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COMMONWEALTH OF VIRGINIA
STATE COMMISSION ON CONSERVATION AND DEVELOPMENT
VIRGINIA GEOLOGICAL SURVEY
ARTHUR BEVAN, *State Geologist*

Bulletin 37
Educational Series No. 2

The Lower York-James Peninsula

BY
JOSEPH KENT ROBERTS

UNIVERSITY, VIRGINIA
1932

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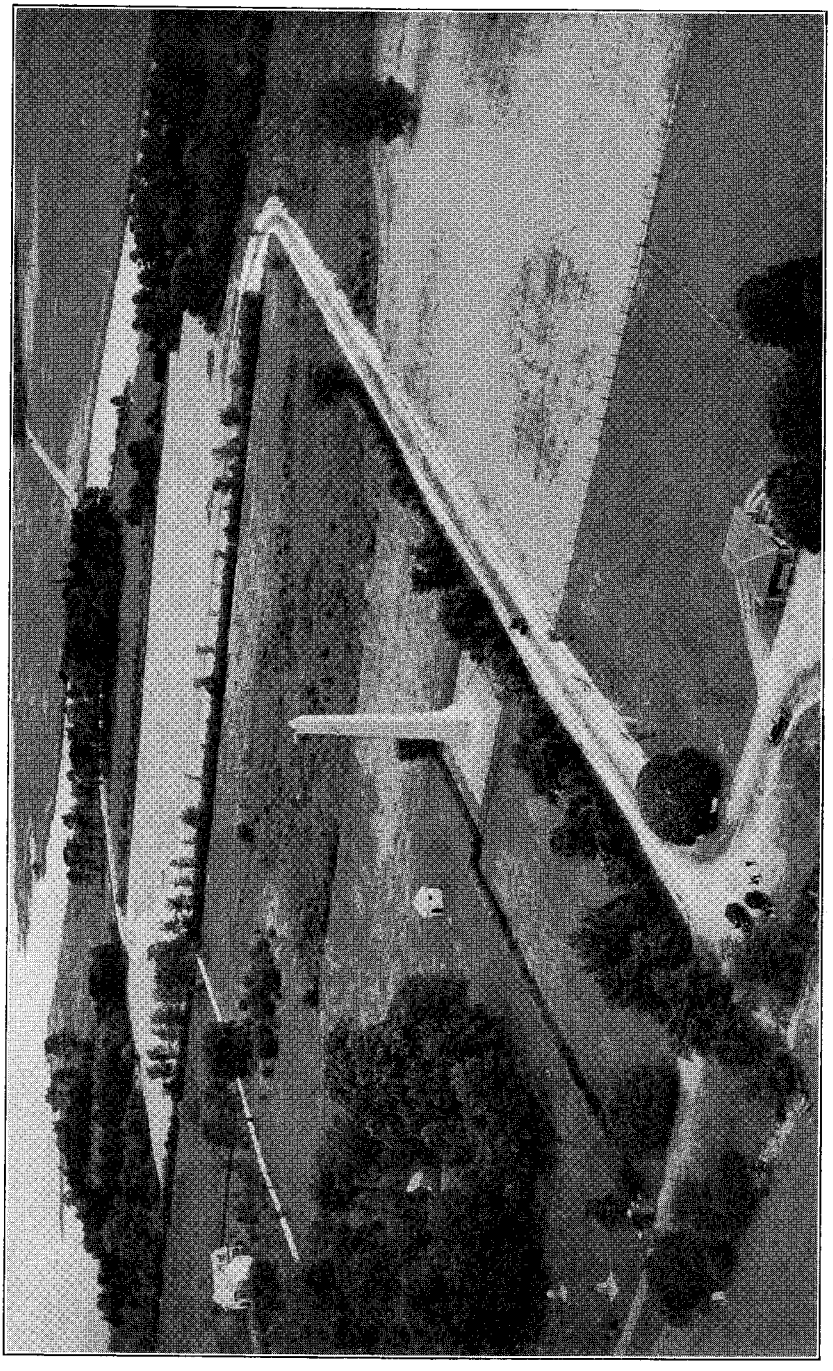
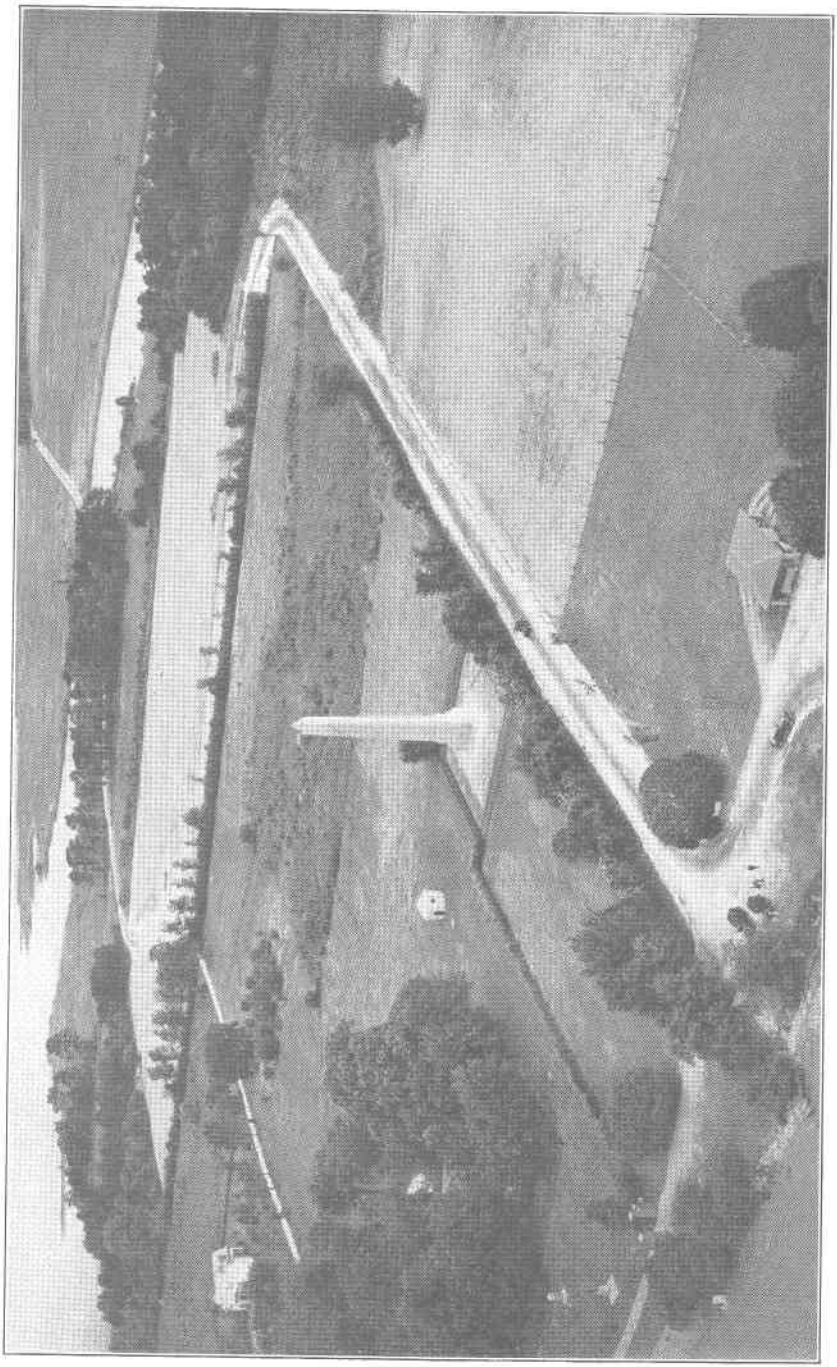


Jamestown Island, site of the first permanent colony in North America. View northeast from above James River. Photograph by U. S. Army Corps, 2nd Photo. Section, Langley Field, Va.



Jamestown Island, site of the first permanent colony in North America. View northeast from above James River. Photograph by U. S. Army Corps, 2nd Photo. Section, Langley Field, Va.

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., November 25, 1931.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 37 of the Virginia Geological Survey series of reports the manuscript and illustrations of a report on *The Lower York-James Peninsula,* by Dr. Joseph K. Roberts, Professor of Geology, University of Virginia.

This report describes concisely the geology of the southeastern half of one of the most historic areas in the United States, but about whose geologic resources and geologic history very little has been published. The region covered by this report includes Elizabeth City, James City, Warwick, and York counties, and thus the Jamestown, Williamsburg, and Yorktown areas and the recently established Colonial National Monument.

This report should be of considerable interest and value to residents of the region, to the many visitors, and to the schools of the State because it presents, so far as possible in non-technical language, the geologic background of the historic Peninsula and its important influence on the colonization and development of this noted region.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
State Commission on Conservation and Development,
Richmond, Virginia, November 25, 1931.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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The Lower York-James Peninsula

By Joseph Kent Roberts

INTRODUCTION

This report summarizes the significant geological features of the southeastern part of the peninsula between York and James rivers, known as "The Peninsula," which is of great interest, for it may be said to be the "Cradle of the Republic." This region lives in history because on every hand it bears evidences of the activities and brave struggles of the early English settlers, which have been repeatedly told in the classroom, in song, and in story. The story is the more interesting, for the birth of a state and of a nation are nowhere better recorded.

In this region there are also records of significant changes through vast periods of time in regard to the relations of land and water; plants and animals which lived upon the land, along the shores, and in the ocean; and materials accumulated by geologic agents; that is, records of the geologic history of the region.

The reader may wonder how evidences of the inorganic and organic changes which transpired in this long-buried past can be interpreted today. About a century ago a noted Scottish geologist, Sir Charles Lyell, following the discoveries of Hutton a few decades before, called the attention of his contemporaries to the fact that the present must be used in, and is the key to, our interpretation of the past. Thus by understanding present geologic conditions, we can apply these known principles to the past and gradually work out the history of more remote periods. It is true that we do not know, and probably never shall know, all of the details of the physical and organic changes that occurred during the ancient epochs. In the main, however, we can discover and understand the important changes which have taken place if we can recognize the features left as records or witnesses of the geologic past.

LOCATION AND EXTENT OF THE AREA

The York-James Peninsula extends from the Fall Zone, at the western edge of the Coastal Plain, southeastward to Chesapeake Bay east of Newport News. (See Fig. 1.) It embraces these

counties:[1] Charles City, Elizabeth City, James City, New Kent, Warwick, York, and portions of Henrico and Hanover counties. Only Elizabeth City, James City, Warwick, and York counties, which comprise the lower, or southeastern, part of the York-James Peninsula, are considered in this report. The major axis of the Peninsula extends in a southeasterly direction for nearly 75 miles. The Peninsula is widest across Charles City and New Kent counties, and it is narrowest in the vicinity of Grove, York County, where James River on the south and York River on the north are only 6 miles apart. Its average width is approximately 18 miles. The main highway (No. 60) from Richmond to Newport News roughly parallels the axis of the Peninsula but is closer to James River.

The area of the Peninsula by counties and the date of origin of each county are shown in Table 1.

TABLE 1.—*Counties in the York-James Peninsula*

County	Area (Square miles)	Date when formed
Charles City	188	1634
Elizabeth City	53	1634
Hanover[a]	512	1721
Henrico[a]	255	1634
James City	163	1634
New Kent	191	1654
Warwick	65	1634
York	136	1634

[a] Western part of the county is in the Piedmont province.

The area discussed in this report contains approximately 417 square miles.

Part of this area lies within the Colonial National Monument, which extends from Yorktown to Jamestown and includes Williamsburg. When fully developed it should be very attractive and popular with visitors. Jamestown (Pl. 1) marks the beginning, in 1607, in North America of a permanent English colony. For a long time it was the capital of the colony. In 1699, the capital was moved to Williamsburg where it remained until 1780 when it was removed to Richmond. Williamsburg (Pl. 2) is probably the oldest incorporated town in this country and is noted from very early

[1] The Peninsula is covered by topographic maps, on a scale of 1 mile to 1 inch, of these quadrangles: Bermuda Hundred, Charles City, Hampton, King William, Mathews, New Kent, Newport News, Richmond, Surry, Toano, Williamsburg, and Yorktown. These maps may be bought from the Virginia Geological Survey, University, Virginia, for ten cents each.

times for the part it played in helping to make Virginia and American history, for its Colonial relations with the mother country, and perhaps mainly for the founding of the College of William and Mary here in 1693. Yorktown (Pl. 3) has been known widely since October 19, 1781, when the surrender of Lord Earl Cornwallis was precipitated by the combined American and French troops. There have been many changes in this region in the past three hundred years, but it is surprising how many of the old Colonial homes are still standing and how well some of them had been preserved even before Mr. J. D. Rockefeller, Jr., began the complete restoration of Colonial Williamsburg. A road is to be built connecting Yorktown with Williamsburg and it will extend along York River through the Naval Mine Depot grounds.

SCOPE OF THE REPORT

The geology of the four counties composing the lower part of the York-James Peninsula is considered mainly from the standpoints of the topography and its effect upon colonization and the developing civilization, the character of the sedimentary rocks exposed in the region, the remains of life, or fossils, in these rocks, the mineral resources of the area, and the geologic history of the region.

PREVIOUS GEOLOGIC STUDIES

The earliest reference of any note to the geology of the lower part of the Peninsula is in 1783 by General Benjamin Lincoln.[2] There have been many brief references to the geology of the region, but the first serious studies were made by William B. Rogers, who was the first State Geologist of Virginia, one-time Professor of Natural Philosophy at William and Mary College, and later Professor of Natural Philosophy at the University of Virginia. Rogers made his first contribution in 1835 on the "Fossil Marls of Lower Virginia,"[3] and from time to time published other contributions. Since the time of Rogers, many geologists have visited the fine exposures of shell marl and other beds at Yorktown, Bellefield, and along James River until these localities have become classic collecting grounds for middle Tertiary fossils. (See Pls. 16-19.) The literature is too voluminous to mention here. The work of Conrad, Finch, Taylor, Lea, Lyell, Dall, Darton, and

[2] Lincoln, Benjamin, An account of several strata of earth and shells on the banks of York River, in Virginia: Am. Acad. Arts and Sci. Mem., vol. 1, pt. 2, pp. 372-373, 1783.

[3] Rogers, W. B., Miocene marl district: Report of the geological reconnaissance of the State of Virginia, 1835. Reprinted in "Geology of the Virginias," New York, pp. 29-44, 1884.

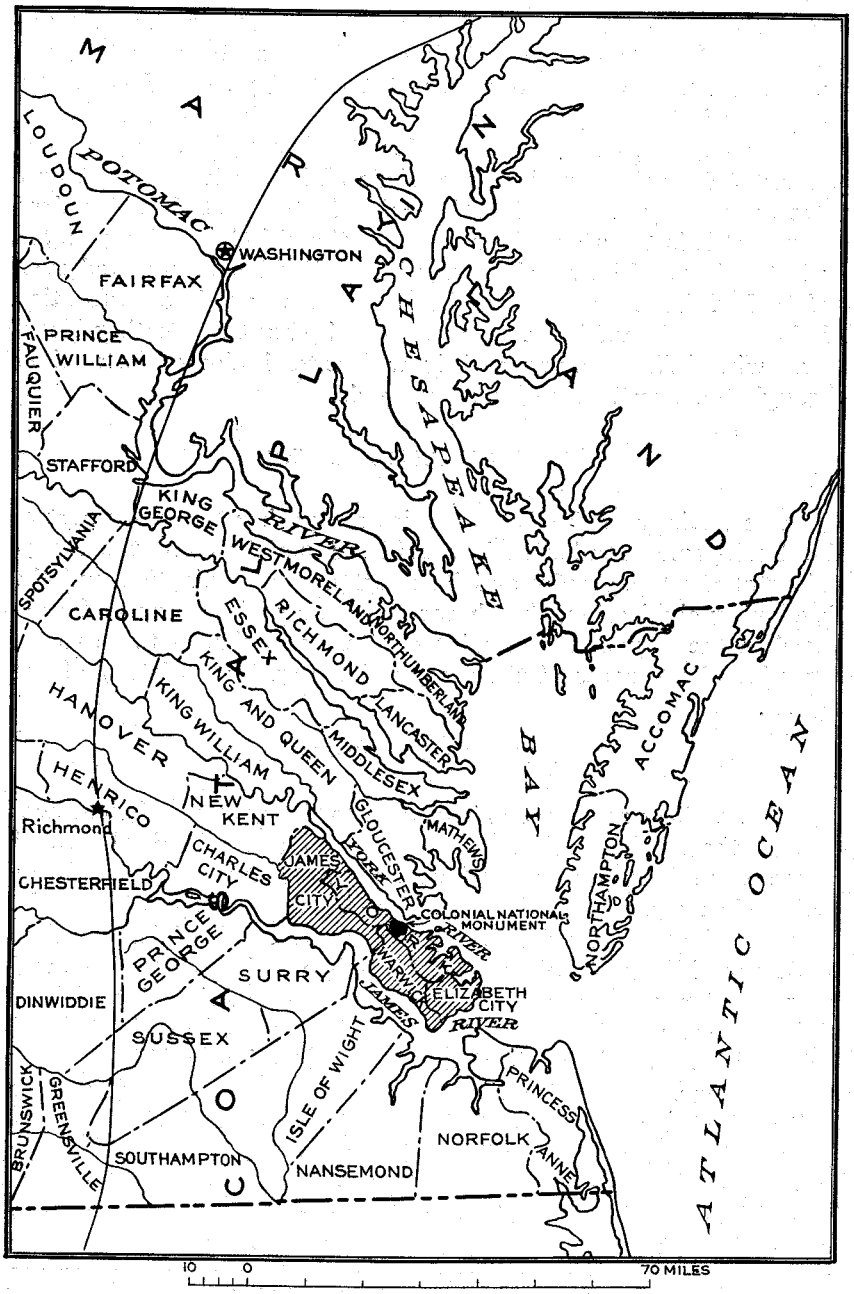


Figure 1.—Index map showing the Peninsula and its relation to the Coastal Plain. The curved line through Richmond and Washington marks the Fall Zone, at the western edge of the Coastal Plain. The shaded area is covered by this report.

Tuomey should also be mentioned. A comprehensive treatise on the Coastal Plain of Virginia[4] was published in 1912. The terraces and surface deposits have been described recently in some detail.[5]

ACKNOWLEDGMENTS

This opportunity is taken to express gratitude to the State Commission on Conservation and Development and to Dr. Arthur Bevan, State Geologist, for making possible the additional field work necessary to complete this report. The writer is grateful to Dr. J. E. Copenhaver and Mr. Henry W. Crenshaw for their assistance in collecting fossils and measuring sections of the formations. Dr. Julia A. Gardner of the U. S. Geological Survey has checked the identification of the thirty typical fossils. Cordial cooperation has been given by Capt. B. H. Green of the United States Navy Mine Depot, Major Kerr of Fort Eustis, the Yorktown Sesquicentennial Headquarters, the National Park Service, Dr. Donald W. Davis of the College of William and Mary, Mr. Archibald M. McCrae of Carter's Grove, Mr. George A. Coleman and Mr. J. M. Dozier of Williamsburg, and Mr. T. W. Crockett of Yorktown. Many citizens of the Peninsula have in various ways rendered assistance which is much appreciated.

[4] Clark, W. B., and others, Physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 4, 274 pp., 1912.

[5] Wentworth, C. K., Sand and gravel resources of the Coastal Plain of Virginia: Virginia Geol. Survey Bull. 32, 146 pp., 1930.

TOPOGRAPHY

GENERAL FEATURES

The York-James Peninsula, or the Peninsula, is a part of the Atlantic Coastal Plain, which extends from northern New Jersey southward to southern Florida. The Coastal Plain of Virginia, or Tidewater Virginia, is one of the five major physiographic divisions of the State. (See Fig. 1.) These divisions differ not only in elevation, topography, types of rocks, and natural resources, but each supports a different people. The inhabitants of Tidewater Virginia largely retain the customs of the English stock and have changed less than those in other parts of the State. The Blue Ridge was to a considerable extent a barrier to the settlers as they pushed westward over the Piedmont region, so that the Great Valley was more easily reached by settlers from northern Virginia and Maryland.

The original settlers apparently reached the shores of Virginia mainly through good fortune. They found their first location along the seacoast unsatisfactory, so they moved up James River, probably in search of a quieter water front, more vegetation, and possibly because of other factors. The pioneer settlers could have pushed inland as far as the site of Richmond but they would have had more Indian tribes between them and the ocean. Hence there may have been many factors which determined the original Colonial site at Jamestown in 1607, of which the peculiar topography, or contour of the land, was one of considerable importance.

The Coastal Plain of Virginia extends from Chesapeake Bay westward to the Fall Zone, which marks the contact between the unconsolidated sediments of the Coastal Plain, sloping gently toward Chesapeake Bay, and the older underlying complex group of igneous and metamorphic rocks of the Piedmont province. The Fall Zone extends from New York City through Philadelphia, Baltimore, Washington, Fredericksburg, Richmond, Petersburg, and Emporia into North Carolina and beyond. Richmond, for example, lies partly in the Coastal Plain and partly in the Piedmont region. The Fall Zone may best be indicated in Virginia as the zone just beyond the inner limit of the tides, thus causing the region to the east to be known as Tidewater Virginia. Navigation up the larger coastal-plain streams to the Fall Zone was very important during the first two hundred years of Colonial life and it is only within the last quarter of a century that such transportation has shown a considerable decline.

DRAINAGE

The drainage pattern of the Peninsula is rather simple. York and James rivers, on the north and south, respectively, are the master streams. James River rises in the mountains far west of the Blue Ridge, cuts through the Blue Ridge in a magnificent water gap at Balcony Falls, and receives numerous tributaries along its course. After passing the Fall Zone at Richmond, it is navigable to its mouth. In former days a canal along James River connected Lynchburg with Richmond. The James is an antecedent stream, that is, it has inherited its course from a previous erosion cycle in the geologic history of the region. The amount of fall in James River from Richmond to its mouth is very small, and the tide ascends the drowned valley to Richmond. Many meanders and extensive floodplain areas have been developed along its course below Richmond and along its major tributaries. (See Pl. 5.) The approximate widths of James River opposite certain places in the lower part of the Peninsula are given in Table 2.

TABLE 2.—*Approximate widths of the lower part of James River*

	Miles
Mouth of Chickahominy River	3.5
Jamestown Island (ferry line)	2.5
King's Mill (old wharf)	2.3
Carter's Grove	2.8
Fort Eustis Wharf	2.0
Burwell Bay	5.7
Mouth of Warwick River	3.7
Newport News	3.2

York River is a very different type of stream. Instead of having its source west of the Blue Ridge and having maintained its course through downcutting as the region was uplifted, it has grown headward across the Coastal Plain until now it rises just west of the Fall Zone. It is thus a consequent stream in its upper course and a drowned stream from West Point to Chesapeake Bay. It is formed by the confluence of Mattaponi and Pamunkey rivers at West Point. Its water is clear and saline and it accommodates shipping as far as West Point. This stream has no meanders and few floodplain areas. The York is a narrow stream compared to the James, as shown by Figure 2 and its width in the cross sections given in Table 3.

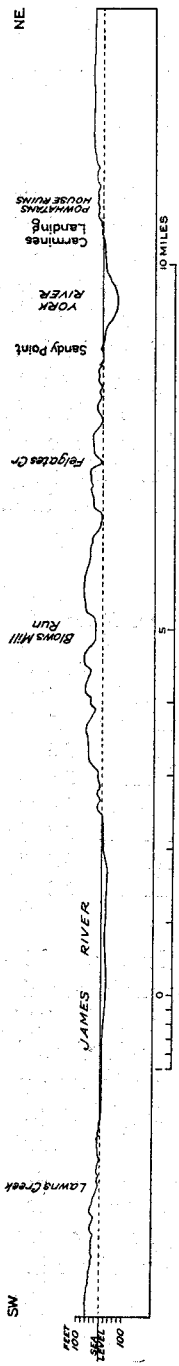


Figure 2.—Profile across the Peninsula and adjacent rivers showing the general character of the topography.

TABLE 3.—*Approximate widths of York River*

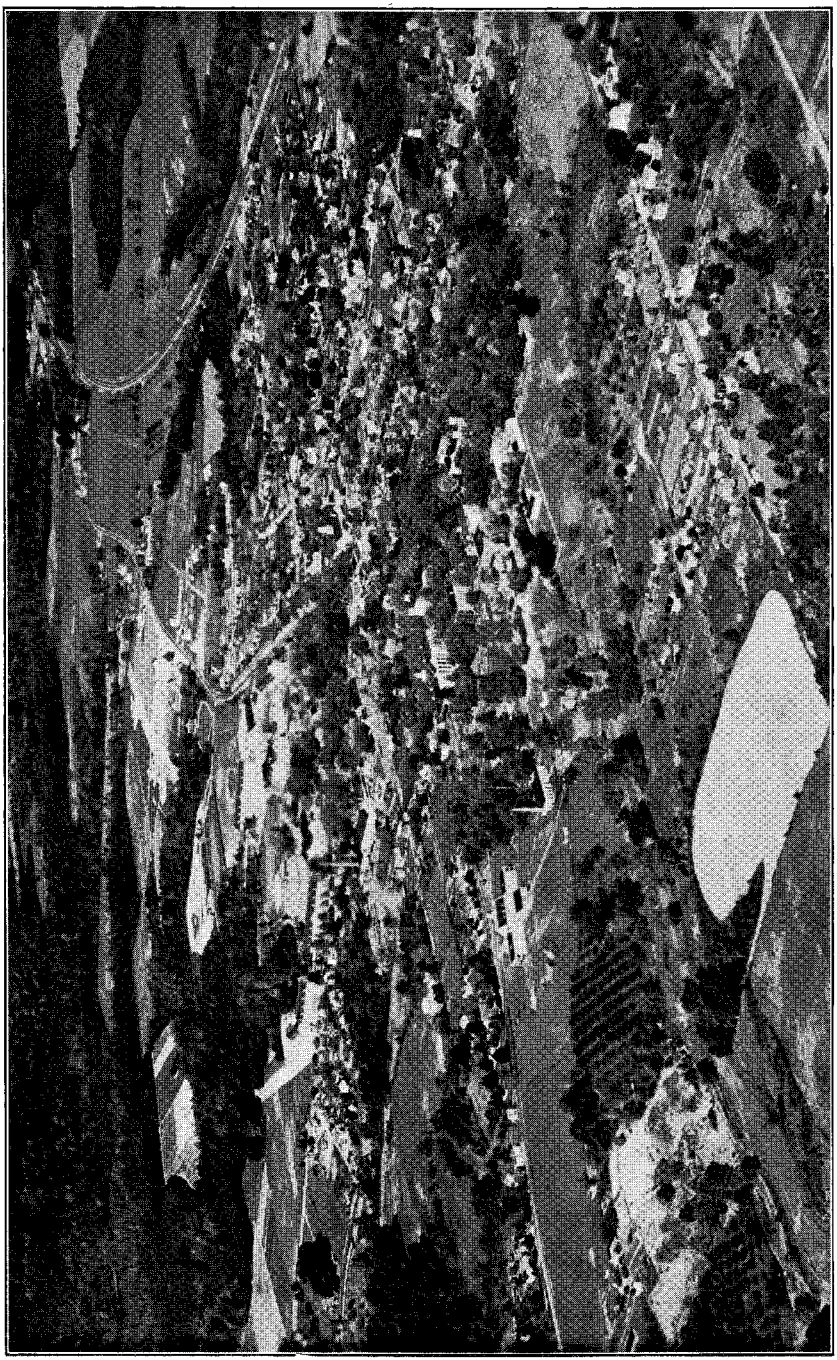
	Miles
New Kent-James City county line	1.8
Mt. Folly	1.5
Scimmino Creek	2.0
Queen Creek	2.2
U. S. Navy Mine Depot (Sandy Point)	1.3
Yorktown-Gloucester Point	0.5
At Chesapeake Bay	2.5

The York and the James have a few abandoned bluffs and these are not very far from the present courses of the rivers.

Most of the many small streams on the Peninsula are short and their courses are swampy. (See Pls. 4-6.) Tributaries of the James are Powhatan, Mill, College, Skiffs, Potash, Deep, and Watts creeks and Chickahominy and Warwick rivers. York River receives Ware, Taskinas, Scimmino, Carter, Queen, King, Felgates, Wormley, Back, and Cheesman creeks, and Poquoson and Back rivers. A low watershed extends about parallel to the axis of the Peninsula, rising towards the northwest and declining to sea-level between Newport News and Hampton. The streams are sluggish and their erosion is mainly lateral.

