9. Tertiary Lithology and Paleontology, Chesapeake Bay Region

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Introduction

Tertiary beds exposed along the Chesapeake Bay and Potomac River southeast of Washington, D.C., have been studied since the early 1800s. Because of their relative proximity to that city, where both the U.S. Geological Survey and the Smithsonian Institution are housed, many geologists and paleontologists have worked on the stratigraphy and fossils. Most of the earliest efforts were taxonomic ones, but Rogers (for a summary see Rogers, 1884) described the Paleocene and Eocene deposits of Virginia. Later work by Darton (1891) drew from these earlier investigations and he proposed the primary lithic division of Coastal Plain sediments in Virginia and Maryland. The term "Pamunkey Formation" was proposed for the glauconitic units, and the overlying shelly sands and marls were named the "Chesapeake Formation." Since then, a steady refinement of the units has led to the present stratigraphic framework.

Geologic Setting

Stratigraphic units exposed in the Chesapeake Bay area consist of Mesozoic and Cenozoic Coastal Plain beds deposited in a tectonic downwarp known as the Salisbury embayment (fig. 1). The Salisbury embayment includes parts of Virginia, Maryland, Delaware, and southern New Jersey and is bordered on the north and south by the South New Jersey arch and the Norfolk arch, respectively. Subsurface data indicate that these arches are characterized by stratigraphic thinning or truncation of formations of Cretaceous and Tertiary age. The basement complex underlying the embayment includes Precambrian and Paleozoic age crystalline rocks and Mesozoic age rift-basin fill. The Salisbury embayment was the site of intermittent marine overlap and deposition during the Early and Late Cretaceous and most of the Tertiary. Beds are of fluvial, deltaic, and open-shelf origin and were deposited in a wedge-like configuration with their thin, westward edge overlapping the Piedmont. To the east, the Coastal Plain deposits thicken to several thousand feet.

The lithology, thickness, and dip of the various formations deposited in the Salisbury embayment are, to a great extent, structurally controlled. This tectonism occurred at several local and regional scales. Tectonism on a regional scale involved tilting of the entire Atlantic continental margin. Of lesser importance was the independent structural movement of the various basins, or depocenters, and the intervening arches, or high areas. These high and low areas moved independently of each other, creating a stratigraphic mosaic that is unique from basin to arch. Various tectonic models include block faulting and possible movement of the landward portions of the Coastal Plain. Parts of oceanic transform faults have been suggested as causes for the arch-basin configuration. Variations in the distribution and thickness of Cretaceous and Tertiary deposits also suggest the gradual migration of basins through time. Other structural deformation in the Salisbury embayment consists of localized, downdropped grabens that occur along northeast-trending lineaments. These grabens are related to early Mesozoic rifting and caused certain areas to be unstable. These areas were reactivated during the Cretaceous and Tertiary, possibly due to sediment loading. The presence of the grabens resulted in structural highs behind which finer sediments accumulated. Thus, each of these various structural elements contributed to the overall depositional patterns on the Coastal Plain and in the Salisbury embayment.

Lower Tertiary deposits consist of glauconitic silty sands containing varying amounts of marine shells. The Tertiary beds are principally marine-shelf deposits. Fluvial, deltaic, and nearshore-shelf facies are generally lacking. The same is true for the upper Tertiary marine beds, which consist of diatomaceous silts and silty and shelly sands. However, sands and gravels of fluvial and deltaic origin cap most of the higher intefluves in the Salisbury embayment area and are thought to be Miocene, Pliocene, and (or) Pleistocene.

The Salisbury embayment had a warm-temperate to subtropical marine setting throughout much of its history. During the late Tertiary, a portion of the temperate molluscan fauna became endemic. Abrupt cooling in the late Pliocene caused a major local extinction involving these taxa that had been successful since the Oligocene.

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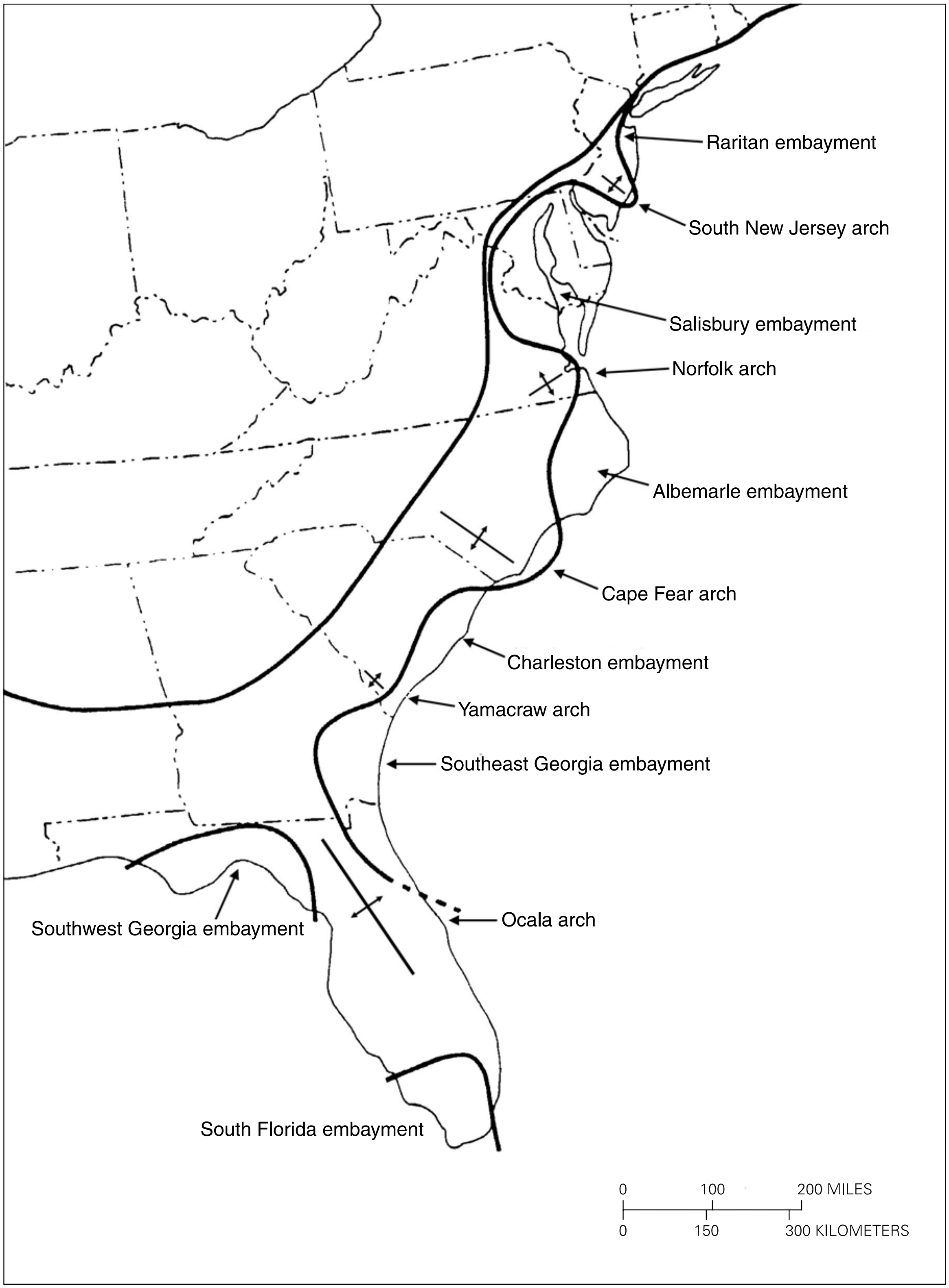

Figure 1. Map showing principal basins and arches of the Atlantic Coastal Plain.

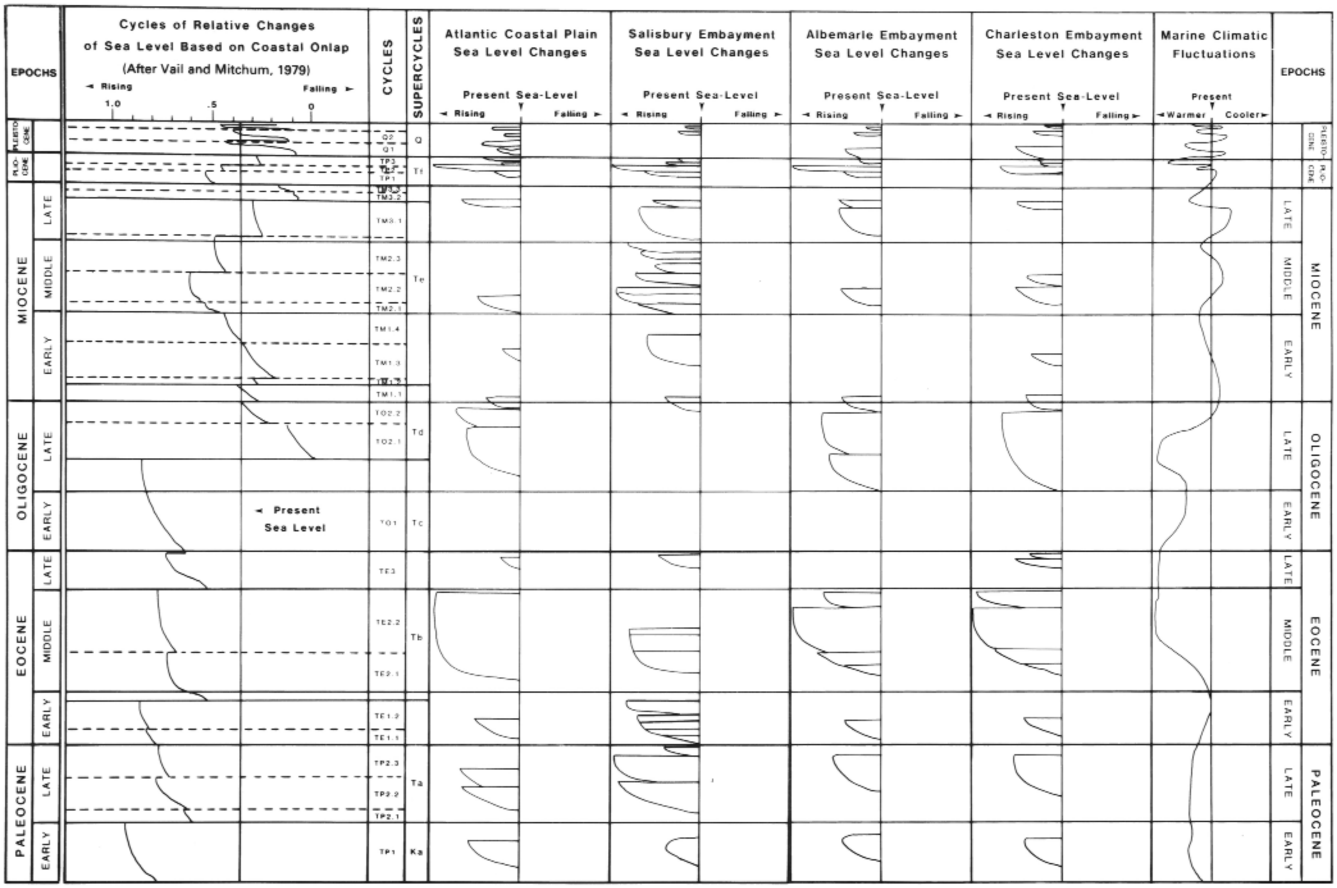

Figure 2. Onlap-offlap history of the Atlantic Coastal Plain, based on onshore outcrop and subsurface data. Sea-level fluctuations in the Salisbury, Albemarle, and Charleston embayments are plotted against a chart of cycles and supercycles by Vail and Mitchum (1979). Data from the basins are combined to approximate global sea-level events as seen along the Atlantic Coastal margin. The marine climate curve represents conditions in the Salisbury embayment and is based on data from fossil molluscan assemblages.

Tertiary History of the Salisbury Embayment

The Salisbury embayment and the entire Atlantic Coastal Plain have had a complex history. In contrast to "passive margin" descriptions, this was a structurally dynamic area whose sedimentary history clearly shows the effects of structural movement as well as of global sea-level events. To identify and eliminate local tectonic "noise" and detect actual global sea-level changes, one must compare the detailed stratigraphic records of several embayments. In figure 2, the sea-level curves of three principal Atlantic Coastal Plain basins (Salisbury embayment, Albemarle embayment, and Charleston embayment) are summarized. A fourth curve for the Atlantic Coastal Plain combines the data obtained in the three basins and attempts to show the actual record of sea-level fluctuations. These curves are plotted against the cycles and supercycles of Vail and Mitchum (1979). The curves are based on our interpretations of onshore outcrop and subsurface data. We have made no attempt to plot sea-level changes beyond the present coastline. The following trends occur and are based on the onlap relations of formations in the three basins.

Paleocene

In the middle early Paleocene, there is agreement for a moderately strong marine pulse. This pulse is evidenced by the Brightseat Formation in the Salisbury embayment (figs. 3, 4A), the Jericho Run Member of the Beaufort Formation in the Albemarle embayment, and the Black Mingo Formation in the Charleston embayment. Another strong onlap sequence occurred during the late Paleocene and lasted almost that entire period. In the Salisbury embayment, beds associated with the event are included in the Aquia Formation (fig. 4B). There are at least two recognizable sea-level pulses, represented by the Piscataway and Paspotansa Members, involved in that sequence. A final small transgression, probably only in the Salisbury embayment, resulted in the deposition of the Marlboro Clay (fig. 4C).

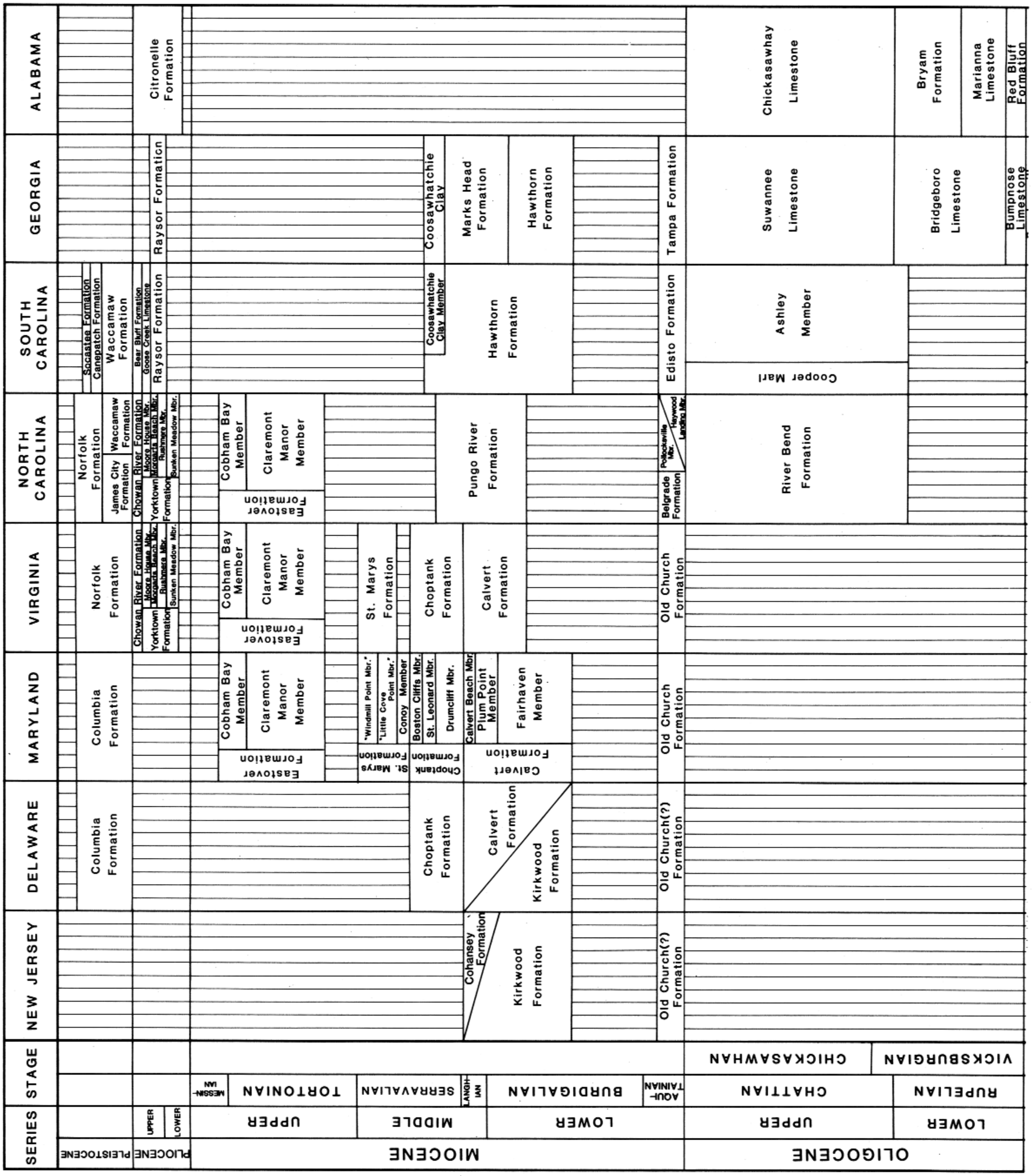

Figure 3. Correlation chart showing Tertiary units from New Jersey to Alabama.

