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CHESAPEAKE BAY REGION

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CHESAPEAKE BAY REGION

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CHESAPEAKE BAY REGION

By Lloyd W. Stephenson, C. Wythe Cooke, and
Wendell C. Mansfield

INTRODUCTION

The purpose of excursion A–5 is to afford visitors to the Sixteenth International Geological Congress an opportunity to see as many representative geologic localities in the Chesapeake Bay region as can conveniently be reached in the available time. The localities selected are mainly the larger and better exposures of the Cretaceous, Tertiary, Quaternary, and Recent formations and include many of the principal fossil localities.

The route and the localities are indicated on the map of the Chesapeake Bay region shown in Plate 1.

GEOGRAPHY AND PHYSIOGRAPHY

The Chesapeake Bay region is a part of the Coastal Plain and, as defined for the purposes of this guidebook, includes portions of Virginia, Maryland, and Delaware. The area extends from the Virginia-North Carolina line on the south to Delaware Bay on the north and from the eastern edge of the Piedmont Plateau on the west to the Atlantic coast. The western boundary of the area from Delaware Bay to the North Carolina line is about 270 miles (435 kilometers) long. The width of the Coastal Plain on the north, adjacent to Delaware Bay, is 70 miles (113 kilometers); along a line running from Washington southeast to the coast, 115 miles (185 kilometers); and on the Virginia-North Carolina line, 85 miles (137 kilometers). The area, including Chesapeake Bay and its tributaries, is estimated at 20,000 square miles (51,800 square kilometers). The geographic position of the Chesapeake Bay region in the Coastal Plain is shown in Figure 1.

The Coastal Plain in the Chesapeake Bay region ranges in altitude from sea level to a maximum of about 300 feet (91 meters) above sea level along its western boundary. This boundary is determined by the contact of the softer Cretaceous or even younger rocks with the more ancient harder crystalline rocks of the Piedmont Plateau. This boundary is generally known as the Fall Line, though strictly it is not a line but a zone 1 to 5 miles (1.6 to 8 kilometers) or more in width. (See pl. 1.)

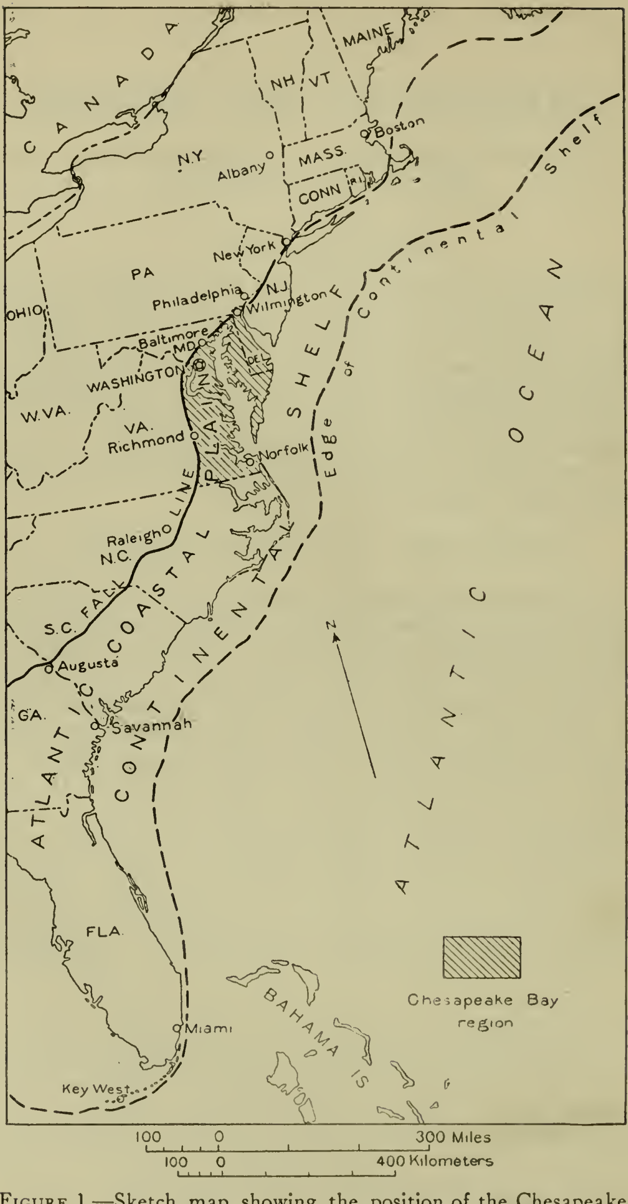


Figure 1.—Sketch map showing the position of the Chesapeake Bay region in the Atlantic Plain

The altitude of the eastern part of the Piedmont Plateau near the Fall Line is greater than that of the Coastal Plain, reaching a maximum of about 520 feet (158 meters). The streams, where they pass from this higher country to the Coastal Plain, increase their grade and cut down through the overlapping Coastal Plain sedimentary rocks into the underlying hard crystalline rocks, thus producing rapids. From the foot of the rapids the streams pass out over the softer, more easily eroded sediments of the Coastal Plain.

The Fall Line as generally understood is a line connecting the lowermost points on the streams at which the crystalline rocks produce rapids or markedly affect the topography on the stream banks. As thus defined it coincides with the eastern edge of the Fall Zone. The Fall Line in this sense therefore marks the head of navigation on most of the larger rivers in the Chesapeake Bay region, and this has been the determining factor in the selection of the sites of cities and large towns, of which Baltimore on the Patapsco, Washington on the Potomac, Fredericksburg on the Rappahannock, Richmond on the James, and Petersburg on the Appomattox are the principal examples.

The most striking physiographic feature of the Chesapeake Bay region is the great and intricate dendritic system of navigable waterways that ramify through it. (See pl. 1.) Chesaapeake Bay, which is really an estuary, is the main trunk of this system. The principal tributaries on the west include from south to north the James, York, Rappahannock, Potomac, Patuxent, and Patapsco Rivers. These "rivers" also would more properly be called estuaries. On the east are Pocomoke and Tangier Sounds, the Choptank River, Eastern Bay, and the Chester, Sassafras, and Elk Rivers. In Chesapeake Bay and all of its western tributaries except the York and Patuxent Rivers tidewater extends to the Fall Line. In Virginia the Coastal Plane has long been known as Tidewater Virginia.

Although the term "Coastal Plain" seems to suggest a level area, the Chesapeake Bay region is by no means a featureless plain. It includes extensive tracts of nearly level plain lying less than 100 feet (30 meters) above the sea, but there are also considerable tracts which are more or less dissected and range from rolling to moderately hilly. The nearly level areas include most of Delaware, most of Maryland east of Chesapeake Bay, and that part of Virginia east of the bay (the "Eastern Shore"), and about one-third of Tidewater Virginia; narrow terrace plains also extend up the valleys of the larger estuaries to the fall line. The hilly areas embrace most of the Coastal Plain of Maryland lying between Chesapeake Bay and the Potomac River (the "Western Shore" of Maryland), and most of the northern, central, and western parts of Tidewater Virginia. Minor hilly tracts occur in the northern part of the Eastern Shore of Maryland and in northern Delaware.

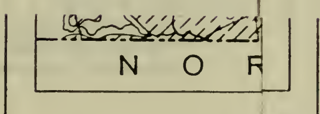
The nearly level parts of the Chesapeake Bay region are mainly emerged marine terrace plains of Pleistocene age. The hilly tracts are older, higher terrace plains of Pleistocene and Pliocene age, which have been more or less dissected; these older plains are believed to be in part of marine origin and in part of fluviatile origin, though opinions differ as to the relative importance of marine and river agencies in producing them. The altitude given on page 14 for each terrace represents very nearly the height above the present sea level of the seas and estuaries in which they were formed—that is, the position of the old shore line. The Talbot and lower terraces are not everywhere easily separable from each other and have in the past been grouped under the name Talbot. The restricted definition of the Talbot formation is explained by Cooke in a recent paper (35, p. 510)[1] and is followed in this guidebook.

GENERAL GEOLOGIC FEATURES

The Coastal Plain in the Chesapeake Bay region is underlain by sedimentary formations composed of sand, clay, marl, diatomaceous earth, and gravel, which range in age from early Cretaceous to Recent. These materials are for the most part unconsolidated or only partly consolidated, but in certain of the formations indurated layers are interbedded with the softer materials. The sediments of the Coastal Plain rest upon a basement which, so far as known, consists mainly of pre-Cambrian crystalline rocks, including schist, gneiss, granite, gabbro, diorite, and related rocks, with a very small proportion of early Paleozoic (Ordovician) rocks and Triassic sediments (27). In Stafford, Prince William, and Fairfax Counties, Virginia, a narrow belt of Ordovician rocks (Quantico slate) is overlapped in part by Lower Cretaceous sediments (26, pp. 70–72; 27). During a long period of pre-Cretaceous erosion the surface of the basement rocks was worn down to a peneplain, and on this surface the sediments of the Coastal Plain were deposited.

These sedimentary beds as a whole form a wedge-shaped mass, with the thin edge lying along the inner margin of the plain and the thick part underlying the coast and the adjacent waters of the Atlantic Ocean. The aggregate thickness of these sediments has not been determined at any place along the immediate coast, but at Fort Monroe, Virginia, crystalline basement rock was encountered at a depth of 2,240 feet (683 meters) below

[1] Numbers in parentheses refer to the bibliography on pp. 48–49.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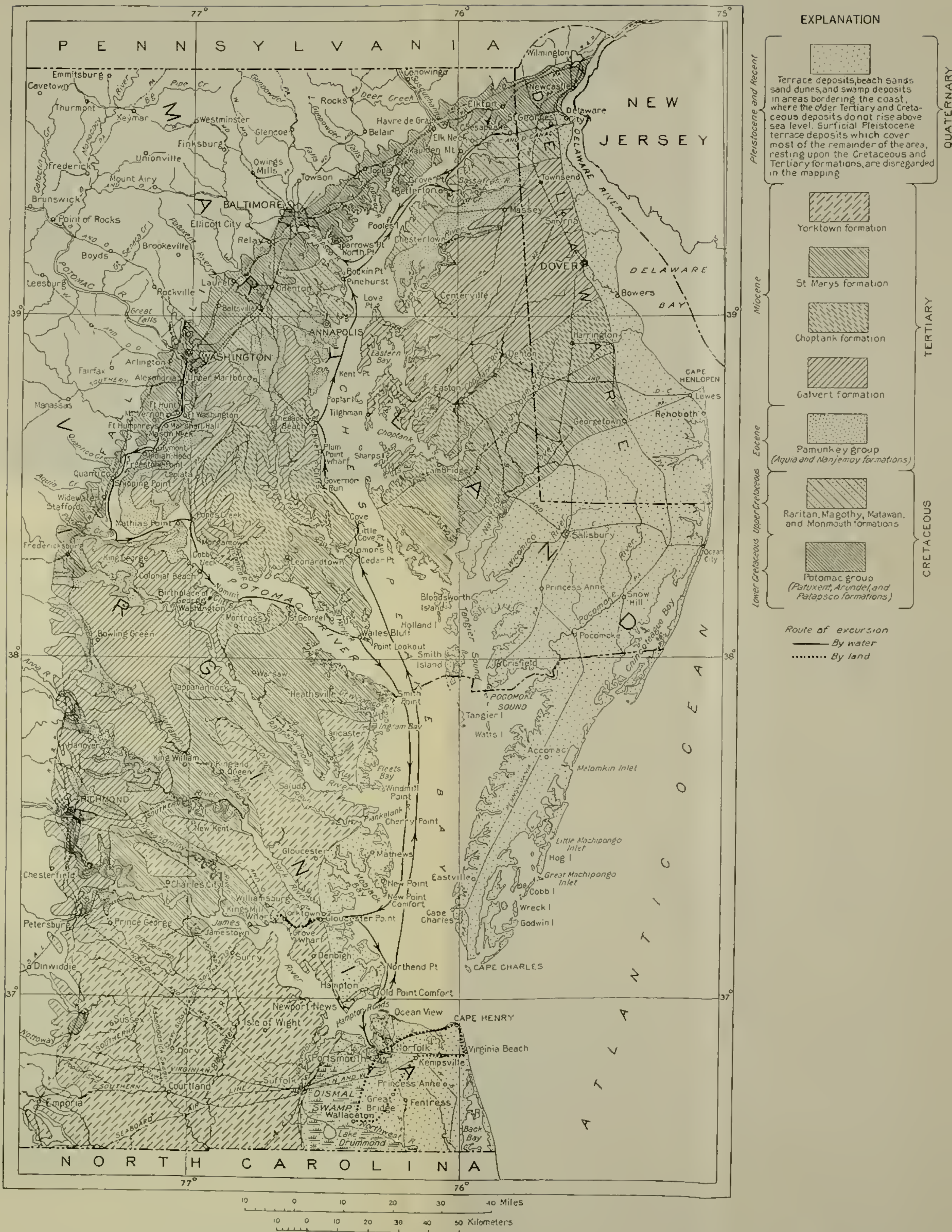

GEOLOGIC MAP OF CHESAPEAKE BAY REGION

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Geologic formations in the Chesapeake Bay region (Virginia, Maryland, and Delaware)

