies of the Norfolk Formation (Plate 1) is a source of well-sorted sand. The sand generally ranges in thickness from 20 to 45 feet and crops out in a north-south belt less than 1 mile wide from the Pagan River southward to Chuckatuck. The only operating pit in this facies (R-2654) is that of the Southern Materials Company at Benns Church (Figure 11). The sand is dredged, washed, screened, and shipped by truck to users throughout the area.

The coquina facies of the Yorktown Formation (Figure 6) is used as a source of calcium carbonate for cement manufacture. The coquina (R-2654) is composed of more than 90 percent well-rounded shell fragments and ranges in thickness from a few feet to more than 40 feet. It crops out, in isolated patches of variable thickness, in a belt just east of the Suffolk scarp from the James River south to Chuckatuck. The only producing pit in this coquina is that of the Lone Star Cement Corporation at Chuckatuck. The overburden, about 5 to 15 feet of Sand Bridge formation and saprolite developed on the Yorktown Formation, is removed by dragline. The coquina is then stripped off and washed to remove matrix and iron oxides. The Lone Star Cement Corporation is also dredging silty clay from the Nansemond River; the silty clay is loaded onto barges and transported, along with several barges of coquina, to the processing plant in Norfolk where these materials are utilized in the manufacture of cement.

The Battery Park Fish and Oyster Company calcines oyster shells to produce lime. In addition, they provide shell which is suitable for sub-base in highway construction.

ENGINEERING PROPERTIES

Standard penetration and unconfined compressive strength measurements may be similar for a given formation and may be used in conjunction with other data for correlation purposes. Standard penetration, measured in blows-per-foot, is described as the number of blows, from a 140-pound hammer dropped 30 inches, needed to advance a split-spoon sampler 1 foot (American Society for Testing Materials, 1964, p. 50-52). The standard penetration value for each 2-foot sample interval was determined from blow counts taken during drilling operations. A Soiltest pocket penetrometer was used to determine the unconfined compressive strength, a measure of consistency, of each 2-foot sample interval. The tip of the penetrometer was inserted 0.25 inch into

Table 1.—Test characteristics of formations studied.

	STANDARD PENETRATION			UNCONFINED COMPRESSIVE STRENGTH		
Formation	*Number of core borings*	*Number of determinations*	*Average blows/ft.*	*Number of core borings*	*Number of determinations*	*Average tons/ft²*
Norfolk	6	59	11.3	6	9	.98
Windsor						
Upper mbr.	25	134	13.4	18	46	1.65
Lower mbr.	46	248	15.9	28	40	1.39
Bacons Castle						
Silt facies	1	14	18.5	1	6	3.3
Sand facies	3	16	9.8	3	1	0.5
Sedley	51	203	6.5	37	56	0.7
Yorktown	56	192	12.2	40	57	1.1

a flat surface cut on one end of a 5-inch core representative of the interval sampled. The compressive strength, in tons/ft^2, was read from the gauge. Samples were taken from 60 core borings made during the summers of 1966 and 1967; and the total number of samples analyzed from each formation are listed in Table 1. The data show that the variation in consistency among the different units in these field tests may be used to differentiate between the stratigraphic units in the area. It should be realized that these values are averages and that many properties such as grain size, grain shape, sorting, ground-water conditions, mineralogy, weathering, age, and stratigraphic position affect the compaction and consistency of a stratigraphic unit.

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APPENDIX

REFERENCE SECTIONS

Reference sections for each of the stratigraphic units cropping out in the area of study are listed here. Wherever possible, exposures rather than borings were used as reference sections. All these sections were in good condition in September, 1967.

SECTION A: YORKTOWN FORMATION (COQUINA FACIES)

Exposure (Plate 1, location 7) on north-south face of Lone Star Cement Corporation pit just north of Chuckatuck, Nansemond County. Altitude of top of section is 26 feet. Lowermost unit of this composite section crops out 200 feet east of above exposure along east-west face. Faunal identifications by Gerald H. Johnson (personal communication).

	Thickness Feet
Sand Bridge formation, silty-clay facies	
Silt, brown, clayey, trace of medium sand, brownish-gray areas, pebble and cobble gravel concentrated near base. Gradational contact with saprolite developed on Yorktown	3.5 (exposed)
Yorktown Formation, coquina facies	
Upper portion	
Coquina, reddish-gray to blue, horizontally bedded, composed of subangular to rounded shell fragments of fine-sand size, trace of quartz sand. Contains abundant whole *Crepidula,* and less abundant microgastropods, *Donax,* barnacles, *Ostrea,* Bryozoa fragments, and echinoid plates and spines. Uppermost 1 foot is red sandy silt saprolite developed on coquina	3
Coquina, blue to reddish-gray, nearly horizontal beds composed of well-rounded, tabular, water-worn shell fragments of medium-sand size, trace of quartz sand. Diverse fauna includes abundant *Crepidula* and *Donax* and less abundant *Ostrea, Pecten,* barnacles, echinoid plates and spines, broken pelecypod shells, and microgastropods. Disarticulated *Pecten* shells, with convex side up, are concentrated near base. Sharp contact with the middle member	6
Middle portion	
Coquina, bluish-gray, steeply dipping beds. Composed of alternating beds of thin (0.5 ft. max.) purplish-red indurated coquina with silt matrix and thicker (1.5 ft. max.) beds of tan friable coquina of medium-sand size. Fauna is diverse but not as abundant as in coquina beds above and below. Contains abundant *Donax* and *Crepidula,* and less abundant *Polinices,* microgastropods, fragments of Bryozoa, barnacles, and echinoid spines and plates. Shells and shell fragments are well rounded and abraded. Sharp contact with the lower member	8.5

