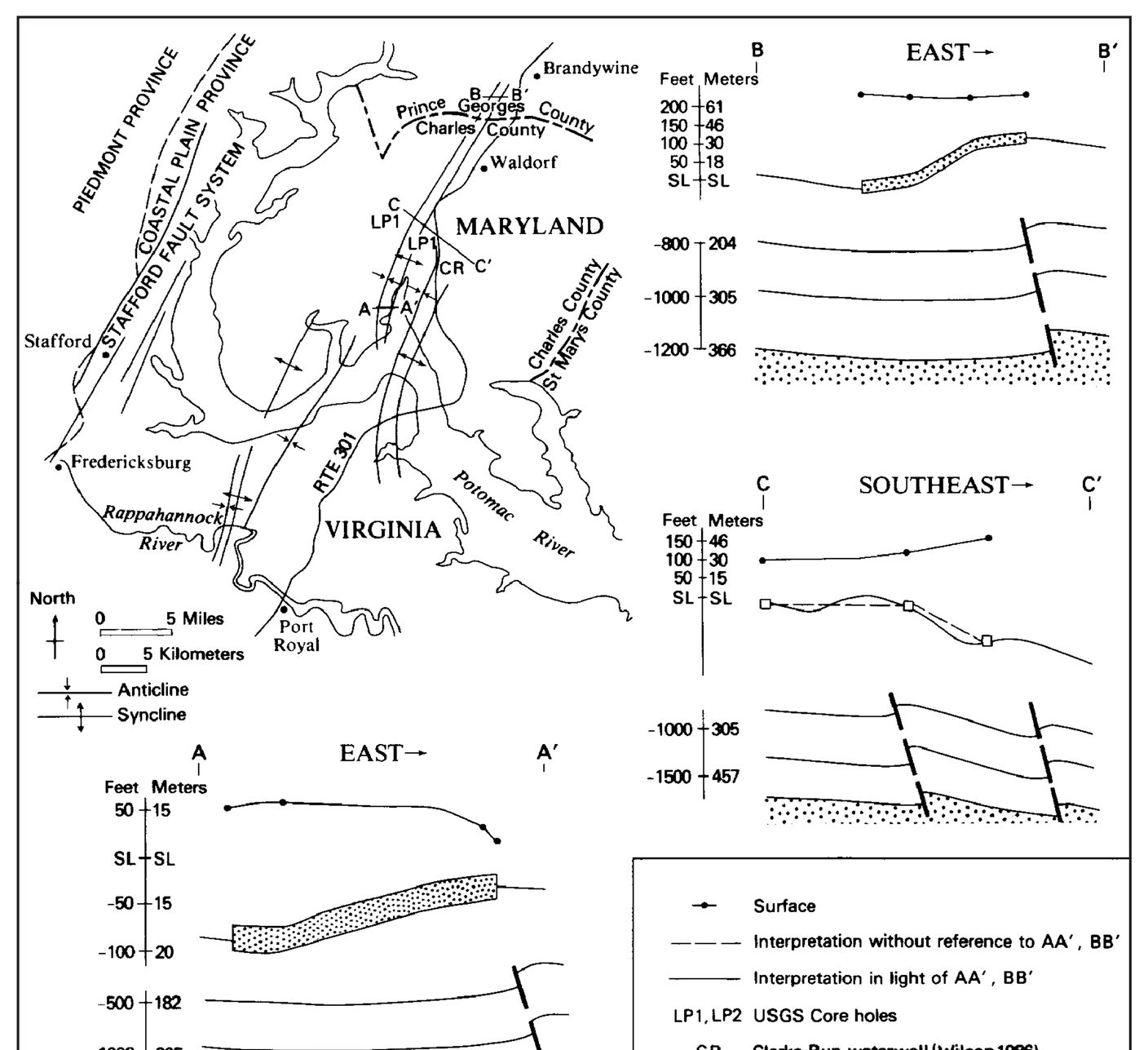
Geologic Map of Charles County, Maryland



STRUCTURE

The Coastal Plain section is about 900 ft (275 m) thick just east of the Potomac River and about 1650 ft (500 m) at the eastern edge of the county. Beneath the Coastal Plain units are older Mesozoic sedimentary and igneous rocks contained in discontinuous northeast-trending extensional basins. The extent of these basins in Charles County is not known due to sparse data. The basement is composed of several metamorphic rock types similar to those exposed in the Piedmont Province west of the Fall Zone (Daniels and Leo, 1985; Hansen and Edwards, 1986).

There appear to be two structural domains: the western third of the county is part of a faulted and folded block with northeast-trending structures; the eastern part of the county has southeast-trending structures. The western block extends to the Fall Zone and contains the Stafford Fault System and Port Royal-Brandywine structures (Mixon and Powars, 1984) (fig. 1). The faults originate in the basement and penetrate the Coastal Plain cover where it is thin, as in the Stafford, Va., area. A thicker sedimentary section such as in Charles County responds to the underlying faults by warping. The attitudes and offsets of the faults and the shapes of the folds in the western block suggest episodic west-northwestward compression since the Early Cretaceous (Mixon and Powars, 1984; Newell, 1984; Prowell, 1983, 1988). East of Zekiah Swamp, Charles County appears to be underlain by a southeastward-trending trough that may be controlled by basement faults. The different response to northwestward compression in this region as compared with that of the western area is probably related at least partly to the thickness of the Coastal Plain section and the relative position of the two domains within the Salisbury Embayment. At the inner edge of the Coastal Plain, the sediment responds in a brittle manner, and fractures and displacements result. Where Coastal Plain deposits are thicker and the angle between the direction of compression and the edge of the basin differs from 90 by more than a few degrees, the basement rocks may respond by fracturing and faulting at 30 to 45 to the compression, and the sediment may respond by warping into local en echelon arches and basins along the same trends.