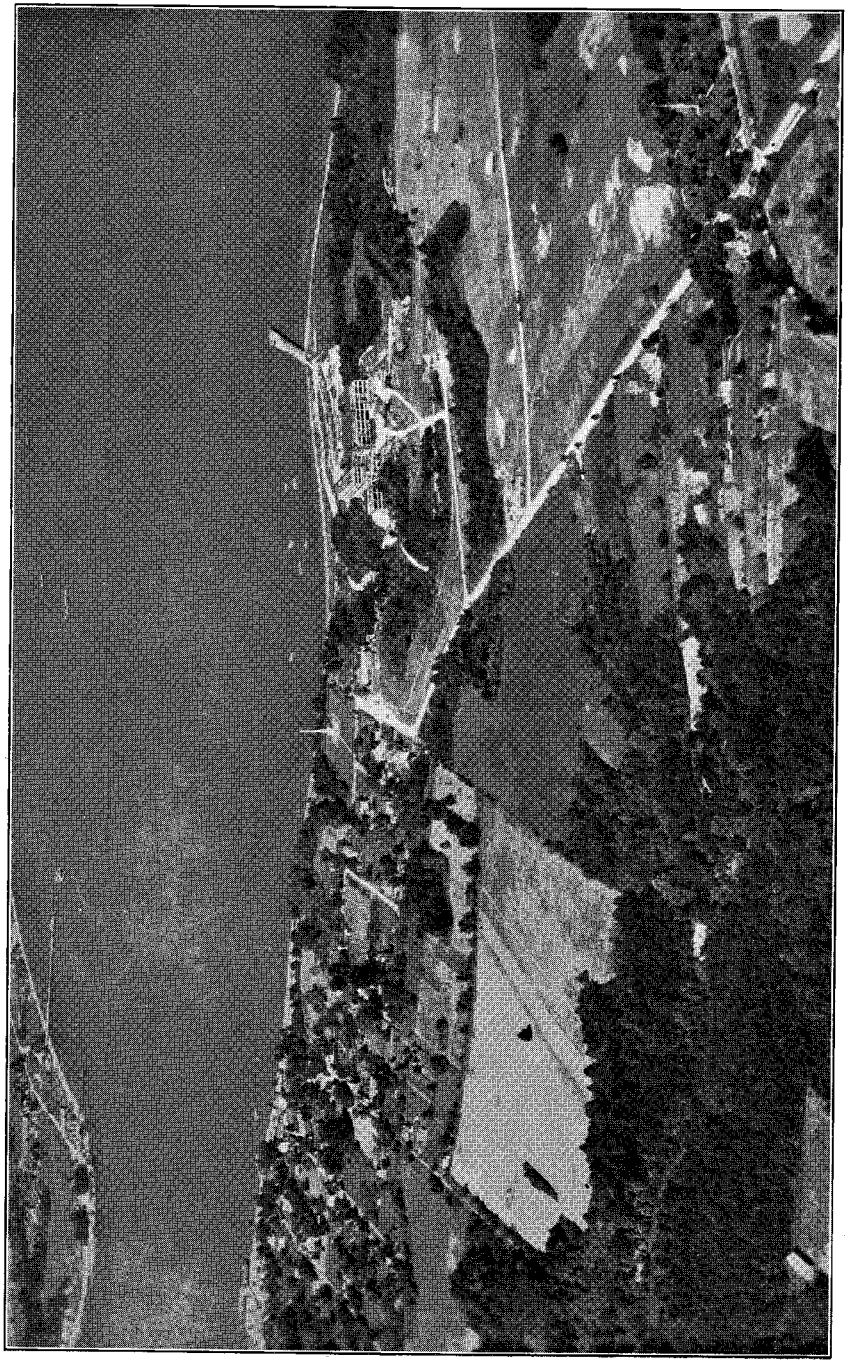
HARBORS

No better harbors are known in American waters than Hampton Roads in the lower James, Chesapeake Bay, and York River. (Pl. 3.) This was well demonstrated during the War between the States and the World War. York River at Yorktown has a depth of about 80 feet in its main channel. The United States Navy has a mine depot 1 mile above Yorktown and a fueling station 2 miles to the southeast. Large war vessels can be acommodated far up the James and during the War between the States one of the main navy yards of the Confederate States of America was located at Richmond. Hampton Roads has an area

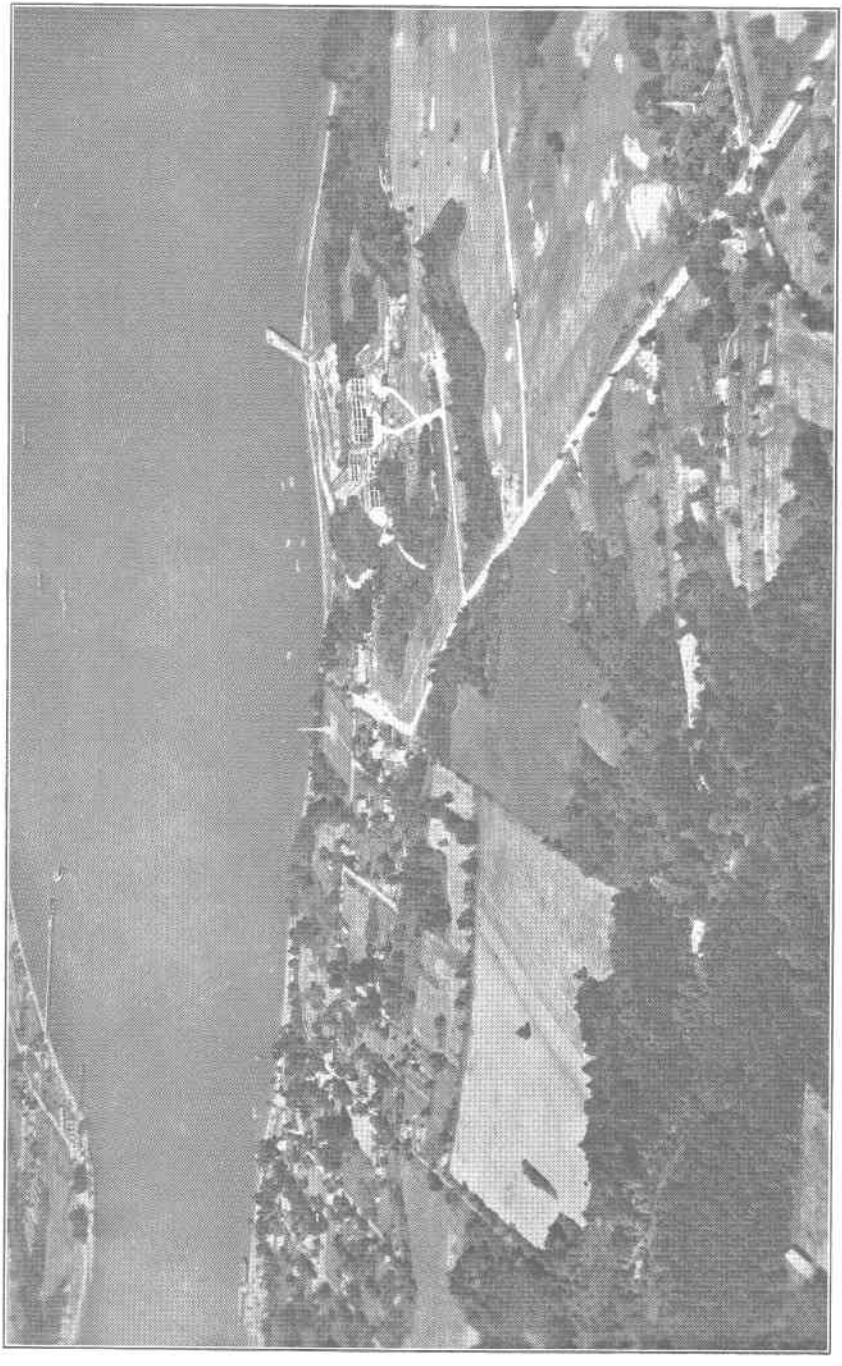


Williamsburg, the Colonial Capital of Virginia. Note the flat surface of the Coastal Plain. Aeroplane photograph from State Commission on Conservation and Development.

Williamsburg, the Colonial Capital of Virginia. Note the flat surface of the Coastal Plain. Aeroplane photograph from State Commission on Conservation and Development.



The Yorktown area. Looking northeast across York River to Gloucester Point. Aeroplane photograph from State Commission on Conservation and Development.



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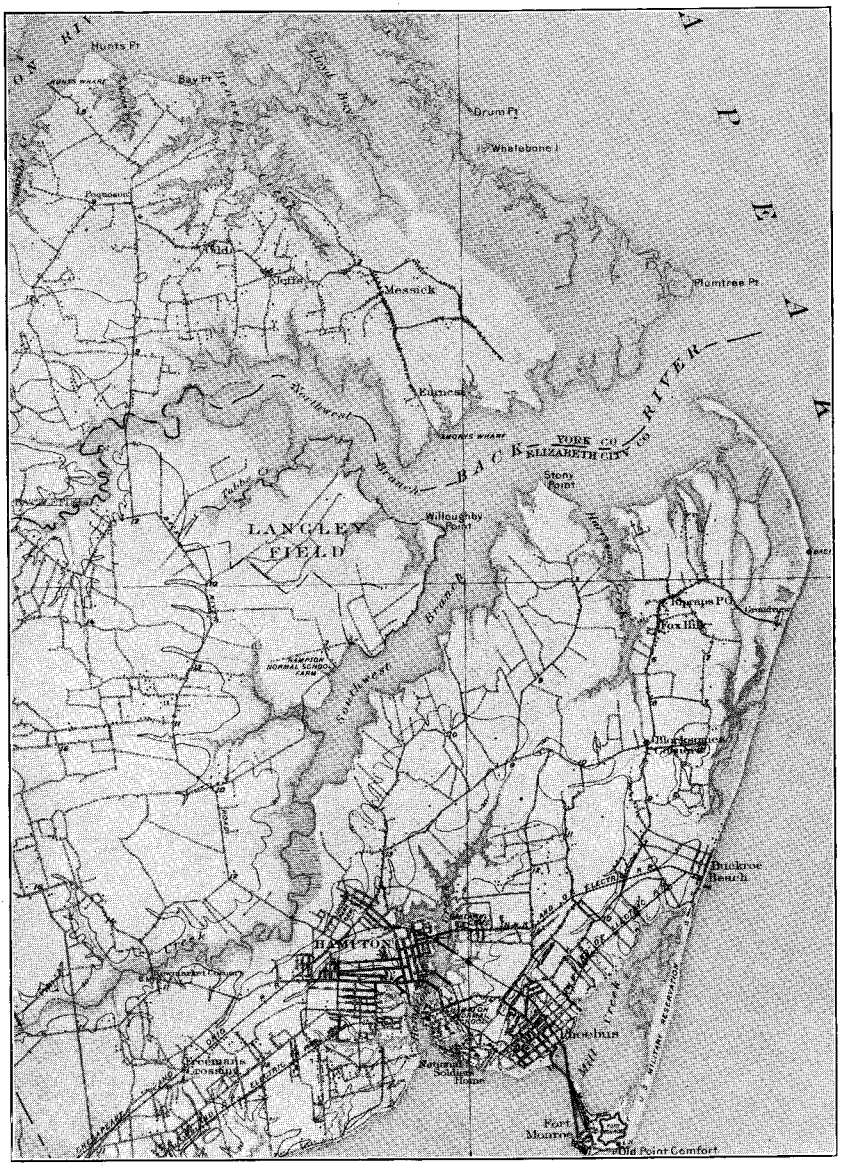
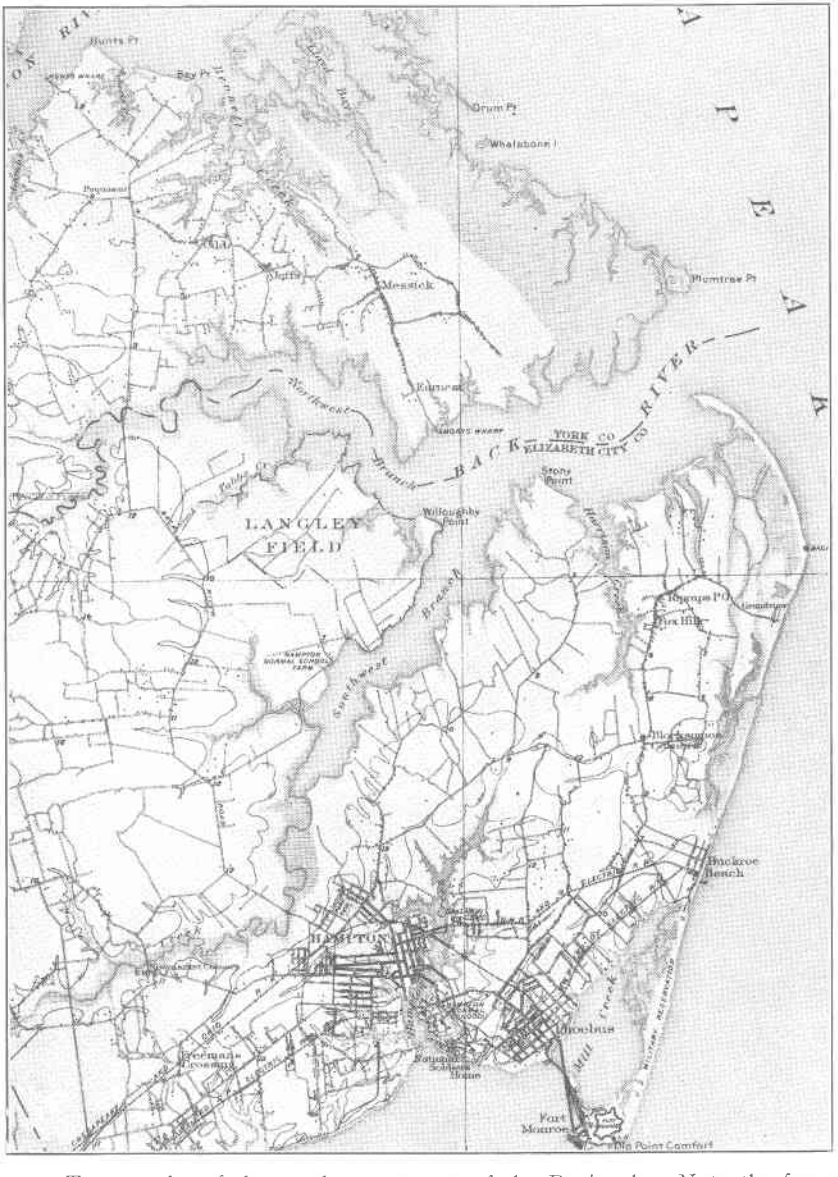


Topography of the southeastern part of the Peninsula. Note the frayed coast line, due to submergence, and the low relief of the Coastal Plain. (See pp. 9-11.) (Part of the Hampton sheet.) Scale, 1 inch equals 2 miles; contour interval, 10 feet.



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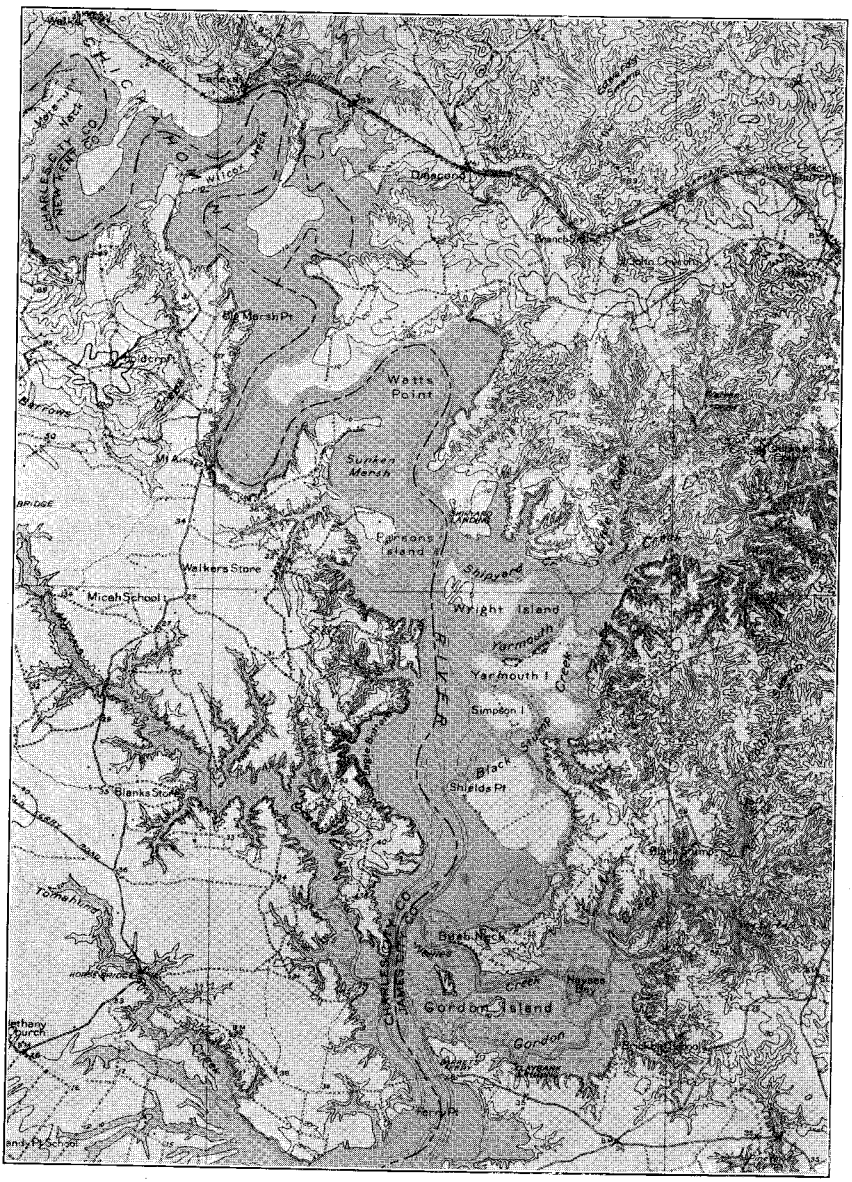
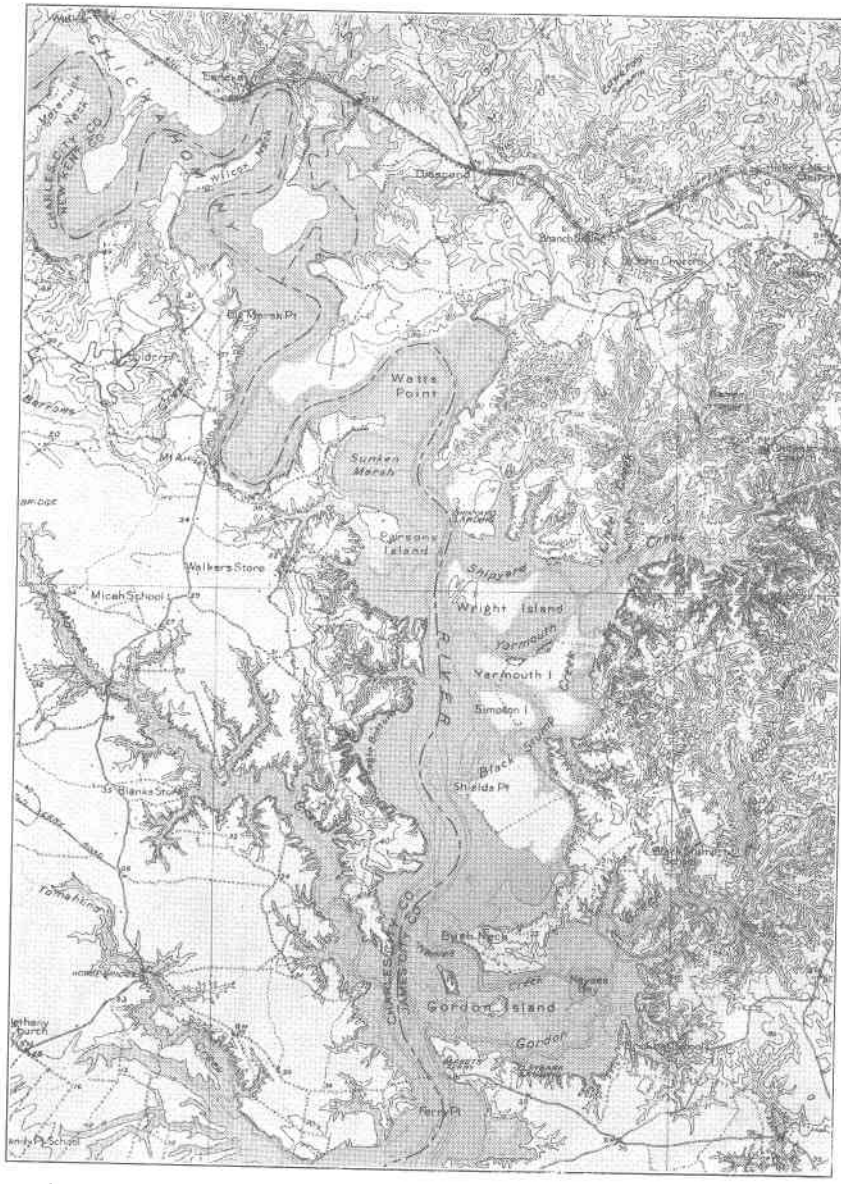


Topography along Chickahominy River near its mouth. The valley has been drowned due to subsidence of the area relative to sea-level, making many swamps. (See pp. 7-11.) (Part of the Toano sheet.) Scale, 1 inch equals 2 miles; contour interval, 10 and 20 feet.



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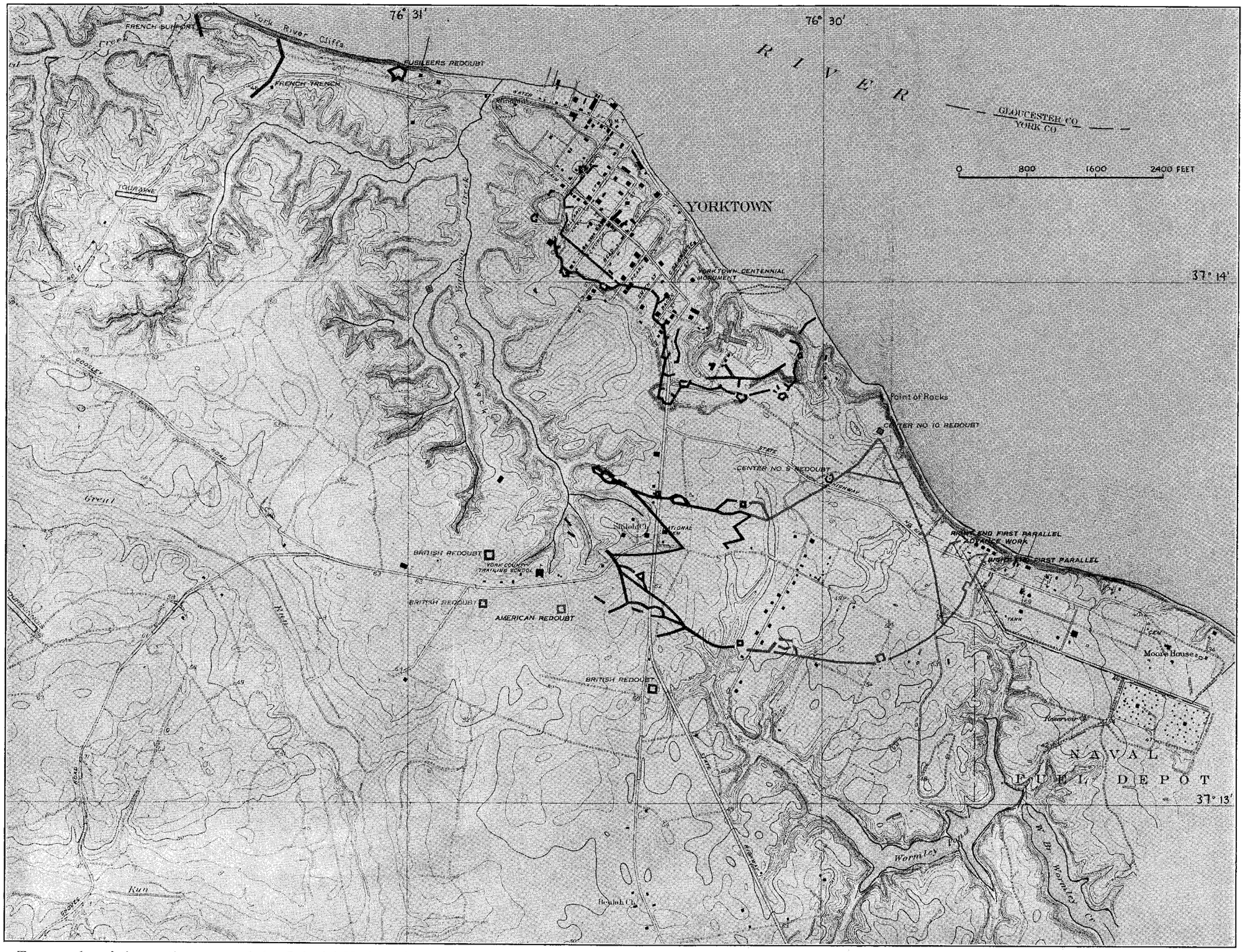


Topography of the northern part of the Colonial National Monument. (Part of the map of the Colonial National Monument and Yorktown Battlefield, Va. U. S. Geol. Survey, 1931.) Contour interval, 5 feet. Note the undulatory surface of the Coastal Plain, the dissection by young valleys, and the cliffs along York River. (See pp. 9-11.)

Topography of the northern part of the Colonial National Monument. (Part of the map of the Colonial National Monument and Yorktown Battlefield, Va. U. S. Geol. Survey, 1931.) Contour interval, 5 feet. Note the undulatory surface of the Coastal Plain, the dissection by young valleys, and the cliffs along York River. (See pp. 9-11.)

of about 75 square miles, an average depth of about 100 feet, and an average width of about 4 to 4½ miles.

ELEVATION AND RELIEF

The York-James Peninsula is a dissected plain (Fig. 2) whose elevation is nowhere more than 150 feet above sea-level and the average elevation is much less. (See Pls. 4-6.) On the basis of elevation the Peninsula may be divided into a lower portion comprising Elizabeth City County (Pl. 4), most of Warwick County, and about half of York County, and an upper portion comprising parts of Warwick and York counties and all of James City County (Pl. 5). The lower eastern portion is about 25 feet and the upper portion is from 60 to 75 feet above sea-level. There are many acres of marsh and mud flats in Elizabeth City County and, to a less extent, in Warwick and York counties. These mud flats are covered by water at high tide and represent a third, or lower, level which will in time probably become land. (See Pl. 7.) Vegetation has gained a foothold on many of these flats and is converting them into marshy areas. Small streams meander over many of them. These flats are saline like those of the Eastern Shore of Virginia.

The western portions of York and Warwick counties are rolling and James City County towards the west is more hilly. The high elevations are best shown along York and James rivers. The more conspicuous bluffs along James River are located between Carter's Grove (Pl. 8) and old King's Mill wharf. East of Carter's Grove the cliffs are lower and at Fort Eustis they have disappeared. West of King's Mill, the cliffs again disappear and the region becomes flat in the vicinity of Jamestown Island. (See Pl. 1.) This island is rather small and much of it swampy. A channel has been cut through the neck of the peninsula, thus forming an island.

TERRACES

Several terraces have been recognized on the Virginia Coastal Plain and have been described in the literature. Such features of low relief were not noted by the geologists of a century ago. They are gently seaward-sloping, narrow plains separated as a rule from each other by low escarpments. They were formed in part by planation by ocean waves and currents and by streams and in part by the deposition of sediments on the eroded platforms. No special study of the terraces of the Peninsula was made for this report.

Clark and others[6] recognized five terrace levels on the Virginia Coastal Plain, namely, the Lafayette, Sunderland, Wicomico,

[6] Op. cit., pp. 48-51.

Talbot, and Recent. Stephenson[7] divided the Talbot terrace in North Carolina into the Chowan as an upper level and the Pamlico as a lower level. Wentworth[8] has recently described the terraces in this region, further subdividing the Pamlico into the Dismal Swamp above and the Princess Anne below. The southeastern part of the Peninsula contains remnants of five terraces, being from highest and oldest to lowest and youngest, the Sunderland, Wicomico, Chowan, Dismal Swamp, and Princess Anne. (See Fig. 3.)

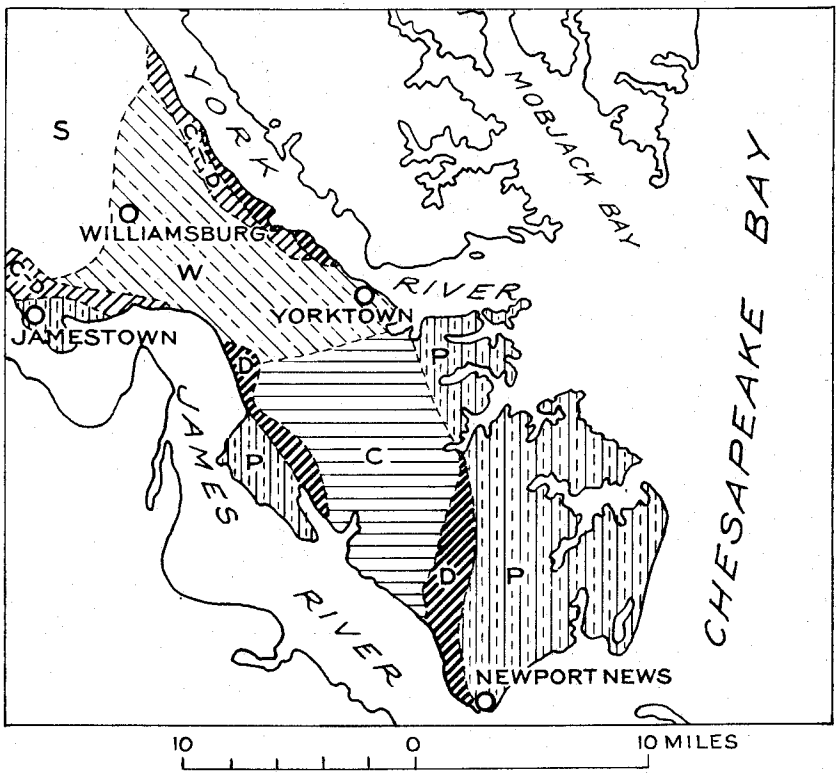


Figure 3.—Sketch map of the Pleistocene terraces on the Peninsula. S, Sunderland; W, Wicomico; C, Chowan; D, Dismal Swamp; C-D, Undifferentiated Chowan-Dismal Swamp; P, Princess Anne. (Adapted from Virginia Geol. Survey Bull. 32, Fig. 24, 1930.)

According to Wentworth, Elizabeth City County is almost wholly on the marine Princess Anne terrace consisting of loam and fine sand at the surface but having some coarse gravel at the base.

[7] Stephenson, L. W., The coastal plain of North Carolina; the Cretaceous, Lafayette, and Quaternary formations: North Carolina Geol. Survey Bull. 3, pp. 328-329, 1912.

[8] Wentworth, C. K., Sand and gravel resources of the Coastal Plain of Virginia: Virginia Geol. Survey Bull. 32, 1930.

Warwick County is on the Princess Anne, Dismal Swamp, Chowan, and Wicomico terraces. As York County extends from Chesapeake Bay inland for about 30 miles parallel to York River, it contains parts of all five terraces mentioned above. James City County is reported to be mainly on the Sunderland terrace with remnants of the younger terraces along the bordering rivers.

GEOGRAPHY

CLIMATE

The climate is rather mild especially near the ocean, even during the summer. Temperature changes are felt in Tidewater Virginia because the humidity is frequently high, making the summer heat oppressive and the winter chill penetrating. At night along the Bay and near the larger streams the breezes are usually cool. The region does not have destructive tornadoes. The winds are strongest and most frequent during March and sometimes during the autumn. During the day the heat is more evident midway between the James and the York than along the rivers. Sanford[9] states that the mean annual temperature over a period of 15 years at Williamsburg was 56.3°F., and at Hampton it was 58.8°F. July was found to be the month of maximum temperature at Williamsburg: the mean reported by Sanford was 78°F., while at Hampton the mean was 77.5°F. The average minimum temperature in February, the month of lowest temperature, was 34.6°F. at Williamsburg and 39.9°F. at Hampton. The record at Hampton was for a period of 23 years. More recent data obtained by the U .S. Weather Bureau are similar to these records.

The rainfall is plentiful and well distributed. Snow is not rare. The mean annual precipitation at Williamsburg for 11 years was 45.86 inches. According to the U. S. Weather Bureau the rainfall at Williamsburg for 1931 was 44.95 inches. In the Dismal Swamp area it was about 52 inches. The maximum rainfall occurs from June to August and the minimum from October to December. The U. S. Weather Bureau states that the precipitation diminishes across Tidewater Virginia in a northwesterly direction. The prevailing direction of the wind in this area is southwest.

TIDES

The semidiurnal tides register more or less regularly at Yorktown and all points along the larger and smaller streams. They vary somewhat, but in general the tide tables for Norfolk can be relied upon to a high degree. Along the bluffs at Yorktown the tide varies from 2 to 3 feet. When the high tide coincides with a storm and a strong wind the rivers and Bay have an exceptionally high tide.

FORESTS

The forests comprise a varied group of trees, some of which are peculiar to the Coastal Plain, whereas others have wider dis-

[9] Sanford, Samuel, The underground water resources of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 5, p. 8, 1913.

tribution. The pines and oaks are especially plentiful and noticeable along State Highway No. 60. As a rule the forests abound in ferns, and the common brake fern *Pteris aquilina,* is widespread. The vegetation shows a range from the dry land types, such as poplars, certain oaks, and hickories to the swamp types, such as cypress.

A list of the common trees is given in Appendix A.

DESCRIPTION OF FORMATIONS

The geology of the bedrock formations of the Peninsula is not especially complex, but it requires an understanding of the principles of sedimentation and a knowledge of the guide fossils to decipher the geological history of this region. The generalized succession of formations of the Coastal Plain of Virginia is given in Table 5 below. Their structure and relation to the underlying crystalline rocks are shown in Figure 4.