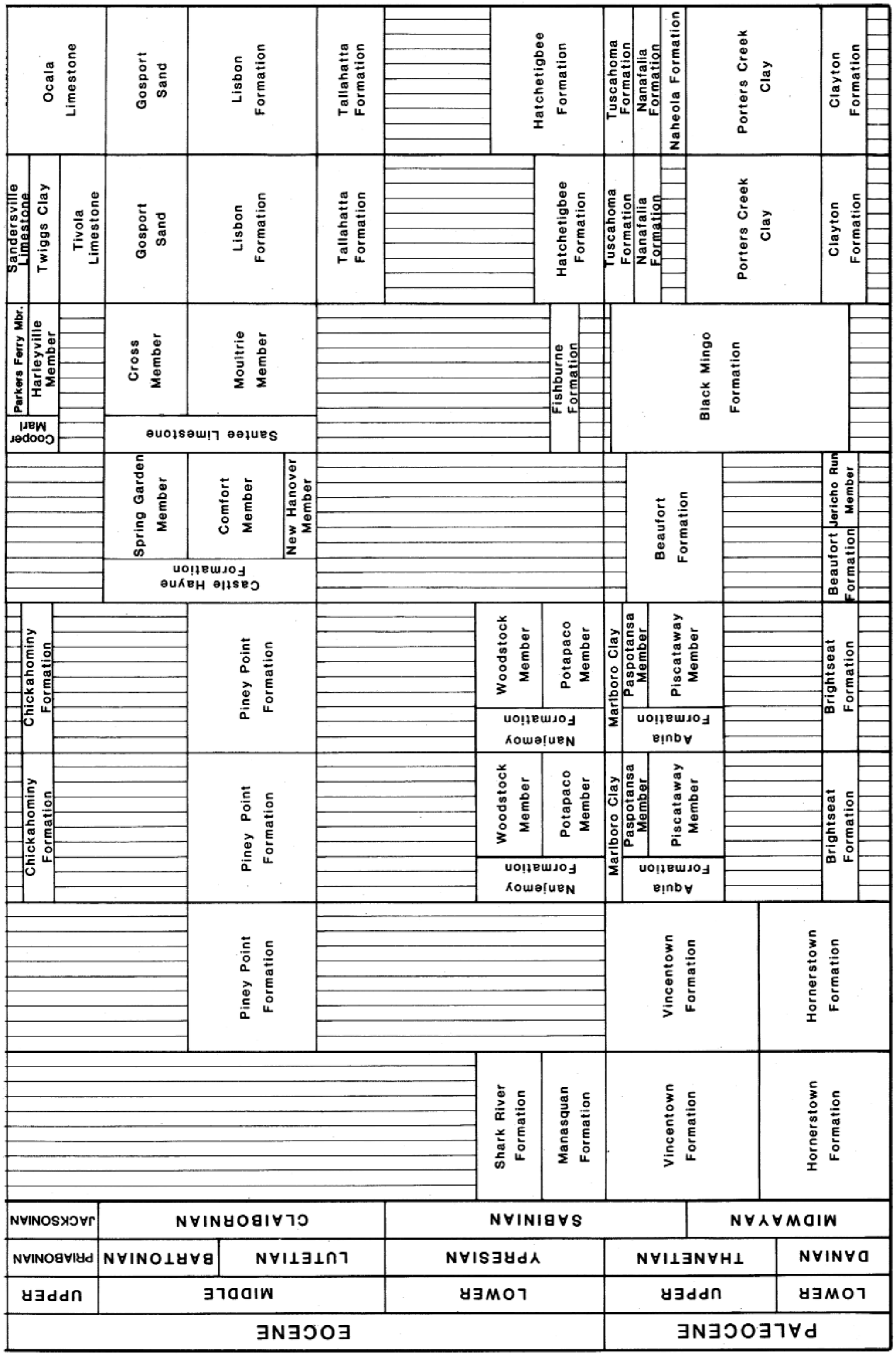

Figure 3. Continued

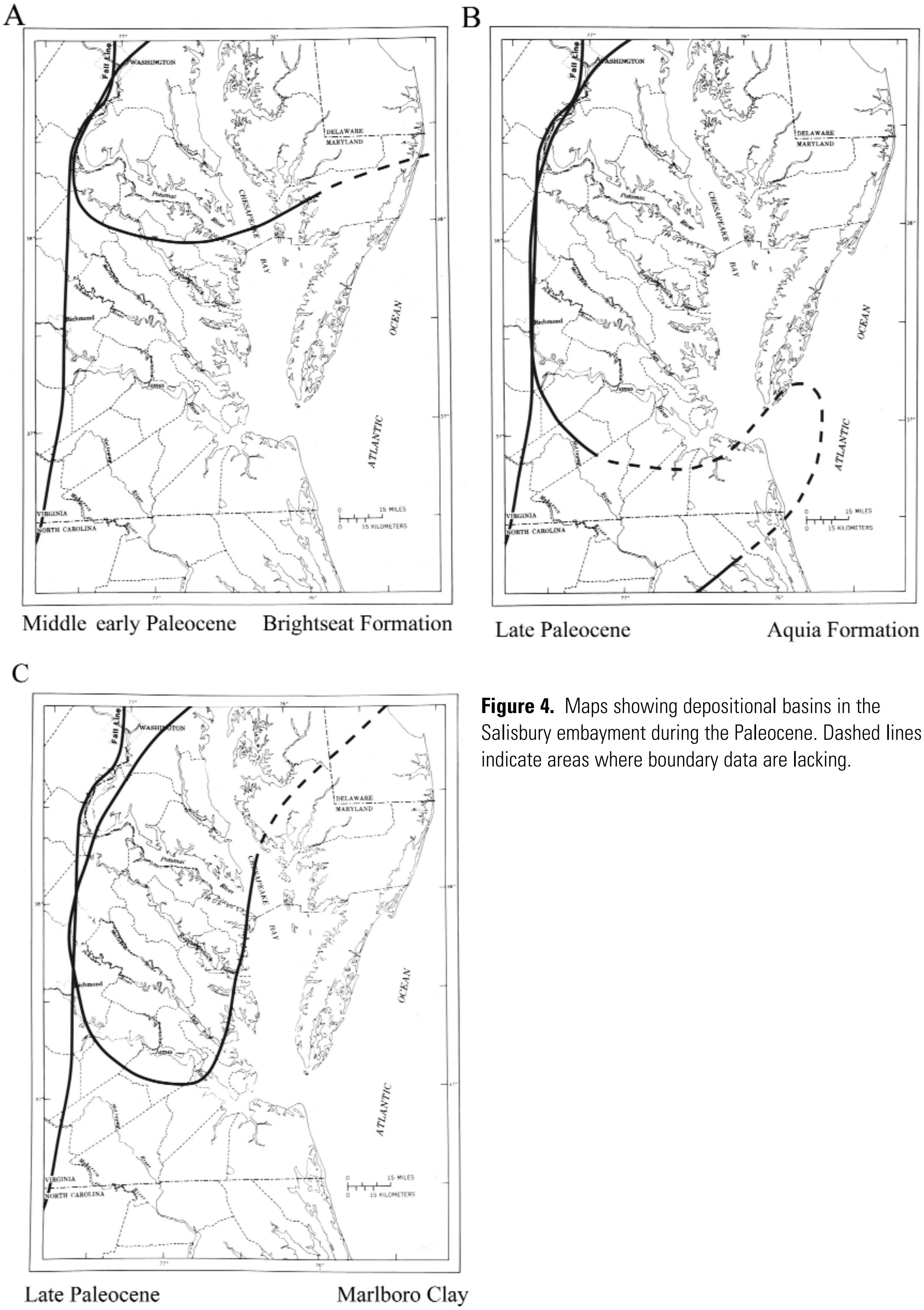

Figure 4. Maps showing depositional basins in the Salisbury embayment during the Paleocene. Dashed lines indicate areas where boundary data are lacking.

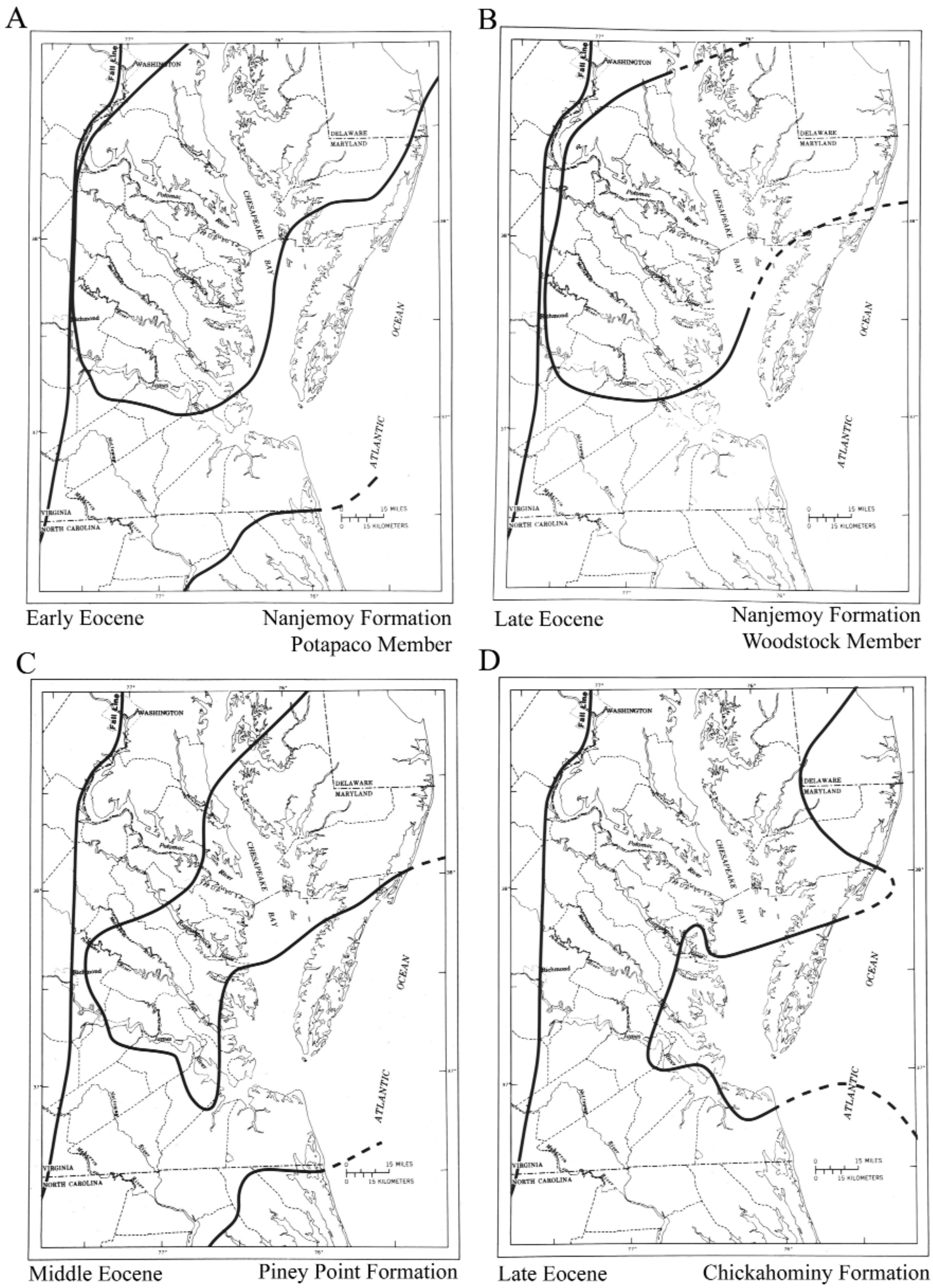

Figure 5. Maps showing depositional basins in the Salisbury embayment during the Eocene. Dashed lines indicate areas where boundary data are lacking.

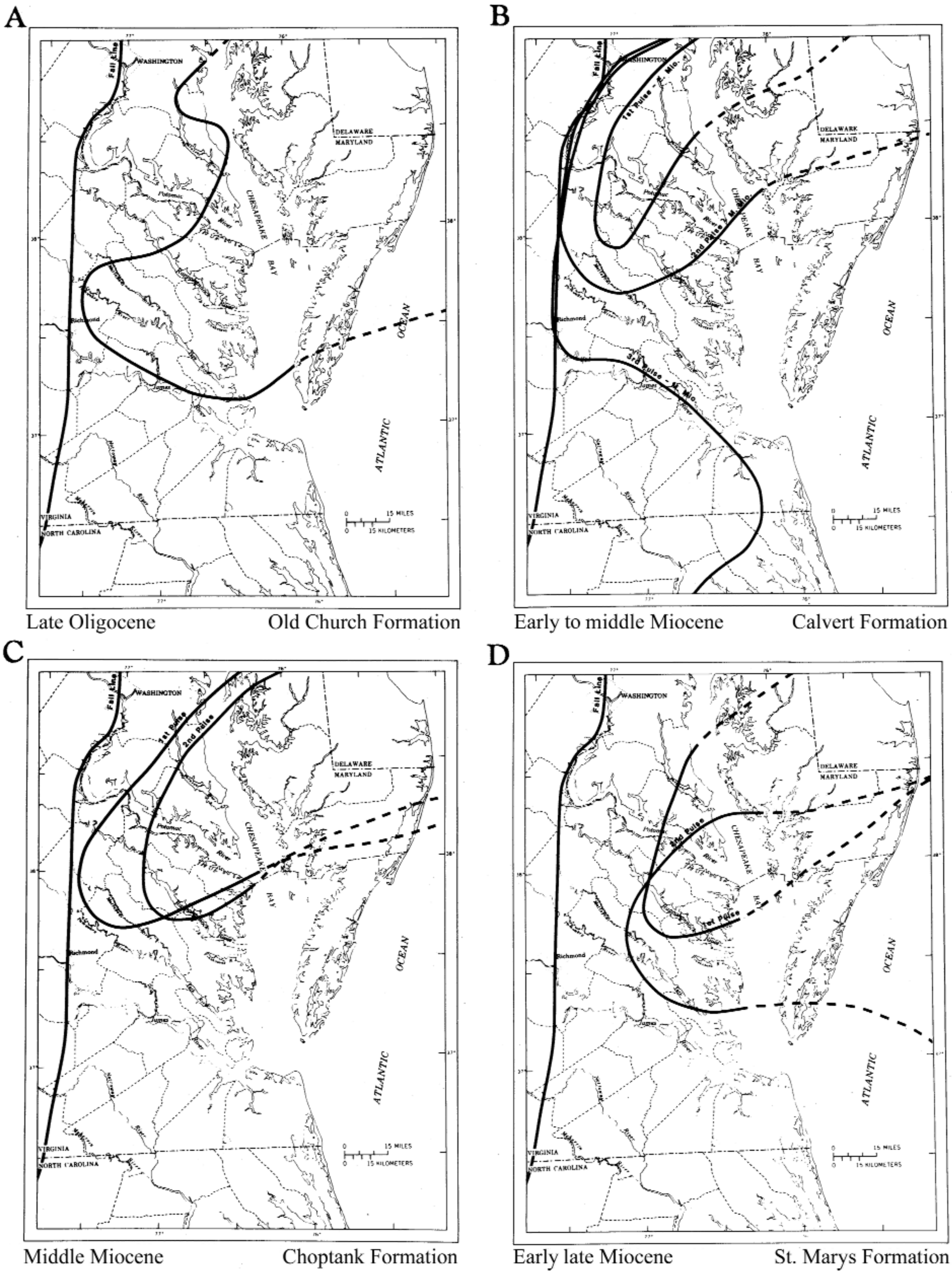

Figure 6. Maps showing depositional basins in the Salisbury embayment from the late Oligocene through the middle Miocene. Dashed lines indicate areas where boundary data are lacking.