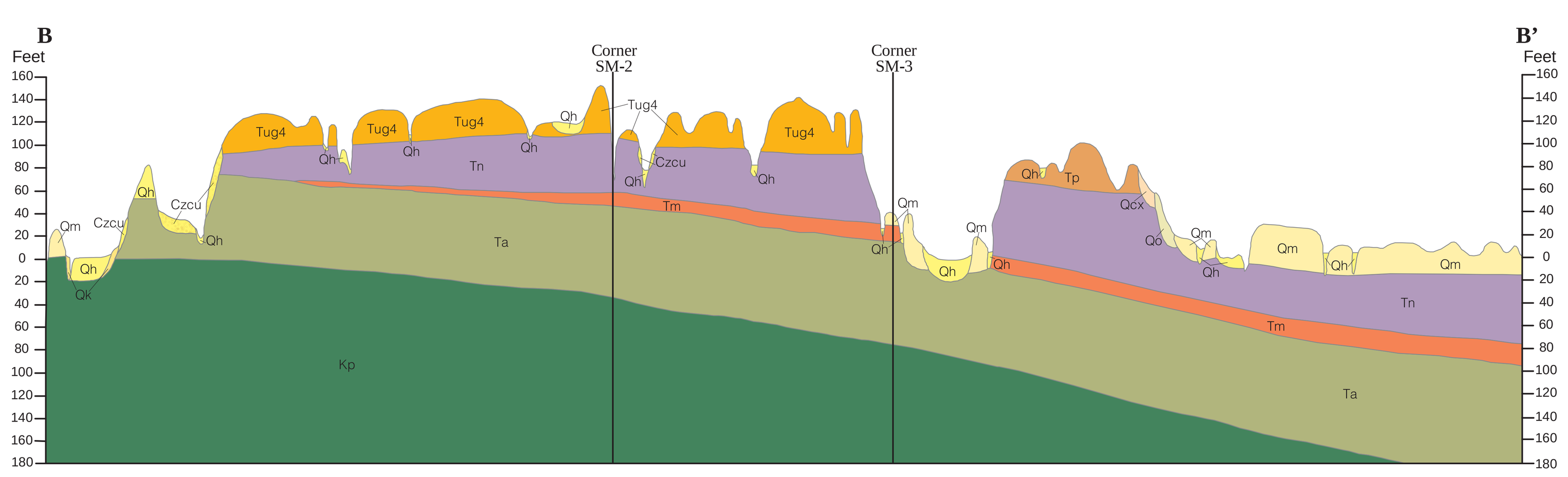
The distribution of lithologic facies within many of the Coastal Plain units appears to reflect control of depositional patterns by tectonic movements and structures. Whereas a passive erosional surface may explain the textural and mineralogic trends of a single unit, the effects of topography would be damped by subsequent erosion and deposition unless the relief was maintained tectonically. In other words, if superimposed or even adjacent but offset channels or lows and associated positive areas can be inferred from the distribution of sediments in two or more successive units that record deposition over millions of years, it is reasonable to conclude that the features are tectonically controlled. In Charles County, such control is inferred for units ranging in age from the Holocene through at least the Paleocene and possible through much of the Mesozoic as well. A similar interpretation for nearby part of the Virginia Coastal Plain was made earlier by Newell (1984).

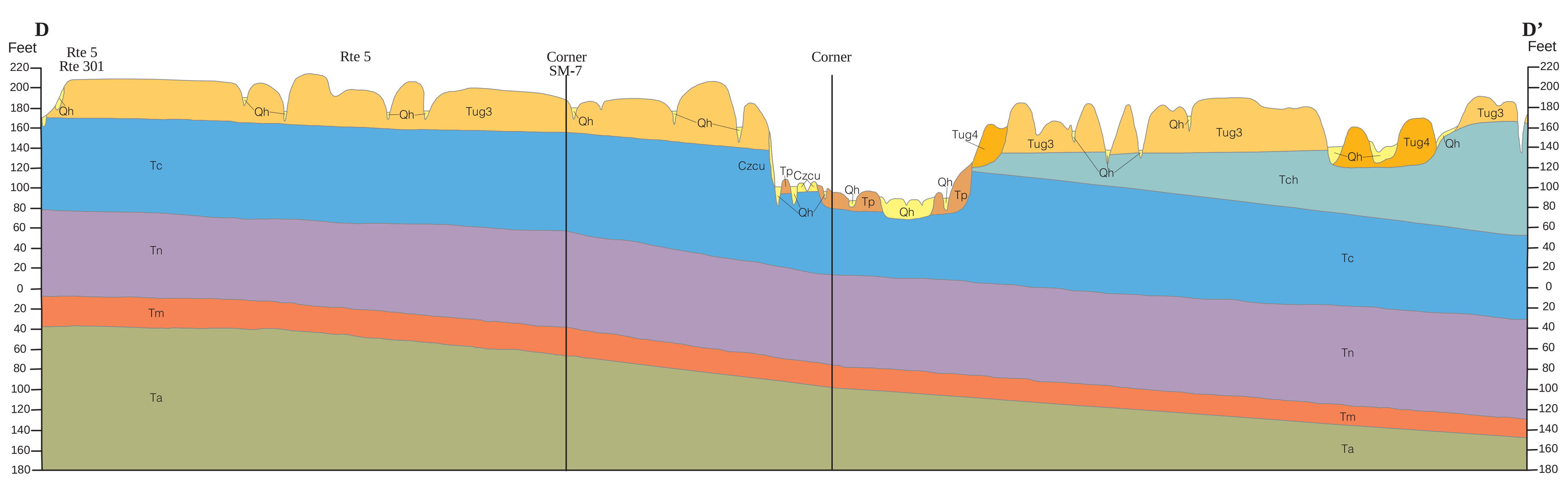
Table 1. Regional correlations of Miocene and younger units.