GEOLOGIC TIME

As new discoveries are made the older the earth appears to be. Its antiquity is so great and the beginning is so far back in the undecipherable past that we lose sight sometimes of the fact that the earth had a beginning. As far as we are able to discern, the end is equally remote. Yet it should be remembered that our earth is a finite body which had a beginning and will have an end. As the succession of rock formations and their contained fossils have been carefully studied, it has been found that the beds were deposited in a definite sequence, representing definite units of geologic time. (See Table 4.) In a section of horizontal or slightly disturbed beds, the oldest are at the bottom. Hence the true succession of geologic events can be deciphered.

Geologic time is divisible into eras, periods, epochs, and ages, according to the degree of recorded changes in physical conditions and in the faunas and floras. An era, such as the Mesozoic, is the largest unit of geologic time characterized by profound changes in continental masses and by very marked changes in plant and animal life, generally with the appearance of several new races and the reduction or extinction of several old races. A geologic period, such as the Cretaceous, is characterized by one or more distinct races of organisms, a pronounced shift in the relations of land and sea, or a complete oscillation of the strand line from a transgressing to a retreating sea. Each era consists of several periods. An epoch, such as the Miocene, is a somewhat arbitrary division of a period, the main characteristic being a distinct fauna or a more or less homogenous group of beds. Ages are small subdivisions of an epoch, usually marked by the occurrence of a few persistent fossils, for example, certain species of *Pecten* and *Venus*.

Table 4 shows the common units of geologic time, some of the most characteristic types of life during the successive eras, and the geologic periods and epochs of which there are records in the exposed formations of the Coastal Plain in Virginia.

TABLE 4.—*The geologic time scale*

Era	Characteristic life	Period	Epoch
Cenozoic [a]	Mammals, mollusks and flowering plants.	*Quaternary* [a]	*Recent* [a] *Pleistocene*
		Tertiary	*Pliocene* *Miocene* Oligocene *Eocene*
——(*b*)——			
Mesozoic	Cycads, ammonites, giant reptiles, and birds.	*Cretaceous* Jurassic Triassic	
——(*c*)——			
Paleozoic	Invertebrates, and beginning of fishes, amphibians, reptiles, and land plants.	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian	
——(*d*)——			
Proterozoic	Primitive invertebrates.		
Archeozoic	Primitive aquatic life.		

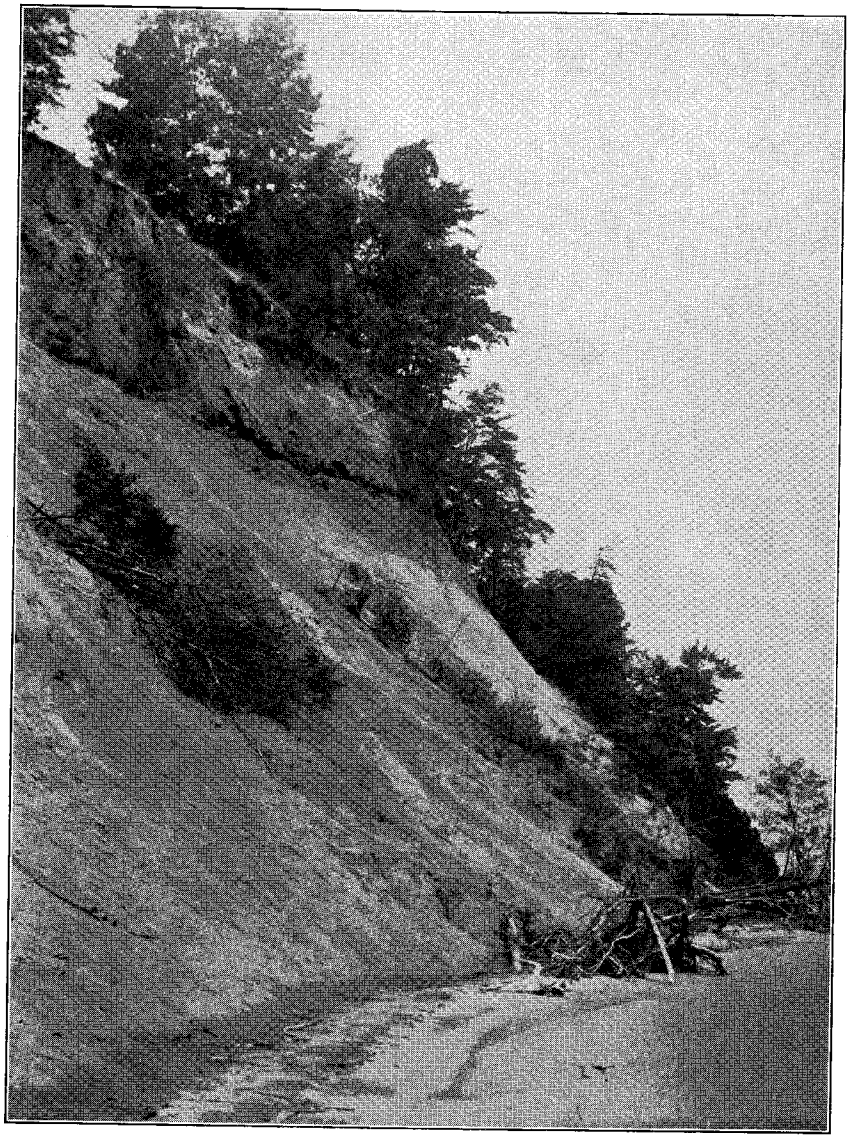
a Those italicized are represented in the Coastal Plain of Virginia.
b Formation of old Rocky Mountains in western North America.
c Formation of ancestral Appalachian Mountains in eastern North America.
d Great land mass Appalachia along Atlantic Coast.

TABLE 5.—*Sedimentary formations of the Coastal Plain of Virginia*

Era	System	Series	Formation	Thickness (Feet)	Characteristics
Cenozoic	Quaternary	Recent	Alluvium	0-20	Clay, silt, sand, and gravel; partly marine and partly fluvial.
			—Unconformity—		
		Pleistocene	Princess Anne	15-20	Clay, sand, and gravel; partly marine and partly fluvial.
			—Disconformity—		
			Dismal Swamp	20±	
			—Disconformity—		
			Chowan	25±	
			—Disconformity—		
			Wicomico	40±	
			—Disconformity—		
			Sunderland	40-50	
			—Disconformity—		
	Tertiary	Pliocene	Brandywine	50±	Sand and gravel; of marine and fluvial origin.
			—Disconformity—		
		Miocene	Yorktown	125	Sand, clay, coquina, and diatomite; largely marine.
			—Unconformity—		
			St. Mary's	150	
			—Disconformity—		
			Choptank	50	
			—Disconformity—		
			Calvert	200	
			—Disconformity—		
		Oligocene	(Absent)		
		Eocene	Nanjemoy	125±	Greensand, sand, and clay; largely marine.
			—Disconformity—		
			Aquia	200+	
			—Unconformity—		
Mesozoic	Cretaceous	Upper	(Not exposed)		
		Lower	Patapsco	150±	Lignitic clay, arkosic sand, sandstone, and gravel; mostly non-marine.
			—Disconformity—		
			Patuxent	250-300	
			Great unconformity		

Mud flats along Chesapeake Bay. Note the meandering courses of the sluggish streams. (See p. 9.) Aeroplane photograph from State Commission on Conservation and Development.

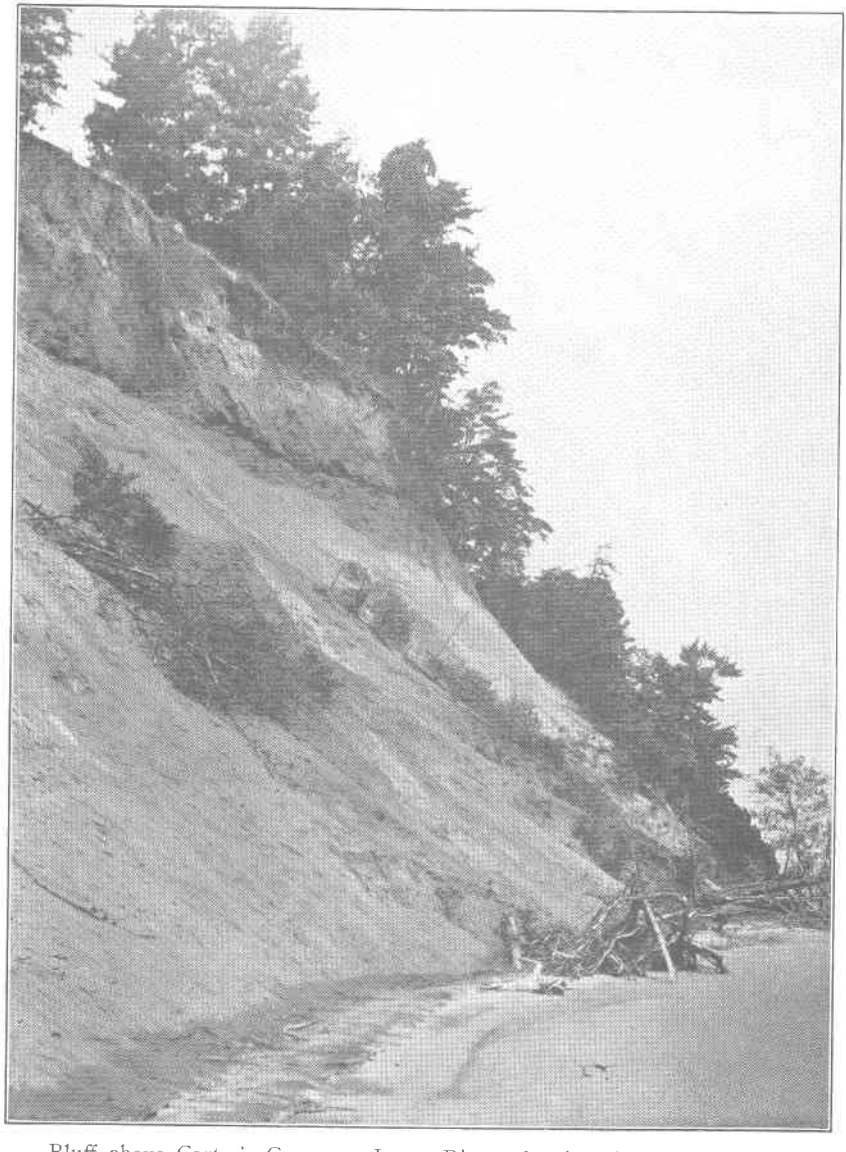
Mud flats along Chesapeake Bay. Note the meandering courses of the sluggish streams. (See p. 9.) Aeroplane photograph from State Commission on Conservation and Development.



Bluff above Carter's Grove on James River, showing the Yorktown formation. The base of the formation is below river level and the top is at the break in the slope. (See pp. 9 and 21.) Photograph by the author.

ERRATUM

Legends for Plates 8 and 10 should be interchanged



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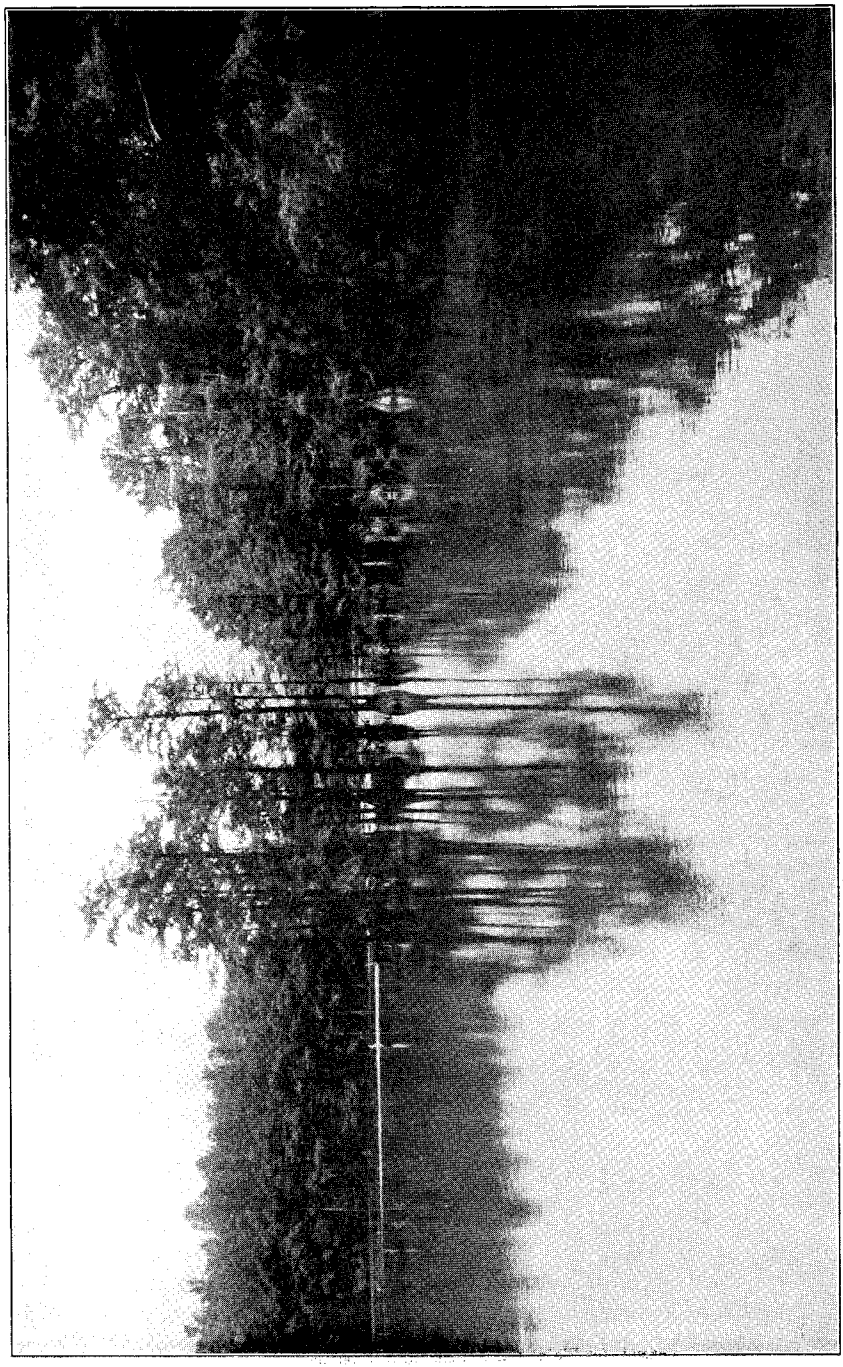
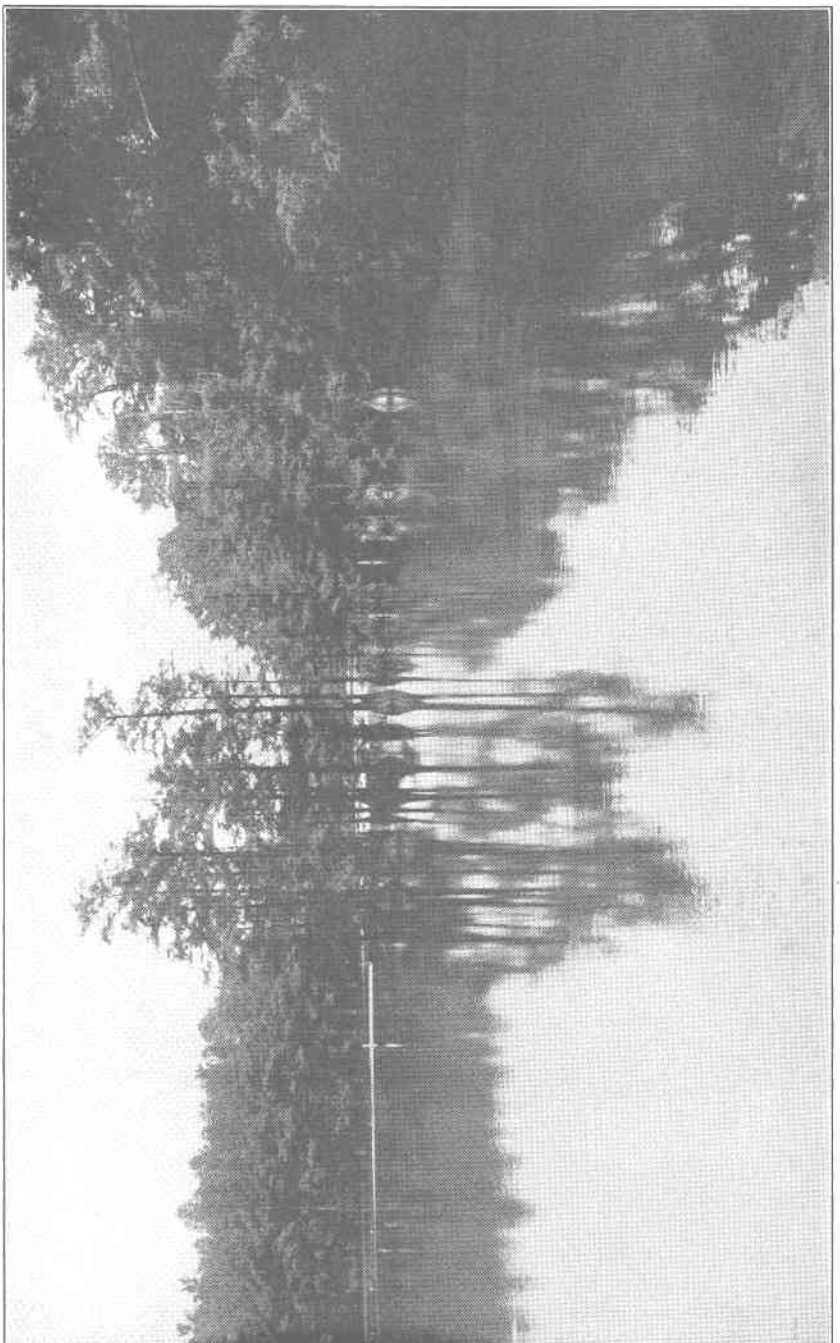
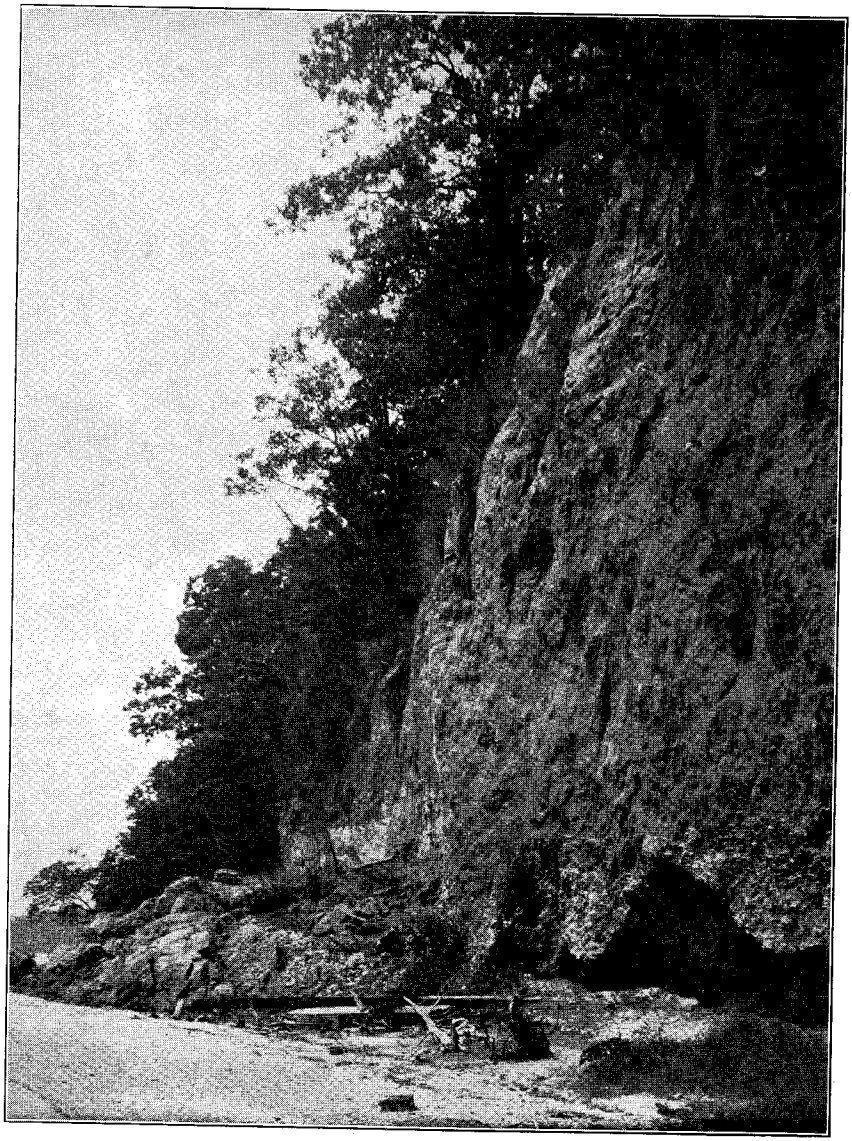


Jolly Pond, a cypress swamp in James City County. One mile west of James River Church. Photograph by the author.



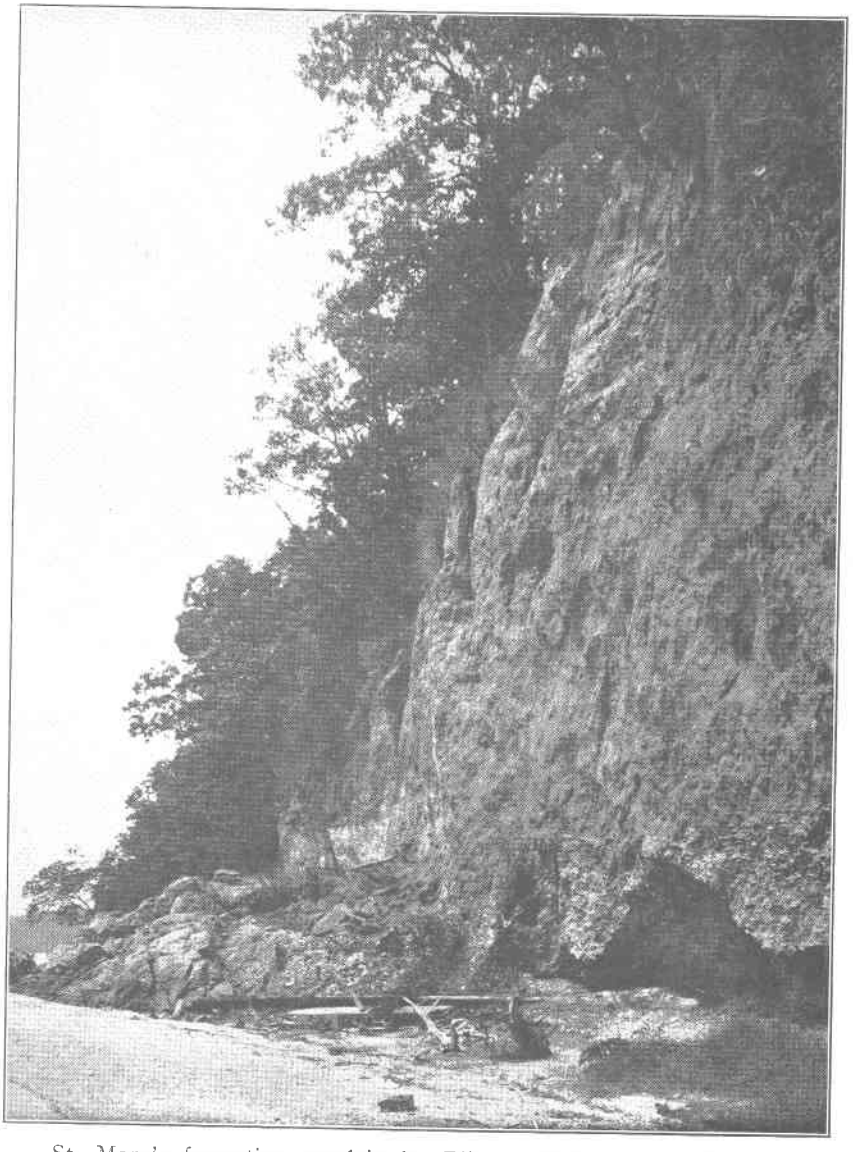
Jolly Pond, a cypress swamp in James City County. One mile west of James River Church. Photograph by the author.



St. Mary's formation overlain by Pliocene-Pleistocene beds. At Mt. Folly, on York River, 9 miles southwest of West Point. (See p. 19.) Photograph by the author.

ERRATUM

Legends for Plates 8 and 10 should be interchanged



St. Mary's formation overlain by Pliocene-Pleistocene beds. At Mt. Folly, on York River, 9 miles southwest of West Point. (See p. 19.) Photograph by the author.

ERRATUM

Legends for Plates 8 and 10 should be interchanged

CRETACEOUS SYSTEM

LOWER CRETACEOUS FORMATIONS

The Lower Cretaceous rocks of the Coastal Plain of Virginia are not exposed in the Peninsula, as they crop out only along the western margin of the Coastal Plain.[10] Good exposures are found along James River just below Richmond. These rocks undoubtedly exist far below the surface of the lower part of the Peninsula for the exposed beds dip gently seaward beneath the younger sediments and they have been recognized in deep drill holes in Mathews County and at Old Point Comfort. (See Fig. 4.) The Lower Cretaceous beds in Virginia have been subdivided into the Patuxent and Patapsco formations.

According to Berry[11] the older Patuxent formation consists largely of light-colored sands containing much material derived from the decay of the old crystalline rocks upon which they were unconformably deposited. In places the formation contains beds of lignitic clay and deposits of gravel, locally cemented into a firm conglomerate. Plant fossils have been obtained from some of the clays.

In the deep well at Fortress Monroe, the contact of this formation with the crystalline basement rocks was reached at a depth of 2,246 feet.[12]

The Patapsco formation is possibly present at a considerable depth in this area, because it crops out in northern Virginia and at a single locality along James River below Richmond. It resembles the Patuxent formation but contains much more clay and sand. Plant fossils have been found in it.

UPPER CRETACEOUS FORMATIONS

Sediments of late Cretaceous age are known in deep wells at Old Point Comfort and at Norfolk but nowhere in Virginia have outcrops been found, inasmuch as these beds are concealed by a thick cover of younger sediments.

Darton[13] reports the beds to be at least 65 feet thick in the vicinity of Norfolk and to consist chiefly of greensand, sand, clay, and shell marl. Fragments of plant fossils and of typical fossil marine invertebrate shells from the wells at Norfolk made certain the identification of these beds.

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[10] Their distribution is shown on the geologic map of Virginia, 1928, and in Bull. 4, Plate I, 1912, both published by the Virginia Geological Survey.

[11] Berry, E. W., Lower Cretaceous [of the Virginia Coastal Plain]: Virginia Geological Survey Bull. 4, pp. 61-86, 1912.

[12] Berry, E. W., op. cit., p. 64.
Darton, N. H., U. S. Geol. Survey Geol. Atlas, Norfolk folio (No. 80), p. 4, 1902.

[13] Darton, N. H., op. cit., p. 2.

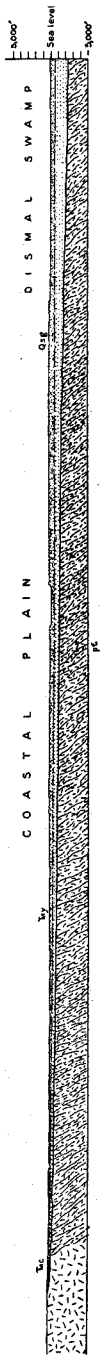


Figure 4.—Structure section through the Coastal Plain province. It extends from the vicinity of Petersburg southeast through Dismal Swamp, but conditions are similar in the Peninsula. pC, pre-Cambrian rocks; Tmc, Calvert formation; Tmy, Yorktown formation; Qsg, Terrace sand and gravel. (From Geologic map of Virginia, Virginia Geol. Survey, 1928.)

TERTIARY SYSTEM

The bedrock sediments of the Tertiary system have been subdivided into four series, namely, from the bottom upwards, Eocene, Oligocene, Miocene, and Pliocene.

EOCENE FORMATIONS

Beds of Eocene age are exposed only in the western part of the Coastal Plain, chiefly along the heads and upper courses of the tidal rivers. Outcrops are found along the James as far east as City Point and a few miles beyond. These beds consist mainly of greensand, loosely cemented sandstone, clay, and shell marl.

The Eocene beds have been subdivided into the Aquia formation below and the Nanjemoy formation above. They do not crop out in the Peninsula but have been identified in deep wells in this area. In the well at Fortress Monroe, Eocene beds are reported to be slightly more than 200 feet thick, with the base at a depth of 840 feet.

OLIGOCENE FORMATIONS

Deposits of Oligocene age have not been recognized anywhere in Virginia, either in outcrops or in deep wells. They are apparently absent on the Coastal Plain as far south as South Carolina.

MIOCENE FORMATIONS

GENERAL FEATURES

In the four eastern counties of the York-James Peninsula, the oldest exposed sediments consist of sand, clay, marl, and coquina of Miocene age. Most of these beds carry abundant fossils which identify them as belonging to the St. Mary's and Yorktown formations. The Choptank formation, next below the St. Mary's formation in the

Coastal Plain of northern Virginia and in Maryland, is not known in the Peninsula. The Calvert formation, at the base of the Miocene, crops out in a broad belt east of the Fall Zone, and along the upper courses of all the tidal rivers, such as the James and the York. It is not exposed in the southeastern half of the Peninsula but is present below the St. Mary's formation.

CALVERT FORMATION

The Calvert formation is the lowest division of the Miocene series and receives its name from Calvert County, Maryland, where it was first recognized and studied. It crops out in this region along James River as far east as Bermuda Hundred and City Point, and along Pamunkey River to the southeast boundary of Hanover County.

It is composed in the main of fine sand with considerable clay, marl, and diatomite. Greensand is found in some places. The diatomite is one of the most striking materials in the Calvert formation, being very light-colored and composed largely of the remains of tiny plants (diatoms). It is important on account of its possible commercial value.[14]

The Calvert formation is reported to be about 200 feet thick. Because of its eastward dip it is far below the surface in the lower part of the Peninsula.

ST. MARY'S FORMATION

This formation was named by Shattuck[15] from exposures in St. Mary's County, Maryland. It is the oldest formation exposed in the lower counties of the Peninsula. It is reported to lie conformably upon the Calvert formation near the Fall Zone where the contact is exposed. The St. Mary's formation in Virginia is recognized mainly by the fossils contained in the beds, but the position and the composition of the beds also aid in its identification.

The formation is well exposed on York River at Mt. Folly, James City County, 9 miles southeast of West Point. (See Pl. 10.) The area around Jamestown Island is shown on geologic maps as being underlain by the St. Mary's formation, but this formation is not exposed.

The St. Mary's formation is composed chiefly of sand and clay, with certain beds containing greensand. As a general rule, fossils are abundant in these beds but very scarce on the lower part of the Peninsula. The sand of this formation is commonly gray, but much of it is yellow to brown, being stained by iron oxides. In some places beds of sand have been consolidated into a sandstone of considerable strength, the cement being hydrated iron oxides. Such beds may be seen a short

[14] For a detailed discussion of this formation, see Virginia Geol. Survey Bull. 4, pp. 126-140 and 243-245, 1912.