Age		Group	European equivalent	Formation		General character	Fossils
Quaternary.	Recent.					Loam, clay, sand, gravel, and swamp deposits.	
	Pleistocene.		(?)	Princess Anne formation. Pamlico formation. Talbot formation (restricted). Penholoway formation. Wicomico formation. Sunderland formation. Coharie formation(?). Brandywine formation.		Surficial terrace deposits, marine and nonmarine, including gravel, sand, clay, and local swamp deposits containing much fossil wood. Except locally these formations do not exceed 30 or 40 feet (9 to 12 meters) in thickness.	Fossils have come chiefly from the Talbot and Wicomico formations and include marine invertebrates (chiefly mollusks), swamp deposits containing cypress stumps, knees, and seeds, diatoms, miscellaneous plant débris, and a few bones and teeth of elephants and other vertebrates.
Tertiary.	Pliocene(?) (marine? and nonmarine).		(?)	Bryn Mawr (?) formation 40± feet (12 meters).		Alluvial-fan and high-level terrace deposits. Gravel, coarse sand, and loam, lying 300 feet (91 meters) or more above sea level; occurs in isolated areas along inner margin of Coastal Plain and along the eastern border of the Piedmont Plateau.	No fossils.
	Miocene.	Chesapeake group (marine).	Pontian(?) and Sarmatian.	Yorktown formation, 145 feet (44 meters).		Sand, blue sandy clay, thick beds of fragmental shells, and beds of well-preserved shells.	Marine invertebrates (mollusks abundant) and a few bones.
			Tortonian.	St. Marys formation, 0–180 feet (0–55 meters).		Greenish-blue clay, sand, and sandy clay, locally indurated by hydroferrous oxide. Includes fossil zones 21–24. (See p. 36.)	Marine invertebrates (mollusks abundant) and vertebrates, including bones of cetaceans and a few bones of fish and reptiles.
				Choptank formation, 0–175 feet (0–53 meters).		Fine yellow quartz sand, bluish-green sandy clay, and slate-colored clay, with a few interbedded indurated layers. Includes fossil zones 16–20. (See p. 36.)	Marine invertebrates (mollusks abundant) and fish teeth, chiefly of sharks.
				Calvert formation, 0–200 feet (0–61 meters).	Plum Point member, 0–145 feet.	Bluish green sandy clay and marl; contains an abundance of fossil marine organic remains, chiefly mollusks, but including diatoms; weathers to grayish-brown and buff. Includes fossil zones 4–15. (See p. 36.)	Marine invertebrates (mollusks abundant), plants, including diatoms and leaves, and vertebrates, including bones of cetaceans, a few reptilian bones and teeth, fish teeth, and a few fish bones.
					Fairhaven member, 0–62 feet.	Dark-green diatomaceous earth bleaching to white or weathering through buff to brown, with a sandy zone 1 to 10 feet (0.3 to 3 meters) thick along the base; the earth consists of vast numbers of diatom tests embedded in a matrix of finely divided quartz. Includes fossil zones 1–3. (See p. 36.)	
	Eocene.	Pamunkey group (marine).	Ludian(?) to Sparnacian(?) inclusive.	Nanjemoy formation, 0–125 feet (0–38 meters).	Woodstock member, 50–60 feet.	Fine homogeneous greensand and greensand marl. Includes zones 16 and 17. (See pp. 17, 18.)	Marine invertebrates, a few fish teeth, and a few plants.
					Potapaco member, 60–65 feet.	Greensand, argillaceous and in places gypsiferous. Includes zones 10–15. (See pp. 17, 18.)	Marine invertebrates.
				Aquia formation, 0–125 ± feet (0–38 meters).	Paspotansa member, 50 feet.	Thick-bedded greensand, interbedded in upper 10 feet (3 meters) with limestone layers composed largely of *Turritella mortoni* Conrad; weathers to greenish gray and reddish brown. Includes zones 8 and 9. (See pp. 17, 18.)	Marine invertebrates.
					Piscataway member, 50 feet.	Greensand and greensand marl, argillaceous in lower part and including two interbedded limestone layers in upper part. Includes zones 1–7. (See pp. 17, 18.)	Marine invertebrates and a few bones of crocodiles, turtles, and fish.
Cretaceous.	Upper Cretaceous (Gulf series).		Senonian. Maestrichtian.	Monmouth formation (marine), 0–100 feet (0–30 meters).		Dark to nearly black, more or less glauconitic sand, weathering to red and pink; in general the beds are homogeneous and massive and are unconsolidated except where they are locally indurated by ferruginous cement.	Marine invertebrates and a few vertebrates, including fish and reptilian bones and teeth.
			Senonian. Campanian.	Matawan formation (marine), 0–100 feet (0–30 meters).		Dark micaceous sandy clay, black clay, lighter sand, and sandy clay; the sands are in places glauconitic; the bedding is in general more regular and more continuous than in underlying formations.	Marine invertebrates and a few vertebrates, including fish and reptilian bones and teeth.
			Senonian. Emscherian(?).	Magothy formation (estuarine), 0–100 feet (0–30 meters).		Light-colored sand, locally coarse and conglomeratic, and subordinate drab or chocolate-brown clay; finely divided lignitic material is common; amber occurs with the lignite; the deposits are irregularly bedded and change rapidly both horizontally and vertically.	Abundant plants; in New Jersey a considerable marine molluscan fauna, but in Maryland only a few molluscan remains.
			Cenomanian.	Raritan formation (estuarine), 0–250 feet (0–76 meters).		Irregularly bedded white or buff sand and white, pink, drab, and variegated clay, changing rapidly both horizontally and vertically; locally the sands are coarse and even gravelly, but arkosic material is not common.	Plants and, in New Jersey, a few reptilian bones and a few fresh and brackish water mollusks.
	Lower Cretaceous.	Potomac group (nonmarine).	Albian.	Patapsco formation, 100–360 feet (30–110 meters).		Irregularly bedded clay, sand, and gravel, the clay predominating; the clay is variegated in red, drab, and chocolate-brown, is lignitic in places, and carries some iron ore; the sand and gravel are generally arkosic and more or less cross-bedded.	Abundant plants and a few fresh-water mollusks (*Unio*).
			Barremian.	Arundel formation, 0–150 feet (0–40 meters).		Typically drab, more or less lignitic clay, with nodules, geodes, flakes, and ledges of earthy iron carbonate or siderite; locally sand is interbedded with clay.	Plants, reptilian remains, and a few poorly preserved fresh-water mollusks.
			Neocomian.	Patuxent formation, 0–500 feet (0–152 meters).		Irregularly bedded, cross-bedded sand and gravel, generally more or less arkosic, indurated in places by hydrous iron oxide or by silica to soft or hard sandstone; clay interbedded with sand, in the form of pellets, thin layers, and lenses of differing sizes up to large masses, prevailingly white but in part purple, red, maroon, lavender, brown, and yellow.	Plants.
Pre-Cambrian.	Crystalline rocks including granite, gneiss, schist, diorite, gabbro, and serpentine.						No fossils.

sea level in a deep well on the lowest terrace plain (Pleistocene), only a few feet above sea level, and similar bedrock was reached near Mathews, in Mathews County, Virginia, at a depth of 2,307 feet (704 meters) in a well located on the same low terrace plain. It is probable that the depth to the basement rocks along the coast is somewhat greater than that shown by the two Virginia wells, although the actual depth must remain problematical until tested by deep wells, or perhaps by geophysical methods. The sediments do not end at the present coast but extend out under the Atlantic Ocean at least as far as the edge of the Continental Shelf (the submerged continuation of the Coastal Plain), which, adjacent to the Chesapeake Bay region, lies 70 to 120 miles (113 to 193 kilometers) east of the coast. (See fig. 1.) If the basement surface on which the sediments rest continues to slope uniformly eastward the sediments must increase in thickness at least as far as the edge of the Continental Shelf, beyond which they should thin out rapidly as they merge into the oozes of the ocean bottom. Off the Chesapeake Bay region the Continental Shelf is comparable in extent to the Coastal Plain.

The Patuxent, the oldest formation of the series of Coastal Plain sedimentary rocks, is of Lower Cretaceous age and crops out farthest inland, just east of the fall line. Its beds dip gently toward the coast at the rate of 50 to 90 feet to the mile and pass under the beds of the next younger formation. Generally the successively younger formations crop out in belts successively nearer to the coast; but in certain parts of the area exceptions to this geographic distribution are caused by the transgressive overlap of younger upon older formations, as indicated on the geologic map. The rate of dip of the formations becomes progressively more gentle, the youngest beds of all being nearly flat or inclined coastward at only a foot or two to the mile.

The accompanying table indicates the classification of the geologic formations and their character, estimated thicknesses, and fossil content. The areal distribution of the formations or groups of formations is shown on Plate 1.

GEOLOGIC HISTORY

The peneplaned surface of pre-Cambrian crystalline rocks that underlies the sediments of the Coastal Plain may be taken arbitrarily as a starting point in sketching the geologic history of the Chesapeake Bay region. During most of Paleozoic time and during most of the Triassic and Jurassic periods of Mesozoic time this region was above the sea and was subject to erosion. One narrow band of Paleozoic (Ordovician) rocks underlies the western margin of the Coastal Plain sediments in Stafford and Prince William Counties, Virginia. During the Triassic period certain parts of this old land surface west of the Chesapeake Bay region were depressed, either by downwarping or by downfaulting, and the lowlands thus formed were filled with continental deposits of sand, gravel, clay, and coal; these deposits form the Newark group. Representatives of this group have been observed beneath the sediments of the Coastal Plain in one small area in Virginia, but they have not been identified in well borings in the Coastal Plain. So far as known, therefore, the unconformity between the pre-Cambrian rocks and the basal Cretaceous sediments of the Coastal Plain represents a nearly uninterrupted period of erosion in the Chesapeake Bay region.

At the beginning of the Cretaceous period the Chesapeake Bay region and the adjacent Piedmont Plateau, to the west, together presented a broad, maturely peneplaned land surface standing relatively low with respect to sea level, bounded somewhere on the east, perhaps as far east as the edge of the Continental Shelf, by the western shore of the Atlantic Ocean. Early in Cretaceous time a strip of country along the inner edge of the present Coastal Plain was depressed, probably downwarped, and simultaneously the Piedmont Plateau was uplifted. The linear axis of this depressed area was approximately parallel to the Atlantic coast. What effect this crustal deformation had on the position of the shore line is not known, but there is no evidence that any part of the Coastal Plain in the Chesapeake Bay region was flooded by ocean waters during Lower Cretaceous time. No marine Lower Cretaceous deposits were recognized in the deep wells at Fort Monroe and Mathews, Virginia.

Although the depressed area along the inner margin of the Coastal Plain did not sink deep enough to admit ocean waters, it formed a dumping ground for sediments brought in by streams from the higher country immediately to the west. In this way the continental deposits of sand, clay, and gravel composing the Patuxent formation of the Potomac group were laid down on flood plains to a maximum thickness of 500 feet (152 meters). In favorable parts of this basin of deposition plants were entombed and preserved in great abundance, and on the evidence of these organisms the Patuxent formation has been correlated with the Neocomian (Lower Cretaceous) of Europe (18, p. 172).

The deposition of the Patuxent formation was followed by a period of uplift and erosion, after which, as a result of renewed downwarping of the same basin, sand, clay, and subordinate lignite of the Arundel formation of the Potomac group were deposited to a maximum thickness of 130 feet (40 meters). These sediments are also nonmarine and were doubtless laid down on flood plains and in fresh-water swamps. They not only contain an abundance of fossil plants, but locally have yielded reptilian remains, including dinosaur bones in considerable abundance and a few crocodilian remains, and fresh-water mollusks. These organisms are interpreted to indicate the Barremian age of the formation.

The Arundel deposition was followed by another period of uplift and erosion, believed to have been long enough to cover all of Aptian time, at the end of which deposition of the same general type as that of the Arundel was renewed, and sand, clay, and gravel, including some lignite, were deposited to a maximum thickness of 360 feet (110 meters), constituting the Patapsco formation, the youngest of the Potomac group. Abundant plant remains and a few fresh-water mollusks (*Unio*) have been obtained from this formation and the plants are believed to indicate Albian age.

The deposition of the Patapsco was followed by uplift and erosion, and the hiatus thus produced marks the separation of the Lower and Upper Cretaceous sediments of the area. The length of this erosion interval is problematic, but it extended throughout the Atlantic and Gulf Coastal Plain and was probably of considerable length. It was ended by a gentle coastward tilting of the Chesapeake Bay region, probably accompanied by a slight uplift of the adjacent Piedmont Plateau. The ocean waters crept inland across the tilted surface but did not cover all of the area in which the continental sediments forming the Potomac group had previously been deposited. The Raritan, the lowermost of the Upper Cretaceous formations, was formed along the eastern margin of the belt of outcrop of the Potomac group, where streams from the west brought large quantities of fine sand and clay and deposited them in estuaries, lagoons, and marshes and on low plains; some gravel and coarse sand were interbedded with the finer materials. Continued slow coastward tilting permitted the sediments to accumulate in an irregularly bedded mass to a maximum thickness of 250 feet (76 meters). The Raritan formation completely overlaps the Potomac group in northeastern Maryland and northern Delaware. In Maryland the formation has yielded only fossil plants, but in New Jersey a few reptilian bones and a few fresh-water and brackish-water mollusks have been found in it. On the evidence afforded by the plants the formation is correlated with the Cenomanian.

The deposition of the Raritan formation was followed by a period of uplift and erosion of considerable duration, perhaps representing all of Turonian time, and this was followed in turn by renewed tilting and the deposition of the Magothy formation, which consists of a maximum of 100 feet of sand and clay resembling those of the Raritan but including lignitic material with which amber occurs in places. These deposits were a little more closely associated with marine conditions than those of the Raritan, for a few marine mollusks have been found in them. Plant remains are abundant and have been interpreted to indicate the Turonian age of the Magothy formation, but fossil mollusks obtained from the formation in New Jersey are of kinds that have not been found in deposits of undoubted Turonian age and suggest that the Magothy can not be older than lower Senonian (Emscherian).

Uplift and renewed erosion succeeded the deposition of the Magothy formation, but this period of land conditions was probably of relatively short duration. Then came further tilting, the axis of which was sufficiently far inland to bring the ocean waters across the Coastal Plain to or perhaps a little beyond the present belt of outcrop of the Upper Cretaceous formations. In these waters was deposited the Matawan formation, consisting of a maximum of 100 feet (30 meters) of sand and clay, generally darker and more evenly bedded than the deposits of the older formations and containing some glauconite. Abundant marine invertebrates point unmistakably to the marine origin of these sediments; a few fish and reptilian bones and teeth have also been found. These organisms indicate the Campanian (Senonian) age of the formation.

Again there was uplift and a relatively short period of erosion, and again coastward tilting brought the ocean waters flooding in across the area. In these waters was deposited a maximum of about 100 feet (30 meters) of fine, more or less glauconitic, homogeneous sand, which forms the Monmouth, the uppermost of the Upper Cretaceous formations in this part of the Coastal Plain. In places this sand contains an abundance of well-preserved invertebrate remains and a few of vertebrates, including fish and reptilian bones and teeth. The invertebrates indicate the upper Senonian, probably the Maestrichtian age of the formation.

The deposition of the sand of the Monmouth formation was brought to an end by an uplift or a lowering of sea level, which affected not only the Chesapeake Bay region but the entire Atlantic and Gulf Coastal Plain; indeed, a change of sea level at this time appears to have been general throughout the world. The change may not have been profound, as measured in hundreds of feet, but it caused the Atlantic and Gulf shore line to retreat perhaps as far as the edge of the Continental Shelf. The erosion interval that followed was long enough to permit the surface of the Coastal Plain to be reduced to a peneplain. The interval was longer in the North Atlantic Coastal Plain than in the Gulf region; it marks the dividing line between the Upper Cretaceous and Eocene epochs.

Subsidence of the Coastal Plain, which terminated this major period of land conditions, began first in the Gulf region, where the sea came in across the low-lying land and received in its moderately deep waters the sediments forming the Midway group. That these deposits are not found north of Georgia indicates that land conditions continued in the north Atlantic region during Midway time. The subsidence, however, eventually affected the Chesapeake Bay region, where the sea again advanced across the Coastal Plain. The record of this inundation is found in the Pamunkey (Eocene) group of formations.

The Pamunkey group consists of greensand and greensand marl,[2] argillaceous in some layers and including several interbedded layers of limestone, the whole having a maximum thickness of more than 200 feet (61 meters). The group has been divided into the Aquia and Nanjemoy formations, and each of these formations into two members, but no unconformities have been recognized between the subdivisions of the group, and it may be treated as a unit. The beds are in general homogeneous and massive and indicate deposition in moderately deep water, and this suggests that the shore line of the Pamunkey sea was several miles farther inland than the present belt of outcrop of the group. The beds contain an abundance of invertebrate remains, including many well-preserved mollusks; vertebrates are represented by a few fish and reptilian bones and teeth. The invertebrates unquestionably ally the Pamunkey group with the Eocene. The exact time equivalence of the group with respect to the Eocene deposits of other parts of the United States and of other countries has not been definitely determined. However, the group may tentatively be regarded as including representatives of the Wilcox and Claiborne groups and possibly of the Jackson group of Alabama. It perhaps includes representatives

[2] The term "marl" in its generally accepted sense is applied to clay containing a rich admixture of carbonate of lime. It has, however, been loosely applied to many different substances, particularly to natural earthy deposits used for fertilizer, and these various usages are so generally distributed through the literature on the Coastal Plain that any attempt to restrict the term seems impracticable. The United States Geological Survey uses the term for any earthy, generally incoherent material that is appreciably calcareous or glauconitic, and qualifying adjectives are used to distinguish the different kinds of marl, such as shell marl, greensand marl, sandy marl, and clay marl.

of the European Eocene from the Sparnacian to the Ludian, inclusive. In the Potomac River Valley from Washington southward the deposits of the Pamunkey group transgress completely across the Upper Cretaceous formations and rest upon the deposits of the Potomac group (Lower Cretaceous).