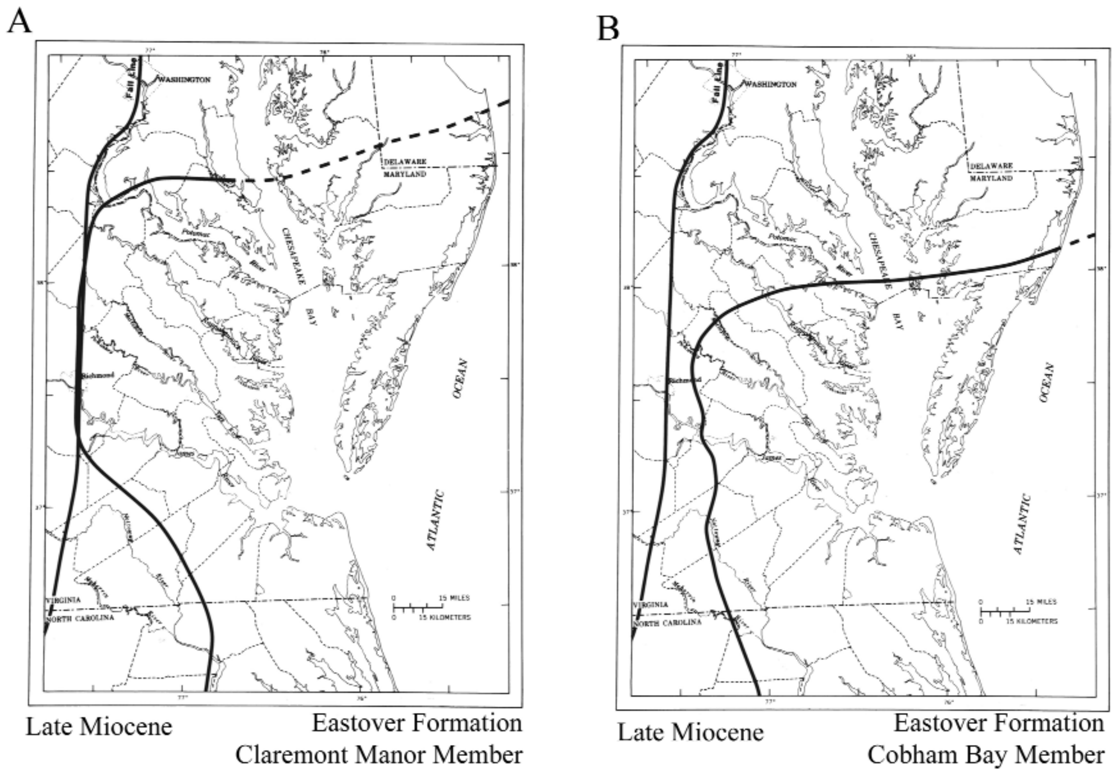

Figure 7. Maps showing depositional basins in the Salisbury embayment during the late Miocene. Dashed lines indicate areas where boundary data are lacking.

Eocene

During the early Eocene a moderately strong transgression occurred in the Salisbury embayment (Potapaco Member of the Nanjemoy Formation, fig. 5A). In the late early Eocene a second transgression occurred, which is reflected in the Salisbury embayment by the Woodstock Member of the Nanjemoy Formation (fig. 5B).

The most extensive transgression during the Tertiary occurred in the middle Eocene. In Virginia and Maryland it took place during the middle middle Eocene and resulted in the deposition of the Piney Point Formation (fig. 5C). To the south, this transgression consists of carbonate beds: Castle Hayne Formation in North Carolina; Moultrie Member of the Santee Limestone and McBean Formation in South Carolina and Georgia; and Lisbon Formation in Georgia and Alabama. Beds associated with this event are present in all areas of the Gulf Coastal Plain. It is clear that these deposits record a global sea-level rise. At least five small transgressions are reflected in the middle Eocene sequence, but they are plotted as a single event in figure 2 because of the lack of correlative data. During the late Eocene, a small-scale transgression took place in Virginia (the Chickahominy Formation of Cushman and Cederstrom, 1945; fig. 5D). This thin unit contrasts with the thick stratigraphic sequence deposited in the Gulf area at that time. That record suggests a high sea-level stand, but the meager upper Eocene record in the Atlantic basins indicates a general sea-level lowering, unless most of that area was tectonically emergent.

Oligocene

During the early Oligocene, a thick sequence of beds was deposited in the Gulf, while in the Atlantic region there are only thin subsurface units of that age. In the late Oligocene, data indicate a relative highstand, which resulted in the deposition of beds in the Charleston embayment, Albemarle embayment, and the Gulf. During the very late Oligocene or very early Miocene a brief, small-scale, high stand left a sedimentary record in the Salisbury embayment (Old Church Formation, fig. 6A). In spite of the thinness of these deposits, their widespread occurrence is good evidence for a global sea-level rise and the submergence of much of the Atlantic Coastal Plain (Ward, 1985).

Miocene

Following the Old Church transgression and a brief regression, onlap in the Salisbury embayment during the Miocene is characterized by nearly continuous sedimentation punctuated by short breaks, resulting in a series of thin, unconformity-bounded beds. Three of these transgressions produced the silty sands and diatomaceous clays of the Calvert Formation (Shattuck, 1902, 1904; fig. 6B). The diatom assemblages indicate the first and second transgressions occurred in the late early Miocene, and the third in the early middle Miocene (Abbott, 1978; Andrews, 1978). The axis of the depocenter was still to the northeast and it was apparently a restricted basin. Diatomaceous clays accumulated deep in the embayment while coarser grained, sandy deposits predominated in a seaward direction. Small-scale marine pulses brought coarser sediments deep into the embayment and stillstands resulted in clay accumulations. This formed cyclic deposits of alternating thick beds of clay and sand. Each of the Calvert pulses was successively more extensive; the third pulse partially overlapped the Norfolk arch and extended into the Pungo River Formation sea in the Albemarle embayment.

In the middle and late middle Miocene, the Salisbury embayment was again the site of two brief transgressions. Both were less extensive than the earlier Calvert seas and brought coarser sediments deeper into the embayment (fig. 6C). Beds of the first transgression, including the Drumcliff and St. Leonards Members (of Gernant, 1970) of the Choptank Formation, unconformably overlie the Calvert Formation. The second pulse of the Choptank, which corresponds to the Boston Cliffs Member of Gernant (1970), unconformably overlies beds of the first pulse. Molluscan assemblages indicate cool-temperate to warm-temperate, shallow-shelf, open-marine conditions.

In the early late Miocene, another pair of marine transgressions occurred in the Virginia-Maryland area (fig. 6D). Predominantly clayey sands were deposited, with some beds containing a prolific and diverse molluscan assemblage. These beds, which have been assigned to the St. Marys Formation, conformably overlie the Choptank Formation and, in turn, are unconformably overlain by beds of the second pulse, which corresponds to Shattuck's (1904) "Zone 24." Both units contain abundant and diverse molluscan assemblages that indicate shallow-shelf, open-marine, warm-temperate to subtropical conditions. During the second pulse, the locus of marine deposition shifted substantially to the south. This shift indicates an end of the northeast depositional alignment that appeared to have dominated in the Salisbury embayment from the Paleocene to the middle Miocene. After the shift, the principal basinal area was centered in Virginia, while Maryland was largely emergent.

After a break of approximately 1.5 to 2.0 m.y., marine sedimentation resumed with a large-scale transgression in the late late Miocene (fig. 7A). It began with localized subsidence in central Virginia that caused the deposition of a thick sequence of inner-bay, shallow-shelf sediments, termed the Claremont Manor Member of the Eastover Formation (Ward and Blackwelder, 1980). The Claremont Manor Member is a poorly sorted mixture of clay and sand with the finer material concentrated in the westward portion of the basin. Toward the center, fine-grained sands dominate and contain large concentrations of mollusks in the beds. Some of the nearshore clays deposited at that time contain appreciable concentrations of diatoms. Molluscan assemblages found in the Claremont Manor Member are less diverse than in either of the previous pulses in the St. Marys Formation and are less diverse than the subsequent Cobham Bay Member of the Eastover Formation. The composition of the fauna suggests cool to mild temperature conditions in a somewhat protected and restricted embayment.

After a brief lowstand, a high sea-level pulse in the late Miocene resulted in a very thin, but widespread, marine deposit termed the Cobham Bay Member of the Eastover Formation (Ward and Blackwelder, 1980; fig. 7B).

Stratigraphy

Pamunkey Group

Brightseat Formation

The Brightseat Formation, named by Bennett and Collins (1952) for outcrops in Prince George's County, Maryland, consists of olive-black (5*Y* 2/1), micaceous, clayey and silty sands. Ward (1985) reported that the Brightseat Formation crops out as far south as the Rappahannock River in Virginia. The Brightseat sea occupied principally the northeastern portion of the Salisbury embayment and was separated from the Albemarle embayment to the south by the Norfolk arch (fig. 4A). In its type area, 1.0 mile (mi) west-southwest of Brightseat, Prince Georges County, Md., mollusks are abundant, but only the calcitic forms are well preserved. Away from the type area, the macrofossils are leached, leaving only molds and casts. In the Prince Georges County area, the Brightseat Formation unconformably overlies marine deposits of the Severn Formation (Upper Cretaceous). To the south, on the Potomac and Rappahannock Rivers, it overlies fluvial deposits of the Potomac Group (Lower Cretaceous). Beds now placed in the Brightseat Formation were originally assigned, with some reservations, to "Zone 1" of the Aquia Formation (Clark and Martin, 1901).

On the right bank of Aquia Creek (Stop 1) (see figure 8 for locality map), the Brightseat Formation unconformably overlies the Patapsco Formation of the Potomac Group. The Brightseat Formation is, in turn, unconformably overlain by the Aquia Formation. Macrofossils at the locality are leached and are present only as rare molds and casts, but the micaceous silty sand, nearly devoid of glauconite, distinguishes the unit. The Brightseat Formation is not known to either crop out or exist in the subsurface south of the Rappahannock River exposures; however, it has been identified in cores from the Dismal Swamp area near Norfolk.

Hazel (1968, 1969), studying the ostracodes of the

Brightseat Formation in the type area, found the unit to be equivalent to the upper part of the Clayton Formation in Alabama, and placed it in the *Globoconusa daubjergensis-Globorotalia trinidadensis* zone on the basis of planktic foraminifers. He showed the Brightseat Formation to be early Paleocene in age and placed it in the upper part of the Danian Stage. According to Gibson and Bybell (1984), calcareous nannofossils present in the Brightseat Formation indicate its placement in nannoplankton zone NP 3 (of Martini, 1971).

Aquia Formation

The use of the term "Aquia" as a stratigraphic unit was first introduced by Clark (1896). He gave the name "Aquia Creek Stage" to beds that crop out in the vicinity of Aquia Creek, Stafford County, Va. The concept of the unit was soon revised, and it was renamed the Aquia Formation by Clark and Martin (1901). Bennett and Collins (1952) restricted Clark's and Martin's (1901) earlier definition of the Aquia Formation when beds placed in "Zone 1" by Clark and Martin were designated the Brightseat Formation. It is the Aquia Formation, in this restricted sense, that unconformably overlies the Brightseat Formation in the northeastern area of its range and unconformably overlies Lower Cretaceous deposits south of the Rappahannock River. The Aquia Formation consists of clayey, silty, very shelly, glauconitic sand. It crops out in a continuous arc from the upper Chesapeake Bay to the area around Hopewell, Va., on the James River. Both members of the Aquia Formation, the Piscataway and Paspotansa, are recognized along the Potomac, Rappahannock, Mattaponi, Pamunkey, and James Rivers, and both are extremely fossiliferous (see figure 4B for the basinal outline of the Aquia).

Macrofossils in the Aquia Formation locally are well preserved but more commonly are leached, making recovery difficult. Microfossil groups consist of ostracodes, foraminifers, pollen, dinoflagellates, and calcareous nannofossils. Microfossil work has indicated placement of the Aquia Formation in the upper Paleocene. Gibson and Bybell (1984), on the basis of calcareous nannofossils, placed the Aquia Formation in zones NP 5–9.

Piscataway Member

The Piscataway Member of the Aquia Formation was named by Clark and Martin (1901) from exposures along Piscataway Creek, Prince Georges County, Md. It included seven "zones," which were traceable along the Potomac River in the type area of the Aquia Formation. "Zone 1" of Clark and Martin (1901) has since been recognized as a distinct unit by Bennett and Collins (1952) and was termed the Brightseat Formation. Study of the lectostratotype section (principal reference section designated by Ward, 1985; Stop 2) of the Aquia Formation and the Piscataway and Paspotansa Members has revealed the most significant lithic change to be at the "Zone 5"-"Zone 6" contact of Clark and Martin (1901). There it changes from a poorly sorted, clayey sand to a very well sorted, micaceous, silty, fine-grained sand. Ward (1985) proposed that the boundary between the two members be placed between Beds 5 and 6 and that the base of the Paspotansa be extended downward to include "Zones 6 and 7" of Clark and Martin (1901). Beds 2 to 5, assigned to the Piscataway Member, consist of clayey, silty, poorly sorted glauconitic sands containing large numbers of macrofossils, principally mollusks. The mollusks are concentrated in beds of varying thicknesses and are cemented at several intervals into locally traceable indurated ledges. Large bivalves, which include *Cucullaea*, *Ostrea*, *Dosiniopsis*, and *Crassatellites* (see pl. 1), are the most conspicuous taxa. The quartz sand present in the Piscataway Member is usually poorly sorted, angular, and clear. Glauconite is extremely abundant, ranging from sand-size pellets to coatings on and in molluscan fossils. The sand, glauconite, and mollusks are interspersed in a clayey, silty matrix producing a very tough, olive-gray (5*Y* 4/1) calcareous marl. Glauconite percentages range from a low of 20 percent in far updip localities to 70 percent or more in the more seaward parts of the basin.

Paspotansa Member

The Paspotansa Member of the Aquia Formation, described by Clark and Martin (1901), received its name from Passapatanzy Creek, a tributary of the Potomac River in Stafford County, Va. As originally defined, the Paspotansa included "Zones 8 and 9" of Clark and Martin (1901). However, as previously discussed, Ward (1985) recommended that Beds 6 and 7 also be included in the Paspotansa Member. Bed 6 consists of an olive-gray (5*Y* 4/1), very fine grained, micaceous, glauconitic sand containing large numbers of *Turritella mortoni*. Beds 7 and 8 consist of olive-black (5*Y* 2/1), fine-grained, glauconitic sand, with scattered, thin *Turritella* beds. Bed 9 is an olive-black (5*Y* 2/1), fine-grained, glauconitic sand containing large numbers of closely packed *Turritella* in beds of varying thickness. The thicknesses of the units, as well as their fossil content, vary from locality to locality, but several characteristics are internally consistent. The Paspotansa Member consists of fine- to very fine grained, silty, well-sorted, micaceous, glauconitic and quartzose sand in massive or very thick beds. This texture is strikingly different from the underlying poorly sorted, clayey, shelly, glauconitic and quartzose sand of the Piscataway Member. The Paspotansa Member is usually overlain by a gray (*N* 7, when fresh), tough clay termed the Marlboro Clay. This bed, where present, makes the recognition of the upper boundary of the Paspotansa Member relatively easy. Where the Marlboro Clay is absent, the well-sorted, fine-grained sands of the Paspotansa Member may be distinguished from the overlying, clayey, highly bioturbated, poorly sorted glauconitic sands of the Potapaco Member of the Nanjemoy Formation.

As in all formations in the Pamunkey Group, the glauconite content of the Paspotansa Member of the Aquia Formation varies with proximity to the paleoshoreline. Percentages are much lower near the perimeter of the basin, in some areas less than 10 percent. Seaward, in an eastward direction, the glauconite content may reach 90 percent. The nature of the shell deposits within the Paspotansa Member further serves to distinguish that unit from the underlying Piscataway Member and the overlying Nanjemoy Formation. Massive glauconitic sands containing considerable numbers of large *Turritella* in thin beds or lenses characterize the Paspotansa Member, in striking contrast to the very shelly, silty sands of the Piscataway Member, which are usually dominated by loosely packed, medium-size to large bivalves. Also notable is the massive nature of the Paspotansa Member, often exposed in the high vertical walls of bluffs along the Potomac, Rappahannock, and Pamunkey Rivers. Where very fresh, the unit is dark-olive-black (5*Y* 2/1). Where partially weathered, it is grayish-orange (10*YR* 7/4), and where very weathered, it appears yellowish-orange (10*YR* 7/6), because of the oxidation of iron in the glauconite.

The Paspotansa Member apparently disconformably overlies the Piscataway Member, but the nature of the contact is commonly obscured. Clark and Martin (1901) described the nature of the contact between "Zones 6 and 8" along the bluffs below Aquia Creek, but the most notable lithic change occurs at the contact between their "Zones 5 and 6" (Ward, 1985). On the Rappahannock and Mattaponi Rivers, the contact between the two members is obscured by slumping and poor outcrops. Along the Potomac River, however, the contact between the two members is sharp and undulating. No phosphate accumulations or burrows are present, indicating only a brief period of nondeposition.