[15] Shattuck, G. B., The Miocene problem of Maryland: Science, new ser., vol. 15, p. 906, 1902.

distance southeast of Mt. Folly. The texture is fairly uniform, ranging from fine- to coarse-grained. The sand consists largely of quartz, most of which is transparent, but some is milky-white. Some of the sand grains are well rounded. Gravel is in places scattered through the beds but does not occur in layers.

The interbedded clay of the St. Mary's formation is blue to gray and unconsolidated except in a few layers near sand-clay contacts. Iron oxides impart a yellow to yellowish-brown color to it. The texture is uniform except for a few fragments of molluscan shells. Water flows out in places at the sand-clay contacts where the clay is the bottom member. The clay occurs in definite beds as much as 3 feet thick. It weathers into small blocks.

The St. Mary's formation elsewhere in Virginia commonly contains shell marl, but this facies does not crop out on the Peninsula in James City County or to the east. Nearly 100 years ago, W. B. Rogers[16] reported the occurrence of greensand in the vicinity of Williamsburg and Clark[17] and others regarded it as being in the St. Mary's formation. A small deposit of greenish sand is exposed 1 mile southwest of Williamsburg on the Jamestown road, but this exposure contains Yorktown fossils.

Geologic section at Mt. Folly, James City County

	Feet
Quaternary	
Soil, reworked grayish sand	3
Sand, yellowish-brown, medium to coarse texture, no fossils, no apparent bedding, vertical fractures	18
Miocene	
St. Mary's formation	
Sand with subordinate amounts of clay; sand fine to medium, upper part brown and lower part light-gray and spotted	45
Sand, gray, fine to medium; containing only *Melina* and *Venus;* generally covered by talus	20

YORKTOWN FORMATION

The name for this formation was proposed in 1906 by Clark and Miller[18] from Yorktown where fossiliferous beds are well exposed. No

[16] Rogers, W. B., Some observations on the Tertiary marl of lower Virginia: A reprint of annual reports and other papers on the geology of the Virginias, pp. 1-20, New York, D. Appleton & Co., 1884.

[17] Clark, W. B., and others, op. cit., pp. 141-142, 150, 151, 154.

[18] Clark, W. B., and Miller, B. L., Clay deposits of the Virginia Coastal Plain, Virginia Department of Agriculture and Immigration, Geol. Survey of Virginia, Geol. Ser. Bull. 2, pp. 19-20, 1906.

more appropriate name could have been chosen, because the best exposures of this formation are found along the south bank of York River above and especially below Yorktown. (See Pls. 11 and 12.) This area for the past one hundred years has been a favorite collecting place for Tertiary fossils.[19]

The Yorktown formation extends from Mathews County, Va., southward into North Carolina. It is exposed in James City, Warwick, and York counties, but in Elizabeth City County it is concealed beneath younger beds. The best exposures are found along York and James rivers. There are very few outcrops between these rivers due to the mantle of younger deposits.

The Yorktown formation consists of coquina, sand, clay, sandy clay, and marl in variable degrees of consolidation. The thickness of the entire formation is not more than 150 feet. The main differences between the Yorktown and the older Miocene formations to the west are the occurrence of coquina, the subordinate amount of sand, and the presence of certain fossil faunas which are known only in the Yorktown beds. (See Pls. 16-19.)

The coquina member is about 50 feet thick. It occurs well up in the formation between abundantly fossiliferous members. Much of it is strongly cross-bedded. (See Pl. 11.) It is composed of finely broken marine molluscan shells, a few of which are surprisingly well preserved, cemented together by calcareous material and colored by iron oxides, which have acted in part as a cementing agent. Some of it is very soft, but in places it is a consolidated resistant rock which has been used locally as a building stone. The foundation and walls of Grace Episcopal Church at Yorktown are built of the coquina with both the interior and exterior stuccoed. Cornwallis' Cave on the southeastern edge of Yorktown is excavated in this coquina.

Northwest of Yorktown the coquina has been attacked by the waves and the salt water, so that it contains many cavities and irregular projections. Southeast of Yorktown, the cliffs of coquina have been undercut by the waves and large talus blocks have broken off and fallen into the water. (See Pl. 11.) The rock breaks down after some exposure and forms a very good soil. No exposures similar to those at Yorktown are found elsewhere on York River and none on James River.

Most of the beds of sand contain fragments of shells, iron oxides, and other impurities. Where free of impurities, the sand is gray, consists mostly of quartz, and is unconsolidated. The larger grains are rounded and frosted. Iron oxides are responsible for the coloration of most of the sands. Thin layers of sand are consolidated at the sand-clay contacts. A considerable thickness of ferruginous sandstone is exposed at Camp Penniman on York River.

[19] Many students have taken trips here in past years. In the last six years, the writer has taken more than 800 students and visitors to Yorktown to collect fossils and see the prominent river bluffs.

The clay part of the formation varies from a slightly sandy clay to a slightly clayey sand. Most of the clay is dark-blue when wet and light grayish-blue when dry. Bedding is rather distinct and more so in beds free of sand. All of the observed clay contains fossils. Above Yorktown it is sandy and fossils are less abundant. Two miles southeast of Yorktown the clay is more sandy and is very fossiliferous. (See Pl. 12.) The *Crepidula* bed occurs here with individual shells about as abundant as in the *Chama congregata* bed at Carter's Grove on James River. The clay-sand contact shows very well 2 miles southeast of Yorktown, where the clay is plastic and is overlain by grayish sand. Water flows from this contact zone. The *Crepidula* clay beds dip up-stream and within 400 yards the coquina beds dip down-stream. This change in dip may be due to settling as the soluble materials were dissolved by ground water.

As the contact between the Yorktown and St. Mary's formations has not been observed in this region their relation here is unknown. Sections of the Yorktown formation are given below.

Section of Yorktown formation on York River, 1 mile southeast of Yorktown

	Feet
Sand, gray to white, medium texture, unconsolidated, non-fossiliferous	8
Sand, brown to yellowish-brown, medium texture, non-fossiliferous, base uneven	3
Coquina, bedding and cross-bedding well developed; upper half very fossiliferous; dips slightly to the east	13
Coquina, yellowish-brown, shells very comminuted; mass well consolidated, cross-bedded; contains a few well-preserved fossils	14

Section of Yorktown formation on York River, 2 miles southeast of Yorktown

	Ft.	In.
Quaternary		
Sand and loam, reworked	6	
Miocene		
Yorktown formation:		
Sand, medium-grained, yellowish-brown at top; contains numerous shell fragments, being between sand and coquina in composition. Towards the base the sand becomes green, contains more quartz, and the fossils are better preserved. Sharp conformable contact with the clay below	10	

Yorktown formation—Continued	Ft.	In.
Clay members:		
a. Brown clay containing few fossils; a very uneven contact with underlying clay due to weathering and irregular deposition of iron oxides	2	
b. Dark-blue clay, many *Crepidula*	1–3	
c. Medium-gray clay, abundant *Crepidula*	2	6
d. Pecten zone		6+
e. Blue clay, very abundant *Crepidula*	1–4	
f. Blue clay, very few fossils, weathered at top to a grayish-brown and an uneven contact	1–4	

(River along which Recent sand covers older Yorktown beds.)

Geologic section at Carter's Grove, on James River, James City County

	Feet
Quaternary	
Soil, yellow-brown, sandy	1–2
Sand, brown to yellow, mainly medium- to fine-grained, some coarse and well-rounded	8
Terrace gravel, mostly of rounded quartz boulders embedded in sand similar to that above	1¼
Sand, yellow-brown, bedding less apparent, and texture finer than in top layer; vertical jointing; uneven bottom surface	14
Miocene	
Yorktown formation:	
a. *Chama congregata* zone, containing a few other genera of fossils	7
b. *Venus tridacnoides* zone, containing very large shells of a few other genera and smaller shells of numerous genera	1
c. *Chama congregata* zone, main bed containing also many other genera	6
d. *Crassatellites* zone with *Venus, Glycymeris, Cardium,* and other genera	1½
e. Pecten bed with several species and numerous other genera	4
f. *Venus* zone, containing other species than *V. tridacnoides* and also other genera	1

In certain places along York River, notably at a point one-fourth of a mile south of Yorktown, there are beds composed almost wholly of fossil shells with very little interstitial material. Probably the most typical deposit is near the junction of Felgate Creek with York River on the property of the United States Navy. Thirty-five species of

fossils have been found here in sandy clay which has a thickness of 10 feet. The material is not consolidated and the shells may be collected without difficulty. The principal fossils are mollusks, with some corals, shark and whale remains, and numerous barnacles. Shell marl from a pit in this bed has been used for roads on the Navy Mine Depot property, and it makes a good temporary surface.

PLIOCENCE DEPOSITS

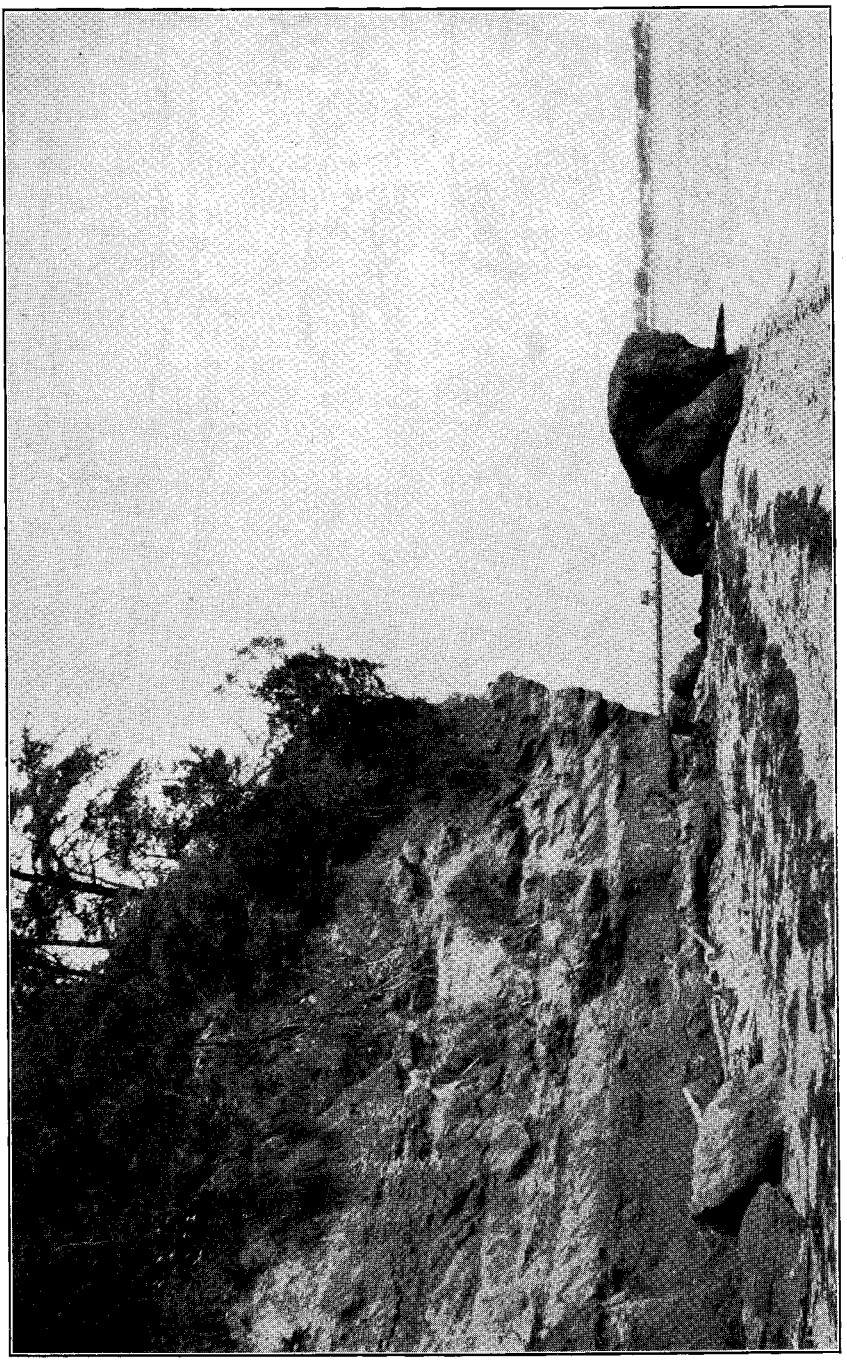
Certain deposits of sand and gravel have long been known on the Coastal Plain where they are found to lie upon various bedrock formations. In the Fall Zone, they rest unconformably upon Lower Cretaceous beds and towards the east upon successively younger Tertiary formations, including the Yorktown formation. West of the Fall Zone they lie upon the crystalline rocks of the Piedmont region. About 3 miles southeast of Yorktown these deposits of sand and gravel are covered by sediments of Pleistocene and Recent age. (See Pl. 13.) The same relations can be seen along James River in the vicinity of Carter's Grove. From their position upon the Yorktown formation, it is certain that the age of these deposits is post-Miocene or Pliocene. There is everywhere a sharp and distinct break between these deposits and the underlying formations. There is no sharp break at the top and, as in some places there is a gradation upward into the similar Pleistocene deposits, these sands and gravels may be partly Pliocene and partly Pleistocene in age.

This deposit of reddish-brown sand and gravel of a variable thickness was called Lafayette[20] from the outcrops in Lafayette County, Mississippi. The name "Lafayette" has been abandoned because the term has since been applied to deposits of different ages. The name Brandywine has been used by some geologists to designate these deposits, and other terms have been used in the past century.

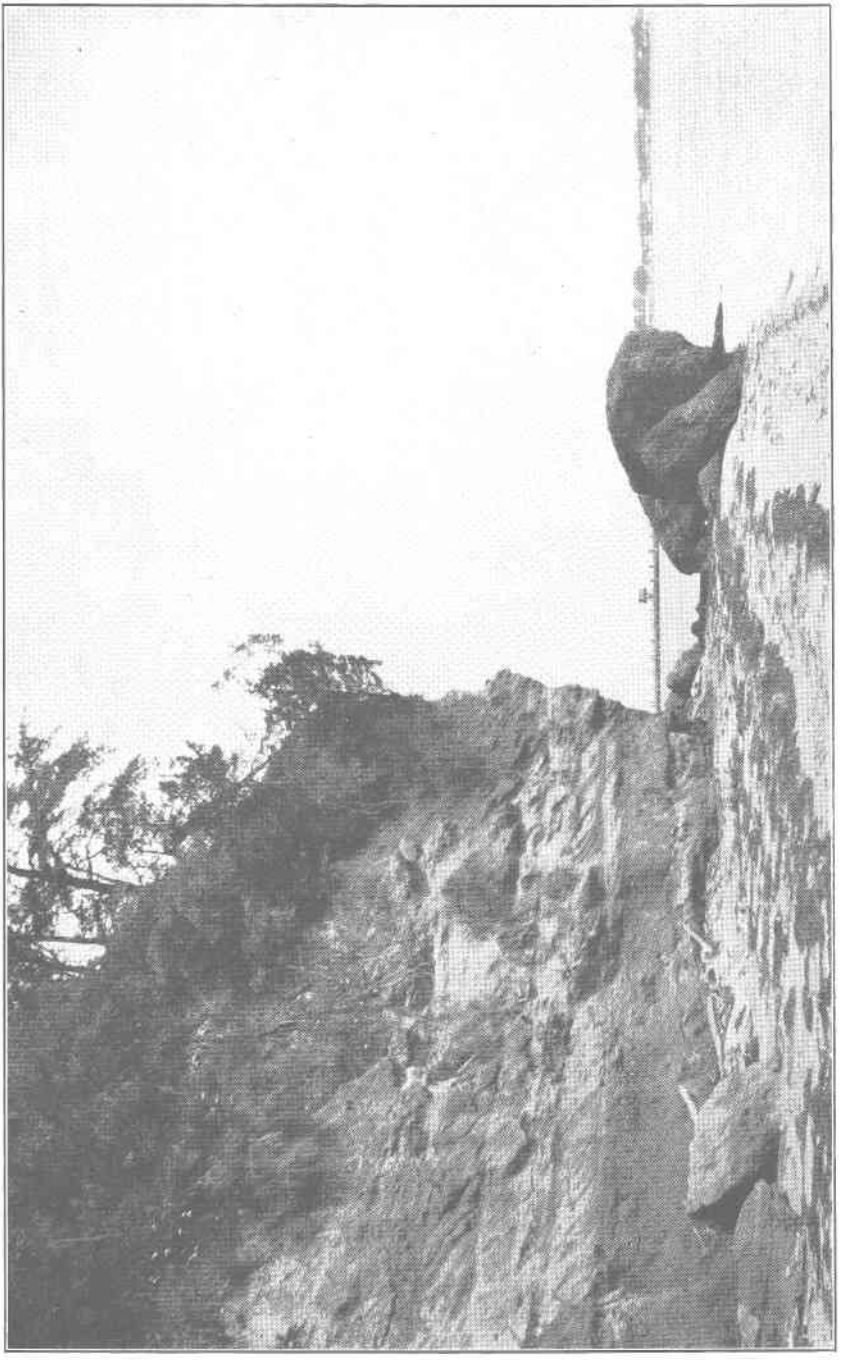
These deposits are found over most of the lower part of the Peninsula, but there are no known outcrops in Elizabeth City County. They are composed largely of sand with subordinate amounts of gravel. The sand is coarse, well rounded, and is generally coated with iron oxide. Quartz grains are abundant, and feldspar and other minerals from the crystalline rocks of the Piedmont region occur in variable amounts. Iron oxides occur as very thin coatings on the grains, and being opaque the percentage of iron seems to be high but probably does not exceed 6 per cent. Some thin layers are cemented by iron oxide. There is no trace of fossils in this sand. Bedding is not well developed but some cross-bedding is found.

The best exposures occur east of Williamsburg and also 1 mile to the west on the Jamestown road. There are good exposures at Mt.

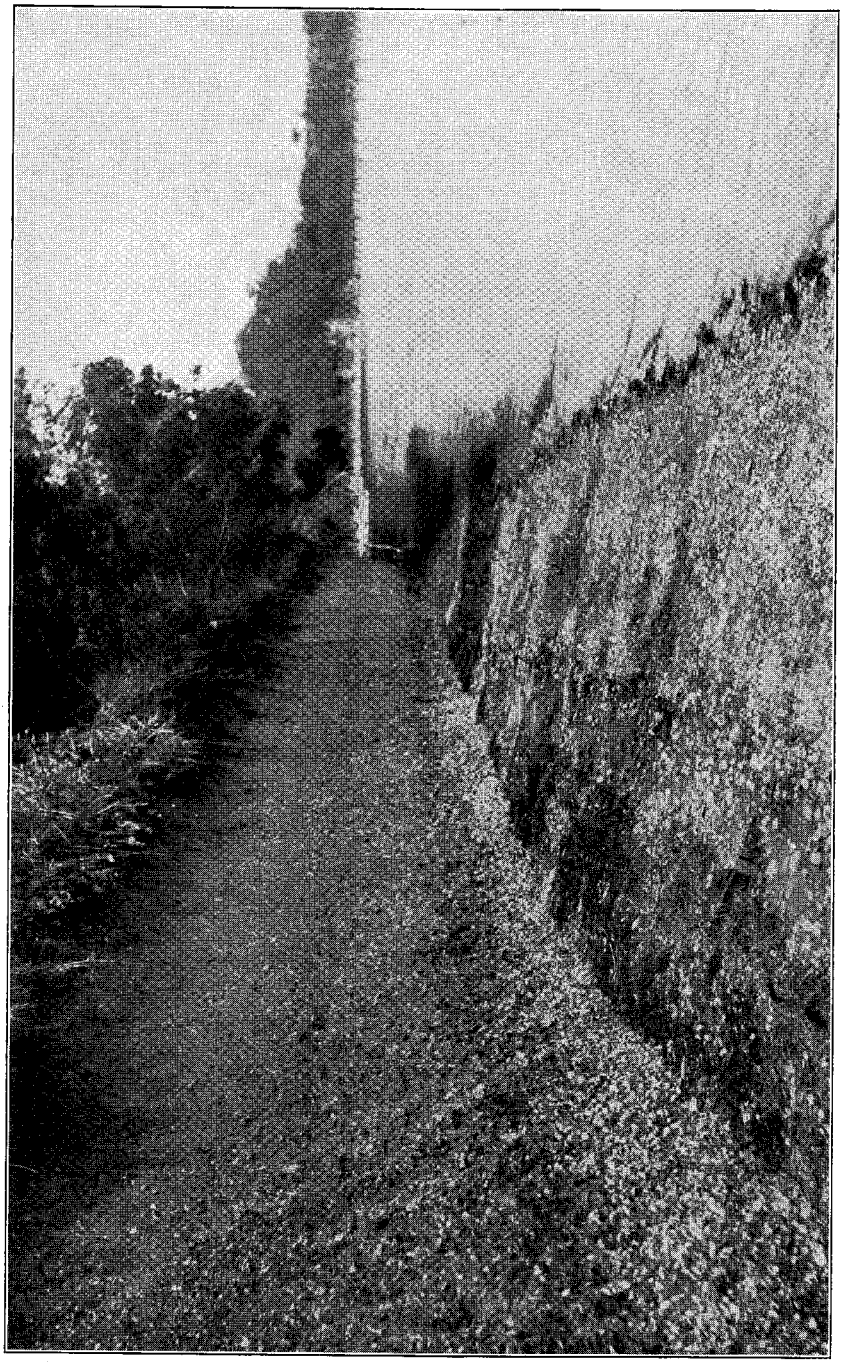
[20] McGee, W. J., The Lafayette formation: U. S. Geol. Survey 12th Ann. Rep. pt. 1, p. 497, 1891.



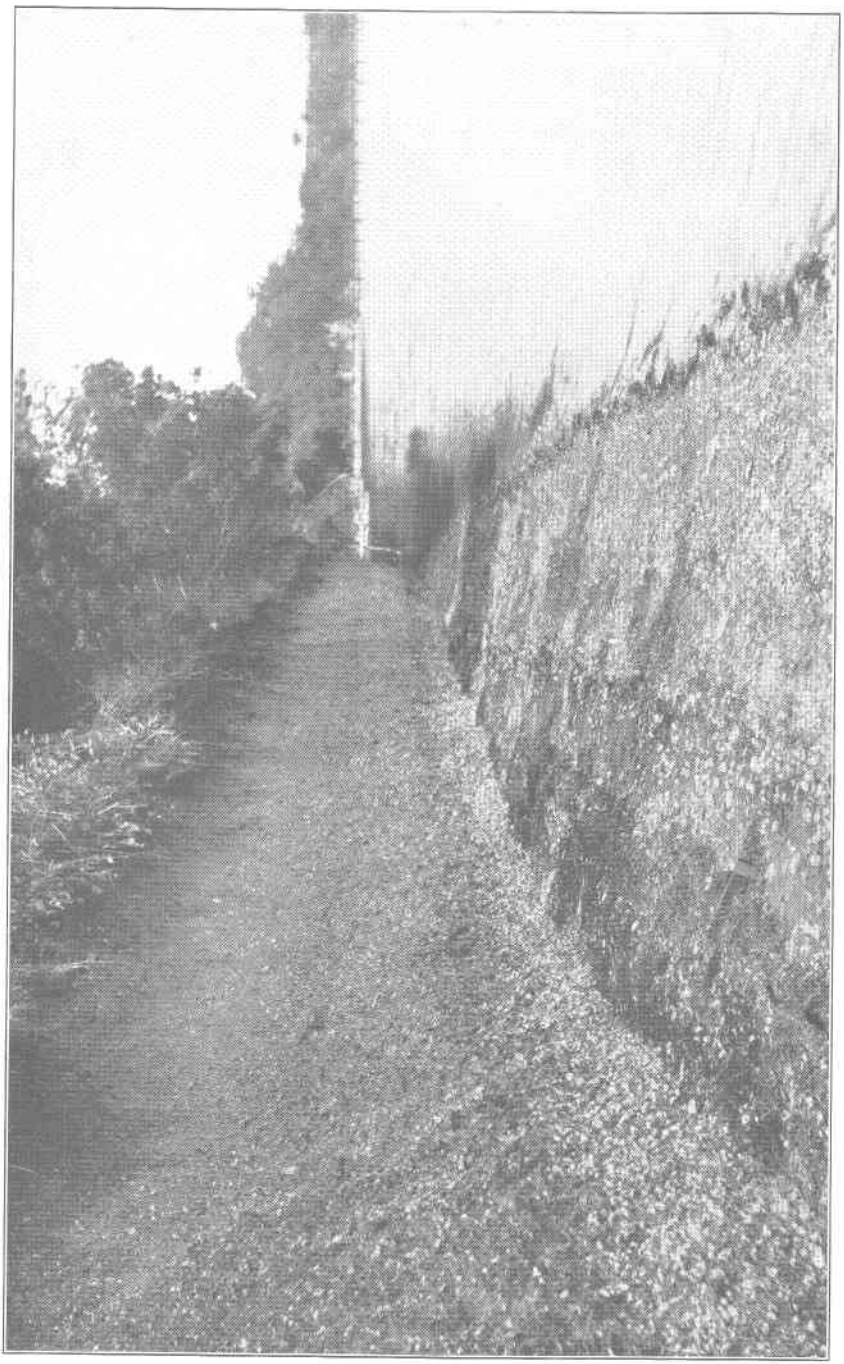
Yorktown formation along York River, 1 mile southeast of Yorktown. Note bedding, cross-bedding, and talus blocks at base of bluff. (See pp. 21-22.) Gloucester Point in the distance. Photograph by the author.



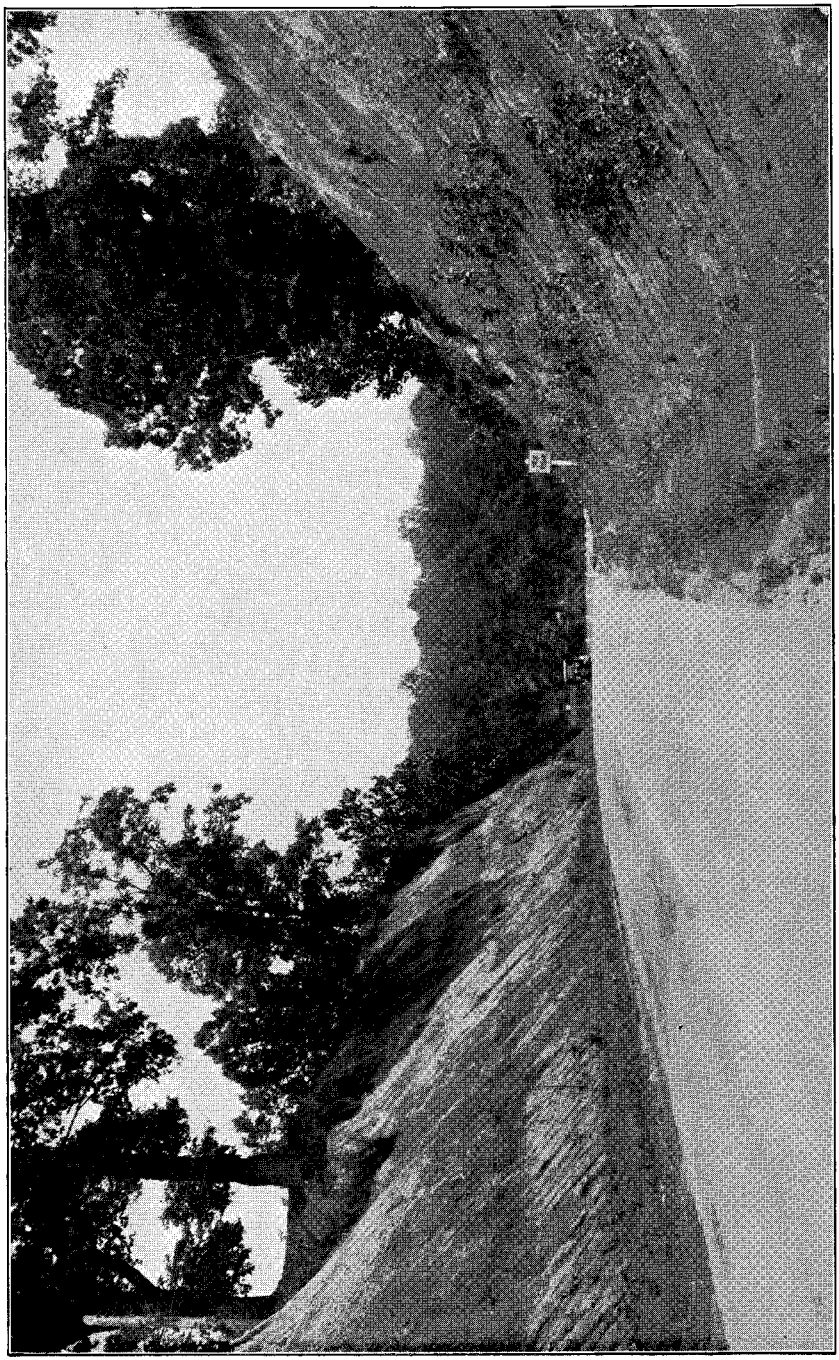
Yorktown formation along York River, 1 mile southeast of Yorktown. Note bedding, cross-bedding, and talus blocks at base of bluff. (See pp. 21-22.) Gloucester Point in the distance. Photograph by the author.



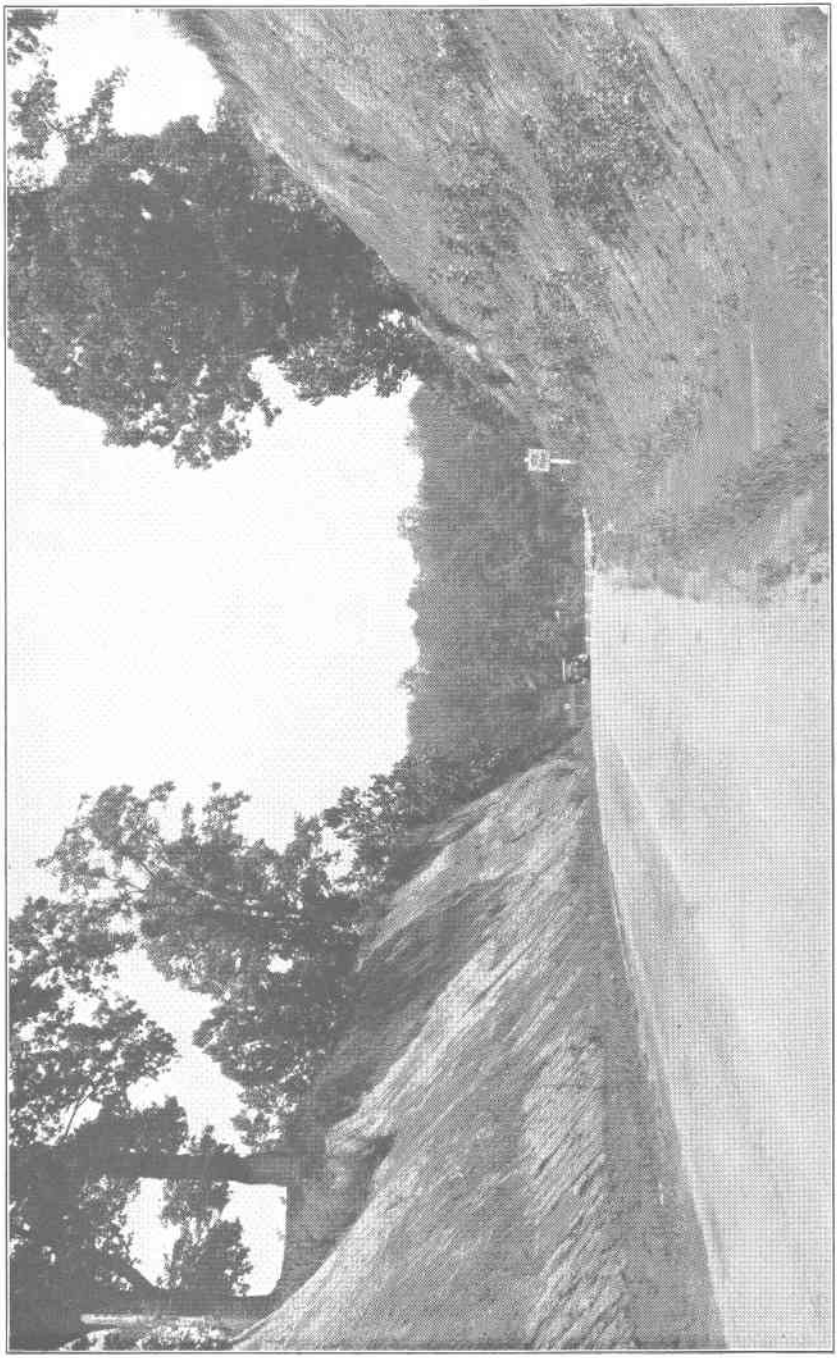
Bluff in the Yorktown formation, showing the three *Crepidula* zones. (See pp. 21-22.) North of the Moore House, 2 miles southeast of Yorktown. Photograph by the author.



