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Tertiary Molluscan Assemblages from the Salisbury Embayment of Virginia

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ABSTRACT

The Tertiary strata of the Salisbury embayment of Maryland and Virginia contain an excellent record of molluscan assemblages for the last 65 million years. Various basin configurations, sea-level fluctuations, and climatic trends combined to produce a habitat increasingly provincial in nature, in which a predominately temperate assemblage evolved. Paleocene and Eocene molluscan assemblages closely resemble those in the Gulf states such as Alabama and Mississippi. Lower Oligocene beds in the Salisbury embayment are known to occur only in several deep boreholes, but upper Oligocene beds crop out. These beds contain mollusks that became the dominant taxa during the Miocene and most of the Pliocene. Some of the taxa, such as *Glossus, Ecphora, Chesapecten*, and *Marvacrassatella*, were extremely successful in the temperate Miocene–Pliocene embayment but became extinct during the post-Yorktown (late Pliocene) sea-level fall. That event, during which both sea level and temperatures dropped, resulted in the apparent extinction of approximately 55% of the Yorktown species. The Chowan River embayment, which followed in the late Pliocene, lacked many of the previously abundant taxa and was inhabited principally by subtropical species, which migrated northward as temperatures rose.

Key Words: Chesapeake Bay, paleogeography, mollusks, extinctions, climate

INTRODUCTION

Tertiary beds exposed along the shores of the Chesapeake Bay and its tributaries contain an excellently preserved record of marine transgressions. This record consists of a number of unique, mappable beds, each with its own assemblage of marine fossils, that may be traced and correlated over the Maryland and Virginia Coastal Plains.

In order to reconstruct the geologic history of the Chesapeake Bay area, a thorough knowledge of the lithologic nature of the various beds is necessary. With these data assimilated, a series of models approximating the changing basinal areas can be constructed.

The fossil assemblages, consisting principally of mollusks, help to correlate the lithic units and give valuable information on the paleoenvironment and paleoecology. Assemblages can be correlated confidently to time-equivalent geologic units to the south and help to develop a regional paleogeographical model.

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 (Figure 1) (Ward, 1984). The Salisbury embayment includes

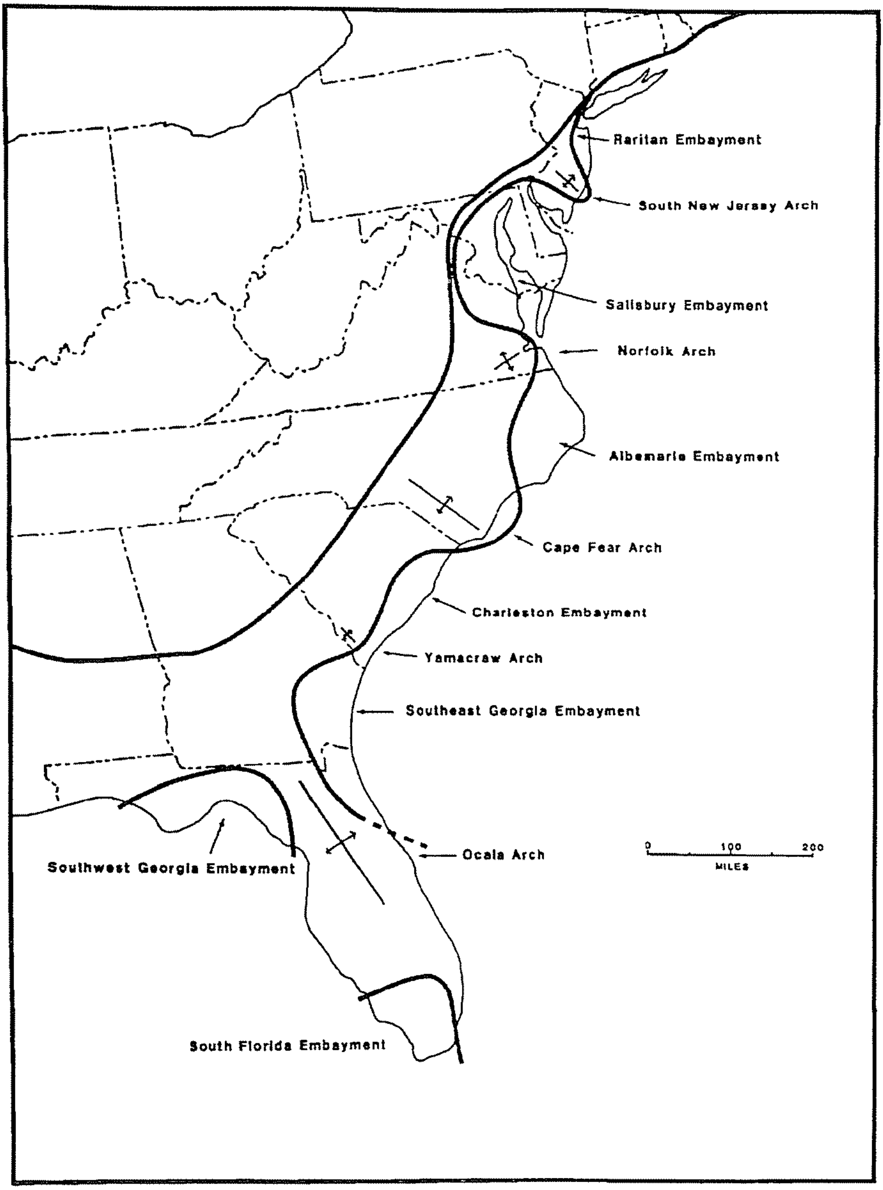

FIGURE 1. Map showing principal basins and arches of the Atlantic Coastal Plain.

