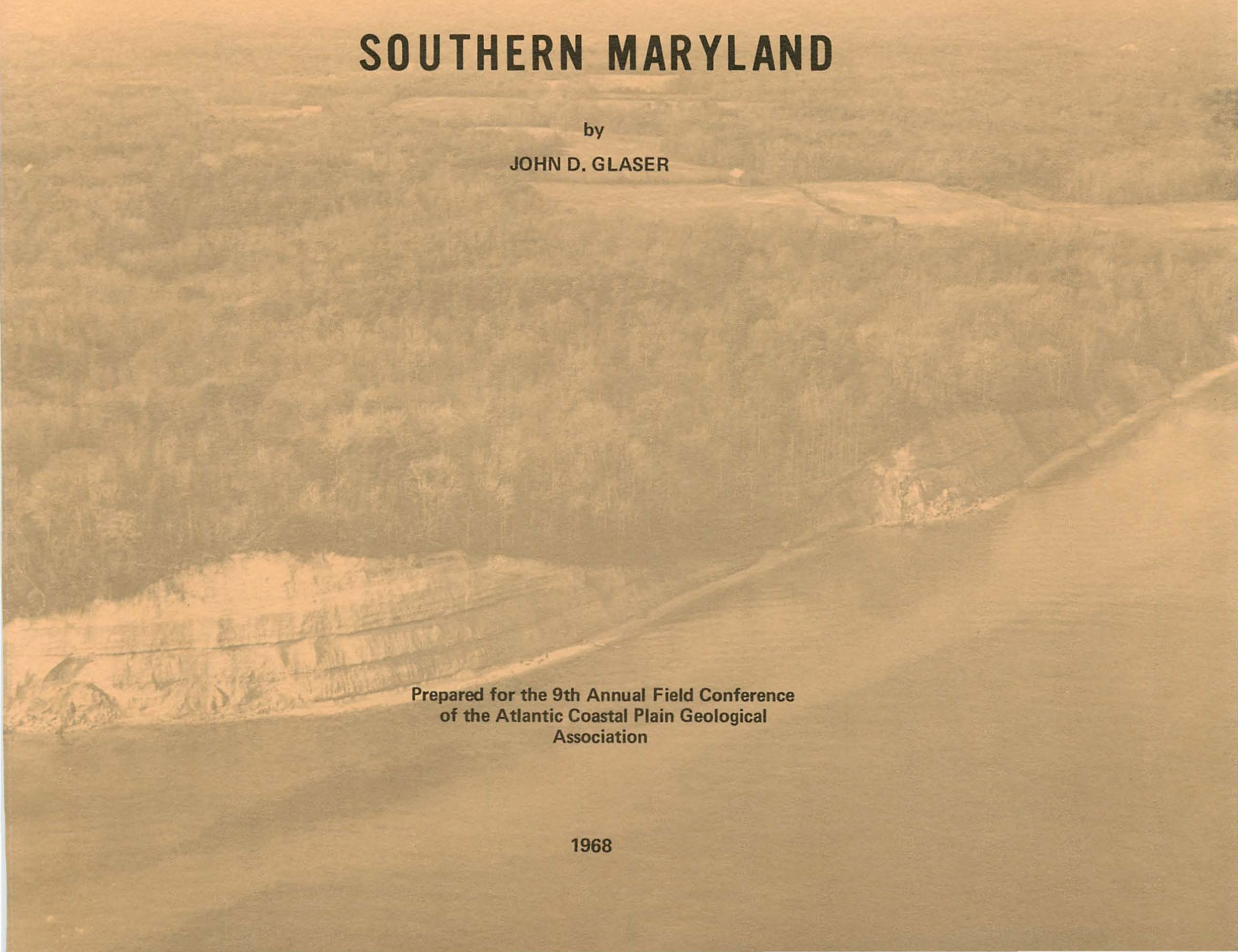
MARYLAND GEOLOGICAL SURVEY
GUIDEBOOK NO. 1

KENNETH N. WEAVER, DIRECTOR

COASTAL PLAIN GEOLOGY OF SOUTHERN MARYLAND

by

JOHN D. GLASER



Prepared for the 9th Annual Field Conference of the Atlantic Coastal Plain Geological Association

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INTRODUCTION

This guidebook has been prepared for the 9th Annual Field Conference of the Atlantic Coastal Plain Geological Association. Southern Maryland, the area selected for the field trip, has much to recommend it, from both a geologic and an historical point of view. The lower portion of the Southern Maryland peninsula served as a backdrop for the early 17th century explorations of Captain John Smith and bears numerous landmarks of colonial settlement in the New World. The "Cliffs of Calvert", first described by Smith, contain what are perhaps the finest fossiliferous Miocene exposures in the United States and yielded the first American fossil *(Ecphora quadricostata)* to be figured in a publication (Lister, 1685).

The trip has been arranged to cover representative exposures of Coastal Plain rocks ranging in age from Early Cretaceous to Miocene. In this manner, the participants may best become acquainted with the stratigraphic succession in the Maryland Coastal Plain, and more importantly, with the numerous unresolved problems in deciphering the sedimentological and structural history of the region. Despite the fact that the type areas of many widespread rock stratigraphic units in the Middle Atlantic Coastal Plain are located in Southern Maryland, only in recent years has intensive study on the part of numerous researchers begun to reveal the details of stratigraphy and structure. Much remains to be done.

ACKNOWLEDGMENTS

Thanks are due to H.J. Hansen and E.T. Cleaves, staff members of the Maryland Geological Survey, and K.N. Weaver, Director, for critical review of the text and road log. Many of their suggestions were incorporated into the final manuscript. Hansen, in particular, is responsible for several of the illustrations in the Guidebook. The author also wishes to thank G.J. Brenner for the section on Potomac Group palynology.

GEOGRAPHY AND PHYSIOGRAPHY

The Southern Maryland Coastal Plain, comprised of Anne Arundel, Prince Georges, Calvert, Charles, and St. Marys Counties, constitutes a 1,900-square-mile peninsula bounded on the east by Chesapeake Bay, by the Potomac River to the south and west, and by the Fall Zone to the north (fig. 1). The area is intensely urbanized within the Baltimore-Washington corridor but mostly rural over the main mass of the peninsula to the south. The urban portion of the region is an important segment of the rapidly-developing Atlantic Coast "megalopolis". In contrast, better than half of the remaining two-thirds of Southern Maryland is farmland with tobacco the major crop. Most of the rest is wooded.

The physiographic features of Southern Maryland have developed largely in response to Pleistocene sea-level changes. Repeated steepening and flattening of stream gradients with attendant formation and dissection of fluvial terraces, as well as the drowning of river valleys, have played a major role in shaping the present-day topography.

The greater part of Southern Maryland, in contrast to the Eastern Shore of Maryland and most of the Delaware and New Jersey Coastal Plains, is a well-dissected upland area, declining in elevation from 400 feet in the vicinity of the Fall Zone to less than 100 feet near the Bay shore. Stream valleys are commonly deep and narrow, affording local relief of 100 feet or more. With approach toward the major estuaries to the east and south, elevations fall off rapidly, and valleys tend to broaden and shallow with accompanying lessening of local relief. Bordering the lower reaches of the Potomac and Patuxent Rivers are large flat undissected areas lying between 10 and 25 feet above sea level.

The axial portion of the peninsula is dominated by a high, southeasterly sloping plain which is undergoing rapid dissection along its margins. Large areas along the axis, however, such as the region north and northeast of La Plata (fig. 1), have not been reached by headward erosion and are notably flat with no surface drainage.

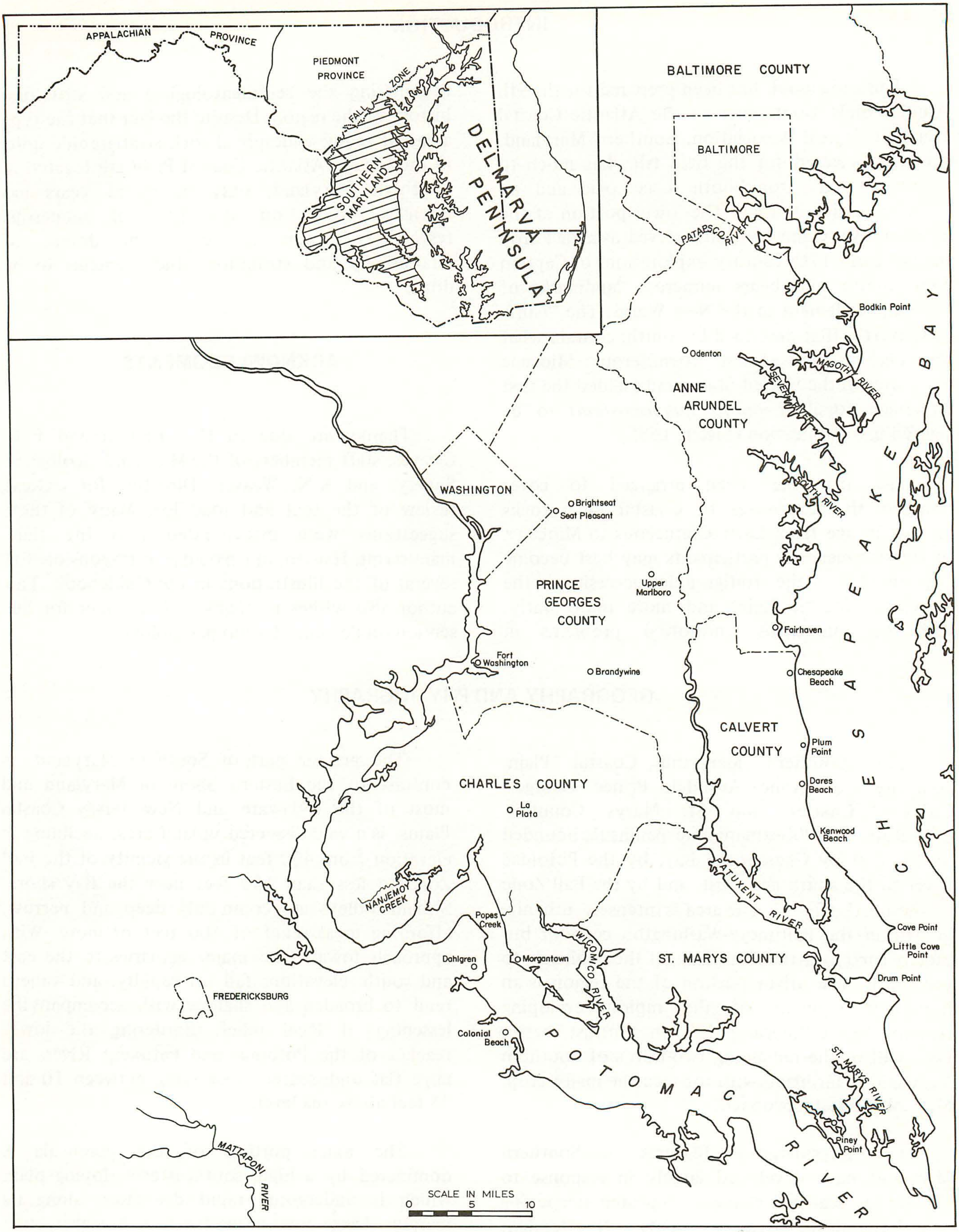

Figure 1. Index map of Southern Maryland showing geographic names employed in text.

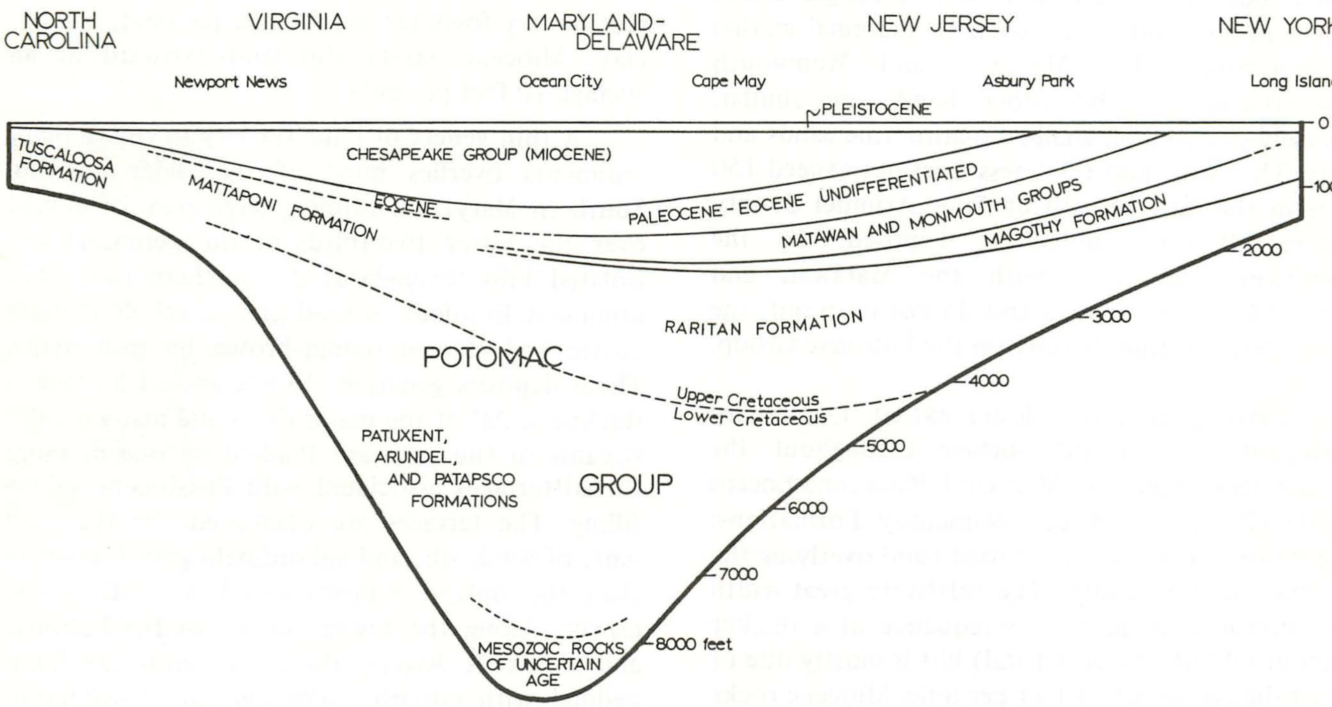

Figure 2. North-south diagrammatic cross-section of the Chesapeake-Delaware Embayment showing probable startigraphic arrangement of basin fill (modified from Glaser, 1967, fig. 15).

REGIONAL GEOLOGY

The outcropping rocks in Southern Maryland range in age from Early Cretaceous to Holocene, and owing to the relatively great degree of dissection, are better exposed here than elsewhere in the Maryland Coastal Plain. All of these sediments are, with local exceptions, unconsolidated, and consist of sand, silt, clay, and gravel, in order of decreasing overall abundance. Bedding strikes generally northeast-southwest and dips eastward to southeastward at very low angles, mostly less than 1° ; consequently, the various formations crop out in successive, crudely arcuate belts which young southeastward (pl. 1).

The Fall Line, or Zone, which defines the northwest boundary of the Coastal Plain, marks the overlap of Lower Cretaceous alluvial sediments (Potomac Group) onto the Precambrian crystalline complex of the Piedmont, in this area mostly gneisses, schists, and gabbroic rocks. Such crystalline rocks comprise the basement upon which the Coastal Plain sequence rests throughout the Middle Atlantic region. The basement surface in this region is warped into a shallow, open-ended, east-plunging basin (fig. 2) variously termed the Chesapeake-Delaware (Murray, 1961) or Salisbury Embayment (Richards, 1948). As presently mapped, Southern Maryland lies very nearly along the Embayment axis. Lower Cretaceous sediments make up the greater portion of the basin fill; beneath Southern Maryland, better than 75% of the sediment thickness is comprised of these rocks (fig. 3).

Overlying the Potomac Group in Southern Maryland and cropping out in a narrow sinuous belt immediately to the southeast, is a thin sequence of Upper Cretaceous sediments made up of the Magothy, Matawan, and Monmouth Formations. The basal unit, the Magothy, includes interbedded sand, clay, and subordinate gravel laid down in a complex of fluvial to marginal marine environments. The Matawan and Monmouth Formations, on the other hand, are similar, sparsely-glauconitic, shallow-marine fine sands and silts. The combined thickness does not exceed 150 feet in the outcrop belt of Anne Arundel County where all three units are exposed. To the southwest, however, both the Matawan and Magothy are overlapped and do not crop out, the Monmouth resting directly on the Potomac Group.

Tertiary and, to a lesser extent, Quaternary sediments are at the surface throughout the remainder of Southern Maryland. Paleocene-Eocene strata (Brightseat, Aquia, Nanjemoy Formations; Marlboro Clay) occupy a broad band overlying the Monmouth Formation. The relatively great width of outcrop is in part a consequence of a thicker section (about 250 feet total) but is mostly due to lesser dips of about 25 feet per mile. Miocene rocks crop out over a very large area of Southern Maryland. All of St. Marys and Calvert, and much of Charles and Prince Georges Counties have Miocene strata either at the surface or immediately beneath a relatively thin Late Tertiary to Quaternary cover. These sediments, belonging to the Calvert, Choptank, and St. Marys Formations (Chesapeake Group), total in outcrop about 250 feet of very fossiliferous, fine marine sand, silt, and clay. Miocene strata dip southeastward at an average 10 feet per mile.

A thin veneer of Late Tertiary to Quarternary sediments overlies most of the older units in Southern Maryland, capping large areas of upland over the lower two-thirds of the peninsula and isolated hills throughout the northern third. The dominant lithology is sand and gravel, commonly coarse and stained orange-brown by iron oxide. These deposits generally do not exceed 50 feet in thickness. All of the major rivers and many smaller streams in the area are flanked by one or more fluvial terraces associated with Pleistocene valley-filling. The terraces are composed, for the most part, of sand, silt, and subordinate gravel, younger than the upland deposits and less weathered in aspect. Along the lower courses of the Potomac and Patuxent Rivers, these sediments are interbedded with estuarine silts and dark fossiliferous clays.