The Paspotansa Member crops out in a broad arc from the Eastern Shore of Maryland to the James River in Virginia (see fig. 4B). Clark and Martin (1901, p. 73) described the Paspotansa Member from the Chester River in Kent County, Md., and their descriptions of the sections on the Severn and South Rivers in Anne Arundel County, Md., indicate the presence of the unit there. Additional sections are described in the Upper Marlboro area of Prince Georges County, where the Paspotansa Member includes a heavy concentration of bryozoans. The most extensive outcrops of the member extend along the Virginia shore of the Potomac River from the mouth of Aquia Creek to below Fairview Beach. Between Potomac Creek and Aquia Creek (Stop 2), 61.5 feet (ft) (18.8 meters (m)) of the Paspotansa Member occurs in steep, almost vertical bluffs, which have been weathered to a reddish-orange color. This section was designated the principal reference section (lectostratotype locality) of the Paspotansa Member by Ward (1985). Several distinct shell beds are present, as well as several discontinuous ledges of boulder-size concretions. Other shell concentrations, consisting principally of large, current-oriented *Turritella mortoni* (see pl. 2), occur in lens-shaped masses.

Marlboro Clay

Clark and Martin (1901, p. 65) first applied the term "Marlboro clay" to sediments included in "Zone 10" of Clark (1896, p. 42). The name was derived from exposures of that unit near Upper Marlboro, Prince Georges County, Md. Clark and Martin (1901) considered this unit to be the basal unit of the Potapaco Member of the Nanjemoy Formation. Clark and Miller (1906) briefly described the outcrop area of the "Marlboro clay" across Maryland and Virginia and included it in the basal bed of the Nanjemoy Formation. Clark and Miller (1912) again included the pink clay as the basal bed in the Nanjemoy Formation. However, at only one locality, below Hopewell, Va., on the James River (Clark and Miller, 1912, p. 115), is a specific outcrop section described. Darton (1948), in a short note, described the areal extent of the Marlboro Clay and referred to that unit as the basal member of the Nanjemoy Formation. This had the effect of formalizing the name. A more detailed study, including a detailed geologic map by Darton (1951), also placed the Marlboro Clay as the basal bed of the Nanjemoy Formation. Glaser (1971), however, was the first to formally propose the elevation of the Marlboro Clay to formational rank. This restricted the original concept of the Nanjemoy Formation and, more specifically, that of the Potapaco Member. This treatment of the Marlboro Clay, as a separate formation, was continued by Reinhardt and others (1980).

Glaser (1971, p. 14) characterized the Marlboro Clay as "a silvery-gray to pale-red plastic clay interbedded with much subordinate yellowish-gray to reddish silt." Glaser noted that both the lower and upper contacts of the Marlboro Clay were sharp and nongradational and probably represented at least a brief hiatus between the underlying and overlying units. A more recent study by Reinhardt and others (1980) on a core from Westmoreland County, Va., concluded that the Aquia-Marlboro contact was somewhat gradational, whereas the upper Marlboro-Nanjemoy contact was sharp and was marked by burrows into the underlying Marlboro Clay.

The areal distribution of the Marlboro Clay was mapped by Darton (1951) and schematically shown by Glaser (1971), but no detailed study of the formation has been made in much of the Virginia Coastal Plain. Outcrops of the Marlboro Clay examined by us have been limited to those found on the Potomac, Mattaponi, Pamunkey, and James Rivers. Outcrop patterns indicate a spotty, although widespread, occurrence of the unit.

Because of the lack of calcareous fossils, the age of the Marlboro Clay has been assigned principally on the fact that it occurs between the Aquia and Nanjemoy Formations. This brackets its age but does not afford primary evidence. A detailed study of a core from Oak Grove, Westmoreland County, Va., by Gibson and others (1980) and Frederiksen (1979) afforded the best paleontologic evidence of its age. The consensus of pollen and dinoflagellate data suggested an age of very late Paleocene and possibly very early Eocene. Mixing of the two floral assemblages may have occurred through reworking and bioturbation or the unit may contain the Paleocene-Eocene boundary.

Nanjemoy Formation

Beds now included in the Nanjemoy Formation were first studied in detail by Clark (1896), who divided them (along with those now included in the Aquia Formation) into "zones." Those "zones" above the "Aquia Creek Stage" of Clark (1896) were numbered 10 through 17. "Zone 17" was named the "Woodstock Stage." Clark and Martin (1901) revised this terminology and placed their "Zones 10 through 17" in the "Nanjemoy Formation or Stage." The Nanjemoy Formation was divided into the "Potapaco Member or substage" including "Zones 10–15" and the Woodstock Member including "Zones 16 and 17." In this same publication Clark and Martin (1901, p. 65) introduced the term "Marlboro clay," informally, for part of their "Zone 10." In a brief, preliminary report on the stratigraphy of the Virginia Coastal Plain, Clark and Miller (1906) dropped the stage and substage terminology and referred only to the Aquia and Nanjemoy Formations. Clark and Miller (1912) continued this usage and retained both as formations. The "Marlboro clay" was briefly mentioned again (Clark and Miller, 1912, p. 103) but was specifically reported from only one locality (Clark and Miller, 1912, p. 115). The zonation of beds and their breakdown into members was retained only for those well-studied exposures along the Potomac River. South of the Potomac, assignment only to formation was attempted. The term "Marlboro Clay" was finally formalized by Darton (1948), but the unit was retained as a basal member of the Nanjemoy. This removed the Marlboro Clay ("Zone 10," in part, of Clark) from beds previously included in the Potapaco Member. The Marlboro Clay was retained as a member of the Nanjemoy until Glaser (1971) elevated it to formational rank. This, in effect, restricted the original concept of the Nanjemoy Formation, and only part of "Zone 10" and "Zones 11–17" remained in that formation. Beds younger than "Zone 17" were not included in the original description or sections of the Nanjemoy Formation but were later lumped under the term "Nanjemoy Formation" by Clark and Miller (1912).

Potapaco Member

The Potapaco Member of the Nanjemoy Formation was described by Clark and Martin (1901, p. 65) and received its name from "…the word Potapaco found on the (Captn. John) Smith and others early maps…" The Potapaco Member included "Zones 10 to 15" of Clark and Martin (1901). Part of their "Zone 10" included the Marlboro Clay. Clark (1896), Clark and Martin (1901), and Clark and Miller (1912) described the beds ("Zones") found in the Potapaco Member at sections upriver from Popes Creek on the left bank of the Potomac River, Charles County, Md. The section described by Clark and Martin (1901, p. 70, Section VIII) was designated the principal reference section (lectostratotype) of the Nanjemoy Formation and the Potapaco Member by Ward (1985). The exposure is just downstream of Stop 6 in this report.

The following terminology is used for the series of four beds that have been recognized in the Potapaco Member (lettered from oldest to youngest) (from Ward, 1984, 1985):

Bed D—Concretion-bed Potapaco
Bed C—Burrowed Potapaco
Bed B—Bedded Potapaco
Bed A—Nonbedded Potapaco

Bed A—Nonbedded Potapaco

Bed A is found on the Potomac, Rappahannock, Mattaponi, and Pamunkey Rivers. It consists of a clayey, silty, fine-grained sand that contains scattered, small mollusks including *Venericardia potapacoensis* Clark and Martin, 1901 (see pl. 3). Glauconite occurs in relatively small amounts in the sand-size fraction in updip areas, but glauconite percentages increase in a seaward direction. Small phosphate pebbles are common. The bed is estimated to be 15 to 20 ft (4.6–6.1 m) thick and, in most places, unconformably overlies the Marlboro Clay. Bed A is distinguishable from Bed B by its darker color, lack of bedding, and less clayey texture. Calcareous fossils are generally leached, leaving only molds and casts. The unit is present on the right bank of the Potomac River 1.75 mi (2.8 km) below Fairview Beach in King George County, Va. (Stop 4).

The lithic and faunal makeup of Bed A suggests an initial marine pulse and basal transgression in contrast to the quiet, protected embayment indicated by the Marlboro Clay. Physical and paleontologic evidence indicates that little time occurred in the break between the Marlboro Clay and Bed A of the Potapaco Member.

Low molluscan diversity and small glauconite percentages suggest restricted conditions during the deposition of Bed A. In spite of this evidence, renewed marine influence is apparent. Dinoflagellate assemblages are marked by reduced diversity; the flora is dominated by a single taxon, indicating restricted marine conditions (L.E. Edwards, written commun., 1984). Mollusks, in general, are poorly preserved but where present are low in diversity.

Calcareous nannofossils found in the Oak Grove core in Westmoreland County (Gibson and others, 1980), from the interval just above the Marlboro Clay, probably come from Bed A and indicate the placement of that bed in calcareous nannoplankton zone NP 10 (early Eocene). Assemblages of pollen, dinoflagellates, foraminifers, and ostracodes substantiate this placement.

Bed B—Bedded Potapaco

Bed B, the most striking unit in the Potapaco Member, is easily recognized by its thinly bedded appearance. This appearance is due to the accumulation of a small bivalve, *Venericardia potapacoensis* Clark and Martin, 1901, in vast numbers along many discontinuous, thin bedding planes. Bed B varies in thickness from locality to locality. Its exact thickness in surface exposures is difficult to determine because of poor outcrops. It is estimated to range from only a few feet (about 1 m) to more than 15 ft (4.6 m) thick. The sediment in Bed B consists of olive-gray (5*Y* 4/1), very clayey, glauconitic sand to sandy clay. The clay, when fresh, appears to be grayish orange pink in color (5*YR* 7/2) and contains varying amounts of fine- to medium-size glauconite and quartz sand. Glauconite content ranges from less than 10 percent in the westernmost exposures to more than 75 percent with increasing distance eastward (seaward). Bedded concretions ranging up to boulder size are common in Bed B. These nodules, although sometimes regionally traceable, are not sufficiently stratigraphically continuous to be used as marker beds.

Sedimentological and faunal characteristics of Bed B indicate deposition in a shallow, somewhat restricted embayment. Glauconite grains, which appear to be concentrated in burrows, are common. The burrows and the concentrations of abraded bivalves along bedding planes suggest shallow depths, probably not below wave base. Glauconite-coated, worn, disarticulated valves of *Venericardia* indicate periods of slow sediment accumulation. Bivalves may be concentrated along those winnowed zones because of intermittently favorable bottom conditions or storms. Elsewhere in the section, where soft clays inhabited by burrowing organisms predominated, the bottom may not have been suitable for the settlement of bivalve larvae. The molluscan assemblage of Bed B is dominated (up to 95 percent of the assemblage) by *Venericardia potapacoensis* Clark and Martin, 1901 (pl. 3).

Bed C—Burrowed Potapaco

Above the thin-bedded clayey sand of Bed B is a series of sandy clays to clayey sands that are easily recognizable by their intensely burrowed appearance. Bedding, if it was ever present, has been obscured by bioturbation except along a few very thin planes. Along those surfaces sedimentation appears to have been interrupted and is marked by local diastems, by a concentration of glauconitic sand, and by glauconite-filled burrows extending down into the underlying sediment. These stratigraphic breaks, if that is what they are, have not been traced over a wide area and may be only local, possibly current-scoured surfaces. The dominant lithic characteristic of Bed C is its very clayey texture; grains of fine- to medium-grained sand-size glauconite are interspersed in a grayish-orange-pink (5*YR* 7/2) clay matrix. In some areas, the concentration of glauconite is such that the lithology is best described as a clayey sand. This very clayey, glauconitic texture is typical of the entire Potapaco Member, but the intensely burrowed nature of the unit is unique to Bed C. The macrofossil component of Bed C consists principally of small or broken, poorly preserved mollusks that are concentrated in burrows and make up a small percentage of the bed. Thicknesses of as much as 20 ft (6.1 m) have been observed in outcrop.

Bed C overlies Bed B with no distinct contact between the two, suggesting a gradation from one environmental regime to another. In most of its outcrop area, Bed C is overlain by the Woodstock Member of the Nanjemoy Formation. On the Pamunkey River, at least, Bed C is overlain by a thin bed (Bed D), 1.5 to 3.0 ft (0.5–0.9 m) thick, of clayey, very glauconitic sand marked by a series of boulder-size concretions. The contact between Bed C and this younger unit, Bed D, is abrupt and is marked by a sharp, but burrowed, contact indicating a probable diastem. Elsewhere, where Bed D is missing, the Bed C-Woodstock boundary is disconformable and is marked by an abrupt change in lithology, a lag deposit of phosphate, bone, pebbles, and wood in the lower part of the Woodstock Member, and burrows containing Woodstock sediment extending several feet into the underlying Bed C. The olive-black (5*Y* 2/1), very fine grained, well-sorted, micaceous, glauconitic sand of the Woodstock Member is easily distinguishable from the very clayey, burrowed sand of Bed C. This contact has been observed on the Patuxent, Potomac, Mattaponi, and Pamunkey Rivers. Upriver of Popes Creek on the left bank of the Potomac River, Charles County, Md., the area in which Bed C should descend to water level is slumped and obscured by weathering of the cliff face.

Dinoflagellate assemblages indicate near-shore or high-energy conditions that had an abundant source of nutrients (L.E. Edwards, written commun., 1984). On the basis of the dinoflagellate flora, Bed C may be correlated with calcareous nannoplankton zone NP 10 or 11.

Bed D—Concretion-bed Potapaco

Bed D crops out only along the Pamunkey River below the mouth of Totopotomoy Creek in Hanover County, Va., and therefore is discussed only briefly here. Bed D, in its small outcrop area, consists of 1.5 to 3.0 ft (0.5–0.9 m) of clayey, very glauconitic sand and has sharp upper and lower contacts. Both the upper and lower contacts are marked by abrupt changes in lithology and color and contain concentrations of quartz and phosphate pebbles, and wood. Burrows at both contacts extend down into the underlying beds. The high glauconite content of Bed D makes it easily distinguishable from the lighter colored clays of Bed C and the less glauconitic silty sand of the basal portion of the overlying Woodstock Member. The bed is marked by a line of boulder-size concretions, which occur in the middle of the unit.

Woodstock Member

The Woodstock Member of the Nanjemoy Formation was first proposed by Clark and Martin (1901, p. 66) for beds of glauconitic sand exposed near Woodstock, "an old estate situated a short distance above Mathias Point," King George County, Va. The term "Woodstock" had previously been used by Clark (1896) to describe the Woodstock Stage, a unit defined principally by its fauna. Clark and Martin (1901) described the Woodstock Member as consisting of their "Zones 16 and 17." The bluff described by Clark (1896, p. 40, Pl. IV, Section III) and Clark and Martin (1901, p. 70, Section IX) exhibits both the Potapaco and Woodstock

Members. Stop 5 of this guidebook was designated the lectostratotype section by Ward (1985).

The Woodstock Member consists of olive-black (5*Y* 2/1), very fine grained, well-sorted, silty, glauconitic sands. The glauconite content increases markedly from a low of 10 to 15 percent in its most inland outcrops to 70 to 80 percent in its most seaward exposures. Carbonaceous material in the form of logs, branches, and nuts is abundant. The Woodstock Member unconformably overlies the Potapaco Member and is unconformably overlain either by the Piney Point Formation in the James and Pamunkey River areas or by younger beds on the Mattaponi, Rappahannock, and Potomac. The lower contact with the Potapaco Member is an easily recognized feature that may be seen from the Patuxent River to the Pamunkey River. There is a significant faunal and floral change at this boundary, although it represents only a relatively brief hiatus. The Woodstock Member may be distinguished from the underlying Potapaco Member by its fine-textured, micaceous, massive appearance, which differs from the very clayey, poorly sorted, bioturbated texture of the underlying Potapaco Member.

Molluscan assemblages in the Woodstock Member are diverse and abundant and are scattered throughout the fine matrix (pl. 4). Many of the taxa are new, and their stratigraphic significance is, at present, poorly understood. A number of species were listed by Clark and Martin (1901) as being present in the Woodstock Member, but the list is in serious need of updating. Large valves of *Venericardia ascia* Rogers and Rogers, 1839, are concentrated along bedding planes in some areas but are easily distinguished from the much smaller *Venericardia potapacoensis* found in the Potapaco Member. Along the Potomac River above Mathias Point on the right bank (Stop 5) and below Popes Creek on the left bank (Stop 6), the Woodstock Member is overlain by transgressive sediments of the Calvert Formation that range from early to middle Miocene in age. The contact is marked by a basal lag concentration of phosphate and quartz pebbles, a burrowed surface, and an abrupt lithic change from glauconitic sand to olive-brown, clayey, phosphatic sand. At the end of the bluffs, downriver from Popes Creek (below Stop 6), a very thin tongue of burrowed, gray clay and a bed of glauconitic sand occur between the typical, easily recognized Woodstock Member and the Calvert Formation. These two beds thicken downstream but are beveled off upstream south of Popes Creek. Macrofossils are leached from the beds, but dinoflagellates indicate that they are early Eocene in age (L.E. Edwards, written commun., 1984). Therefore, we include them in the Woodstock Member in spite of their different lithologies. We believe that these units are represented in the Oak Grove core by the clay and sand beds shown as occurring in the upper part of the Nanjemoy by Reinhardt and others (1980, fig. 1).