	Thickness Feet
Lower portion	
Coquina, bluish-gray, nearly horizontal beds, friable, composed of shell fragments of medium-sand size. Contains abundant *Crepidula,* and fewer *Donax,* barnacles, *Pecten* fragments, and immature *Glycymeris;* finer fraction includes abundant micro-gastropods, echinoid plates and spines, fragments of Bryozoa, and abraded porcelaneous Foraminifera	3 (exposed)

Comments: The three members of the coquina facies merge, to form a thick section of almost horizontally bedded coquina, about 500 feet east of the north face (as exposed on August 12, 1967). Analysis of apparent dips in the middle member indicates that the true dip of the cross-bedded strata of the middle member is towards the northwest.

SECTION B: SEDLEY FORMATION

Exposure and hand-auger boring (Plate 3, location 9) on south side of State Road 600, 0.45 mile northeast of State Road 637, Isle of Wight County. Altitude of top of section is 53.2 feet.

	Thickness Feet
Windsor Formation	
Sand, reddish-orange, medium, trace of coarse sand, becomes coarser and purplish gray near base. Base marked by granule and pebble gravel layer. Sharp contact with the Sedley	9.5 (exposed)
Sedley Formation	
Clay, laminated, gray, silty, mottled with red, and sand, reddish-orange, fine to medium, clayey. Clay laminae continuous laterally but disturbed in places (Figure 8)	5.2
Sand, bluish-gray, fine, trace of medium sand, clayey, some thin gray clay laminae. Trace of fine pebble gravel	6.3

Comments: The laminated facies of the Sedley is well exposed here.

SECTION C: BACONS CASTLE FORMATION

Exposure and hand-auger boring (Plate 3, location 10) in borrow pit 200 feet east of State Road 637, just south of bridge over Lake Cahoon, Nansemond County. Altitude of top of section is 45.0 feet. Altitude of top of boring is 33.2 feet.

	Thickness Feet
Bacons Castle formation, sand facies	
Sand, deep reddish-orange, medium to coarse with fine pebble gravel, and laminae with concentrations of opaque minerals (Figure 9). Well-developed trough-type cross laminae dipping eastward. Base of formation marked by ferricrete layer and concentration of pebble and cobble gravel. Sharp contact with the Sedley	11.8

	Thickness Feet
Sedley formation	
Silt, dark reddish-orange, very fine sandy, disseminated ferricrete crusts throughout. Sharp contact with the Yorktown	3.2
Yorktown Formation	
Silt, yellow, fine sandy, fossiliferous	3.0 (exposed)

Comments: The basal pebble and cobble gravel layer contains several decomposed rock fragments.

SECTION D: WINDSOR FORMATION

Core boring W-1211 on farm road 300 feet northwest of State Road 634, 0.35 mile northeast of U. S. Highway 460, Nansemond County. Altitude of top of boring is 76.4 feet.

	Thickness Feet
Windsor Formation	
Sand, gray, medium, trace coarse sand, clayey (40%) in top 10 feet. Grades down into sand, medium to coarse, gray, clayey (20%), with gray clay platelets parallel to stratification	18.0
Sand, grayish-white, coarse, high percentage of opaque minerals, becomes tannish-orange near base. Some thin lenses of gray silt. Sharp contact with the Sedley	17.0
Sedley formation	
Silt, dark-blue, clayey, with very thin laminae of fine, slightly clayey sand. Top 0.5 foot is oxidized dark reddish brown with ferricrete crusts	10.0
Sand, tan and gray, medium, laminated, slightly clayey, some small chunks of bluish-gray clay. Sharp contact with the Yorktown	6.0
Yorktown Formation	
Silt, blue, sandy, highly fossiliferous, mostly small whole shells and shell fragments less than 1 cm wide	4.0 (exposed)

Comments: The lowest part of the upper member and all of the lower member of the Windsor Formation are shown in this core boring.

SECTION E: NORFOLK FORMATION (SAND FACIES)

Core boring (Plate 1, location 5) just south of house on farm road east of State Highway 10, 0.9 mile northwest of intersection with U. S. Highway 258 at Benns Church, Isle of Wight County. Altitude of top of boring is 42.0 feet.