After the deposition of the Pamunkey group there was another emergence of the Chesapeake Bay region, accompanied by a retreat of the Atlantic shore line, and the new land surface was subjected to the agencies of erosion. This period of land conditions was evidently of long duration in this region, for there are here no sediments laid down during the Oligocene epoch, which in the Gulf region is represented by the Vicksburg group, nor any sediments correlative with what, in the Gulf region and in tropical America, are generally classed as lower Miocene deposits (Aquitanian and Langhian of Europe). This period of erosion in the Chesapeake Bay region was therefore long enough to embrace all of Oligocene and lower Miocene time.

In middle Miocene time renewed downwarping again brought the sea in across the Coastal Plain in a great embayment which not only included the Chesapeake Bay region but extended southward into North Carolina. This sea in southern Virginia and adjacent parts of North Carolina spread westward across the older Eocene and Cretaceous deposits and lapped against the crystalline rocks along the eastern edge of the Piedmont Plateau. In it were deposited the sediments of the Chesapeake group, which has a maximum thickness of over 700 feet (213 meters). This group has been divided, in ascending order, into the Calvert, Choptank, St. Marys, and Yorktown formations. Starting with diatomaceous earth at the base, it includes a succession of sands, sandy clays, clays, and intervening shell beds. With rare exceptions these beds are unconsolidated, and the beds of shells and shell-bearing sands and clays have yielded rich collections of mollusks and other marine organisms.

Unconformities representing relatively minor periods of uplift and erosion have been recognized at the tops of the Calvert, Choptank, and St. Marys formations. In Virginia the St. Marys formation transgresses the Choptank and Calvert formations, and in southern Virginia the Yorktown formation transgresses westward over all older formations of the Coastal Plain and rests upon the crystalline rocks of the Piedmont Plateau.

On the basis of fossil plants and cetacean bones the Calvert formation has been correlated with the Tortonian (middle Miocene) of Europe. On the basis of the molluscan remains the Choptank and St. Marys formations have also been correlated, though somewhat less confidently, with the Tortonian. The molluscan faunas of the Yorktown show an advance over those of the St. Marys, new elements appearing and more primitive types becoming extinct, and on this basis the Yorktown formation is correlated with the upper Miocene.

The deposition of the Chesapeake group ended with regional uplift and erosion, and the apparent absence of the Yorktown formation in Maryland indicates that uplift began there earlier than it did farther south in Virginia. The geographic, stratigraphic, and structural relations of the formations of the Chesapeake group in Maryland, Virginia, and North Carolina are shown in Figures 2, 3, and 4 (31). The Duplin marl (see fig. 2) is an upper Miocene formation in North Carolina, which is correlated with the upper part of the Yorktown formation of Virginia.

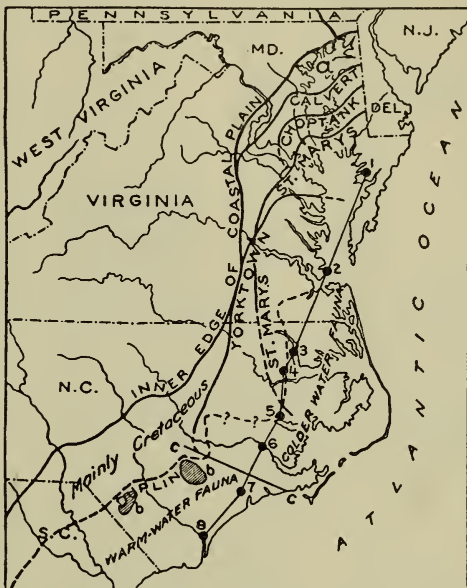


Figure 2.—Inner limits of the formations of the Chesapeake group and of the Duplin marl of North Carolina. *a*, Area occupied by Eocene and Cretaceous deposits in Virginia and Maryland; *b*, westernmost patches of Duplin marl in North Carolina; *c-c*, line separating late Miocene beds with "colder-water fauna" from those of the same age with "warmer-water fauna." Numbered line indicates location of section shown in Figure 4

In late Miocene or early Pliocene time the larger rivers built up extensive alluvial fans of clay, sand, and gravel, where they debouched from the Piedmont upon the plain left bare by the retreat of the sea. The shore line then probably lay somewhat inland from its present position, for among fossils dredged from the Dismal Swamp Canal, in Virginia and North Carolina, recorded by Woolman (10, p. 414), one species, *Arca limula*, if correctly identified, is believed to indicate the presence of marine Pliocene deposits at least this far inland. It was at this time that the high-level gravel deposits in the vicinity of Washington were laid down.

During Pliocene time there was differential upwarping which affected a broad area in the Chesapeake Bay region and as a result of which the now drowned valleys of Chesapeake and Delaware Bays and the Potomac, Rappahannock, York, and James Rivers and their tributaries were carved by the streams in the uplifted sediments.

The Pliocene epoch ended with warping or tilting of the Atlantic coast of the United States. The entire Coastal Plain of the New England States was deeply submerged (see fig. 1), and in the Chesapeake Bay region nearly all of the Coastal Plain was covered by shallow water, but in the States south of Virginia a wider strip of the Coastal Plain remained land. A result of this warping of the continent is the unequal distances to which tides now extend up the rivers. In the Hudson River the tides are felt as high up as Albany, about 150 miles (241 kilometers) inland from the edge of the Coastal Plain; in the Susquehanna they reach only 4 or 5 miles (6 to 8 kilometers); in the Potomac they reach Little Falls, about 3 miles (4.8 kilometers) inland; in the James the head of the tide lies very nearly at the fall line; in the Roanoke tidewater stops about 50 miles (80 kilometers) below the fall line; and in the Peedee it stops 75 miles (120 kilometers) or more below the fall line.

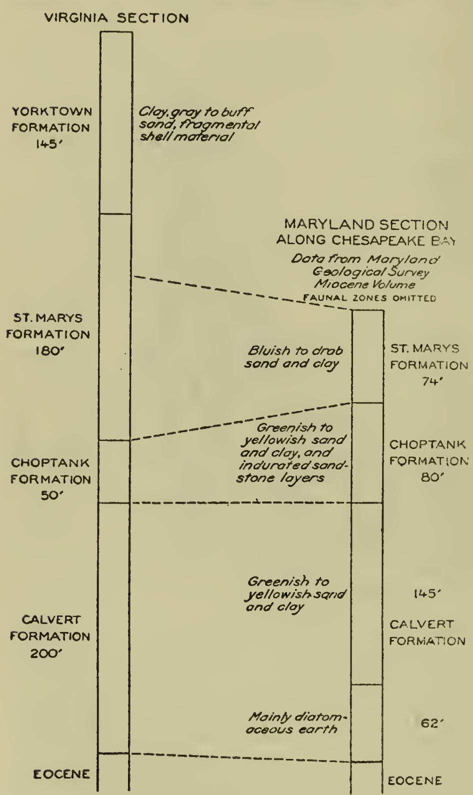


FIGURE 3.—Columnar sections of the Miocene of Maryland and Virginia

The Pleistocene appears to have been an epoch of stability of the continent in the Chesapeake Bay region but of instability of the ocean level (32, pp. 577–589). The sea rose and fell upon a presumably stationary land, varying in depth with the quantity of water imprisoned in the continental ice caps. The glacial epochs were therefore times of low sea level, and the interglacial epochs times of high sea level. The low-water marks left by the glacial seas are, presumably, all below present sea level, but a series of horizontal raised shore lines or beaches that bound the Pleistocene marine terraces are interpreted as marking the high levels of the interglacial seas.

As a result of the late Pliocene downwarping the sea covered a large part of the Coastal Plain in the Chesapeake Bay region at the beginning of Pleistocene time. It may have stood as high as 270 feet (82 meters) above its present level, although some geologists (36) believe that there are no marine Pleistocene deposits higher than 100 feet (30 meters) above sea level in this region. If the higher figure is correct, the seashore in early Pleistocene time stood not far from the outer edge of the Piedmont Plateau, the lower courses of all the rivers were deeply drowned, and tides extended far up the valleys into the Piedmont. At the onset of the first glacial epoch sea level was materially lowered. The streams reoccupied their Pliocene valleys and remained in them until the ice melted away and the rising sea flooded them and converted them into estuaries. This alternate draining and drowning was repeated during each recurring glacial and interglacial stage, but it is assumed that during each new interglacial stage the sea stood a little lower than during the preceding one, for the shore line and raised beaches form a descending series in which each is supposed to be younger than the next higher. Sea level today must stand considerably above its lowest stage at the climax of the glaciation.

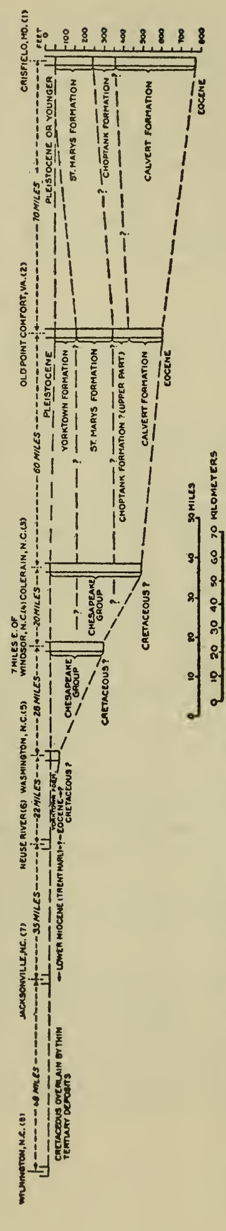


Figure 4.—Section from Crisfield, Maryland, to Wilmington, North Carolina, showing the thinning out of the Chesapeake group southward. (See fig. 2)

The Pleistocene terraces, named in order from the higher and older to the lower and younger, are the Brandywine, Coharie, Sunderland, Wicomico, Penholoway, Talbot, Pamlico, and Princess Anne. The altitude of the shore line that bounds each has been approximately determined. The Brandywine terrace is defined by the shore at 270 feet (82 meters) above sea level; the Coharie, about 215 feet (66 meters); the Sunderland, 170 feet (52 meters); the Wicomico, 100 feet (30 meters); the Penholoway, 70 feet (21 meters); the Talbot, 40 to 45 feet (12 to 14 meters); the Pamlico, 25 feet (8 meters); and the Princess Anne, 12 feet (3.6 meters).

ITINERARY

Washington to Glymont, Maryland
(21 miles, or 34 kilometers)

Washington Channel is the principal harbor of the Nation's Capital. (See pl. 1.) The channel is nearly 2 miles (3.2 kilometers) long and about 2,000 feet (610 meters) wide and is separated from the Potomac River by Potomac Park. Features of geologic, physiographic, geographic, and historic interest that lie within view from the boat along the route of the excursion are indicated below, and detailed descriptions are given of significant sections at certain localities.

During normal times the water in the Potomac estuary is fresh or nearly so from Washington southward for 25 to 30 miles (40 to 48 kilometers) owing to the great volume of fresh water brought into the head of the estuary by the river from the country above Washington. It is noteworthy that during the protracted drought of 1930, when the river was at its lowest recorded stage, crabs found their way up the estuary as far as Washington, and young barnacles attached themselves to objects along the beaches at least as far up the estuary as Freestone Point.

The Army War College is on the left bank near the mouth of Washington Channel, just north of the mouth of the Anacostia River, which joins the channel from the northeast. The southernmost point of Potomac Park on the right is known as Hains Point. The Naval Air Station and Bolling Field (an Army air field) are located on an artificially made plain less than 10 feet (3 meters) above sea level, due east of Hains Point across the common mouth of the channel and the Anacostia River.

Across the Potomac River to the west, opposite Hains Point, is a Pleistocene terrace plain known as the Penholoway plain, lying 50 to 60 feet (15 to 18 meters) above sea level, and on the sky line farther to the west may be seen the tree-covered eastern edge of the Pleistocene Sunderland terrace plain, which here lies 150 to 160 feet (46 to 49 meters) above sea level. The sky line of the same terrace plain may be seen to the east overlooking a narrow strip of the low Pleistocene terrace plain known as the Pamlico, which borders the east side of the river for several miles below Hains Point. From the boat as it proceeds southward from Hains Point, structures that may be seen rising prominently above the sky line are, from east to west, the dome of the Capital Building, the Washington Monument, the Lincoln Memorial, and the towers of the Arlington wireless station. The new Washington and Mount Vernon Boulevard follows the west shore closely.

The historic town of Alexandria occupies the west shore of the river about 4 miles (6.4 kilometers) south of Hains Point, and on a hill west of the town, rising prominently above all other structures in the vicinity, is the George Washington Masonic Memorial, which was dedicated in 1932 to the memory of the first President of the United States. Alexandria is built upon the Talbot terrace plain, which is a Pleistocene plain intermediate in age and altitude between the Penholoway plain and the Pamlico plain.

The Potomac River throughout its tidal portion from Washington to its junction with Chesapeake Bay, a distance by the river of about 110 miles, is not strictly a river but an estuary. If the theory of glacial control of sea level is true, the river has been an estuary during most of Pleistocene time. During the first interglacial stage the estuary was broader and the head of tide farther up the valley than now, and each successive interglacial stage brought it nearer to its present position and width. At the time the Brandywine plain was covered by the sea tidewater must have extended almost as far as Harpers Ferry, an air-line distance of 40 to 45 miles (64 to 72 kilometers) above Washington.

Examples of the terrace plains formed at different positions of sea level in the Potomac estuary during Pleistocene time will be within view of the boat at many places. The two low plains, the Pamlico and Talbot, form conspicuous shore and near-shore features throughout extensive stretches, and the

Sunderland plain constitutes the sky line almost continuously along both sides of the Potomac nearly to its mouth.

About 7 miles (11 kilometers) south of Alexandria, where the river has narrowed down to only half a mile, Fort Washington occupies a point on the east shore, and the abandoned site of old Fort Hunt lies a little to the west of the west shore. About 2½ miles (4 kilometers) below Fort Washington is Mount Vernon, home of George Washington and mecca of thousands of visitors from near and far. It stands on the west shore overlooking a long stretch of the river on a remnant of the Sunderland terrace plain at an altitude of a little more than 120 feet (36 meters).

If the bluff at Mount Vernon afforded a clean-cut exposure of the beds composing it, the section would show 90 to 100 feet (27 to 30 meters) of irregularly bedded arkosic sand and clay of Cretaceous age, overlain by 15 to 20 feet (4.5 to 6 meters) of a Pleistocene terrace deposit. Clay lenses near the base have yielded 28 species of fossil plants, on the basis of which the containing beds have been correlated with the Patapsco formation of the Potomac group.

At Fort Humphreys Military Reservation, 3 miles (4.8 kilometers) below Mount Vernon, a bluff similar to that at Mount Vernon, known as Whitestone Bluff, rises 120 feet (36 meters) above the beach. Good exposures of arkosic sandstone of Lower Cretaceous age occur in the lower part of the bluff. Eight species of fossil leaves interpreted to be of Patapsco age have been collected from a sandy clay layer 40 to 50 feet (12 to 15 meters) above the base, but this layer is no longer clearly exposed.