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 Cretaceous and Tertiary age formations. 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 near the present coastline.

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 included block-faulting and possible movement of the landward extensions of oceanic transform faults. 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, down-dropped grabens that occur along northeast-southwest 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. This 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 interfluves in the Salisbury embayment area and are thought to be Miocene, Pliocene, and/or Pleistocene ages.

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

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

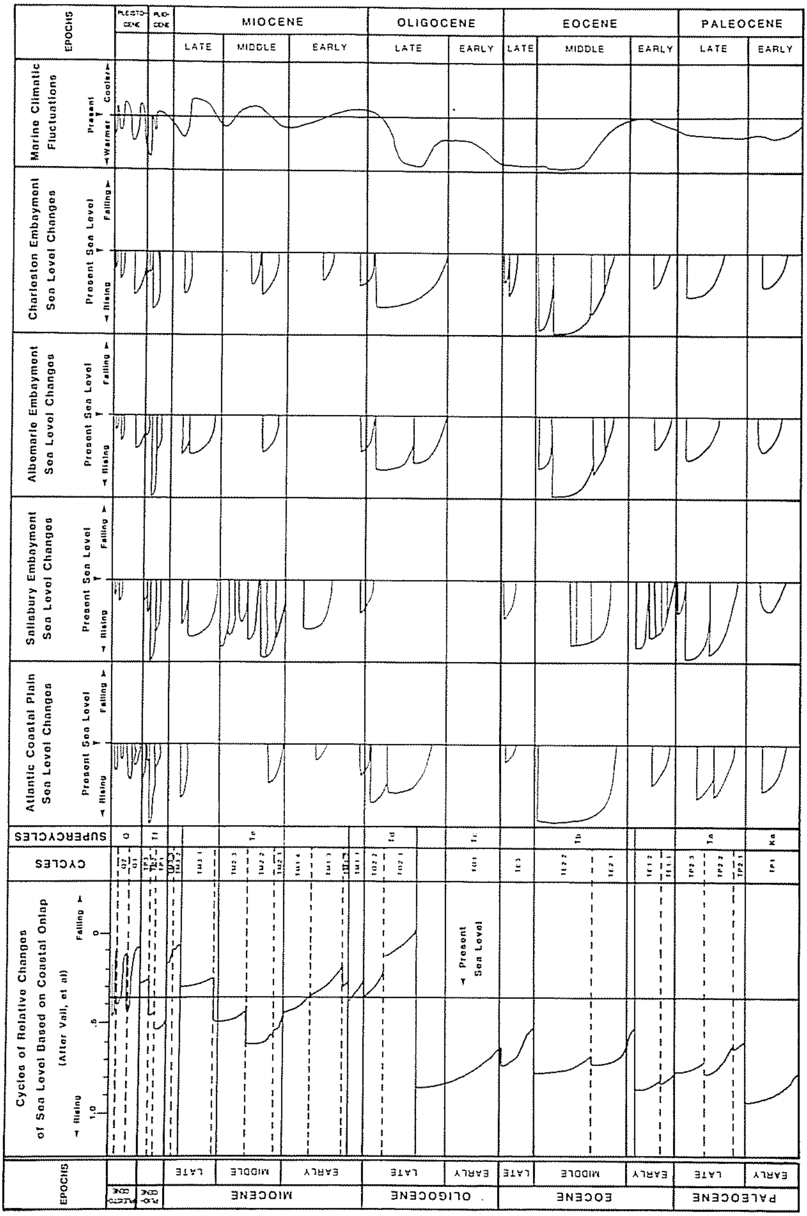

FIGURE 2. Onlap-offlap history of the Atlantic Coastal Plain, based on onshore outcrop and subsurface data. Sea-level fluctuations in the Salisbury, Albemarle, and Charleston embayments are plotted against a chart of cycles and supercycles by Vail and Mitchum (1979). Data from the basins are combined 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.