	Thickness Feet
Norfolk Formation, sand facies	
Sand, yellowish-orange, medium to coarse, trace of silt in top 3.0 feet	8.0
Sand, pale yellowish-orange, coarse, trace of pebble gravel. Gradational contact with the silty-sand facies	3.0

	Thickness Feet
Norfolk Formation, silty-sand facies	
Silt, dark-gray, sandy	4.0
Sand, moderate-blue, fine, silty. Contains the following fossils: *Nassarius trivittatus* (Say), *Epitonium humphreysii* (Kiener), *Retusa canaliculata* (Say), *Epitonium rupicolum* (Kurtz), *Mulinia lateralis* (Say), *Nuculana acuta* (Conrad), *Anadara transversa* (Say), *Noetia ponderosa* (Say), and *Arca* sp. (Identifications by H. G. Richards). Sharp contact with the Yorktown	10.5
Yorktown Formation	
Sand, bluish-white, fine, clayey, highly fossiliferous	5.0 (exposed)

Comments: The fauna in the Norfolk Formation is of Pleistocene age and has characteristics of forms found in a shallow open sea. All the species are known to be living in Virginia waters today (H. G. Richards, written communication).

SECTION F: NORFOLK FORMATION (CLAYEY-SAND FACIES)

Exposure (Plate 2, location 8) on northeast side of State Road 626 just southeast of bridge over Mt. Holly Creek, Isle of Wight County. Altitude of top of section is 21.0 feet.

	Thickness Feet
Norfolk Formation, clayey-sand facies	
Silt, purplish-gray, sandy, fine, massive, some orange mottling	4.0 (exposed)
Clay, purplish-gray, silty, trace fine sand, blocky, some reddish-orange mottling	1.0
Sand, purplish-gray, medium, clayey, massive	1.5
Sand, orangish-tan, medium to coarse, thin irregular streaks of gray silty clay	1.5
Sand, gray, medium to coarse, clayey, white specks, poorly sorted	4.0 (exposed)

Comments: This section illustrates the rapid horizontal and vertical variation in texture which is characteristic of the upstream portion of this facies (Figure 12).

SECTION G: NORFOLK FORMATION (SILTY-SAND FACIES)

Exposure (Plate 1, location 1) on beach along James River, 0.25 mile east of State Road 665 along private driveway located 0.15 mile south of junction of State Roads 665 and 704, Isle of Wight County. Altitude of top of section is 23.0 feet.

	Thickness Feet
Sand Bridge formation, clayey-sand facies	
Sand, grayish-brown, fine to medium	0.9 (exposed)
Sand, yellowish-orange, fine to medium, clayey	6.6

	Thickness Feet
Sand, gray, mottled with yellow, fine to medium. Becomes darker toward base where ferricrete layer is developed. Sharp contact with the Norfolk	7.4
Norfolk Formation, silty-sand facies	
Silt, blue, fine sandy, soft, some thick laminae of sand, fine to medium, slightly clayey	4.6
Sand, blue, fine, silty, some chunks of blue silt	2.3 (exposed)

SECTION H: SAND BRIDGE FORMATION (SILTY-CLAY FACIES)

Exposure and hand-auger boring (Plate 1, location 3) in drainage ditch southeast of junction of State Highway 10 and 32 and State Road 704, Isle of Wight County. Altitude of top of section is 25.4 feet.

	Thickness Feet
Sand Bridge formation, silty-clay facies	
Clay, pale-olive, silty, thin irregular laminae of fine sand, small, well-rounded pebble and cobble gravel disseminated throughout upper half of section. Small calcareous concretions in basal portion	7.1 (exposed)
Clay, brown, sandy, irregular olive-gray mottling, high percentage opaque minerals. Sharp contact with the Yorktown	2.5
Yorktown Formation	
Silt, red, clayey, soft	0.8
Silt, reddish-brown, clayey, abundant shell fragments	0.9
Sand, blue, fine, clayey, very fossiliferous, clay content decreases upwards	3.0 (exposed)

SECTION I: SAND BRIDGE FORMATION (CLAYEY-SAND FACIES)

Exposure (Plate 4, location 11) (Figure 4) at Wilkerson Landing, northeast shore of Nansemond River, 1.75 miles southwest of Nansemond River Bridge (U. S. Highway 17); access to exposure by private road off State Road 628, Nansemond County. Altitude of top of exposure is 21.0 feet.

	Thickness Feet
Recent sediments	
Sand, light olive-gray, silty, numerous burned and disarticulated oyster shells and some Indian artifacts of Early Woodland Culture (Col. Wm. McCord, written communication)	1.7 (exposed)
Sand Bridge formation, clayey-sand facies	
Silt, light olive-gray, sandy, irregular yellow mottling	1.0

	Thickness Feet
Sand, yellowish-orange, fine, trace of silt, irregular yellow mottling in upper half	8.6
Sand, dusky-yellow, clayey. Sharp contact with the Yorktown	1.5
Yorktown Formation	
Silt, very dark-red, sandy, well indurated, nodular masses and laminae of ferricrete	1.8
Sand, dark yellowish-orange, fine, clayey, very fossiliferous	6.1 (exposed)

SECTION J: SAND BRIDGE FORMATION (UPPER MEMBER, SILTY-SAND FACIES)

Hand-auger boring (Plate 1, location 4) on southwest corner of intersection of State Roads 665 and 668, Isle of Wight County. Altitude of top of boring is 24.0 feet.