Best evidence, at this time, of the age and correlation of the Woodstock Member is found in the dinoflagellate and calcareous nannofossil assemblages. Calcareous nannofossils in the Putney Mill core, New Kent County, Va., indicate an approximate equivalence with nannofossil zone NP 12 (L.M. Bybell, written commun., 1984). This zone also was reported in the Oak Grove core (Gibson and others, 1980) in the interval between 227.0 and 269.4 ft (69.2 and 82.1 m). L.M. Bybell (written commun., 1984) now believes that only the 69.2- to 82.1-m interval in the Oak Grove core contains calcareous nannofossils indicative of nannoplankton zone NP 12.

The Woodstock sea occupied a broad embayment reaching from at least the Patuxent River in Maryland to a short distance south of the James River in Virginia (fig. 5B). The locus of the embayment was somewhat south of the Potomac River.

Chesapeake Group

The term "Chesapeake Formation" was introduced by Darton (1891, p. 433) for a series of beds in southeastern Maryland and Virginia that consists of sands, clays, marls, diatomaceous clays, and shell fragments. Dall and Harris (1892) elevated the unit to group status and included all stratigraphically equivalent beds at the same horizon from Delaware to Florida. Shattuck (1902) subdivided the Chesapeake Group in Maryland into (in ascending order) the Calvert Formation, Choptank Formation, and St. Marys Formation. Shattuck (1904) greatly expanded this work and described the units, and their contained molluscan fauna, in detail. Clark and Miller (1906) expanded the definition of the Chesapeake Group by including the Yorktown Formation in Virginia. Clark and Miller (1912) included beds along the Chowan River in Bertie County, N.C., in the Yorktown Formation. Mansfield (1944) also included the Chowan River beds in the Yorktown. Blackwelder (1981) named those beds the Chowan River Formation; he split the unit into two members, the Edenhouse Member (lower) and the Colerain Beach Member (upper), and included this new formation in the Chesapeake Group.

Ward (1985) recommended that a new unit, the Old Church Formation, be included in the Chesapeake Group. The Old Church Formation is a calcareous, shelly sand that contains only small amounts of glauconite. It unconformably underlies the Calvert Formation and unconformably overlies the Piney Point Formation. It is easily differentiated from the underlying, very glauconitic beds of the Pamunkey Group. It is unclear whether Darton (1891) or Clark and Miller (1912) actually observed the unit that Ward (1985) termed the Old Church. Therefore, where they would have placed the Old Church Formation is unclear.

The following units constitute the Chesapeake Group:

- Chowan River Formation
  - Colerain Beach Member (upper Pliocene)
  - Edenhouse Member (upper Pliocene)
- Yorktown Formation
  - Moore House Member (upper Pliocene)
  - Morgarts Beach Member (upper Pliocene)

Rushmere Member (upper Pliocene)
Sunken Meadow Member (lower Pliocene)

Eastover Formation
Cobham Bay Member (upper Miocene)
Claremont Manor Member (upper Miocene)

St. Marys Formation
Windmill Point Member (upper Miocene)
Little Cove Point Member (upper Miocene)
Conoy Member (lower upper Miocene)

Choptank Formation
Boston Cliffs Member (upper middle Miocene)
St. Leonard Member (middle middle Miocene)
Drumcliff Member (middle middle Miocene)

Calvert Formation
Calvert Beach Member (lower middle Miocene)
Plum Point Marl Member (lower middle Miocene)
Fairhaven Member (lower and lower middle Miocene)

Old Church Formation (upper Oligocene and lower Miocene)

Only beds of the Calvert, Choptank, St. Marys, and Eastover Formations crop out in the field trip area and are described here.

Calvert Formation

The Calvert Formation was named and described by Shattuck (1902, 1904) for Miocene beds exposed along the Calvert Cliffs in Calvert County, Md. Sections for the Calvert Formation were given by that author, principally along the Chesapeake Bay, but he described a few other localities in Maryland. The Calvert Formation in Virginia was first mentioned by Clark and Miller (1906), and it was soon thereafter mapped in the Richmond area by Darton (1911). Clark and Miller (1912) documented, rather completely, the extent of the Calvert and other Coastal Plain units; no such exhaustive treatment has since been attempted. More recently, descriptions have been published in guidebooks, treating exposures described by Clark and Miller (1912) (see Stephenson and others, 1933; Ruhle, 1962). Shattuck (1904) described 15 "zones" or beds in the Calvert Formation.

Fairhaven Member

The Fairhaven Member of Shattuck (1904) included "Zones 1–3." "Zones 1 and 2" are two basal transgressive sands that accumulated during the first Calvert pulse or sea-level rise (see fig. 6B). "Zone 3," a massive series of diatomaceous clays, includes most of the Fairhaven Member. "Zone 3" contains two distinct marine pulses (Beds 3–A, 3–B), which exhibit basal transgressive lags and fining-upward sequences. Exposures at the Kaylorite pit on Ferry Road, Calvert County, Md. (Bed 3–A), and the lower 10 ft (3.0 m) of the Fairhaven Member below Popes Creek, Charles County, Md. (Bed 1), contain beds associated with the first pulse of the Calvert. At Popes Creek, this bed is separated from the remaining, upper portion of the Fairhaven Member by a phosphate pebble lag indicating an unconformity or at least a diastem. This lower unit (Bed 1) was named the Popes Creek Sand Member by Gibson (1982, 1983) and was excluded from the Fairhaven even though it was included in that unit by Shattuck (1904) as "Zone 1" (Bed 1). Beds associated with the first transgression can be found as far south as the area of Wilmont on the Rappahannock River, Westmoreland County, Va. Beds of the second pulse are known as far south as the vicinity of Reedy Mill on the Mattaponi River, Caroline County, Va.

Plum Point Marl Member

The Fairhaven Member is overlain, unconformably, by a series of shelly sands that is interbedded with diatomaceous clays and grouped under the term Plum Point Marl Member. This series contains a number of identifiable pulses: the first pulse includes "Zones 4 to 9" (of Shattuck, 1904), the second pulse includes "Zones 10 and 11," the third pulse includes "Zones 12 and 13," and the fourth pulse includes "Zones 14–16." The pulses are included in the area plotted as the third pulse on figure 6B. "Zone 16," as exposed at Calvert Beach, Calvert County, Md. (Stop 10), was originally included in the Choptank Formation by Shattuck (1904). This miscorrelation and the fact that "Zone 16" contains "Choptank fossils" led to its inclusion in that unit despite its very different lithology and the presence of a striking unconformity. Mollusks that characterize "Zones 17 and 19" of the Choptank Formation make their first appearance at least as far down in the sequence as "Zone 14," and some taxa may be present in "Zone 12." It was recommended that "Zones 14–16" be included in the Calvert Beach Member and kept in the Calvert Formation (Ward, 1984). The Plum Point Marl Member, as a lithic entity, is recognizable only as far south as the Westmoreland Cliffs in Westmoreland County, Va. Farther to the southeast, beds equivalent to the Plum Point Marl Member grade into silty, diatomaceous clays that resemble the Fairhaven.

Mollusks are common in the Calvert Formation but are well preserved only in beds along the Chesapeake Bay in Calvert County, Md. Some of the common forms are (pl. 5)

Astarte cuneiformis
Bicorbula idonea (Conrad, 1833)
Cyclocardia sp.
Ecphora tricostata Martin, 1904
Lirophora latilirata (Conrad, 1841)

Lucinoma contracta (Say, 1824)
Marvacrassatella melinus (Conrad, 1832)
Melosia staminea (Conrad, 1839)
Mercenaria sp.
Pecten humphreysii Conrad, 1842

Choptank Formation

The Choptank Formation was named and described by Shattuck (1902, 1904) for the shelly, sandy Miocene beds exposed along the Choptank River, Talbot County, Md., and in the Calvert Cliffs in Calvert County, Md. The Choptank was originally composed of "Zones 16 through 20" of Shattuck (1904). Ward (1984) recommended the placement of "Zones 14–16" in the Calvert Beach Member, as defined by Gernant (1970), and expanded by Ward (1984). Blackwelder and Ward (1976) recommended that "Zone 20," or the Conoy Member of Gernant (1970), be removed from the Choptank Formation and placed in the St. Marys Formation. Distribution of the Choptank beds is shown in figure 6C.

The Choptank Formation consists of three members (in ascending order): the Drumcliff (Bed 17), St. Leonard (Bed 18), and Boston Cliffs (Bed 19). The Drumcliff and St. Leonard Members are best seen along the Chesapeake Bay in Calvert County from Scientists Cliffs to the Baltimore Gas and Electric Powerplant. On the Patuxent River they are best seen in the vicinity of Drumcliff (Jones Wharf) in St. Marys County. Mollusks commonly found in the Choptank Formation are shown in plate 6.

St. Marys Formation

The St. Marys Formation was named and described by Shattuck (1902, 1904) for Miocene beds exposed along the Calvert Cliffs in Calvert County, Md., and along the St. Marys River, St. Marys County, Md. The St. Marys can be seen overlying the Choptank Formation (Bed 19) in the Westmoreland Cliffs on the Potomac River. There, the Eastover Formation unconformably overlies the St. Marys. The St. Marys was divided into three members by Ward (1984): Conoy Member ("Zone 20" of Shattuck, 1904), Little Cove Point Member ("Zones 21–23" of Shattuck, 1904), Windmill Point Member ("Zone 24" of Shattuck, 1904). The Windmill Point Member can be identified near Tappahannock on the Rappahannock River and at White Oak Landing on the Mattaponi River. Mollusks commonly found in the St. Marys Formation are shown on plate 7. The distribution of the St. Marys beds is shown in figure 6D.

Eastover Formation

The Eastover Formation of Ward and Blackwelder (1980) was named for shelly sands on the James River in Surry County, Va. These beds are present in the uppermost portion (top 50 ft; 15 m) of the Westmoreland Cliffs on the Potomac River. Some of the upper beds in the southern Calvert Cliffs may represent a marginal-marine, inner bay facies of the Eastover Formation. The Eastover Formation was divided into the Claremont Manor and Cobham Bay Members by Ward (1980).

Claremont Manor Member

Two facies of the Claremont Manor Member are very evident: a sandy, basal transgressive portion which grades into a silty clay containing many diatoms and an overlying clayey sand. Mollusks in the Claremont Manor Member are low in diversity and are usually poorly preserved (pl. 8). The distribution of the Claremont Manor Member is shown in figure 7A.

Cobham Bay Member

The Cobham Bay Member consists of very shelly, well-sorted sand and unconformably overlies the Claremont Manor Member. The unit is quite thin and is approximately 12.0 ft (3.6 m) thick at Cobham Wharf, Surry County, Va., the type area. The distribution of the Cobham Bay Member is shown in figure 7B.

Mollusks in the Cobham Bay Member are much more diverse than those in the Claremont Manor Member and probably represent open-shelf, warm conditions.

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FIELD TRIP STOP DESCRIPTIONS FOLLOW

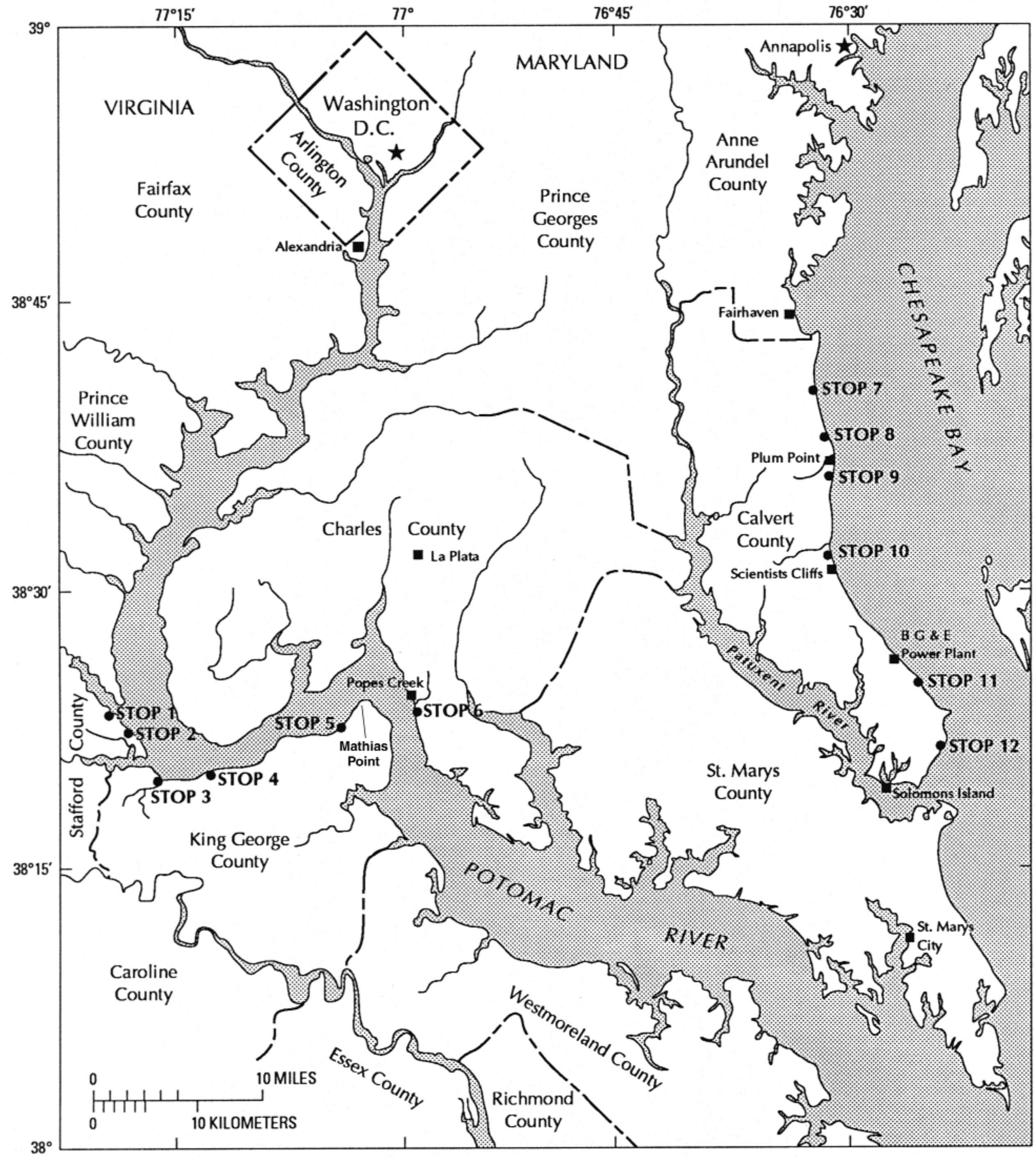


Figure 8. Map showing location of field trip stops.

Field Trip Stop Descriptions

Potomac River Sections

Stop 1. Aquia Creek.

Right bank of Aquia Creek, 0.5 mi (0.8 km) above Thorney Point, Stafford County, Va.

	ft	m
Sloped and covered by vegetation	3.0	0.9
Paleocene		
Aquia Formation		
Piscataway Member		
Sand, grayish-orange (10*YR* 7/4), silty, fine-grained, very glauconitic, poorly sorted, weathered, and leached; some molds and casts	9.0	2.7
—Unconformity—		
Brightseat Formation		
Sand, dark-olive-black (5*Y* 2/1), micaceous, clayey, silty, very fine grained, well-sorted in the lower half, weathered to grayish-orange in the upper half; an 8-in (20-cm)-thick indurated capping present at the lower end of the exposure but beveled off at the upper end of the exposure	7.0	2.1
—Unconformity—		
Lower Cretaceous		
Patapsco Formation		
Sand, well-consolidated, clayey, silty, light-blue-gray (5B 7/1); burrowed and eroded upper surface	0.0–1.0	0.0–0.3
—Sea Level—		

Below the mouth of Aquia Creek, most of the good exposures are on the Virginia shore for the next 5.0 mi (8.0 km). The bluffs immediately downriver of the mouth of Aquia Creek are the site of the lectostratotype section of the upper Paleocene Aquia Formation. Ward (1985, p. 62) described the section as follows.

Stop 2. Aquia Creek.