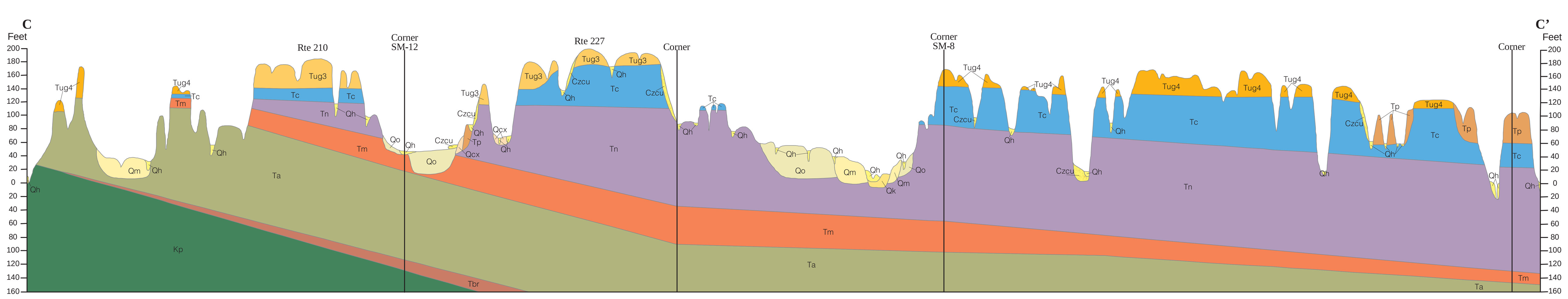
STRATIGRAPHIC AGE	VIRGINIA COASTAL PLAIN MAP Mixon and others, 1989	THIS MAP	EASTERN SHORE (1) = Owens and Denny, 1978, 1979a, and 1979b (2) = Mixon, 1985
HOLOCENE	---------- Qh and some Qu	(Ccu) Cenozoic colluvium (Qh*) Holocene deposits	---------- Qal (1), Qtm (1)
PLEISTOCENE	Poquoson Formation and Lynnhaven Formation	(Qk) Kent Island Formation	Kent Island Formation (1)
	Sedgefield Formation	(Qm) Maryland Point Formation	Nassawadox Formation (2) and Ironshire Formation (1)
	Shirley Formation	(Qo) Omar Formation, estuarine facies	Omar Formation (1)
	Chuckatuck Formation and Charles City Formation	(Qcx) Chicamuxen Church Formation	----------
PLIOCENE	Windsor Formation Bacon's Castle Formation Yorktown Formation	(Tp) Park Hall Formation (Tug4) Upland Gravel 4 (Tug3) Upland Gravel 3	Walston Silt (1) Beaverdam Sand (1) ----------
MIOCENE	Choptank Formation Calvert Formation	(Tch) Choptank Formation (Tc) Calvert Formation	Choptank Formation (1) Calvert Formation (1)

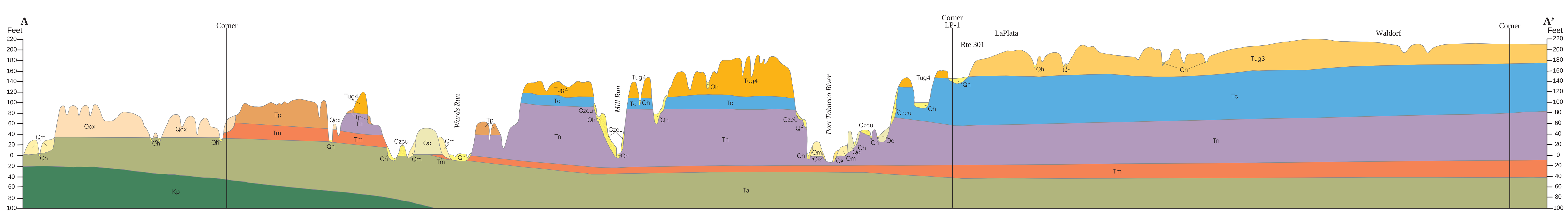
*Qh is designated Qal on Maryland Geological Survey geologic maps for all counties except Charles and St. Marys.

Cross Sections
Vertical Exaggeration ≈ 50 x









DESCRIPTION OF MAP UNITS

Czcu

CENOZOIC COLLUVIUM UNDIVIDED -- Poorly sorted, massive to crudely bedded clay to cobble-size material, yellow to deep red-brown in older deposits. Bedding is subparallel to lower contact. Larger clasts are matrix supported. Matrix and larger clasts were derived from underlying Cretaceous to Pleistocene units. Clasts of iron oxide-cemented zones are common. Colluvium forms by slow creep or mass movement downhill. Accumulations form intermittently on intermediate slopes, probably during extended periods of moderate rainfall. In Charles County, colluvium is typically 3-10 ft (1-3 m) thick. The thickest, most extensive colluvium forms as aprons at toes of scarps bounding Quaternary terraces. Similar accumulations along scarps between Pliocene deposits are deeply weathered and dissected.

Qh

HOLOCENE DEPOSITS UNDIVIDED -- Unconsolidated deposits beneath the adjacent to modern swamps and waterways. Poorly sorted sand and gravel, well-sorted sand, silt, and clay. Coarser sediment is tan except where it is dark green to black due to locally reworked glauconite; finer sediment is greenish gray to black due to incorporation of organic material and fine grained reworked glauconite. Beds along the Potomac and Wicomico River contain sparse brackish water clam shells *(Rangia cuneata)* as well as locally abundant lenses of shells reworked from units as old as Paleocene. Depositional environments inferred for material mapped as Qh include tidal marsh, river, and swamp. Thickness ranges from 2-20 ft (1-6 m) and possibly thicker in some channels. Windblown sand deposits, typically less than 1 ft (0.3 m) thick, are present in a few open areas such as plowed fields but are not shown on the map.