	Thickness Feet
Sand Bridge formation, silty-sand facies	
Sand, tannish-gray, very fine, trace of silt; grades down into orange-tan sand at base. Sharp contact with the Norfolk	11.0 (exposed)
Norfolk Formation, silty-sand facies	
Sand, dark-gray, very fine, silty, thin clay laminae, high percentage opaque minerals, wood fragments near base of boring	8.4 (exposed)

SECTION K: SAND BRIDGE FORMATION (SILTY-CLAY FACIES)

Plastic-tube boring (Plate 1, location 2) on north side of State Road 704, at base of power pole in front of Beale Construction Company (Figure 14), 0.1 mile west of State Highway 10, Isle of Wight County. Altitude of top of section is 30.0 feet.

	Thickness Feet
Sand Bridge formation, silty-clay facies	
Silt, dark-brown, sandy, fine	1.2 (exposed)
Clay, brown, trace fine sand and pebble gravel, grades down into orange-tan and tan	1.8
Sand, pale-brown, fine to coarse, clayey	0.7
Norfolk Formation, sand facies	
Sand, pale-tan, fine to medium, well-sorted, finer at base, high percentage opaque minerals	2.1 (exposed)

Comments: The contact between the Sand Bridge and Norfolk formations is gradational over a vertical distance of less than 1 foot. This section documents the unconformable overlap of the Sand Bridge formation onto the older Norfolk Formation at the Suffolk scarp (Figure 5).

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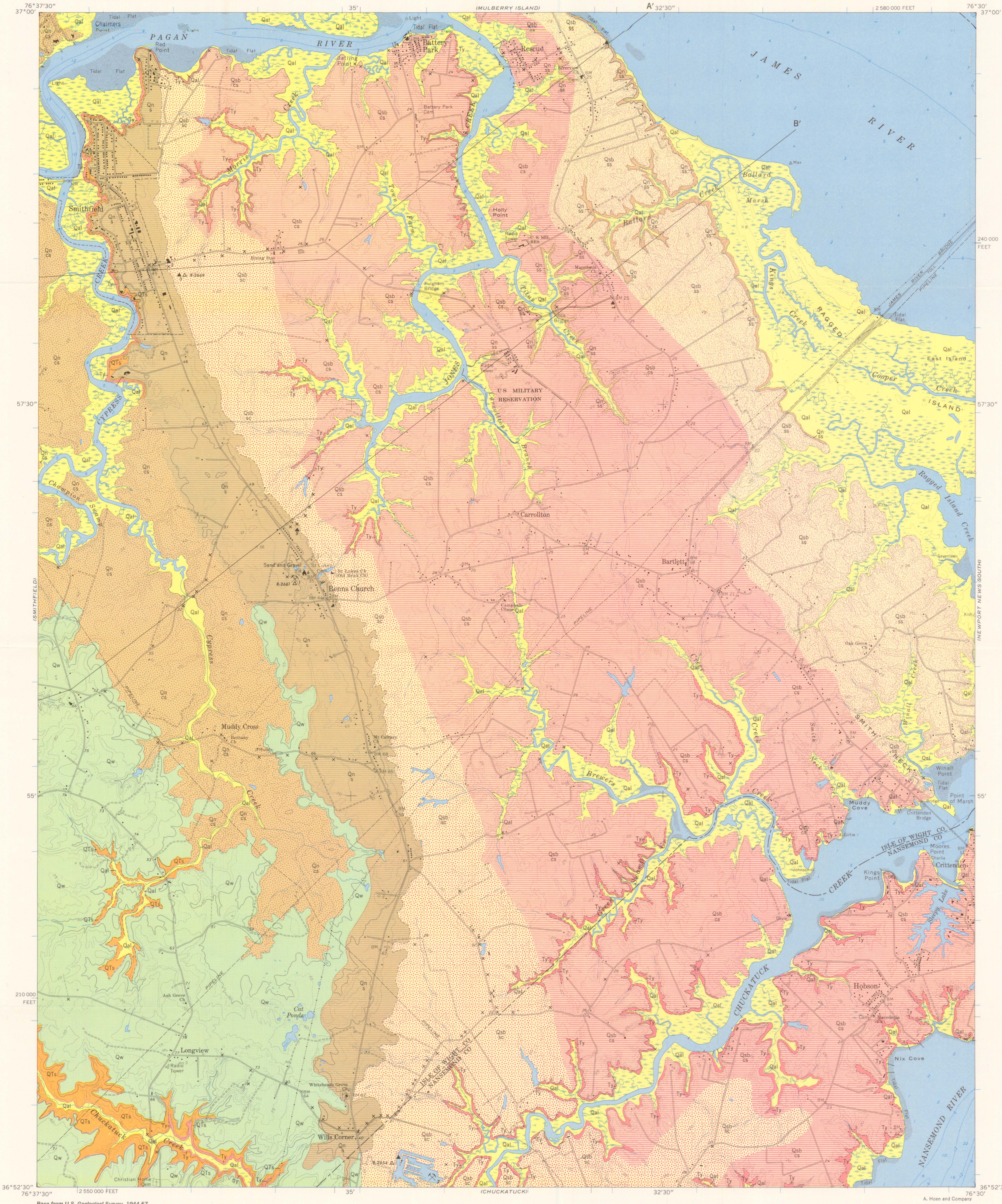
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base from U.S. Geological Survey, 1944-57
Benns Church Quadrangle, 7½ Minute Series.