The bluff 0.3 mile (0.5 kilometer) east of Glymont Wharf (see pl. 2, *A*) exposes a section in the edge of the Wicomico terrace plain, nearly 80 feet (24 meters) high, which is overlooked within half a mile to the east by the Sunderland terrace plain, more than 120 feet (36 meters) high.

Inasmuch as a succession of Eocene exposures on the Potomac River will be visited it is appropriate to insert here a generalized section of the Eocene of Maryland, as it is subdivided into formations, members, and zones, and a diagram (fig. 5) showing in columnar form the stratigraphic relations of sections exposed at different localities along the river from Glymont to Popes Creek. Both are adapted from Clark and Martin (11, pls. 5, 6).

General section of Eocene strata in Maryland

[Adapted from Clark and Martin (11, p. 64, pl. 5)]

	Feet	Meters
Nanjemoy formation:		
Woodstock member—		
Greensand, with *Ostrea sellaeformis*, *Meretrix subimpressa*, *Venericardia potapacoensis*, etc. (zone 17)	80	24
Greensand, with few fossils, chiefly *Venericardia potapacoensis* (zone 16)	40	12
Potapaco member—		
Greenish-gray argillaceous sand with inconstant indurated layer at top and with many typical fossils (zone 15)	20	6.1
Greenish-gray argillaceous sand, with bands of gypsum crystals (zone 14)	8	2.4
Light-gray greensand, with *Venericardia potapacoensis* (zone 13)	8	2.4
Greenish-gray argillaceous sand (zone 12)	8	2.4
Indurated argillaceous greensand (zone 11)	2	.6
Argillaceous greensand with clay bed at base (zone 10)	25	7.6
Aquia formation:		
Paspotansa member—		
Interstratified indurated layers and greensands with many *Turritella mortoni* (zone 9)	17	5.2
Light greenish-gray greensand, with *Turritella mortoni*, *Cucullaea gigantea*, *Crassatellites alaeformis*, *Ostrea compressirostra*, etc. (zone 8)	30	9.1
Piscataway member—		
Greensand, with fragments of shells of lower beds (zone 7)	7	2.1
Greensand, with corals (zone 6)	1	.3
Indurated greensand, with *Pholadomya marylandica* and *Phenacomya petrosa* (zone 5)	2	.6
Greensand (zone 4)	8	2.4
Indurated greensand (zone 3)	3	.9
Dark greensand with many fossils, including *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga*, *Crassatellites alaeformis*, and *Ostrea compressirostra* (zone 2)	18	5.4
Greensand, in places argillaceous (zone 1)	30	9.1

The section at Glymont as adapted from Clark and Martin (11, p. 68) is as follows:

Section at Glymont, Maryland

	Feet	Meters
Pleistocene, Wicomico formation: Gravel and loam	20	6
Unconformity.		
Eocene, Piscataway member of the Aquia formation:		
Glauconitic sand, light green, underlain by argillaceous sand, with few fossils (zone 4)	10	3
Greensand, indurated (zone 3)	1	.3
Greenish marl with numerous fossils including *Ostrea compressirostra*, *Crassatellites alaeformis*, *Turritella mortoni*, *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga* (zone 2)	21	6.4
Argillaceous glauconitic sand for the most part without fossils, but containing indeterminate plant remains and molluscan casts at the base (zone 1)	8	2.4
Unconformity.		
Lower Cretaceous, Patapsco formation: Variegated clays	20	6
	80	24.1

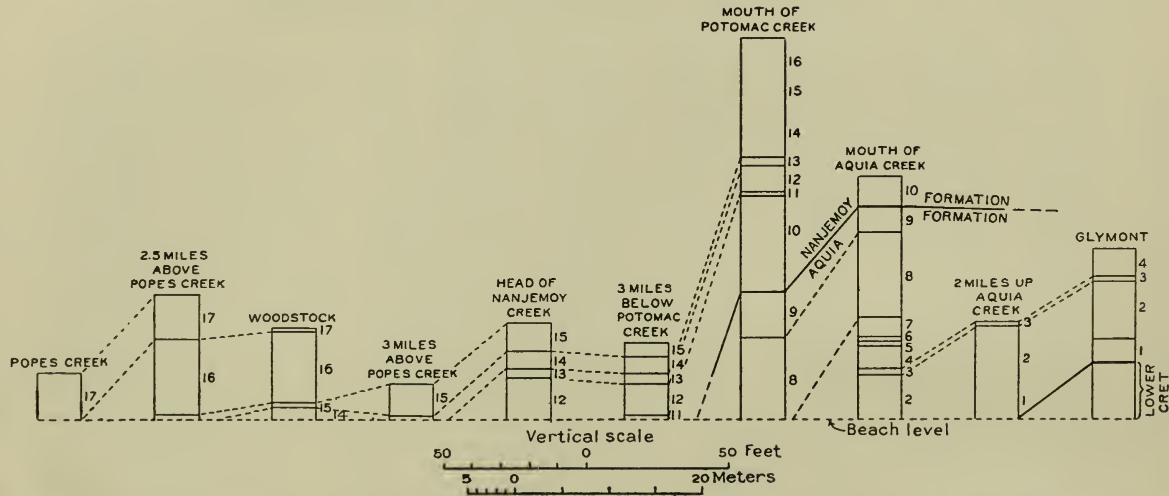


FIGURE 5.—Columnar sections of Eocene strata in the Potomac Valley. Zones are numbered in ascending order from 1 to 17. [Adapted from Clark and Martin (11, p. 68, pl. 6)]. (See generalized section, p. 17.)

The so-called variegated clays of the Cretaceous in this section are in reality mainly fine argillaceous sand, though some layers consist of sandy clay, and at the east end of the bluff a lens of purplish hackly clay rises 8 or 10 feet (2.4 to 3 meters) above the beach.

The Cretaceous-Eocene contact at Glymont is sharp, gently undulating and irregular in detail. The Eocene greensand within 2 or 3 inches (5 to 7.5 centimeters) of its base contains small subangular to smoothly rounded quartz pebbles, phosphatic nodules, and internal phosphatic molds of mollusks. Small borings filled with Eocene greensand extend from the contact down into the Cretaceous sand to maximum depths of 3 inches (7.5 centimeters). A near view of the Cretaceous-Eocene contact is shown in Plate 2, *A*.

Glymont, Maryland, to Freestone Point, Virginia
(6 miles, or 9.6 kilometers)

Good exposures of sand and clay belonging to the Potomac group of the Lower Cretaceous may be seen from the boat in bluffs at the Indian Head proving grounds (now abandoned), and opposite Indian Head, bordering the north shore, is a wide expanse of the Talbot terrace plain at altitudes of 30 to 38 feet (9 to 11 meters) above sea level. This tract forms the southern portion of the peninsula known as Mason Neck, which lies between Gunston Cove on the northeast and Occoquan Bay on the southwest.

At Freestone Point (19, p. 71), in a bluff about 100 feet (30 meters) high at the south side of the entrance to Occoquan Bay, about 3¼ miles (5.2 kilometers) west by south of Indian Head, 70 to 80 feet (21 to 24 meters) of gray arkosic sand and sandstone of the Patuxent formation of the Potomac group (Lower Cretaceous) is well exposed. The material is very coarse and pebbly, and great blocks of the more indurated parts have fallen to the beach as a result of the undermining action of the waves.

Freestone Point to Quantico, Virginia
(5.5 miles, or 8.8 kilometers)

The Patuxent formation of the Potomac group, chiefly arkosic sand and sandstone, with some interbedded clay, is exposed along the west shore and in railroad cuts near the shore, at several places between Freestone Point and a point about 2 miles (3.2 kilometers) north of Quantico. The country back of these exposures rises 100 to 200 feet (30 to 61 meters) above sea level and appears to be a dissected portion of the Coharie terrace plain. Exposures of the Patapsco formation of the Potomac group appear in low bluffs on each side of the mouth of Quantico Creek. (See fig. 6.)

Along the east shore of the same stretch of the river the Patapsco formation is exposed here and there in low bluffs cut mainly in the edge of the Talbot terrace plain. In the hills east of these bluffs the Patapsco is unconformably overlain by the Aquia formation of the Eocene.

Quantico adjoins a United States Marine Corps reservation. The main part of the town is built upon a portion of the Talbot terrace plain, which is 1½ miles (2.4 kilometers) long and half a mile (0.8 kilometer) wide and lies 30 to 40 feet (9 to 12 meters) above sea level.

A low bluff at Shipping Point, at the mouth of Quantico Creek, 0.6 mile (0.96 kilometer) north of the wharf at Quantico, reveals the section shown in Figure 6.

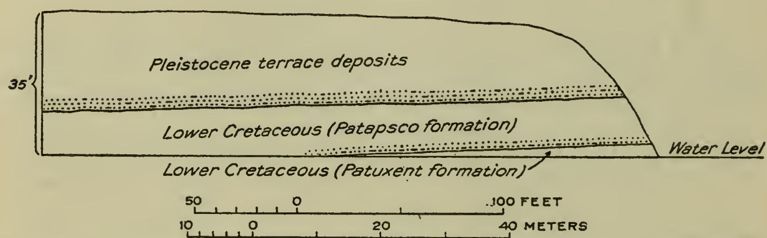


FIGURE 6.—Section at Shipping Point, near Quantico, Virginia. Shows the following beds:

Pleistocene, Talbot formation: Loam and sand with a gravel bed 2 to 5 feet (0.6 to 1.5 meters) thick along base; much softer than underlying beds.

Unconformity.

Lower Cretaceous, Patapsco formation: Sandstone, medium to fine, light gray, irregularly bedded, more or less argillaceous, rather soft, with an irregular conglomerate 2 to 10 inches (5 to 25 centimeters) thick along base; the pebbles are chiefly quartz.

Unconformity, undulating.

Lower Cretaceous, Patuxent formation: Sandstone, gray, coarse, arkosic, cross-bedded, with scattered smooth to subangular pebbles.

QUANTICO TO BLUFFS NEAR AQUIA CREEK, VIRGINIA (10 miles, or 16 kilometers)

Brown Flying Field lies on a southward continuation of the Talbot terrace plain, 1½ to 3 miles (2.4 to 4.8 kilometers) south of Quantico.

Several good exposures of the Patapsco formation (Lower Cretaceous) occur along the west shore 3 to 4 miles (4.8 to 6.4 kilometers) south of Quantico, less than a mile north of Wide-

A. CRETACEOUS-EOCENE CONTACT IN BLUFF ON POTOMAC RIVER NEAR GLYMONT WHARF, MARYLAND

Photograph by L. W. Stephenson.

B. BLUFF ON POTOMAC RIVER 0.6 MILE (0.96 KILOMETER) SOUTH OF POPES CREEK STATION, MARYLAND

Showing the Nanjemoy (Eocene) formation overlain by the Calvert (Miocene) formation, overlain by Pleistocene terrace deposits. Photograph by L. W. Stephenson.

A. BASE OF BLUFF ABOUT A MILE (1.6 KILOMETERS) SOUTHEAST OF THE MOUTH OF AQUIA CREEK, VIRGINIA

Showing zones 2 to 4 of the Aquia formation. Photograph by Maryland Geological Survey.

B. LIMESTONE LARGELY COMPOSED OF TURRITELLA MORTONI, FROM THE AQUIA FORMATION ABOUT A MILE SOUTHEAST OF THE MOUTH OF AQUIA CREEK, VIRGINIA

Photograph by Maryland Geological Survey.

water station. The formation consists of strongly cross-bedded arkosic sand, irregularly interbedded with lenses and layers of hackly clay. At one place a quarter of a mile (0.4 kilometer) below the mouth of Tank Creek a lens of sandy clay contains many large chunks and smaller fragments of lignitized wood. Several species of Lower Cretaceous plants have been identified from this locality. The hills back of these exposures probably represent a dissected portion of the Coharie terrace plain.

A peninsula about 3 miles (4.8 kilometers) long, west of the river and north of Aquia Creek, affords a good example of a low Pleistocene terrace, probably the Talbot.

Low bluffs along the Maryland side of the river afford exposures of the Aquia formation of the Eocene, overlain by Pleistocene terrace deposits. On the same side, 3½ miles (5.6 kilometers) south of Quantico, a reminder of the World War is afforded by a tangle of steel and concrete skeletons of a multitude of ships which, hastily built for wartime purposes and useless as merchant ships in times of peace, were assembled in Mallows Bay and burned. Only the incombustible material remains as a grim reminder of the cost and waste of war.

The Eocene Aquia formation receives its name from Aquia Creek. Almost all of the Aquia formation and the basal bed of the overlying Nanjemoy formation are exposed at a bluff about a mile southeast of the mouth of this creek. A notable feature here is the abundance of large slabs of *Turritella*-bearing marlstone which have fallen from the highest bed of the Aquia formation (zone 9). (See pl. 3.) The section is as follows:

Section on the Potomac River a mile southeast of the mouth of Aquia Creek, Virginia

[Adapted from Clark and Martin (11, p. 69)]

	Feet	Meters
Miocene (?), Calvert formation (?): Fine light-yellow sand with white clay near the base	26	8
Unconformity.		
Eocene:		
Nanjemoy formation—Fine light-green sand containing a few glauconitic grains (zone 10)	10	3
Aquia formation—		
Paspotansa member—		
Limestone, thick-bedded, arenaceous, and glauconitic, interstratified with unconsolidated layers of partly weathered greensand, the indurated layers largely filled with the shells of *Turritella mortoni* (zone 9)	10	3
Fine gray or green sand containing several irregular bands of *Turritella mortoni*, also *T. humerosa*, *Cucullaea gigantea*, *Crassatellites alaeformis*, and *Ostrea compressirostra* (zone 8)	30	9.1

	Feet	Meters
Eocene—Continued.		
Aquia formation—Continued.		
Piscataway member—		
Dark greensand, chiefly filled with broken shells of *Meretrix ovata* var. *pyga* and *Crassatellites alaeformis* (zone 7)	7	2.1
Dark greensand containing whole shells (zone 6)	1	.3
Indurated layer of light-colored greensand filled with *Turritella mortoni*, *T. humerosa*, *Crassatellites alaeformis*, *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga*, *Panopea elongata*, and *Pholadomya marylandica* (zone 5)	2	.6
Greensand marl containing the same species as zones 2 and 3 (zone 4)	8	2.4
Indurated layer of dark greensand with *Crassatellites alaeformis*, *Meretrix ovata* var. *pyga*, *Dosiniopsis lenticularis*, and *Ostrea compressirostra* (zone 3)	2	.6
Greensand marl with *Dosiniopsis lenticularis*, *Meretrix ovata* var. *pyga* and *Crassatellites alaeformis* (zone 2)	16	4.9
	112	34

Bluffs near Potomac Creek, Virginia

The next stop will be made on the Virginia shore about 3 miles (4.8 kilometers) below Aquia Creek at a bluff near the mouth of Potomac Creek, an estuarine tributary of the Potomac River. Here are exposed the upper part of the Eocene Aquia formation (including a bed of *Turritella mortoni*), the Potapaco member of the Eocene Nanjemoy formation, and part of the Miocene Calvert formation. A hiatus separates the Nanjemoy from the Miocene, for the Woodstock member of the Nanjemoy formation is missing, and the Calvert formation does not represent the lowermost known Miocene. The section is as follows:

Section in center of bluff at Potomac Creek, Virginia

[Adapted from Clark and Martin (11, p. 69)]

	Feet	Meters
Miocene, Calvert formation:		
Fine yellowish sand containing red and brown bands	15	4.6
White gritty clay with Miocene fossils at the base including *Chione* and *Phacoides*	5	1.5
Unconformity.		
Eocene:		
Nanjemoy formation, Potapaco member—		
Sand, greenish gray, argillaceous, slightly glauconitic (zone 15)	38	11.6
Argillaceous sand containing bands of selenite crystals (zone 14)	4	1.2
Sand, light gray, glauconitic, with *Venericardia potapacoensis* (zone 13)	3	.9
Sand, greenish gray, argillaceous (zone 12)	8	2.4

	Feet	Meters
Eocene—Continued.		
Nanjemoy formation, Potapaco member—Continued.		
Indurated greensand with *Venericardia potapacoensis* (zone 11)	1	0.3
Sand, greenish gray, glauconitic, with casts of *Meretrix* (zone 10)	25	7.6
Aquia formation, Paspotansa member—		
Limestone, thick-bedded, arenaceous and glauconitic, interstratified with layers of partly weathered greensand, the indurated strata composed largely of the shells of *Turritella mortoni* (zone 9)	12	3.7
Greensand bed, much weathered in its upper part and filled chiefly with *Turritella mortoni* in several thick layers; also *T. humerosa*, *Cucullaea gigantea*, *Crassatellites alaeformis*, *Ostrea compressirostra*, and many other species (zone 8)	25	7.6
	136	41.4

Potomac Creek to Popes Creek, Maryland
(17 miles, or 27 kilometers)

The general course of the Potomac River from Washington to the mouth of Potomac Creek is south by west. The river makes a sharp bend to the left at Potomac Creek and continues in a nearly straight east-northeast direction throughout the Nanjemoy Reach, a long stretch sometimes referred to by rivermen as the "10-mile stretch." The inner shore of this great elbow, on the Maryland side, is bordered by an unusually fine example of the Talbot terrace plain 1 to 2 miles (1.6 to 3.2 kilometers) wide and 20 to 30 feet (6 to 9 meters) above sea level. This plain extends as far as Nanjemoy Creek, beyond which the surface of Cedar Point Neck affords a broad and equally fine example of the Pamlico terrace plain, 10 to 20 feet (3 to 6 meters) above sea level.

The lower terraces are rather poorly developed in a narrow belt along the south shore of the Nanjemoy Reach, in Virginia, and back of them a steep scarp rises to the dissected crest of the Sunderland terrace plain at altitudes of 120 to 150 feet (36 to 46 meters) or more. Exposures of the Aquia and Nanjemoy formations of the Eocene occur in places in the wave-cut edges of the low terraces.

The water in the Nanjemoy Reach is normally brackish, and this stretch of the river is about the upstream limit of the range of the edible oyster, *Ostrea virginica* Gmelin.

The river makes a sharp bend to the right at the end of the Nanjemoy Reach and continues in a south-southeast course to and beyond Colonial Beach.

A fine series of bluffs on the Maryland side of the river, extending from a point 1½ miles (2.4 kilometers) north of Popes Creek south by east for about 3½ miles (5.6 kilometers), affords excellent exposures of the upper part of the Nanjemoy formation (Eocene), overlain by the diatomaceous earth forming the lower part of the Calvert formation (Miocene). (See pl. 2, *B*.)

The first bluff below the wharf at Popes Creek station shows the Woodstock member of the Eocene Nanjemoy formation and the diatomaceous earth of the Miocene Calvert formation. The section is as follows:

Section in bluff 0.6 mile below Popes Creek station, Maryland

[Adapted from Clark and Martin (11, p. 71)]

	Feet	Meters
Pleistocene: Gravel, sand, and loam	25?	7.6
Unconformity.		
Miocene, Calvert formation (Fairhaven member): Diatomaceous earth	40+?	12.2
Unconformity.		
Eocene, Nanjemoy formation (Woodstock member):		
Brown glauconitic clay, much oxidized in places	2	.6
Pinkish-brown clay nodules in glauconitic clay	½	.1
Dark glauconitic clay with many fossil casts	4	1.2
Calcareous concretions with occasional fossils	½	.1
Argillaceous greensand with many casts and occasional shells	3	.9
Concretions with large shells of *Hercoglossa tuomeyi*	½	.1
Argillaceous greensand with abundant fossils, including *Meretrix subimpressa*, *Venericardia potapacoensis*, *Hercoglossa tuomeyi*, *Turritella potomacensis*, *Mesalia obruta*, *Protocardia lenis*, *Modiolus alabamensis*, *Corbula subengonata*, *Mitra potomacensis*, and many other forms (zone 17)	6	1.8
	81½?	24.6

In this section the lower 12 feet (3.6 meters) of the Calvert formation consists mainly of sandy diatomaceous earth, and in the basal 2 or 3 inches (5 to 7.5 centimeters) the sand is coarse and contains scattered quartz pebbles reaching a maximum diameter of 1 inch. The Eocene-Miocene contact is irregular in minor detail, and borings half an inch to 1½ inches (1 to 3 centimeters) in diameter, made by some undetermined animal organism and filled with Miocene sand, extend down into the Eocene to maximum depths of 15 inches (37.5 centimeters).

Popes Creek, Maryland, to Colonial Beach, Virginia (10.5 miles, or 16.8 kilometers)

The bluffs at Popes Creek continue southward along the east shore, becoming lower, however, by reason of the fact that the high Sunderland terrace at Popes Creek is succeeded to the south by lower terraces that form a broad, steplike descent to the Pamlico terrace level in the vicinity of Morgantown. Good exposures occur in these bluffs for about 2 miles (3.2 kilometers) south of Popes Creek and show that the Eocene-Miocene contact descends very gradually toward the river level. It is estimated that the contact should reach the river somewhere near Morgantown.

South of Morgantown may be had a distant view of the Pamlico and Talbot terrace plains, which together form an extensive lowland east of the river, embracing about the southern half of Cobb Neck, a broad peninsula intervening between the Potomac River and the Wicomico River.

Colonial Beach is built upon a low plain that is correlated with the Pamlico terrace plain, but the Talbot, the next higher terrace plain, is well developed within a few miles to the north and west. A few feet of the Calvert formation (Miocene) overlain by Pleistocene terrace deposits, is exposed in low wave-cut cliffs between Colonial Beach and Wilkerson Wharf (Potomac Beach).

Colonial Beach to Nomini Cliffs, Virginia
(10 miles, or 16 kilometers)

On leaving Colonial Beach the traveler gets a distant view of the long east-west series of bluffs known as Horsehead, Stratford, and Nomini Cliffs. Between Colonial Beach and the Horsehead Cliffs about the only features of geologic interest that can be readily seen from the boat are a series of low, sharply outlined wave-cut bluffs, which mark the edge of the Talbot terrace plain (Pleistocene) along the south shore. These bluffs expose the Calvert formation (Miocene) along their base, overlain by Pleistocene terrace deposits.

About 5 miles (8 kilometers) southeast of Colonial Beach a tall white shaft that marks the recently restored birthplace of George Washington may be seen in the distance at Wakefield, up the valley of Popes Creek, Virginia.

The Horsehead, Stratford, and Nomini Cliffs form a series of northward-facing bluffs about 6 miles (9.6 kilometers) long, extending from a point a mile east of the mouth of Popes Creek eastward nearly to Currioman Bay. The continuity of the cliffs is broken by the valleys of five or six small creeks that enter the Potomac from the south. The bluffs between these valleys rise to heights of 140 feet (42.6 meters) or more above the beach level and are in general so steep as to be scalable only with difficulty, if at all. (See pl. 4, *A*.) About 1½ miles (2.3 kilometers) south of the Stratford Cliffs is Stratford, the birthplace of the distinguished Confederate general of the Civil War, Robert Edward Lee.

These cliffs afford exposures of the upper part of the Calvert, all of the Choptank, and the lower part of the St. Marys formation of the Chesapeake group of the Miocene. In general these formations are less fossiliferous here than in the Calvert Cliffs on Chesapeake Bay, in Calvert County, Maryland. (See fig. 10.) At one place in the lower part of the Nomini Cliffs, however, fossils are abundant in the Choptank formation.

The stratigraphic and structural relationships of the formations exposed in the cliffs are shown in Figure 7. The normal dip of the Miocene beds in this area is to the east or southeast at the rate of 8 or 10 feet to the mile (3.9 to 4.8 meters to the kilometer), but near the center of the Nomini Cliffs there is a distinct downwarp of the beds, causing a steepening of the dip east of the Stratford Cliffs and a slight reversal of dip at the east end of the Nomini Cliffs. The section to be visited is at the lowest part of this syncline.

The Calvert formation in these sections consists mainly of a rather compact greenish-gray diatomaceous sandy clay. It carries a few poorly preserved invertebrate fossils (*Ecphora tricostata* Martin, *Pedalion maxillatum* (Deshayes), *Pecten madisonius* Say, *Isocardia* sp.) and vertebrate remains. The upper limit of the formation is drawn along a line that is about 5 feet (1.5 meters) above a thin bed carrying many *Isocardia*. This *Isocardia* bed may represent the *Isocardia* bed referred to zone 14 of the Calvert formation in the Miocene of Maryland. (See fig. 10.) Future study may necessitate a slight raising or lowering of this line of contact as drawn between the Calvert and Choptank formations. The upper surface of the Calvert as now defined is only slightly inclined to the east in the Horsehead and Stratford Cliffs; east of the Stratford Cliffs it dips more steeply and is 10 to 15 feet (3 to 4.5 meters) below beach level in the syncline in the Nomini Cliffs, but at the east end of these cliffs it rises again to an altitude 8 or 9 feet (2.4 to 2.7 meters) above the beach.

The lowest bed of the Choptank formation, which overlies the Calvert formation, is believed to represent zones 16 to 18 of the Miocene of Maryland. This bed consists of greenish-gray clayey sand and at the section to be visited, about 1½ miles (2.4 kilometers) west of the east end of the Nomini Cliffs, it is fossiliferous in two layers, one within 3 feet (0.9 meter) above the beach and the other about 10 to 12 feet (3 to 3.6 meters) higher. Fossils contained in the lower layer include *Crassatel-*

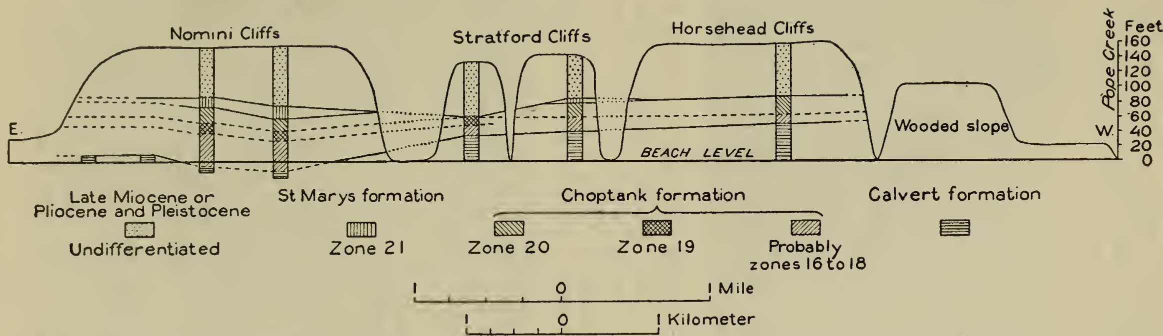


FIGURE 7.—Columnar sections showing Miocene formations overlain by younger surficial deposits in the northward-facing Horsehead, Stratford, and Nomini Cliffs, Potomac River, Westmoreland County, Virginia

lites turgidulus (Conrad), *Phacoides crenulatus* (Conrad), *Diplodonta subvexa* (Conrad)?, a large variety of *Isocardia fraterna* (Say), *Cardium* sp., and *Venus plena* (Conrad)? In Maryland *Crassatellites turgidulus* occurs only in zone 17 of the Choptank formation.

Zone 19, forming the middle part of the Choptank formation consists of dark-brown soft fossiliferous sand with a sandstone layer about 2 feet (0.6 meter) thick at the top containing many individuals of *Pecten madisonius*. The following species have been collected from this sand: *Arca staminea* Say, *Pecten madisonius* Say, *Pecten marylandicus* Wagner, *Astarte obruta* Conrad, *Crassatellites marylandicus* (Conrad), *Thracia* sp., *Dosinia* sp., and *Corbula idonea* Conrad. In the Choptank formation of Maryland *Crassatellites marylandicus* has been found only in zone 19.

The upper part of the Choptank formation consists of sandy clay. It carries a few vertebrate fossils but no invertebrates. It is believed to correspond to zone 20 of the Choptank formation of Maryland.

Zone 21, which represents the lower part of the St. Marys formation, consists of very plastic clay. Molds of mollusks were found in this clay in the Nomini Cliffs. In the section at the west end of the Stratford Cliffs this clay is only a few feet thick and carries *Turritella plebeia* Say, *Turritella variabilis* Conrad, *Glycymeris subovata* (Say) var., *Arca* sp. (young individual), *Ostrea disparilis* Conrad, *Astarte* aff. *A. obruta* Conrad, *Euloxa latisulcata* (Conrad), *Chione* cf. *C. athleta* Conrad, *Spisula confraga* (Conrad), and *Corbula* sp.

Nomini Cliffs, Virginia, to Wailes Bluff, Maryland (27 miles, or 43 kilometers)

From the Nomini Cliffs to Wailes Bluff, Maryland, the river ranges in width from 4 to 8 miles (6.4 to 12.8 kilometers), the bordering land is low on both sides, and the shores are extensively indented with tributary estuaries. No high lands come close to the shore, and the only geologic sections are those afforded by low cliffs cut by the waves in the edges of the Pamlico and Talbot terrace plains. Most of these sections expose only Pleistocene terrace deposits.