DESCRIPTIONS OF FORMATIONS

CRETACEOUS

Potomac Group

The oldest outcropping strata in the Maryland Coastal Plain belong to the Potomac Group of Early and early Late Cretaceous age (Neocomian to Cenomanian). The component formations are, from oldest to youngest, the Patuxent, Arundel, Patapsco, and Raritan. Potomac rocks are exposed in a much-dissected arcuate band extending from Raritan Bay in central New Jersey southwestward paralleling the Fall Zone to Fredericksburg, Virginia. The outcrop belt is broadest, reaching fifteen miles in width, between Baltimore and Washington, and narrows toward either end to five miles or less (pl. 1). In New Jersey, all of the exposed strata belong to the Raritan Formation, whereas only the Patuxent and Patapsco Formations are represented in the Virginia outcrop. Southern Maryland contains the type areas of the Patuxent, Arundel, and Patapsco Formations; here all three units are maximally developed in outcrop.

The Potomac Group is composed of gravel, sand, silt, and clay, the proportions of each lithology varying widely, both laterally over short distances and vertically. As is commonly the case with alluvial sediments, lenticular bedding and vertical repetition of essentially similar rock types have made division of the Potomac Group into mappable subunits a subject of continued debate.

System	Series	DELAWARE	MARYLAND	VIRGINIA
TERTIARY	PLEISTOCENE	COLUMBIA GROUP: OMAR FM. COLUMBIA GROUP: BEAVERDAM FM.	COLUMBIA GROUP: WALSTON FM.; SALISBURY FM. (interfingering with LOWLAND DEPOSITS)	LOWER TERRACE SAND AND GRAVEL
	PLIOCENE?	BRYN MAWR FM.	UPLAND GRAVELS	UPLAND GRAVEL AND SAND
	MIOCENE	CHESAPEAKE GROUP UNDIFFERENTIATED	CHESAPEAKE GROUP: YORKTOWN FM.* ST. MARYS FM. CHOPTANK FM. CALVERT FM.	CHESAPEAKE GROUP: YORKTOWN FM. ST. MARYS FM. CHOPTANK FM. CALVERT FM.
	OLIGOCENE	(hatched)	(hatched)	(hatched)
	EOCENE	PINEY POINT FM.* UNIT C* UNIT A* RANCOCAS FM.	PINEY POINT FM.* CHICKAHOMINY FM.* PAMUNKEY GROUP: NANJEMOY FM. MARLBORO CLAY AQUIA FM.	CHICKAHOMINY FM.* PAMUNKEY GROUP: NANJEMOY FM. MARLBORO CLAY AQUIA FM.
	PALEOCENE	UNIT B*	PAMUNKEY GROUP: BRIGHTSEAT FM.	
CRETACEOUS	UPPER CRETACEOUS	MONMOUTH GROUP: RED BANK FM. MT. LAUREL-NAVESINK FM.	MONMOUTH FM.	MATTAPONI FM.*
		MATAWAN GROUP: WENONAH FM. MERCHANTVILLE FM.	MATAWAN FM.	
		MAGOTHY FM.	MAGOTHY FM.	
		POTOMAC FM.	POTOMAC GROUP: RARITAN FM.	
	LOWER CRETACEOUS	POTOMAC FM.	POTOMAC GROUP: PATAPSCO FM. ARUNDEL FM. PATUXENT FM.	POTOMAC GROUP: PATAPSCO FM. PATUXENT FM.

* Subsurface only

Table 1. Correlation of Cretaceous, Tertiary, and Quaternary Formations of Delaware, Maryland, and Virginia.

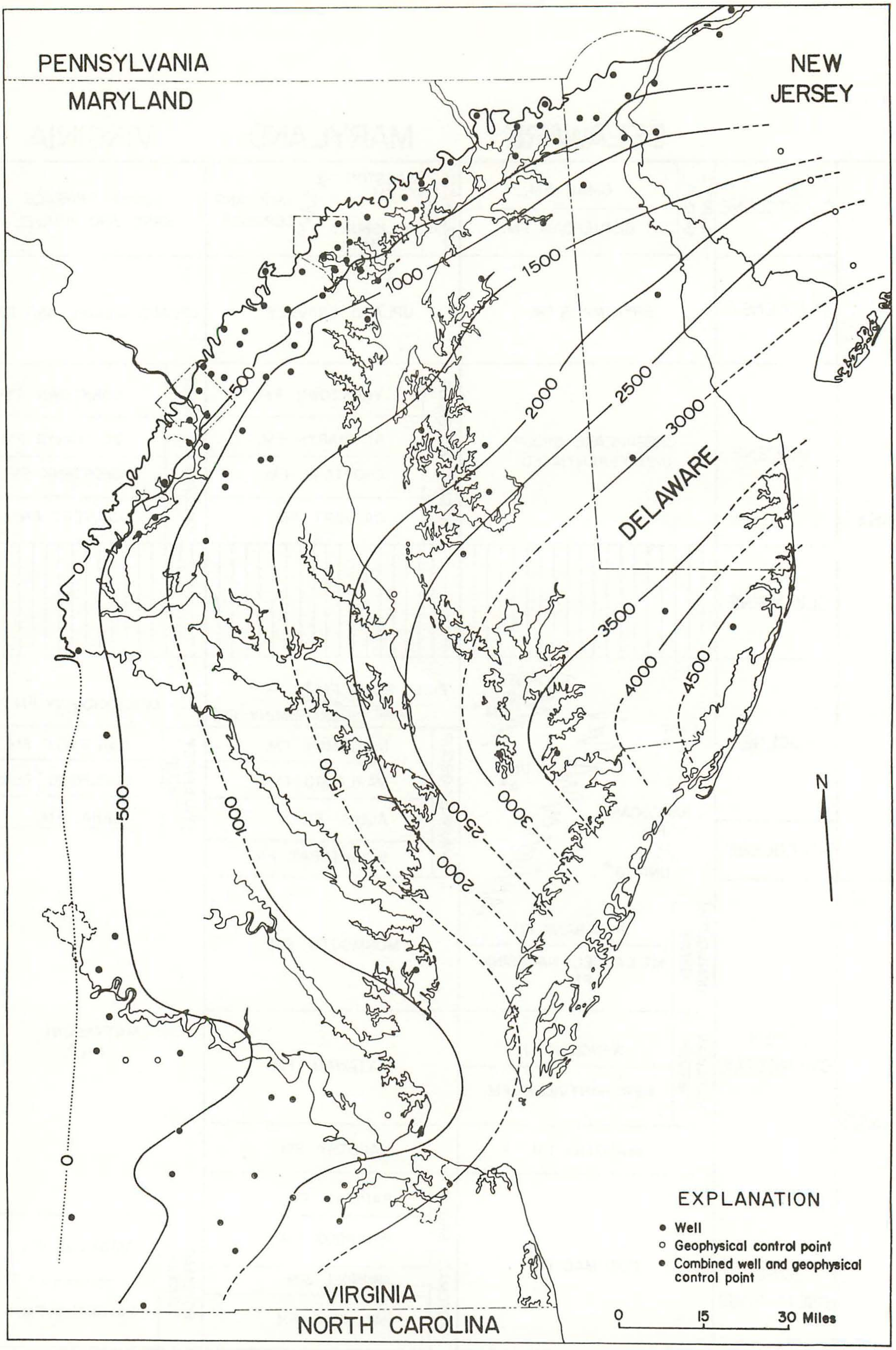

Figure 3. Isopach map to the Potomac Group (after Glaser, 1967, fig. 10).

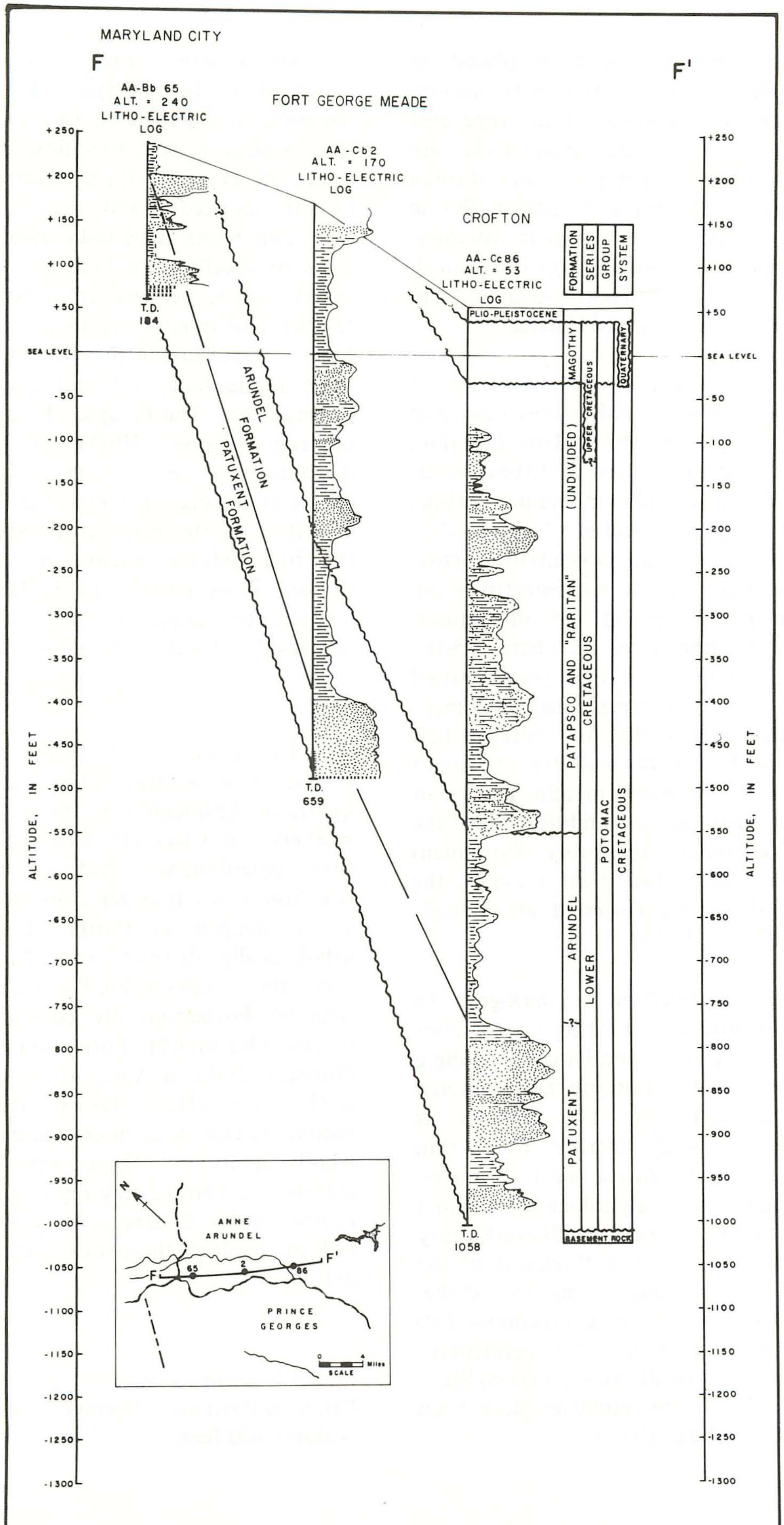

Figure 4. Geologic dip cross-section of Cretaceous rocks from Maryland City to Crofton (after Hansen, 1968, pl.7.)

Historically, much weight has been placed on paleobotanic evidence in recognition of the various formations, particularly outside of the type area where marker units such as the Arundel clay are absent and the Patuxent, Patapsco, and Raritan Formations are not lithologically distinct. Within Southern Maryland, however, maximum lithologic differentiation in the Potomac Group is obtained, and three rock units - Patuxent, Arundel, and Patapsco-Raritan(?) - can be discriminated.

The Patuxent Formation is comprised of medium to coarse, pale-gray sand, pebbly sand, and gravel interbedded with relatively thin, similarly-colored lenticular clays. Patuxent sands are angular and show only moderate sorting, commonly containing considerable interstitial clay. Both sands and gravels are essentially orthoquartzitic. Abundant trough cross-stratification, large-scale inclined bedding, cut and fill features, and clay pebble conglomerates are characteristic. Minor lithologies include red and gray mottled clay, drab lignitic clay, and ferruginous conglomerate. Sediment thickness within the outcrop belt ranges from a few feet in the Fall Zone to about 250 feet at the eastern outcrop margin. The age of the Patuxent Formation, as established by the flora, is late Neocomian (probably Barremian) (Brenner, 1963). Other than plant remains, the only known fossils of the Patuxent are a single *Unio* and a fish (Clark, 1916).

The Arundel Formation, a dark-gray to maroon, tough lignitic clay bearing conspicuous sideritic concretions, overlies the Patuxent along a forty-mile segment of the outcrop belt centered around Baltimore (pl. 1). The contact is undulatory and commonly marked by a thin iron-cemented ledge, suggesting a hiatus; however, in that the Arundel is not palynologically distinct from the Patuxent Formation, any disconformity present is certainly minor. The thickness of the Arundel clay varies notably along the strike, ranging from 10 feet or less to a maximum 150 feet. In addition to floral remains, the fragmentary remains of eight species of dinosaur, a crocodile, a turtle, a garfish, and a few mollusks have been taken from this unit (Clark, 1916).

Succeeding the Arundel in Southern Maryland is the Patapsco Formation, a thick sequence of interbedded variegated silty clay and fine to medium, gray to yellow sand. Patapsco clay lenses are typically thick, internally massive, and brightly mottled in red, yellow, gray, and purple hues. Pure white clays and dark-gray, highly lignitic clays are locally important. Sands and subordinate gravels, where present, are grossly similar in both texture and mineralogy to those in the Patuxent Formation, although they tend to be finer grained, more argillaceous, and contain a less-varied heavy mineral suite. The Patapsco Formation is Albian in outcrop (Brenner, 1963), and rests with minor disconformity on the Arundel clay or on the Patuxent Formation where the Arundel is absent. The flora of the Patapsco is extensive, containing the first definite angiosperms in the Maryland Coastal Plain (Berry, 1911; Brenner, 1963); in contrast, the fauna is notably poor, consisting only of a few fresh-water pelecypods.

The presence or absence of the Raritan Formation in Southern Maryland remains an open question. Although mapped in the area by most workers, e.g. Clark (1916) and Darton (1947), no firm paleobotanic evidence to support this conclusion has thus far come to light. Moreover, strata mapped as Raritan Formation are not lithologically distinct from Patapsco sediments. Thus, those rocks of the Potomac Group above the Arundel Formation are collectively termed the Patapsco-Raritan(?) Formation. The uppermost Potomac strata in Anne Arundel County contrast with typically clayey Patapsco-Raritan(?) sediments elsewhere in containing relatively clean, wholly quartzose, sheet-form sands and minor gravels. Such strata may represent the true Raritan Formation in Southern Maryland, but the total lack of fossils in these rocks has thus far prevented dating.

The maximum thickness of the Patapsco-Raritan(?) Formation in the outcrop belt is about 500 feet.

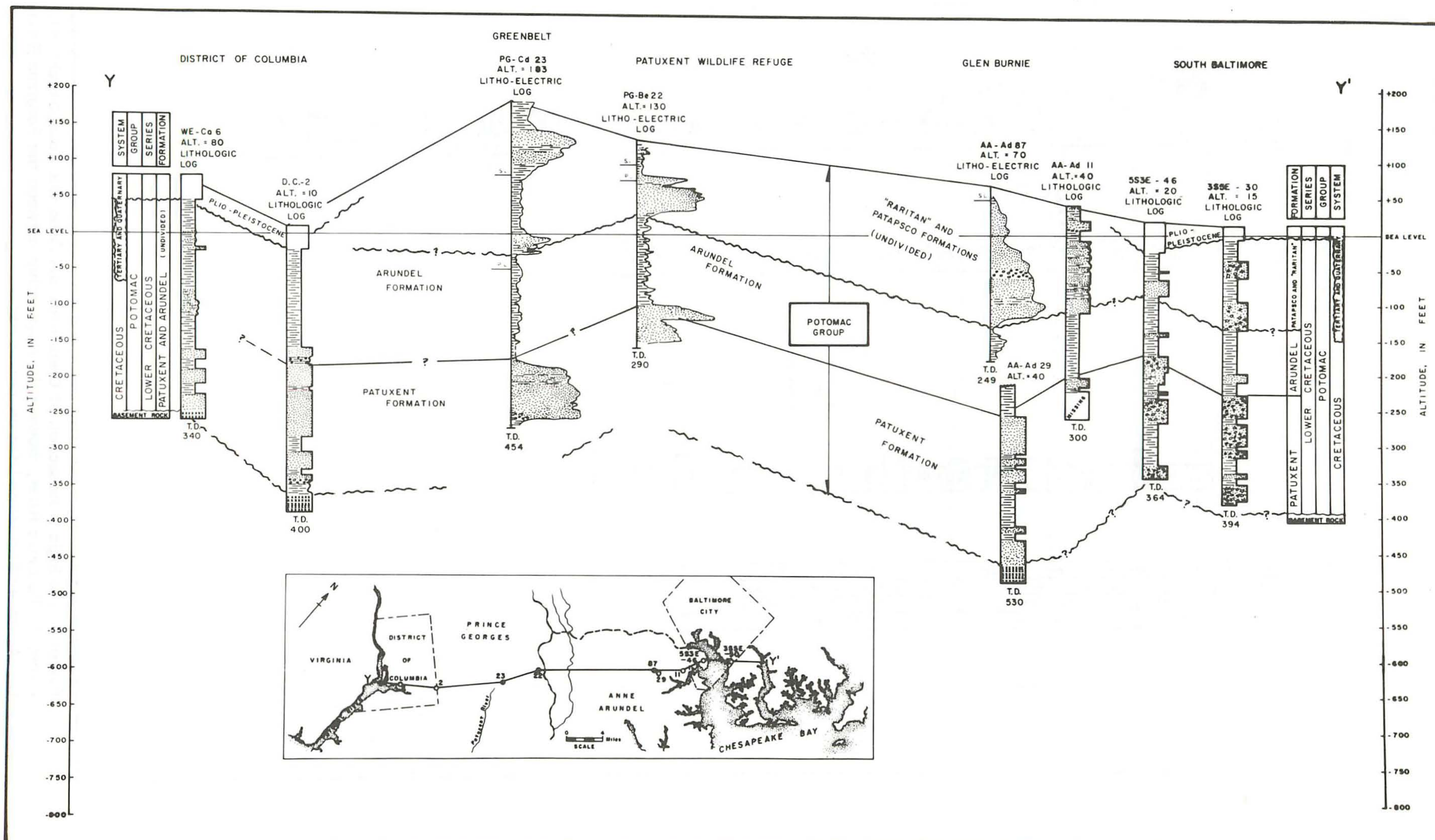

Figure 5. Geologic strike cross-section of Cretaceous rocks from Washington, D.C. to Baltimore (after Hansen, 1968, pl. 16.)