Right bank of the Potomac River, 1.5 mi (2.4 km) below the mouth of Aquia Creek, Stafford County, Va.

	ft	m
Covered	5.0	1.5
Eocene		
Nanjemoy Formation		
Sand, yellowish-gray (5*Y* 8/1), weathered, moderately glauconitic, fine-grained	5.0	1.5
Paleocene		
Marlboro Clay		
Clay, light-gray (*N* 8), weathered; where this bed is absent there is a distinct line between the Aquia Formation and the overlying bed of Nanjemoy Formation	0.0–0.75	0.0–0.23
Aquia Formation		
Paspotansa Member		
Sand, weathered, grayish-orange (10*YR* 7/4), glauconitic, fine-grained; contains large number of *Turritella* in lenses, bands, and large indurated masses	35.0	10.7

Sand, olive-black (5*Y* 2/1), fine-grained, well-sorted, silty; scattered, poorly preserved *Turritella*	25.0	7.6
Sand, olive-black (5*Y* 2/1), glauconitic, very fine-grained, well-sorted; many *Turritella* ("Zone 6" of Clark and Martin, 1901)	1.5	0.5
—Unconformity—		
Aquia Formation		
Piscataway Member		
Sandstone, light-olive-gray (5*Y* 6/1), indurated, glauconitic: many molds and casts, some siliceous replacements ("Zone 5" of Clark and Martin, 1901)	2.0	0.6
Sand, olive-gray (5*Y* 4/1), very glauconitic, silty, clayey, very shelly, poorly sorted; packed with large bivalves and *Turritella*. Appears light-olive-gray (5*Y* 6/1) from a distance because of large numbers of mollusks present; preservation, poor to moderate; irregularly indurated in beds where *Ostrea* are concentrated	12.0	3.7
—Sea Level—		

Stop 3. Belvedere Beach.

Right bank of the Potomac River, 0.3 mi (0.5 km) above Belvedere Beach, King George County, Va.

	ft	**m**
Covered	5.0	1.5
Paleocene		
Aquia Formation		
Paspotansa Member		
Sand, olive-black (5*Y* 2/1), fine-grained, well-sorted, silty, micaceous, glauconitic; many *Turritella*, scattered as well as in distinct bands; common *Ostrea sinuosa*; moderate molluscan diversity	12.0	3.7
—Sea Level—		

Stop 4. Fairview Beach Marina

Right bank of the Potomac River, just 100 yd below the Fairview Beach Marina, King George County, Va. (Ward, 1985, p. 64).

	ft	**m**
Sloped and covered	5.0	1.5
Eocene		
Nanjemoy Formation		
Potapaco Member (Bed A)		
Sand, grayish-yellow (5*Y* 8/4), weathered, clayey, fine-grained, poorly sorted, glauconitic	6.0	1.8
—Unconformity—		
Paleocene		
Marlboro Clay		
Clay, light-gray (*N* 7), somewhat weathered, blocky	6.0	1.8
Aquia Formation		
Paspotansa Member		
Sand, grayish-yellow, silty, very weathered; molds of *Turritella mortoni*	2.5	0.8
—Sea Level—		

Stop 5. Woodstock Member lectostratotype.

Right bank of the Potomac River (high bluffs), 2.0 mi (3.2 km) above Mathias Point, King George County, Va.

	ft	m
Pleistocene		
Sand, orange, coarse-grained	5.0	1.5
Conglomerate, sand, gravel, cobbles, boulders	3.0	0.9
—Unconformity—		
Miocene		
Calvert Formation		
Fairhaven Member		
Clay, yellowish-gray (5*Y* 8/1), silty, somewhat sandy near base, weathered, blocky, diatomaceous, phosphate pebbles and coarse-grained sand along basal contact	17.0	5.2
—Disconformity—		
Eocene		
Nanjemoy Formation		
Woodstock Member		
Sand, pale-greenish-yellow (10*Y* 8/2), weathered, fine-grained, micaceous; molds and casts; upper surface very eroded and burrowed with as much as 3 ft (0.9 m) of relief	25.0	7.6
Sand, olive-black (5*Y* 2/1), silty, very fine grained, micaceous, glauconitic; small mollusks with moderate preservation	15.0	4.6
—Sea Level—		

Stop 6. Popes Creek.

Left bank of the Potomac River, 0.95 mi (1.5 km) below the mouth of Popes Creek, Charles County, Md.

	ft	m
Pleistocene		
Conglomerate, yellowish-orange, weathered; gravel, sand, cobbles, boulders	25.0	7.6
Miocene		
Calvert Formation		
Fairhaven Member		
Clay, light-yellowish-gray (5*Y* 9/1), blocky, diatomaceous	10.0	3.0
Sand, yellowish-gray (5*Y* 8/1), silty	2.0	0.6
—Disconformity—		
Clay, light-yellowish-gray (5*Y* 9/1), blocky	0.5	0.2
Sand, yellowish-gray (5*Y* 8/1), silty	5.0	1.5
Sand, olive-brown (5*Y* 4/4), silty, phosphatic, pebbles	1.5	0.5
Sand, yellowish-gray (5*Y* 7/2), silty	2.5	0.8
Sand, olive-brown (5*Y* 4/4), silty, phosphatic, pebbles	2.0	0.6
—Unconformity—		
Eocene		
Nanjemoy Formation(?) The following unit is provisionally placed in the Woodstock Member.		
Sand, olive-gray (5*Y* 4/1), medium-grained, very glauconitic; many molds and casts; unit becoming thicker downstream	0.75	0.23
—Disconformity—		

Nanjemoy Formation		
Woodstock Member		
Sand, olive-black (5*Y* 2/1), very fine grained, micaceous, silty, glauconitic; many small mollusks, poorly preserved	5.0	1.5
Concretions, olive-gray (5*Y* 4/1), calcareous, sandy, glauconitic, rounded	5.0	1.5
Sand, olive-black (5*Y* 2/1), very fine grained, micaceous, silty, glauconitic; many small mollusks, moderately preserved	5.0	1.5
—Sea Level—		

Chesapeake Bay Section

Stop 7. Randle Cliffs (northern end).

High bluff just south of Chesapeake Beach, Calvert County, Md.

	ft	**m**
Soil	2.0	0.6
—Unconformity—		
Miocene		
Choptank Formation		
Boston Cliffs Member		
Silt, sandy, blocky (Bed 19)	7.0	2.1
—Unconformity—		
Drumcliff and St. Leonard Members, undivided		
Silt, sandy, blocky (Beds 17, 18)	10.0	3.0
Calvert Formation		
Calvert Beach Member		
Silt, clayey, blocky (Bed 15)	6.0	1.8
Sand, silty, shelly (Bed 14)	17.0	5.2
Plum Point Member		
Silt, clayey, blocky (Bed 13)	6.0	1.8
Sand, silty; poorly preserved shells (Bed 12)	3.0	0.9
Silt, clayey, blocky (Bed 11)	2.0	0.6
Sand, silty; very shelly (Bed 10)	10.0	3.0
—Unconformity—		
Sand, silty; many Corbulids concentrated in bands (Beds 4–9)	35.0	10.7
Fairhaven Member		
Silt, clayey, blocky, burrowed (Bed 3)	2.0	0.6
—Sea Level—		

Stop 8. Camp Roosevelt.

3.7 mi south of the mouth of Fishing Creek at Chesapeake Beach, Calvert County, Md.

	ft	**m**
Soil	2.0	0.6
—Unconformity—		
Miocene		
Choptank Formation		
Boston Cliffs Member		

Silt, sandy, fine-grained, with sand near base (Bed 19)	14.0	4.3
Drumcliff Member		
Sand, silty, clayey; poorly preserved shells (Bed 17)	1.0	0.3
—Unconformity—		
Calvert Formation		
Calvert Beach Member		
Silt, clayey, blocky (Bed 15)	10.0	3.0
Sand, silty, clayey; poorly preserved shells (Bed 14)	10.0	3.0
Plum Point Member		
Silt, clayey, blocky (Bed 13)	7.0	2.1
Sand, silty, shelly (Bed 12)	4.0	1.2
—Unconformity—		
Silt, clayey, blocky (Bed 11)	4.0	1.2
Sand, silty; very shelly (Bed 10)	12.0	3.7
—Unconformity—		
Sand, silty; many small *Varicorbula* concentrated in several distinct bands (Beds 4–9)	25.0	7.6

Stop 9. Plum Point.

1.0 mi (1.6 km) south of Plum Point, Calvert County, Md.

	ft	**m**
Miocene		
Choptank Formation		
Boston Cliffs Member		
Silt, clayey, blocky (Bed 19)	17.0	5.2
St. Leonard Member		
Silt, clayey, blocky (Bed 18)	9.0	2.7
Drumcliff Member		
Sand, silty, clayey; some preserved shells (Bed 17)	4.0	1.2
Calvert Formation		
Calvert Beach Member		
Silt, clayey, blocky, laminated (Bed 15)	10.0	3.0
Sand, silty, clayey; moderately shelly (Bed 14)	15.0	4.6
Plum Point Member		
Silt, clayey, blocky (Bed 13)	13.5	4.1
Sand, silty, clayey; poorly preserved mollusks (Bed 12)	2.5	0.8
Silt, clayey, blocky (Bed 11)	10.0	3.0
Sand, silty; very shelly (Bed 10)	9.0	2.7
—Sea Level—		

Stop 10. Parkers Creek.

Just above Scientists Cliffs, Calvert County, Md.

	ft	**m**
Covered with vegetation	1.5	0.5
Miocene		
St. Marys Formation		
Clay, silty	4.9	1.5
Choptank Formation		
Boston Cliffs Member		
Sand, silty, fine-grained; many mollusks	13.1	4.0

St. Leonard Member		
Sand, clayey, silty, well-burrowed; some molds of mollusks	14.7	4.5
Drumcliff Member		
Sand, very shelly, fine-grained; many large mollusks, well-preserved	13.1	4.0
Calvert Formation		
Calvert Beach Member		
Sand, silty, fine-grained; scattered, small, poorly preserved mollusks	6.5	2.0
Sand, shelly, silty; many mollusks, especially *Glossus*	4.9	1.5
Plum Point Member		
Clay, blocky, silty	9.8	3.0
Sand, shelly, silty; many, poorly preserved mollusks	0.9	0.3
Clay, blocky, silty	4.2	1.3
—Sea Level—		

Stop 11. Baltimore Gas and Electric Powerplant.

The section given below, now inaccessible, was described from a bluff just upbay from the powerplant, Calvert County, Md. A similar section near Rocky Point, below the plant site, will be visited instead.

	ft	**m**
Pleistocene(?)		
Miocene		
St. Marys Formation		
Little Cove Point Member		
Soil	1.5	0.5
Sand, pebbly, coarse-grained	10.0	3.0
Sand, silty, fine-grained; molluscan molds	14.7	4.5
Sand, fine-grained, burrowed, clean, well-sorted	3.2	1.0
Sand, medium-grained, well-sorted	3.2	1.0
Shell hash, clayey, sandy; very worn mollusks	1.9	0.6
Clay, sandy; scattered, small fragmented mollusks	4.9	1.5
Clay, sandy; scattered, small, poorly preserved mollusks	1.3	0.4
Clay, sandy; scattered, small shells	4.9	1.5
Sand, shelly, fine-grained	1.5	0.5
Clay, blocky; molluscan molds	1.9	0.6
Sand, clayey, fine-grained	5.1	1.6
Clay, blocky; molluscan molds abundant along thin horizontal planes	5.1	1.6
Choptank Formation		
Boston Cliffs Member		
Sand, shelly, fine-grained; abundant large mollusks, upper 1.0 m (3.3 ft) indurated	5.1	1.6
St. Leonard Member		
Sand, silty, fine-grained, very burrowed; mollusks scarce, scattered, poorly preserved	5.1	1.6
Drumcliff Member		
Sand, shelly, silty, fine-grained; abundant mollusks, cetacean remains common	10.4	3.2

Stop 12. Little Cove Point.

Bluff, 0.6 mi (1.0 km) downbay from Little Cove Point, Calvert County, Md.

	ft	m
Pliocene(?)		
Sand, grayish-orange (10*YR* 7/4), interbedded with thin clay layers, flaser-bedded, ripple-marked	30.0	9.1
Sand, reddish-orange (10*YR* 5/6) medium- to coarse-grained, burrowed, crossbedded, with pebbles and cobbles at base	5.0	1.5
Miocene		
St. Marys Formation		
Little Cove Point Member		
Sand, yellow-orange (10*YR* 5/6), poorly sorted, burrowed	13.0	4.0
Sand, olive-gray (5*Y* 4/1), fine-grained, silty, interbedded with silty clay	15.0	4.6
Sand, olive-gray (5*Y* 4/1), silty, fine-grained; molluscan molds only	11.0	3.4
Sand, olive-gray (5*Y* 4/1), silty, fine-grained, glauconitic; abundant mollusks	5.0	1.5
Sand, olive-gray (5*Y* 4/1), silty, fine-grained; few mollusks	6.0	1.8
Sand, olive-gray (5*Y* 4/1), fine-grained, very shelly; mollusks dominated by *Turritella*, many worn	1.0	0.3
Sand, grayish-olive-gray (5G 4/1), silty, fine-grained, burrowed; small, fragile mollusks	3.0	0.9

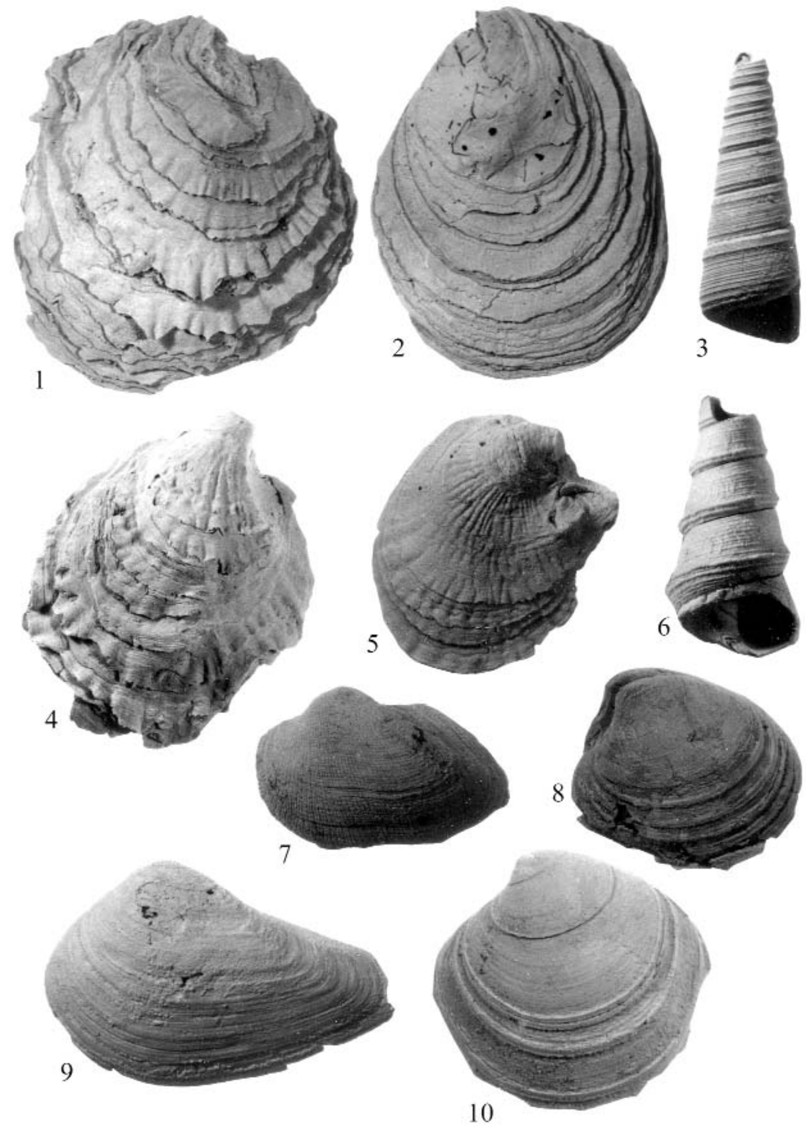


PLATE 1.

[Mollusks common in the Piscataway Member of the Aquia Formation. All specimens were collected from the Pamunkey River 0.5 mi (0.8 km) east of Wickham Crossing, Hanover County, Va. (USGS Locality 26337)]

FIGURE 1, 2, 4, 5. *Ostrea alepidota* Dall, 1898.
1. Left valve of specimen (USNM 366570); length 73.5 mm, height 85.1 mm.
2. Right valve of specimen (USNM 366470); length 65.4 mm, height 82.6 mm.
4. Left valve of specimen (USNM 366472); length 58.9 mm, height 74.3 mm.
5. Left valve of specimen (USNM 366473); length 36.3 mm, height 44.6 mm.

3. *Turritella humerosa* Conrad, 1835.
Apertural view of an incomplete specimen (USNM 366471); height 32.5 mm.

6. *Turritella mortoni* Conrad, 1830.
Apertural view of incomplete specimen (USNM 366474); height 35.8 mm.

7. *Cucullaea gigantean* Conrad, 1830.
Left valve of specimen (USNM 366475); length 42.4 mm, height 27.4 mm.