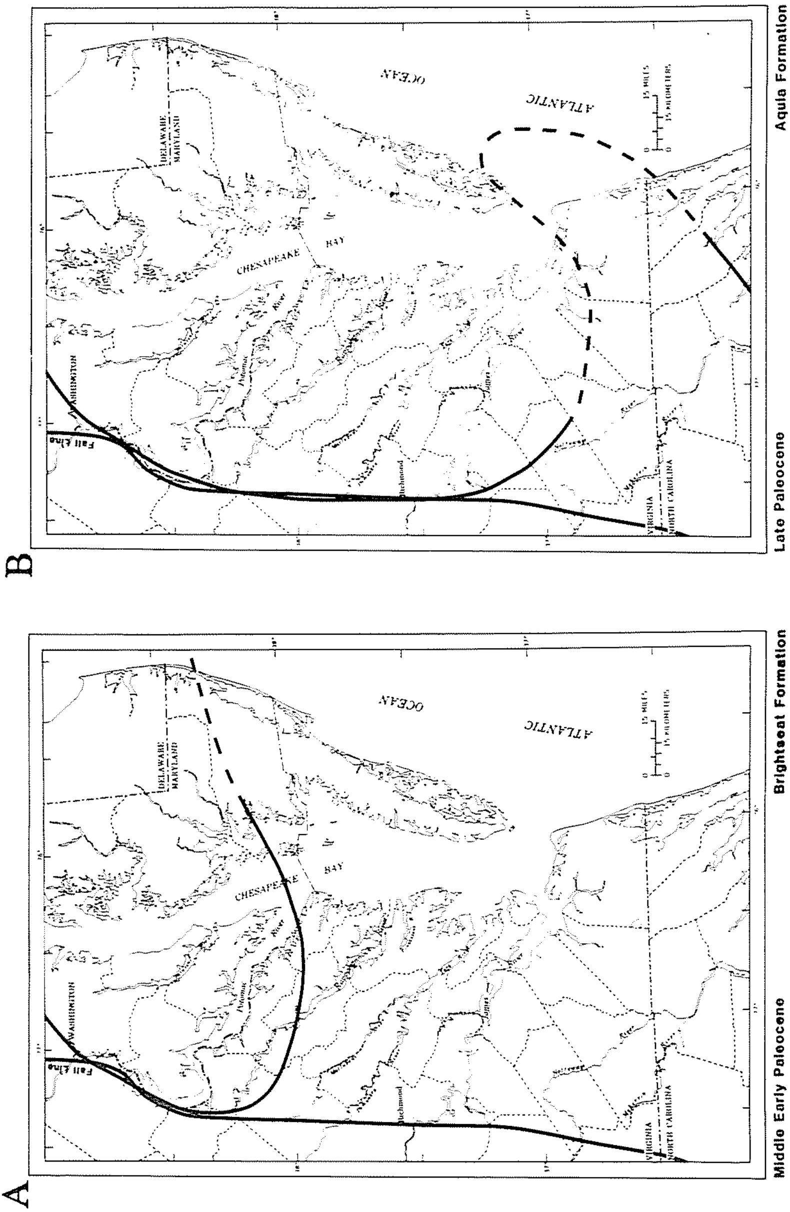

FIGURE 3A & 3B. Maps showing depositional basins during the Paleocene. Dashed lines indicate areas where boundary data are lacking.

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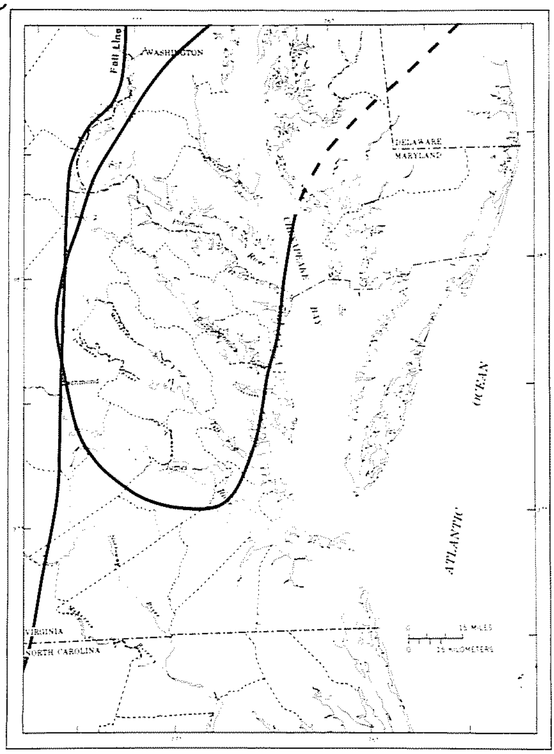

Late Paleocene Marlboro Clay

FIGURE 3C. Maps showing depositional basins during the Paleocene. Dashed lines indicate areas where boundary data are lacking.

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 super-cycles of Vail and Mitchum (1979). The curves are based on my interpretation of onshore outcrop and subsurface data. No attempt has been made to plot sea-level changes beyond the present coastline. The trends discussed below are based on the onlap relationships of formations in the three basins.

PALEOCENE

In the middle early Paleocene, there is evidence of a moderately strong marine pulse. Sediments of the Brightseat Formation in the Salisbury embayment (Figure 3A), the Jericho Run Member of the Beaufort Formation in the Albemarle embayment, and the Black Mingo Formation in the Charleston embayment were deposited during this transgression. Another extensive onlap sequence occurred during the late Paleocene and lasted almost that entire period. In the Salisbury embayment, beds associated with the latter event are included in the Aquia

Formation (Figure 3B). 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 (Figure 3C).