Bluff in the Yorktown formation, showing the three *Crepidula* zones. (See pp. 21-22.) North of the Moore House, 2 miles southeast of Yorktown. Photograph by the author.



Post-Miocene deposits along the Jamestown road three-fourths of a mile west of Williamsburg. (See p. 24.)
Photograph by the author.



Post-Miocene deposits along the Jamestown road three-fourths of a mile west of Williamsburg. (See p. 24.)
Photograph by the author.

Folly on York River and at Carter's Grove on the James. These exposures show little or no gravel, and, so far as observed, none of the gravel beds are more than 1 foot thick. The gravel is of about the same mineral composition as the sand. The pebbles are generally rounded, although some are flattened. Some are 2 to 3 inches in diameter, but the average size is probably less than an inch. The gravel contains no fossils of contemporaneous life. Some pebbles contain fossilized remains of Paleozoic bryozoa, brachiopods, and corals. These sand and gravel deposits were deposited by streams on flood-plains which have since been dissected into terraces.

PLEISTOCENE AND RECENT DEPOSITS

The Pleistocene deposits on the Peninsula, formerly known as the Columbia group,[21] comprise bedded sands, clays, and loam. Elsewhere on the Coastal Plain gravel occurs. The Columbia group has been divided into the Sunderland, Wicomico, and Talbot formations.[22] The Talbot beds have been subdivided in places into the Chowan and Pamlico formations.[23] The Pamlico has recently been divided into the Dismal Swamp and Princess Anne formations.[24] It is impossible to separate the formations except by their lithology and topographic position, as no fossils have been found in them. Their general distribution on the Peninsula has recently been shown by Wentworth. (See Fig. 3.)

The Pleistocene deposits are best exposed southeast of Carter's Grove and above King's Mill wharf, both on James River, in bluffs from 5 to 25 feet high. (See Pl. 14.) They consist of interbedded sand and clay. Another good exposure is at old Bellefield on the United States Navy Depot property where the entire outcrop is clay and sandy clay.

The Pleistocene sand is light-gray and contains much quartz. It carries small amounts of rounded grains of magnetite, which is concentrated at the edge of the water at the base of the bluff. The sand is medium- to fine-grained. It contains considerable clay which is light- to medium-gray when dry and quite plastic when wet. It contains abundant carbonized plant fragments but in such a comminuted condition that they could not be identified.

Recent deposits are found mainly in Elizabeth City County (Pl. 15), in small exposures in Warwick and York counties, and in swamps and small streams between James and York rivers. They consist of

[21] McGee, W. J., The geology of the head of Chesapeake Bay: U. S. Geol. Survey 7th Ann. Rept., p. 594, 1888.

[22] Shattuck, G. B., The Pliocene and Pleistocene deposits of Maryland: Maryland Geol. Survey, Pliocene and Pleistocene, p. 65, 1906.

[23] Stephenson, L. W., The Coastal Plain of North Carolina; the Cretaceous, Lafayette, and Quaternary formations: North Carolina Geol. Survey Bull. 3, pp. 258-277, 1912.

[24] Wentworth, C. K., Sand and gravel resources of the Coastal Plain of Virginia: Virginia Geol. Survey Bull. 32, pp. 35-36, 1930.

gravel, sand, and mud formed in part under marine, swamp, and fresh-water conditions. (See Pl. 7.) Numerous mud flats are now being formed under marine conditions along York and James rivers. Muds are being deposited along the smaller streams and vegetation is accumulating in the swamps. Clays and muds are extensive on the flood-plains but are not very thick. They are commonly light-colored and quite plastic. The chief coloring agents are organic matter and some iron oxides. The sands are gray and fairly transparent.

MIOCENE FOSSILS

GENERAL FEATURES

Collecting fossils was fascinating for many people long before either the origin or the practical value of fossils was known. Among the many favorable localities in Virginia, the exposures at Yorktown and Carter's Grove are noted for the great abundance, number of species, and excellent preservation of the fossils and the accessibility of the outcrops. (See Pls. 8, 11, 12, and 16-19.)

Many collections of fossils have been made in the past century from the Yorktown bluffs. Clark and Miller[25] reported 123 species of fossils from these bluffs. Advanced classes of the writer have collected 92 species and the writer has collected 110 of the reported 123 species. Collecting along the bluffs is best done at low tide. At places where waves undercut and disintegrate the bluffs, as many as 42 species have been found. The material along the edge of the river is a reworked bed in the process of formation of a new deposit. There are very few Recent forms to be confused with the Miocene fossils and they are easily recognized.

SUGGESTIONS FOR COLLECTING

For the benefit of those who may be interested in collecting some typical fossils from the Yorktown beds, several good localities are listed and the fossils found at each are briefly described. The number of species differs at these places, but with careful collecting each locality will yield a large number.

Along York River, 1 to 2¼ miles southeast of Yorktown, is the best locality on the Peninsula. Here some 90 species may be collected, the vast majority being mollusks, about equally divided between the pelecypods and gastropods. The most abundant fossil found in these bluffs is a species of *Crepidula,* a gastropod having a rather deep double chamber and a spiny exterior, when not eroded or broken. (See Pl. 18.) There are also many other forms which are numerous, as is shown in the list of the very common fossils. (Table 6.) An extensive development of coquina is found here and many fossils can be collected from it.

York River beach, one-fourth of a mile above Yorktown, is the best place to collect some of the very small pelecypods. The blue sandy clay on the beach carries species of *Leda* and *Yoldia.* The coquina just within the United States Navy Mine Depot property and near this locality shows better the effects of solution and wave erosion than any other exposure.

Along York River beach at Bellefield, which now is on the reservation of the United States Navy Mine Depot, excellent places to make collections are a stretch of beach about 1 mile along the river and a

[25] Clark, W. B., and Miller, B. L., Physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 4, pp. 168, 170, 172 and 174, 1912.

marl pit near the mouth of Felgate Creek. The beach is the best place to collect the large coral, *Septastrea,* and vertebrae of whales. At least 65 species of invertebrate shells can be collected here, most of which are large forms.

Another good locality is York River beach at old Camp Penniman. This locality is reached by turning east across the Chesapeake and Ohio Railway, half a mile southeast of Williamsburg and bearing to the left at the end of the concrete road. This property is owned by Mr. J. M. Dozier of Williamsburg, who allows access to the beach. This locality is best for the large *Arca idonea,* the numerous small ribbed *Pecten clintonius,* very abundant large pectens, vertebrae, ribs, and earbones of whales, and teeth and vertebrae of sharks. About 50 species of other fossils have been collected at this place, in addition to some foraminifera. Another locality about 1 mile up the river affords excellent collecting.

James River beach at Carter's Grove is on the property of Mr. Archibald M. McCrea, who is liberal in allowing paleontologists to collect from the bluffs (Pl. 8), which are the highest along the river. The predominant fossil here is *Chama congregata,* which makes up thick beds. It is almost as abundant here as *Crepidula fornicata* is below Yorktown. The largest and most abundant pectens are found here, including many specimens of *Venus tridacnoides* and of *Panopea* sp.

Camp Wallace, just above Carter's Grove, does not offer a very good opportunity for collecting, because the bluffs are not high and are largely covered by vegetation.

James River beach at King's Mill, south of the old wharf, is a good place for collecting fossils, especially foraminifera. Pectens are rather abundant. The property is accessible from the main Richmond-Newport News highway (No. 60), and has long been a favorite collecting place. About 75 species can be collected here, including scarce forms, such as *Pholas* and certain small gastropods.

One mile west of Williamsburg, on the Jamestown road across College Creek, Yorktown beds crop out on both sides of the road (Pl. 14), but the best exposure is in the bank of the small stream. This outcrop has been mapped as the St. Mary's formation, but all the fossils observed so far are Yorktown in age. This is the only good inland exposure on the Peninsula. About 35 species of fossils in a fairly good state of preservation may be collected here.

TYPES OF FOSSILS

The majority of the fossils in the Yorktown formation are mollusks, but there are other invertebrate and some vertebrate remains. Clark and Miller[26] determined and arranged by phyla, or groups, the species known to them. The writer has added bryozoans, echinoderms,

[26] Clark, W. B., and Miller, B. L., op. cit., pp. 167-174, 1912.

coelenterates, and protozoons.[27] There are also many microfossils, being abundant in some zones, which the collector often passes over in the field.

The mammalian fossils consist of vertebrae, ribs, and ear bones of whales, all of which are fragmentary. On only a few vertebrae are the spines or processes preserved. The size of the vertebrae ranges from about 1 to 6 inches across. In some the length greatly exceeds the diameter, in some the reverse is true, and some are about equidimensional. The ear bones are arcuate and have a deep groove, resembling in shape a hand grenade. The fish remains consist of shark teeth and a few vertebrae. Most of the teeth are small, being about one-fourth of an inch in length, but some are 2 inches long. The vertebrae have conical depressions at each end and none are more than 1 inch long.

The kind of fossil arthropod common to all the exposures is the barnacle, *Balanus concavus,* which is found attached to almost any kind of object. It may be as much as an inch in diameter at the base and an inch high. Tips of crustacean claws have been found in a few places, but no part of the carapace has been observed. A few ostracods occur in the sandy clay; the writer has identified 5 species and there are others not identified. All of these forms except the barnacles are microscopic.

The mollusks exceed all others in number of species, and the collector may at first think there are few other kinds of fossils. (See Pls. 16-19.) In general the ratio of pelecypods to the gastropods is about 3 to 2. Many of these forms are unique and are easily recognized in the field. Many species are difficult to determine; for example, the pectens as a genus are easy to identify but the species are very difficult. The same is true for the genera *Venus, Turritella, Astarte, Fulgur,* and many others. Certain pelecypods are so odd, for example, the shipworm, *Teredo,* that they are not hard to identify. A fossil *Teredo* resembles in shape a worm more than any other organism and the layman fails to see any resemblance of this calcareous tube to a bivalve or even to a spiral gastropod. *Ecphora* is one of the gastropods which is so outstanding in all of its characteristics that it is the oddest of all its allies; its ugliness, as has been said, renders it attractive. The visitor never forgets the shape and size of the pectens and fulgurs, the shape and thickness of *Venus,* the graceful spire of *Turritella,* and the relative abundance of *Chama* and *Crepidula.* The only large scaphopod is the slightly curved and striated one, *Dentalium,* which is widespread on the Peninsula.

The brachiopods are represented by one species, having two small conical, black valves, but it is nowhere abundant. It is rarely more than three-fourths of an inch in length and its width and thickness are less. At least two species of bryozoa occur; one is a dendritic form, the colony becoming as much as 3 inches long, and the other is a veil-

[27] The protozoons were studied in 1930 by Frank Anderegg, for a Master's thesis at the University of Virginia.

like colony found upon many of the molluscan shells and on other objects. There are several other species which the specialist on bryozoa would recognize.

The phyla of worms and echinoderms are sparingly represented. Only one small species of *Vermes* has been found, attached to some molluscan shell. Because of its shape it is known as *Spirorbis*. Only one species of an echinoid has been found, but a large number of spines occur in the sands. The echinoid test is 1 inch or less in diameter. The external surface is well ornamented and covered with spine bases, or tubercles. Neither the *Spirorbis* nor the echinoid is common, being found only by a careful collector.

There are two very unlike species of corals, which are easy to find. One is the genus *Astrangia*, in which the individual tubes, or corallites, are almost or wholly separate. It is attached to molluscan shells. The other genus, *Septastrea*, grew in large colonies and the corallites are grown together. Some colonies are 2 feet long. The *Astrangia* is most commonly found at Yorktown, and the *Septastrea* at Bellefield and along James River from Carter's Grove to King's Mill.

The protozoons are represented by microscopic foraminifera and radiolaria. Thirty-seven species have been determined and described from the Yorktown formation, but this does not fully cover the collections. No study has been made of the radiolaria or of the microscopic plants, the diatoms. These microorganisms occur in the very fine sands and in sandy clays, where they are well preserved.

PRESERVATION OF FOSSILS

Most of the fossils are preserved in their original forms. The outermost of the three layers of the shell is always absent, as this epidermal layer is organic and disappears during the initial stages of fossilization. The innermost, or nacreous, layer has disappeared in most of the fossils except *Nucula*, which retains its shiny inner surface. The middle, or prismatic, layer in most forms is well preserved. Molds of *Venus, Pecten, Turritella* and a few other forms are frequently found in the sands and coquina. As a rule they are composed of consolidated mud and are rarely of calcite.

The internal features of the pelecypods are well preserved in detail, showing the sizes and positions of the muscles, sinuses, and pallial lines. (See Fig. 5.) The spines of such forms as *Crepidula* are generally lost, either through the solvent action of ground water or by erosion when the sediments were being deposited. The thin margins and fine spines of many forms are broken. Some very large mollusks, as *Scaphella, Pecten clintonius, Dosinia, Crepidula plana,* and *Cardium* have thin valves, which are often broken, especially in *Cardium*.

In many of the forms, particularly the pelecypods, a round hole is found near the beak or the vital point of the valve where the soft

body was encased. This hole, which is conical and largest at the outer surface, was made by a carniverous gastropod, *Drillia,* so named from its habit of drilling the living forms for food. Even the spiral shells of *Drillia* show such perforations. Thick valves in the adult stage of *Venus tridacnoides* do not show such *Drillia* borings.

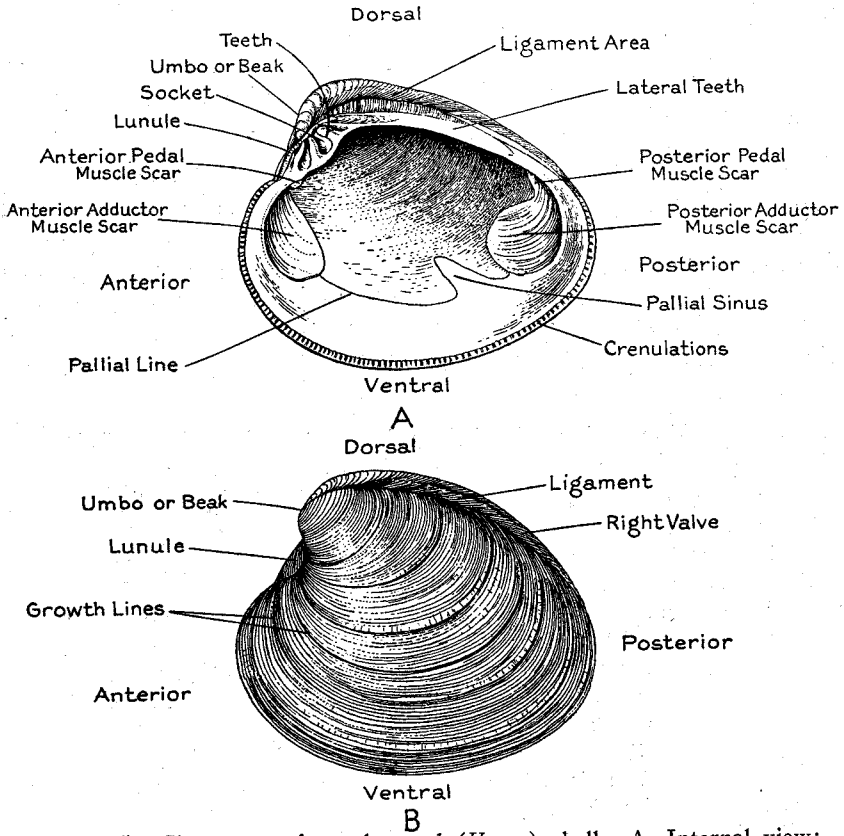


Figure 5.—Characters of a pelecypod (*Venus*) shell. A, Internal view; B, External view.

Certain valves of pelecypods, as *Pecten, Venus,* and *Ostrea,* have very uneven and modified external surfaces, with a network of depressions and occasional perforations. These depressions may be due to the dissolving of the more soluble portions of the shells. It does not seem that there is sufficient variation in the composition of the shells to cause thus the development of uneven surfaces. It has been suggested by Dr. Donald W. Davis, of the College of William and Mary, that these features may be due to a boring sponge.

Despite the many hazards existing during and since the time of fossilization the shells are well preserved. Conditions of fossilization must have been almost ideal to have allowed the preservation of such

large numbers and varieties of fossils as are found in the Yorktown and associated formations. There must have been extensive wave action during Yorktown time, as is indicated by the thick beds of fragmental shells, or coquina. And yet in this cross-bedded material with all the evidence of vigorous wave action, delicate shells are fairly well preserved. The clay contains, in many respects, the most poorly preserved fossils; they are not broken but are very fragile. The clay holds water and keeps the fossils continually wet. Organic acids seeping through the clay have probably aided in solution of the shells. The sandy clay contains better preserved shells than the pure clay.

PRINCIPAL YORKTOWN FOSSILS

It is difficult to select the ten or fifteen most significant fossils in the Yorktown formation. Such a list has been often requested. Table 6 contains, in the writer's opinion, thirty of the most significant and abundant fossils which can be collected from the beach and bluffs at Yorktown. In six years of experience with large numbers of students, these appear to be the common ones which the average collector would gather.

TABLE 6.—*Thirty significant fossils from the Yorktown formation at Yorktown*

Arthropod
- Balanus concavus Bronn

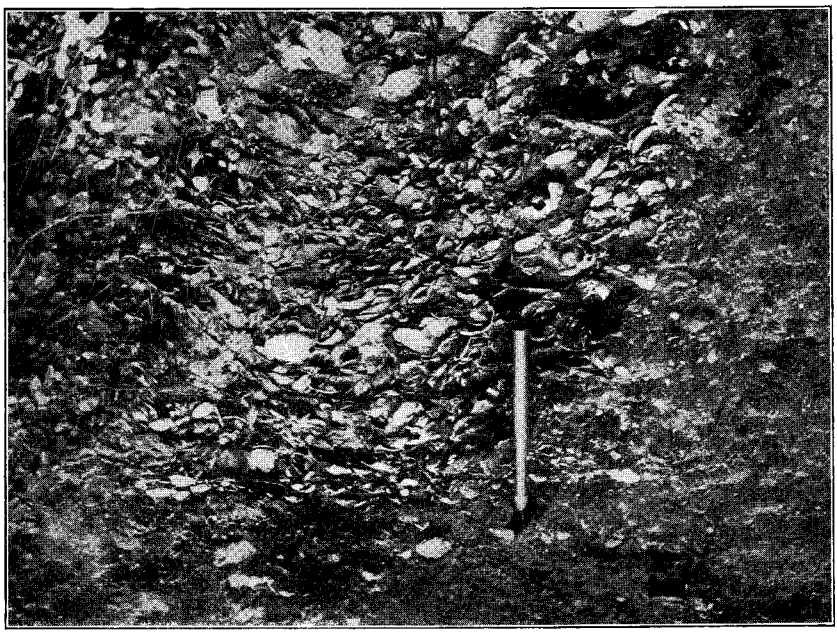
Gastropods
- Calliostoma philanthropus Conrad
- Crepidula aculeata var. costata Conrad
- Crepidula plana Say
- Crucibulum constrictum Conrad
- Ecphora quadricostata Say
- Fissuridea redimicula Say
- Oliva litterata Lamark
- Polynices heros Say
- Turritella alticostata Conrad
- Vermetus virginica Conrad

Scaphopod
- Dentalium attenuatum Say

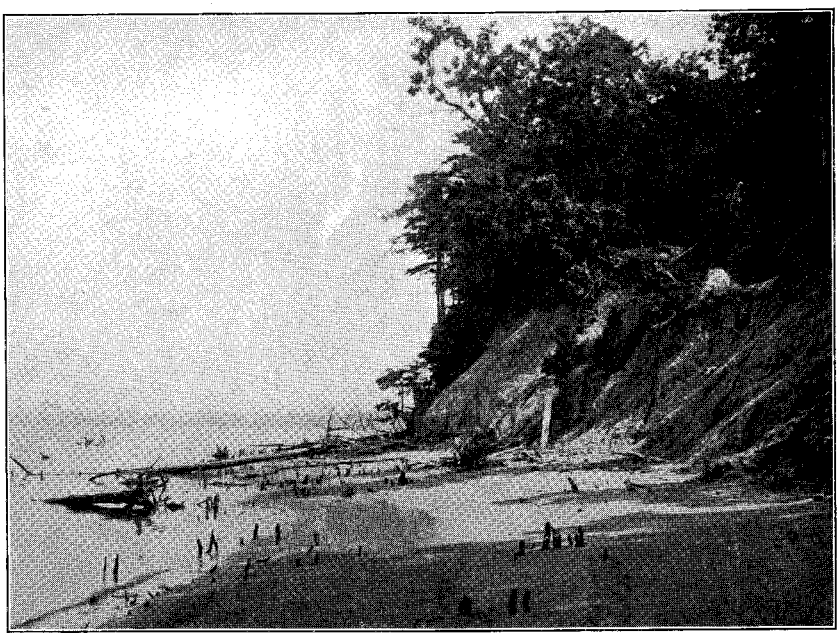
Pelecypods
- Arca centenaria Say
- Arca incile Say
- Asaphis centenaria Conrad
- Astarte undulata Say
- Carditamera arata Conrad
- Crassatellites undulatus Say
- Dosinia acetabulum Conrad
- Glycymeris americana De France
- Glycymeris subovata Say
- Ostrea disparilis Conrad
- Pecten jeffersonius var. edgecombensis Conrad
- Pecten madisonius Say
- Plicatula marginata Say
- Teredo calamus Lea.
- Venericardia granulata Say
- Venus tridacnoides Lamark

Corals
- Astrangia lineata Conrad
- Septastrea marylandica Conrad

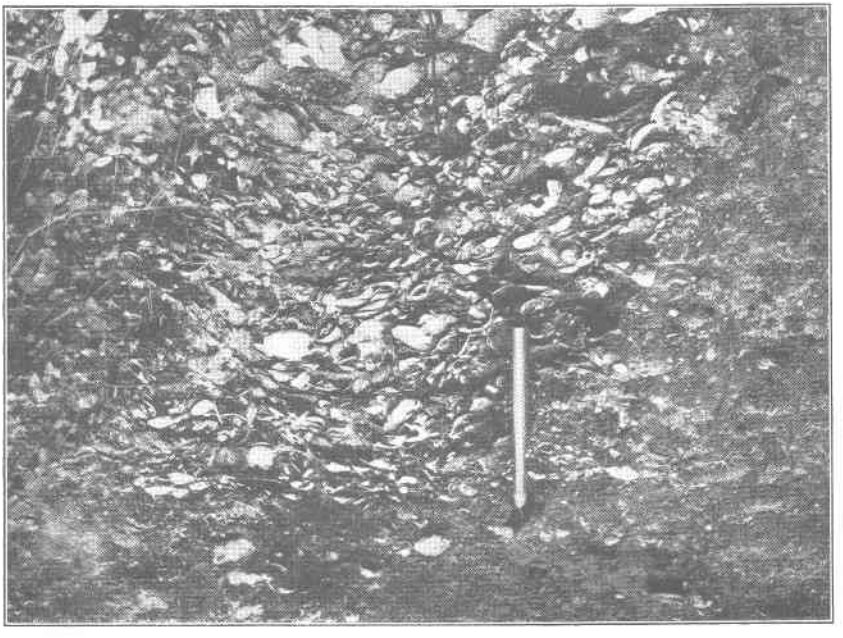
The thirty fossils which have been selected as most characteristic of the Yorktown formation are illustrated on Plates 16-19. These forms were collected by the writer. The accompanying explanations give the names of the genera and the species, and state briefly, in as non-technical language as possible, the most significant characteristics of the fossil shells by which they can be recognized by the amateur collector. The terms commonly used in describing gastropod and pelecypod shells are indicated in Figures 5 and 6.



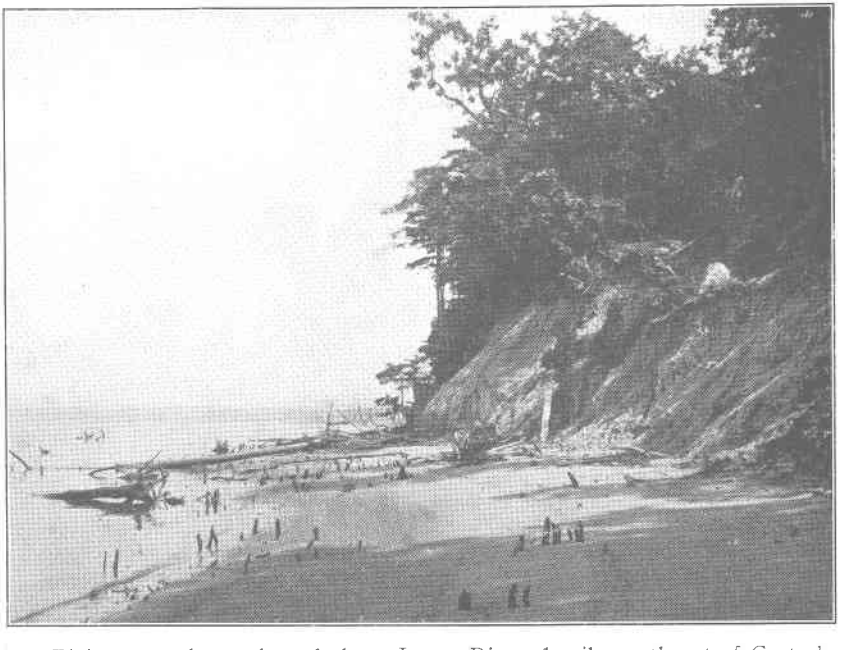
A. Fossils in outcrop of Yorktown formation. Along the Jamestown road 1 mile west of Williamsburg. Photograph by the author.



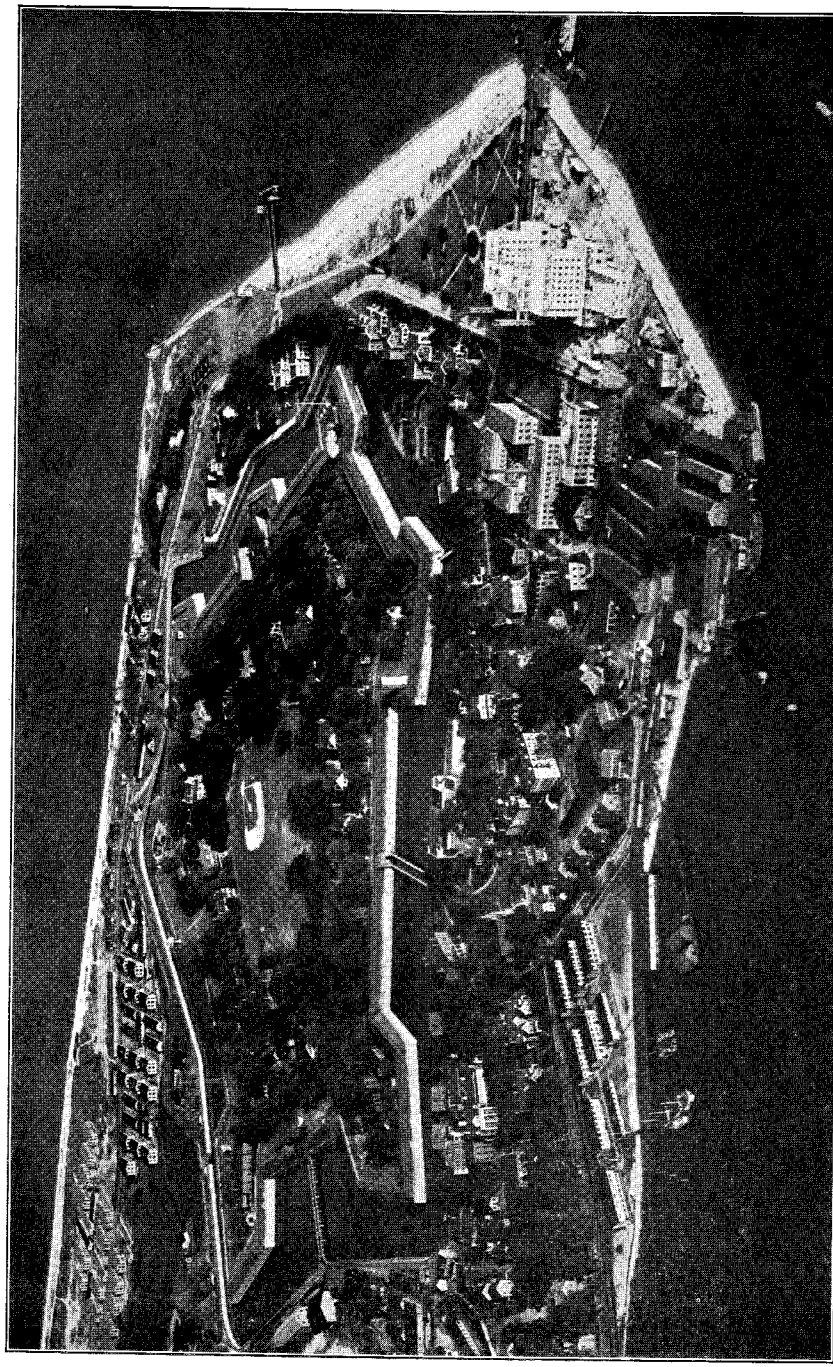
B. Pleistocene clay and sand along James River, 1 mile southeast of Carter's Grove. Cypress roots along river. Photograph by the author.