Qk

KENT ISLAND FORMATION (UPPER PLEISTOCENE) -- Mainly fine- to medium-grained, moderately sorted to poorly sorted silty sand, tan to orange, with minor gray silty to sandy dewatered clay. Deposits of this formation are found along the Potomac River and the lower reaches of other streams, but are most significant on Cobb Neck, Cedar Point Neck, and the head of Zekiah Swamp Run estuary. Wavy, subhorizontal bedding planes about 2-4 inches (5-10 cm) apart are typical in sandier parts of the unit west of Nanjemoy Creek. Common minerals, derived mainly from adjacent highlands, include quartz, glauconite, ilmenite, leucoxene, staurolite, rutile, tourmaline, zircon, kaolinite, vel111lculite, goethite, and gibbsite.
A single ^{14}C date on wood chips from a Kent Island Formation clay bed in the vicinity of the Goose Bay Aggregate Company's docking facility south of Chicamuxen Creek is 20,500 +/- 500 years (M. Rubin and R.M. Mixon, USGS, written communication, 1986). The Kent Island Formation in Charles and St. Mary's Counties and the eastern shore of the Chesapeake Bay was deposited mainly in an estuary and it correlates with similar deposits south of the Potomac River (Poquoson and Lynnhaven Formations, Mixon and others, 1989). Peat samples in the Kent Island and age-equivalent Sinepuxent Formation east of the Chesapeake Bay have yielded ^{14}C dates in the 24,000-37,000 BP range (Owens and Denny, 1978). In the type area, the Kent Island Formation originally included two estuarine units (Owens and Denny, 1979a). Owens (pers. comm., 1988) now separates those units; the upper, which contains the dated peat samples, belongs to the Kent Island Formation in the revised sense, and the lower unit is probably part of the Ironshire Formation.
In Charles County, the lower contact of the Kent Island Formation is an erosional unconformity marked by a layer of pebbles and either root casts or burrows, on units of Pleistocene to Cretaceous age. The unit is typically 5-20 ft (1.5-6 m) thick with the top of the unit at about 20 ft (6 m) elevation, and the base at about sea level.

Qm

MARYLAND POINT FORMATION (UPPER PLEISTOCENE) -- Fine- to coarse-grained sand, well-sorted to poorly sorted, grayish orange, in the upper third of the unit; poorly sorted silty gray to olive clay in most of the lower part, and olive gray pebbly sand at the base. The clay contains plant fragments in places. Most of the sediment was reworked from adjacent highlands. Oyster beds with sandy mud matrix are found at 2-10 ft (1-4 m) above sea level in bluffs east and west of Maryland Point. Wavy bedded white and orange sand exposed for kilometers between Nanjemoy Creek and the Prince George's County line, broken by overgrown areas of slumping, are also part of the Maryland Point Formation.
The unit extends into St. Mary's County and correlates with beach and shallow marine facies, east of Chesapeake Bay (Ironshire Formation, Owens and Denny, 1979a; Nassawadox Formation, Mixon, 1985), and south of the Potomac River (Sedgefield Formation, Mixon and others, 1989). Corals in the part of the Norfolk Formation (Oaks and others, 1974) that is correlative with the Maryland Point and Ironshire Formations have a uranium-disequilibrium-series age of about 70,000 years (Szabo, 1985). The lower contact is an erosional unconformity marked in places by pebbles, cobbles, and root casts. In Charles County, the Maryland Point Formation is usually found overlying Miocene and older units. It is typically 25-40 ft (8-14 m) thick with the upper contact about 30 ft (9 m) and the lower contact at about 0-10 ft (0-3 m) below sea level.

Qo

OMAR FORMATION, ESTUARINE FACIES (UPPER PLEISTOCENE) -- In Charles County, mud and muddy fine sand grading downward to fine gravel with coarse sand matrix. Typically weathered, with colors ranging from yellow to brown. Most extensive just south of the Prince George's County line; along the Potomac River , also present in narrow erosional remnants of fluvial terraces. Omar sediment derived from surrounding highlands contains minerals such as quartz, ilmenite, kaolinite, illite, vermiculite, goethite, and gibbsite. The Charles County deposits are part of the Omar Formation that was described east of Chesapeake Bay (Owens and Denny, 1979a); the Omar correlates with the Shirley Formation south of the Potomac (Mixon and others, 1989). A coral from equivalent deposits in a bluff near the mouth of the Rappahanock River gave a uranium-disequilbrium-series age of about 180,000 years (Mixon and others, 1982). The lithologic sequence in the Omar Formation in Charles County is more similar to that of the Shirley Formation in Virginia than to the Omar Formation in St. Mary's County. One interpretation is that the lower half of the depositional cycle (transgressive phase) is recorded in Charles County, and the upper half (regressive phase) is preserved in St. Mary's County.
The Omar is unconformably overlain by the Maryland Point and Kent Island Formations, and by Holocene deposits. This contact lies below 20-30 ft (6-15 m) elevation. The upper depositional surface of the unit reached about 50 ft (15 m). The lower contact is an erosional unconformity on the Chicamuxen Church and older formations. Thickness ranges from 10-50 ft (3-15 m).

Qcx

CHICAMUXEN CHURCH FORMATION (MIDDLE TO LOWER PLEISTOCENE) -- Silty clay and muddy fine sand, grading downward to pebbly mud or sand; colors are typically grayish yellow, orange, and brown. Dominant minerals are quartz, illmenite, kaolinite, vermiculite, gibbsite, and goethite. The Chicamuxen Church Formation is the main Pleistocene unit between Sandy Point and Maryland Point on the Potomac River where surface elevations are between about 70 and 90 ft (21-27 m). It accumulated in a stream and estuary system.
The Chicamuxen Church Formation is present in St. Mary's County and is correlated with the Chuckatuck and Charles City Formations (undivided) in Virginia (Mixon and others, 1989). In North and South Carolina, a unit in this stratigraphic position has yielded several coral uranium-disequilibrium-series dates of about 450,000 years (Szabo, 1985), and has normal magnetic polarity (Liddicoat, 1979, 1981), indicating an age less than-about 700,000 years. In most places, the Park Hall Formation, Tug4, and Tug3 were eroded prior to deposition of the Chicamuxen Church Formation. The depositional surface of the unit is at about 70-90 ft (21-27 m), and the thickness ranges from 35-55 ft (11-17 m). It is unconformably overlain by the Omar Formation in a few places.

