Geology of the Round Bay Quadrangle, Anne Arundel County, Maryland

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By JAMES P. MINARD

With a section on DINOFLAGELLATE-ACRITARCH PALYNOLOGY

By FRED E. MAY

and a section on CRETACEOUS POLLEN

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Description of Coastal Plain formations on the west side of Chesapeake Bay and their relations with correlative units to the northeast

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By JAMES P. MINARD

ABSTRACT

Six Coastal Plain formations and one group crop out in the Round Bay quadrangle near the inner edge of the Atlantic Coastal Plain physiographic province. The quadrangle lies astride the Severn River, in Anne Arundel County, near Annapolis, Md. The seven stratigraphic units aggregate as much as 128 m in outcrop. In ascending order, the units are: the upper part of the Potomac Group and the Magothy, Matawan, and Severn Formations, all of Cretaceous age; the Brightseat and Aquia Formations of Paleocene age and the Calvert Formation of Miocene age.

Quaternary deposits are thin and cover only small areas; they are all mapped under one unit. Several small, thin deposits of Tertiary alluvium are mapped separately.

The largely unconsolidated Cretaceous and Tertiary formations consist chiefly of quartz, glauconite, clays, muscovite, chlorite, lignite, feldspar, and pyrite. Quaternary sediments are mostly locally derived sands, silts, and clays with some gravel and, in the finer sediments, considerable amounts of organic matter.

The Cretaceous and Tertiary units strike generally northeast; the younger the formation, the more easterly it strikes. Dips are gentle, 3.6 to 15 m per kilometer toward the southeast, and decrease upward through the section.

The Round Bay quadrangle is near the southern limit of several formations that thin progressively toward the southwest from New Jersey. Some pinch out between Betterton, on the eastern shore of Chesapeake Bay, and Round Bay, on the western shore, whereas others are present only as thin remnants 1–2 m thick. Resources of the quadrangle include abundant ground water, sand, and high land values near water.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Round bay quadrangle encompasses about 150 km^2 astride the Severn River, just northwest of the outskirts of Annapolis in Anne Arundel County on the western shore of Chesapeake Bay.

PURPOSE AND HISTORY OF INVESTIGATION

Geologic mapping of the Round Bay quadrangle (pl. 1) was undertaken as a southwestern continuation of the detailed (1:24,000 scale) quadrangle mapping and geologic studies by Minard, Owens, Sohl, May, and Christopher along the inner edge of the Coastal Plain in New Jersey, Delaware, and Maryland done as part of the Chesapeake Bay Project begun in 1965 to meet the need for detailed mapping along strike toward the southwest, primarily to correlate the formations that persist and to recognize areas of facies changes, overlaps, and pinchouts. The mapping has progressed from northeast to southwest on an every-third-to-fifth-quadrangle basis, as described in more detail in the Betterton report (Minard, 1974, p. 1–4). The last quadrangle mapped was the Betterton, 54 km to the northeast on the Eastern Shore of Chesapeake Bay (fig. 1). Because the noncontiguous mapping has left gaps, considerable geologic reconnaissance and topical study has been done between mapped quadrangles. A discussion of the regional stratigraphy from Betterton, Md. to Raritan Bay, N.J., is given in the Betterton report (Minard, 1974). Most of this discussion will not be repeated here. The main focus in this report is the stratigraphy in the Round Bay quadrangle as compared with that in the Betterton area.

ACKNOWLEDGMENTS

For their contributions to the works of the report, I should like to thank Norman F. Sohl, James P. Owens, Melodie Hess, and Jack A. Wolfe, of the U.S. Geological Survey, and Don G. Benson, Jr., formerly at Virginia Polytechnic Institute. Benson identified dinoflagellates from beds of Cretaceous and Tertiary age and correlated ages; Wolfe identified pollen and spores from beds of Cretaceous age and assigned ages; Hess X-rayed clay size fractions and separated heavy minerals; Sohl identified megafossils, and Owens identified heavy minerals.

I should like to thank John Glaser, of the Maryland Geological Survey, for his visits and discussions in the field. I thank my brother Bud for his assistance in the difficult sampling of steep bluffs and the many property owners who generously granted permission to cross their land. I particularly thank the people of the community of Sherwood Forest for permission to operate a boat from their docking facilities on the Severn River.

Fieldwork was done mostly during short periods in the fall of 1974, spring and fall of 1975, and spring of 1976.

PREVIOUS INVESTIGATIONS

Early investigations in the Round Bay quadrangle and adjacent areas were climaxed by the fairly detailed work of Clark (1916), who mapped the geologic formations in