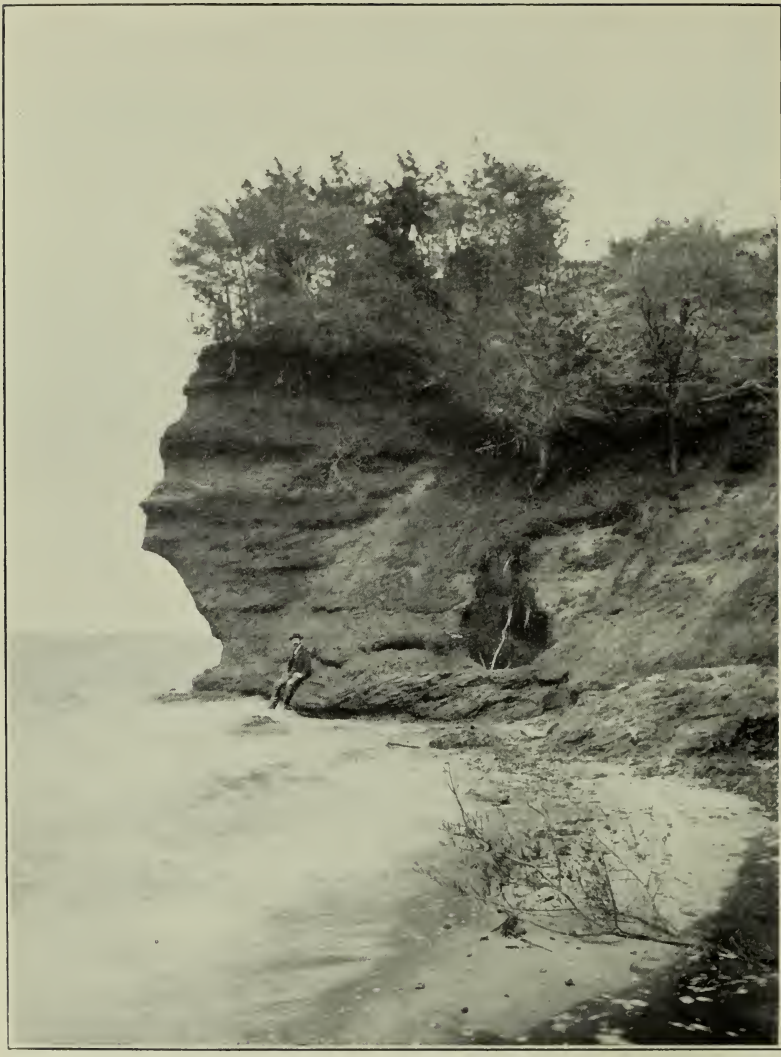
Wailes Bluff (29, pp. 129–132; pl. 4, *B*) is on the north shore of the Potomac River, 3 miles (4.8 kilometers) northwest of Point Lookout, which is at the mouth of the river. The bluff is about half a mile long and rises 15 feet (4.5 meters) above the

A. STRATFORD CLIFFS, 9 MILES (14.4 KILOMETERS) SOUTHEAST OF COLONIAL BEACH, VIRGINIA

Showing the Calvert and Choptank formations of the Miocene overlain by undifferentiated loose sand and gravel of late Miocene or Pliocene and Pleistocene age. Photograph by L. W. Stephenson.

B. WAILES BLUFF, POTOMAC RIVER, 3 MILES (4.8 KILOMETERS) NORTHWEST OF POINT LOOKOUT, MARYLAND

Showing sand and clay and an interbedded layer of oyster shells of the Pamlico formation of the Pleistocene. Photograph by W. C. Mansfield.



PROMINENT PROJECTING BLUFF ON YORK RIVER 0.6 MILE (0.9 KILOMETER) SOUTHEAST OF YORKTOWN, VIRGINIA

Showing fragmental beds *e* and *f* of the Yorktown formation (Miocene), overlain by Pleistocene terrace deposits. The man in the picture is the late Prof. William Bullock Clark, of Johns Hopkins University. Photograph by N. H. Darton.

beach; it affords a clean-cut section of sand and clay, which is referred to the Pamlico formation of the Pleistocene. The locality is notable for the large number of fossil mollusks, in an excellent state of preservation, belonging to the species *Ostrea virginica* Gmelin, *Venus mercenaria* Linnaeus, *Rangia cuneata* (Gray), and *Mulinia lateralis* (Say). The section is described below, and a photograph of the bluff is reproduced in Plate 4, *B*.

Section at Wailes Bluff, St. Marys County, Marlyand

	Feet	Meters
Buff sand and gravel, unfossiliferous	6–8	1.8–2.4
Mainly coarse to fine grained angular quartz sand packed with *Ostrea virginica*	1–3	.3–.9
Unconformity, probably of slight time significance.		
Bluish clay, containing *Rangia cuneata* and many *Venus mercenaria*	0–1	0–.3
Mainly greenish compact clay mixed with a small amount of quartz sand and a few quartz boulders; contains vast numbers of *Mulinia lateralis* in filled pockets or borings made by some undetermined animal organism	1–5	1.2–1.5

The two lower beds of this section have yielded 31 species of mollusks and 3 species of crustaceans; and bed 3 has yielded 12 species of mollusks.

Wailes Bluff, Maryland, to Yorktown, Virginia (70 miles, or 113 kilometers)

On its way from Wailes Bluff, Maryland, to Yorktown, Virginia, the boat, after passing Point Lookout, will traverse the lower reaches of Chesapeake Bay, which here ranges in width from 13 to 24 miles (21 to 39 kilometers). The course lies nearer to the west shore, which is indented by many large and small tributary estuaries, notable among which are the Great Wicomico River, the Rappahannock River, the Piankatank River, and Mobjack Bay. These estuaries are bordered by an extensive plain, which viewed as a whole is 50 miles (80 kilometers) long from north to south and 2 to 15 miles (3.2 to 24 kilometers) wide from east to west and ranges in altitude from sea level to 24 feet (7.3 meters). This is a magnificent development of the lower terrace plains and affords an unexcelled example of low marine terraces intricately dissected by innumerable drowned valleys, which mark the drainageways of an earlier time, when the plains stood higher above sea level.

On the distant sky line to the west may be seen the eastern dissected edges of the Sunderland and Wicomico terrace plains, overlooking the great expanse of the two lower plains. Far to the east across the bay, the low-lying peninsula known as the Eastern Shore of Virginia is barely discernible; it is made up largely of the lower terrace plains.

Yorktown (19, pp. 19, 20, 158–175, pl. 8) overlooks the narrow entrance (half a mile (0.8 kilometer) wide) of the York River, a spacious but largely undeveloped natural harbor. Here the last important battle of the Revolutionary War was fought, in 1781, and here Cornwallis surrendered to Washington. In commemoration of this event a tall monument of Maine granite has been erected at a commanding point on the edge of the Wicomico terrace plain, on which the main part of the town is built. The place of the surrender is approximately marked by a small monument near a national cemetery, half a mile south of the large granite shaft. It was here also that in 1862, during the Civil War, Gen. George B. McClellan, in command of the northern forces, laid siege to the southern forces under Gen. Joseph E. Johnston and eventually forced them to fall back to Williamsburg, another historic town about 10 miles (16 kilometers) northwest of Yorktown. The old customhouse, built in 1715, and the house of Thomas Nelson, a signer of the Declaration of Independence, are still standing on the main street of Yorktown.

The type section of the Yorktown formation, the uppermost of the four formations composing the Chesapeake group of the Miocene, is exposed in a series of bluffs along the south shore of the York River within 2 miles (3.2 kilometers) southeast of the ferry landing. (See pl. 5.) The Yorktown formation has been divided into two faunal zones, zone 1 below and zone 2 above. Only the beds of zone 2 are exposed in these bluffs. (See fig. 8.) A notable structural feature of these beds is their northwestward dip in an area where the normal regional dip is to the east or southeast. The deformation indicated by this reversal of dip must have taken place in post-Miocene time but before the formation of the Pleistocene terraces. It is probably to be correlated with the uplift that resulted in the cutting of the valley now occupied by Chesapeake Bay and its tributaries.

The following is a list of the more common and more significant species of fossil organisms found in the beds of the Yorktown formation shown in Figure 8.

Bed *f*:
- Caecum stevensoni Meyer.
- Glycymeris americana (Defrance).
- Ostrea disparilis Conrad.
- Pecten jeffersonius edgecombensis Conrad.
- Plicatula marginata Say.
- Crassatellites undulatus (Say).
- Venericardia granulata Say.
- Astarte concentrica Conrad.
- Venus tridacnoides Lamarck.

Bed *e*:
- Glycymeris subovata (Say).
- Pecten jeffersonius edgecombensis Conrad.
- Astarte coheni Conrad.
- Crassatellites undulatus (Say).
- Crassinella galvestonensis Harris.
- Venericardia granulata Say.
- Cardium acutilaqueatum Conrad.
- Semele subovata (Say).
- Mulinia congesta (Conrad).
- Panope reflexa (Say).

Bed *c*:
- "Drillia" pyrenoides Conrad.
- Turritella alticostata Conrad.
- Crepidula aculeata costata Morton.
- Crepidula plana Say.
- Fissuridea redimicula (Say).
- Arca (Striarca) centenaria Say.
- Arca (Noëtia) incile Say.
- Ostrea sculpturata Conrad.
- Pecten jeffersonius edgecombensis Conrad.
- Crassatellites undulatus (Say).
- Crassinella galvestonensis Harris.
- Venericardia granulata Say.
- Venus plena (Conrad).
- Asaphis centenaria (Conrad).

Beds *a* and *b*:
- "Drillia" lunata (H. C. Lea).
- Oliva sayana Ravenel.
- Lirosoma sulcosa (Conrad).
- Fusinus exilis (Conrad).
- Ptychosalpinx altilis (Conrad).
- Ptychosalpinx laqueata (Conrad).
- Scalaspira strumosa Conrad.
- Turritella alticostata Conrad (abundant).
- Crepidula aculeata var. costata Morton.
- Calliostoma philanthropus (Conrad).
- Calliostoma virginicum (Conrad).
- Fissuridea redimicula (Say).
- Yoldia laevis (Say).
- Arca (Noëtia) incile Say.
- Ostrea sculpturata Conrad.
- Pecten jeffersonius edgecombensis Conrad.
- Pecten virginianus Conrad.
- Pecten decemnarius Conrad.
- Phacoides (Lucinoma) contractus (Say).
- Cardium virginianum Conrad.
- Dosinia acetabulum Conrad.
- Callocardia sayana (Conrad).
- Teredo calamus H. C. Lea.

Yorktown to old Kings Mill Wharf, Virginia (10 miles, or 16 kilometers)

A side trip will be made overland from Yorktown to the old Kings Mill Wharf, on the James River, near which occur exposures of the Yorktown formation. Leaving Yorktown the

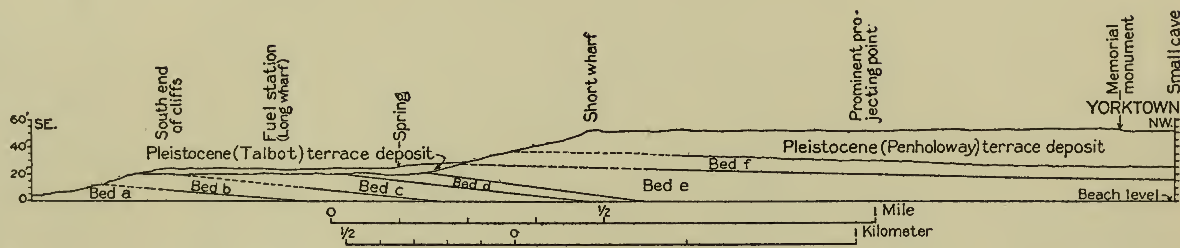


FIGURE 8.—Diagrammatic representation of the beds of zone 2 of the Yorktown formation, exposed in a series of bluffs along the south shore of the York River within 2 miles southeast of Yorktown, Virginia. The Miocene beds differentiated in these bluffs are characterized as follows:

Fragmental beds:

(*f*) Similar to bed *e*, but the cross-bedding is less steep, and broken shells are less numerous.
(*e*) Cross-bedded clay and sand with fragmental and entire shells.

Sandy beds:

(*d*) Loose sand with a few *Spisula* and *Tellina*.
(*c*) Gray coarse-grained sand, very fossiliferous, with many *Crepidula*, *Striarca*, and *Pecten*.
(*b*) Gray sand, unfossiliferous in the lower part, containing a few *Crepidula* in the upper part.
(*a*) Gray to buff sand containing many *Turritella* in the lower part and a few *Crepidula* in the upper part.

road follows the shore of the York River for a short distance and then gradually rises within a mile to the Wicomico terrace plain, at an altitude of about 74 feet (23 meters). It follows this somewhat dissected plain at altitudes of 70 to 90 feet (21 to 27 meters) nearly to the railroad near Blows Mill Run, where it descends to the Penholoway, the next lower terrace plain, a dissected portion of which it follows for the next 2 or 3 miles (3.2 to 4.8 kilometers). Before reaching Grove it again ascends to the Wicomico plain, which it follows to the crest of the bluff at the abandoned site of Camp Wallace, a World War training camp, which is about 1¼ miles (2 kilometers) east of the old Kings Mill Wharf (19, pp. 305–310).

A line of bluffs on the north shore of the James River 3½ to 7 miles (5.6 to 11.2 kilometers) southeast of Williamsburg exposes the upper part of zone 1 and the lower part of zone 2, of the Yorktown formation. The best section, in a bluff about half a mile (0.8 kilometer) east of the old Kings Mill Wharf (1¾ miles (2.8 kilometers) northwest of old Grove Wharf), is represented in Figure 9. A list of the more common fossils found here and of the less common ones that are useful in zonal differentiation is given below:

Zone 2 (layers *w* to *z*):
- Mollusks—
  - Turritella alticostata Conrad (rare).
  - Calliostoma philanthropus (Conrad) (rare).
  - Fissuridea redimicula (Say) (rare).
  - Arca (Noëtia) incile Say.
  - Arca (Striarca) centenaria Say.
  - Ostrea sculpturata Conrad (rare).
  - Pecten decemnarius Conrad (rare).
  - Pecten virginianus Conrad (rare).
  - Pecten jeffersonius edgecombensis Conrad.
  - Astarte coheni Conrad (rare).
  - Astarte undulata Say.
  - Astarte symmetrica arata Conrad (rare).
  - Crassatellites undulatus (Say).
  - Chama congregata Conrad.
  - Cardita arata (Conrad) (rare).
  - Venericardia granulata Say.
  - Mulinia congesta (Conrad) (occurs near the top of zone 2).
- Corals—
  - Astrangia lineata (Conrad).
  - Septastrea marylandica (Conrad) (occurs in the lower part of zone 2).

Zone 1 (layer *v*):
- Mollusks—
  - Conus marylandicus Green (rare).
  - Scaphella (Aurinia) mutabilis (Conrad) (rare).
  - Fusinus propeparilis Mansfield (rare).
  - Turritella pilsbryi Gardner.

Zone 1 (layer *v*)—Continued.
 Mollusks—Continued.
  Crucibulum grande (Say) (rare).
  Glycymeris subovata plagia Dall.
  Ostrea disparilis Conrad (rare?).
  Pecten jeffersonius Say.
  Pecten clintonius Say (occurs in the lower part of the bed).
  Modiolus pulchellus Olsson.
  Astarte undulata vaginulata Dall.
  Astarte exaltata Conrad (common).
  Crassatellites undulatus cyclopterus Dall.
  Venericardia granulata Say.
  Phacoides anodonta (Say).
  Cardium virginianum Conrad (rare).
  Isocardia carolina Dall (rare).
  Chione cortinaria (Rogers) (rare).
  Teredo calamus H. C. Lea.
 Coral—
  Septastrea marylandica (Conrad).

The old Kings Mill Wharf is about 6 miles (9.6 kilometers) east of the site of Jamestown, the first permanent English colony in America (founded in 1607); it was there that representative government was inaugurated in America and that the first American Anglican church was built. The bluffs near Grove Wharf were visited by Charles Lyell in 1841 (6, p. 108) and were studied by William B. Rogers and several other pioneer American geologists and paleontologists.

Yorktown to Norfolk, Virginia
(35 miles, or 56 kilometers)

From Yorktown the boat will proceed eastward into Chesapeake Bay, thence southeastward and south, skirting the west shore, whose low indented outline is like that north of the York River already described, and, turning to the west at Old Point Comfort, will enter Hampton Roads, the busy and spacious harbor of Norfolk. It was in Hampton Roads that in 1862, the second year of the Civil War, the *Merrimac* and the *Monitor*, forerunners of modern steel-clad warships, engaged in a fierce battle which ended in victory for the little *Monitor* and the continuation of control, by the Union forces, of Fort Monroe and other strategic points.