Paleocene mollusks were relatively diverse and essentially the same assemblage occurred from Maryland to Texas. The assemblage was dominated by large *Turritella*, but also common were very large *Ostrea*, culminating in *Ostrea sinuosa*, which can be 28 cm in diameter. The fauna seems to indicate warm, temperate marine conditions.

EOCENE

During the early Eocene a moderately extensive transgression occurred in the Salisbury embayment (Potapaco Member of the Nanjemoy Formation, Figure 4A). In the late early Eocene a second transgression occurred, which is reflected in the Salisbury embayment by the Woodstock Member of the Nanjemoy Formation (Figure 4B).

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 (Figure 4C). To the south, equivalent strata consist 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; Figure 4D). This thin unit contrasts with the thick stratigraphic sequence deposited in the Gulf area at that time. The Gulf deposits suggest 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.

The molluscan assemblages in the lower Eocene were meager by comparison with those in the Paleocene but by the middle Eocene they were extremely diverse. The mollusks in the late Eocene of Virginia are unknown, since the beds are only in the subsurface. Evidence in Alabama suggests a large extinction at the end of the middle Eocene, a repopulation during the late Eocene, and another large extinction event at the end of the Eocene. The Salisbury embayment was at least subtropical during the Eocene with a tropical setting just to the south of the Norfolk Arch, in the Carolinas.

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 relatively high stand, 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,

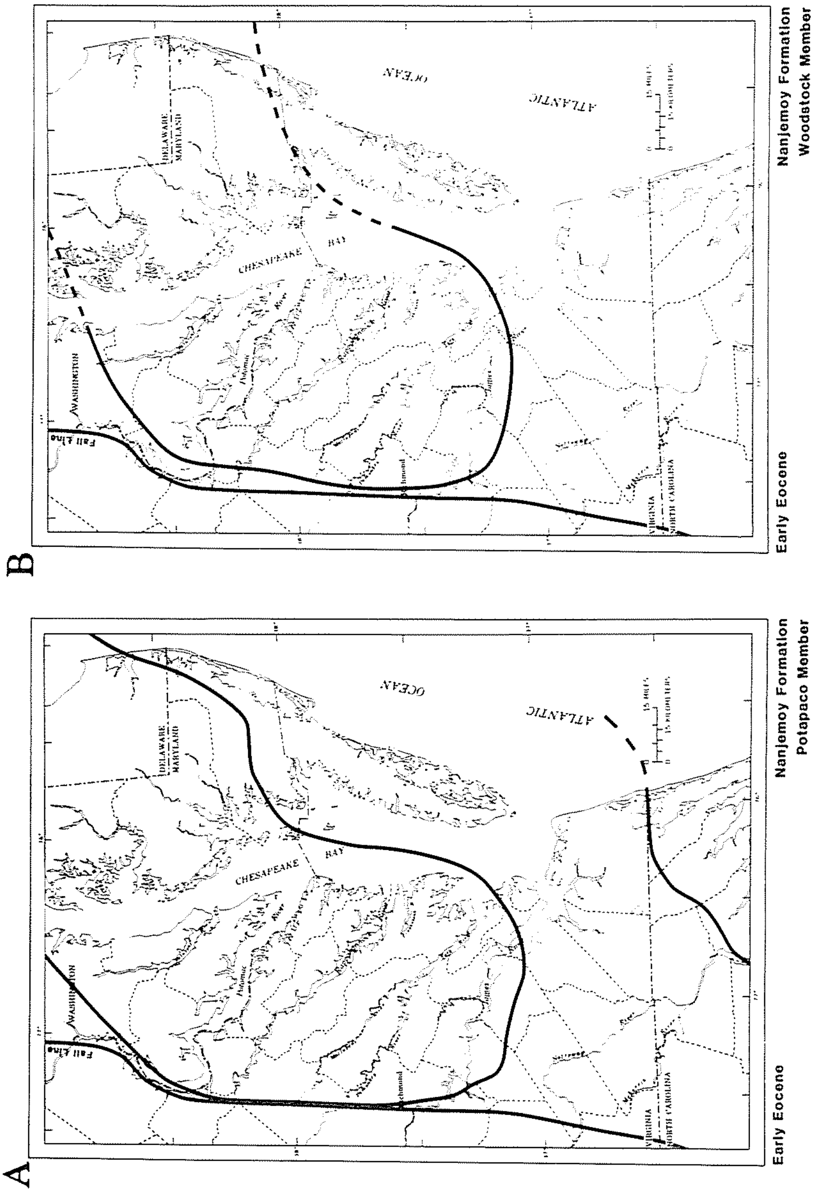

FIGURE 4A & B. Maps showing depositional basins during the Eocene. Dashed lines indicate areas where boundary data are lacking.