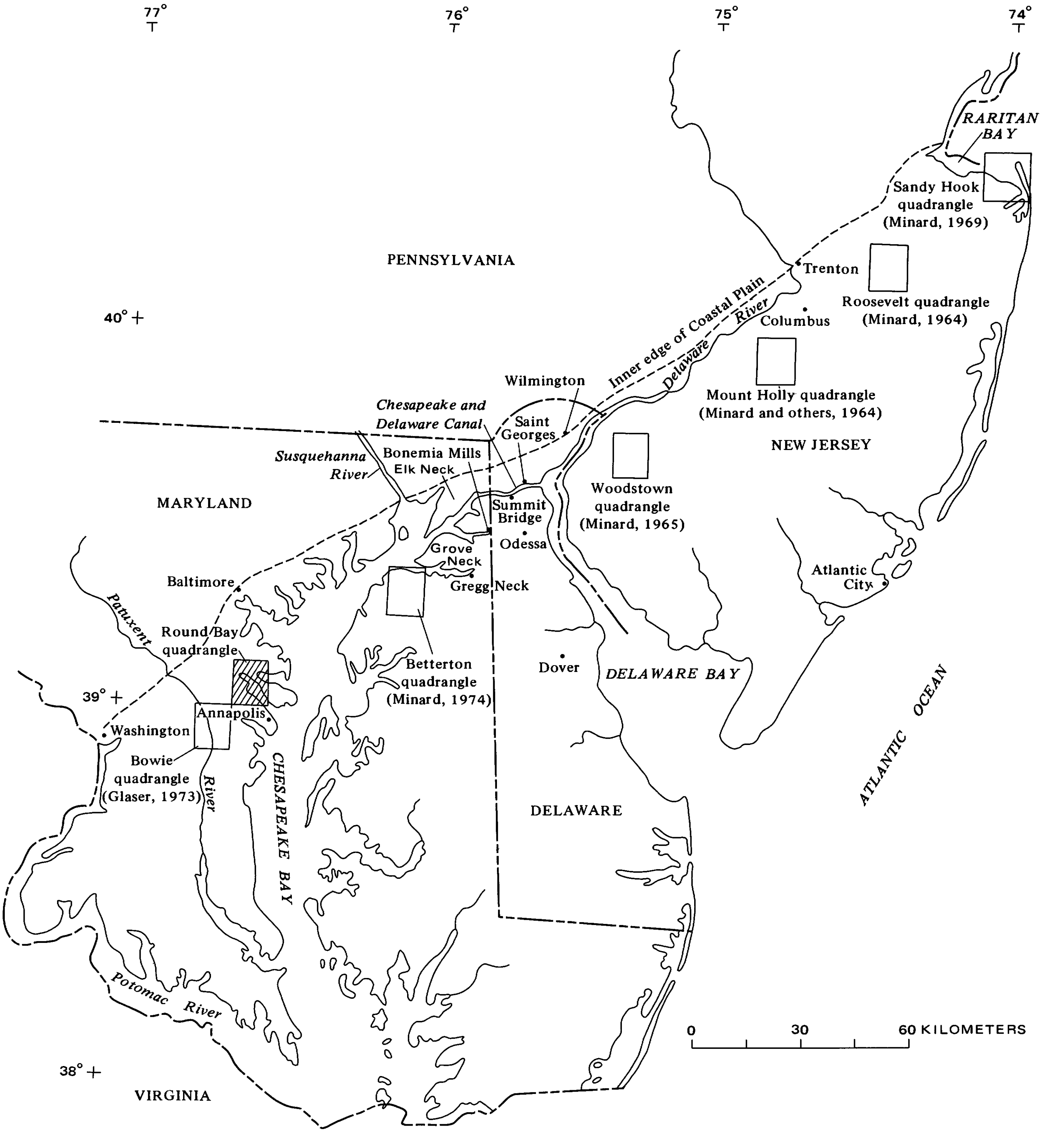


FIGURE 1.—Index map of the Coastal Plain from the Potomac River northeastward to Raritan Bay, showing selected mapped quadrangles.

Anne Arundel County at a scale of 1:62,500. Since then, many topical studies have been completed and reports published. The only systematic detailed mapping since 1916 other than Darton's (1938–39) map and reports on the sand and gravel deposits of Eastern Maryland and the Round Bay quadrangle, is that by John Glaser (1973) in the Bowie quadrangle adjacent to the southwest (fig. 1).

In mapping the Betterton quadrangle, Minard (1974), was able to subdivide the Matawan Formation and substitute the Mount Laurel Sand for the Monmouth Formation for the first time in that area (table 1). For reasons explained in the section on stratigraphy in this report, these groups are not divided in the Round Bay quadrangle. Although Glaser (1973) substituted the formation name Merchantville for the Matawan Group in the Bowie quadrangle, he did not subdivide the stratigraphic interval. Later (1976), in Anne Arundel County, he grouped the Matawan and Monmouth together.

The history of geologic investigations of the formations of Cretaceous and Tertiary age in the coastal Plain of Maryland, Delaware, and New Jersey is discussed in detail by Clark (1916, p. 34–50), Greacen (1941, p. 8–19), and Groot, Organist, and Richards (1954).

TABLE 1.—*Modern correlations of Coastal Plain formations in Maryland, Delaware, and New Jersey*

System	Series	Group	New Jersey	Delaware	Delaware / Maryland	Maryland	Betterton quadrangle, Kent County, Md.		Round Bay quadrangle, Anne Arundel County, Md.
			Owens and Minard, 1960, and Minard, 1964, 1969	Jordan, 1962	U.S. Geol. Survey, 1967	Cleaves and others, 1968	Minard, 1974	Age	This report
Tertiary	Miocene(?) and Pliocene(?)		Cohansey Sand	Miocene and Pliocene: Chesapeake Group (in part)	Chesapeake Group (in part)	Chesapeake Group (in part)			
	Miocene		Kirkwood Formation						Miocene: Calvert Formation (lower part)
	Eocene	Rancocas Group	Manasquan Formation	Sub-surface: Piney Point Formation		Sub-surface: Piney Point Formation			
				Rancocas Formation		Pamunkey Group: Nanjemoy Formation			
	Paleocene		Vincentown Formation		Vincentown Formation	Aquia Formation	Vincentown Formation		Pamunkey Group: Aquia Formation
			Hornerstown Sand		Hornerstown Sand	Brightseat Formation	Hornerstown Sand		Brightseat Formation
Cretaceous	Upper Cretaceous	Monmouth Group	Tinton Sand	Redbank Formation		Monmouth Formation		Maestrichtian	Severn Formation
			Red Bank Sand						
			Navesink Formation	Mount Laurel-Navesink Formation					
			Mount Laurel Sand		Mount Laurel Sand		Mount Laurel Sand		?——?
		Matawan Group	Wenonah Formation	Wenonah Formation		Matawan Formation		Campanian	Matawan Formation
			Marshalltown Formation		Marshalltown Formation		Marshalltown Formation		
			Englishtown Formation		Englishtown Formation		Englishtown Formation		
			Woodbury Clay						
			Merchantville Formation	Merchantville Formation	Merchantville Formation		Merchantville Formation		
			Magothy Formation	Magothy Fm.	Magothy Fm.	Magothy Fm.	Magothy Fm.	C-S[1]	Magothy Formation
	?								
	Lower Cretaceous		Raritan Formation / Potomac Group	Potomac Formation	Potomac Group	Potomac Group	Potomac Group		Potomac Group (upper part)

[1] C–S = Coniacian and Santonian

PHYSIOGRAPHY

The Round Bay quadrangle area is a somewhat dissected to well-dissected sandy plain typical of the Atlantic Coastal Plain. Elevations range from sea level to 63.3 m. Two flooded river valleys, the Severn and Magothy, extend northwestward through the quadrangle, dividing the land unit into three areas.

The north half of the quadrangle is less dissected and has less relief than the south half; the north part is largely underlain by loose sands of the Potomac Group and Magothy Formation, whereas the south half is largely underlain by the more compact and finer material of the Matawan and Severn Formations, and resistant beds in the Aquia Formation. Several broad, flat-topped interfluves in the west-central and east-central parts of the quadrangle owe their distinctive landforms to layers of iron oxide-cemented sandstone, mostly in the top of the Magothy Formation. Many hills in the northern part of the quadrangle owe their relief to this iron-oxide cementation, mostly in the Magothy Formation but some in sands of the Potomac Group. In the southern part of the quadrangle, the presence of iron-oxide cemented layers, which are common in the sands of the Aquia Formation, partly explain the steep slopes and prominent hills characteristic of this part of the quadrangle.

The southeast-flowing Severn and Magothy Rivers and their tributaries drain most of the quadrangle. The southwest part of the quadrangle drains southward into South River. A small area in the extreme northwest part drains northward, entering the Patapsco River south of Baltimore. Another small area, in the extreme northeast part, drains into Chesapeake Bay.