Tp

PARK HALL FORMATION (UPPER PLIOCENE) -- Silty, fine-grained sand, and fine- to medium-grained sand and clay interbedded with medium- to coarse-grained sand with pebbles, cobbles, and boulders. Coarser material is common at the base. Typical colors of finer grained and poorly sorted material are pink, pale brown, or medium yellow orange. Unlike younger units, the Park Hall contains a large component of sediment derived directly from the Piedmont, Triassic basin, and Appalachian Mountains, as well as locally derived clasts. Sparse pollen is present in Park Hall clay beds at a few localities in St. Mary's County. Oak, pine, hickory, sweet gum, and black gum indicate a warm, temperature climate. The presence of a few specimens of exotics such as *Pterocarya* and *Ulmus (Zelkova)* indicate a Pliocene age (L.A. Sirkin, USGS and Adelphi University, written communication, 1980).
The Park Hall is found mainly in discontinuous meander scars south from Chicamuxen Creek to the Route 301 bridge over the Potomac River. The coarse-grained fluvial facies is best exposed in the Goose Bay Aggregates pit in western Charles County; the fine-grained estuarine facies is well exposed in cliffs near Popes Creek. Much of the formation was eroded during entrenchment of the Potomac in the Pleistocene.
The estuarine and fluvial beds composing the Park Hall Formation in Charles County are correlated with the Walston Silt of the Delmarva Peninsula (Owens and Denny, 1979b), and with shelly marine beds of late Pliocene age on the Chowan River in North Carolina (Blackwelder, 1981). The lower contact in most places is an erosional unconformity on the pre-Pliocene units; Upland Gravel 3 and 4 were probably removed by erosion that preceded deposition of the Park Hall. The Park Hall is unconformably overlain by the Chicamuxen Church Formation. The estuarine beds of the Park Hall reach a maximum surface elevation of just over 120 ft (36.5 m); the base is usually between 60-70 ft (18-21 m). Fluvial beds that are probably part of the Park Hall Formation may be found as high as 150 ft (46 m). If the Park Hall is correctly correlated with the Windsor Formation of Virginia, the late Pliocene deposits in Charles County have been uplifted more than 30 ft (9 m) relative to those in Virginia.

Tug4

UPLAND GRAVEL 4 (UPPER PLIOCENE) -- Poorly sorted fine- to medium-grained sand; lenses of muddy sand and clay; grading downward to gravelly mud or medium- to coarse-grained sand. The finer grained parts of the formation are typically gray to pink; the coarser parts are yellow and orange. Tug4 covers about half the upland area of Charles County. A 50-ft- (31-m-) deep channel at Ironsides was filled with gravel and upward-fining sand during and after Tug4 time. The lower contact of Tug4 is an unconformity on pre-Pliocene formations; the highest elevation of the unit is about 180 ft (55 m). Erosion prior to accumulation of the Park Hall Formation removed some Tug4 adjacent to the proto-Potomac River.
Tug4 can be distinguished from the Park Hall Formation and Tug3 by geomorphology, mineralogy, and texture. Tug4 is separated from Tug3 and the Park Hall Formation by low scarps that represent the northern bank of the proto-Potomac River during Tug4 time and the most landward position of the estuary beach during Park Hall time. In many places, the scarps are covered by colluvium or have been eroded back into the older unit. The scarp between Tug4 and Tug3 is most easily discerned in steep slopes descending to the Patuxent River; the scarp between Tug4 and the Park Hall Formation is most apparent in parts of St. Mary's County and in the Popes Creek area of Charles County.
Differences in the mineralogy of the weathering profiles help to distinguish the Pliocene units. Depth of the weathering front defined by the development of dioctahedral vermiculite and destruction of illite or illite-smectite is less than 3 ft (1 m) for the Park Hall, about 10 ft (3 m) for Tug4, and about 14-15 ft (4.5 m) for Tug3. In addition, the sandier parts of Tug4 and Tug3 contain a larger portion of tourmaline and zircon than does the Park Hall Formation. These minerals are resistant to weathering; within deposits from a single source-rock province, they reflect the greater age of the units in which they are more abundant. The description given by Oaks and Coch (1973) for the "sand facies" of the Bacons Castle Formation in southeastern Virginia resembles the material in Charles County assigned to Tug4. The Virginia deposits are interpreted as fluvial, unconformably overlying the Yorktown Formation; the widespread gravelly deposits that cut out Tug3 in Charles County are also largely regressive fluvial deposits except in a few places where burrowed, interbedded sand and clay beds suggest an estuarine environment (at 160 ft (49 m) near the St. Mary's County line). If the correlation of the deposits is correct, Tug4 in Charles County has been uplifted over 50 ft (15 m) relative to Bacons Castle deposits in Virginia. Tug4 may also correlate with the Beaverdam Sand (Owens and Denny, 1979a) of the Delmarva Peninsula. If the Park Hall Formation and Tug4 in Charles County are indeed correlative with the Walston Silt and the Beaverdam Sand, there may be little time represented by the unconformity between the two Charles County formations (J.P Owens, oral communication, 1987).