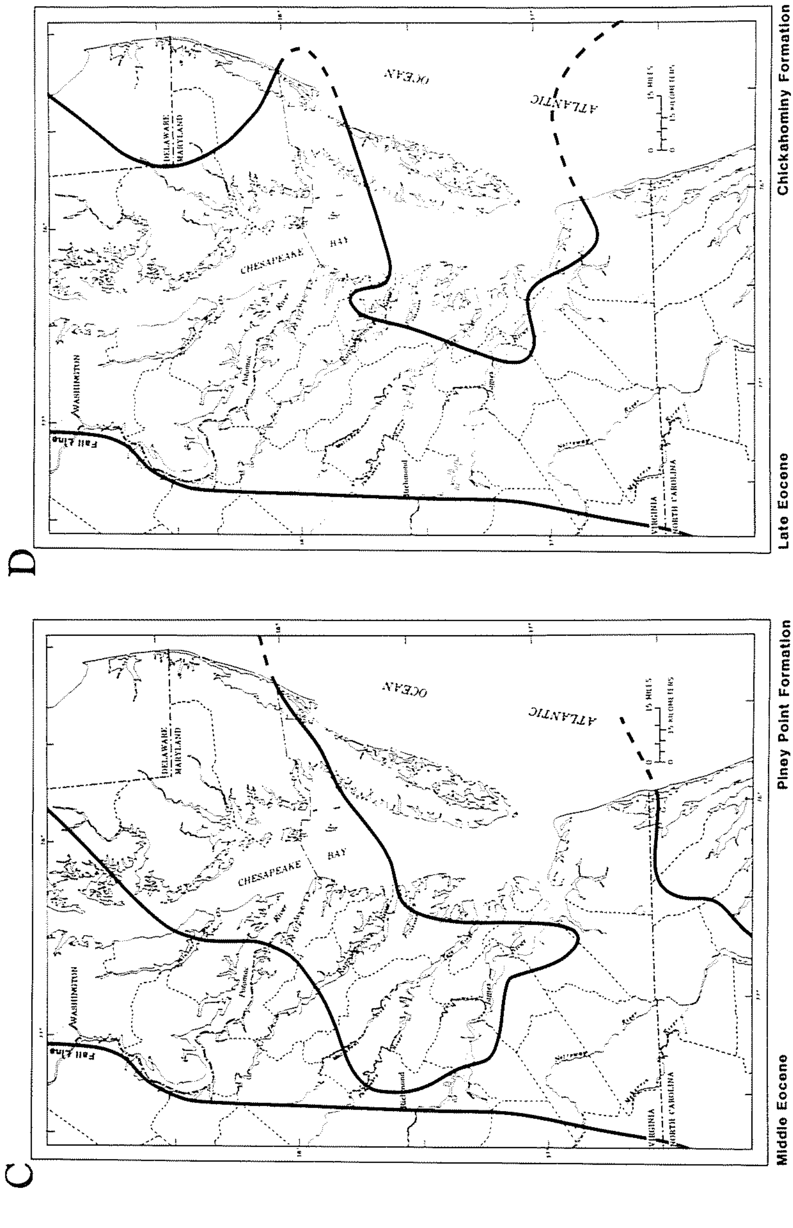

FIGURE 4C & D. Maps showing depositional basins during the Eocene. Dashed lines indicate areas where boundary data are lacking.