A trip will be made overland from Norfolk to Dismal Swamp and to Virginia Beach and the sand dunes of Cape Henry. The route of this trip, except in the sand-dune area, will be over the Pamlico and Princess Anne terrace plains. The name Princess Anne was applied by Wentworth (33, p. 81) to a terrace plain about 12 feet above sea level that in places is separated from the next higher terrace, the Pamlico (Dismal Swamp terrace of Wentworth), by a low, moderately well defined escarpment that suggests a shore line. This escarpment is typically developed east and southeast of Barneys Corner. The "Dismal Swamp" terrace is regarded as identical with the Pamlico terrace by Cooke (35, p. 513) because it has the same shore line as the Pamlico. The Pamlico shore line lies about 25 feet (8 meters) above sea level; that of the Princess Anne about 12 feet (4 meters). Both plains are indented by numerous marginal dendritic estuaries, which have the appearance of small drowned valleys, but a large part of the plain is flat and undissected.

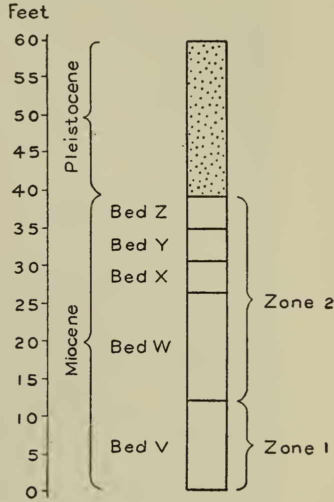


FIGURE 9.—Section on the north shore of the James River east of old Kings Mill Wharf. The beds differentiated are as follows:
Pleistocene (Penholoway) terrace deposit: Buff sand, clay, and gravel.
Miocene (Yorktown formation):
Zone 2:
(*z*) Gray to buff sand containing *Mulinia congesta* and *Panope*.
(*y*) Laminated clay.
(*x*) Sand containing *Venus tridacnoides* and *Panope*.
(*w*) Coarse sand, very fossiliferous, with *Chama congregata* predominating.
Zone 1:
(*v*) Loose gray to buff sand, containing *Pecten jeffersonius*, *P. clintonius* (in lower part), and *Turritella pilsbryi*.

Dismal Swamp (7, pp. 313–339; 13, pp. 1–4) is a great expanse of flat, undrained swampy land in Virginia and North Carolina having a north-south extent of 38 miles (61 kilometers) and a maximum east-west extent of about 25 miles (40 kilometers) and lying 15 to 20 feet (4.5 to 6 meters) above sea level. (See pls. 6 and 7.) The swamp is bounded on the west by a sharply developed north-south escarpment known as the Nansemond escarpment, which marks the boundary between the Pamlico terrace plain on the east and the higher Talbot and Wicomico terrace plains on the west. Shaler says of Dismal Swamp (7, p. 313): "It belongs altogether to that group of inundated lands where the lack of drainage is due to an original deficiency of slope, combined with the flow-retarding influence of vegetation on the movement of the water from the land." In the midst of the swamp, about 20 miles (32 kilometers) south-southwest of Norfolk, is Lake Drummond, a picturesque shallow subcircular lake about 2¾ miles (4.4 kilometers) in diameter.

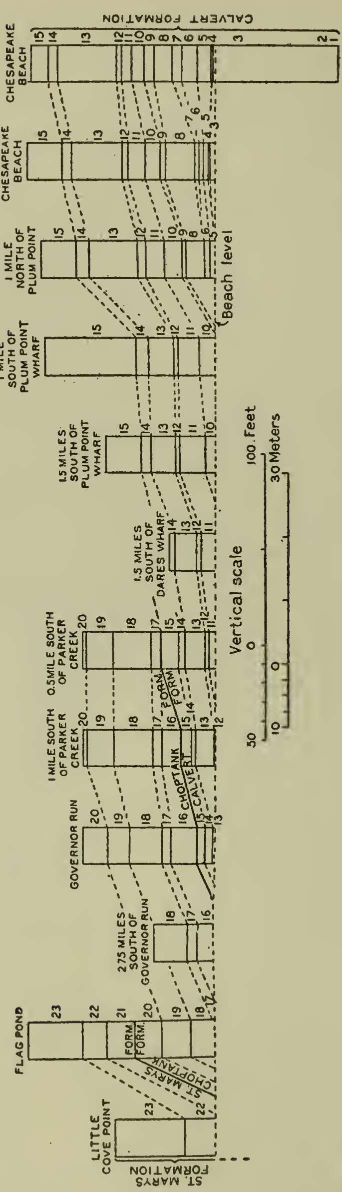


FIGURE 10.—Columnar sections of Miocene strata in Calvert Cliffs, Maryland. Paleontologic zones are numbered in ascending order from 1 to 23; zones 1–15 equal the Calvert formation; zones 16–20 equal the Choptank formation; zones 21–23 equal part of the St. Marys formation. Adapted from Shattuck (14, pl. 5)

A TYPICAL VIEW OF VEGETATION IN THE DISMAL SWAMP, VIRGINIA

In the foreground are numerous cypress "knees" and a large cypress tree. Photograph by I. C. Russell.

CYPRESS TREES IN LAKE DRUMMOND, DISMAL SWAMP, VIRGINIA

Photograph by I. C. Russell.

A. WINDWARD SIDE (EAST) OF THE GREAT SAND DUNE AT CAPE HENRY, VIRGINIA

Showing stumps of trees that were first covered by sand and subsequently uncovered, as the dune moved westward. Photograph by L. W. Stephenson.

B. STEEP WESTERN (LEEWARD) SLOPE OF THE GREAT SAND DUNE AT CAPE HENRY, VIRGINIA

Showing trees that have been partly buried and killed by the westward-moving sand. Photograph by L. W. Stephenson.

On the way from Lake Drummond to Cape Henry by way of the Great Bridge and Kempville, a glimpse may be had near Barneys Corner, 2 miles (3.2 kilometers) southwest of Kempville, of the escarpment that separates the Pamlico and Princess Anne terraces.

The sand dune area at Cape Henry (13, pp. 1–2) has long been a feature of great interest to geologists and physiographers. (See U. S. Geol. Survey topographic map of Cape Henry, Virginia.) The dune area, including the tree-grown swamp back of the main dune, is about 6 miles (9.6 kilometers) long from northwest to southeast, has a maximum width of nearly 3 miles (4.8 kilometers) and is bordered on the seaward side by a broadly curved beach convex to the northeast. The main dune has a maximum height of about 90 feet (27 meters). The dune is moving slowly inland, burying a pine forest, and the stumps of trees that were buried on the leeward side have reappeared on the windward side. (See pl. 8.) The dune area is geologically of Recent origin.

Norfolk, Virginia, to Calvert Cliffs, Maryland (110 miles, or 177 kilometers)

From Norfolk the excursion will proceed to the Calvert Cliffs, on Chesapeake Bay, in Calvert County, Maryland. The better part of a day will be required for this part of the journey.

The Calvert Cliffs (14, pp. lxix–cxxxvii, 130–401, pls. 5–7) are a series of eastward-facing wave-cut cliffs on the west shore of Chesapeake Bay. They rise to a maximum height of about 140 feet (42.6 meters) and are scattered along a north-south stretch of shore line about 25 miles (40 kilometers) long. Successively from north to south they afford good exposures of the Calvert, Choptank, and St. Marys formations of the Miocene Chesapeake group, the beds of which dip gently to the southeast. These formations have been divided into fossil zones from below upward as follows: Calvert formation, zones 1 to 15; Choptank formation, zones 16 to 20; St. Marys formation, zones 21 to 24. Columnar sections of the beds exposed at 12 localities along the Calvert Cliffs and the stratigraphic relation of these sections to one another are shown in Figure 10. Fossils occur in great abundance in places, and visits will be made to selected localities at which representative collections can be made from these formations.

Little Cove Point.—The following section is exposed at Little Cove Point, on Cheaspeake Bay, about 3½ miles (5.6 kilometers) north of the mouth of the Patuxent River:

Section at Little Cove Point, Maryland

[Adapted from Shattuck (14, p. xcl)]

	Feet	Meters
Undifferentiated uppermost Miocene, Pliocene, and Pleistocene:		
Red and yellow loam, sand, and gravel	62	18.9
Unconformity.		
Miocene, St. Marys formation:		
Bluish sandy clay. Eight feet above the base is a fossil layer made up mainly of *Turritella plebeia*. Other species occurring in this clay bed are *Terebra* (*Hastula*) *simplex* Conrad, *Pleurotoma* (*Hemipleurotoma*) *communis* Conrad, *Busycon coronatum* (Conrad), *Buccinofusus parilis* Conrad, *Alectrion peralta* (Conrad), *Bulliopsis marylandica* Conrad, *Turritella plebeia* Say, *Arca idonea* Conrad, *Dosinia acetabulum* Conrad (zone 23)	30	9.1
Bluish sandy clay containing layers of fossils, among which are *Pleurotoma* (*Hemipleurotoma*) *communis* Conrad, *Mangilia parva* (Conrad), *Alectrion peralta* (Conrad), *Bulliopsis integra* Conrad, *Turritella plebeia* Say, *Arca idonea* Conrad, *Dosinia acetabulum* Conrad (zone 22)	17	5.2

Governor Run.—At Governor Run, 12 miles (19 kilometers) northwest of Little Cove Point, the following section is exposed:

Section at Governor Run, Maryland

[Adapted from Shattuck (14, p. xc)]

	Feet	Meters
Pleistocene: Reddish sandy loam	5	1.5
Unconformity.		
Miocene:		
Choptank formation—		
Reddish sand (zone 20)	13	4
Yellowish sandy clay carrying characteristic fossils (zone 19): *Arca staminea* Say, *Pecten madisonius* Say, *Astarte obruta* Conrad, *Crassatellites marylandicus* (Conrad), *Macrocallista marylandica* (Conrad), *Corbula idonea* Conrad	12	3.6
Yellowish sandy clay carrying a few poorly preserved fossils (zone 18)	18	5.5
Yellow sand carrying characteristic fossils (zone 17): *Turritella plebeia* Say, *Arca staminea* Say, *Pedalion maxillatum* (Deshayes), *Pecten madisonius* Say, *Crassatellites turgidulus* (Conrad), *Astarte thisphila* Glenn, *Isocardia fraterna* Say, *Macrocallista marylandica* (Conrad), *Corbula idonea* Conrad	5	1.5
Bluish sandy clay (zone 16)	13	4
Calvert formation—		
Bluish clay (zone 15)	4	1.2
Brownish sandy clay carrying *Isocardia fraterna* (zone 14)	4	1.2
Bluish clay (zone 13)	1	.3
	75	22.8

Plum Point Wharf.—The next section to be visited is about a mile south of Plum Point Wharf, which is 7½ miles (10.4 kilometers) north of Governor Run.

Section a mile south of Plum Point Wharf, Maryland

[Adapted from Shattuck (14, p. ixxxviii)]

	Feet	Meters
Miocene, Calvert formation:		
Sandy clay, fossiliferous, yellowish, grading into yellow sand in its lower portions (zone 15)	48½	14.8
Brownish sandy clay containing *Isocardia fraterna* (zone 14)	7	2.1
Bluish clay breaking with conchoidal fracture (zone 13)	13½	4.1
Brownish sandy clay carrying imperfect fossil casts (zone 12)	2½	.8
Unfossiliferous bluish clay (zone 11)	11	3.4
Greenish sand bearing characteristic fossils (zone 10): *Siphonalia devexa* (Conrad), *Turritella plebeia* Say, *Turritella indenta* Conrad, *Turritella variabilis* Conrad vars., *Glycymeris parilis* (Conrad), *Arca subrostrata* Conrad, *Pecten madisonius* Say, *Crassatellites melinus* (Conrad), *Astarte cuneiformis* Conrad, *Cytherea* (*Antigona*) *staminea* Conrad, *Corbula idonea* Conrad	9	2.7
	91½	27.9

Chesapeake Beach.—At Chesapeake Beach, 6 miles (9.6 kilometers) north of Plum Point Wharf, the following section is exposed:

Section at Chesapeake Beach, Maryland

[Adapted from Shattuck (14, p. xxxvi)]

	Feet	Meters
Miocene, Calvert formation:		
Yellow sandy clay (zone 15)	9	2.7
Yellow sandy clay (zone 14)	5	1.5
Blue sandy clay changing to yellowish-brown sandy clay in the upper 12 feet (3.6 meters); fossiliferous throughout upper portion (zone 13)	32	9.8
Greenish-brown sandy clay, bearing fossil casts (zone 12)	2½	.8
Greenish-brown sandy clay (zone 11)	5	1.5
Grayish-green sand containing some clay, in which occur *Turritella indenta*, *Phacoides anodonta*, *Crassatellites melinus*, *Astarte cuneiformis*, *Ostrea sellaeformis* [?], *Pecten madisonius*, *Macrocallista marylandica*, *Atrina harrisii*, *Arca subrostrata*, *Glycymeris parilis*, etc. (zone 10)	6	1.8
Greenish sandy clay carrying scattered layers of *Corbula elevata* (zone 9)	6	1.8
Greenish sandy clay apparently devoid of fossils (zone 8)	9	2.7
Greenish sandy clay carrying scattered layers of *Corbula elevata* (zone 7)	6	1.8
Greenish sandy clay carrying large numbers of *Corbula elevata* (zone 6)	8	2.4
Greenish sandy clay carrying *Thracia conradi* (zone 5)	7	2.1
Greenish sandy clay carrying *Ostrea percrassa* (zone 4)	½	.2
	96	29.2

In this section zones 4 and 10 are the most conspicuous. Zones 1 and 2, and all but 3 or 4 feet (0.9 to 1.2 meters) at the top of zone 3, representing the Fairhaven diatomaceous earth member of the Calvert formation, lie below the beach level but have been penetrated in wells. Zone 4, which is about 6 inches (15 centimeters) thick, is at the base of the Plum Point marl member of the Calvert formation (see fig. 10); it carries many individuals of *Ostrea percrassa* Conrad and can be traced about 2½ miles (4 kilometers) down the shore. Zone 10 is very fossiliferous and has furnished many of the species that have been described from the Calvert formation; the zone is easily traced down the shore, gradually dipping until at the section 1 mile (1.6 kilometers) below Plum Point Wharf (see p. 39) it is well exposed just above the beach level, beyond which to the south it disappears below beach level within 2 or 3 miles (3.2 to 4.8 kilometers).

Chesapeake Beach to Bodkin Point, Maryland (32 miles, or 51 kilometers).

The west shore of Chesapeake Bay between Chesapeake Beach and Bodkin Point, at the mouth of the Patapsco River, is similar to the Virginia shore in the lower reaches of the bay between the mouth of the Potomac River and Norfolk. The land is low and is intricately indented with drowned valleys, the largest of which, named from south to north, are the West, South, Severn, and Magothy Rivers. The Pamlico and Talbot terrace plains are mainly represented in these flat lowlands, but the edges of the higher Wicomico and Sunderland plains may be seen in the distant sky line to the west.

Annapolis, the capital of the State of Maryland and the site of the United States Naval Academy, is on the south shore of the Severn River 1½ to 3 miles (2.4 to 4.8 kilometers) west of its junction with the bay.