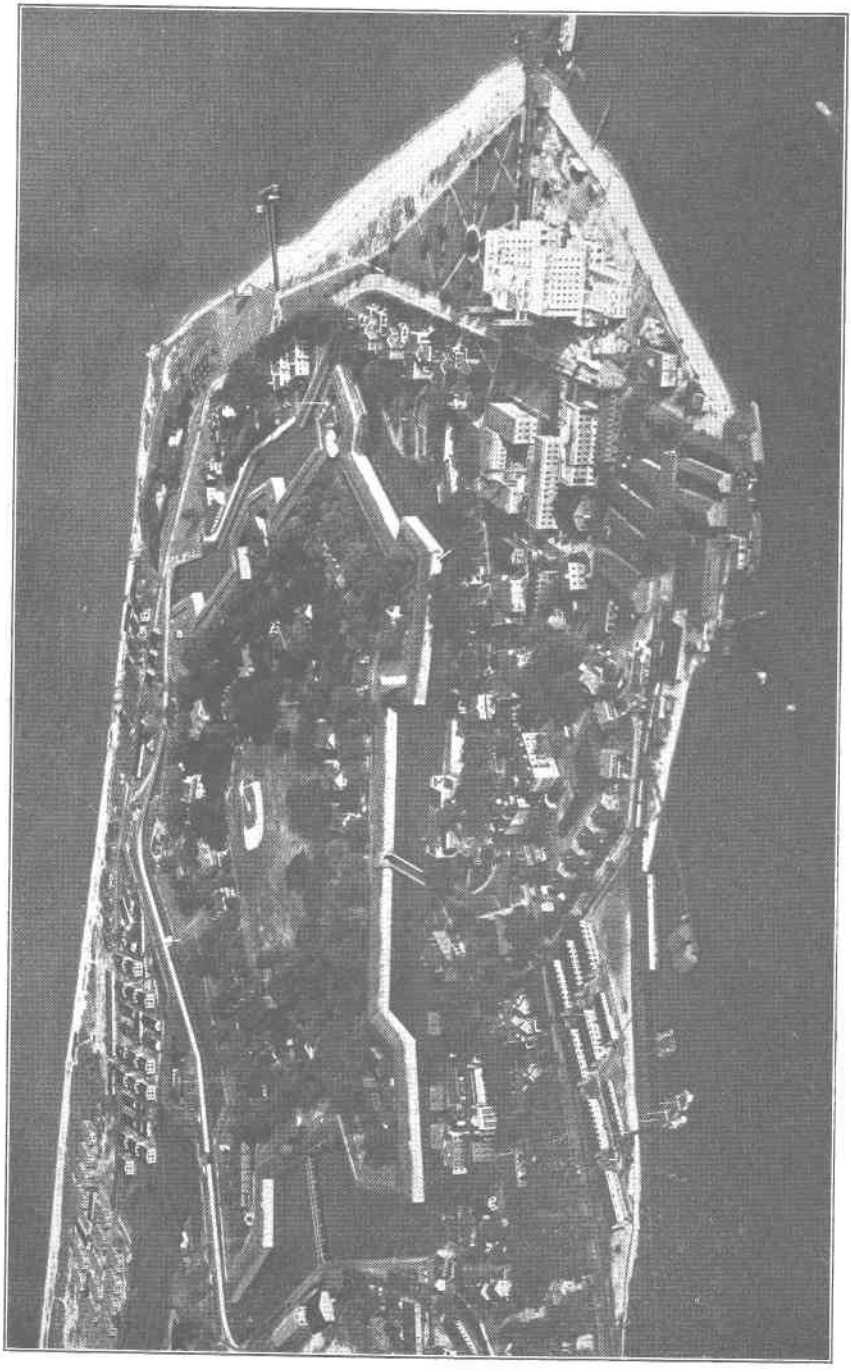
A. Fossils in outcrop of Yorktown formation. Along the Jamestown road 1 mile west of Williamsburg. Photograph by the author.



B. Pleistocene clay and sand along James River, 1 mile southeast of Carter's Grove. Cypress roots along river. Photograph by the author.



Old Point Comfort sand spit and Fortress Monroe. Looking northeast from Hampton Roads. Aeroplane photograph from State Commission on Conservation and Development.



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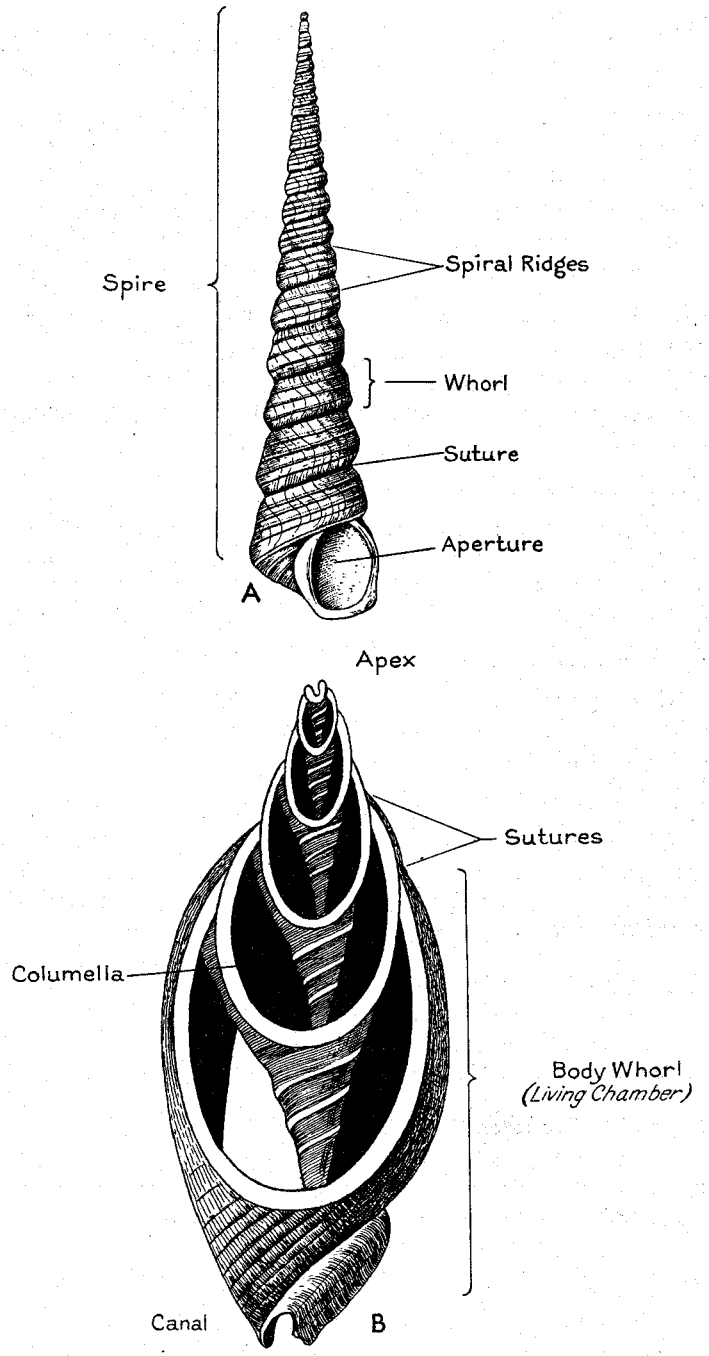


Figure 6.—Characters of gastropod shells. A, External view of a *Turritella* shell; B, Longitudinal section through a *Mitra* shell.

PLATE 16

1. *Septastrea marylandica;* a compact coral colony.

   CHARACTERISTICS: Individual corallites are 4 to 8 mm. wide, closely packed together and not separate as in *Astrangia;* individuals are five- or six-sided; in large colonies as much as 2 feet long.

2. *Astrangia lineata;* a branching coral; one colony attached to a *Crepidula* valve which shows the effects of a boring sponge or solution.

   CHARACTERISTICS: Individual corallites branching, cylindrical and conical, and not grown together except at base; partitions (septa) numerous, radiating from a point, and very thin; always attached.

3. *Arca centenaria;* external and internal views.

   CHARACTERISTICS: Exterior shows many fine ribs radiating from the beak and concentric growth lines; many transverse teeth; triangular area between the teeth and beak; front and rear portions rounded; muscle scars show well.

4. *Arca incile;* external and internal views.

   CHARACTERISTICS: Coarse ribs, about 27 in number, radiating from the beak; few concentric growth lines; inner lower margin notched by ribs; upper margin has many transverse teeth.

5. *Glycymeris americana;* external and internal views.

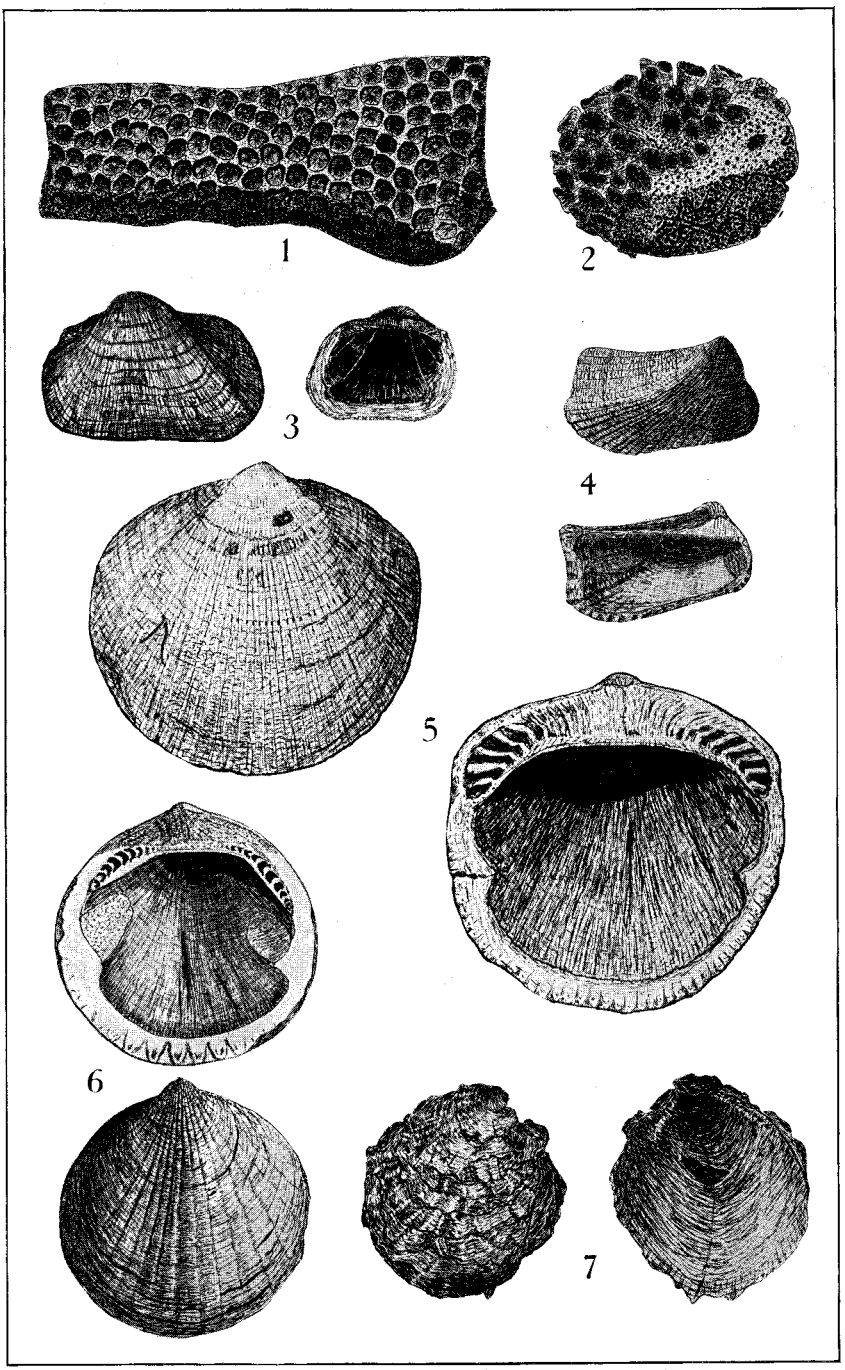
   CHARACTERISTICS: Valves almost bilaterally symmetrical, depressed at top; small-ribs radiating from beak, and more distinct concentric growth lines; teeth, muscle scars, and marginal area very distinct; large ridges on lower inner margin.

6. *Glycymeris subovata;* internal and external views.

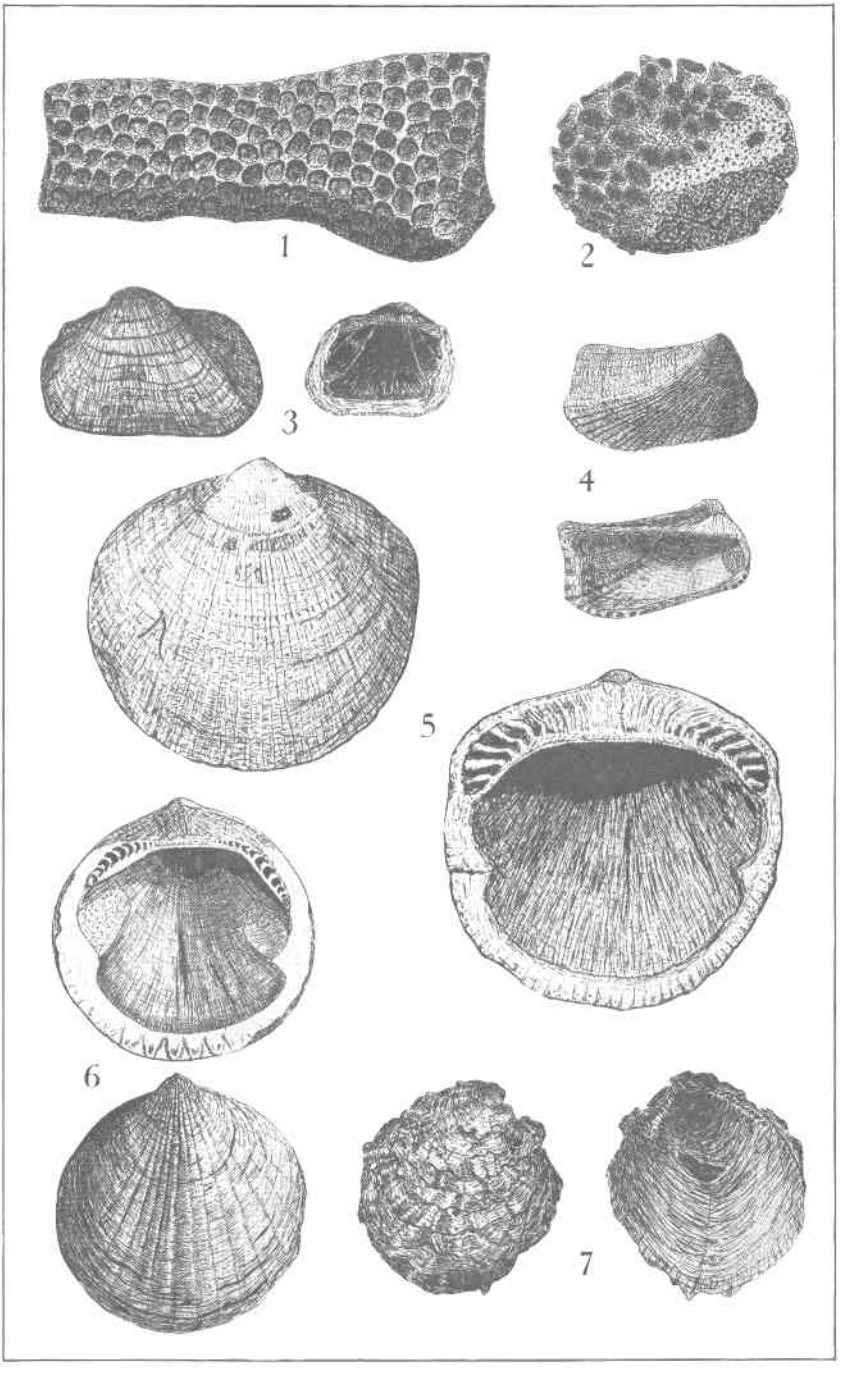
   CHARACTERISTICS: Valves almost round and almost bilaterally symmetrical; heavy ribs radiate from fairly prominent beak; faint concentric lines; double ridges on lower inner margins; teeth and muscle scars very distinct.

7. *Ostrea disparilis;* external and internal views.

   CHARACTERISTICS: One flat valve showing concentric growth lines, and one deep valve having numerous ribs and growth lines; hinge area narrow; muscle scar crescent-shaped and slightly to one side.



Typical fossils from the Yorktown formation. 1 and 2, corals; 3-7, pelecypods. About two-thirds natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)



Typical fossils from the Yorktown formation. 1 and 2, corals; 3-7, pelecypods. About two-thirds natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)

PLATE 17

1. *Pecten jeffersonius var. edgecombensis;* external view.

   CHARACTERISTICS: Valves almost bilaterally symmetrical; slightly longer than high; 16 to 17 prominent ribs, each having 4 or 5 ridges with small spines pointing downward; the intervening depressions generally show 3 ridges; ears well developed. One large muscle scar showing on interior and a triangular pit at top of valve.

2. *Pecten madisonius;* external and internal views.

   CHARACTERISTICS: Valves slightly higher than wide and one valve nearly flat; approximately 16 ribs, each having about 3 ridges; ribs show well on the interior; muscle scar high in valve; ears about equal, making the valves almost bilaterally symmetrical.

3. *Plicatula marginata;* internal, bottom, and external views.

   CHARACTERISTICS: Closely resembles *Ostrea;* valves are higher than long; show from 5 to 6 high ribs and growth lines, and are pointed at hinge and rounded at base; teeth curved and generally show slightly; one muscle scar, having a smooth margin.

4. *Astarte undulata;* external and internal views.

   CHARACTERISTICS: Triangular shell with lower portion rounded; exterior marked by concentric lines; inner lower margin shows crenulations; pointed beak, having depressed area in front; 3 teeth in one valve and 2 in the other.

5. *Crassatellites undulatus;* external and internal views.

   CHARACTERISTICS: Valve broadly rounded in front and narrowly rounded in rear; valve rather thick with very small inner cavity; beak slightly to front; high teeth and deep sockets; exterior shows many growth lines and a ridge extending from beak to rear; deep muscle scars, becoming deeper towards the center, and pronounced pallial line connecting the scars.

6. *Venericardia granulata;* external view, showing a *Drillia* boring and an internal view.

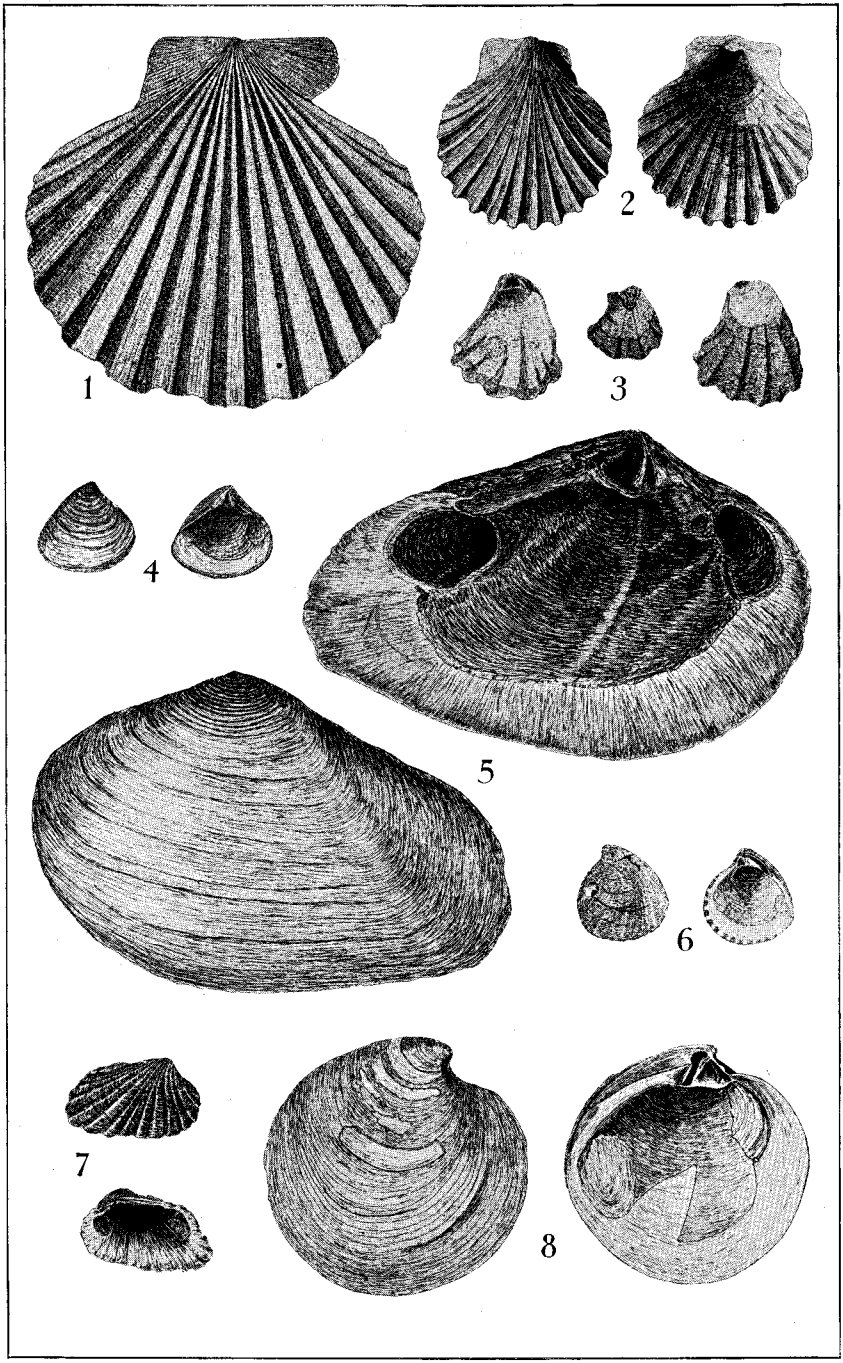
   CHARACTERISTICS: Valves almost circular, slightly longer than high; lower edge of valves notched; beaks almost central and curved backwards; prominent teeth; about 25 ribs curving backwards towards bottom of valves; numerous concentric lines; exterior closely resembles small *Glycymeris* except for curvature of ribs.

7. *Carditamera arata;* external and internal views.

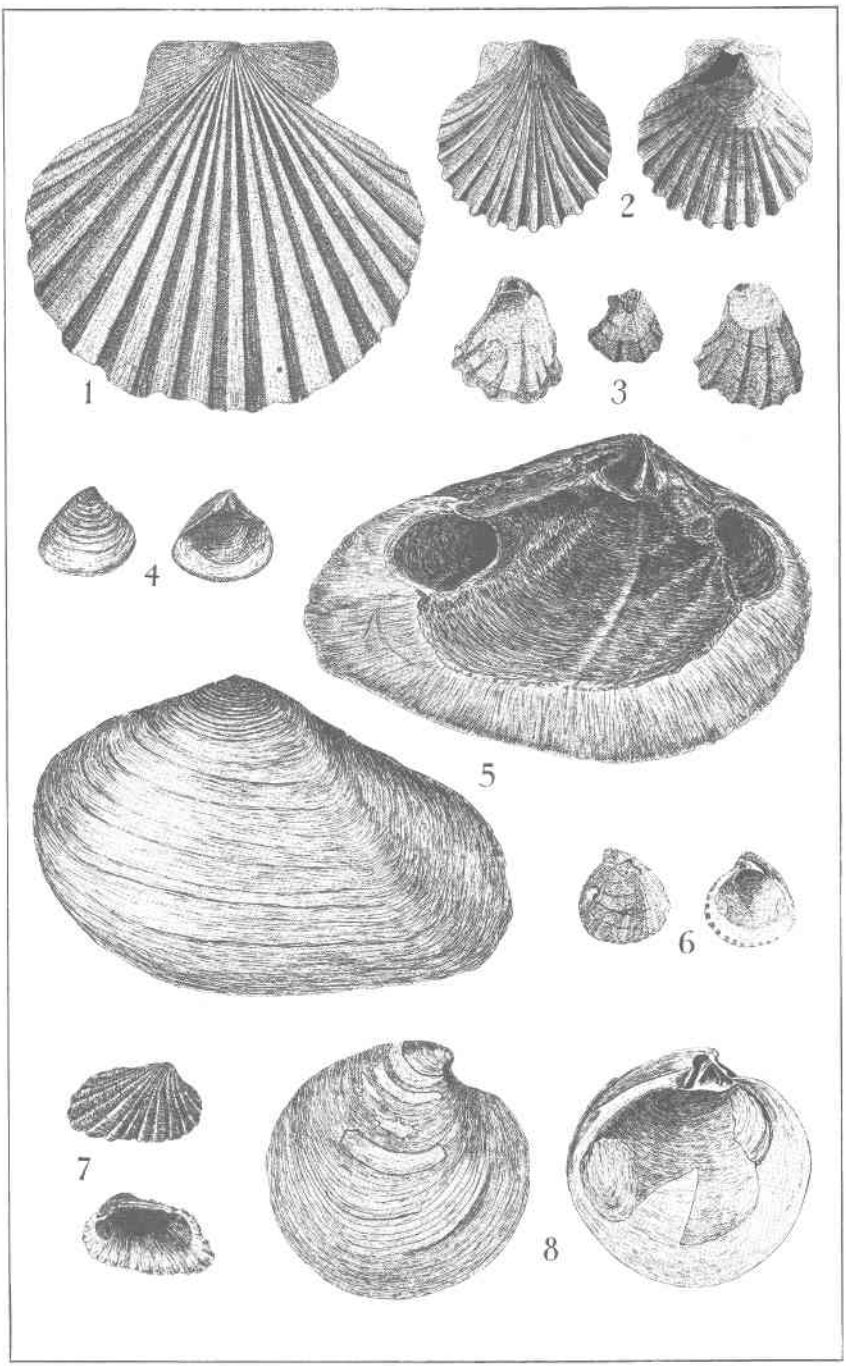
   CHARACTERISTICS: About 15 coarse ribs radiating from the beak, thus resembling *Arca;* beak far to the front with teeth immediately beneath, very unlike those of *Arca;* shell margins at top and bottom parallel, sides sloping at about same angle; lower margin strongly notched by the ribs.

8. *Dosina acetabulum;* external and internal views.

   CHARACTERISTICS: Valves almost round and rather thin; exterior has conspicuous concentric growth lines; 3 teeth in one valve and 4 in the other; muscle scars high in shell.



Typical fossil pelecypods from the Yorktown formation. About one-half natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)



Typical fossil pelecypods from the Yorktown formation. About one-half natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)

PLATE 18

1. *Venus tridacnoides;* external and internal views.

   CHARACTERISTICS: Valves very massive and thick; beak nearer anterior part; teeth very large, 2 in left valve and 3 in right valve; many very small ribs and growth lines; undulations in posterior part of valves; outer edge of valve shows many notches; muscle scars very deep towards center; angular sinus below posterior muscle scar and pallial line connects scars.

2. *Asaphis centenaria;* internal and external views.

   CHARACTERISTICS: Oblong valves with smooth margins; many ribs and concentric growth lines; beak slightly toward the front; 3 teeth in one valve and 2 in the other; muscle scars show fairly well.

3. *Teredo calamus;* showing different shapes of tubes.

   CHARACTERISTICS: Tubelike, slightly curved but never coiled, commonly soft, easily broken, and white; walls up to 3 mm. thick and internal diameter up to 8 mm.; known length of tube 4 inches.

4. *Dentalium attenuatum;* a cross section and four side views.

   CHARACTERISTICS: Slightly curved; open at end of cone; 12 to 16 ribs and numerous growth lines; diameter gradually increases and may attain 1¾ inches.

5. *Fissuridea redimicula;* top and side views.

   CHARACTERISTICS: Cap-shaped or low cone with many fine ribs radiating from the top; shows growth lines; small opening (foramen) at top towards the front; base is oval; ratio of length to width is about 3 to 2; height is less than the width.

6. *Calliostoma philanthropus;* aperture and spire, top view, and side view.

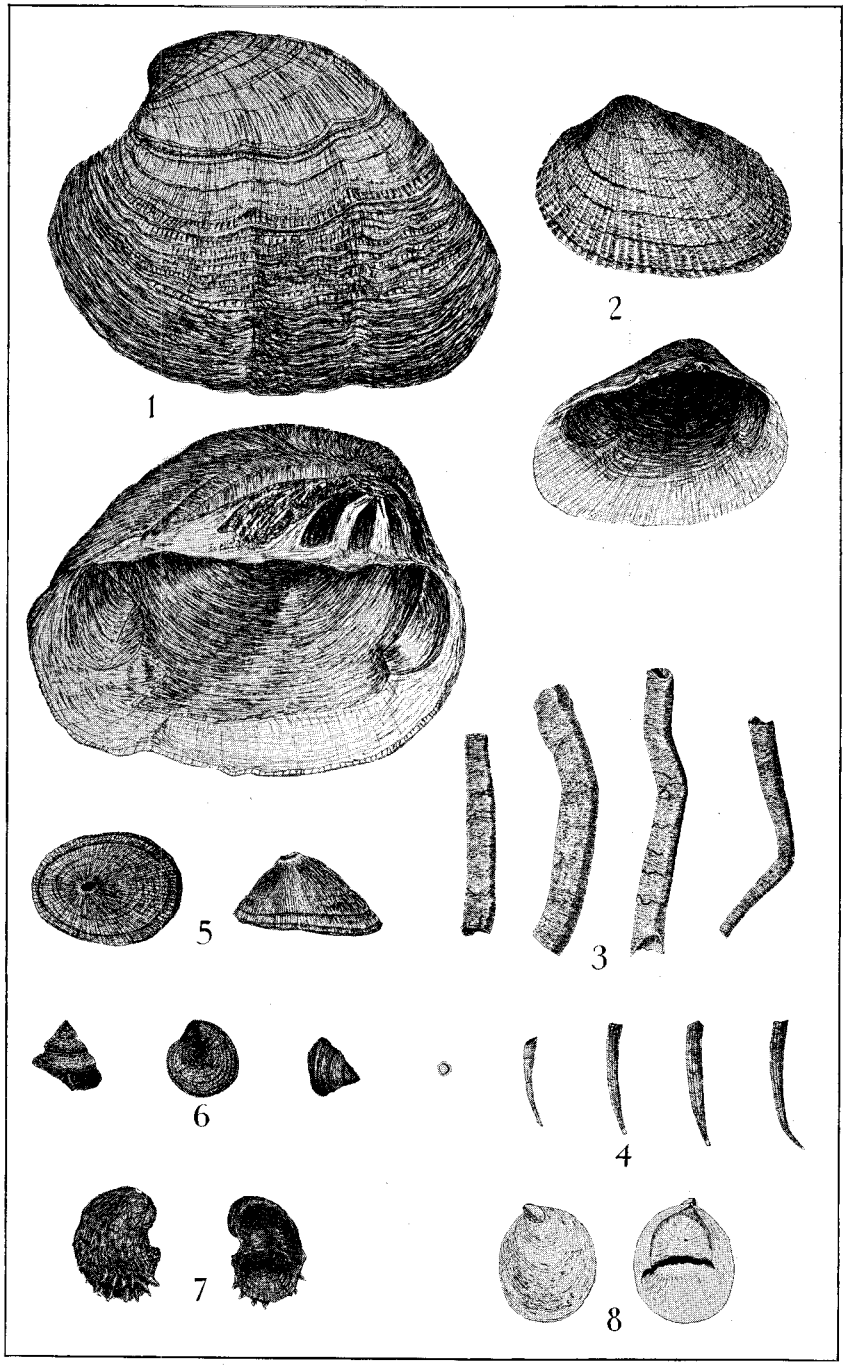
   CHARACTERISTICS: Spire low, very pointed, and conical; each spiral, or whorl, angular near the base; spiral line shows development of beads; large opening; very smooth interior, generally with bright surface.