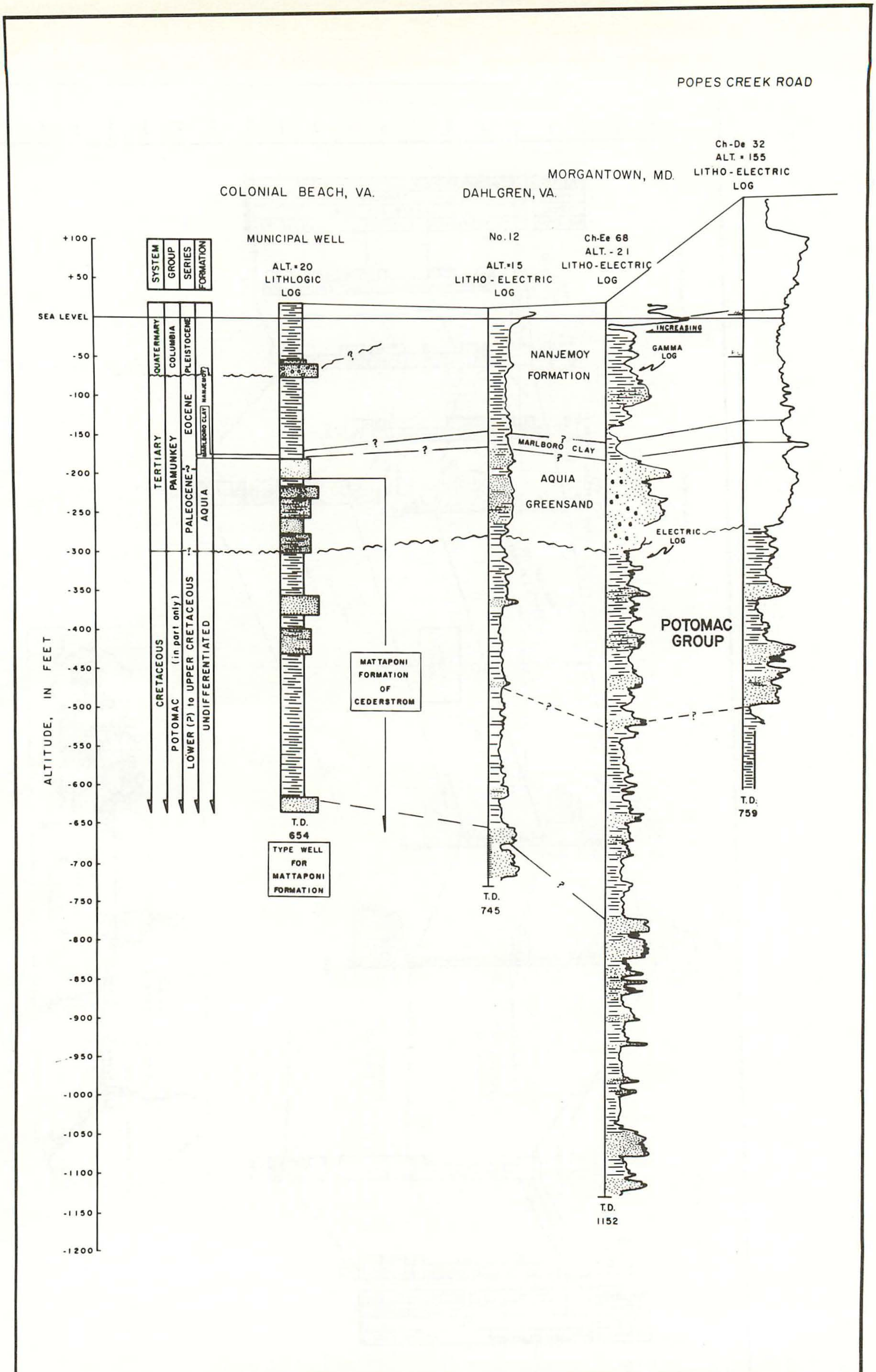

Figure 6. Geologic cross-section of Cretaceous and Paleocene-Eocene rocks extending across the Potomac River, showing the relationship between the Potomac Group and the Mattaponi Formation (Hansen, pers. comm.).

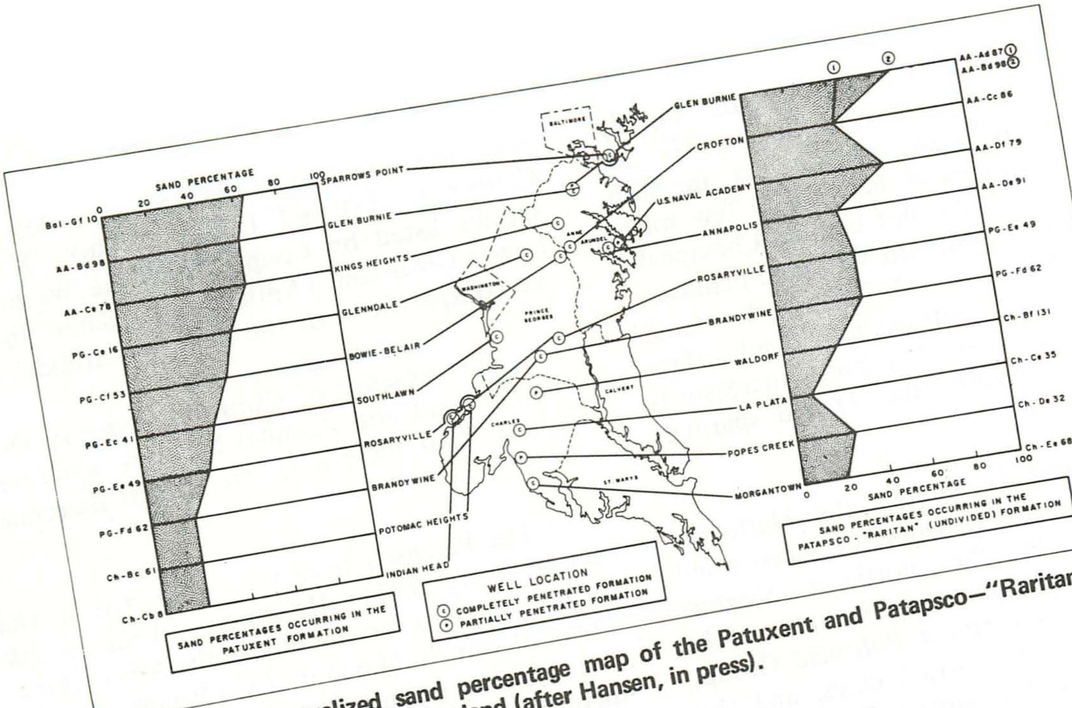

Figure 7. Generalized sand percentage map of the Patuxent and Patapsco—"Raritan" Formations in Southern Maryland (after Hansen, in press).

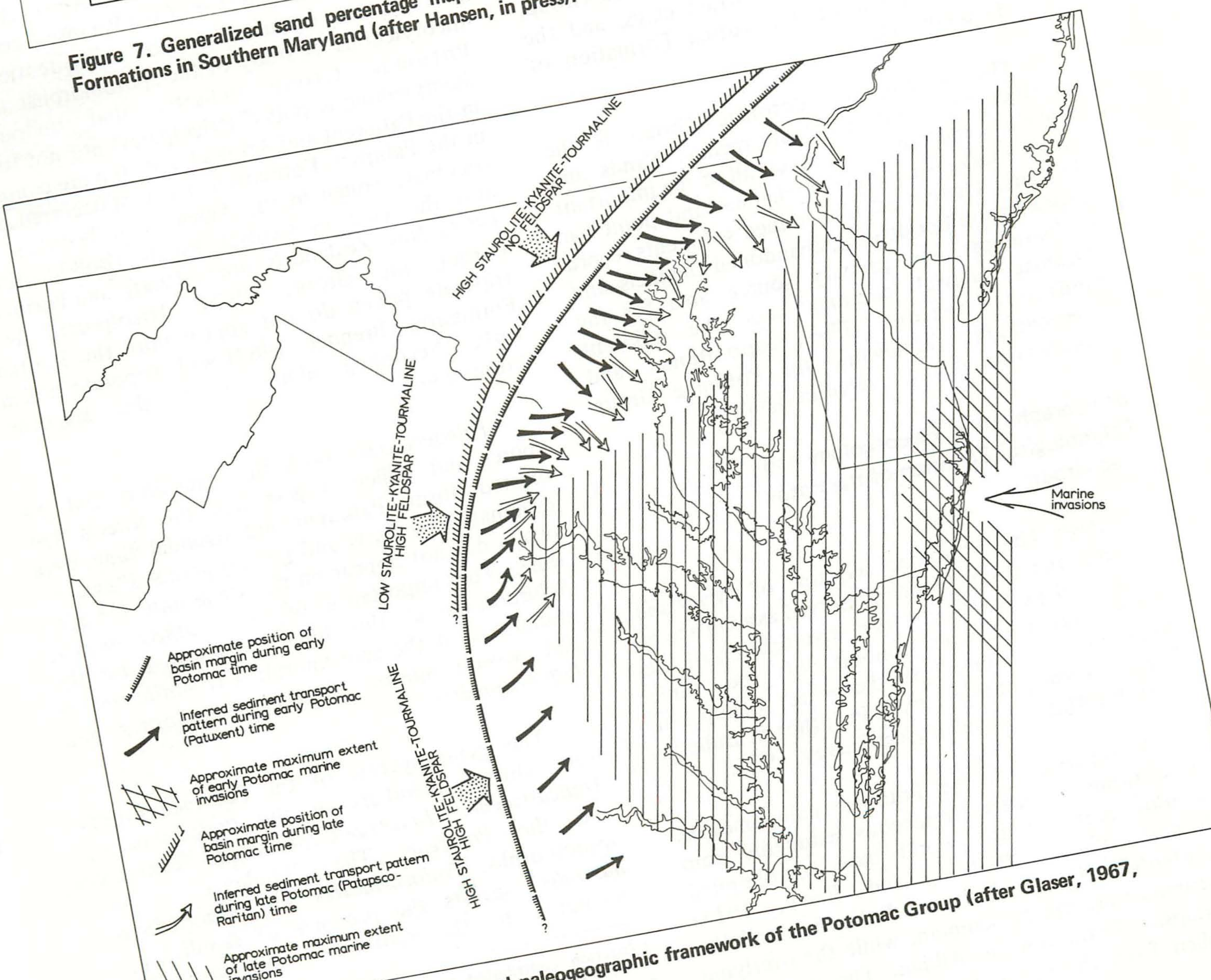

Figure 8. Depositional and paleogeographic framework of the Potomac Group (after Glaser, 1967, fig. 115).

The Potomac Group thickens rapidly southeastward toward the axis of the basin (fig. 3). The outcrop rock units are distinct in both lithologic and geophysical logs for a few miles down the dip (fig. 4, 5), but beyond Chesapeake Bay and in the lower Southern Maryland peninsula, the Patuxent, Arundel, and Patapsco-Raritan(?) Formations are poorly defined in the subsurface. The Potomac Group becomes increasingly argillaceous to the south (fig. 7) and sparingly glauconitic.

Cederstrom (1957) erected the Mattaponi Formation to encompass all Upper Cretaceous and Paleocene strata in the northern Virginia subsurface. The Mattaponi thus includes rocks correlative with the uppermost Potomac Group, chiefly gray and brown mottled clays, and the Paleocene portion of the Aquia Formation of Maryland (fig. 6).

The outcropping Potomac Group is the product of a fluvial-deltaic regime. Sands and gravels in the Potomac exhibit all of the important sedimentary structures of channel and point bar deposits, whereas the fine-grained sediments record deposition in floodbasins, abandoned channels, and backswamps. The primary source area for the Potomac alluvial complex was the adjacent Piedmont region. The depositional and palegeographic framework for Potomac Group sedimentation is summarized in figure 8.

Stratigraphic Age, Paleoecology and Palynological Zonation of the Potomac Group[1]

Age: The Potomac Group of Maryland contains an extremely well preserved assemblage of spores and pollen. A detailed investigation of the total palynological content of the three formations[2] within the Potomac Group of Maryland was published by this author in Bulletin 27 of the Maryland Geological Survey, 1963.

Comparison of the Potomac palynomorphs with those in other Cretaceous sediments from various parts of the world have corroborated Berry's (Clark, Bibbins, and Berry, 1911) contention that the Patuxent Formation and the Arundel Clay are Neocomian, while the overlying Patapsco Formation is Albian. The spores and pollen from the Patuxent-Arundel Formation are very similar to that of the Wealden as described by Couper (1958) and Lantz (1958b). Of the 43 species listed by Couper from the Wealden and Lower Greensand (Aptian) of England, 26 (60%) are conspecific with the Patuxent-Arundel forms.

The presence of *Clavatipollenites hughesii* in the Patuxent and Arundel horizons is believed to indicate that these units are at least Barremian in age.

The Patapsco flora was considered of Albian age by Berry (1911). He considered the megaflora of the Patapsco very much like the Albian floras of Portugal, which, like that of the Patapsco, contains the first occurrence of unquestionable dicotyledons. A study of the sporomorphae in the Potomac Group indicates that undoubted dicotyledonous pollen (tricolpates) are not found in the Patuxent and Arundel units but are common in the Patapsco Formation. The first occurrence of tricolpate pollen in the Albian, as in Maryland, is also the case in Central Russia (Bolkhovitina, 1953), New Zealand (Couper, 1960), and Portugal (Groot and Groot, 1962). Tricolporate and triporate pollen do not appear until the Raritan Formation (Brenner, 1967) with triporate pollen only becoming abundant in the Magothy Formation.

Paleoecology: Both the macroflora and the spores and pollen suggest that the forests that existed during Patuxent and Arundel time were dominated by ferns and gymnosperms. Flowering plants did not appear on the scene until Patapsco time. The importance of the *Cyatheaceae* and *Schizaeaceae* at this time is indicated by the abundance of the sporomorph, *Cyathidites minor* and several species of *Cicatricosisporites* and *Trilobosporites.*

The gymnosperms of the Potomac forests were chiefly members of the *Podocarpaceae, Araucariaceae, Taxaceae-Cupressaceae* complex, and the *Pinaceae.* The abundance of the sporomorphs, *Podocarpidites* and *Araucariacites australis* suggests the presence of families now restricted to the southern hemisphere. Other

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1/ Section contributed by G.J. Brenner, Dept. Geology, State University of N.Y., New Paltz, N.Y.

2/ The Potomac Group, as presently recognized by the Maryland Geological Survey and the U.S. Geological Survey, includes the Raritan Formation as well as the Patuxent, Arundel, and Patapsco.

common gymnosperms, now extinct, produced such pollen as *Eucommiidites troedssonii, Exesipollenites tumulus,* and perhaps *Clavatipollenites hughesii.* The affinities of the tricolpate pollen is not known, although similar pollen is produced by members of *Salicaceae, Tetracentraceae, Trochendraceae,* and *Ranunculaceae.* The *Araucaria-Agathis* type pollen does not become abundant until the upper part of the Patapsco horizon.

The assemblage of spores and pollen found in the Potomac sediments suggests that the forests during this time might be compared with those now found in the warm temperate rainforests of New Zealand. On North Island, the forests are dominated by broad-leaf conifers such as *Agathis australis* (Kauri forest), *Phyllocladus glauca, Podocarpus dacrydioides,* and *Dacrydium cupressinum.* The undergrowth supports a luxuriant growth of all varieties of ferns, from epiphytes that cover the tree trunks to the tall tree ferns of *Cyathea* and *Dicksonia. Podocarpus dacrydioides* is the dominant tree of the swampy wet soils of the Kuhikatea forests.

The presence of abundant fern pollen in the Potomac Group which is now found only in members of the *Gleicheniaceae* and *Schizaeaceae* indicates warm humid conditions.

The total assemblage of the spores and pollen from the Potomac Group, when compared to the present vegetation, suggests a warm temperate to subtropical rainforest, similar to some of the New Zealand and Australian broadleaf evergreen forests.

Palynological Zonation: The Potomac Group has been divided into two primary palynological zones, Zones I and II, and two subzones of Zone II, Zone IIA and Zone IIB. The nature of these zones is as follows:

Zone I (Patuxent-Arundel)

1. No tricolpate pollen.
2. *Classopollis torosus* and *Exesipollenites tumulus* are more abundant than in Zone II.
3. *Clavatipollenites hughesii* and *Araucariacites australis* are rare.
4. Bisaccates are not as abundant as in Zone II.
5. *Cyathidites minor* and schizaeaceous spores are more abundant in this zone.

The following species are restricted to Zone I:

Cicatricosisporites dorogensis
Ephedripites virginiaensis
Klukysporites lunaris
Parvisaccites amplus

Zone II (Patapasco)

1. The first undoubted angiosperms (tricolpates) appear at the base of Subzone A increasing in numbers in Subzone B.
2. *Araucariacites australis* and *Clavatipollenites hughesii* become abundant in Subzone B.