STRATIGRAPHY OF THE ROUND BAY QUADRANGLE

The stratigraphic units exposed in the Round Bay quadrangle consist mainly of a succession of one group and six sedimentary formations of Cretaceous and Tertiary age that range in individual thickness in outcrop from 1 to 33 m and aggregate as much as 128 m. Small deposits of Pleistocene and Holocene age and older alluvium of Pliocene age range in thickness from 1 to 6 m. The thicknesses of the units in the quadrangle and at several locations to the northeast are shown in table 2.

The pre-Quaternary sediments are mostly continental clays to gravels at the base and marine silts and sands in the upper part of the section. Locally beds within the formations are cemented by iron oxide into resistant layers and ledges. The Quaternary deposits mostly range in grain size from clay to sand. Gravel is sparse and cobbles and boulders rare: these sediments are largely of locally derived alluvial material but include narrow strips of beach sand and tidal marsh deposits.

The exposed units of Cretaceous age are, in ascending order, the upper part of the Potomac Group, the Magothy Formation, the Matawan Formation, and the Severn Formation, a name reintroduced to replace the Monmouth in Maryland. These units are overlain by the Brightseat and Aquia Formations of Paleocene age and by the lower part of the Calvert Formation of Miocene age.

LOWER AND UPPER CRETACEOUS SEDIMENTARY ROCKS

POTOMAC GROUP

The Potomac Group consists mostly of continental deposits of gravelly sand, silt, and clay. The name Potomac was first used by McGee in 1886, when he assigned the name Potomac Formation to the sequence of unconsolidated nonmarine sediments along the inner edge of the Coastal Plain in Maryland and Virginia. A few years later the name was raised to group rank by Clark and Bibbens (1897, p. 481) and the stratigraphic sequence making up the Potomac Group was divided into four formations: Patuxent, Arundel, Patapsco, and Raritan (oldest to youngest). As studies of plant remains and pollen evolved, ages were assigned by Berry (1910; 1911), Dorf (1952, p. 2169), and Brenner (1963, p. 33). Brenner zoned the Potomac Group, assigning the Patuxent and Arundel to Zone I and the Patapsco to Zone II with subdivisions A and B (in ascending order). This was the first attempt at subdividing and refining since Berry established ages based on leaf imprints and plant remains in 1911.

According to these studies and those by Owens (1969, p. 86–91) and Hansen (1969, p. 1923–1924) in the Maryland area, the accepted ages up to that time seemed to be Early Cretaceous for the Patuxent, Arundel, and Patapsco stratigraphic units, Late Cretaceous for the Raritan or its equivalent(?) in the Maryland area. As recent definitive palynological studies continued, they led to further refinement of the ages of the Cretaceous section, particularly the lower formations in the northern Atlantic Coastal Plain (fig. 2). Palynology has been a boon in dating these largely continental deposits.

In 1969, Doyle (1969, p.9) suggested a younger age (possibly middle Cretaceous) for the Patuxent and Arundel. Wolfe and Pakiser (1971, p. B37) agreed with this age, at least for all except possibly the lower part of the Patuxent. Doyle believed (p. 12, 13) the Patapsco to be almost certainly no older than early Albian, and that it may in fact be younger. Wolfe and Pakiser (p. B37) considered the lower part of the Patapsco to be somewhere in the later half of the Albian. The Raritan has been, in part, dated as middle or late Cenomanian (Doyle, 1969, p. 14), which is significantly younger than the typical Patapsco of

TABLE 2.—*Approximate thicknesses of formations and equivalents in outcrop in areas along strike from northeastern New Jersey to southwestern Maryland*

[See Figure 1]

Lithologic unit	Location or Area					
	Round Bay	Betterton	Saint Georges to Odessa	Woodstown	Columbus	Raritan Bay
	Meters					
Cohansey	——	——	——	30–40	30–40	20
Kirkwood or Calvert	15	——	——	15–25	15–20	1–2
Vincentown or Aquia	30–33	25–30	30	10–12	12–15	11
Hornerstown-Brightseat	3–6	0–4	6	6–8	6–9	5
Tinton	——	——	——	——	——	6
Red Bank } Severn	12.6	} ——	} ——	——	0–15	36
Navesink } Severn	——	} 21–43	} 52	2–5	8–9	8
Mount Laurel	?	} ——	} ——	15–25	7–12	8
Wenonah }	1–2	} ——	} ——	5–8	8–20	8
Marshalltown }	——	5	5	3–5	3–5	3–4
Englishtown	0–2	5	5	7–8	25	43
Woodbury }	1	} 6–12	} 14	8–9	15	15
Merchantville }	——	} ——	} ——	15	15	15
Magothy	6–12	9–10	8–10	10	10	60–90
Raritan	——	——	——	——	——	45
Potomac	350	225–275	210	70–100	60	——

Maryland. "Older beds [than the Raritan] which promise to close the gap [from lower Albian to Middle Cenomanian] between the Patapsco and Raritan, are becoming known to the south of Raritan Bay and in the subsurface, as are younger beds of presumed Turonian age (South Amboy Fire Clay Member) in the Raritan Bay area" (Doyle, 1969, p. 14). This interval between the Potomac and Raritan, first designated informally as Zone III by Doyle (oral commun., Aug. 4, 1971), is now formally Zone III (Doyle and others, 1975, p. 441. See fig. 3). This places it above Brenner's Zone II (Doyle, 1969, p. 3). Wolfe and Pakiser (1971, p. B38) suggested that the "so-called Raritan of Maryland probably represents the uppermost part of the Patapsco Formation." It appears that the age of the Potomac Group in the Round Bay quadrangle ranges from late Early Cretaceous to early Late Cretaceous.

The Potomac Group crops out over about one-half of the northern half of the Round Bay quadrangle. The thickness of the total section, surface and subsurface, in the quadrangle is something of the order of 330—350 m. This thickness is based on data from a well drilled in February 1976 on the hill north of Union Church near Herald Harbor (Fred Mack, U.S. Geol. Survey WRD, oral commun., Dec. 7, 1976). Of this section, about the upper 30 m is exposed in the quadrangle. This part of the section consists of alternating beds of clay, silt, sand, and gravel, (mostly fine 4—10 mm; sparse pebbles to 40 mm are present locally). It is predominantly light gray to very light gray and yellowish gray but contains a number of yellowish-brown layers and zones of iron-oxide staining. Some moderate reddish-brown to moderate-red clay beds and ironstone layers are present, and some coarse-grained beds contain fragments of clay. Conspicuous bedding, both horizontal and cross, is typical, indicating the fluvial nature of much of the formation. The maturity of the sediments suggests either advanced weathering in the source area or a high-energy depositional environment, or both.