GEOLOGIC MAP OF THE BENNS CHURCH QUADRANGLE, VIRGINIA

Geology by N. K. Coch

MN GN
6½°
116 MILS
0°57'
17 MILS
UTM GRID AND 1965 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 10 FEET
WITH SUPPLEMENTAL 5-FOOT CONTOURS

VIRGINIA
QUADRANGLE LOCATION

1968

EXPLANATION

QUATERNARY

Qal — Recent (RECENT)
Alluvium, estuarine-beach sediments, and fluvial-estuarine fills.

Unconformity

Qsb (sc, cs, ss) — Sand Bridge formation (PLEISTOCENE)
Upper member: facies- sc, *marsh and lagoon silty clay;* cs, *tidal channel clayey sand; and* ss, *fluvial and lagoon silty sand. Lower member too thin to be designated on map.*

Unconformity

Qn (cs, s, ss) — Norfolk Formation (PLEISTOCENE)
Upper member: facies- cs, *fluvial and estuarine clayey sand;* s, *beach and dune sand; and* ss, *brackish marine silty sand. Lower member too thin to be designated on map.*

Unconformity

Qw — Windsor Formation (PLEISTOCENE)
Marine and estuarine sand and silt.

Unconformity

QTs — Sedley formation (PLIOCENE (?))
Marine and estuarine silt and fine sand; not mappable under highest elevations of Isle of Wight plain.

Unconformity

TERTIARY

Ty — Yorktown Formation (MIOCENE)
Marine silt, sand, and clay; coquina.

CONTACTS

———	exposed
- - - -	approximate
·······	covered or inferred

QUARRIES AND PLANT

ACTIVE QUARRY
1. Southern Materials Company, Inc.—sand and gravel
2. Lone Star Cement Corporation—marl

PLANT
1. Battery Park Fish and Oyster Company—oyster shells

STRATIGRAPHIC CONTROL

× Locations at which samples were collected to determine subsurface formation and facies contacts.

△ R-2654 Location of sample representative of lithologies mapped.

▲ BC-131 Location where a representative stratigraphic section was examined.

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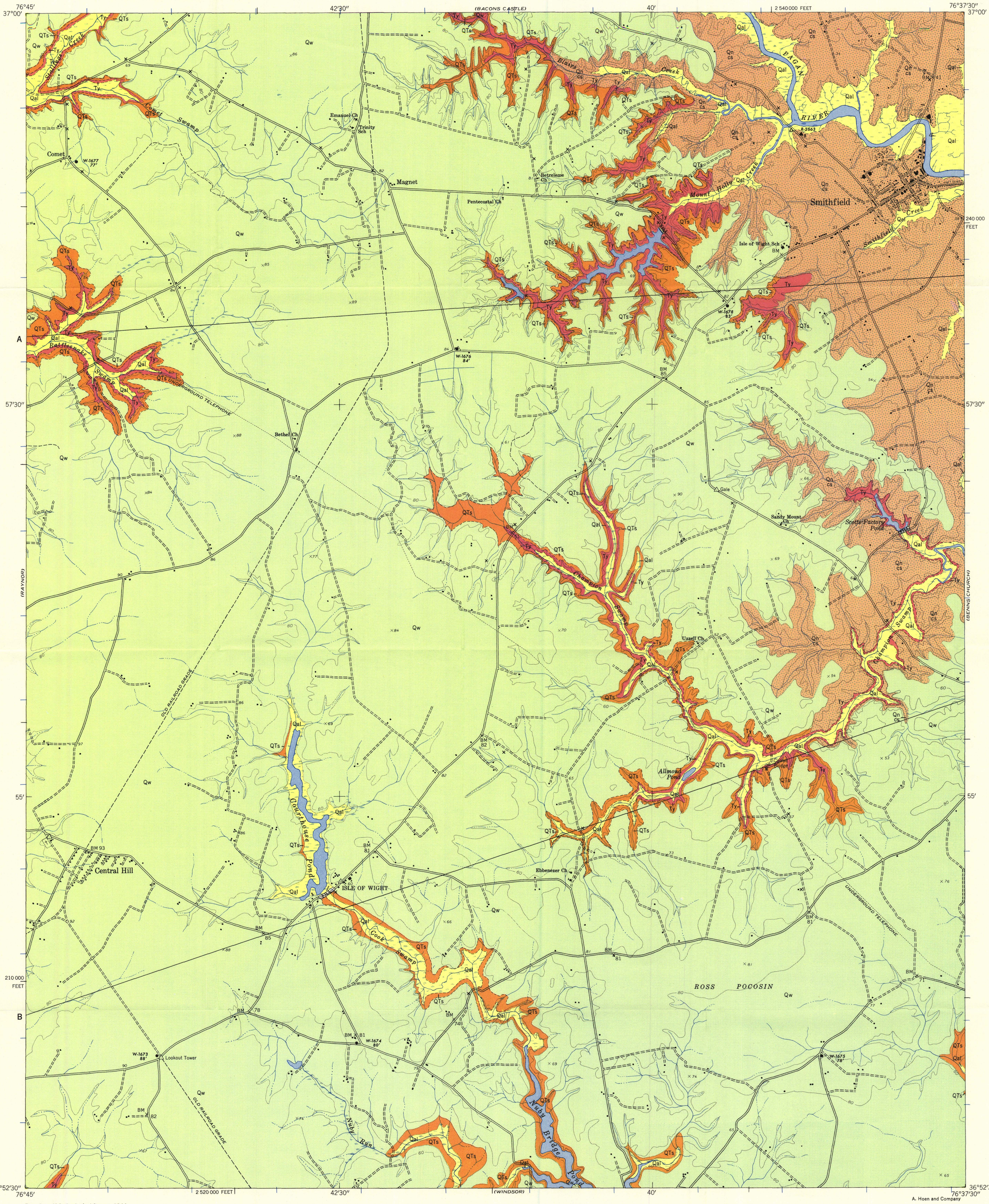