The following common species are restricted to Zone II (both Subzones):

Apiculatisporis babsae
Ceratosporites parvus
Lycopodiacidites irregularis
Matonisporites excavatus
Nonosulcites chaloneri
Podocarpidites epistratus
Tricolpopollenites micromunus
Tricolpopollenites minutus

Subzone B:

Cicatricosisporites patapscoensis
Neoraistrickia robusta
Taurocusporites spackmani
Rugubivesiculites reductus

Magothy Formation

Disconformably overlying the Potomac Group through most of Southern Maryland is the Magothy Formation of Turonian age (Brenner, pers. comm). The Magothy outcrop belt is confined to Anne Arundel County (pl. 1), although this unit is widespread in the subsurface through much of the peninsula. Exposures are generally poor and are largely restricted to the upper Severn-Magothy River region and the area south and east of Odenton (fig. 1). The Magothy is about 60 feet thick in outcrop, and is characterized by loosely-bedded, sharply angular, "sugary" quartzose sands, mostly white in color. The sands are notably free from interstitial clayey materials but commonly contain considerable sand-sized lignite, lending a salt-and-pepper aspect to the sediment. Concentrations of lignite also occur on bedding planes and on cross-bedding foreset surfaces. Interbedded with the sands, particularly along the eastern outcrop margin and basinward, are dark-gray, silty, lignitic clays. Such clays are commonly finely-interlaminated with pale-gray silt or fine sand, resulting in a highly distinctive lithofacies. In contrast, Magothy exposures along the southwestern outcrop margin near Odenton contain notably coarse materials—very coarse sands and ferruginous gravels—commonly cemented by limonite.

Fauna is absent in the Magothy of Southern Maryland; however, strata assigned to this unit in central New Jersey contain a small molluscan assemblage, termed by Weller (1907) the *Lucina cretacea* suite. A considerable flora, containing many distinctive angiosperms, does however occur in the Maryland rocks, which Brenner (*in* Hansen, 1968) regards as Turonian.

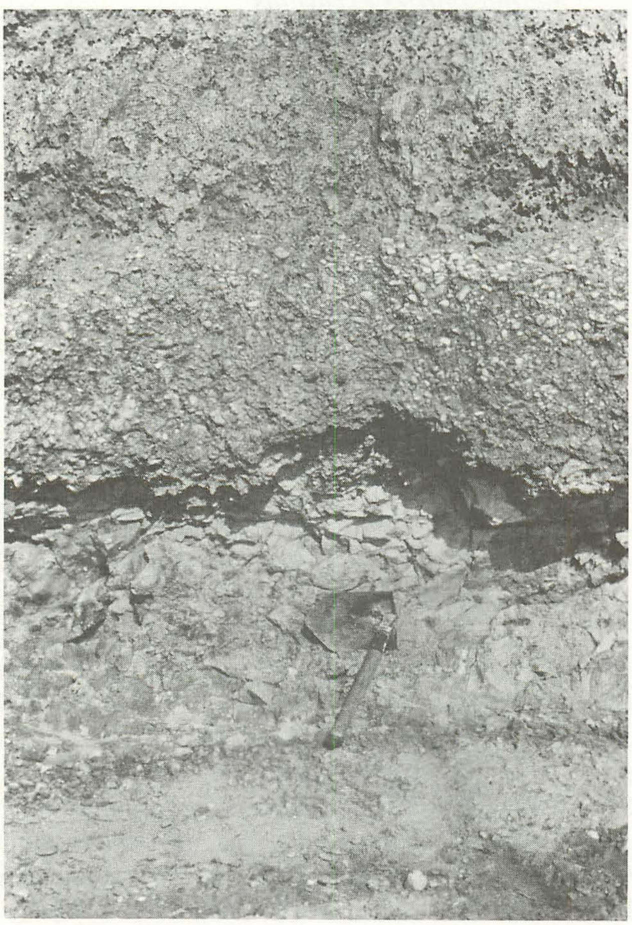

Figure 9. Basal gravel of the Monmouth Formation disconformably overlying Patapsco mottled clay, Fort Washington (Stop 3).

The outcropping Magothy Formation is in part fluvial and in part lagoonal or estuarine. Downdip, in the Southern Maryland subsurface, the Magothy is predominantly arenaceous and constitutes an important aquifer (Otton, 1955), regarded by Hansen (1968) as a strandline sand.

Matawan Formation

The outcropping Matawan Formation, like the Magothy, is confined to Anne Arundel County where it overlies the latter unit with apparent disconformity. The Matawan is thin, ranging from 20 to 50 feet in thickness, is poorly exposed, and is relatively unstudied. Weathered exposures can be seen in the banks of the Severn River in the vicinity of Round Bay, and in numerous cuts along the Defense Highway (Md. 450) west of the South River (fig. 1).

The unweathered Matawan is typically a dark-green to black, micaceous, sparsely glauconitic, silty clay with little trace of internal stratification. The color in weathered outcrops is considerably paler, approaching grayish-brown or buff. Concretionary crusts and irregular lumps of yellow-brown limonite are abundantly developed near the surface.

Matawan clays in Southern Maryland have yielded a rather small fauna of poorly-preserved mollusks, including several representatives of the *Exogyra ponderosa* zone, suggesting a Campanian age (Clark, 1916). The Matawan is the oldest wholly marine unit in the Maryland Coastal Plain. The meagre faunal evidence suggests open shelf deposition, thus bringing to completion the initial major transgression of the sea into the Embayment.

Monmouth Formation

Monmouth strata are exposed in a relatively narrow, irregular belt which crosses the whole of Southern Maryland from the Magothy River in eastern Anne Arundel County southwestward to the Potomac River at Fort Washington (pl. 1). The Monmouth thins notably to the southwest, ranging from about 50 feet in Anne Arundel to 20 feet or less in western Prince Georges County. The contact between the Matawan Formation and the overlying

Monmouth is sharp and disconformable although generally quite horizontal. Southwest of the Patuxent River, however, both the Magothy and Matawan Formations are overlapped, bringing basal Monmouth beds onto progressively older Patapsco rocks to the southwest.

The Monmouth Formation closely resembles the underlying Matawan, but tends to be somewhat coarser and less homogeneous. Fine, micaceous, clayey sands with a variable glauconite content are the dominant lithology. Some beds contain fifty percent or more of glauconite whereas other more arenaceous beds show only trace amounts of glauconite. In western Prince Georges County where the Monmouth transgresses the Patapsco Formation, a twelve-inch bed of quartzose gravel is the basal Monmouth sedimentation unit (fig. 9). Moreover, quartz pebbles and granules are sporadically distributed through the lower sands of the formation. Sediment color and weathering characteristics are similar to those of the Matawan.

The Monmouth fauna in Southern Maryland is considerably richer and better preserved than that of the Matawan, encompassing fishes, crabs, and some 140 species of mollusks (Clark, 1916). The molluscan assemblage includes *Exogyra costata, Eutrephoceras dekayi,* and *Sphenodiscus lobatus,* three highly distinctive and widely distributed Late Cretaceous forms, suggesting a Maastrichtian age for the Maryland Monmouth (Cooke, 1952). Thus, the Maryland rocks are correlative with only the upper portion of the Monmouth Group of New Jersey, namely the Red Bank Sand.

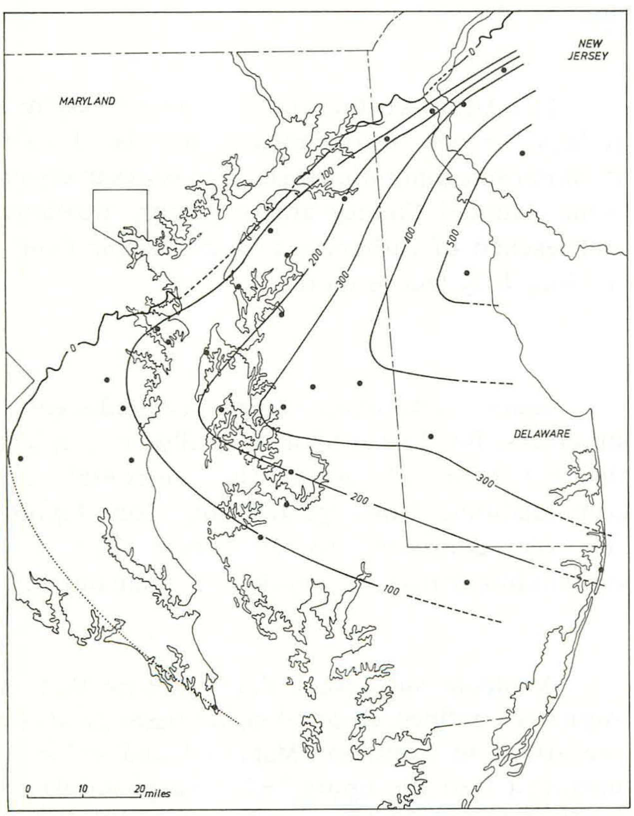

Figure 10. Isopach map of the combined Matawan and Monmouth Formations (after Glaser, 1967, fig. 14).

Most Monmouth outcrops in Southern Maryland are weathered to varying degrees and lack fossils, most of the carbonate having been removed through groundwater leaching. The last shells to be dissolved are commonly the oysters; these may be found in various stages of preservation in many exposures.

The Monmouth and Matawan cannot usually be separated in borings without detailed paleontologic study; consequently, the two units are generally lumped. The region of maximum subsidence during latest Cretaceous time apparently lay to the northeast in New Jersey (fig. 10). Further, the thinning and rapid pinching out of Monmouth strata at the zero isopach is not accompanied by a lithofacies change, suggesting that the Monmouth and perhaps the Matawan Formations originally covered a broader area southwest of their present limits from which they were stripped by very late Cretaceous or early Tertiary erosion.

TERTIARY

PALEOCENE-EOCENE

Brightseat Formation

Lower Paleocene strata are quite thin and very restricted in outcrop in Southern Maryland, and in fact were not recognized until 1952 when Bennett and Collins erected the name Brightseat Formation to designate early Paleocene rocks exposed near the town of Brightseat in western

Prince Georges County (fig. 1). Recent work by Nogan (1964), Drobnyk (1965), and Hazel (1968) has done much to amplify our knowledge of these rocks.

The exposed Brightseat encompasses about eleven feet of gray to gray-brown, argillaceous, micaceous, phosphatic, fine sand. Phosphatic granules and pebbles up to an inch or two in diameter are concentrated in burrows near the top of the unit. Irregular layers and pods are well-cemented by calcite. The sand is very sparsely glauconitic and contains scattered small molluscan shells. The fossiliferous exposures are confined to small stream valleys in the vicinity of Seat Pleasant near the D.C. line (fig. 1). In this area, a basal four-inch shell bed containing well-preserved Paleocene mollusks overlies glauconitic, argillaceous sand of the Monmouth Formation. The contact is apparently slightly disconformable in that earliest Paleocene fauna is absent in the basal Brightseat. Hazel, employing ostracod correlation, has assigned the Brightseat a lower Danian age. Sedimentation probably took place in the sublittoral zone in about 300 feet of water (Nogan, 1964). Brightseat sediments thicken basinward in the Southern Maryland subsurface to the east and south, reaching maximum accumulations of about 75 feet.

Aquia Formation

The Aquia Formation, of late Paleocene through early Eocene age, embraces about 100 feet of very fossiliferous, glauconitic sand which is well-exposed over a large portion of Southern Maryland. The outcrop belt reaches a maximum eleven miles in width and trends northeast-southwest from Sandy Point on Chesapeake Bay to Indian Head on the Potomac River (pl. 1). Aquia greensands disconformably overlie the late Cretaceous Monmouth Formation throughout the northeastern part of the outcrop belt. The contact is sharp, with coarse, reddish-brown, ferruginous sandstone resting on fine, dark-gray, argillaceous Monmouth sand. Near Washington, the Aquia overlies the Brightseat with apparent minor disconformity. The contact is marked by abundant burrows as well as concentrations of coarse sand and phosphatic pebbles; however, the planktonic foraminiferal fauna of the uppermost Brightseat is continuous through the basal Aquia (Hazel, 1968). Southwest of Washington, Aquia sands successively overlie Monmouth and Patapsco strata, and beyond the Potomac River, they ultimately transgress the Patuxent Formation (Calver and others, 1963).

The Aquia Formation is typically a dark greenish-gray, variably glauconitic, well-sorted, fine to medium silty sand. In Southern Maryland, the sand tends to coarsen upward in the section, and Drobnyk (1965) has noted that a coarsening trend is also apparent northeastward along strike. The glauconite content varies as well, ranging from less than 20% to as much as 70%. Calcite-cemented sandstone beds up to two feet in thickness are widespread and distributed throughout the formation. A large fauna, including crocodiles, turtles, a number of fishes, and over 100 mollusks, has been described from the Aquia Formation (Clark and others, 1901). Common and characteristic molluscan species include *Ostrea compressirostra, Turritella mortoni,* and *Cucullaea gigantea. T. mortoni* is particularly abundant and diagnostic, forming nearly pure accumulations at a number of horizons.

The Aquia weathers rapidly upon exposure to reddish-brown ferruginous sand laced with anastomosing limonitic crusts. Exposures in eastern Anne Arundel County are commonly weathered and leached of carbonate to considerable depths, reaching fifty feet or more.

Aquia sands exhibit very few sedimentary structures. Bedding cannot generally be seen with the exception of apparently horizontal shell accumulations. Mottling, resulting from textural and color contrasts between burrow fillings and surrounding matrix, is prevalent in some outcrops.

Available subsurface data indicate that the Aquia is confined to an elongate basin paralleling the strike in Southern Maryland and extending northeast into the upper Delmarva peninsula and southwest into Virginia (Shifflett, 1948). To the southeast, the Aquia thins and wedges out beneath Middle and Upper Eocene beds. Maximum thicknesses in Southern Maryland of about 200 feet occur along a line extending from central Charles through southern Prince Georges to southern Anne Arundel County (Otton, 1955).

The Aquia Formation (as well as the underlying Coastal Plain rocks through the Lower Cretaceous) in the Brandywine area (fig. 1) is warped into an elongate domal structure some eight miles in length with a closure of more than 50 feet, increasing to 135 feet in the Patuxent Formation (Ball Associates, 1959). The structure has been drilled in detail by the Washington Gas Light Co. anticipatory to development of a gas storage field in the Patuxent with a capacity of four billion cubic feet or more.

Aquia sedimentation was essentially regressive. The basal part of the formation reflects water depths similar to those of the Brightseat environment. Progressive shoaling followed, and the uppermost beds were probably deposited in very shallow water (Drobnyk, 1965).

Marlboro Clay

The Aquia Formation is overlain in Southern Maryland by a thin but highly distinctive marker bed named by Darton (1948) the Marlboro Clay. The Marlboro is not well-exposed, partly because it is thin, but also because potential outcrops, particularly in steep valley walls, are generally covered by slumped younger materials. The clay is very thin, four to ten feet, in southwestern Charles County, but thickens to twenty to twenty-five feet northeastward along the strike in southern Prince Georges and Anne Arundel Counties. The lower contact with the Aquia Formation in updip exposures probably records a minor hiatus; the uppermost few inches of Aquia sand are limonite-cemented and exhibit gypsum casts. However, cores of the contact in downdip sections show a transition zone of several inches marked by interbedded gray-green glauconitic sand and silvery-gray Marlboro Clay.

The Marlboro is composed of pale-red to silvery-gray plastic clay with thin lenses of very pale-gray silt. In a gross sense, the gray clay is most prominent in the upper and lower third of the unit whereas pale-red to reddish-brown hues characterize the middle third. The interbedded silts range in thickness from a fraction of an inch to two feet and generally exhibit fine, even laminations, or less commonly, micro cross-lamination. Lignite is sporadically distributed through the unit as tiny flecks to sections of logs twelve inches or more in length. Small pyrite concretions are common in some beds, and occasional gypsum casts may be seen.

Macrofauna is rare and is limited to scattered impressions of small mollusks. Nogan (1964) reports several species of arenaceous Foraminifera from the basal portion of the Marlboro. Silt and sand-filled burrows are common, particularly near the lower and upper boundaries of the Clay. A very shallow, probably brackish water environment seems indicated for this unit, climaxing the regressive cycle begun with Aquia deposition. The position of the Marlboro between lower Wilcox (Aquia) and upper Wilcox-Claiborne (Nanjemoy) strata effectively brackets its age; Cooke (1952) suggests correlation with the Tuscahoma Sand of the Gulf section.

The Marlboro underlies most of Southern Maryland as well as a large portion of Northern Virginia, but has not been recognized in wells to the east of Chesapeake Bay.

Nanjemoy Formation

The Nanjemoy Formation overlies the Marlboro Clay throughout Southern Maryland, outcropping in the walls of all of the major stream valleys from South River southwestward to the Potomac (fig. 1, pl. 1). In the intervening divides, the Nanjemoy is generally hidden by overlap of the Calvert Formation or by Plio-Pleistocene Upland Gravels.

The Nanjemoy-Marlboro contact is quite sharp; however, glauconitic sand of the Nanjemoy fills abundant anastomosing burrows in the upper few feet of the clay, conveying the impression of isolated clay blocks "floating" in the sand.

The exposed Nanjemoy constitutes somewhat less than 100 feet of dark greenish-gray, argillaceous silt and sand. It resembles the Aquia to a large degree but is more argillaceous and lacks the hard sandstone beds characteristic of the Aquia. Beds of dark-gray silty clay up to 15 feet thick are present in the Nanjemoy of southern Prince Georges County. Nanjemoy sands tend to coarsen upward; in the vicinity of Upper Marlboro, very coarse sand with small pebbles makes up the uppermost part of the formation. The glauconite content varies much as in the Aquia; medium to coarse sands commonly contain 50% or more of glauconite. With the exception of thin clay lenses which appear roughly horizontal, bedding can rarely be seen in the sands. The prevalent sedimentary structure is mottling produced by abundant burrowing.