7. *Crepidula aculeata var. costata;* showing spines, a smooth exterior, and an internal view.

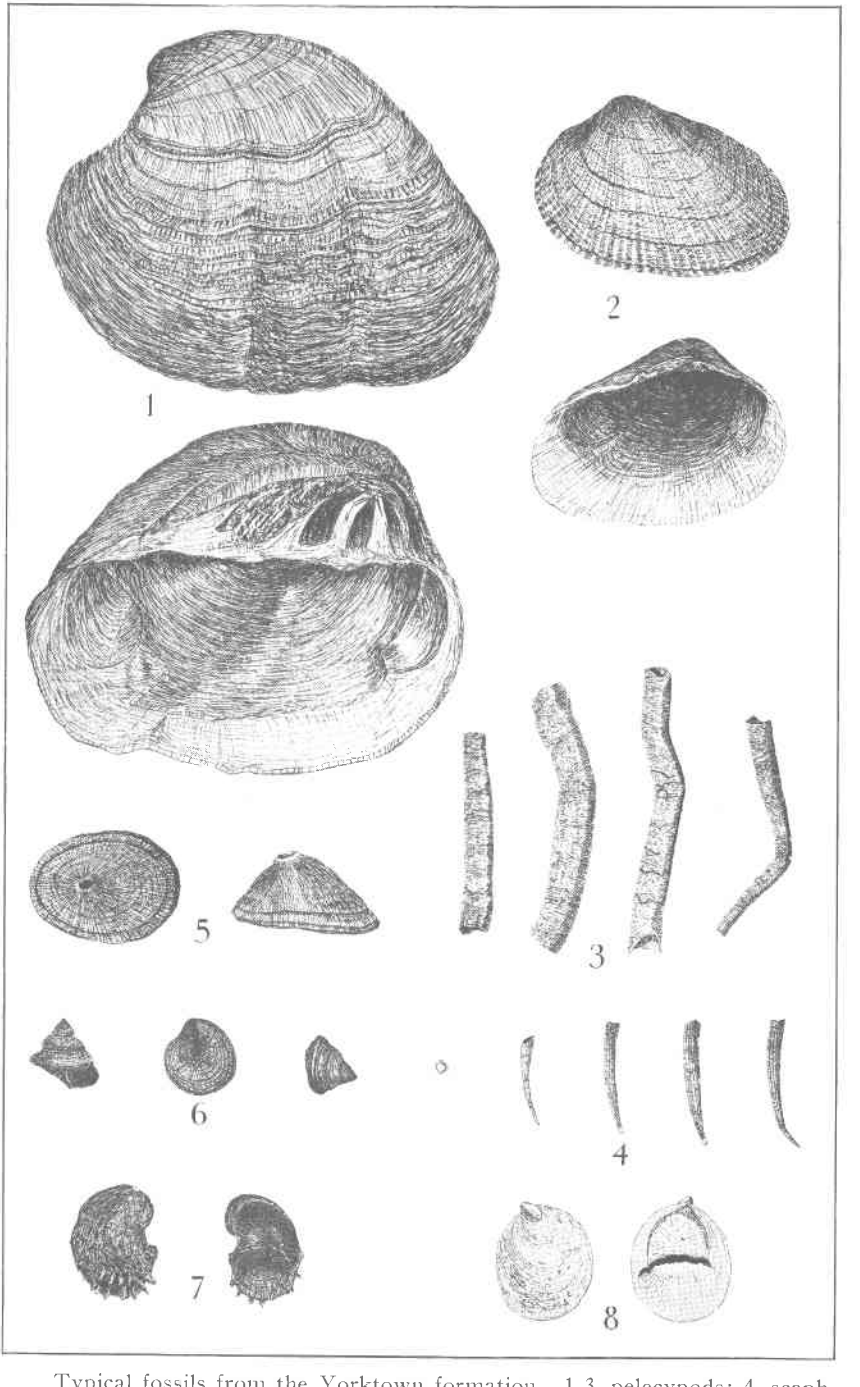
   CHARACTERISTICS: Shell deep and thick as compared to *C. aculeata;* has a thick partition, short spire, and a few spines.

8. *Crepidula plana;* external and internal views.

   CHARACTERISTICS: Smooth exterior with a few concentric growth lines; partial septum or interior partition; very flat; interior rather shallow compared to *C. fornicata.*



Typical fossils from the Yorktown formation. 1-3, pelecypods; 4, scaphopod; 5-8, gastropods. About one-half natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)



Typical fossils from the Yorktown formation. 1-3, pelecypods; 4, scaphopod; 5-8, gastropods. About one-half natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)

PLATE 19

1. *Crucibulum constrictum;* top, bottom, and side views.

   CHARACTERISTICS: Low cone, pointed to one side; ridges radiate from near the point; internal valve attached to one side of shell.

2. *Polynices heros;* top view showing aperture and umbilicus, side view showing *Drillia* boring and aperture, and side view showing spire.

   CHARACTERISTICS: Spire low but distinct; height slightly greater than the diameter; opening nearly semicircular and white on inside; deep conical opening (umbilicus) at side of the opening.

3. *Turritella alticostata;* a *Drillia* boring in one shell.

   CHARACTERISTICS: Spire high, graceful, and very sharp; each whorl enlarged towards base and shows 2 or 3 ridges, flattened in the middle; no depression near the mouth; opening nearly circular.

4. *Vermetus virginica;* showing the coils.

   CHARACTERISTICS: Shell coiled irregularly; striations and cross lines on most shells, having the appearance of wrinkles, but some shells are smooth.

5. *Oliva litterata;* aperture, back view, and spire.

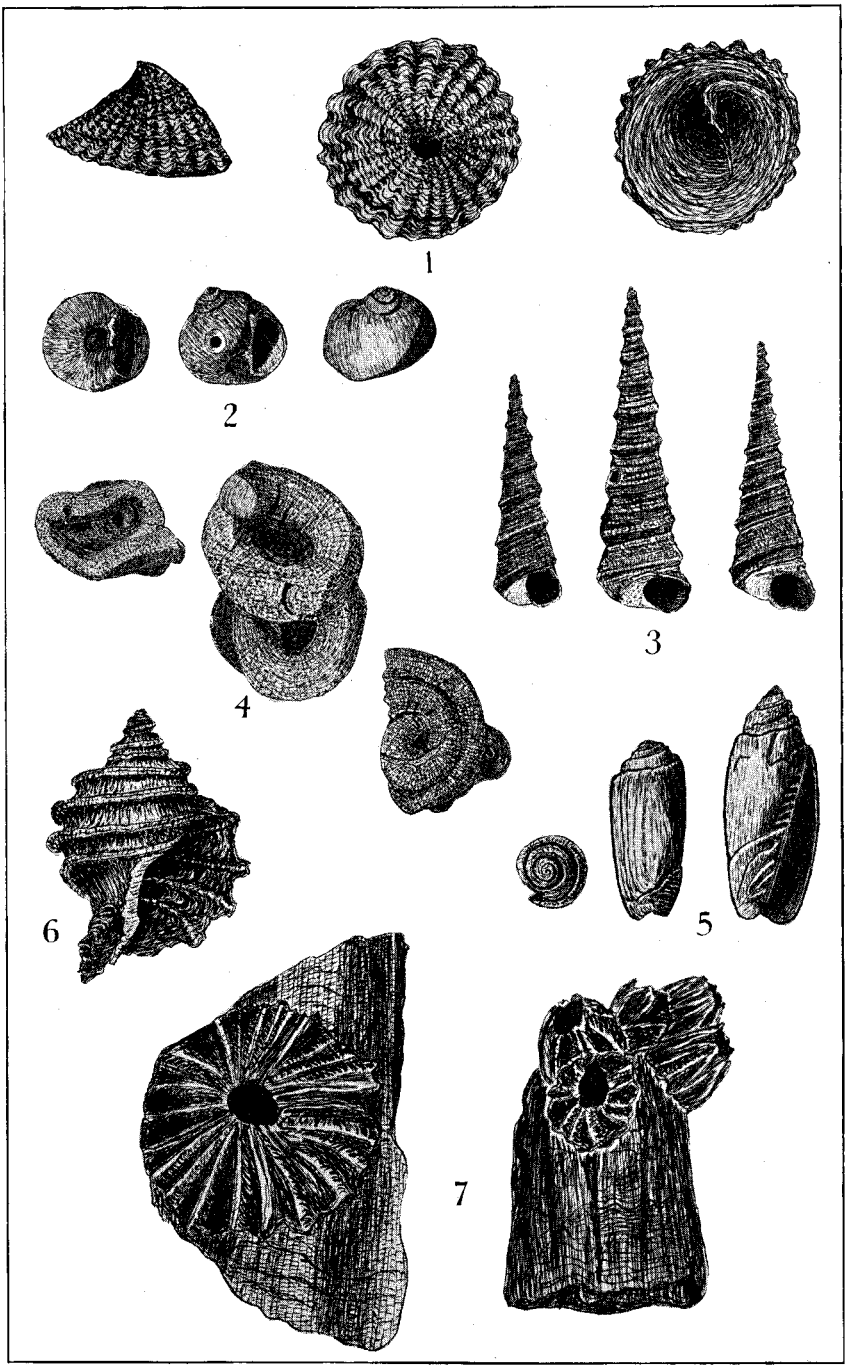
   CHARACTERISTICS: Shell cylindrical, widest above the middle; surface generally brilliant; spire low; opening long; outer lip thicker towards lower end; several small ridges on inner lip.

6. *Ecphora quadricostata;* showing spire and ribs.

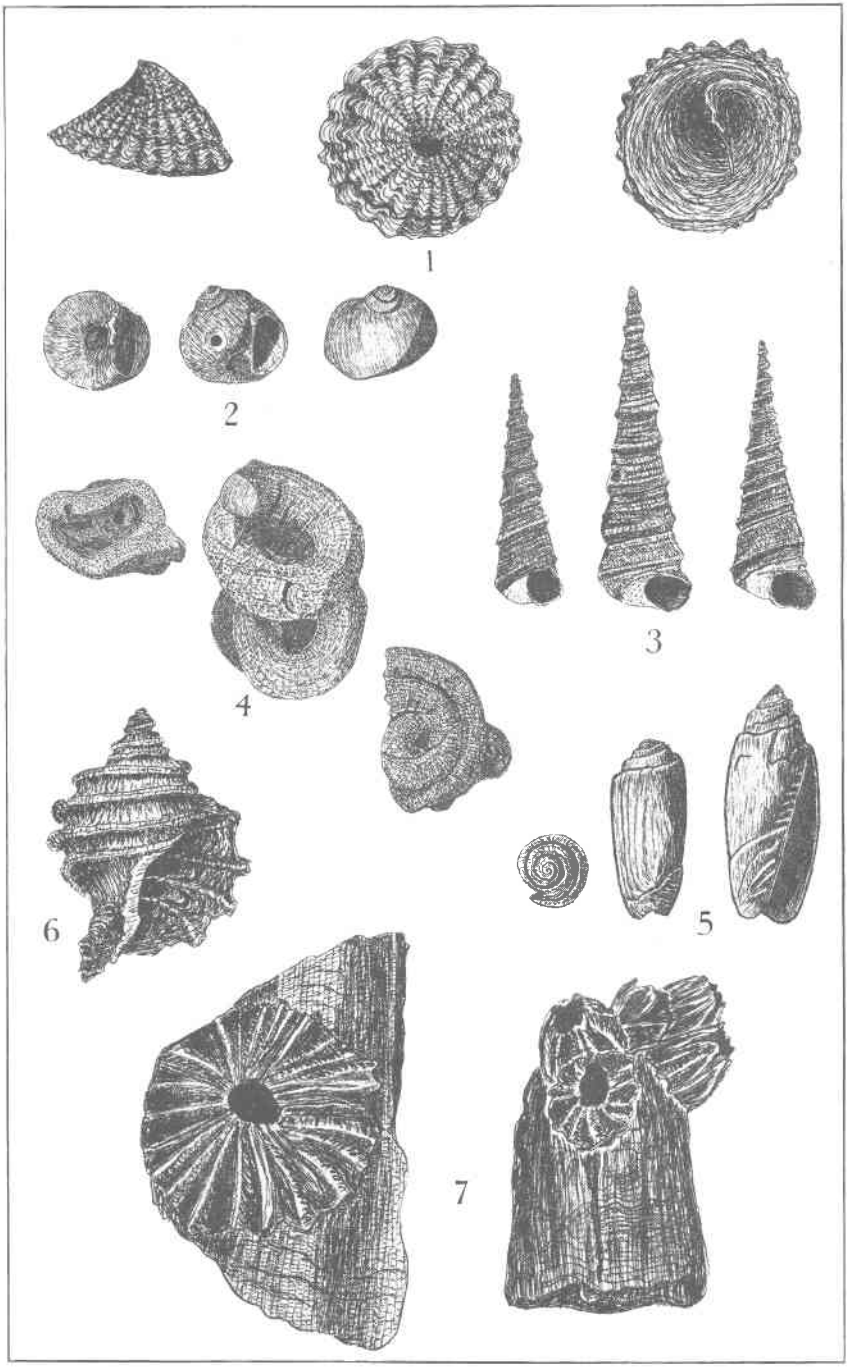
   CHARACTERISTICS: Four large spiral ridges (costae), T-shaped in larger forms; high spire in small forms and lower spire in large ones; opening nearly round; groove from the opening deep but short.

7. *Balanus concavus;* top view and one large form with several smaller ones attached to it.

   CHARACTERISTICS: Individuals are truncated cones, made up of several almost triangular plates; always attached to other objects or to each other; opening at top commonly very small; ratio of height to diameter is generally about 2 to 3.



Typical fossils from the Yorktown formation. 1-6, gastropods; 7, barnacles. About three-fourths natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)



Typical fossils from the Yorktown formation. 1-6, gastropods; 7, barnacles. About three-fourths natural size. (Drawn by R. L. Auldridge and F. B. Grinnell, Jr.)

MINERAL RESOURCES

GENERAL FEATURES

The mineral resources of a region are commonly of primary interest to most of the inhabitants. The residents of Tidewater Virginia were interested in the local mineral deposits long before the first geologic investigations were made, as is evidenced by the operation, long before the Revolutionary War, of crude smelters. Shortly after the first settlement was founded, a considerable quantity of the yellowish ferruginous clay was sent to England in the belief that it contained gold. Deposits of metallic minerals are rare in the Coastal Plain of Virginia. Small deposits of limonite, magnetite, and other minerals, chiefly of scientific interest, are found locally. None of them are believed to be now of commercial value. The main resources of this area are sand, gravel, clay, and marl.

Sand.—There is probably not a square mile of the Peninsula which does not contain some sand, as this is the most widespread kind of sediment. Comparatively small amounts of sand are found in the Yorktown formation. Most of the St. Mary's formation in James City County is composed of sand. The Brandywine formation is largely sand with scattered gravel. The Pleistocene beds carry an abundance of sand and the Recent deposits contain large amounts.

Sand has many uses in industry, but the use of the sand on the Peninsula is limited because of certain impurities and other factors. The Miocene (Yorktown and St. Mary's) sand is difficult to obtain except from exposures along James and York rivers. Deposits of Miocene sand occur commonly in thin beds and contain shell fragments. The texture of the sand is fairly uniform and very little gravel is found in it. This sand has not been extensively used. It apparently could be used as building, engine, and molding sand and some of the very light-gray sand may be suitable for the cheaper grades of glass.

All of the Pliocene (Brandywine) sands are colored a rather deep brownish- to yellowish-red by hydrated iron oxides. These sands are found over most of James City, York, and Warwick counties and are exposed in nearly all excavations for roads, railroads, and buildings. They offer slight commercial possibilities.

The Pleistocene terrace sand has a fine texture and is interbedded with clay. The color is generally very light. Certain layers contain considerable magnetite sand but not enough to make the color very dark. Occurrences of Pleistocene terrace sand are found along James River in James City County and along York River in James City and York counties. They are not now being used. Sands of Recent age are being used from deposits along many of the smaller streams and from several places along James and York rivers. The sand is being obtained mainly for local building uses.

Gravel.—This very necessary material for modern buildings and roads is found over much of the Coastal Plain. It is found in the four lower counties of the Peninsula, where it is used for road building and other construction. Some has been used for railroad ballast. The gravel, regardless of its geologic age, is composed largely of rounded quartz pebbles.

The St. Mary's and Yorktown formations contain no commercial gravel. The best gravel is found in the Pliocene (Brandywine) and Pleistocene terrace deposits. Sand is the dominant type of sediment in the Pliocene deposits but there are scattered lenses of gravel. Considerable sand is mixed with these gravels and the two are generally used together on roads, as pointed out by Watson[28]. In James City County several small pits have been opened from time to time in these gravel beds. Gravel is now being obtained for road construction from a pit in the Pliocene deposits west of Williamsburg.

Gravel of Pleistocene age, probably reworked from the older beds, occurs in a few places. It differs mainly from the older gravels in the scarcity or absence of iron oxides. No Pleistocene gravel is being used at present. Gravel of Recent age is found along some of the streams and some has been obtained by dredging.

Clay.—Clay is found throughout the four counties of the lower York-James Peninsula, and it is the most plentiful of the non-metallic mineral resources. It is of Miocene, Pliocene, and Pleistocene age. It was from this clay that the early settlers made bricks for their fortifications, churches, homes, and the capitols at Jamestown and Williamsburg. Nearly all of the clay is of low grade and it is used at present chiefly in the manufacture of brick. Some of it would probably make good drain tile and low-grade pottery.

The Miocene clay crops out principally northwest and southeast of Yorktown. It is so sandy, and even the less sandy varieties are so full of fossil shells that practically none of it is of economic value.

The Pleistocene clay has been extensively used. It grades into the Recent clay to such an extent that it would be difficult to make a choice between them for making brick. The Pleistocene clay makes a brick of very light color. The best exposures are along James River southeast of Carter's Grove, northwest of King's Mill, and along York River on the United States Navy Mine Depot property.

The Recent clay is found over most of the region along the smaller streams and along the floodplains of James and York rivers. From the early days, this clay has been the main source of material for bricks. Pleistocene and Recent clays have been used in brick manufacture at Hampton, Newport News, Morrison, and on the Peninsula wherever native clay has been burned.

[28] Watson, T. L., *In* Physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 4, p. 242, 1912.

All of the bricks used in the early buildings were hand made. Most of them were of large dimensions. In 1931 two companies were making bricks to be used in the reconstruction of Colonial Williamsburg. The actual sites of the first brick kilns and clay pits are not known, but the poor means of transportation in early days prohibited hauling the clay or clay products any great distance. It is a commonly related story that the older brick structures of the region were made from bricks brought over from England. Probably some few bricks were imported, but most of them were made in small kilns near the building sites.

There are several brick plants, either operating or temporarily closed, at Hampton, Newport News, and some of the smaller towns. The amount of clay for brick manufacture is unlimited on the Peninsula.

One of the more interesting plants is that of the Pinedale Clay Products Company, located about 2 miles east of the junction of Chickahominy and James rivers. This plant is making bricks for the restoration of the old Masonic building at Williamsburg. (See Pl. 20.) All of the bricks are hand made. The clay used by this company is probably of Recent age, though the lower part may be of Pleistocene age. It is a very plastic clay of light-gray color when dry. It burns to a light-red, or sometimes to a dull-gray, the color varying with the iron content and temperature of the kilns. The clay is a floodplain deposit which was formed in a cut off area of James River. It is free from grit and gravel.

The clay is taken from the shallow pit, ground with water, and then placed into hand molds, one box holding six bricks. These bricks measure 9 by 4½ by 2½ inches when placed in the sun for drying. After being air dried they are packed into the kilns for burning. The kiln has a capacity of 50,000,000 bricks. The kilns are burned for one week at 2,200° F. and allowed to cool for one week. The loss in shrinkage is approximately 16 per cent. This clay makes a very good brick for building and resembles the bricks made three hundred years ago. On one side the bricks are stamped, in the molds, "Jamestown Colony." The Pinedale Company is doing some beautiful experimental work in pottery and ceramic materials.

Marl.—The marl occurring at Yorktown and other places in York, Warwick, and James City counties is of two types. One type is a coquina consisting of a very finely divided mass of shells containing numerous large shells, cemented by calcium carbonate ($CaCO_3$) and colored by iron oxides. The other type consists of more perfectly preserved shells closely packed together. Both types contain much lime, but the content of clay and sand is rather variable.

The coquina is used locally for road metal and to a small extent for agricultural purposes. The deposit of coquina at Yorktown was used

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in the early days for building material, for example, in Grace Church. The marl makes a very good surfacing material for roads, though it does not wear very long. It has been used on the grounds of Navy Mine Depot. The marl pit located on York River at Wormley Creek is the largest one open at the present time.

The large bluff of coquina southeast of Yorktown was sampled and tested about 20 years ago with a view to manufacturing Portland cement. The Jamestown Portland Cement Corporation at Yorktown and the Colonial Portland Cement Corporation at Grove were chartered some 20 years ago. The Yorktown Company drilled a well and made numerous investigations preliminary to starting a factory. It was found that the coquina contained too little alumina and too much iron oxide, hence no production was realized.

A small pit was opened about 10 years ago in the shell marl, half a mile south of Yorktown. Marl from this pit was used locally to a small extent, on the land as fertilizer.

The fortifications of Cornwallis at Yorktown were made in the coquina; except on the western edge of the town, where they were constructed out of the sand overlying the Miocene deposits.

Ground water.—It has been known for some 80 years that artesian conditions exist on the Coastal Plain of Virginia. Ground-water conditions in the Peninsula have been described by Sanford.[29] The deep wells at Old Point Comfort, Lambert's Point, and other places were the first practical ones in the Coastal Plain. At Fortress Monroe a well drilled in 1902 to a depth of 2,251 feet, penetrated the entire thickness of Tertiary and Cretaceous sediments and about 8 feet of the crystalline rock. The well of the Chamberlain Hotel at Old Point Comfort was drilled in 1896 to a depth of 945 feet, but the water was too saline for other uses than flushing.

Certain conditions must be present for artesian water. (1) There must be porous rocks to receive, store, and furnish passage for the water falling upon the surface. (2) There must be impervious material, such as clay or shale, above the porous layer in order to prevent the escape of the water under pressure. (3) The intake zone of the surface water must be considerably higher than the mouth of the well, which is due to the porous beds dipping from the zone of intake toward the well. (4) Precipitation must be sufficient to keep the ground water replenished. The distance of the well from the source of the water, the number and flow of the artesian wells, and other factors affect the rate and amount of flow.

The artesian well drilled about 20 years ago at Yorktown by the Jamestown Portland Cement Corporation was located on the flood-plain

[29] Sanford, Samuel, Underground water resources of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 5, pp. 159-163, 196-200, 284-286, and 292-295, 1913.

of York River about half a mile southeast of the Yorktown monument. This well, according to the best information obtainable, was more than 400 feet deep. The water rose about 5 feet above the surface in a constant stream about 1 inch in diameter. This well continued to flow until about 1920, when a development company drilled another well. The second well is more than 400 feet deep and now yields a stream about 3 inches in diameter.

"In 1931 the National Park Service drilled a well at Yorktown, Va., to obtain a supply of water for use during the Yorktown celebration held in October, 1931. Following the Sesquicentennial celebration the well was made a part of the water-supply system for the Colonial National Monument.

"The well was drilled by the hydraulic rotary method of construction and an 18-inch casing was set at a depth of 380 feet. Water-bearing formations were encountered at depths of 385 to 425 feet and 697 to 717 feet. Water from the formation at 697 to 717 feet was found to be high in chlorides and not acceptable for domestic use. No unmixed sample of water was obtained from this depth but a partial analysis of a sample of water that was a composite of water from the upper water-bearing horizon located at 385 to 425 feet and the lower horizon contained 1,800 parts per million of chloride as shown by analysis No. 1 attached. [See Table 7.]

"The lower horizon yielded approximately 600 gallons per minute under a drawdown of about 50 feet. Prior to pumping the static water level in the well was approximately 40 feet below the ground surface.

"In view of the unsatisfactory quality of the water from the horizon at 697 to 717 feet the lower portion of the well was plugged and sealed and 25 feet of screen connected to 10-inch casing was set with the upper part of the screen at a depth of 395 feet. The well was then packed with gravel and developed in the usual manner. The yield of the upper horizon was reported to be about 60 gallons per minute. A partial analysis of a sample of water that was taken after the lower part of the well had been plugged but before the well had been pumped contained 565 parts per million of chloride as shown by analysis No. 2. [See Table 7.]

"A partial analysis of a sample of water obtained from the 10-inch flowing well of the Yorktown Hotel Corporation is given in the table as analysis No. 3. This well is located on the beach to the rear of the hotel property and is reported to have been drilled to a depth of about 400 feet. The well yielded 15 gallons per minute by natural flow and supplied 250 gallons a minute under a drawdown of about 70 feet when pumped."[30]

[30] Data furnished by the United States Geological Survey, March 30, 1932.

TABLE 7.—*Partial analyses of water from wells in Yorktown, Va.*[31]
(Parts per million; Margaret D. Foster, analyst.)

	1	2	3
Calcium (Ca) (by turbidity)	140	16	10
Bicarbonate (HCO_3)	382	720	830
Sulphate (SO_4) (by turbidity)	200	72	44
Chloride (Cl)	1,800	565	375

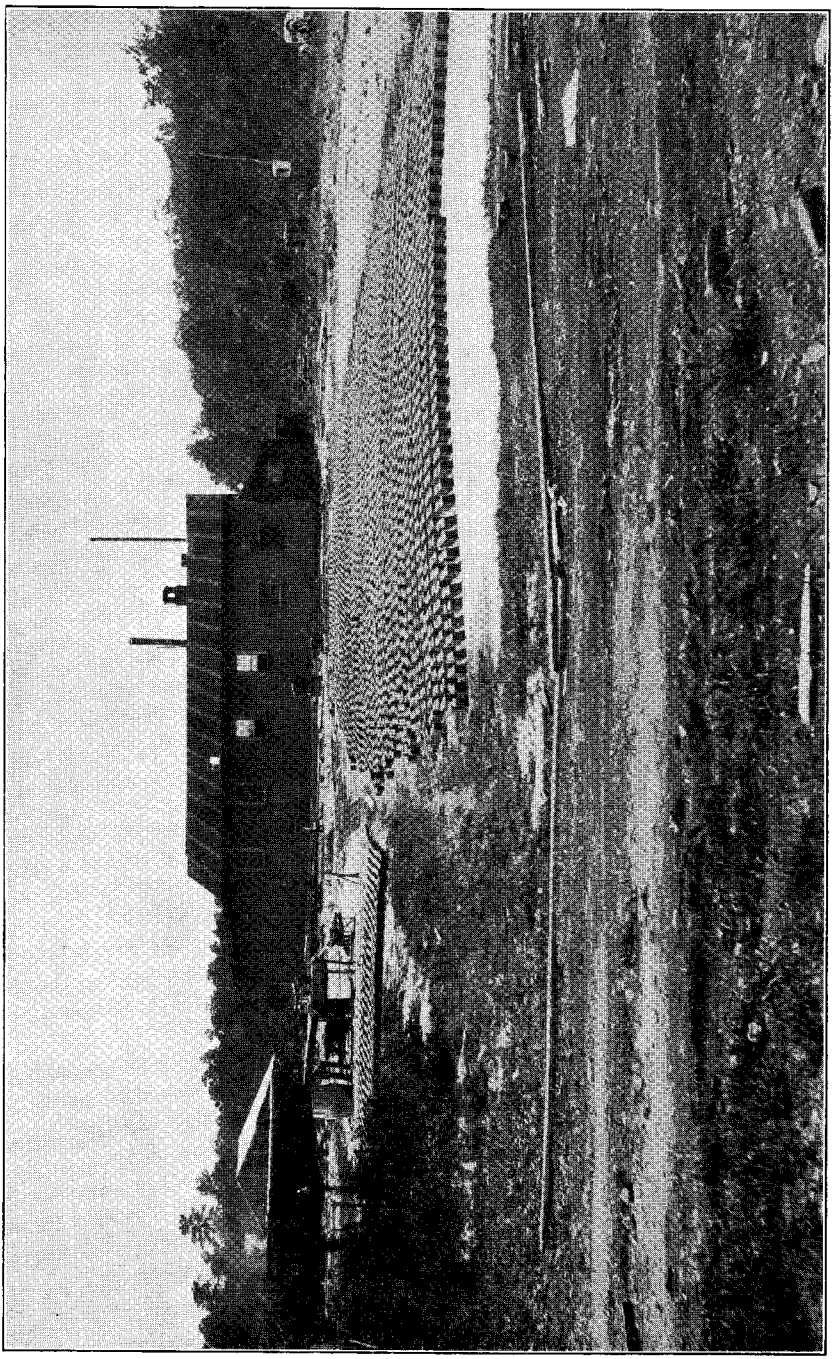
1. Drilled well of Colonial National Monument. Composite of water from upper and lower strata. Sample collected by A. G. Fiedler, August 28, 1931.
2. Same well as No. 1 at 395 to 420-foot depth. Sample collected by A. G. Fiedler, September 13, 1931.
3. Drilled well 400 + feet, 10 inches in diameter, owned by Yorktown Hotel Corporation. Sample collected by A. G. Fiedler, August 24, 1931.

There are many ordinary non-flowing wells on the Peninsula. The earlier ones are dug wells, whereas most of the later ones were drilled. Their depths vary from 15 to 40 feet. Most of the water contains so much lime as to be noticeable to the taste. None of the wells inland yield any salt water, but salt is found in wells near Chesapeake Bay in Elizabeth City County.