Tug3

UPLAND GRAVEL 3 (LOWER TO UPPER PLIOCENE) -- Predominantly interbedded medium sand and gravel with coarse sand matrix; cobbles in lower part; pebbles floating in poorly sorted sandy silt cap at the top in many places. Brick red color common in steeper slopes; orange to tan in flatter land. Fluvial deposits of Tug3 cover the highest uplands in Charles County, reaching an elevation of 230 ft (70 m) west of Waldorf. The base of the formation is about 175 ft (53 m) in the same area. The thickness is as much as 55 ft (17 m).
The original detrital mineralogy of Tug3 is best preserved in the clayier beds. The presence of feldspar, epidote, garnet, and illite in addition to more resistant minerals such as quartz and kaolinite reflects a source west of the Fall Zone. Gibbsite, diagenetic vermiculite and the red and orange colors prevalent in the more permeable lithologies of the unit reflect a long history of weathering. Bedding in Tug3 is usually subparallel, indistinct, and fairly horizontal.
Channels a few meters deep and tens to hundreds of meters wide are present in a few places. Trough crossbeds are sparse. The textures, bedforms, and lack of burrows and fossils indicate a fluvial environment of deposition. The pebbly silt cap may be an overbank deposit (Hack, 1955), a long term accumulation of windblown material illuviated into the B soil horizon, colluvium, or material gathered by a combination of these processes.
Tug3 unconformably overlies units with ages ranging from Paleocene to Miocene. It has been eroded and replaced by all younger units, but mainly by Tug4. Similar fluvial deposits assigned to Tug3, as well as shelf deposits of the Yorktown Formation, occur in St. Mary's County. In Virginia, both fluvial and marine shelf deposits are assigned to the Yorktown Formation. Gravelly sediments of the Yorktown in Virginia contain the burrows of marine organisms up to an elevation of 210 ft (64 m). This high stand of the Yorktown sea, recorded in Virginia, cannot be recognized in Southern Maryland where regression may have destroyed the evidence. Thus, the upland fluvial sediments of Southern Maryland assigned to Tug3 may be of Yorktown age, but the hard evidence is lacking.

Tch

CHOPTANK FORMATION (MIDDLE MIOCENE) -- Grayish olive, fine, well-sorted sand to silty sand interbedded with dark greenish gray, silty clay. In outcrop and the upper parts of some drill holes, the sand of the Choptank has weathered to a dark yellow-orange color and the clay has a tan color. Beds, which are typically on the order of tenths of inches to inches (millimeters to centimeters) thick, are in many places destroyed by bioturbation. Burrows up to three-fourths inch (1.5 cm) across filled with clean fine sand are common in some places; elsewhere, a massive, mottled appearance may be due to thorough bioturbation. The landward edge of the Choptank Formation is just east of Gilbert Swamp Run below an elevation of about 188 ft (57 m). It is unconformably overlain by Pliocene and Pleistocene estuarine deposits. The lower contact is subtle; in many places it appears to be marked only by a change from fine sand of the Choptank above to clay-rich Calvert below. Thickness of the unit ranges from about 80 ft (24 m) at the St. Mary's County line to a few inches (centimeters) three miles (5 km) west.
Fossils are preserved in the Choptank of Charles County mainly as casts and molds. Common genera in the Choptank are *Mercenaria*, *Macrocallista*, *Turritella*, *Glossus*, and *Balanus* (L. W .Ward, written communication, 1987). Three taxa found in the Oaks core in northwest St. Mary's County are *Cardium*, Turritella, and fragments of an amber colored, phosphatic-shelled brachiopod, *Discinisca* (L. W. Ward, oral communication, 1987). Based on correlation with beds in St. Mary's and Calvert Counties, the age of the Choptank in Charles County is middle middle Miocene (Andrews, 1978; Ward, 1984a). It was deposited on an open shelf under less than 200 ft (60 m) of water (Gibson, 1971), and the shore facies, presumably deposited farther west, has been eroded and replaced by younger units.

Tc

CALVERT FORMATION (LOWER AND MIDDLE MIOCENE) -- Grayish olive to dark greenish olive, very fine-grained, well-sorted quartz sand, fine sandy clay, and rare medium- to coarse-grained sand. The sands weather to tan, yellow, and orange; the weathered clays are white, gray, and pale green. The Calvert crops out in stream valleys and cliffs in many parts of the county except within 3 miles (5 km) of the Potomac River in the northwest and within 6 miles (10 km) of the river in the southwest. In Charles County, the Calvert reaches a maximum elevation of about 180 ft (55 m) beneath upland deposits near Waldorf and a maximum thickness of about 100 ft (30.5 m) in the same area. The regional dip of the base of the Calvert in Charles County is about 25 feet per mile (4.5 m/km) to the southeast.
Layers with phosphatic sand grains and pebbles, thin phosphatic shells, chalky calcareous shells, and diatoms are present at many levels in the formation. Phosphatic zones in the Calvert have a brownish cast. Bedding in the Calvert is commonly indistinct due to bioturbation. In some areas, thin alternating beds of silt and silty clay or silt and fine sand are preserved. On the basis of diatoms, the Calvert is of early to middle Miocene age (Andrews, 1978). The Calvert is overlain by Pliocene age upland deposits throughout most of the county, so its upper contact is generally an unconformity representing 11-13 m.y. Along the eastern edge of the county, the Calvert is overlain by the Choptank Formation of middle middle Miocene age; there, the unconformity is subtle and represents little time.
In most places, the lower contact of the Calvert Formation rests upon the Nanjemoy Formation of middle Eocene age. In the extreme southeastern part of the county, the Piney Point Formation (late Eocene) and the Old Church Formation (early Miocene-late Oligocene) may be present beneath the Calvert, judging from data in Virginia (Ward, 1984b) and St. Mary's County (unpublished data, USGS). All three of the older units have lithologies distinctly different from that of the Calvert, and phosphatic sand and phosphatic and quartz pebbles are commonly found at and just above the base of the Calvert. The underlying unit is usually riddled with large burrows filled with sand and rare pebbles from the Calvert Formation. Most of the Calvert was probably deposited in a shallow shelf environment, in water less than 200 ft (60 m) deep (Gibson, 1971).