The molluscan fauna of the Nanjemoy Formation contains many forms in common with the Aquia, but is notably smaller, with about half the number of species reported from the earlier unit (Clark and others, 1901). By far the most abundant Nanjemoy species is *Venericardia potapacoensis;* this form is restricted to the Nanjemoy and may be found in nearly every outcrop, in some cases forming substantial shell beds. The Nanjemoy fauna has not been subjected to detailed study by any modern workers; Shifflett (1948) found no forms younger than early Claiborne, and Cooke (1952) suggested a late Wilcox age for the Nanjemoy on the basis of the macrofauna.

This formation reaches a maximum thickness of about 250 feet downdip along a line trending northeast- southwest through northern St. Marys and central Calvert Counties. Beyond this line to the southeast, the Nanjemoy thins and is rapidly replaced by younger Eocene strata. The presence of Wilcox-Claiborne beds under the lower Delmarva Peninsula is doubtful, only Jackson strata having been reported.

Piney Point Formation

The Piney Point Formation is wholly a subsurface unit, confined in Southern Maryland to the lower halves of Calvert and St. Marys Counties (fig. 1). The name Piney Point was proposed by Otton (1955) to designate heretofore unnamed Upper Eocene strata conformably overlying the Nanjemoy Formation in the vicinity of Piney Point in southern St. Marys County (fig. 1). The presence of a Jackson foraminiferal assemblage in the subsurface of Calvert County and portions of the lower Eastern Shore was first noted by Shifflett (1948); correlative rocks have subsequently been identified in portions of northeastern Virginia and southern Delaware.

The Piney Point consists of twelve to sixty feet of light-gray to yellowish-green, medium to coarse glauconitic sand interbedded with cemented shell beds. With decreasing glauconite content, the sands tend toward grayish-white in color.

The gradational contact and complementary thickness relationship between the Nanjemoy and Piney Point units as well as the generalized upward coarsening of the sands suggests a major Eocene offlap sequence, followed by the withdrawal of the sea from Southern Maryland until Middle Miocene time.

MIOCENE

Chesapeake Group

Calvert Formation

The third and final major transgression of the sea into the Embayment was initiated in Middle Miocene time with deposition of the Calvert Formation. Calvert rocks are at the surface over a very large area of Southern Maryland as a consequence of their low dip, about ten to fifteen feet per mile. The outcrop belt reaches some thirty miles in width. The sediments are well-exposed over much of the area, particularly so in high bluffs rimming Chesapeake Bay in Calvert County, and in the banks of the Patuxent and Potomac Rivers.

The Calvert Formation in Charles and most of southern Prince Georges Counties is blanketed by a thin, upland sheet of erosionally-resistant Plio-Pleistocene sand and gravel, and outcrops are confined to the walls of stream valleys and deep road cuts. In contrast, however, the eastern portion of the area flanking the Patuxent River and extending into northern Calvert and southern Anne Arundel Counties lacks such a gravel cover, and the topography developed on the erosionally-weak Calvert rocks is knobby and rough with steep, narrow stream valleys.

The Calvert Formation overlies the Nanjemoy disconformably over most of the outcrop area. The contact is notably planar and is marked by a zone of intense burrowing; Calvert clayey sand fills tubular and U-shaped burrows extending twelve inches or more into the upper Nanjemoy greensand. Updip, the Calvert follows much the same pattern of transgressive overlap as earlier units, overlying successively older rocks from northeast to southwest, specifically those of the Aquia and Monmouth Formations and ultimately the Potomac Group. Along much of the Coastal Plain margin in Virginia, these strata have overlapped all older units and rest on crystalline rocks of the Piedmont.

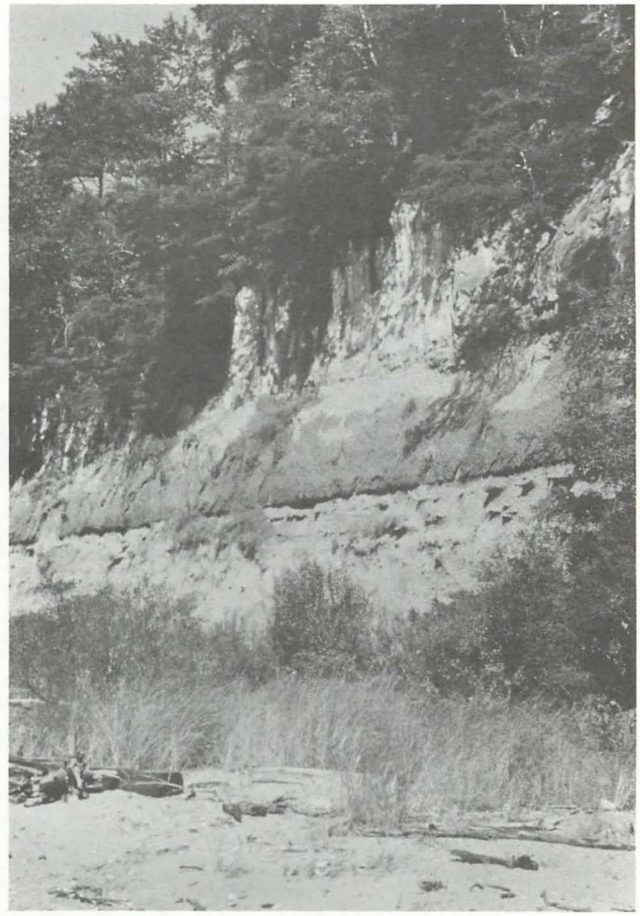

Figure 11. Weathered greensand of the Nanjemoy Formation disconformably overlain by fine sand and diatomaceous silt of the lower Calvert Formation (Fairhaven Member), Popes Creek (Stop 6).

The Calvert Formation reaches a maximum thickness of about 180 feet in outcrop, and has been divided into two members: the Fairhaven and the Plum Point Marls.

The Fairhaven Member, named for the small community of Fairhaven in southern Anne Arundel County (fig. 1), encompasses the lower sixty feet, more or less, of Calvert strata. Almost all of the exposed Miocene sediments in Charles, Prince Georges, and Anne Arundel Counties can be assigned to this Member; high cliffs at Fairhaven and along the Potomac at Popes Creek (fig. 11) expose nearly the entire thickness of the Fairhaven. The basal ten to twenty feet of the unit are composed of poorly-sorted, very argillaceous sand, medium to coarse just above the Eocene contact and grading to fine or very fine upward in the section. Dark-gray phosphatic clasts, fragments of bone, and small quartz pebbles are distributed through the sand, but are most abundant in the basal few feet. Overlying the sand is a bed of diatomaceous earth, 4 to 17 feet in thickness, composed of up to sixty percent diatom tests in a matrix of quartz silt and montmorillonitic clay. Both upper and lower boundaries of the diatomaceous earth are gradational; in fact, diatom tests occur throughout the Fairhaven but generally do not exceed ten percent of the sediment outside of this bed. The upper portion of the Fairhaven is rather homogeneous, fine to very fine, argillaceous sand. Stratification cannot be seen in most exposures of these rocks. A pervasive mottling, the effect of abundant burrowing, is apparent in nearly every outcrop and is most pronounced in partly-weathered sections. The sediment, when fresh, is olive-gray to olive-brown. Upon exposure,

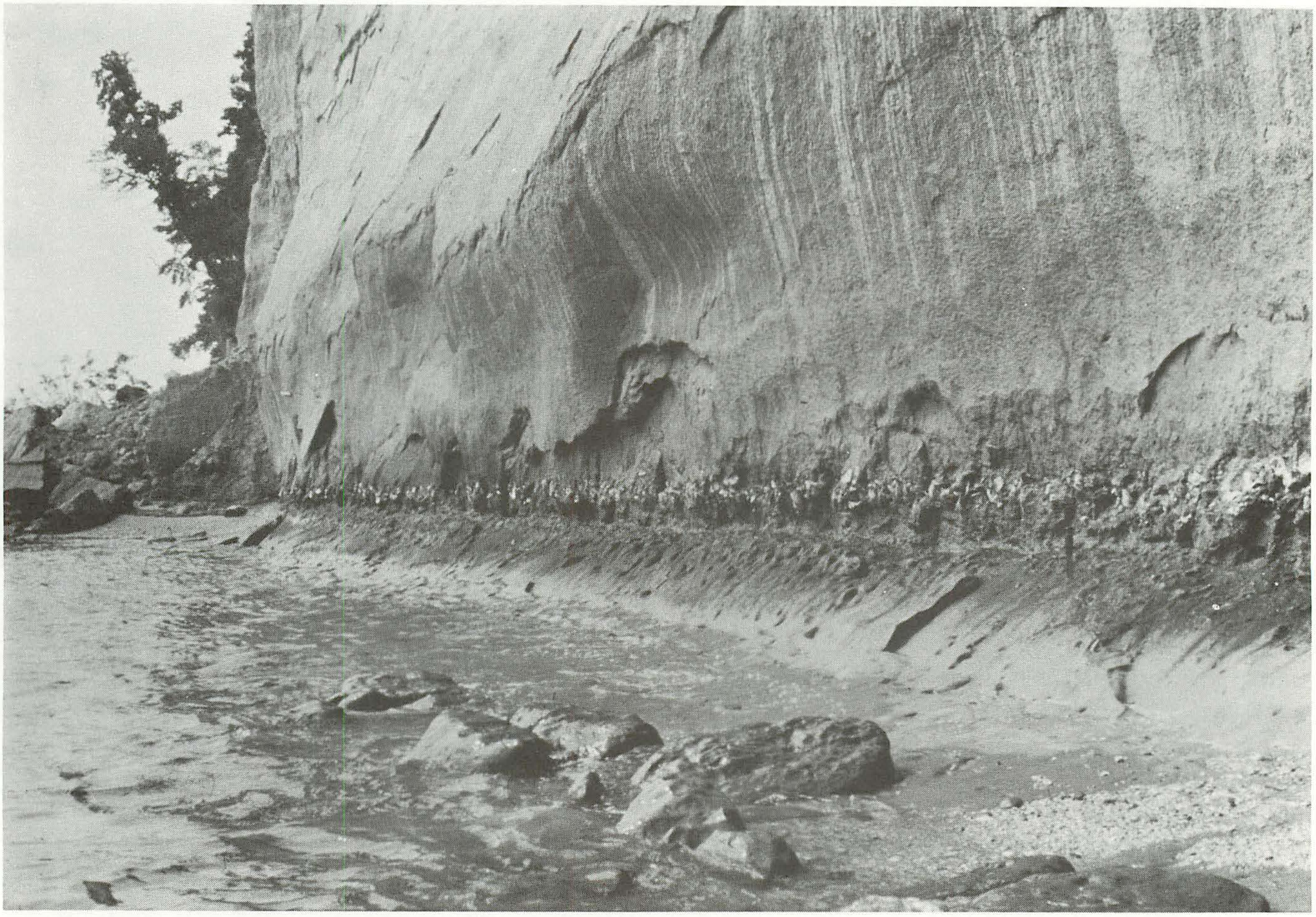

Figure 12. Fairhaven Member of the Calvert Formation overlain by the Plum Point Marls, Randle Cliff, Calvert County, Maryland.

the color rapidly pales to light-gray or light-brown, and in deeply weathered materials, to nearly white. This color transition is especially pronounced in the case of the diatomaceous earth.

Fauna is sporadically distributed through the Fairhaven, composed for the most part of pelecypods such as *Chlamys, Pecten,* and *Lucinoma* sp., shark teeth, fish vertebrae, and other bone fragments. The sediments have been deeply leached and practically all carbonate removed, such that only molds and casts of the mollusks remain. Gibson (1962) reports microfauna, excepting diatoms, absent from all but the upper few feet of sediment.

Overlying the Fairhaven Member are the Plum Point Marls, named for the fine exposures near Plum Point on the Bay shore of Calvert County (fig. 1). The distribution in outcrop of the Plum Point Member is considerably more restricted geographically than that of the underlying Fairhaven. Exposures are confined to the northern two-thirds of Calvert and the southern tip of Prince Georges County. Excellent, nearly continuous exposure can be seen in a fourteen-mile reach of the Calvert Cliffs extending from Chesapeake Beach to Kenwood Beach.

The nature of the Fairhaven-Plum Point Marls contact suggests a hiatus in sedimentation. The uppermost Fairhaven is extensively-bored, blue-gray, silty clay capped by a six-inch biostrome of *Ostrea percrassa* (fig 12). The dip of the oyster bed is at variance with the regional dip of the overlying Plum Point beds, indicating a disconformity (Dryden, 1936). The Plum Point Marls, in contrast to the Fairhaven, are abundantly fossiliferous and are amenable to subdivision into a number of beds or "zones" based on fossil content or lithology or both. Historically, from six to twelve such "zones" have been defined, depending upon the individual worker and his particular viewpoint (Clark and others, 1904; Dryden, 1930, 1936). General agreement exists on the presence in the Calvert cliffs of a thick, laterally-traceable shell bed ("Zone 10") near the base of the Member. "Zone 10" is widespread and diagnostic of the Calvert Formation, cropping out along the length of the cliffs and at a number of inland exposures in northern Calvert and southermost Prince Georges Counties. The shell bed is overlain by two very similar beds of massive silty clay separated by a thin sandy interval containing numerous vertebrate fossils ("Zones 11, 12, and 13"). The sediments both above and below this sequence are variably-fossiliferous, fine-grained argillaceous sands and silts. Color and weathering characteristics resemble those of the Fairhaven.

Macrofossils, including a number of vertebrates and mollusks, are abundant and well-preserved in the Plum Point Marls. The molluscan fauna is exceptionally rich with 231 described species (Clark and others, 1904).

The maximum thickness of the Plum Point Marls in outcrop is about 120 feet.

The Calvert Formation represents deposition in relatively cool, shallow marine waters (Gibson, 1962). The fauna in the upper beds of the unit points to gradually shoaling conditions and warmer water.

Choptank Formation

The Choptank Formation is relatively thin with rather ill-defined upper and lower limits as a unit. The lower contact with the Calvert Formation is reportedly unconformable, although this relationship is difficult to see in outcrop. However, an abrupt faunal change does occur, presumably at this contact (Gibson, 1962). The top of the Choptank is equally difficult to place in exposures; the overlying St. Marys Formation rests conformably on the Choptank with the contact generally being drawn within a barren clay sequence.

In Southern Maryland, a maximum of about sixty feet of Choptank strata is present within the outcrop belt. The latter crosses the area from northeast to southwest, occupying portions of northern and central Calvert County and the northwestern half of St. Marys County (pl. 1). Exposures are generally poor inland from the major estuaries. Excellent outcrops, however, are to be found in the Calvert Cliffs from Dares Beach southward to Cove Point.

The Choptank lithology varies from dense, gray-green clay to yellowish-brown sand. This unit, like the Calvert, was early subdivided into "zones", numbered 16 through 20 (Clark and others, 1904). Two of these, 17 and 19, are well-defined shell beds, readily identified in outcrops and in borings. Both are composed of tightly- packed molluscan shells in a matrix of yellowish-brown, well-sorted, fine to medium sand. The lower of the two beds, "Zone 17", ranges from six to thirty feet in thickness, whereas the upper bed shows less thickness variation, ranging from twelve to fifteen feet. The intervening Choptank beds are mostly unfossiliferous, gray-green to bluish-green sandy clay or silt.

The Choptank macrofauna, although notably rich, is smaller than that of the underlying Calvert, comprising some 190 species of mollusks, a few fishes, echinoderms, bryozoans, and a single coral (Clark and others, 1904). The microfauna is equally rich. Choptank sediments were deposited in very shallow, moderately-warm, marine waters (Gibson, 1962). The lower portion of the unit apparently represents a continuation of the shoaling conditions begun in the Calvert, whereas the upper beds point to slightly deeper water.

The Choptank Formation, with the exception of a few exposures along the south shore of the Potomac, is restricted to Maryland. In most of Virginia, the St. Marys Formation rests unconformably on the Calvert. Moreover, Choptank strata are apparently absent in some downdip borings in southern Calvert and St. Marys Counties.

St. Marys Formation

Exposures of the St. Marys Formation are confined, in Southern Maryland, to the lower portions of Calvert and St. Marys Counties (fig. 1, pl. 1). The unit receives its name from the St. Marys River in the latter county. Throughout most of this area, younger sediments, chiefly sand and gravel, effectively mantle the Miocene units, limiting outcrops to the Bay shore and the banks of the Patuxent, Potomac, and St. Marys Rivers. The most complete exposures of St. Marys sediments are in the Calvert Cliffs near Little Cove Point where about forty-five feet of section has been measured.

Interbedded dense, bluish-gray clay and similarly-colored fine, argillaceous sand composes much of the St. Marys. Placed in the zonal framework, the St. Marys comprises "Zones" 21 through 24 (Clark and others, 1904), these based mostly on the vertical abundance and composition of the molluscan fauna. In southern St. Marys County, the sands are commonly abundantly glauconitic, resembling the typical Paleocene-Eocene lithology but generally finer-grained. Calcite-cemented sandstones are not uncommon in the upper part of the unit. The maximum thickness of St. Marys sediments in Southern Maryland is about 80 feet.

The macrofauna is dominated by gastropods, which number 98 of the 166 species of mollusks present (Clark and others, 1904). Microfauna is abundant with benthonic foraminifera comprising the bulk of the forms. Gibson's (1962) analysis of the foraminiferal fauna indicates moderately shallow-water deposition with the upper Choptank deepening trend continued into the lower St. Marys, followed by shoaling in the upper beds.

PLIOCENE-PLEISTOCENE

Upland Deposits

A relatively thin veneer of gravel, sand, and silt is the surface formation over approximately one-third of Southern Maryland, unconformably overlying all of the older units from Lower Cretaceous to Miocene. The bulk of these sediments comprise a partly-dissected sheet extending south and southeast from Washington and covering large areas in Prince Georges, Charles, and St. Marys Counties as well as the lower part of Calvert County. However, many smaller areas of similar materials are isolated in fragmented patches along the Fall Zone, capping scattered upland areas throughout the northern portion of the region. The common denominators are lithologic similarity and elevation. The northern sediment patches lie at elevations of 200 to 500 feet. The base of the more or less continuous sheet to the south declines from 300 feet near Washington to about 100 feet in southern St. Marys County. The dominant lithology of these materials is medium to coarse sand, pebbly sand, and gravel.