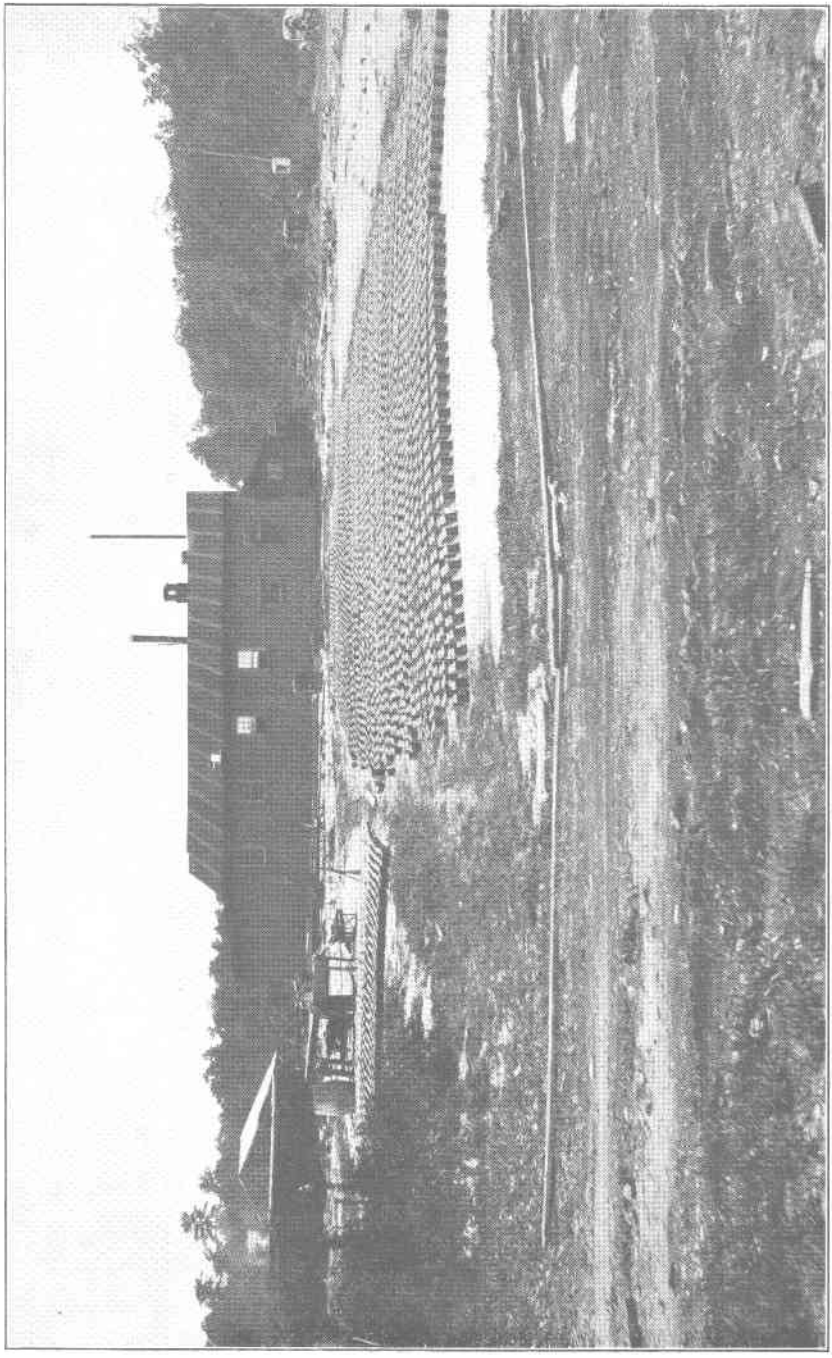
Nowhere is the ground-water level far beneath the surface. Small springs and seepages are fairly abundant but there are no large springs.

Other minerals.—In addition to the above mineral resources small deposits of low-grade limonite may be mentioned. Thin seams of limonite are found in the Yorktown formation, as a rule at the sand-clay contacts. Such deposits are now merely of scientific interest, but it is possible that iron from some of them might have been used in the early colonial smelters. Several minerals, such as magnetite and ilmenite, occur in the sands, in quantities of scientific interest only.

[31] Data furnished by the United States Geological Survey, March 30, 1932.



Part of the brick plant of the Pinedale Clay Products Corporation, 2 miles east of the mouth of Chickahominy River. Hand-made bricks drying in the sun. Photograph by the author.



Part of the brick plant of the Pinedale Clay Products Corporation, 2 miles east of the mouth of Chickahominy River. Hand-made bricks drying in the sun. Photograph by the author.

Drowned valley of Roberts Creek, an estuary along Chesapeake Bay. (From W. T. Lee, The Face of the Earth as Seen from the Air: Spec. Pub. No. 4, Am. Geog. Soc., New York. Used by permission.)

Drowned valley of Roberts Creek, an estuary along Chesapeake Bay. (From W. T. Lee, The Face of the Earth as Seen from the Air: Spec. Pub. No. 4, Am. Geog. Soc., New York. Used by permission.)

GEOLOGIC HISTORY

The geologic history of the Coastal Plain has been simple compared to that of the remainder of the State. When the formations of the region are examined critically, the observer is impressed with the part that oscillation of sea-level and erosion, as expressed in unconformities, have played. The region has repeatedly undergone elevation and depression relative to sea-level. The sediments occur in beds which slope gently toward the sea. In these beds are preserved evidences of some of the physical and organic changes that occurred from late Mesozoic time to the present day.

PRE-CRETACEOUS EVENTS

Lower Cretaceous beds are found lying upon the Piedmont pre-Cambrian crystalline rocks along the Fall Zone in the vicinity of Richmond, Fredericksburg, and other places. (See Fig. 4.) It is possible that Paleozoic and Triassic beds may have been lying in places upon the granite, gneiss, and schist when the Cretaceous sediments were deposited. Just how far east of the Fall Zone these old rocks were exposed at the beginning of Cretaceous time, it is impossible to say. Some geologists think the old Piedmont land surface may have extended to the edge of the Continental Shelf, far beyond the present coast line. Evidence along the Fall Zone proves that this Piedmont complex was an eroded land surface upon which the Lower Cretaceous sediments were deposited unconformably. The highlands of earlier geologic periods had been worn down to sea-level by incessant stream erosion until much of the region resembled a peneplain.

CRETACEOUS EVENTS

With the opening of the Cretaceous period, the Coastal Plain was submerged by a sea which advanced westward toward the present Fall Zone, over the lowland which had been produced by the planation of the underlying folded crystalline rocks. (See Figs. 4 and 7.) Along the western edge of this sea were bays and estuaries in which were deposited sand, gravel, and subordinate amounts of clay. These sediments were formed in part by the reworking of materials on the old land surface, during its submergence, and in part from uplands to the west along the streams of that time. Various fossil plants in the clays show a strand line near the areas where they are found. The depth of the waters is unknown, but the clastic sediments, their irregular bedding, and the fossils of land plants suggest relatively shallow waters. Small masses of lignite indicate local swampy conditions.

After a considerable amount of sediment, which today constitutes the Patuxent formation, was deposited the region again became land

and was subjected to erosion. This fact is indicated by the absence in Virginia of the Arundel beds which lie conformably on the Patuxent in Maryland.

After some period of time in which no sediments were deposited, this area again was submerged and the Patapsco sediments were accumulated. The time break between the Patuxent and Patapsco formations is indicated also by the difference in plant fossils. Fossil faunas are scarce or absent in these Lower Cretaceous beds but may occur to the east, being concealed by younger beds. Towards the close of Patapsco time the region was again elevated and a long interval elapsed during which land conditions prevailed.

Upper Cretaceous beds containing distinctive marine fossils have been reached by drills around Norfolk and Old Point Comfort. The position of the late Cretaceous strand line can not be determined, as these beds do not crop out and there are no drill records of them west of Norfolk. The beds are overlapped by Tertiary formations somewhere east of the Fall Zone.

TERTIARY EVENTS

It is not definitely known whether this area was again elevated at the close of Cretaceous time, but apparently elevation took place in Maryland and New Jersey. Through Tertiary time there were repeated times of emergence and submergence. (See Fig. 7.) In these seas there lived a prolific diverse fauna, mostly molluscan, if the known fossils are representative. The shores were clothed with a heavy vegetation, as shown by plant fossils at several horizons.

Marine Eocene deposits near the Fall Zone indicate that the shore was much farther west than during late Cretaceous time. It has been thought that the large amounts of glauconite in the Eocene deposits indicate shallow seas with an adjacent low-lying land, but this point is not fully settled. After the deposition of the land-derived sands and clays, the sea withdrew eastward; how far can not be determined.

Normally one would expect to find some sediment of Oligocene age, but the sequence is broken, for no one has recognized Oligocene sediments in this part of the Coastal Plain. Their absence can be accounted for by land conditions with little or no sedimentation, overlapping by younger beds, or sedimentation followed by complete or nearly complete erosion. Land conditions would most satisfactorily explain their absence, and this is the accepted view at the present time.

In Miocene time the sea again transgressed the land far to the west, for Lower Miocene beds are found at Richmond. These beds were discovered more than a century ago by W. B. Rogers, and collections of their fossil diatoms were made. These diatoms are the siliceous remains of many marvelous microscopic plants. The lower beds (Calvert)

are found on the eroded surface of the Eocene beds, thus making an unconformity which shows uplift, erosion, subsidence, and renewed deposition. At the close of Calvert time the sea again withdrew to the east, and the returning sea deposited the St. Mary's formation unconformably upon the Calvert.

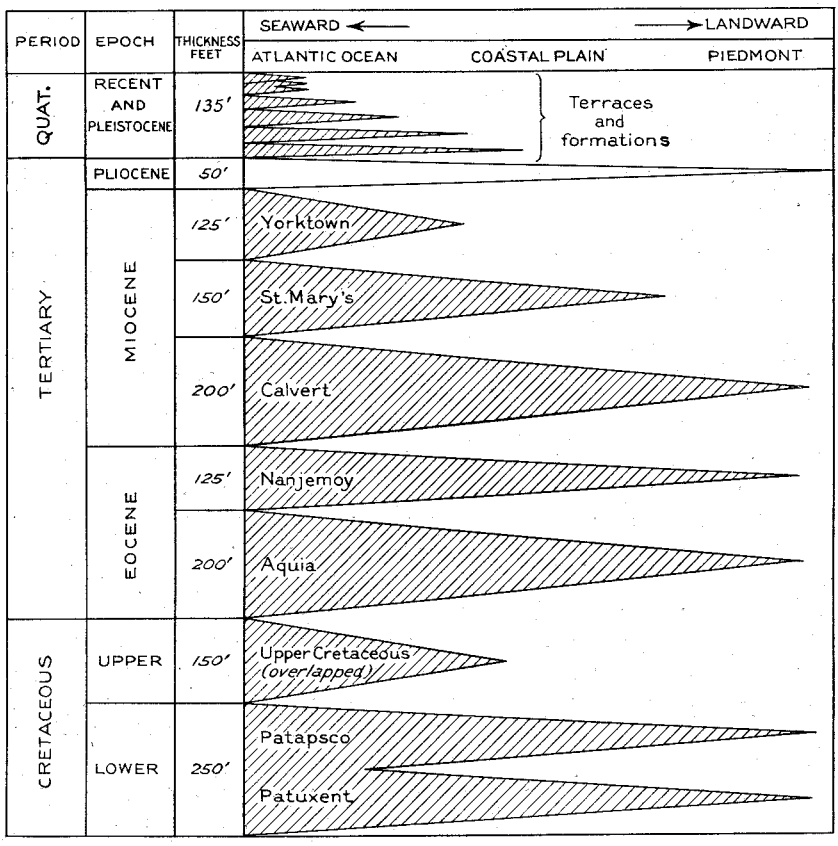


Figure 7.—Ideal diagram showing successive invasions and retreats of the sea during the Cretaceous, Tertiary, and Quaternary periods, over the middle part of the Coastal Plain in Virginia. Shaded areas indicate submergence.

The interval of time between deposition of the Calvert and St. Mary's formations must have been of considerable duration, because in Maryland the Choptank formation was deposited between them. The St. Mary's shore line was not as far west as the Calvert. Sands and clays deposited in this sea contain marine fossils, some of which are similar to those of the Calvert formation but many are different. At the close of St. Mary's time, the region was uplifted and the surface was subject to erosion.

Another sea then transgressed the land, but not so far to the west as the St. Mary's sea. During this minor cycle the Yorktown beds of sand, clay, and coquina were formed. The mass of broken shells which compose the coquina (Pl. 11) is an excellent witness of the stormy seas of that time. A slight change in the faunas took place during this time. Invertebrate life was abundant and varied in these seas, as is attested by the fossil shells in many of the sediments. At the close of Yorktown time, the Coastal Plain was again elevated and an uneven surface produced by erosion. As the sea withdrew, James and York rivers followed the retreating shore and became more or less established in their lower courses.

Some minor changes probably occurred at later times. In Pliocene time, sand, gravel, and clay were deposited over the western part of the Coastal Plain. No fossils have been found in these beds. Whatever the source of these deposits, which overlie the Yorktown beds and extend also westward into the Piedmont region, it seems apparent no sea has transgressed far to the west since Yorktown time.

The general oscillations of the strand line over the Coastal Plain, as inferred from available data, are shown diagrammatically in Figure 7.

PLEISTOCENE AND RECENT EVENTS

During Pleistocene time there were several minor submergences and emergences of this area, each giving rise to terrace deposits of sand and gravel. (See Fig. 3.) None of these sea invasions were as extensive as those of the Tertiary epochs. These terraces were formed largely by wave erosion along the shores of successive seas. At present the waves of Chesapeake Bay and the tidal estuaries can be seen at similar work, cutting away the bluffs (Pls. 8 and 11) and making submerged terraces. Boulders, which were probably carried down streams by floating ice, are found in places, as for example along the James, in some of the Pleistocene gravels.

Chesapeake Bay was formerly a great river valley through which flowed the Susquehanna, with the James, Potomac, and other streams as tributaries. The old Susquehanna probably flowed between Cape Charles and Cape Henry, over the emerged Continental Shelf and emptied into the Atlantic far east of the present shore. Changes in the outline of the coast and in the attitude of the land probably influenced, to some extent, the stream courses. An event of major geologic and economic importance was the recent submergence of the old deep river valleys, thus creating Chesapeake Bay, Hampton Roads, and the drowned valleys of the James and the York. Many small tributaries also were drowned. (See Pl. 21.)

The Piedmont province and the Coastal Plain have been physiographic neighbors for many epochs, but the Coastal Plain has been alter-

nately above and below the sea, whereas the Piedmont province has apparently been land during Cenozoic time. The Piedmont region has contributed large amounts of sediment to building up the Coastal Plain and the submerged Continental Shelf east of this plain. The present Coastal Plain bears somewhat the same relation to Chesapeake Bay and the Continental Shelf as that of the Piedmont region to the present Coastal Plain region in Patuxent and Calvert times.

RELATION OF GEOLOGIC TO HUMAN HISTORY

There is generally some relation between the geologic conditions and the development of the civilization of any particular region. The colonists in 1607, after a long and hazardous journey across the rough Atlantic, finally sought the quiet waters of the drowned James Valley at Jamestown Island and freedom from the sand hills and swamps around the Capes. After the settlement of this region was established and the population began to increase, the movement was westward into less swampy land. As the settlers depended upon water transportation for long distances, the lands along the larger streams were more in demand; hence the border lands of the James have the oldest settlements. For a long time, and even today to some extent, travel was controlled by the broad estuaries of the James and the York. When the region became more densely populated and iron deposits, other mineral resources, and excellent soils were found farther west, colonization continued westward until the Piedmont, Great Valley, and the mountains were occupied.

It should be noted that all the old Colonial buildings are made of brick, which is sometimes explained by the colonists having followed the same type of building as was common in the mother country at that time. It is more likely that the colonists made and used brick because clay was close at hand and was, in fact, the only available material, except timber, for building purposes. No stone buildings were erected on the Coastal Plain during Colonial times, because of the lack of building stone in this part of the State, although stone houses were then common in England.

GLOSSARY

Technical terms are here defined briefly in the sense in which they are used in this report. For more extended discussion the reader is referred to standard text-books on geology.

Age. A small division of geologic time characterized by a few persistent fossils, such as certain species of *Pecten* and *Venus*.

Alluvial. Deposits made by streams.

Ammonite. A kind of cephalopod.

Amphibia. A class of vertebrates of which the salamanders, newts, and frogs are modern representatives. Amphibians when young have gills, like fishes, and live in water; in later life they live on land and breathe by means of lungs.

Antecedent stream. A stream which has held its course across an upwarped area; for example, James River.

Anthozoa. A group of coelenterates, embracing the corals and sea-anemones. Have hard parts either of calcium carbonate ($CaCO_3$), which are preserved, or of a horny substance, not often preserved.

Aperture. An opening, as in the test or shell, through which an organism extends soft tissues or takes in food.

Appalachia. The great land mass that existed in Paleozoic time, where now are the Piedmont province, Coastal Plain, and the western part of the Atlantic Ocean. It furnished the gravels, sands, and muds that make up the clastic rocks of the Blue Ridge and the Valley.

Archeozoic. The oldest rocks of which there is any record. Archeozoic rocks underlie all the younger rocks of the earth's crust.

Arenaceous. Sandy; containing considerable sand.

Argillaceous. Clayey; containing considerable clay.

Arkose. A sandstone or conglomerate composed largely of undecayed feldspar.

Artesian water. Ground water under sufficient pressure to rise above the water-bearing bed.

Arthropoda. A major group, or phylum, of invertebrates characterized by an exoskeleton and jointed appendages; comprises the crustacea, insects, and other forms.

Barnacle. An arthropod which in early life attaches itself to a foreign object. It is a great nuisance to wharves, bottoms of ships, and other marine structures. (See Cirripedia.)

Baselevel. The lowest level to which land can be eroded by streams and running water.

Beak. In pelecypods or other bivalves it is the part of the shell which may be pointed and lies above the hinge line.

Bedding plane. The surface between two adjacent beds of sedimentary rock.

Bedrock. Solid rock. It underlies all loose surface materials.

Bivalve. The common name for the group of mollusks known as the pelecypods, such as oysters, characterized by two equal or subequal valves.

Brachiopoda. A class of mollusk-like invertebrates distinguished by having two unlike valves (dorsal and ventral) and a pedicle which is attached to foreign objects.

Bryozoa. A class of the mollusk-like invertebrates, characterized by having minute tests; of colonial habit and having much the appearance of a veil or mosslike mass.

Calcareous. Containing considerable calcium carbonate ($CaCO_3$); limy.

Carniverous. Pertaining to organisms which use animals as food by preying upon them.

Cenozoic. The latest era of geologic time, comprising the Tertiary and Quaternary periods; includes the present. Characterized by the great development of mammals and flowering plants.

Cephalopoda. A phylum of mollusks having a distinct subcentral head, a beaked mouth, and tentacles in place of a foot; cuttlefish, nautilus.

Cirripedia. A group of arthropods, commonly known as barnacles; attached to some object and having the body covered by plates.

Clastic. Composed of particles of other rocks.

Coastal Plain. The eastern portion of the State, sloping gently from the Fall Zone to the Atlantic Ocean; Tidewater Virginia. The rocks are composed of soft unconsolidated sediments, chiefly sands and clays.

Coelenterata. An invertebrate phylum embracing the corals, graptolites, and other forms; characterized by a single body cavity and with or without a test or hard parts.

Conformable. Describes adjacent parallel beds of sedimentary rock, the materials of which were deposited, in general, more or less continuously.

Conglomerate. A sedimentary rock composed of cemented gravel.

Consequent stream. A stream which begins in a region after uplift and whose course is determined by the topography or inequalities of the land surface.

Coquina. A consolidated mass of shell fragments.

Coral. See Anthozoa and Coelenterata.

Corallite. An individual coral, as distinguished from the colony or reef.

Correlation. Determining the rocks at different places to be of the same age, or to belong to the same formation.

Cretaceous. The last period of the Mesozoic era; characterized by the beginning of flowering plants, and by the dominance and the extinction of large reptiles and ammonites.

Cross-bedding. Oblique bedding within a layer of sediment; generally restricted to sands. Caused by change in the direction of the water or air currents transporting the sediments.

Crustacea. A group of arthropods embracing such forms as lobsters, crayfish, and the extinct trilobites.

Dendritic. The pattern of a stream and its tributaries, which resembles the venation of a leaf; the common type of drainage on the Coastal Plain.

Diatom. A type of microscopic green plant, having a siliceous test or skeleton. Makes up thick layers of rock called diatomite.

Dip. Maximum inclination of beds to the horizontal.

Disconformity. A break, or hiatus, in sediments, in which the bedding planes above and below the break are parallel. The hiatus is due to non-deposition or erosion of sediments.

Dorsal. Connected with or pertaining to the back.

Echinodermata. An invertebrate phylum characterized by an exoskeleton of a five-fold pattern (radial symmetry) and double body cavity; examples, star fish and sea urchins.

Echinoidea. A class of echinoderms, commonly known as the sea urchins, whose globular test is stemless, has a five-fold symmetry, and is covered with spines.

Eocene. The oldest subdivision of Tertiary time, in which began most modern or Recent stocks. Representative sediments in Virginia are exposed near the Fall Zone from Potomac River to North Carolina.

Epoch. A division of a geologic period.

Era. The longest division of recorded geologic time, such as Mesozoic and Cenozoic, characterized by a great cycle of life development and outstanding physical events.

Erosion. Wearing away of rocks by geologic processes.

Exoskeleton. An external skeleton or outer covering of invertebrates.

Fall Zone. The zone separating the unconsolidated sediments of the Coastal Plain from the crystalline rocks of the Piedmont province, in which the large streams have rapids or low waterfalls.

Fauna. An assemblage of animals that lived at one time or in one place.

Ferruginous. Sediments containing iron oxides, commonly as coatings on the particles or as cements; containing iron.

Flood-plain. Flattish land along a river underlain by sediments deposited by the river.

Fluvial. Pertaining to a river.

Foramen. An opening in the test, through which threads of protoplasm, tissues, or stalks, are projected for feeding, anchorage, and other purposes.

Foraminifera. One of the two fossil groups of Protozoa; mostly small to microscopic; tests are commonly calcareous. Abundant fossils in some Coastal Plain sediments.

Formation. A mass of sediments or rocks in which there are dominant fossil types or outstanding physical characteristics. A homogeneous lithologic unit.

Fossil. From the Latin word, "fosssilium" meaning anything dug up. The remains and traces of former organisms which may be preserved as original parts, such as teeth, bones, and shells, or as altered or petrified objects, such as carbonized or calcified remains.

Fosssiliferous. Containing fossils.

Gastropoda. A class of mollusks; most of them have one valve coiled, as in the snails; the other valve (operculum) fits the aperture of the coiled one. Very common fossils in some Coastal Plain formations.

Glauconite. A greenish mineral composed of a hydrous silicate of iron and potassium; upon weathering it produces a brownish and fertile soil; found in certain beds of Eocene and Miocene age in the Coastal Plain.

Gneiss. A banded crystalline metamorphic rock, having some cleavage.

Gradient. Rate of descent of a stream or a slope.

Granite. A granular crystalline igneous rock composed of quartz, feldspar, and other minerals.

Greensand. A glauconitic sand.

Ground water. Underground water, which fills cavities in the rocks.

Hiatus. A break or gap in the sequence of formations, due to non-deposition or erosion.

Horizon. A definite zone in a formation.

Igneous rocks. Rocks that were originally molten material; example, granite.

Indurated. Hardened by pressure or addition of cementing substances; e. g., shale is indurated mud.

Invertebrates. Animals which do not have a notochord or spinal cord; examples, clams, snails, crabs.

Lamellibranchs. Bivalves; pelecypods, a class of mollusks; examples, clam and oyster.

Laminae. Very thin layers of sedimentary rock.

Limonite. A mixture of hydrated iron oxides; dark-brown to nearly black; gives a yellow-brown streak.

Lithology. The physical character of rocks.

Loam. A deposit of clay and sand of a fine to medium texture.

Malacostraca. Modern crustaceans having thirteen segments and thirteen appendages.

Mammalia. Vertebrates whose young are fed by milk from the mammilary glands of the female.

Marine. Pertaining to the ocean.

Marl. A deposit of calcareous clay with or without fragments of fossil shells; impure limestone.

Meandering. Pertaining to streams that wind in broad curves, for example, Pamunkey River.

Mesozoic. An era of geologic time comprising the Triassic, Jurassic, and Cretaceous periods. Characterized by the dominance of the cycads, ammonites, and the large reptiles; first flowering plants.

Metamorphic rocks. Rocks that were originally either igneous or sedimentary and which have been altered by heat, pressure, and water; examples, marble and slate.

Metamorphism. The processes of great alteration of rocks, as by pressure and heat, whereby the resultant rock is unlike the parent rock.

Miocene. A subdivision of Tertiary time; characterized by certain forms of invertebrates, about 50 per cent of which are still living.

Mold. The imprint of a fossil shell upon the sediment that surrounds or fills it.

Molluscoidea. An invertebrate phylum which is mollusk-like in appearance. It comprises two rather heterogeneous classes, the brachiopoda and bryozoa.

Mollusks. Meaning "soft bodied." Invertebrates whose bodies are covered by two valves (right and left). This phylum comprises five classes, namely, pelecypoda, gastropoda, scaphopoda, amphineura, and cephalopoda.

Oligocene. A subdivision of Tertiary time during which 15 to 20 per cent of certain modern forms of mollusks was living.

Operculum. A cover or lidlike part of a shell.

Ostracoda. A group of arthropods bearing a close resemblance to the crustacea. The individuals are covered with two equal valves; mostly small forms.

Paleozoic. An era of geologic time comprising the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian periods. The time of great development of fernlike plants, shelled invertebrates, and the early vertebrates.

Pallial. A line present in most pelecypod shells along which the mantle is attached to the valve.

Pedicle. A stalk or stem of an invertebrate.

Pelecypoda. A class of mollusks commonly known as shell fish, bivalves, or lamellibranchs. The essential features are two equal or subequal valves (right and left), opened by a C-spring cartilage and closed by one or two muscles.

Period. A major division of an era, characterized by a cycle of physical and organic changes.

Permeable. Having a texture that permits the movement of ground water.

Phylum. A major plant or animal group, based on structure and the degree of development or balance between generalization and specialization.

Physiography. A branch of geology which treats of the surface features of the earth, emphasizing both the processes and the results as expressed in the land forms.

Piedmont. A geologic province extending from the Coastal Plain or Fall Zone on the east to the Blue Ridge on the west. Underlain principally by crystalline rocks, such as granite, gneiss, and schist.

Pisces. A class of vertebrates, commonly known as the fishes, having an axial system of bones and appendages in the form of fins; bodies with few exceptions are covered with scales.

Pleistocene. The older division of the Quaternary period, preceding the Recent time. Commonly known as the glacial epoch, or "ice age," during which ice sheets advanced from Canada far south into the United States. During this time the mastodon, Irish elk, and saber-tooth tiger became extinct.

Pliocene. The last subdivision of Tertiary time, during which there lived about 50 to 60 per cent of modern forms of mollusks.

Pre-Cambrian. (1) All recorded geologic time before the beginning of the Paleozoic era. (2) Very old crystalline rocks, as in the Piedmont province.

Protozoa. The most primitive phylum of animals; embraces two fossil groups, the radiolaria and foraminifera. Many forms living at present are not found as fossils, and vice versa.

Proterozoic. The era of geologic time extending from the Archeozoic era to the Paleozoic era. Embraces the youngest systems of pre-Cambrian rocks.

Province. A region characterized by the same, or closely similar, features; for example, the Coastal Plain province.

Quartz. A very common mineral composed of silica (SiO_2); colorless to white; very hard (scratches glass).

Quaternary. Second period of the Cenozoic era, consisting of Pleistocene and Recent time. Often called the "glacial period."

Radiolaria. A class of one-celled microscopic protozoa whose protoplasm secretes a test composed of silica (SiO_2).

Recent. Geologic time since the glacial epoch, including the present.

Relief. Difference in elevation in an area; irregularities of the surface.

Rill-marks. Tiny channels left on a sandy beach by the undertow.

Ripple-marks. Small furrows, or troughs and ridges, made in sand by waves and currents in shoal water.

Sandstone. A sedimentary rock composed of cemented grains of sand which is commonly quartz.

Scaphopoda. A class of mollusks characterized by a cone-shaped test of calcium carbonate; of small size and living mostly on the surface of the oceans.

Sea-urchins. A class of echinoderms. (See Echinoidea.)

Sedimentary rocks. Sediments deposited in beds mainly by wind, water, and organisms. Most of them contain fossils. Examples, sandstone, shale, and limestone.

Septum. A division or partition in an organism, as in the shell of corals.

Series. Two or more sedimentary formations.

Siliceous. Composed of silica (SiO_2). Many organisms form their tests of silica from ocean waters, soils, and other media.

Spire. The tapering portion of the test, as of a gastropod.

Strand line. A beach or shore-line.

Stratified. In bed or layers.

Stratigraphy. A branch of geology which treats of the strata, or layers of rocks, as to their character, thickness, sequence, age, and correlation.

Structure. Arrangement of rocks in the earth's crust.

Structure section. A vertical section showing the rocks as they would appear in the wall of a deep cut.

Subsequent streams. Streams not dependent on the original topography but whose development has been along belts of less resistant rock.

Symmetry. Refers to the orderly arrangement of the parts of an organism, such as bilateral and radial. In bilateral symmetry, the parts are so arranged that when divided equally by a plane one side will be a mirror image of the other; in radial symmetry, the parts are arranged similar to the radii of a circle or the spokes of a wheel.

System. All the rocks formed during a geologic period; for example, Cretaceous system.

Talus. A pile of coarse angular rock fragments at the base of a cliff or along a slope below the cliff.

Terrace. A benchlike flat above a stream; part of a former valley floor.

Tertiary. The older period of the Cenozoic era; characterized by flowering plants and mammals and by sea invasions on the Atlantic Coastal Plain.

Test. The hard parts, shell, or external skeleton developed by organisms; particularly applicable to the lower types of animals, such as the foraminifera, radiolaria, sponges, and corals.

Tidewater Virginia. Same as Coastal Plain province. The tide from the ocean extends up the major rivers to the Fall Zone.

Topography. The surface form, or shape, of the land.

Unconformity. A break or hiatus in the sequence of strata in which the beds above and below the break lie at an angle to each other.

Valve. One of the two separate parts of a pelecypod or brachiopod shell.

Ventral. Relating to the lower surface of the body.

Vermes. Worms; an invertebrate phylum represented by fossil jaws, trails, and borings.

Umbilicus. A depression around which the test is coiled, as in coiled foraminifers and gastropods.

Vertebrates. The phylum of animals characterized by the presence of a notocord or a spinal cord; comprises the fossil classes, fishes, amphibians, reptiles, birds, and mammals.

Water table. The upper surface of the zone saturated with ground water.

Weathering. The slow action of geologic agents at or near the surface whereby rocks decay and disintegrate.

Whorl. A complete turn in the spire of a gastropod.

APPENDIX A

Common Trees in the Coastal Plain of Virginia

The following list of common trees which is in general representative of the Coastal Plain, was furnished the writer by Professor Alfred Akerman, University of Virginia. This is not an exhaustive list of the trees in the Peninsula but contains only those of common occurrence. Trees like the catalpa, ginkgo, and yew, which are not natives of the region, are not included.

Pinus echinata	Short-leaf pine
P. serotina	Pond pine
P. taeda	Loblolly pine
P. virginiana	Scrub pine
Taxodium distichum	Cypress
Juniperus virginiana	Red cedar
Juglans cinerea	Butternut
	White walnut
J. nigra	Black walnut
Carya cordiformis	Bitternut hickory
	White hickory
C. glabra	Pignut hickory
C. alba	Mockernut hickory
	White hickory
Salix nigra	Black willow
Populus deltoides	Carolina poplar
	Cottonwood
Betula nigra	River birch
Carpinus caroliniana	Hornbeam
Fagus grandifolia	Beech
Castanea pumila	Chinquapin
Quercus alba	White oak
Q. stellata	Post oak
Q. prinus	Swamp chestnut oak
Q. rubra	Southern red oak
Q. velutina	Black oak
Q. palustris	Pin oak
Q. marilandica	Black jack oak
Q. nigra	Water oak
Q. phellos	Willow oak
Ulmus alata	Winged elm
Celtis occidentalis	Hackberry
Morus rubra	Red mulberry
Magnolia glauca	White bay
Lirodendron tulipifera	Yellow poplar
Sassafras officinale	Sassafras
Liquidambar styraciflua	Red gum

Common trees—Continued

Platanus occidentalis	Sycamore
Prunus serotina	Wild cherry
Robinia pseudacacia	Yellow locust
Ilex opaca, and other species	Holly
Acer rubrum	Red maple
Tilia sp.	Basswood Linden
Cornus florida	Dogwood
Nyssa sylvatica	Black gum
Diospyros virginiana	Persimmon
Fraxinus americana	White ash
Hamamelis virginiana	Witch hazel
Alnus sp.	Alder

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