8. *Pitar pyga* Conrad, 1845.
Left valve of a double-valved specimen (USNM 366476); length 46.3 mm, height 38.9 mm.

9. *Crassatellites capricranium* (Rogers, 1839).
Left valve of specimen (USNM 366477); length 59.1 mm, height 38.6 mm.

10. *Dosiniopsis lenticularis* (Rogers, 1839).
Left valve of specimen (USNM 366478); length 47.1 mm, height 44.5 mm.

PLATE 2.

[Mollusks common in the Paspotansa Member of the Aquia Formation. All except figure 5 were collected from the Potomac River, 0.3 mi (0.5 km) above Belvedere Beach, King George County, Va.]

FIGURE 1. *Cucullaea gigantea* Conrad, 1830.
Left valve of specimen (USNM 366479); length 83.3 mm, height 71.8 mm.

2. *Pycnodonte* sp.
Left valve of specimen (USNM 366480); length 74.2 mm, height 74.6 mm.

3. *Turritella mortoni* Conrad, 1830.
Apertural view of specimen (USNM 366481); height 105.0 mm.

4, 8. *Ostrea sinuosa* Rogers and Rogers, 1837.
4. Left valve of specimen (USNM 366482); length 152.8 mm, height 134.3 mm.
8. Right valve of specimen (USNM 366482); length 98.8 mm, height 118.3 mm.

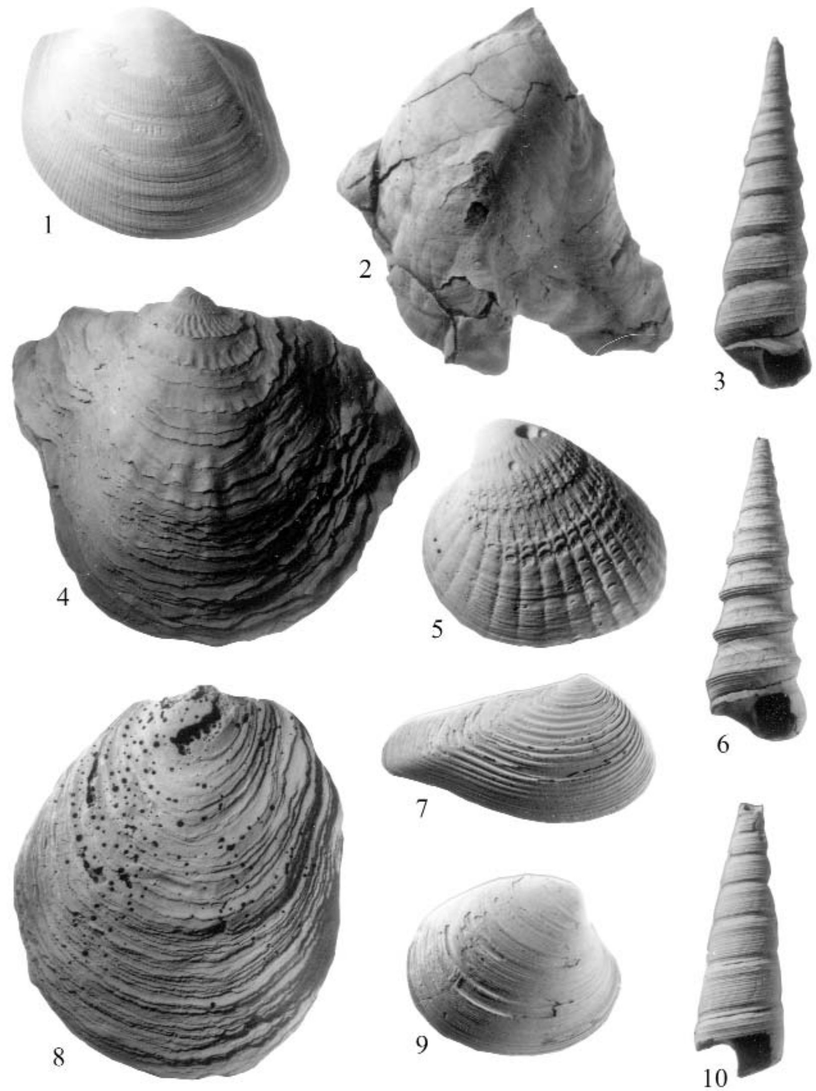
5. *Venericardia regia* Conrad, 1865.
Left valve of specimen (USNM 366483) from the Potomac River, 0.1 mi (0.3 km) below the mouth of Passapatanzy Creek, King George County, Va. USGS Locality 26341); length 75.4 mm, height 71.7 mm.

6. *Turritella mortoni* Conrad, 1830.
Apertural view of nearly complete specimen (USNM 366484); height 92.3 mm.

7. *Crassatellites alaeformis* Conrad, 1830.
Right valve of specimen (USNM 366485); length 51.9 mm, height 22.7 mm.

9. *Pitar pyga* Conrad, 1845.
Right valve of specimen (USNM 366486); length 33.6 mm, height 28.1 mm.

10. *Turritella humerosa* Conrad, 1835.
Apertural view of an incomplete specimen (USNM 366487); height 49.8 mm.



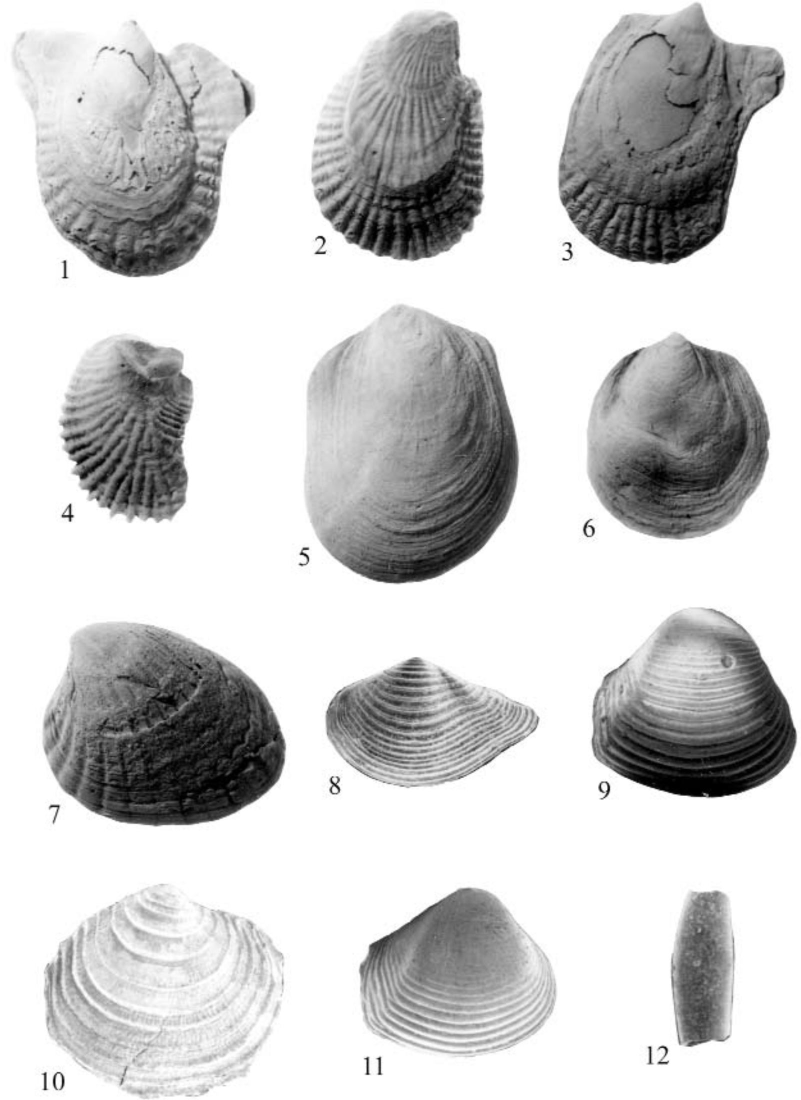


PLATE 3.

[Mollusks common in the Potapaco Member of the Nanjemoy Formation. Figures 1, 3, and 5 from the Pamunkey River, 0.8 mi (1.3 km) below Hanovertown, Hanover County, Va. (USGS Locality 26377). Figures 2, 4, and 6 from the Pamunkey River, 0.45 mi (0.72 km) above the mouth of Millpond Creek on the right bank, Hanover County, Va. (USGS Locality 26424). Figures 7–9, 11, and 12 from the Potomac River, 2.3 mi (3.9 km) above Popes Creek, Charles County, Md. (USGS Locality 26425). Figure 10 from the Rappahannock River, opposite Goat Island, Caroline County, Va. (USGS Locality 26360)]

FIGURE

1. *Cubitostrea* sp.
   Left valve of specimen (USNM 366488); length 48.5 mm, height 51.6 mm.
2. *Cubitostrea* sp.
   Left valve of specimen (USNM 366489); length 35.7 mm, height 50.4 mm.
3. *Cubitostrea* sp.
   Left valve of specimen (USNM 366490); length 37.7 mm, height 58.5 mm.
4. *Cubitostrea* sp.
   Left valve of specimen (USNM 366491); length 18.7 mm, height 27.6 mm.
5. *Cubitostrea* sp.
   Right valve of specimen (USNM 366492); length 47.9 mm, height 56.2 mm.
6. *Cubitostrea* sp.
   Right valve of specimen (USNM 366493); length 18.8 mm, height 21.4 mm.
7. *Venericardia potapacoensis* Clark and Martin, 1901.
   Left valve of specimen (USNM 366494); length 29.0 mm, height 24.1 mm.
8. *Nuculana parva* (Rogers, 1837).
   Right valve of specimen (USNM 366495); length 4.62 mm, height 2.85 mm.
9. *Vokesula* sp.
   Right valve of specimen (USNM 366496); length 4.48 mm, height 4.20 mm.
10. *Lucina* sp.
   Right valve of specimen (USNM 366497); length 5.14 mm, height 4.66 mm.
11. *Vokesula* sp.
   Right valve of specimen (USNM 366498); length 4.29 mm, height 3.65 mm.
12. *Cadulus* sp.
   Lateral view of incomplete specimen (USNM 366499); length 3.45 mm.

PLATE 4.

[Mollusks common in the Woodstock Member of the Nanjemoy Formation. Figures 5, 6, and 10–14 from the Pamunkey River, in a small ravine, 0.63 mi (1.01 km) south-southeast of the mouth of Totopotomoy Creek, Hanover County, Va. (USGS Locality 26403). Other localities are as described below]

FIGURE 1. *Glycymeris* sp.
Right valve of specimen (USNM 366500) from the Pamunkey River at the termination of Va. 732, Hanover County, Va. (USGS Locality 26393); length 22.0 mm, height 21.0 mm.

2–4. Specimens from the Potomac River, 0.95 mi (1.53 km) below the mouth of Popes Creek, Charles County, Md. (Stop 6) (USGS Locality 26397).

2. *Cubitostrea* sp.
Left valve of specimen (USNM 366501); length 13.8 mm, height 20.2 mm.

3. *Cubitostrea* sp.
Left valve of specimen (USNM 366502); length 11.8 mm, height 17.0 mm.

4. *Cubitostrea* sp.
Right valve of specimen (USNM 366503); length 12.0 mm, height 22.0 mm.

5. *Nuculana* sp.
Right valve of specimen (USNM 366504); length 4.14 mm, height 2.56 mm.

6. *Macrocallista subimpressa* (Conrad, 1848).
Left valve of specimen (USNM 366505); length 21.3 mm, height 13.9 mm.

7–9. Specimens from the Pamunkey River, just upstream of the old Newcastle Bridge, Hanover County, Va. (USGS Locality 26405).

7. *Corbula aldrichi* Meyer, 1885.
Right valve of specimen (USNM 366506); length 10.0 mm, height 7.5 mm.

8. *Venericardia ascia* Rogers and Rogers, 1839.
Right valve of specimen (USNM 366507); length 41.4 mm, height 37.5 mm.

9. *Venericardia ascia* Rogers and Rogers, 1839.
Right valve of specimen (USNM 366508); length 62.6 mm, height 54.1 mm.

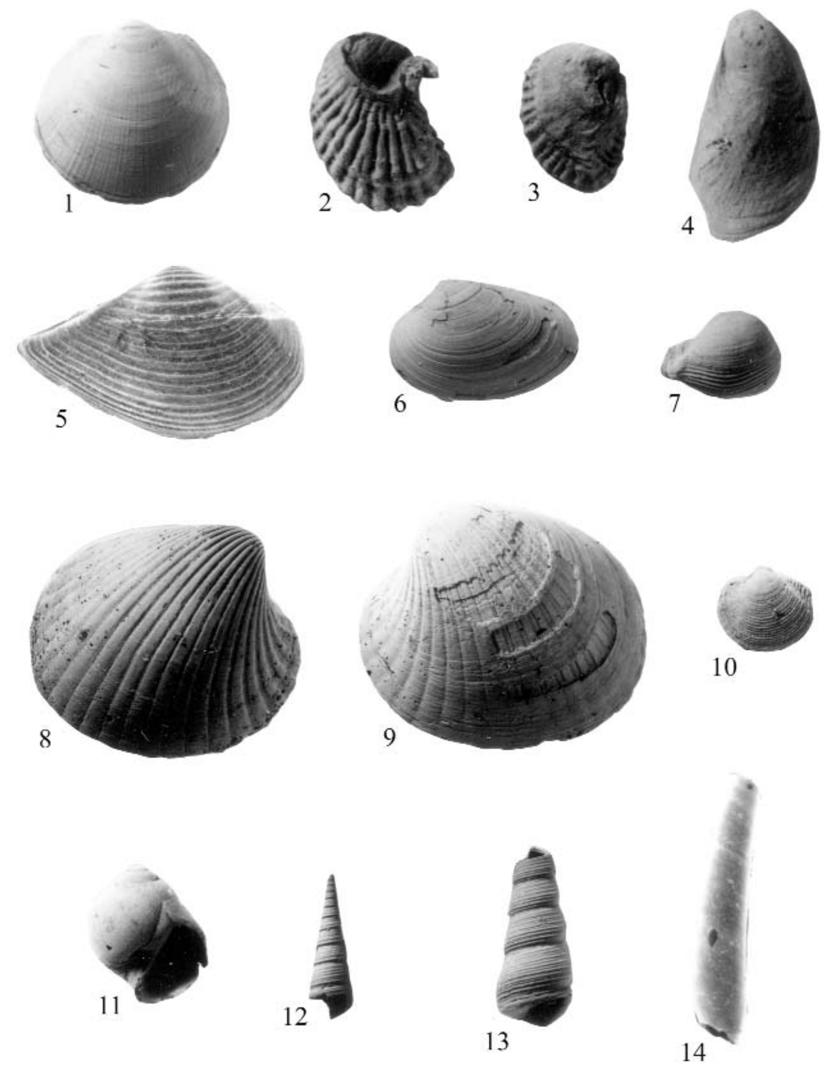
10. *Lucina dartoni* Clark, 1895.
Left valve of specimen (USNM 366509); length 6.1 mm, height 5.2 mm.

11. *Lunatia* sp.
Apertural view of specimen (USNM 366510); height 14.2 mm.

12. *Turritella* sp.
Apertural view of incomplete specimen (USNM 366511); height 12.2 mm.

13. *Turritella* sp.
Apertural view of incomplete specimen (USNM 366512); height 14.4 mm.

14. *Cadulus* sp.
Lateral view of nearly complete specimen (USNM 366513); height 4.93 mm.



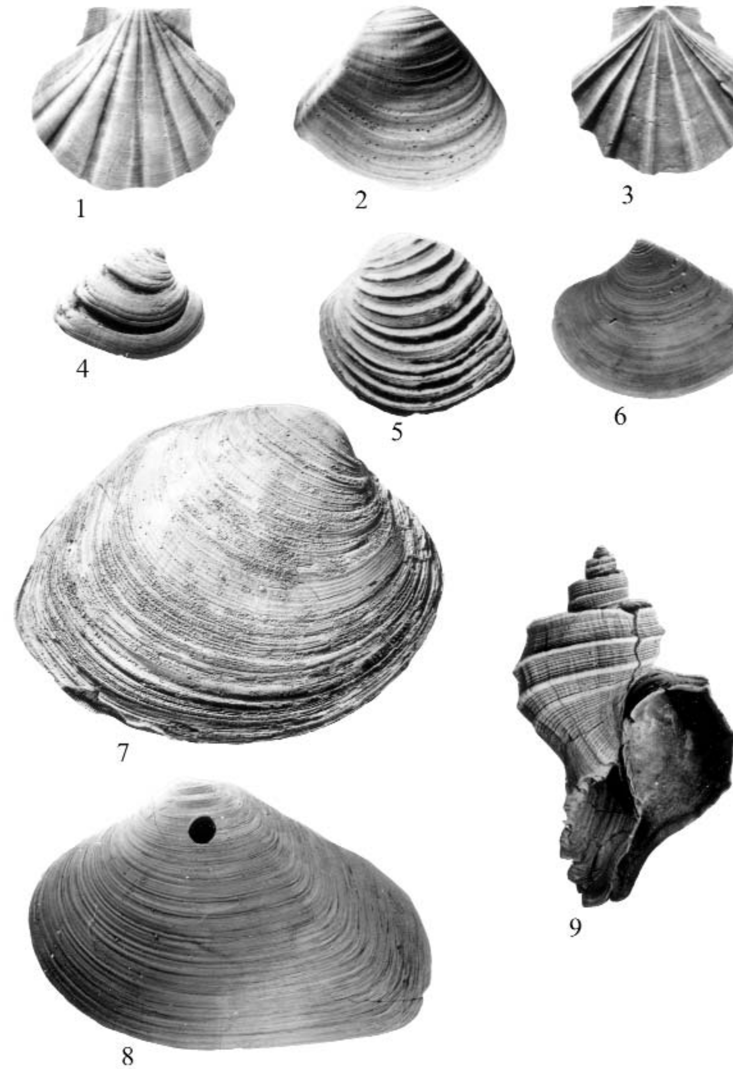


PLATE 5.