East of the bay are the low-lying lands of the Eastern Shore of Maryland, including Tilghman, Poplar, and Kent Islands, which, with the exception of a few small areas, lie less than 20 feet (6 meters) above sea level.

Wave-cut cliffs 20 to 40 feet (6 to 12 meters) high at Pinehurst, a summer-cottage community on the west shore of the bay at Bodkin Neck (15, pp. 97–98; 21, pp. 81–82), three-fourths of a mile to 2 miles (1.2 to 3.2 kilometers) south of Bodkin Point, afford an interesting series of exposures of the Upper Cretaceous Raritan formation, overlain by Pleistocene terrace deposits. A feature of especial interest is a fossil cypress swamp that occupies an erosion depression in the surface of the Raritan formation and is overlain by terrace sand and gravel.

The Raritan formation consists of irregularly bedded pinkish, reddish, gray to dark gray, purple, mottled, and variegated clay, interbedded with cross-bedded medium to coarse grained sand, that is locally indurated to orange-colored, brown, and dark-red ferruginous sandstone. Some of the clay lenses are dark carbonaceous clay containing lignitized logs and fragmental plant remains, and amber has been reported from this locality. The bedding is highly variable, in some places the clay predominating, and elsewhere the sand.

At a place about 1¼ miles (2 kilometers) south of Bodkin Point is an erosion depression in the upper surface of the Raritan formation, which extends below beach level and is filled with a fossil cypress swamp deposit, overlain by terrace gravel and sand. The relation of the Cretaceous to the Pleistocene deposits is illustrated in Figure 11. The swamp deposit is partly concealed by artificial walls erected at the foot of the cliff to prevent the destruction of the land by wave action.

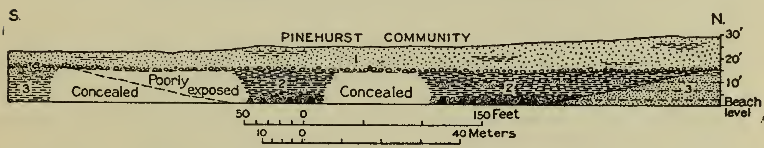


Figure 11.—Section near Bodkin Point, Maryland, showing the relation of the Raritan formation to overlying dark clay bearing cypress stumps and peat and to terrace sand and gravel of the Talbot formation of the Pleistocene. The following beds are exposed:

Pleistocene Talbot formation (restricted)—

Stratified coarse sand with some interbedded clay layers and a thin band of gravel along the base (1).

Unconformity.

At top dark sandy carbonaceous clay with some small pockets and lenses of sand, grading downward into a dark peaty swamp deposit which, in the lower 2 or 3 feet (0.6 to 0.9 meter), is made up of large stumps, knees, and roots of cypress and a miscellaneous accumulation of vegetable matter (2).

Unconformity.

Upper Cretaceous, Raritan formation: At the north end of the section, chiefly medium to coarse sand, irregularly bedded, with some interbedded clay lenses; at the west end, chiefly gray and mottled clay with some sand (3).

Bodkin Neck to Betterton, Maryland
(28 miles, or 45 kilometers)

Chesapeake Bay in the latitude of Bodkin Neck is about 10 miles (16 kilometers) wide. Northward it continues wide for about 12 miles (19 kilometers), but beyond Pools Island, west of

Betterton, it narrows to a minimum of 3 miles (4.8 kilometers). The Patapsco River, at the head of whose tidewater portion is the great harbor of Baltimore, joins the bay just north of Bodkin Neck. The west shore north of the Patapsco is low and is deeply and intricately indented with drowned valleys, including the Back, Middle, Gunpowder, and Bush Rivers, which drain a large area in Baltimore and Harford Counties, Maryland. The east shore is much less deeply indented, the principal estuaries being Fairlee, Worton, and Still Pond Creeks and the Sassafras River, which drain a relatively narrow area in Kent and Cecil Counties, Maryland.

If time permits a stop will be made at a bluff just east of the mouth of Lloyd Creek, 2½ miles (4 kilometers) southeast of Grove Point and 2 miles (3.2 kilometers) east of Betterton, where the following section (21, p. 81) is exposed:

Section east of mouth of Lloyd Creek, east of Betterton, Maryland

[Adapted from Tolchester folio (22, p. 7)]

	Feet	Meters
Pleistocene, Wicomico formation: Pebbles and boulders cemented in places to form a ferruginous conglomerate, in matrix of loose white to yellow sand	12	3.7
Upper Cretaceous, Monmouth formation: Brownish-yellow to gray sand containing many irregular iron crusts roughly arranged in layers	20	6
Upper Cretaceous, Matawan formation: Fine sand, mottled drab, light yellow, and brown, in the upper portion of which are many pebbles about the size of a pea and in the lower portion numerous vertically elongated compact ironstone concretions from 1 to 4½ feet in height, 1½ feet thick, and 1½ to 4 feet wide	28	8.5
	60	18.2

Betterton to Chesapeake City, Maryland
(18 miles, or 29 kilometers)

From Betterton the boat will proceed toward the northeast, entering the Elk River, a tributary estuary that joins the bay from the northeast a few miles south of its head. The river is bordered on the northwest by a hilly upland known as Elk Neck, which probably represents dissected portions of several of the higher Pleistocene terrace plains. On the southeast the river is bordered by lower, much less dissected land belonging mainly to the Wicomico terrace plain (Pleistocene), which has an extensive development in the northern part of the Eastern Shore of Maryland. Immediately bordering the river on both sides are small low areas that represent the Talbot and Pamlico terrace plains.

About 9 miles above the mouth of the Elk River the boat will turn to the east into Back Creek, a small tributary estuary that serves as the approach to the Chesapeake & Delaware Canal, and about 3½ miles (5.6 kilometers) farther will come to Chesapeake City, a village near the western entrance to the canal.

Chesapeake & Delaware Canal, Maryland and Delaware

The Chesapeake & Delaware Canal (8a, pp. 1–4, 21, pp. 78–81; 24, pp. 153–163) is a Government-owned sea-level ship canal connecting the navigable waters of Chesapeake Bay and the Delaware River. The distance from Chesapeake City, the western terminus, to Reedy Point, on the Delaware, the eastern terminus, is 14 miles (22.5 kilometers). For nearly 3 miles (4.8 kilometers) in Delaware the canal was cut through the Pleistocene Wicomico terrace plain, which forms the divide between the two water bodies and which here lies 60 to 80 feet (18 to 24 meters) above sea level. For the remainder of its length the canal traverses lower plains and swamps 40 feet (12 meters) or less above the sea. Deposits of Upper Cretaceous age, including the Magothy, Matawan, and Monmouth formations, are exposed in the slopes of the excavations, and these are unconformably overlain by a surficial covering of Pleistocene terrace deposits. The Cretaceous beds dip gently to the southeast, the oldest, those of the Magothy, appearing at the west end of the canal, and the younger, those of the Matawan and Monmouth formations, appearing successively toward the east as far as St. Georges, Delaware. Stops will be made at selected points along the canal. (See 21, pl. 6, fig. 1.)

The Magothy formation, overlain by the Matawan formation, is exposed from a small lighthouse 9,000 feet (2,740 meters) west of Summit Bridge, which is 4½ miles (7.2 kilometers) east Chesapeake City, eastward to a point 3,000 feet (915 meters) west of the same bridge, where the top of the Magothy passes beneath water level. A section exposed in a bluff near the lighthouse is as follows:

Section on north side of Chesapeake & Delaware Canal about 9,000 feet west of Summit Bridge, Newcastle County, Delaware

	Feet	Meters
Pleistocene terrace deposit: Coarse gravel and sand with a miscellaneous assortment of boulders derived from the rocks of the Piedmont Plateau	5	1.5
Unconformity.		

	Feet	Meters
Upper Cretaceous:		
Matawan formation—Massive sand, fine grained, glauconitic, micaceous, and argillaceous; along the base is a conglomeratic layer 1 to 3 inches thick containing small iron carbonate concretions, marcasite, and clay balls	7	2.1
Unconformity.		
Magothy formation—		
Dark tough clay with scattered lignite particles	3	.9
Loose light-colored sand, coarse, cross-bedded, micaceous and marcasitic, with interbedded dark clay layers and in places many logs of lignite	19	5.8
	34	10.3

The Magothy formation is characterized by irregularity of bedding, so that the details of the section change notably from place to place along the bluff.

The Matawan formation is well exposed along the slopes of the canal from Summit Bridge westward for 3,000 feet (915 meters), where it rises to a maximum of 40 to 45 feet (12 to 14 meters) above water level. Here the covering of Pleistocene sand and gravel (Wicomico) has a thickness of 20 to 25 feet (6 to 8 meters). The continuity of the Matawan outcrop is interrupted by landslides here and there along the bluff. The formation consists of massive dark sand, strongly micaceous, more or less glauconitic and argillaceous, and somewhat marcasitic. The formation contains a few internal and external molds of fossils, but these are not conspicuously abundant; a considerable number of species have, however, been identified from this locality. Most of them came from the lower part of the section, but some were found in dredgings thrown from the canal. A list of the species is given below:

Pelecypoda:
- Leda longifrons Conrad.
- Pinna laqueata Conrad.
- Pholadomya occidentalis Morton.
- Etea carolinensis Conrad.
- Tenea parilis Conrad.
- Cardium eufaulense Conrad?.
- Cardium spillmani Conrad.
- Cardium dumosum Conrad?.
- Panope decisa Conrad.

Gastropoda:
- Amauropsis meekana Whitfield.
- Xenophora leprosa (Morton).
- Turritella delmar Gardner.
- Turritella quadrilira Johnson.
- Laxispira lumbricalis Gabb.
- Anchura rostrata (Gabb).

Cephalopoda:
- Mortoniceras delawarense (Morton).
- Placenticeras placenta (DeKay).

Crustacea:
- Holoparia gabbi Pilsbry.
- Holoparia gladiator Pilsbry.
- Callianassa clarki Pilsbry.
- Callianassa sp.

Pisces:
- Lamna cuspidata Agassiz.
- Corax falcatus Agassiz.
- Ischyrhiza mira Leidy.

The top of the Matawan formation passes beneath water level in the vicinity of the Philadelphia, Baltimore & Washington Railroad bridge 1.3 miles (2.1 kilometers) east of Summit Bridge, and some of the sections along the canal west of the railroad bridge reveal the Monmouth formation overlying the Matawan. Fossils from the Matawan formation have been collected from dredgings thrown from the canal on the north side about a mile east of Summit Bridge, as listed below:

Pelecypoda:
- Cucullaea antrosa Morton?.
- Gervilliopsis sp.
- Pinna sp.
- Pholadomya occidentalis Morton.
- Teredo sp.

Gastropoda:
- Gyrodes abysinna (Morton)?.
- Turritella quadrilira Johnson.
- Turritella sp. (internal molds).
- Pyropsis sp.
- Unidentified gastropods.

Cephalopoda:
- Placenticeras placenta (DeKay)?.
- Mortoniceras delawarense (Morton).

Crustacea: Crab claws.

Pisces: Lamna sp.

The Monmouth formation is exposed from place to place along the canal from the Philadelphia, Baltimore & Washington Railroad bridge eastward to the vicinity of St. Georges. At Briar Point, about 0.8 mile (1.3 kilometers) east of this bridge, the following fossils have been collected from the formation:

Pelecypoda:
- Cucullaea sp.
- Exogyra costata Say.
- Gryphaea mutabilis Morton.
- Gryphaea pusilla Gardner.
- Anomia tellinoides Morton.
- Pholadomya occidentalis Morton.

Cephalopoda: Belemnitella americana (Morton).

Other fossils that have been recorded from different localities between Briar Point and St. Georges include the following species:

Echinodermata: Hemiaster delawarensis Clark.
Pelecypoda:
- Cucullaea vulgaris Morton.
- Arca (Barbatia) uandi Gardner.
- Ostrea falcata Morton.
- Exogyra cancellata Stephenson.
- Gryphaea mutabilis Morton (varieties).
- Pecten venustus Morton.
- Pecten quinquecostatus Sowerby?.
- Paranomia scabra (Morton).
- Anomia argentaria Morton.
- Modiolus burlingtonensis Whitfield.
- Lithophaga ripleyana Gabb.
- Pholadomya occidentalis Morton.
- Veniella conradi (Morton).
- Cardium kümmeli Weller.
- Martesia cretacea Gabb.
- Teredo irregularis Gabb.

Gastropoda:
- Gyrodes petrosa (Morton).
- Turritella encrinoides Morton.
- Laxispira lumbricalis Gabb.
- Pyropsis perlata Conrad.
- Xancus intermedius (Weller).
- Avellana bullata (Morton).

Cephalopoda:
- Placenticeras placenta (DeKay)?.
- Baculites ovatus Say.
- Pachydiscus complexus (Hall and Meek).

Arthropoda: Callianassa mortoni Pilsbry.
Vertebrata: Lamna elegans Agassiz.

The types of at least eight well known Upper Cretaceous species of marine organisms, listed below, came from exposures along the canal.

- Cassidulus florealis (Morton).
- Hemiaster ungula (Morton).
- Ostrea falcata Morton (near St. Georges).
- Ostrea panda Morton (near St. Georges).
- Anomia argentaria Morton (near St. Georges).
- Pholadomya occidentalis Morton.
- Mortoniceras delawarense (Morton).
- Scaphites hippocrepis (DeKay).

Except for the three species found near St. Georges, the exact place along the canal at which the specimens listed were obtained was not indicated in the original descriptions.

Morton's figured specimen of *Placenticeras placenta* (DeKay) (3, p. 36, pl. 2, figs. 1, 2), which is not the type, came from one of the exposures of the Matawan formation along the canal. Morton's nearly complete figured specimen of *Scaphites hippocrepis* (DeKay) (3, pl. 7, fig. 1), which is also not the type, came from the deep cut of the canal near Summit Bridge and therefore from the Matawan formation. Exposures of Cretaceous sand (= "Ferruginous sand") along the canal are described by Morton (3, pp. 17–19), and he also illustrates two transverse sections of the canal, one near Summit Bridge and the other a quarter of a mile (0.4 kilometer) farther west (3, pl. 14).

Chesapeake City to Baltimore, Maryland
(55 miles, or 88 kilometers)

The excursion will proceed from the Chesapeake & Delaware Canal down the Back and Elk Rivers to Chesapeake Bay, thence down the bay to the mouth of the Patapsco River, and thence up the Patapsco to Baltimore. Old Fort Howard, now abandoned, near North Point, formerly guarded the entrance to the river. On a low Pamlico terrace plain (Pleistocene) about 3 miles (4.8 kilometers) up the river on the north shore is Sparrows Point, the site of the mills and shipyards of the Bethlehem Steel Corporation. Bordering the shores within a few miles of the river are examples of all the Pleistocene terrace plains up to and including the Sunderland, which is, however, represented only by scattered erosion remnants.

The Patapsco River, like many others of the so-called rivers of the Chesapeake Bay region, is part of the drowned valley system. It has many small tributary estuaries which are the drowned valleys of an earlier dendritic drainage. One of these small estuaries at the head of the river, known as Northwest Harbor, is the main harbor of the city of Baltimore, a port for sea-going ships and an important industrial, commercial, and educational center.

Baltimore is the terminus of the excursion in the Chesapeake Bay region.

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