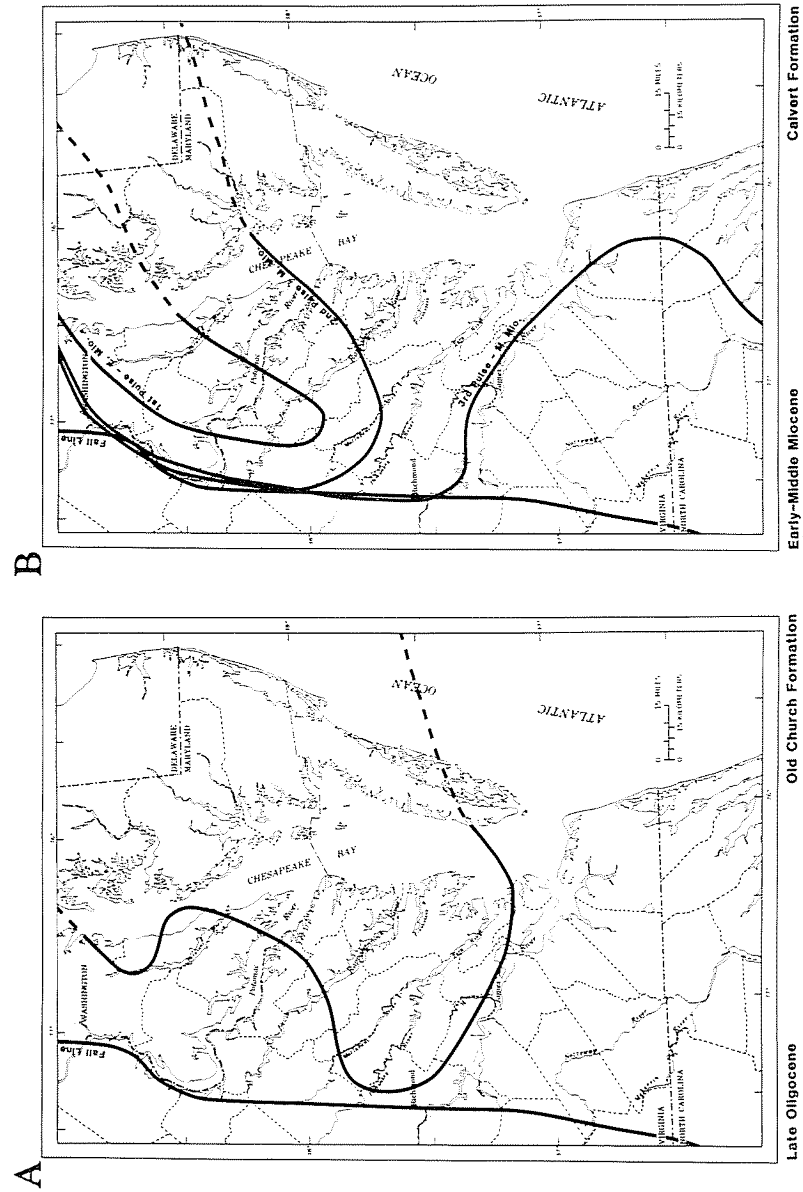

FIGURE 5A & B. Maps showing depositional basins from the late Oligocene thru the middle Miocene. Dashed lines indicate areas where boundary data are lacking.

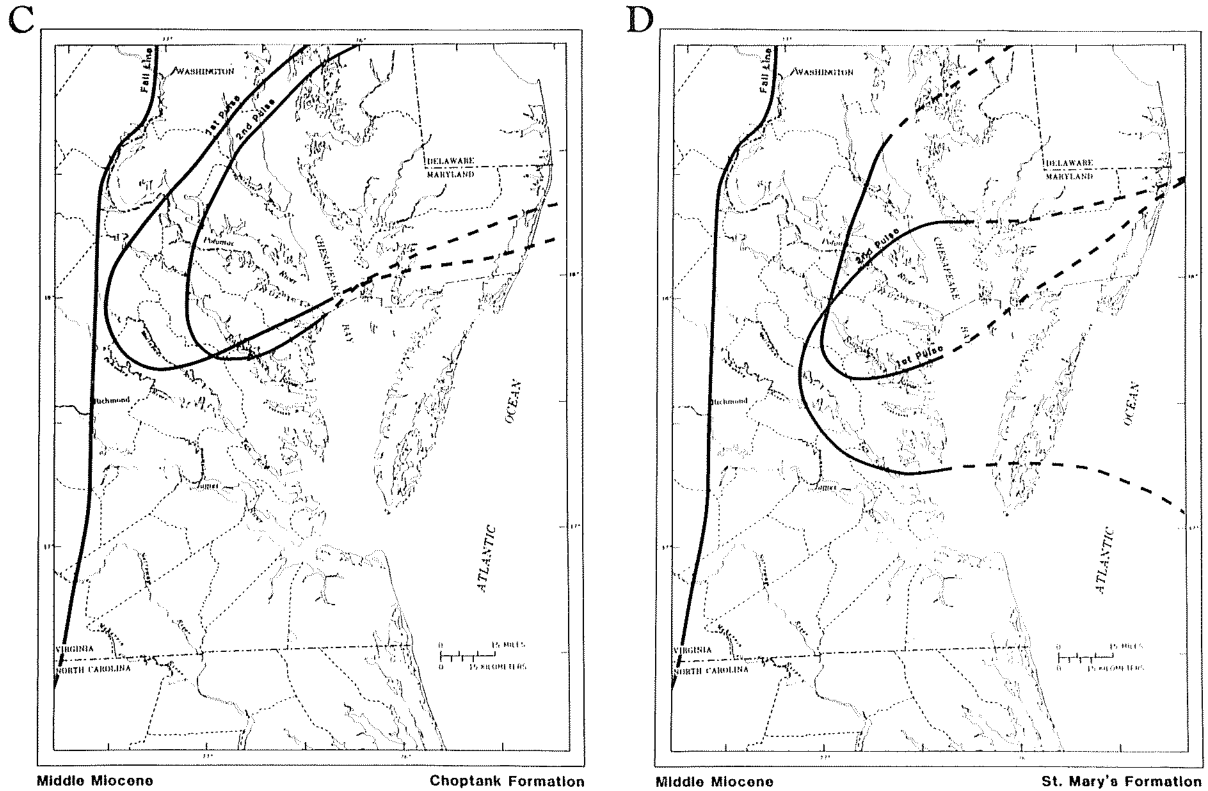

FIGURE 5C & D. Maps showing depositional basins from the late Oligocene thru the middle Miocene. Dashed lines indicate areas where boundary data are lacking.

Figure 5A). In spite of the thinness of these deposits, their wide occurrence is good evidence for a global sea-level rise and the submergence of much of the Atlantic Coastal Plain (Ward, 1985).