Attempts to develop a viable stratigraphic nomenclature for the Plio-Pleistocene sediments of this area have in the past been based on an essentially geomorphic approach. Early workers such as Shattuck (1906) and Cooke (1930) held that most of these sediments originated as marine terraces resulting from repeated submergence and deposition followed by uplift and erosion. This mechanism presumably produced a series of four to six terraces established at elevations ranging from 25 to 270 feet. Later work by Hack (1955), Schlee (1957), and others cast considerable doubt on this hypothesis. It seems clear that the higher terraces, variously termed Bryn Mawr, Lafayette, Brandywine, and Sunderland, are almost certainly fluvial and together constitute the remains of a once-continuous, southeasterly-sloping sediment sheet rather than separate terraces. Hack has termed these sediments "upland deposits", and his usage is followed here. Further, the term is expanded to include isolated patches of high-level sand and gravel in Anne Arundel and northern Prince Georges Counties, heretofore mapped as Brandywine or Sunderland.

The sediments composing the northern upland remnants are predominantly sandy; medium to coarse, poorly-sorted, argillaceous sand, commonly pebbly, is characteristic. Gravels as such are generally confined to the basal beds. These can be notably coarse, in many places with a high percentage of boulders. The upper portion of the deposit is almost invariably oxidized to orange or reddish-brown whereas the unoxidized sediment below is mostly pale-gray to grayish-white. The Upland Deposits are grossly similar to the more arenaceous portions of the Potomac Group, and where these rocks are in contact, the two units are distinguished with difficulty. The most reliable criteria are the presence in the Upland Deposits of crystalline rock clasts and a more diverse heavy mineral suite. These isolated upland patches are usually thin, rarely exceeding forty feet in thickness, and are unfossiliferous.

The morphology and sediment properties of the large, sheetlike deposit to the south have been reported in detail by Schlee (1957). Two members can be discriminated in most areas: a lower gravel member and an upper loam member. The gravel member consists of pale-gray to yellowish-brown, poorly-sorted gravel, sandy gravel, and pebbly clay. Cross-bedding, pebble-imbrications, and channeling are common sedimentary structures. The upper few feet of the gravel are typically partly-indurated with a red silty sand matrix and abundant iron-oxide cemented zones. Below the oxidized zone, the sediment is much cleaner, lacks red pigmentation, and caves readily. The cross- bedding indicates east to southeasterly transport; the percentage of gravel and average pebble size decline as well to the east.

The gravel grades upward into the loam member: massive, mostly homogeneous silt containing scattered sand grains and pebbles. The loam varies from mottled grayish-orange and browish tones to uniform bright-red.

The average thickness of the sediment sheet is 25 to 30 feet. However, the deposits tend to thicken southeastward, reaching 70 feet or more in southern St. Marys County. The gravel clasts are almost wholly siliceous, consisting of vein quartz, sandstone, and chert. Proximal to the Potomac River, however, immature rock types, such as feldspathic sandstone, gneiss, and schist, occur in the gravel, as do anomalously large boulders several feet in diameter.

The Upland Deposits dip southeastward at about five feet per mile, and further, slope gently toward all of the major drainage lines, particularly the Potomac. It is probable that this slope occurs, as Hack (1955) has demonstrated in the Brandywine area, through a series of broad, shallow steps separated by minor stratigraphic breaks. In many areas, however, such as southwestern Charles County, the Upland Deposits appear to decline gradually in elevation and merge, without noticeable lithologic discontinuity or stratigraphic break, with lower terrace materials bordering the Potomac River. In such cases, the contact between the Upland Deposits and lower terraces is arbitrarily placed at 100 feet. This is admittedly a simplistic solution to a relatively complex problem; determination of the precise relationship between these rocks must await detailed geologic mapping aided by careful topographic measurements, an approach successfully employed by Hack in the Brandywine area.

The Upland Deposits, as viewed by both Hack and Schlee, are probably degradational stream sediments deposited by the ancestral, eastward-flowing Potomac River. The River apparently migrated slowly southeastward, and through lateral corrasion spread behind it a thin veneer of channel gravel and floodplain silt over much of Southern Maryland (fig. 13). The Upland Deposits are generally assigned a Pliocene (?) age because they overlie Miocene strata and are bordered by topographically-lower Pleistocene terraces. Plant remains are the only *in situ* fossils which have been found in these sediments, and these suggest a Pleistocene age (Hack, 1955). The presence of anomalously large boulders in the Upland Deposits adjacent to the Potomac River suggests ice-rafting, further supporting an early Pleistocene age for at least a portion of the sediment sheet.

A similar environment of deposition, although probably unrelated to the ancestral Potomac, can be postulated for the northern Upland Deposit outliers.

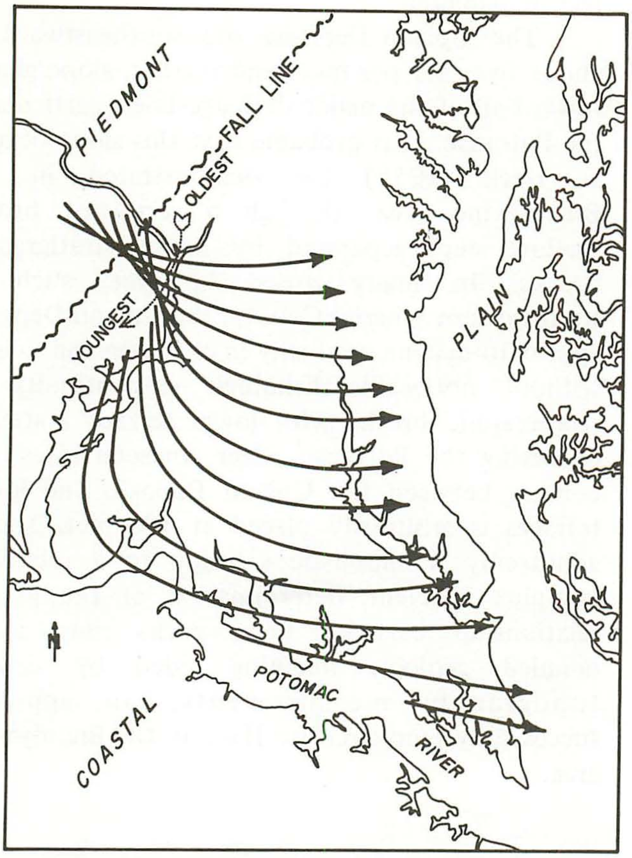

Figure 13. Schematic diagram showing lateral migration pattern of the Potomac River during deposition of the Upland Deposits (after Schlee, 1957, fig. 21).

Lowland Deposits

The term Lowland Deposits has been established to encompass all of the Pleistocene through Holocene sediments lying below 100 feet of elevation. Thus this grouping includes one or more terraces flanking the major estuaries of Southern Maryland as well as alluvium flooring most of the smaller stream valleys, materials formerly mapped as Wicomico or Talbot Formations. Shattuck (1906), in introducing the terms Wicomico and Talbot, envisioned these sediments as marine deposits associated with shorelines at 100 and 42 feet respectively. In fact, however, most of these sediments are undoubtedly fluvial. Moreover, well-defined terraces according at fixed elevations cannot be mapped throughout

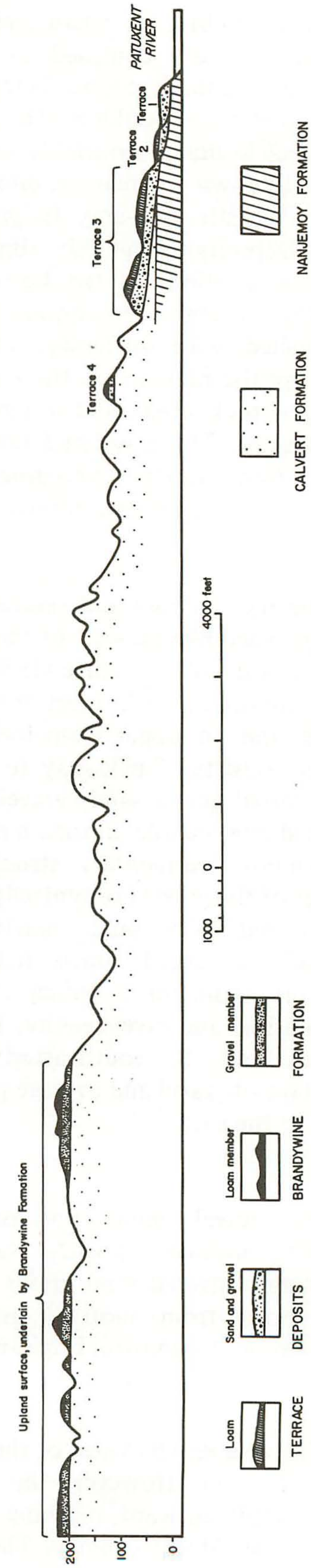

Figure 14. Generalized geologic cross-section from Brandywine to the Patuxent River, Prince Georges County, Maryland, showing the relative positions of the Patuxent River valley terraces and the Upland Deposits (Brandywine Formation) (after Hack, 1955, fig. 24).

much of Southern Maryland. Locally, Dryden (1948) noted terrace scarps at elevations of 30, 43, 55, and 60 feet adjacent to the Potomac River in Charles County, whereas Hack (1955) mapped three terraces below 100 feet in elevation flanking the Patuxent in Prince Georges County (fig. 14). It seems wise, therefore, to collect these sediments under the term Lowland Deposits until such time as sufficient mapping is done to clarify their relationships.

Lithologically, most of these sediments resemble the Upland Deposits to a large degree. Interbedded gravel and coarse sand are prominent. Reddish-brown colors and iron-oxide cementation are not pronounced as in the upland sediments; grayish-white to pale-greenish, less-weathered appearing sediments are the rule. Glauconite, probably reworked from Tertiary units, is a common constituent in the Lowland Deposits. Toward the southern tip of St. Marys County, coarse clastics are interbedded with dark-gray, fossiliferous silts and clayey sediments. The latter beds have yielded a marine to brackish-water fauna of 120 species, mostly mollusks, which Blake (1953) regards as Aftonian in age. *Rangia cuneata, Mulinia lateralis, Mercenaria mercenaria,* and *Ostrea virginica* are common and characteristic of this facies. Peat and woody, organic clays also occur in the lower terraces. Of particular interest are a number of late Pleistocene swamp deposits with *in situ* cypress stumps and knees associated with the Lowland Deposits. Examples occur at Bodkin Point in Anne Arundel County, at Drum Point in Calvert County, and in downtown Washington, D.C. The latter deposits are Sangamon in age, according to Knox (1966), with a lower spruce pollen zone representing the Illinoian glaciation.

The Lowland Deposits vary greatly in thickness, from ten feet or less to as much as 150 feet in southern St. Marys County. Exposures are generally poor as much of the area underlain by these sediments is low, swampy, and relatively undissected.

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Pliocene-Pleistocene

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ROAD LOG

ROAD LOG

First Day, November 1, 1968

Mileage between Points

	Leave Johns Hopkins University campus and proceed south on Howard Street.
2.1	Turn right (west) on Franklin Street (U.S. 40).
0.2	Turn left (south) on Greene Street.
0.7	Greene Street merges with Russell Steeet; continue south on Russell.
1.6	Russell Street merges into the Baltimore-Washington Parkway; continue south on Parkway.
0.6	Several hundred feet to the east of the highway can be seen an abandoned sand pit in the Patuxent Formation. Although the exposure is of mostly grayish-white, argillaceous sand, the film of red clay coating the pit walls gives the impression of a much more clayey section. The Patuxent Formation is a major source of sand and gravel in the Baltimore-Washington area.
0.6	Baltimore City boundary.
0.2	Crest of hill bears a thin capping of Late Tertiary or Early Quaternary Upland Deposits, mostly sand and gravel.
0.7	Patapsco River (Baltimore-Anne Arundel County boundary).
0.9	Baltimore Beltway underpass.
0.7	The next mile and a half of roadway traverses a broad, low hill capped by orange-brown sand and gravel (Upland Deposits) and underlain by Potomac Group sediments. The latter, represented mostly by maroon clay and yellowish, clayey sand, are exposed in the Penn Central railway cut just north of the highway.
1.3	Junction Md. 46 to Friendship Airport.
0.5	Penn Central railway overpass.
2.3	The low road cuts to the left expose red and gray mottled clay and fine, grayish sand of the Potomac Group.
0.4	Dorsey Road (Md. 176) overpass.
2.5	Md. 175 underpass.
2.2	Md. 32 underpass; the National Security Agency is housed in the building complex to the east of the highway.

Mileage Between Points

0.7	Cross Little Patuxent River.
0.9	Bear right on ramp to Md. 198.
0.2	Turn right on Md. 198.
0.2	Red and gray mottled sandy clay of the Patapsco Formation in cuts; gravel wash is talus from thin Upland Deposit capping on small hill to left of highway.
0.2	Patapsco red clay in low cuts to left.
1.4	Cross Patuxent River (Anne Arundel-Prince Georges County boundary).
0.4	Junction Md. 197.
0.4	Town of Laurel, turn left (south) on U.S. Rt. 1.
1.9	Turn right (west) into Contee Road.
1.0	Turn left (south) into Van Dusen Road.
0.3	Turn right (west), continue on Van Dusen Road.
1.3	**STOP No. 1.**

The large complex of pits on both sides of the highway are operated by the Contee Corporation for sand and gravel. Exposed are the lower fifty to one-hundred feet of the Patuxent Formation; basement rocks outcrop in the valley of Bear Branch a mile or so northeast of the pit area. The specific pit to be visited will depend upon the location of active digging operations at the time of the field trip. However, much the same stratigraphy and sedimentary structures can be seen throughout the area.

The section exposed consists of interbedded sand, sandy gravel, and gravel, with minor amounts of pale-grayish clay. Bedding is notably lenticular. Most of the sandy beds and many of the gravels are trough cross-stratified in sedimentation units ranging up to eight feet in thickness. Sediment transport was predominantly southeastward. Other common sedimentary structures which can be seen include graded open-work gravel, clay ball conglomerates, channeling, clay drapes, and large-scale inclined bedding. Secondary features include abundant limonite and hematite cementation, commonly permeability controlled, and diffusion banding. Both sand and gravel are almost wholly siliceous. The pebbles are mostly vein quartz, diluted with quartizite and Appalachian sandstones in the coarser sizes. Minor amounts of chert are also present. Fossils, other than rare silicified wood, are absent in these sediments.

The lower portion of the Patuxent Formation, as here represented, probably reflects deposition by braided streams of notable competence with much of the sediment having accumulated in channel bars, and to a lesser extent, point bars.

In the subsurface, these sands typically produce an electric resistivity curve having a massive or blocky profile (wells AA-Cb 2, fig. 4; PG-Cd 23, fig. 5). Unlike the point bar deposits of meandering rivers (e.g. Patapsco sands in well AA-Cc 86, fig. 4), such sands generally lack discrete fining upward profiles.

0.5 Turn left (south) on Old Gunpowder Road.

1.3 Contee pits to left of highway.

0.7 Turn left (east) into Ammendale Road.

0.7 Extensive sand and gravel operations to right of highway; within a thirty-five square mile area surrounding Stop No. 1 are some seventy-two separate openings for sand and gravel within the Potomac Group, most of these exploiting the Patuxent Formation.

0.2 Bear right, continuing on Ammendale Road.

0.7 Turn right (south) on U.S. Rt. 1.

0.1 Turn left (east) into Ammendale Road.

0.4 Turn left (north) into Old Baltimore Pike.

0.9 Turn left (west) into Muirkirk Road.

0.1 Turn right into Washington Brick Co. property.

STOP No. 2.

The Washington Brick Co. pit, located immediately northeast of the plant, exposes the uppermost beds of the Patuxent Formation, the Arundel Clay, and probably the lower portion of the Patapsco Formation. The Patuxent Formation, represented by pale-gray, cross-bedded pebbly sands and some interbedded lenticular clays, can be seen in a series of openings along the northeast side of the main pit. Red and yellow iron-oxide staining is prominent near the top of the Patuxent section.

The Patuxent is succeeded by about ten feet of tough, massive, dark-gray Arundel Clay, presently being worked at the base of the northeast pit wall. The clay is conspicuously lignitic in places, containing local concentrations of wood fragments up to several feet in length. Large sideritic concretions are also present in the clay.

The dark clay is overlain by 30 to 50 feet of varicolored, massive silty clay, largely maroon to brown in color. Lenses of fine clayey sand and silt occur in the clay near the top of the section. All of the sediments above the gray clay presumably belong to the Patapsco Formation, although dateable plant remains are lacking in this part of the sequence. The Arundel age of the gray clay has been confirmed by Brenner (1963) on the basis of the contained sporomorphae. In other areas within the pit, Patapsco (?) beds directly overlie Patuxent sands, the gray clay being absent.

The Arundel Clay represents deposition in quiet, shallow, fresh-water environments. The association of massive lignitic clay, logs and rooted stumps, terrestrial reptile bones, and the absence of marine fossils suggests sedimentation in shallow, probably discontinuous, backswamp basins maintained by ponded drainage and slow sediment influx. The lithologic association and sedimentary structures in the overlying Patapsco point to floodbasin deposition.

The clay sequence exposed in the Muirkirk Pit extends downdip and is represented at the Patuxent Wildlife Refuge by a 130 foot section (well PG-Be 22, fig. 5). Based primarily on its electric log characteristics, this clay sequence is a mappable stratigraphic unit between Baltimore and Washington, D.C. (Hansen, 1968).

Return to Muirkirk Road and continue east.