Sand constitutes most of that part of the Potomac Group cropping out in the quadrangle. The sands are nearly pure quartz and are mostly loose or weakly cemented. Locally some layers are cemented by iron oxide. The sands constitute a mature sediment as borne out by the mature suite of heavy minerals, mostly zircon, tourmaline, and rutile. Thorough studies of the heavy minerals have been done by Anderson (1948), Bennett and Meyer (1952), and Groot (1955). Locally, as at Elvaton in the northern part of the quadrangle and Lipins Corner a short distance (1.6 km) to the northeast in the southern part of the Curtis Bay quadrangle, the Potomac contains large blocks of cemented sand and fine gravel (fig. 3). Many of the blocks, particularly in the upper part, are opaline cemented quartz sands. Glaser (1976) favors considering these as relict blocks of the Magothy.

Clays are mostly light-gray kaolinite and illite, a rather mature assemblage compatible with the sands. Sparse pyrite concretions are present. The gravels are mature, consisting mostly of rounded quartz and quartzite pebbles, with a trace of hard chert. The sediments of the Potomac Group were probably deposited by a complex river system of channels, flood plains, and cutoff meander swamps. Sparse borings resembling *Ophiomorpha nodosa,* present near the top, may represent a transition to estuarine or marine environments near the close of Potomac deposition.

In the northern part of the quadrangle, Potomac Group sand and clay underlie a gently rolling land sur-

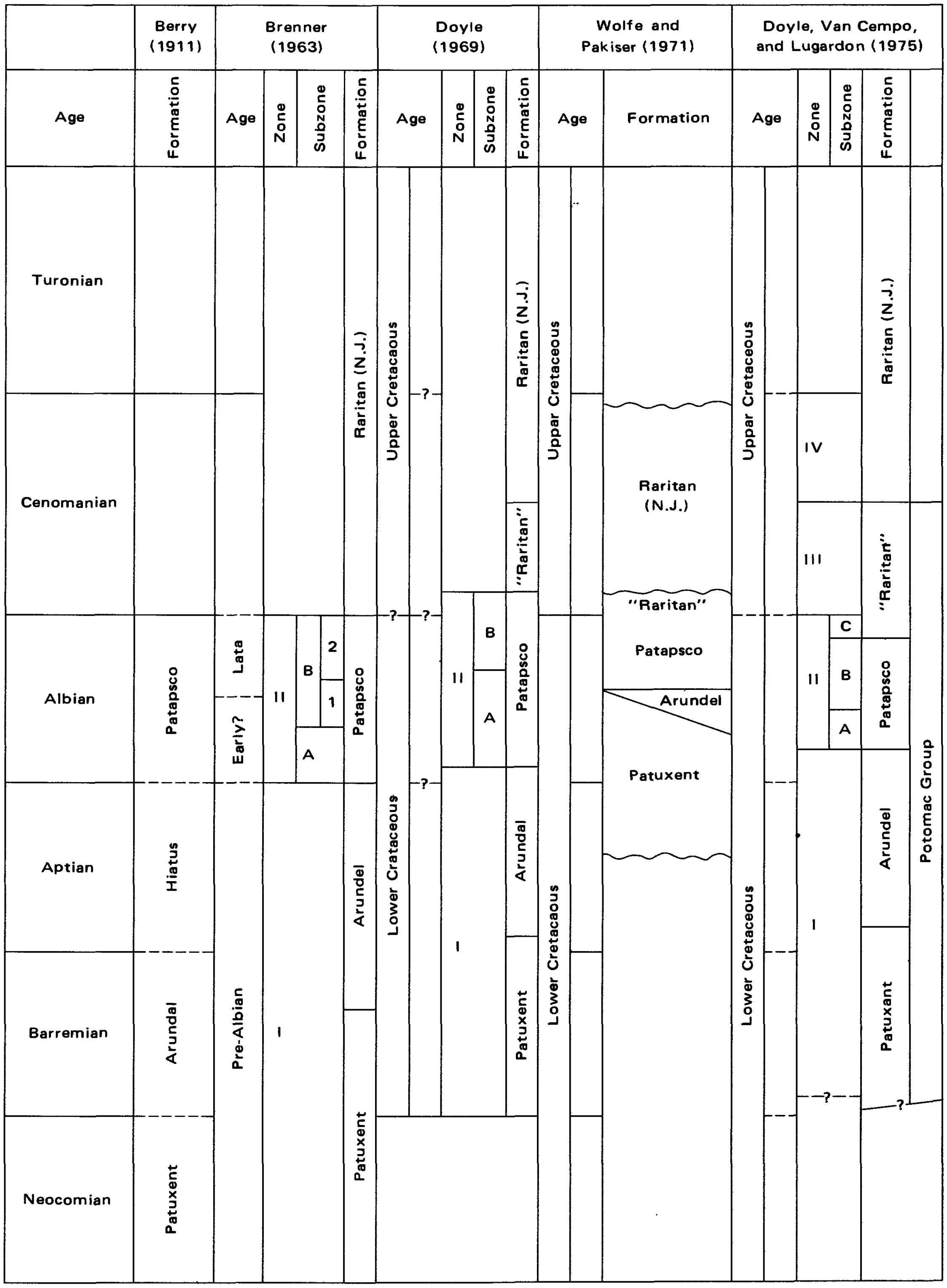


FIGURE 2.—Ages and stratigraphic positions of units of the Potomac Group and Raritan Formation as assigned and refined by various palynologists.

face, largely occupying the long gentle slopes from the hilltop capping Magothy down to stream valley bottoms below. It is best seen in pits, roadcuts, and the cut-banks along the Severn River from Round Bay upstream. Steep outcrops, 3—7 m high, are common, particularly where the sand is cemented by iron-oxide or amorphous

FIGURE 3.—Cemented block of sandstone in the Potomac Group near Elvaton.

silica or is surface case-hardened. At this time, it is probably best exposed in the 12-m-high cut along the north side of Highway 100, 1.6 km east of Elvaton, where alternating beds of fine to coarse sand with pea-size gravel and clay-silt layers crop out in the cut and erosion gullies in its face.

MAGOTHY FORMATION

The Magothy Formation consists of interbedded sand and lignitic clay, originally named and described by Darton (1893) for the excellent exposures along the Magothy River in the Round Bay quadrangle. The type section probably is at North Ferry Point. The formation has been traced and mapped to the northeast across Delaware and New Jersey to Long Island, N.Y., (fig. 1). The Magothy is much thicker in the Raritan Bay area than in the Round Bay quadrangle. For a more detailed regional discussion of the stratigraphy to the northeast, refer to Owens, Minard, and Sohl (1968), Minard (1974, p. 15–19), Perry and others (1975), and Minard, Owens, and Sohl (1976, p. 15–17; figs. 11 and 12).