Molluscan assemblages in the Old Church Formation are mixed, with both tropical and cool water forms present. This condition may have been produced by upwelling along the coast.

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; Figure 5B). 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 predominate in a seaward direction. Small-scale marine pulses brought coarser sediments deep into the embayment and still-stands 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 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 (Figure 5C). Beds of the first transgression, including the Drumcliff and St. Leonard 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 (Figure 5D). 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-temperature 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-southwest 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 1.5–2.0 Ma, marine sedimentation resumed with a large-scale transgression in the late late Miocene (Figure 6A). It began with localized subsidence in central Virginia that caused the deposition of a thick sequence of inner-bay to 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 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 low stand, a renewed transgression 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; Figure 6B).

The marine conditions fluctuated constantly during the Miocene. Conditions in the early Miocene are uncertain with cool-temperate mollusks mixed with warm-temperate and subtropical forms. The middle Miocene appears to reflect cool to mild-temperate conditions. In the early late Miocene increasing molluscan diversity and the presence of some subtropical exotic taxa indicate at least warm-temperate conditions. In the middle late Miocene there was a cooling event followed by increasing temperatures in the late late Miocene. This culminated in a warm-temperate/subtropical molluscan assemblage in the late Miocene. This warm period was followed by an abrupt cooling event, which carried on into the early Pliocene.

PLIOCENE

During the Pliocene, at least four marine transgressions are recorded in southeastern Virginia. The first, a limited, shallow-shelf, temperate-water deposit (Sunken Meadow Member, Yorktown Formation) (Figure 6C), occupied about half the areal extent of the Claremont Manor Member but also overlapped the Norfolk arch extending deep into the Albemarle embayment. A second, more extensive transgression took place in the early late Pliocene (Rushmere Member and Morgarts Beach Member) (Figure 6C). This pulse covered most of the Virginia Coastal Plain, overlapped the Norfolk arch and the Cape Fear arch, and extended as far south as the Southeast Georgia embayment on the Atlantic coast. Sediments deposited during this period within the Salisbury and Albemarle embayments have been termed the Rushmere and Morgarts Beach Members. A brief regression followed the Morgarts Beach but deposition resumed in the southeastern Virginia area with the shelly, bioclastic sands of the Moore House Member. This embayment was restricted to an area north of the Norfolk arch and south of the Piankatank River (Figure 6C). A final transgression during the late Pliocene was centered mainly in northeastern North Carolina but overlapped slightly into southeastern Virginia and resulted in the shelly sands of the Chowan River Formation (Figure 6D).

The moderately diverse early Pliocene molluscan assemblage suggest cool-temperate conditions. During the late Pliocene diversity increased with increasing