Base from U.S. Geological Survey, 1944
Smithfield Quadrangle, 7½ Minute Series.

A. Hoen and Company

GEOLOGIC MAP OF THE SMITHFIELD QUADRANGLE, VIRGINIA

Geology by N. K. Coch

6°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1944

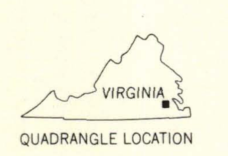
SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET



QUADRANGLE LOCATION

1968

EXPLANATION

QUATERNARY

Qal
Recent
Alluvium, estuarine-beach sediments, and fluvial-estuarine fills.

RECENT

Unconformity

Qn cs
Norfolk Formation
Upper member: facies-cs, fluvial and estuarine clayey sand. Lower member too thin to be designated on map.

Unconformity

Qw
Windsor Formation
Marine and estuarine sand and silt.

PLEISTOCENE

Unconformity

QTs
Sedley formation
Marine and estuarine silt and fine sand; not mappable under highest elevations of Isle of Wight plain.

PLIOCENE (?)

Unconformity

TERTIARY

Ty
Yorktown Formation
Marine silt, sand, and clay; coquina.

MIOCENE

CONTACTS

exposed

approximate

covered or inferred

STRATIGRAPHIC CONTROL

× Locations at which samples were collected to determine subsurface formation and facies contacts.

△ R-2654 Location of sample representative of lithologies mapped.

● W-1675 Location of test boring with altitude of top of hole indicated.

▲ SM-1 Location where a representative stratigraphic section was examined.