Although the Magothy is much thicker (90 m) at Raritan Bay, it maintains a much thinner and fairly uniform thickness of about 6–12 m in outcrop for most of its extent from the vicinity of Columbus, N.J., southwest to the Round Bay quadrangle (table 2). It thins west of the quadrangle and is completely overlapped in outcrop, first by the Matawan, then by the Severn a few miles east of Washington, D.C. (fig. 1). It has been reported in the subsurface in many wells in eastern Maryland but apparently is absent in the subsurface of southern Virginia (Robbins and others, 1975, fig. 4; p. 43–44).

In age, the Magothy in the Round Bay quadrangle seems to be coeval with the apparently stratigraphically equivalent Cliffwood beds of the upper part of the Magothy of New Jersey; these beds were considered by Wolfe and Pakiser (1971. p. B43) to be of early Campanian Age. Wolfe later (1976, p. 4–5) correlates the Magothy at Severn River with beds in New Jersey below the "Cliffwood beds" (Santonian?).

The Magothy typically consists of alternating beds of very fine to fine and medium to coarse, light-gray quartz sand and thin papery to thick blocky layers of medium-gray to generally dark-gray to black clay with much lignite and mica concentrated in thin layers and also scattered throughout. Thicker clay layers typically have thin partings of fine to very fine white quartz sand. Typically, cross and horizontal stratifications are well developed (figs. 5 and 6).

Most of the section is conspicuously bedded sand, with or without thin layers of clay; locally it contains thick (1 m) lenses of clay (fig. 5), pockets or lenses of peaty muck, and many pieces of lignitized wood. Some flattened logs are as much as 10–25 cm across and 1–2 m long. Pyrite crystals and clusters of crystals are common in the lignitic material. Much of the sand is cemented by iron oxide into thin and thick resistant layers; some contain branching burrows filled by coarse to very coarse sand.

Internal structures such as thin horizontal and cross stratification, the abundance of lignite and peaty material, and the faunal content suggests both a high-energy depositional environment such as a beach complex and tidal-fluvial interface, and a low-energy lagoonal type environment. Tidal flat bedding is of several types, flaser, wavy, and thinly interlayered (rythmites) (Reineck and Singh, 1973, p. 101–108). These types of bedding were well exposed in vertical

FIGURE 4.—Thick to thin beds and laminae in the Magothy Formation. Thick basal bed of very light gray, cross-stratified, fine to medium sand grades upward into alternating thin beds and laminae of very light gray and yellowish-brown sand, clay, and peat, overlain by dark-gray to grayish-black peaty clay with thin partings of very light gray, very fine to fine sand. Considerable fine-grained ilmenite is present in the sand. West shore of the Severn River just northwest of Kyle Point.

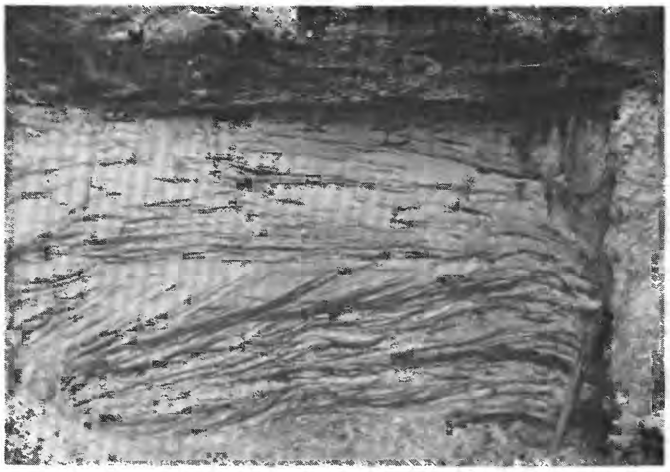


FIGURE 5.—Conspicuous cross stratification in the upper part of the Magothy Formation. Grain size ranges from medium to very coarse. Brownish-black material in the cross beds is peat and lignite. Sand is overlain by a layer of dark-gray to grayish-black lignitic clay about 1 m thick. The clay contains much pyrite and thin, very light gray, fine and very fine sand partings. Wall of a pit between Sunrise Beach Road and Gumbottom Branch in the west-central part of the quadrangle.

cuts along the shoreline along the west shore of Round Bay about 450 m north of Mathiers Point (fig. 6). A tidal, lagoonal, or estuarine influence is further suggested by the presence of certain dinoflagellates. Pollen contained in beds north of Mathiers Point indicate a mixture of Magothy and Englishtown assemblages, suggesting that thin erosional remnants of the Englishtown may be locally present in the area. In internal structure and mineralogy, these beds are reminiscent of Englishtown outcrops in New Jersey.

No fossils were found in the Magothy in the quadrangle, but Glaser (oral commun., April 1976) found mollusks in the formation about 1.6 km southwest of Pigeon House Corner in the Bowie quadrangle, adjacent to the southwest corner of the Round Bay quadrangle.

The Magothy underlies the upper land surface of much of the broad interfluves in the northern part of the quadrangle; toward the latitudinal middle, it underlies middle slopes. The formation is best exposed along the northern part of Round Bay and the lower part of Magothy River, where the formation crops out in steep to vertical cuts at and above water level. It can be seen at this time in pits near the headwaters of Branch Creek, where the thickest (8 m) single exposed section crops out as a well-bedded sand (predominantly cross-bedded) containing lenses of dark-gray clay (fig. 5). It is well exposed at North Ferry Point on Magothy River, the west side of Sullivan Cove, and the shore just northwest of Kyle Point (fig. 4) along the northern part of Round Bay. In many places, the broad flat interfluves expose surface layers of thick ironstone.

FIGURE 6.—Outcrop of the upper part of the Magothy and lower part of the Matawan Formations north of Mathiers Point. Top of the Magothy Formation is about 0.3 m above the top of the shovel handle. Dark clay beds are intercalated with thin beds and laminae of fine to very fine white quartz sand.

MATAWAN FORMATION

The Matawan Formation consists of firm dark-gray clayey glauconitic quartz sand. This is the earliest appearance of glauconite in the Coastal Plain section. The formation was named for the locality in the northeastern part of the Coastal Plain in New Jersey (Clark, 1894). The unit was later raised to group rank and divided into five formations — in ascending order: Merchantville, Woodbury, Englishtown, Marshalltown, and Wenonah (table 1). Type localities for the five formations are designated at places along nearly the entire extent of the inner Coastal Plain outcrop belt in New Jersey from the northeast to the southwest.