1.3	Crest of Hill. Low cuts on both sides of roadway expose reddish-brown, coarse pebbly sand of Upland Deposits capping hilltop; a maximum thickness of 30 feet of these sediments is present in this isolated patch.
0.1	Cuts show mostly grayish-tan, clayey sand with gravel stringers (Upland Deposits).
0.6	Low cuts in red clay of the Patapsco Formation; pebble talus is derived from sand and gravel cap above.
0.7	Junction Baltimore-Washington Parkway, turn right (south) onto access ramp.
1.8	Powder Mill Road overpass; USDA Beltsville Research Center on both sides of highway.
3.3	Greenbelt Road (Md. 193) underpass.
0.4	Capital Beltway, turn right onto ramp to southbound land.
0.1	Enter Capital Beltway south.
0.2	Red Patapsco clay in abandoned excavation to left of highway.
2.9	Large cut in hill to right of highway affords an excellent exposure of the upper Patapsco Formation. The lower half of the cut exposes fine to medium, cross-bedded, clayey sand, the upper few feet of which is discontinuously cemented by iron-oxide to form a resistant ledge. Above this are interbedded lenticular silts and silty clays. The brightly mottled colors are characteristic of the Patapsco Formation.
0.9	Cut bank in low hill to right of highway exposes reddish-mottled sandy clay overlying interbedded fine, gray lignitic sand and dark carbonaceous clay, all within the Patapsco Formation.

4.0	The next four miles of roadway traverses the outcrop belt of the Monmouth and Brightseat Formations, crosses the alluvium-floored valley of Southwest Branch, and enters the Aquia outcrop belt. Good exposures of these rocks enroute are lacking.
	The upper part of the benched road cut to the right at 4.0 miles is cut in yellowish-brown to grayish pebbly sand of an isolated Upland Deposit cap.
	The field trip route from this point to the Indian Head Highway interchange, a distance of about eleven miles, lies mostly on the proximal fringe of the Upland Deposits; these extend southeastward from this point as a more or less continuous sheet. Generally speaking, the most consistently coarse gravels in the sheet are concentrated in this area. The gravel is exposed at numerous points along the route, mostly in road cuts, gullied slopes, and excavations. The Beltway dips into several deep stream valleys enroute which are cut through the Upland Deposits into the Calvert and underlying Aquia Formations, but exposures of these rocks are not visible from the highway.
10.3	The roadway begins to descend into the Potomac River valley at this point, and at about 200 feet elevation, drops gently to a lower terrace within the Upland Deposits, the Sunderland terrace of Shattuck (1906). Lithologic change, with the exception of a slight coarsening of the gravel fraction, is not pronounced.
0.7	Indian Head Highway (Md. 210) underpass. Turn right on ramp to Indian Head Highway southbound.
	Upland deposits resting disconformably on dark-gray, micaceous clayey sand of the Monmouth Formation can be seen in the partly-overgrown cut to the left of the exit ramp. The Monmouth is thin, probably less than 40 feet, at this locality. Finely-laminated pale-gray sand and dark-gray lignitic clay of the Patapsco Formation is exposed in the walls of the deep, narrow stream valley immediately north of the road cut.
0.5	Reddish-brown, much-weathered Aquia greensand outcrops in the gullied bank to the left of the highway.
0.2	Weathered Aquia in road cut to left; the pebbly loam mantling the cut has slumped from above.
0.5	The small stream to the left of the highway has cut through about ten feet of reddish-brown, bouldery, glauconitic alluvium to the underlying Cretaceous. Red and gray mottled sandy clay of the Patapsco Formation is exposed in the stream bed.
0.7	The highway, at this point, begins to cross the broad, alluvium-filled valley of Henson Creek. The mottled purplish and pale-gray clay which can be seen in the eroded hillside to the left of the roadway is probably the upper portion of the alluvial fill. The clay contains considerable selenite as well as pods and lenses of orange-brown, poorly-sorted pebbly sand.

Mileage Between Points

0.6	Cross Henson Creek.
1.4	Turn right (west) on Fort Washington Road.
	The cut bank behind the shopping center to the right shows very coarse, reddish-brown Upland Deposits.
2.6	Gray-brown, fine to medium, clayey, glauconitic sand with scattered pebbles in road cut to left. Included in the Lowland Deposit grouping, these sediments are typical of Shattuck's Wicomico terrace.
0.5	Large pit to right of highway exposes Lowland Deposits of similiar lithology.
0.2	Mottled orange and grayish, fine clayey sand, pebbly in part, in partly-overgrown cut to left (Lowland Deposits).
	Enter Fort Washington National Park.
0.2	Turn left.
0.6	Road end. Follow footpath leading southwest from parking area to base of high bluff overlooking Piscataway Creek.

STOP No. 3.

The bluff at this locality exposes the Patapsco, Monmouth, and Aquia Formations. The sediments, particularly the Aquia, are much weathered and have been leached of carbonate; however, the outcrop does provide perhaps the best exposure of the Monmouth-Patapsco contact in Southern Maryland. In this area, the Monmouth has transgressed the Matawan and Magothy Formations and disconformably overlies Patapsco clays. A recently measured section of the lower, vertical portion of the bluff follows:

MONMOUTH FORMATION	FEET
Sand, fine-grained, silty, argillaceous; dark-gray to brownish-gray; irregularly mottled due to burrowing; contains selenite crystal aggregates to six inches or more in diameter; molds and casts of mollusks common in upper portion.	13±
Gravel; vein quartz pebbles to two inches diameter tightly packed in matrix of dark-gray silty clay; contains irregular masses of gypsum-cemented conglomerate; grades into overlying sand (pebbles become smaller and fewer upward)	1.5

PATAPSCO FORMATION

Clay, silty; tough, blocky; red, pale-gray, and tan mottled; upper few inches contain irregular burrows filled with dark-gray Monmouth silty clay. 17

The Monmouth-Aquia contact may be reached by climbing the talus slope to the right (east) of the vertical portion of the bluff. It is marked by a conspicuous break in slope as the Aquia sand is less resistant to erosion than the finer-grained and more clayey Monmouth sediments. The contact is sharp but irregular due to burrowing, and is marked by a line of small, discoid, siderite concretions. The Aquia at this locality consists of fine to medium, gray-green, relatively clean sand. Glauconite lends a "speckled" aspect to the sand. The higher portion of the bluff still farther to the right is virtually all Aquia, exposing nearly 40 feet of this unit in all. Much of the Aquia in the higher bluff is strongly oxidized and consists of reddish-brown clayey sand.

Most of the Cretaceous-Tertiary section in the western end of the lower bluff has been removed by Pleistocene valley-cutting and replaced by alluvial fill. The fill is grayish-green to pale-gray, glauconitic sand, similar to the Aquia but containing pods and bands of pebbles and cobbles. The alluvium-bedrock contact dips steeply to the left (west) and cuts through the Monmouth and into the Patapsco Formation.

Return to picnic area at the top of the bluff where box lunches will be served.

Return to Fort Washington Road and retrace route to junction Old Fort Road. Turn right.

1.6 Turn right (south) on Indian Head highway (Md. 210)

The next mile of highway descends gradually through 180 feet of elevation to the valley of Piscataway Creek, passing enroute through the Calvert and Nanjemoy Formations, the Marlboro Clay, and part of the Aquia Formation. The cuts are heavily over-grown, and exposures of these units connot be seen.

1.0 Turn left into dirt parking area adjoining Piscataway Creek.

STOP No. 4.

The outcrop is in a low bulff facing Piscataway Creek a few yards east of the highway. Exposed is the upper portion of the Aquia Formation, notably fossiliferous at this locality. The section is as follows:

AQUIA FORMATION FEET

Sand, fine to medium-grained, argillaceous, glauconitic; pale-brownish on surface, gray-green beneath; patchy calcite cementation; fossiliferous with *T. mortoni* the most abundant form. . . . . .15±

Sandstone, pale brownish-gray, calcite-cemented; sparsely fossiliferous; forms overhanging ledge. . . . . .2±

Sand, fine to medium-grained, argillaceous, glauconitic; mottled pale-brown and gray-green; abundantly fossiliferous, shells much decomposed. . . . . .18±

Mollusks identified by Cooke (1952) from this locality include the following:

Odontaspis rutoti (Winkler)
Odontaspis macrota (Agassiz)
Myliobatis sp.
Turritella mortoni Conrad
Turritella praecincta Conrad
Cucullaea gigantea Conrad
Ostrea compressirostra Say
Venericardia planicosta regia Conrad
Dosiniopsis lenticularis (Rogers)
Crassatella alaeformis Conrad
Corbula subengonata Dall

The glauconite content of the sand ranges from 35 to 50 percent, and shows a generalized increase upward in the Piscataway Creek section. Drobnyk (1965) has speculated that this site was a localized depression in the sea floor during Aquia time. The increasing glauconite content reflects a slowing deposition rate due to decreasing current strength.

Return to vehicles and continue south on Indian Head Highway.

The next seven miles of roadway, after ascending the long grade immediately south of Piscataway Creek, lies almost wholly on the Upland Deposits. Exposures are few, consisting of scattered patches of orange-brown loamy sand, pebbly in part, in low cuts along the highway.

7.1 The highway, at this spot, descends a short grade, passing through nearly the entire thickness of the Upland Deposits. The road cuts expose a graded sequence of reddish-brown sand and gravel, consisting of a lower gravelly member overlain by an upper sandy loam.

0.2 Turn left (southeast) on Md. 225.

The abandoned gravel pit visible to the east of the intersection is cut in coarser gravel of a lower Potomac River Terrace. In contrast to the Upland Deposits, these sediments are less mature, containing scattered boulders of crystalline rock up to 24 inches in diameter.

0.6 The road here descends sharply, leaving the lower terrace to cross the alluvial valley of Mattawoman Creek.

Mileage Between Points

0.6	Cross Mattawoman Creek.
0.2	Turn right (southwest) on Md. 224.
0.6	**STOP No. 5.**

The high cut bank a few yards southeast of the highway affords an excellent exposure of Eocene sediments. The section is as follows:

NANJEMOY (?) FORMATION	FEET
Sand, fine-grained, silty, micaceous, very sparingly glauconitic; medium-gray, mottled reddish-brown with iron-oxide crusts near top; sand fills burrows in top of underlying clay and contains molds and casts of pelecypods near base.	10±
MARLBORO CLAY	
Clay, plastic, sticky; silvery to medium-gray, grading to pinkish-brown in ill-defined zones near middle; interbedded with silty clay and silt, pale-gray to pink, as laminae and beds to several inches thick; silt massive, finely-laminated, or micro cross-laminated; clay bears finely-divided lignite as well as small chips and twigs; sporadic tubular burrows filled with fine, gray-green, glauconitic sand; rare impressions of small pelecypods	14
AQUIA FORMATION	
Sand, fine-grained, sparsely-glauconitic; pale-gray to greenish-gray, brownish mottles in upper portion; uppermost 5± inches yellow-brown silty micaceous clay permeated with iron-oxide and containing scattered gypsum casts	10±
Sandstone, fine to medium-grained, calcite cemented, rare glauconite; medium-gray in color; abundantly fossiliferous, *Turritella mortoni* in large numbers; bed discontinuous, occurring as scattered blocks at base of cut	1-1.5

The considerable talus of pebbles and cobbles mantling the upper part of the cut is derived from Upland Deposits on the hilltop above the cut.

Both the Aquia and Nanjemoy (?) sands at this locality are finer-grained and considerably less glauconitic than correlative beds along the strike to the northeast and downdip to the southeast. In the case of the Aquia, Drobnyk (1965) visualizes these finer-grained sediments as deposited in a semi-protected marine embayment in the coastline, perhaps behind barrier bars.

Return to vehicles and retrace route to Md. 225.

0.6 Turn right (southeast) on Md. 225.

2.0 Road cut on right exposes dark greenish-gray, glauconitic Nanjemoy sand; molluscan shells, mostly *Venericardia potapacoensis,* are abundant below a two foot leached zone in the sand. A nearby water well reached the top of the Marlboro Clay at about 40 feet below the cut elevation.

The roadway climbs to the upland surface over the next .2 mile and remains on the Upland Deposits for about the next 3.7 miles.

3.5 Junction Rose Hill Road.

0.2 Roadway begins to descend into the Port Tobacco Creek valley.

1.2 Cross Port Tobacco Creek.

0.1 Junction Valley Road.

1.7 Turn right (south) on U.S. 301.
Town of LaPlata.

0.4 Fine exposure of the gravel member of the Upland Deposits to the left of the highway in cut bank behind shopping center.

0.4 Junction Md. 6; traffic signal.

The next 6.5 miles of the field trip route follows U.S. 301 south and lies wholly on the Upland Deposits. Exposures can be seen in a number of road cuts enroute; many of the cuts are in the upper loam member and show typically massive, bright orange, clayey silt.

4.9 Junction Md. 427 at Bel Alton.

1.5 Turn right (south) on Popes Creek Road.

2.7 Road descends into Popes Creek valley at this point; the road cuts are mostly overgrown but show patches of coarse Upland Deposits, and below, weathered fine whitish sand of the Calvert Formation.

0.2 Cut to left exposes well-stratified, pale-gray pebbly sand belonging to the Popes Creek valley fill (Lowland Deposits).

Cross Penn Central railway tracks.

0.3 Turn into parking area just beyond Popes Creek Bridge.

STOP No. 6.

Walk to the beach opposite the parking area and turn south. Extending southward from this point are a series of high bluffs facing the Potomac River which provide excellent exposures of the uppermost Nanjemoy beds and nearly the entire thickness of the overlying Fairhaven Member of the Calvert Formation. A measured section just south of the Creek is as follows:

CALVERT FORMATION	FEET
Sand, fine-grained, clayey; white to pale-brown in color; massive.	30±
Sand, very fine to fine-grained, silty; pale-gray and brown mottled; abundant burrows defined by color contrast.	4
Diatomaceous silt, diatom content 30 to 60%; pale grayish-orange to nearly white when dry; massive except for scattered burrows.	17
Sand, fine-grained, clayey; yellowish-brown in color.	12±
Sand, fine to medium with admixed coarse grains; pale-brownish; small quartz pebbles, phosphatic fragments, and bits of bone near base.	5
NANJEMOY FORMATION	
Sand, fine to medium-grained, argillaceous, glauconitic; dark gray-green in color; upper surface extensively bored, the burrows filled with Calvert sand; contains numerous large iron-oxide concretions; fossiliferous, shells largely leached from upper portion, *Venericardia potapacoensis* most common form.	22

The diatomaceous bed is quite prominent in the bluffs due to its massive, vertically-jointed character and nearly white color. This material is remarkably light in weight and floats readily when dry. The Calvert-Nanjemoy contact is equally prominent and is marked by a slight overhang of the lowermost Calvert beds. The contact is notably planar for a major disconformity.

The pale colors of the Calvert sediments are typical of the weathered material. The unweathered sediment, including the diatomaceous bed, is olive-green.

The molluscan fauna of the Nanjemoy at this locality includes the following forms (Clark and others, 1901):

CEPHALOPODA

Hercoglossa tuomeyi C. & M.

GASTROPODA

Mangilia bellistriata Clark
Olivula sp.
Volutilithes petrosus (Conrad)
Mitra potomacensis C. & M.
Strepsidura subscalarina Heilprin
Levifusus trabeatus? Conrad
Pyrula penita Conrad
Calyptraphorus trinodiferus Conrad
Turritella potomacensis C.&M.
Mesalia obruta (Conrad)
Calyptraea aperta (Solander)
Tuba marylandica C.&M.

PELECYPODA

Teredo virginiana Clark
Corbula subengonata Dall
Corbula aldrichi Meyer
Corbula oniscus Conrad
Tellina virginiana Clark
Tellina williamsi Clark
Meretrix ovata (Rogers)
Meretrix subimpressa Conrad
Protocardia lenis Conrad
Lucina dartoni Clark
Lucina uhleri Clark
Venericardia marylandica C.&M.
Venericardia potapacoensis C.&M.
Modiolus ababamensis Aldrich
Anomia marylandica C.&M.
Pecten choctavensis Aldrich
Ostrea sellaeformis Conrad
Pteria limula (Conrad)
Glycymeris idoneus Conrad
Cucullaea gigantea Conrad
Leda parva (Rogers)

Leda cultelliformis (Rogers)
Leda improcera (Conrad)
Leda potomacensis C.&M.
Leda tysoni C.&M.
Nucula potomacensis C.&M.

Return to vehicles and retrace route to U.S. 301. Continue north on U.S. 301 to Waldorf Motel (16 miles).

End of first day's trip.

Second Day, November 2, 1968

Leave motel, turning south on U.S. 301.

2.5 Turn left (southeast) on Md. 5.
Town of Waldorf.

1.8 Junction Md. 382 (Beantown Road).

3.6 Junction Md. 488. Highway descends about 100 feet from upland surface to Zekiah Swamp Run. Zekiah Swamp Run occupies a wide, steep-walled valley, and in contrast to most other streams of similar size in Southern Maryland, flows on only a shallow alluvial fill or directly on Miocene bedrock (Hack, 1957).

0.4 Cross Zekiah Swamp Run.

0.7 Junction Md. 232 (Oliver Shop Road).

3.7 Hughesville.
Turn left (east) on Md. 231.
Between Hughesville and Patuxent (next 2.1 miles) are sporadic road cut exposures of brown pebbly loam (Upland Deposits).

2.1 Patuxent; junction Md. 381.

1.9 The local topography, between this point and the edge of the upland about two miles ahead, is noticeably knobby and rolling in character, reflecting increasing dissection of the sand-gravel cap in approaching the Patuxent River.

Mileage Between Points

2.0	Highway descends to the Patuxent River valley. Between the base of the upland scarp and the River, the roadway lies on the youngest Patuxent River terrace (Lowland Deposits).
0.8	Burch-Benedict Bridge, cross Patuxent River.
0.4	The low bluff immediately north of the east end of the bridge exposes about 15 feet of the Calvert Formation overlain by flat-bedded, white, pebbly terrace sand. The cemented shell bed at the waterline is "Zone 10", the most prolific Calvert fossil layer.
2.0	Highway ascends steeply to the upland surface.
0.4	Junction Md. 508.
1.0	Village of Barstow; between Barstow and Md. 2,4 are several poor outcrops of orange-brown pebbly sand in the road cuts.
1.8	Turn left (north) on Md. 2,4.
3.5	Turn right (northeast) on Md. 263 (Plum Point Road). The sand pits on either side of Md. 2,4 at the intersection are cut in well-laminated, fine to medium-grained, white to orange-brown sand belonging to the Pleistocene alluvium of Hunting Creek.
4.0	Bear left on Md. 261.
1.3	Turn left (very sharp turn), continuing on Md. 261.
0.8	Turn right onto dirt road marked "Camp Roosevelt BSA"; proceed .3 mile to parking area. Walk east on dirt track for several hundred yards to beach and turn south, following the beach to the high bluffs overlooking Chesapeake Bay.