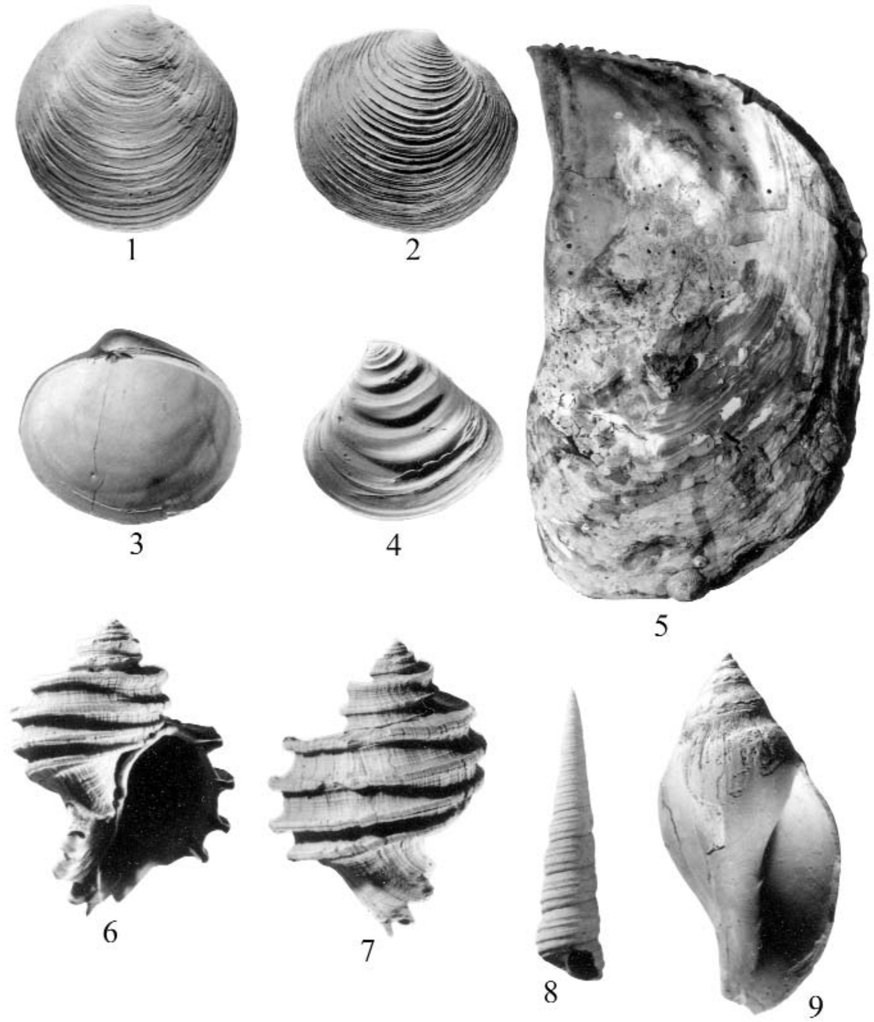
[Mollusks common in the Calvert Formation. Figures 1, 3, 4, and 9 are from Plum Point, on the Chesapeake Bay, Calvert County, Md. (Stop 9). Figures 2, 5, 6,and 8 are from Camp Roosevelt, on the Chesapeake Bay, Calvert County, Md. (Stop 8). Figure 7 is from Mrs. Anderson's Cottages, near Plum Point, on the Chesapeake Bay, Calvert County, Md.]

FIGURE

1. *Pecten humphreysii* Conrad, 1842.
   Right valve of specimen (USNM 380693); length 52.2 mm, height 47.6 mm.
2. *Bicorbula idonea* (Conrad, 1833).
   Right valve of specimen (USNM 380694); length 28.0 mm, height 24.9 mm.
3. *Pecten humphreysii* Conrad, 1842.
   Left valve of specimen (USNM 380695); length 48.4 mm, height 35.5 mm.
4. *Lirophora latilirata* (Conrad, 1841).
   Right valve of specimen (USNM 380696); length 19.9 mm, height 15.6 mm.
5. *Melosia staminea* (Conrad, 1839).
   Right valve of specimen (USNM 380697); length 30.0 mm, height 28.0 mm.
6. *Astarte cuneiformis* Conrad, 1840.
   Left valve of specimen (USNM 380698); length 35.6 mm, height 25.0 mm.
7. *Mercenaria* sp.
   Right valve of specimen (USNM 380699); length 92.5 mm, height 91.4 mm.
8. *Marvacrassatella melinus* (Conrad, 1832).
   Left valve of specimen (USNM 280700); length 80.9 mm, height 51.8 mm.
9. *Ecphora tricostata pamlico* Wilson, 1987.
   Apertural view of specimen (USNM 280701); height 73.6 mm.

PLATE 6.

[Mollusks common in the Choptank Formation]



FIGURE

1. *Stewartia anodonta* (Say, 1824).
   Right valve of specimen (USNM 405221) from Drumcliff (Jones Wharf), on the Patuxent River, St. Marys County, Md. (USGS Locality 26557); length 46.2 mm, height 49.0 mm.
2. *Lucinoma contracta* (Say, 1824).
   Right valve of specimen (USNM 405225) from Calvert Beach, on the Chesapeake Bay, Calvert County, Md.; length 37.8 mm, height 34.0 mm.
3. *Timothynus subvexa* (Conrad, 1838).
   Right valve of specimen (USNM 405227) from Calvert Beach, on the Chesapeake Bay, Calvert County, Md.; length 35.6 mm, height 32.1 mm.
4. *Astarte thisphila* Glenn, 1904.
   Left valve of holotype specimen (USNM 405239) from Drumcliff (Jones Wharf), on the Patuxent River, St. Marys County, Md. (USGS Locality 26557); length 27.0 mm, height 25.3 mm.
5. *Isognomon (Hippochaeta)* sp.
   Left valve of nearly complete specimen (USNM 405192) from Long Beach, on the Chesapeake Bay, Calvert County, Md.; length 105.0 mm.

6, 7. *Ecphora meganae* Ward and Gilinsky, 1988.
   6. Apertural view of holotype (USNM 405320) from Drumcliff (Jones Wharf), on the Patuxent River, St. Marys County, Md. (USGS Locality 26557); height 64.6 m.
   7. Posterior view of the same specimen.

8. *Turritella* sp.
   Apertural view of specimen (USNM 405306) from Drumcliff (Jones Wharf), on the Patuxent River, St. Marys County, Md. (USGS Locality 26557); height 21.4 mm.
9. *Scaphella virginiana* Dall, 1890.
   Apertural view of neotype (USNM 405342) from Drumcliff (Jones Wharf), on the Patuxent River, St. Marys County, Md. (USGS Locality 26557); height 74 mm.

PLATE 7.

[Mollusks common in the St. Marys Formation]

FIGURE 1. *Conus deluvianus* Green, 1830.
Apertural view of neotype (USNM 405343) from above Windmill Point, St. Marys River, St. Marys County, Md. (USGS Locality 26554); height 55.3 mm.

2. *Urosalpinx subrusticus* (d'Orbigny, 1852).
Apertural view of specimen (USNM 405326); height 27.7 mm.

3. *Nassarius (Tritiaria) peralta* (Conrad, 1868).
Apertural view of specimen (USNM 405335) from above Windmill Point, St. Marys River, St. Marys County, Md. (USGS Locality 26554); height 14.9 mm.

4, 6. *Mactrodesma subponderosa* (d'Orbigny, 1852).
4. Exterior of right valve (USNM 405256) from above Windmill Point, St. Marys River, St. Marys County, Md. (USGS Locality 26554); length 103.8 mm, height 78.2 mm.
6. Interior view of left valve (USNM 405257) from the same locality; length 104.2 mm, height 80.9 mm.

5. *Buccinofusus parilis* (Conrad, 1832).
Apertural view of specimen (USNM 405339) from above Windmill Point, St. Marys River, St. Marys County, Md. (USGS Locality 26554); height 101.5 mm.

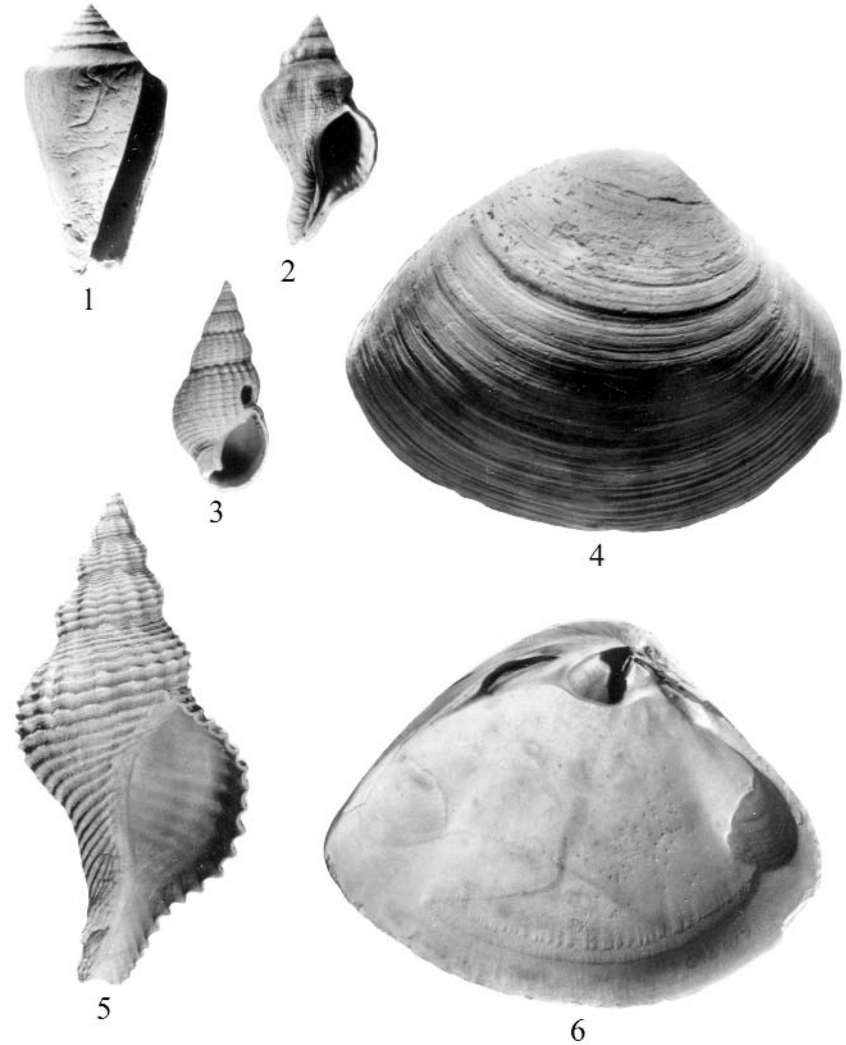


PLATE 8.

[Mollusks common in the Claremont Manor Member of the Eastover Formation. Figures 1, 4, and 6 are from Cobham Wharf, Va. (USGS Locality 26052). Figures 2, 3, 5, 10, and 12 are from just above Sunken Meadow Creek, Surry County, Va. (USGS Locality 26041). Figures 7–9 and 11 are from just below the mouth of Upper Chippokes Creek on the James River, Surry County, Va. (USGS Locality 26042).]

FIGURE 1. *Isognomon* sp.
Right valve of nearly complete specimen (USNM 258347); length 150.3 mm.

2. *Ecphora gardnerae whiteoakensis* Ward and Gilinsky, 1988.
Apertural view of specimen (USNM 258348); height 74.4 mm.

3. *Mercenaria* sp.
Left valve of specimen (USNM 258349); length 93.5 mm, height 75.9 mm.

4. *Glycymeris virginiae* Dall, 1898.
Left valve of specimen (USNM 258350); length 60.5 mm, height 65.1 mm.

5. *"Area" virginiae* Dall, 1898.
Right valve of specimen (USNM 258351); length 82.2 mm, height 57.3 mm.

6. *Lirophora dalli* Olsson, 1914.
Right valve of specimen (USNM 258352); length 19.3 mm, height 17.2 mm.

7. *Dallarca carolinensis clisea* (Dall, 1898).
Left valve of specimen (USNM 258353); length 42.7 mm, height 44.1 mm.

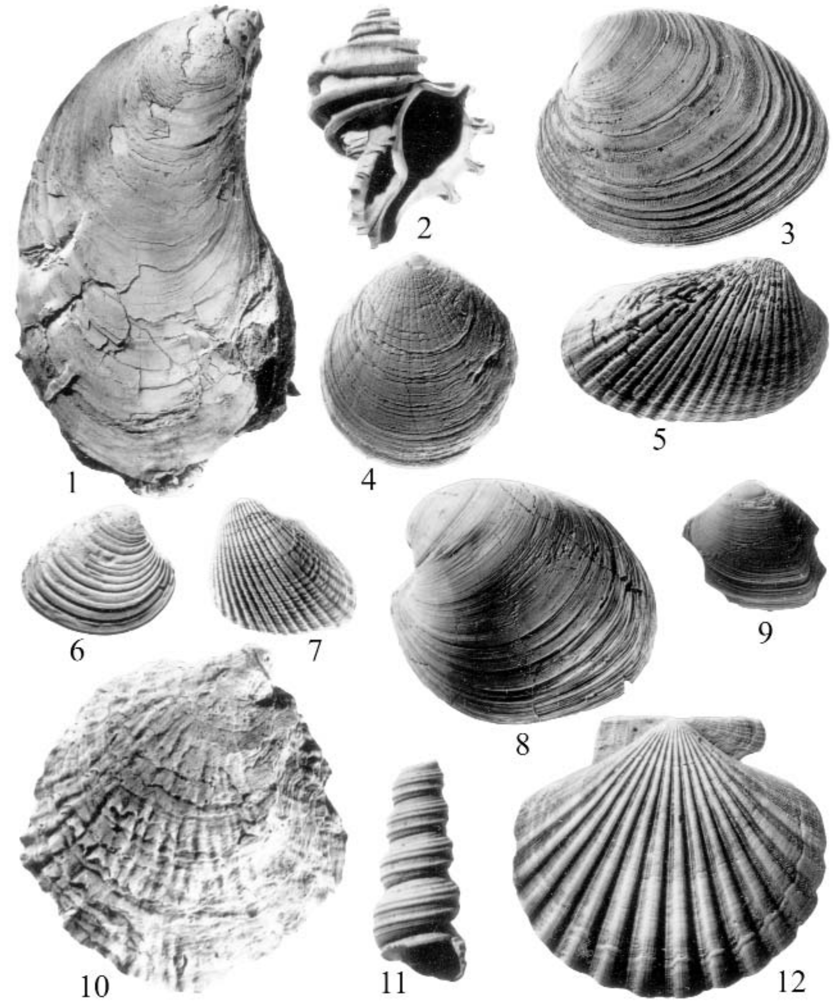
8. *Glossus fraterna* (Say, 1824).
Left valve of incomplete specimen (USNM 258354); length 82.3 mm, height 80.2 mm.

9. *Euloxa latisulcata* (Conrad, 1839).
Left valve of an incomplete specimen (USNM 258355); approximate length 15 mm, height 13.1 mm.

10. *Ostrea compressirostra brucei* Ward, 1992.
Left valve of specimen (USNM 258356); length 97.7 mm, height 111.9 mm.

11. *Turritella plebeia* ssp.
Apertural view of incomplete specimen (USNM 258357); height 98.8 mm.

12. *Chesapecten middlesexensis* (Mansfield, 1936).
Right valve of specimen (USNM 258358); length 98.8 mm, height 91.4 mm.



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