The five formations of the Matawan Group in New Jersey aggregate 85 m (table 2) in combined thickness and are easily defined and mapped because they retain their individual identity nearly all the way southwest along the inner Coastal Plain in New Jersey. The total thickness, however, becomes progressively less toward the southwest; from 85 m in New Jersey the stratigraphic interval occupied by the formations in Delaware has decreased to 23 m (table 2). Thinning continues toward the southwest into Maryland; the total thickness of the Matawan in the Betterton quadrangle, on the Eastern Shore of Chesapeake Bay, ranges between 16 and 22 m. Prior to 1974 the Maryland Geological Survey did not recognize subdivisions of the Matawan, but Minard (1974) subdivided the Matawan in the Betterton quadrangle into three formations, Merchantville, Englishtown, and Marshalltown (table 1). Where traced another 56 km southwest across Chesapeake Bay into Round Bay, it is found to be only 2.4–2.7 m thick, yet thin layers representative of lithologies of several units are still present.

The age of the Matawan in the Round Bay quadrangle is Campanian; it ranges from early Campanian to late Campanian (table 1).

The basal 1–2 m of the Matawan is compact dark-gray, very silty and clayey, poorly sorted quartz sand containing sparse glauconite, lignite, and colorless fine mica. Quartz grains range from very fine to very coarse; granules and small pebbles (30–50 mm) are abundant in the basal 30 cm and in borings in the upper part of this section. These borings typically contain a high percentage of glauconite from overlying beds. Pyrite and selenite crystals are common in unweathered material. Glauconite grains are mostly dusky green fine to medium grained, and botryoidal; a few accordian forms are present. Characteristic heavy minerals include chloritoid, rutile, ilmenite, tourmaline, staurolite, and garnet.

This lower 1–2 m-thick section of the Matawan is lithologically similar to the sparsely glauconitic facies of the Marshalltown Formation in eastern Maryland and both pollen and dinoflagellates strongly suggest correlation with Marshalltown species and suites.

Lying disconformably on the basal 1–1.8 m of Matawan is a 0.6–1.2-m thick section of thin-bedded to massive, dark-greenish-gray to greenish-black, highly glauconitic (20–40 percent) quartz sand facies of the Marshalltown Formation (fig. 7). Grain size is mostly fine to medium, but sparse coarse to very coarse grains and granules are present. Both colorless and green mica are common in the upper part of this glauconite-rich section. Glauconite is mostly fine to medium grained, green, and botryoidal with some accordian forms. Above the glauconite-rich layer is a 0.6–1.2-m sections of the Matawan Formation, which consists of clayey, silty, compact carbonaceous, micaceous quartz sand with sparse glauconite. These upper beds are lithologically similar to the Wenonah Formation.

Dinoflagellates in the glauconite bed and overlying beds are mostly the assemblages characteristic of both the Marshalltown and Wenonah Formations in New Jersey. Pollen indicates close correlation of the less glauconitic beds, in the interval with the Wenonah, whereas the more glauconitic beds, lithologically more characteristic of the Marshalltown, contain little pollen, indicating an environment of deposition farther out on the shelf than the probable inner shelf sediments of the Wenonah.

Sparse, nondiagnostic pelecypod casts were found in the Matawan beds. Ray Christopher (U.S. Geol. Survey, written commun., January 6, 1977) reported that the pollen content in the basal beds of the Matawan suggests basal Merchantville reworked into probable Marshalltown. He also states (this report) that beds near Mathiers Point are equivalent to the Englishtown Formation. This agrees with Minard's statement in the Magothy section that: In internal structure and mineralogy, these beds are reminiscent of Englishtown outcrops in New Jersey."

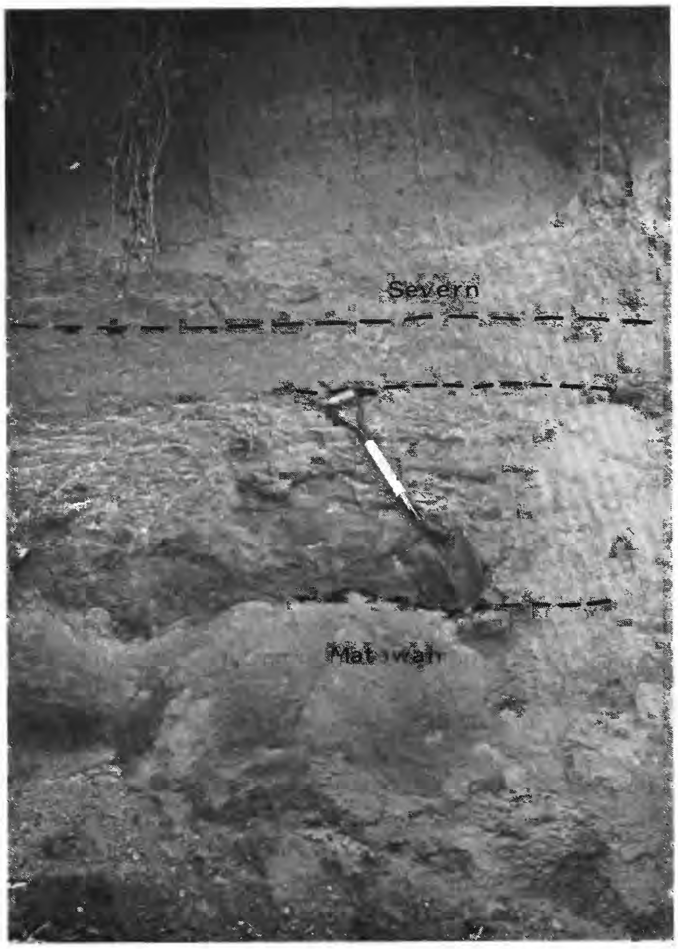


FIGURE 7.—Matawan and Severn Formations; shovel spans greenish-black glauconite-rich bed near the top of the Matawan Formation (note irregular basal contact). Beneath the glauconite bed is about 1.8 m of dark-brownish-gray clayey sand at the base of the Matawan. The top of the Magothy (covered) is 0.3 m above high-water level. Northwest side of Long Point near the middle of Round Bay.

SEVERN FORMATION—REINTRODUCTION OF NAME

Minard, Sohl, and Owens reintroduced the name Severn Formation to replace the entire Monmouth Formation on the western shore of Chesapeake Bay, Md., and to certain correlative units on the Eastern Shore and extending into Delaware. These include the upper part of the Mount Laurel Sand, as mapped and described by Minard (1974, pl. 1, p. 21–24) in the Betterton quadrangle and at Gregg Neck and Bohemia Mills, Md., and at Odessa, Del. Its type locality is designated the east bank of the Severn River at Round Bay (in the Round Bay, Md., 7 ½′ quadrangle) 0.64 km north of

Swan Point. The entire thickness is well exposed here in a single continuous outcrop (fig. 8). The total thickness (about 2.7 m) of the glauconitic gray clayey sand of the Matawan Formation (Campanian) is exposed at the base of the outcrop. It lies directly on the light-gray lignitic sand and clay of the Magothy Formation, the top of which is at high-tide level. Overlying the Matawan is the Severn Formation of Maestrichtian Age; it is 12.6 m thick. The Severn is overlain by a combined thickness of about 9 m of the Brightseat Formation and the lower part of the Aquia Formation, both of Paleocene age.