STOP No. 7.

The cliffs at this locality expose most if not all of the Plum Point Marls Member of the Calvert Formation. A high rate of shore erosion (about three linear feet per year) prevails along much of the length of the Calvert Cliffs (Slaughter, 1949), insuring continually fresh outcrops in which leaching is at a minimum. The accessible portion of the section at this site is as follows:

CALVERT FORMATION	FEET
Plum Point Marls	
Sandy clay; fresh sediment bluish-gray, weathering yellowish; mostly barren of fossils ("Zone 15")	5±

Sandy clay, similar to above; fossiliferous, *Isocardia fraterna* most common form ("Zone 14"). . . . . 4±

Dense silty clay, prismatic jointing prominent; gray to grayish-blue; mostly barren ("Zone 13"). . . . . 6±

Clayey sand, brownish; few poorly-preserved fossils, vertebrate remains common ("Zone 12").. . . . . 2±

Dense silty clay, gray to grayish-blue; mostly barren ("Zone 11"). . . . . 7±

Sand, fine-grained; brown to brownish-green; loosely-bedded; abundantly fossiliferous with about sixty molluscan species identified ("Zone 10").. . . . . .12±

Sandy clay and fine clayey sand, olive-green; scattered bands of *Corbula elevata* ("Zones 5-9"). . . . . 14±

Clayey sand, fine to medium-grained, gray-green to olive-green; contains abundant *Ostrea percrassa* ("Zone 4"). . . . . 1±

Fairhaven Member

Silty clay, hard, brittle; bluish-gray; upper surface much bored ("Zone 3"). . . . . 4±

The Fairhaven-Plum Point Marls contact is presumably a surface of unconformity; the contact dips to the north in contrast to the south to southeasterly dip of the overlying Plum Point beds. The establishment of the *Ostrea* biostrome and the abundantly-bored surface of the Fairhaven lend further support to this conclusion (Dryden, 1936).

"Zone 10", the richly fossiliferous sandy bed midway in the section, has provided most of the fauna of the Calvert Formation, and is traceable as a continuous stratum over a large portion of Southern Maryland. The "Zone 10" fauna consists mostly of species which lived in the area of deposition, but also contains species introduced into the site from nearby communities; Fowler (1966) regards this bed as a "storm wave concentration".

Schoonover (1941) identified the following mollusks from "Zone 10" at this locality:

PELECYPODA

Nucula proxima Say
Nucula taphria Dall

Leda liciata (Conrad)
Leda liciata var. *amydra* Dall
Glycymeris parilis (Conrad)
Anadara subostrata (Conrad)
Pedalion maxillata (Deshayes)
Chlamys madisonius (Say)
Chlamys madisonius bassleri Tucker-Rowland
Anomia sp.
Modiolus ducatelli (Conrad)
Astarte cuneiformis (Conrad)
Astarte cuneiformis var. *obesa* Dall
Astarte cuneiformis var. *parma* Dall
Astarte cuneiformis var. *calvertensis* Glenn
Astarte exaltata Conrad
Eucrassatella melina (Conrad)
Venericardis granulata Say
Saxolucina foremani (Conrad)
Saxolucina anodonta (Say)
Phacoides crenulatus (Conrad)
Phacoides prunus Dall
Erycina speciosa Glenn?
Cardium leptopleurum Conrad
Isocardia mazlea Glenn
Dosinia acetabulum Conrad
Macrocallista marylandica (Conrad)
Callocardia sp.
Antigona staminea (Conrad)
Chione latilirata (Conrad)
Mercenaria rileyi (Conrad)
Tellina producta Conrad
Tellina declivis Conrad?
Semele carinata (Conrad)
Mactra clathrodon Lea
Corbula idonea Conrad
Corbula elevata Conrad
Corbula inaequalis Say
Saxicava arctica (Linn.)
Panopea whitfieldi Dall

GASTROPODA

Volvula iota var. *patuxentia* Martin?
Retusa conulus (Deshayes)
Cylichna calvertensis Martin
Terebra curvilineata var. *calvertensis* Martin
Surcula marylandica (Conrad)
Mangilia parva (Conrad)
Ecphora tricostata Martin
Scala sayana Dall

Niso lineata (Conrad)
Vermetus virginicus (Conrad)
Turritella plebeia Say
Turritella indenta Conrad
Turritella variabilis var. *cumberlandia* Conrad
Turritella variabilis var. B Martin
Turritella variabilis var. *exaltata* Conrad
Tachyrhynchus perlaqueatus (Conrad)
Crucibulum costatum (Say)
Calyptraea aperta (Solander)
Crepidula formicata (Linn.)
Polynices heros (Say)
Polynices hemicryptus (Gabb)
Calliostoma philanthropus (Conrad)
Calliostoma calvertanum Martin
Fissuridea marylandica (Conrad)

Return to vehicles and retrace route to Prince Frederick (intersection Md. 2,4 and Md. 231). Continue south on 2,4.

1.4 Cross Parker Creek.

0.9 Junction Md. 506.

1.5 Junction Md. 264.

3.0 Town of St. Leonard.

4.0 Turn left (east) on dirt road marked "Bechtel"; proceed 1.4 miles to nuclear plant site.

STOP No. 8.

At this site, the Baltimore Gas and Electric Co. plans construction of a $300,000,000 nuclear power plant with an anticipated capacity of 1.6 million kilowatts, scheduled to begin operations in 1973. Power will be available to most of Central Maryland through a dual nuclear steam supply system. A program to study the Miocene stratigraphy and paleontology of the site, initiated by the Maryland Academy of Sciences and financed by the National Science Foundation, the Baltimore Gas and Electric Company, and the State of Maryland, will run concurrently with plant construction and take full advantage of all excavations. Miocene exposures will be examined in the Cliffs at the site, and hopefully, in the large excavation for the main plant, depending upon the stage of construction reached at the time of the field trip.

The upper portion of the Choptank and probably the lowermost St. Marys Formation are exposed in the Cliffs. A recently measured section (Loose, pers. comm., in part) follows:

	FEET
UNDIFFERENTIATED PLIO-PLEISTOCENE AND LEACHED MIOCENE	
Sand, clayey, pale-brown to reddish, iron-oxide stained.	26
UNDIFFERENTIATED MIOCENE	
Clay, greenish-gray with iron-oxide mottling	1
Sand, fine, brown.	1
Sand, fine to medium, and clay, interbedded, gray-green.	13
Sand, gray-brown to rusty-brown mottled.	5
Sand, clayey, gray-green.	2
Clay, sandy, blue-gray.	5
Clay, brown.	2
Clay, blue-gray.	1
Clay, sandy, brownish.	1
CHOPTANK FORMATION	
Clay, massive, blue-gray, scattered shells ("Zone 20").	16
Clay, sandy, blue-gray, contains two thin shell layers ("Zone 20").	2
Sand, clayey in part, brown to gray-brown, abundantly fossiliferous, fauna of about 70 molluscan species ("Zone 19").	16
Clay, sandy, blue-gray, scattered shells ("Zone 18").	8

"Zone 19" is the higher of two, very fossiliferous Choptank shell beds considered by Gibson (1962) to represent very shallow water deposition, probably in less than ten meters of water. Mollusks identified by Schoonover (1941) from this bed at Stop No. 8 include the following:

PELECYPODA

Anadara staminea (Say)
Chlamys madisonius (Say)
Mytilus sp.
Astarte obruta Conrad
Eucrassatella marylandica (Conrad)
Saxolucina anodonta (Say)
Phacoides crenulatus (Conrad)
Diplodonta acclinis (Conrad)
Aligena aequata (Conrad)
Cardium laqueatum (Conrad)
Dosinia acetabulum Conrad
Macrocallista marylandica (Conrad)
Mercenaria campechiensis var. *capax* (Conrad)
Mercenaria plena (Conrad)?
Semele subovata (Say)
Psammobia gubernatoria Glenn
Ensis ensiformis Conrad
Corbula idonea Conrad
Corbula inaequalis Say
Corbula cuneata Say
Panopea americana Conrad

GASTROPODA

Ecphora quadricostata var. *umbilicata* (Wagner)
Turritella variabilis var. *cumberlandia* Conrad
Polynices duplicata (Say)

Return to vehicles and retrace route to Md. 2,4; turn right (north) and return to Baltimore via Md. 2,4, U.S. 301, and Md. 3. A number of good roadside exposures, noted below, can be seen enroute.

33.1 Cut on east side of U.S. 301 just south of Md. 408 exposes dark gray-green glauconitic sand of the uppermost Nanjemoy Formation.

1.8 Abandoned excavation on east side of roadway (U.S. 301) shows weathered Calvert (Fairhaven Member) sediments – pale-gray to brownish, clayey, fine sand with scattered shell molds.

4.5 The partly-overgrown road cut on the east side of U.S. 301 at Queen Anne Bridge Road exposes pale-reddish Marlboro Clay resting on Aquia gray-green glauconitic sand. The Aquia can be seen in a series of cuts between Queen Anne Bridge Road and the Patuxent River, 5.5 miles ahead.

Mileage Between Points

5.5	Sand and gravel pits on either side of the Patuxent River at this point are exploiting Pleistocene terrace deposits (Lowland Deposits).
7.4	Coarse, cross-bedded, white sand of the Magothy Formation is exposed in the abandoned pit located in the median strip of U.S. 301 at Dorrs Corner. Immediately north of the pit, the highway descends sharply to Severn Run which is cut deeply into the underlying Patapsco Formation.
1.0	U.S. 301, after bridging Severn Run, climbs steeply through the Patapsco and Magothy Formations (the latter outcropping in the cut bank to the left of the road at the Benfield Road traffic signal), and levels out on the Matawan Formation. Dark, clayey silt of the Matawan is well-exposed in the cuts for the southbound lane of 301 at the crest of the hill. The remainder of the route to Baltimore traverses, for the most part, Potomac Group sediments. Scattered exposures are visible from the highway enroute.
	End of field trip.

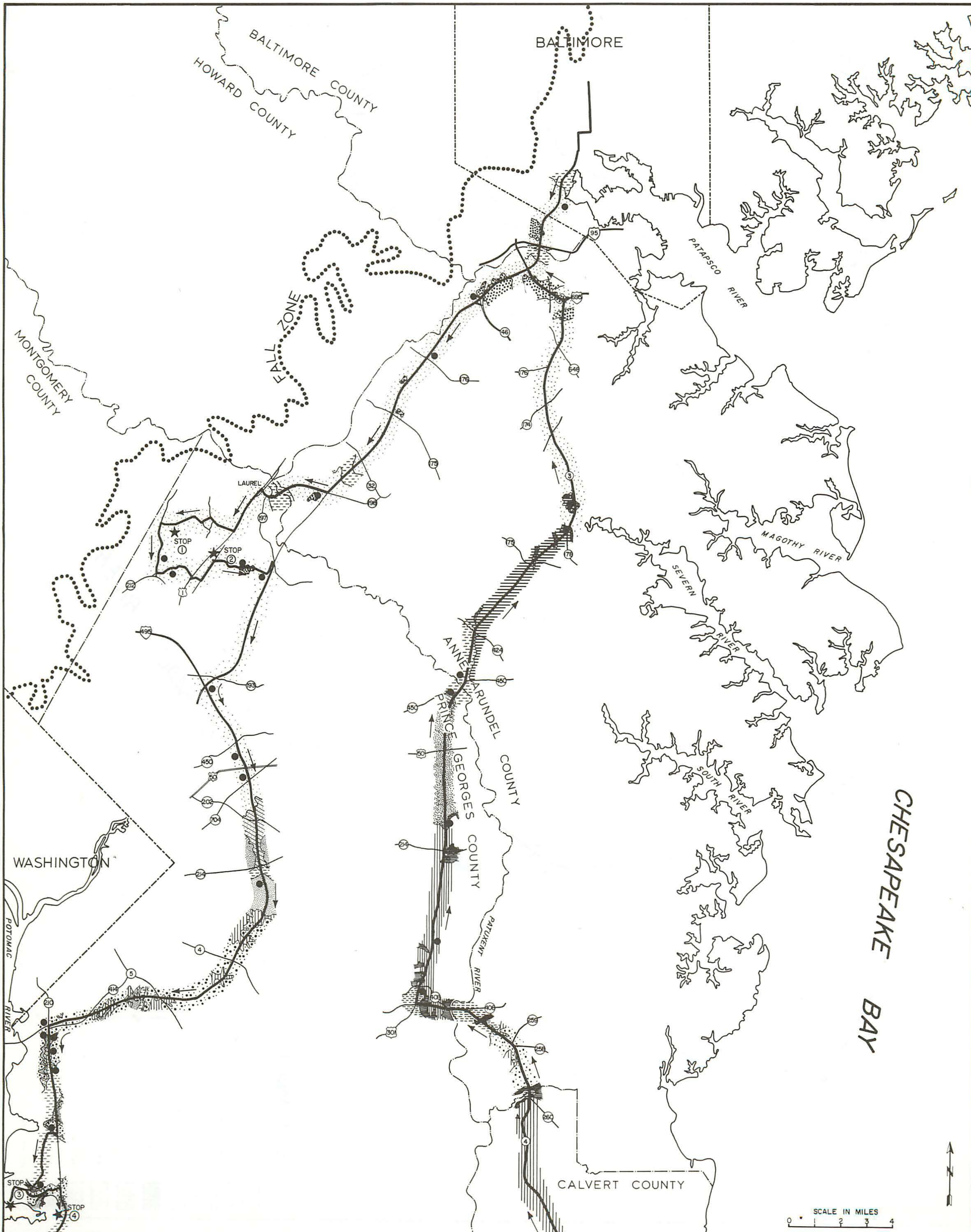

Figure 15. Route map 1.

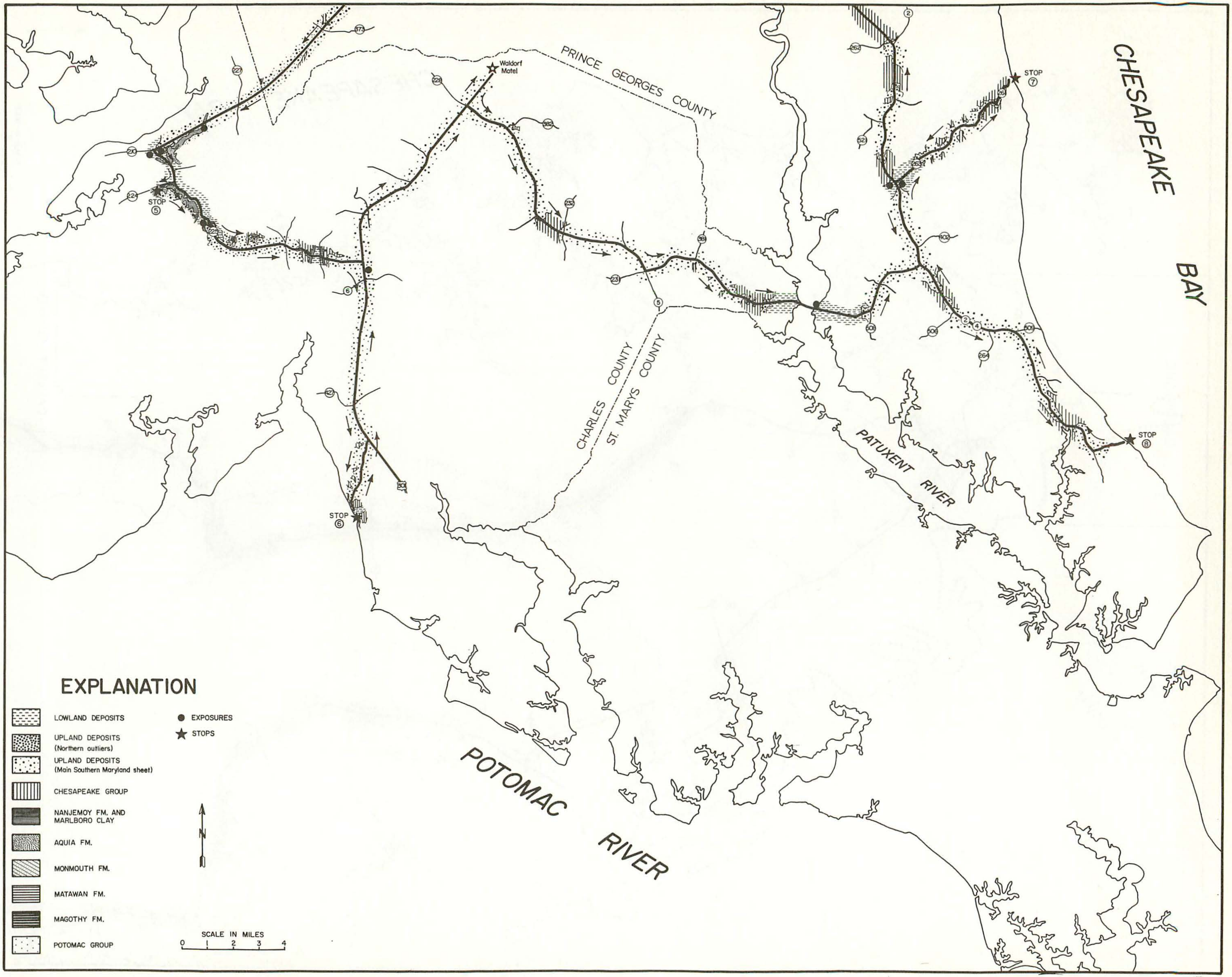

Figure 16. Route map 2.

Coastal Plain Geology Of Southern Maryland

Guide Book No. 1, 1968