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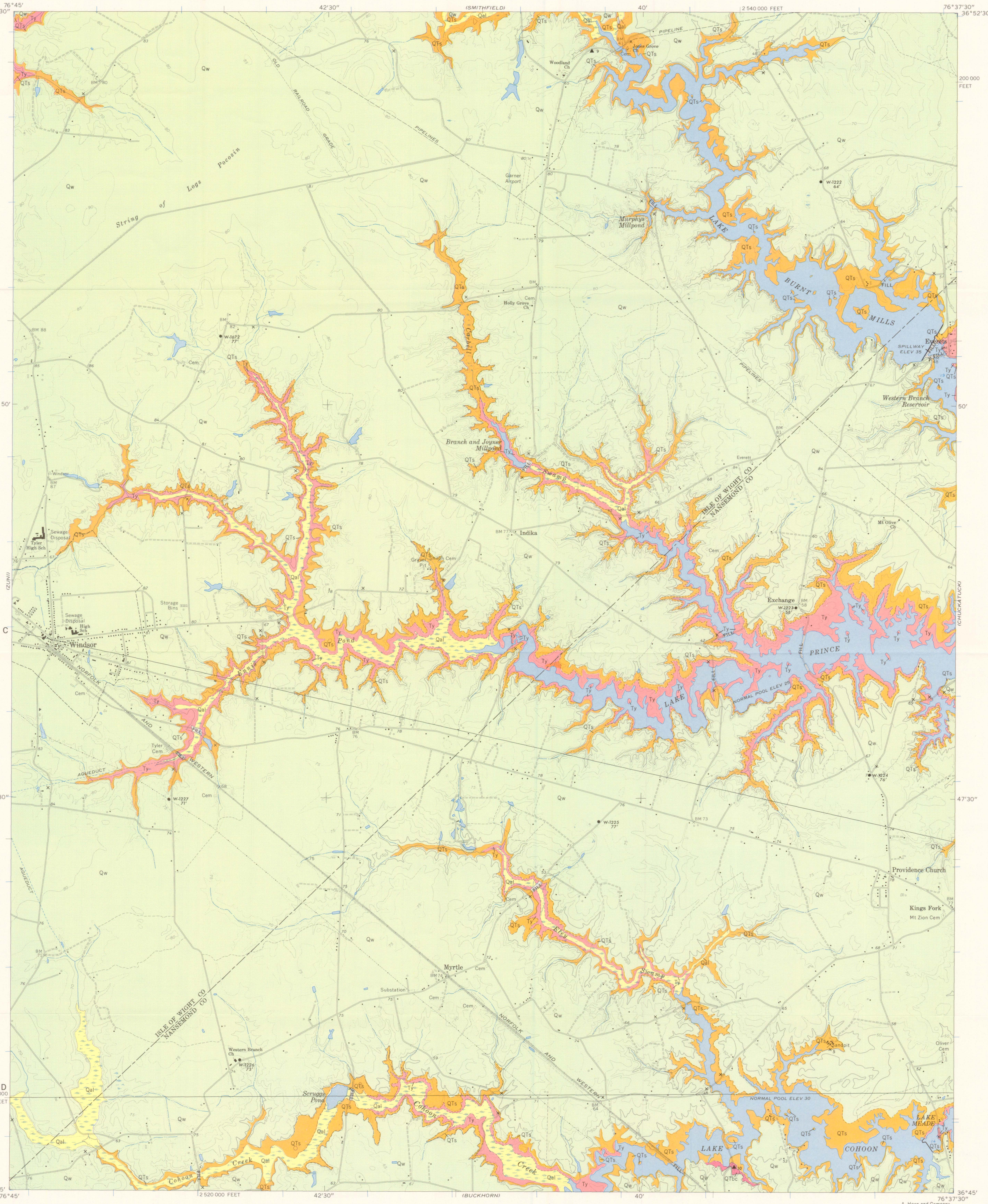

EXPLANATION

QUATERNARY	Qal — Recent. *Alluvium, estuarine-beach sediments, and fluvial-estuarine fills.*	RECENT	
	Unconformity		
	Qw — Windsor Formation. *Marine and estuarine sand and silt.*	PLEISTOCENE	
	Unconformity		
	QTbc — Bacons Castle formation. *Fluvial channel gravel and sand, and floodplain silt; present as isolated patches under Isle of Wight plain.*		
	Unconformity		
	QTs — Sedley formation. *Marine and estuarine silt and fine sand; not mappable under highest elevations of Isle of Wight plain.*	PLIOCENE (?)	
	Unconformity		
TERTIARY	Ty — Yorktown Formation. *Marine silt, sand, and clay; coquina.*	MIOCENE	

CONTACTS

exposed
approximate
covered or inferred

QUARRY

ACTIVE QUARRY
5. R. E. Johnson—sand

STRATIGRAPHIC CONTROL

× Locations at which samples were collected to determine subsurface formation and facies contacts.

● W-1675 Location of test boring with altitude of top of hole indicated.

▲ WI-12 Location where a representative stratigraphic section was examined.

Base from U.S. Geological Survey, 1944
Windsor Quadrangle, 7½ Minute Series.

A. Hoen and Company

GEOLOGIC MAP OF THE WINDSOR QUADRANGLE, VIRGINIA

Geology by N. K. Coch

MN GN
6½° 116 MILS
1°01' 18 MILS
UTM GRID AND 1965 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 10 FEET
WITH SUPPLEMENTAL 5-FOOT CONTOURS