At its type locality the Severn Formation consists of dark- to medium-gray, clayey and silty, poorly sorted, mostly fine- to medium-grained sparsely glauconitic quartz sand containing a fair amount of both very fine and coarse to very coarse quartz grains and granules, colorless mica, and carbonaceous matter. Grain size increases upward towards the middle of the section, whereas glauconite content decreases upwards through the middle but increases again near the top. Several shell beds or former shell beds are present, and near the top is a distinctive bed of medium- to light-gray clay or clay layers about 30 cm thick.

FIGURE 8.—Outcrop of the entire Severn Formation at its type locality north of Swan Point. Top of the Magothy Formation (concealed) lies at the high-water just below line area shown. The 2.7 m of section above this is the Matawan Formation. Above the Matawan is the Severn, 12.6 m thick here. Above the Severn lies about 3.6 m of the Brightseat Formation, capped by about 6 m of the exposed Aquia Formation.

On the Eastern Shore, the Severn Formation is as much as 24 m thick and has at the base a distinctive bed, 2–3 m thick, of very glauconitic, coarse to very coarse quartz sand with granules and small pebbles (Minard, 1974, p. 21–24).

The name Severn Formation at the same type locality was originally proposed by Darton (1891, p. 438–439), who included both the Matawan and Monmouth Formations, which included the entire stratigraphic section between the Magothy Formation below and Pamunkey Group (lower Tertiary) above. The Magothy was included in the Potomac Group until Darton (1893) described it as a formation, and later (1896, p. 124–126) noted that it underlay the Severn, stating (1891, p. 439) that "In Maryland it is a stratigraphic unit, distinctly separable from the New Jersey series as a whole by its homogeneity of constitution; ***". The point to make here is that in New Jersey the Monmouth can be readily divided into several distinctive lithologic units, whereas in Maryland, although fossils suggest correlation with both the Red Bank Sand and Navesink Formation of New Jersey, lithologic homogeneity does not make it feasible to divide the Monmouth on this basis; rather, it is a lithologic unit unique to Maryland and part of Delaware. Contrasted with this is the presence of rocks of distinctively different lithologies in the thin Matawan section, still traceable from New Jersey.

Like the Matawan, the Monmouth in New Jersey is thicker than its stratigraphic interval equivalent in Maryland. It is about 58 m thick in its type area and thins to about 24 m in the southwest part of the state. The thinning in New Jersey is largely accounted for by the thinning to extinction in outcrop of the Red Bank Sand and Navesink Formation, partly compensated for by the thickening of the Mount Laurel Sand in southern New Jersey and Delaware before it thins again toward Chesapeake Bay (fig. 9). In Delaware and on the Eastern Shore of Chesapeake Bay in Maryland, however the Monmouth interval thickens locally to a maximum thickness of about 51 m. This greater thickness is partly accounted for by the reappearance of the Red Bank Sand and possibly the basal part of the Navesink Formation or beds stratigraphically equivalent to these formations but with different source areas. (For a more complete discussion of these beds in Delaware and eastern Maryland, see Minard (1974, p. 21-25)). The thickening here is local; at the west edge of the Betterton quadrangle (fig. 1), a short distance (about 40–45 km) southwest of its maximum

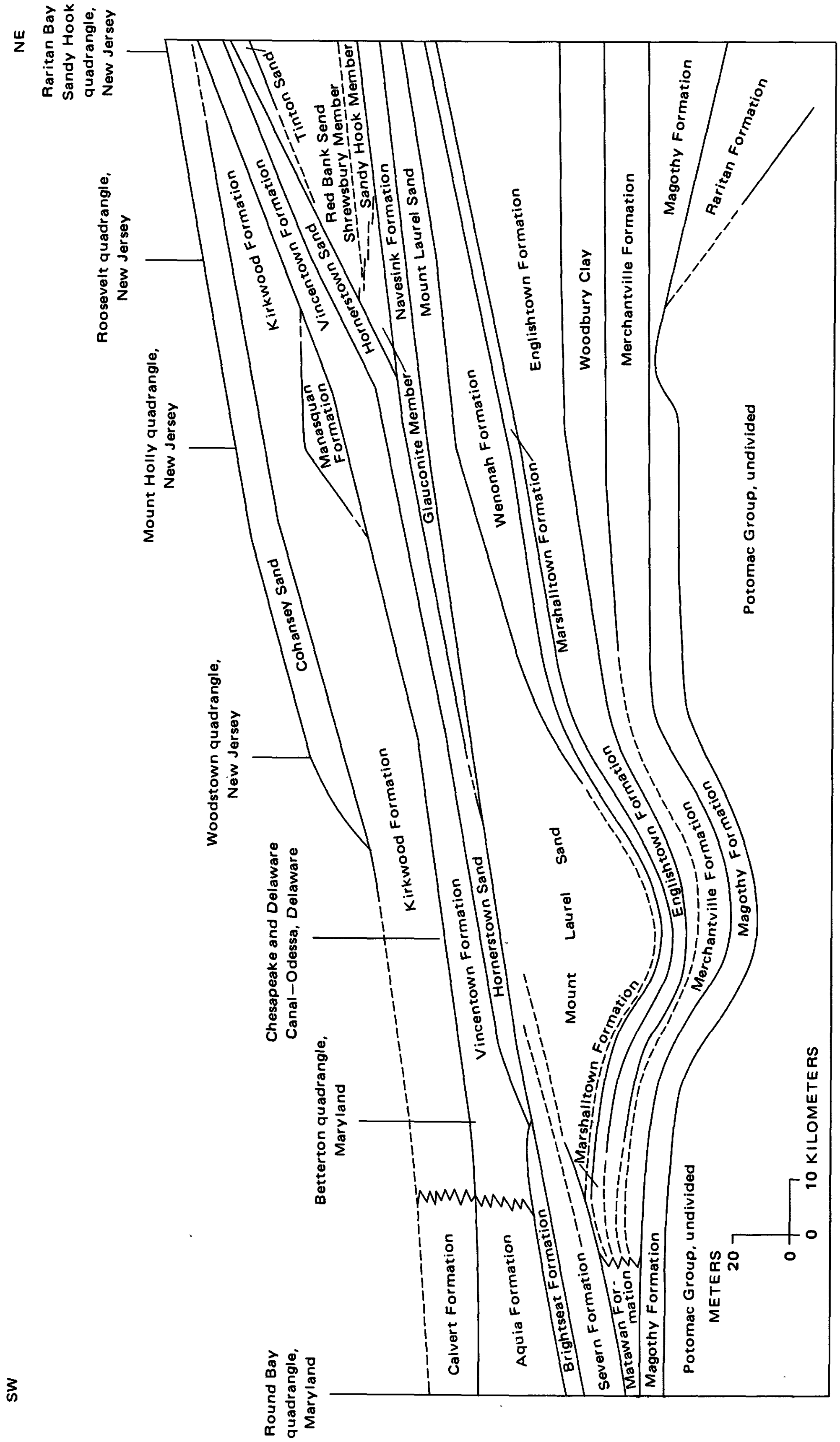


FIGURE 9.—Diagrammatic cross section of the Cretaceous and Tertiary formations, from Raritan Bay, N.J., to Round Bay, Md., showing thinning, thickening, overlaps, pinchouts, and reappearances.