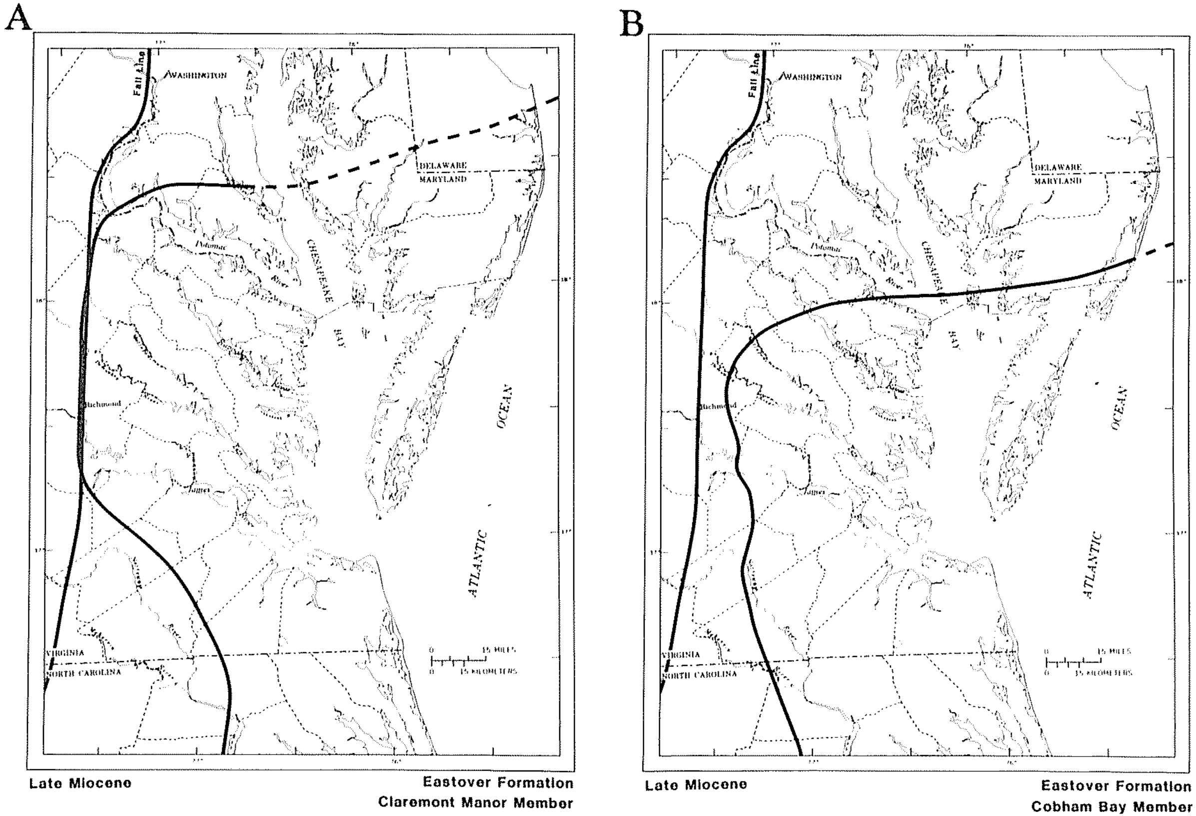

FIGURE 6A & B. Maps showing depositional basins from the late Miocene thru the late Pliocene. Dashed lines indicate areas where boundary data are lacking.

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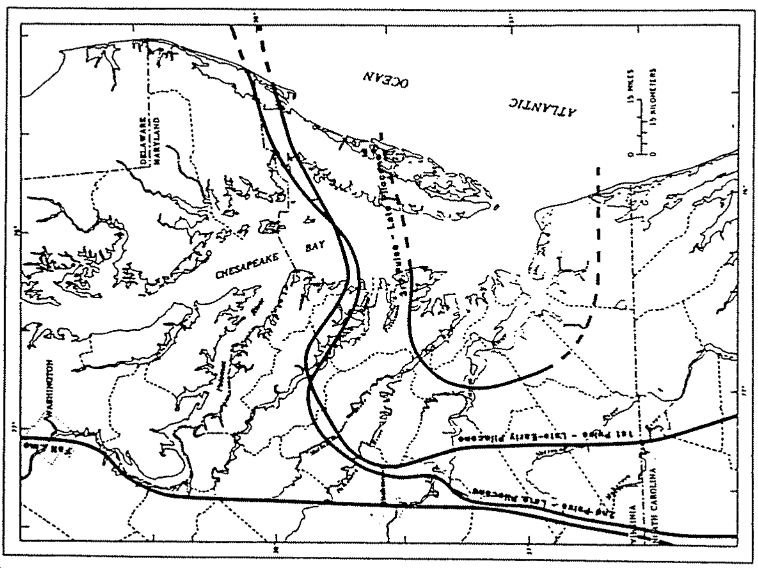

Early–Late Pliocene Yorktown Formation

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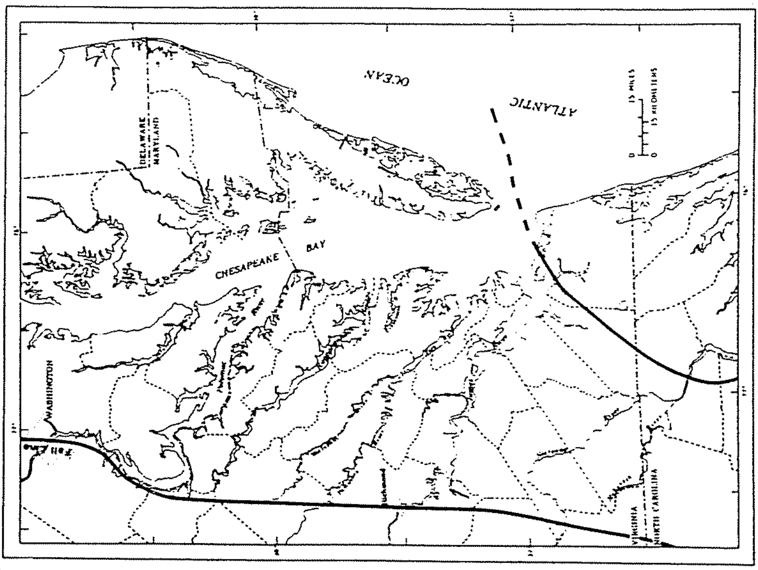

Late Pliocene Chowan River Formation

FIGURE 6C & D. Maps showing depositional basins from the late Miocene thru the late Pliocene. Dashed lines indicate areas where boundary data are lacking.

temperatures. Mollusks in the upper part of the Yorktown Formation indicated warm-temperate to subtropical conditions. In the late Pliocene, at approximately 3.0 3.5 Ma, an abrupt lowering of sea level at the same time there was a severe cooling event produced a large-scale extinction event. This event decimated the temperate fauna, which had predominated since the late Oligocene. A subsequent warming during the late Pliocene (2.0 Ma) accompanied a transgression of the Salisbury embayment (Figure 6D), but many of the taxa so common there previously were missing. During the latest Pliocene and Pleistocene repeated severe cooling events entirely removed the temperate setting and fauna. Today boreal currents meet subtropical ones at the Cape Hatteras axis.

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