VIRGINIA
QUADRANGLE LOCATION

1968

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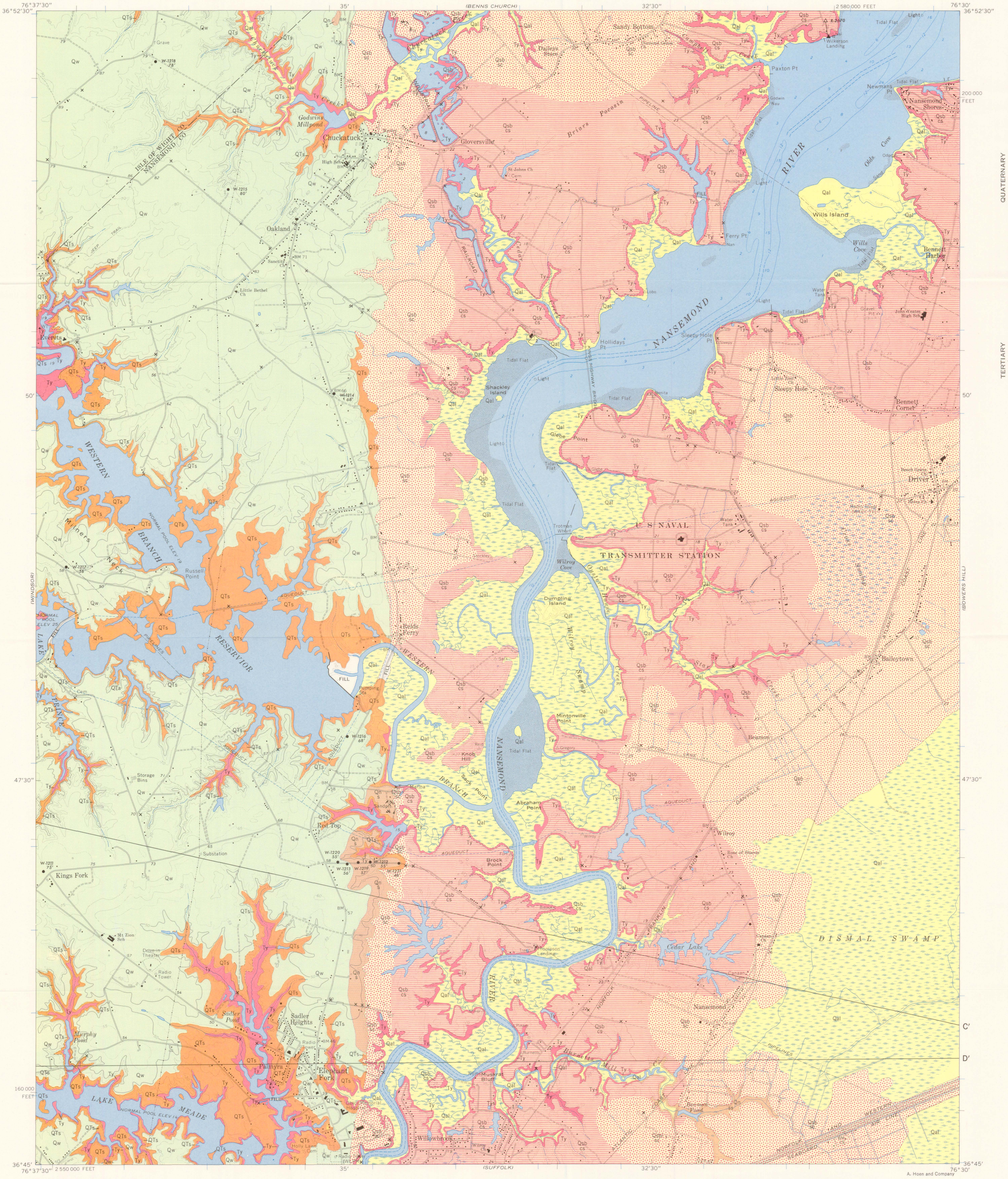

Base from U.S. Geological Survey, CE 1944
Chuckatuck Quadrangle, 7½ Minute Series.

A. Hoen and Company

GEOLOGIC MAP OF THE CHUCKATUCK QUADRANGLE, VIRGINIA

Geology by N. K. Coch

MN
GN
6½°
116 MILS
0°58'
17 MILS
UTM GRID AND 1965 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 10 FEET
WITH SUPPLEMENTAL 5-FOOT CONTOURS

1968

VIRGINIA
QUADRANGLE LOCATION

EXPLANATION

QUATERNARY

RECENT

Qal
Recent
Alluvium, estuarine-beach sediments, and fluvial-estuarine fills.

Unconformity

PLEISTOCENE

Qsb sc cs
Sand Bridge formation
Upper member: facies- sc, *marsh and lagoon silty clay;* cs, *tidal channel clayey sand. Lower member too thin to be designated on map.*

Unconformity

Qn s ss
Norfolk Formation
Upper member: facies- s, *beach and dune sand; and* ss, *brackish marine silty sand. Lower member too thin to be designated on map.*

Unconformity

Qw
Windsor Formation
Marine and estuarine sand and silt.

Unconformity

PLIOCENE (?)

QTs
Sedley formation
Marine and estuarine silt and fine sand; not mappable under highest elevations of Isle of Wight plain.

Unconformity

TERTIARY

MIOCENE

Ty
Yorktown Formation
Marine silt, sand, and clay; coquina.

CONTACTS

exposed
approximate
covered or inferred

QUARRIES AND PLANT

ACTIVE QUARRY
3. Lone Star Cement Corporation—marl
4. R. E. Johnson—sand

PLANT
2. Lone Star Cement Corporation—marl

STRATIGRAPHIC CONTROL

× Locations at which samples were collected to determine subsurface formation and facies contacts.

R-2654 Location of sample representative of lithologies mapped.

W-1675 Location of test boring with altitude of top of hole indicated.

11 Location where a representative stratigraphic section was examined.

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Vertical Exaggeration 20X
Vertical Scale 1″ = 100′

Geology by N. K. Coch

A. Hoen and Company