Tn

NANJEMOY FORMATION (LOWER EOCENE) -- Dark grayish green to olive black (tan to orange where weathered) fine- to medium-grained glauconitic quartz sand and dark greenish gray silty clay. In places the sand is very muddy or contains many small quartz pebbles, and the clay is silty or sandy. Both lithologies contain richly fossiliferous beds including abundant *Venericardia*. The Nanjemoy crops out in valleys in the western half of the county except for the 3- to 4-mile strip adjacent to the north-south stretch of the Potomac River estuary. Its maximum thickness is about 230 ft (70 m) in the eastern part of the county (Dryden and Overbeck, 1948), and its regional dip is eastward at 15-20 ft per mile (3-3.5 m/km). The highest elevation at which Nanjemoy is found is about 125 ft (38 m) in the northwestern part of the county; it reaches sea level at about the Route 301 bridge over the Potomac River. The Nanjemoy is overlain by the Calvert Formation (lower and middle Miocene) or younger units throughout most of Charles County. The Calvert contact is burrowed and marked by sharp lithologic changes, from the muddy fine- to medium-grained quartz sand with abundant phosphate grains in the Calvert to the underlying muddy, medium-grained quartz sand with abundant glauconite and mica typical of the Nanjemoy. The lower contact of the Nanjemoy is also burrowed, and it is marked by an abrupt change to the Marlboro Clay, or, in a few places, the more subtle change to the sand of the Aquia Formation, which in most instances is somewhat better sorted than the Nanjemoy. Both contacts are unconformities, and the upper at least represents a significant loss of time, as the age of the Nanjemoy is early Eocene (calcareous nannoplankton zones NP10-12, L.M. Bybell, USGS, written communication, 1985, and Gibson and others, 1980), and stratigraphically adjacent units are the Paleocene Marlboro Clay below and the Miocene Calvert Formation above.
The Nanjemoy Formation was divided into two members, the lower or Potapaco, and the upper or Woodstock, by Clark and Martin (1901). The main lithologic distinction is that the lower part of the Nanjemoy is much clayier than the upper part. In Charles County clays and sands in the Nanjemoy appear to alternate irregularly and no county-wide division into members has been made. But in the outcrops along the Maryland bank of the Potomac River near Popes Creek, Ward (1984a) placed the contact between the Woodstock and Potapaco at about 10 ft (3 m) above the water level.
The depositional environment is probably shallow shelf (Ward, 1984a). The clayier beds suggest an area or time of quiet water, not affected by waves, tides, or current activity; intercalated sandier zones may reflect the higher energy of waves or currents during episodic storms.

Tm

MARLBORO CLAY (UPPER PALEOCENE - LOWER EOCENE) -- Medium to silvery gray, pink, and light-red; yellow to light-gray where weathered. It is mainly clay or silty clay, with sparse lenses containing dark gray to pink and yellow silt.
The Marlboro is the most distinctive and stratigraphically useful marker unit in Charles County because it is a thin but widespread clay between two dark, glauconitic, micaceous sand units, the Nanjemoy and Aquia Formations. It is found in outcrops roughly 1-6 miles (1.6-10 km) east of the Potomac River estuary, and in the subsurface farther east. The thickness ranges from 0-40 ft (0-12 m) but is typically 10-20 ft (3-6 m) thick. The regional dip is southeastward at 15-20 ft per mile (3-3.5 m/km). Both upper and lower contacts are sharp and burrowed in some places (Glaser, 1971; Ward, 1984a). Elsewhere, material from the Aquia appears to have been reworked into the lowest part of the Marlboro, and some of the top of the Marlboro appears to have been reworked into the base of the overlying Nanjemoy Formation.
Macrofossils have not been found in the Marlboro in Charles County, but microfossils here and elsewhere suggest that the Paleocene-Eocene boundary is contained in the Marlboro (calcareous nannoplankton zone NP9 and NP10, L.M. Bybell, written communication, 1985 and oral communication, 1987, supported by pollen (Frederiksen, 1979; see also Frederiksen and others, 1982) and dinoflagellates (Gibson and others, 1980). The texture and microfossil assemblage suggest that the Marlboro was deposited in a shallow, nearshore marine environment such as a tidal flat (Glaser, 1971) estuary (Gibson and others, 1980).

Ta

AQUIA FORMATION (UPPER PALEOCENE) -- Olive black to olive gray micaceous, glauconitic fine- to coarse-grained quartz sand with a few beds of olive gray silty clay and very fine sandy silt. It crops out in a belt about 4 miles (6 km) wide along the western edge of Charles County, and reaches a maximum elevation of about 110 ft (33 m). Sorting in the sand ranges from moderate to poor. Burrowing has disrupted the primary bedding in most cores and outcrops, and organic activity probably contributed to the poor sorting. Chalky shell fragments occur in beds up to 1.5 ft (0.5 m) thick with fine-grained sand and silt matrix. *Turritella* and *Ostrea* are two of the most abundant mollusks in the Aquia in Charles County. Zones of light gray concretions and hard beds up to several inches (centimeters) thick are common. In most cases they are fine- to medium-grained sand cemented by either calcite or dolomite. Rounded grains of glauconite and goethite, both probably authigenic within fecal pellets, are abundant in most samples of the Aquia (Hansen, 1974).
In most places the Aquia is overlain by the Marlboro Clay, and the contact is a sharp lithologic boundary. Burrows are sparse, and little time is missing. Where the Eocene Nanjemoy Formation directly overlies the Aquia, the contact may be indistinct, and quantitative mineralogy or fossils may be required to delineate it. The lower boundary of the Aquia is sharp where it overlies the Potomac Group or Magothy Formation but is more subtle where the Aquia lies above the Brightseat or Severn Formations. Concentrations of phosphatic clasts occur near the base of the Aquia in most places, and the Aquia is noticeably more glauconitic than the two older formations. The Aquia generally thickens from 30 ft (9 m) at the Potomac River to 175 ft (53 m) on the Patuxent, but it reaches 200 ft (61 m) in the Waldorf area (Dryden and Overbeck, 1948; Hansen, 1974). The regional dip is southeastward at 15-20 ft per mile (3-3.5 m/km).
The texture of the Aquia is coarser where the unit is thicker, toward the northeast and east. Most of the coarse clasts, other than fossils and sand-sized glauconite and goethite, are well-rounded quartz sand grains and pebbles, probably derived from the underlying Potomac Group during transgression of the Aquia sea.
The benthic foraminiferal assemblage suggests that the Aquia in Virginia was deposited under middle to shallow shelf conditions (Gibson and others, 1980). Similar conditions are indicated by the presence of glauconite regionally in the Aquia, even where large, shore-derived pebbles are abundant.
In Virginia, the Aquia Formation has been divided into two members, both of which are late Paleocene age (Clark and Martin, 1901; Ward, 1984a). The type section of the lower member, the Piscataway, is Piscataway Creek, Prince George's County, Maryland (Clark and Martin, 1901). The upper member (Paspotansa) is named after Passapatanzy Creek, King George County, Virginia (Clark and Martin, 1901). Ward (1984a) characterized the lower member as having poorer sorting and more obvious bedding than the upper member. In Charles County, however, wide variations in bedding and sorting exist throughout the Aquia (also observed by Hansen, 1974) and the fossils best indicate the probable correlation with the two members elsewhere. The upper part of the formation contains calcareous nannofossils of zones NP8 and NP9, whereas the lower part is correlated with NP5. In Charles County, the missing zones are reflected in a bed with sparse small phosphatic pebbles and sand at the base of the Paspotansa-correlative part of the Aquia. The Aquia crops out along the Potomac River and about the lower 50 ft (15 m) of the formation in Charles County correlates biostratigraphically with the Piscataway Member as defined by Ward (1984a). The outcrops in Nanjemoy Creek and the upper 150 ft (46 m) of the Aquia correlate with the Paspotansa member.

Tbr

BRIGHTSEAT FORMATION (LOWER PALEOCENE) -- Fine, black, micaceous quartz sand to sandy silt with abundant pyrite and sparse glauconite is typical of the Brightseat Formation in Charles County. The Brightseat is less glauconitic than the overlying Aquia Formation. It is found only in the subsurface (cross section C-C'), but crops out on the Virginia side of the Potomac in Aquia Creek. Its thickness and distribution are not known exactly, but it is most probably less than 20 ft (6 m) thick ("0-30 ft" (0-9 m) in Slaughter and Laughlin, 1966), comprised of discontinuous lenses beneath the eastern half of the county. It is reported to be thicker and more clayey in Prince George's County (Hazel, 1968; Bennett and Collins, 1952). Both the upper and lower contacts are burrowed in places. Phosphate clasts are common in the formation, and are also present at the base of the overlying Aquia Formation. Based on ostracode and foraminiferal paleoecology, the Brightseat Formation was probably deposited on a shallow marine shelf (Hazel, 1969; Nogan, 1964).
Ostracodes, planktonic Foraminifera, and dinoflagellates all indicate a Danian (earliest Paleocene) age for the Brightseat (Hazel, 1968; Whitney, 1984). Distinctive fossils in the Brightseat and stratigraphically adjacent formations indicate breaks in the geologic record at both the upper and lower contacts.

Kp

POTOMAC GROUP (LOWER CRETACEOUS) -- The Potomac Group is composed of poorly sorted mud and muddy to well-sorted medium- to coarse-grained quartz sand with quartz pebble layers. Typical clay colors include pale to bright red, green, and medium gray; sand is commonly gray, tan, or white. In Charles County, outcrops of Potomac Group are found sporadically in cliffs along the east bank of the Potomac River between the Prince George's County line and Liverpool Point. The highest elevation of the Potomac Group, about 50 ft (15 m), occurs in the northernmost part of the county. The clay is distinguished by cross fractures that give a blocky structure not generally found in younger units. The bulk of the clay is gray, with red iron oxide coating the fractures. The few exposures of sand have medium-scale trough and planar cross beds, with most dips to the south, southeast, and east. The sedimentary structures and textures and the lack of marine fossils indicate a fluvial depositional environment.
The upper contact and less than 50 ft (15 m) of the youngest part of the Potomac Group (the Patapsco Formation) are exposed in Charles County. The contact is an unconformity, overlain by units ranging in age from Late Cretaceous (Severn Formation, found in the subsurface of northern Charles County below the base of the cross sections) to Holocene. It is everywhere a sharp contact, commonly with quartz and phosphate pebbles at the base of the overlying unit. The Potomac Group lies on crystalline rocks 700 ft (213 m) below the Potomac River and is about 1350 ft (410 m) thick in the southeastern corner of the county. The regional dip of the crystalline basement surface is southeastward at about 100 ft per mile (18 m/km), and a marker unit in the middle of the Potomac Group dips about 50 ft per mile (9 m/km).
The age of the Potomac Group based on pollen is Early Cretaceous (at least as old as Aptian) to the earliest part of the Late Cretaceous (Cenomanian) (Brenner, 1963; Brenner in Hansen, 1968; Doyle and Hickey, 1976; Brenner in Wilson, 1986).

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ACKNOWLEDGMENTS (McCartan, 1989)

This project was jointly sponsored by the United States Geological Survey (USGS) and the Maryland Geological Survey (MGS), and benefited from the contributions of many people. In the USGS, Margery Bugen, Virginia Gonzalez, Rebecca Architzel, Dennis Duty, Don Queen, and David Soller assisted in the field; most of the mineral separations and clay analyses were performed by Bugen, Gonzales, and Architzel; Wayne Newell, James Owens, Lauck Ward, Robert Mixon, and David Powars discussed the stratigraphy; and Ward, George Andrews, Lucy Edwards, Laurel Bybell, and Les Sirkin (USGS and Adelphi University) identified the fossils. MGS provided size analyses for 50 samples of surficial units. Newell, Ward and Peter Lyttle, USGS, and James Reger, John Glaser, and James Brooks, MGS, reviewed the map and contributed useful suggestions for its improvement.

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