thickness, the section is only 18 m thick (Minard, 1974, p. 10 and fig. 6). In the Round Bay quadrangle (fig. 1), 56 km farther southwest from the Betterton quadrangle, the section has thinned to about 14 m, partly owing to the continued thinning of the Mount Laurel from its maximum thickness in southern New Jersey and Delaware.

The basal part of the Severn is mostly medium- to dark-gray, silty, poorly sorted, fine to medium glauconitic quartz sand containing a fair amount of both very fine and coarse quartz grains, colorless mica, and ilmenite, and sparse lignite. Grain size increases upward toward the middle of the 12.6-m-thick section, where there is a fair amount of coarse to very coarse quartz grains and granules.

Three "shell" beds are present locally; one in the bottom meter, one near the middle of the section, and one near the top. The "shells" are mostly iron-oxide-coated casts and molds in the clayey sand; a few outcrops contain calcareous shells. Pieces of lignite are commonly associated with the shell beds, as is pyrite. Glauconite is present throughout the section, but varies widely in amount; it decreases upward from a fair amount (1–2 percent) in the base, to a trace (less than 1 percent) within the next 7.5 m. From about 8 m above the base, glauconite content increases upward to about 1–2 percent.

Near the top of the Severn Formation is a distinctive bed of montmorillonitic clay. This clay appears to occur continuously throughout the entire area of the Severn outcrop in the Round Bay quadrangle and was seen as far to the southwest as the west bank of the Patuxent River in the Bowie quadrangle (fig. 1); it typically occurs as fragments and thin discontinuous layers in an interval about 30 cm thick 1 m from the top of the Severn. It was found, in one outcrop along the Severn River just south of Rugby Hall, to be as much as 1 m thick. At this outcrop the entire vertical interval occupied by the clay layer is nearly all clay rather than thin layers and fragments in a sand matrix. The clay itself is bedded but has little sand interlayed or intermixed, as is typical in most outcrops.

One of the most distinctive features of the clay bed is its color. Beds above and below the clay may vary from essentially unweathered grayish black and dark gray to oxidized medium light gray and brownish gray, but the clay generally is medium light gray to light gray. Only rarely, where the enclosing beds are oxidized to moderate and light brown, is the clay oxidized to shades of brown, then generally only surficially. Being somewhat more coherent, the exposed edge of the clay bed more nearly approaches verticality than the containing beds, and thereby forms a visible break-in-slope feature in many outcrops.

Lithologically, the Severn is distinguished from the Matawan mainly by a generally coarser grain size particularly more very coarse grains and granules, less glauconite, more mica, its shell beds, and the distinctive clay bed near the top. Where weathered, the Severn ranges in color from medium gray to shades of brownish gray.

The southwest thinning of the thick "Red Bank sands" in Monmouth County, N.J., was early recognized by Clark (1898, p. 185), who stated that

> they do not occur in southern New Jersey, but reappear in Delaware and the eastern counties of Maryland, where their characteristic features are again developed and where they have a thickness in the Sassafras River basin of about sixty feet. They decline somewhat in thickness toward the Chesapeake Bay, and upon the western shore of the Chesapeake cannot be distinguished from other members of the Monmouth Formation.

Although the Severn Formation in the Round Bay quadrangle paleontologically correlates with both the Red Bank Sand and the Navesink Formation of New Jersey, it is lithologically more similar to the Red Bank Sand. The Mount Laurel Sand does not seem to crop out at the base of the Severn in the Round Bay quadrangle as it did in the Betterton quadrangle and to the northeast.

Minard (1974) mapped the Monmouth as Mount Laurel in the Betterton quadrangle on the eastern shore of Chesapeake Bay. He also speculated on subdividing it into the Mount Laurel and Red Bank, with possibly a thin remnant of the Navesink lying between the two (Minard, 1974, p. 21–24, and Minard and others, 1976, p. 40–41). With continued tracing and mapping of the units farther southwest into the Round Bay quadrangle and on nearly to Washington (fig. 1), further discussion on correlation seems necessary, particularly of the lower part of the Severn.

In the Betterton report (Minard, 1974), discussion of the Monmouth interval (Severn) included descriptions of a "persistent distinctive bed of glauconite-rich coarse sand, 8 to 10 feet thick ***" (p. 21). This bed, seen in outcrop or located in the subsurface at several places on the Eastern Shore of Chesapeake Bay in Maryland and in Delaware (Minard, 1974, p. 21–24), was tentatively correlated with the lower part of the Navesink Formation. The bed was not found as a recognizable entity in the Round Bay quadrangle, but it may be present as a thinner, less glauconitic nearer shore unit in the Lanham quadrangle adjacent to the west of the Bowie quadrangle (fig. 1). The bed crops out in an overgrown cut along the north side of U.S. Route 50 just west of Lottsford Vista Road 2.6 km east of the Beltway (Interstate 495), where the Severn lies directly on the light-olive-gray to dusky-red clay of the Potomac Group. There is no Matawan or Magothy here. The basal 1 m of the Severn is dark-greenish-gray, glauconitic (1–2 percent), fine to very fine quartz sand. Above this basal part is a section of about 1 m which is similar in lithology except that it contains, in addition, many greenish rounded quartz granules and pebbles as much as 4 cm in diameter. The pebbles are quartz and quartzite and are distinctively stained green, possibly as a result of leaching of the glauconite by ground water and partial reprecipitation on the pebbles. The fact that the gravel is much coarser than that in the bed on the east shore of Chesapeake Bay may result from its being much nearer the Piedmont and the abundant gravel in the Potomac Group, from which the gravel probably was derived. This is suggested by the mature orthoquartzitic nature of the pebbles that is characteristic of the gravel in the Potomac Group, as compared with a lesser percentage of mature material typical of the gravel derived directly from the Piedmont and Valley and Ridge detritus.

The gravel bed is overlain by dark-gray, micaceous, silty, fine to very fine grained sideritic and iron-crusted quartz sand. This interval is very fossiliferous; most fossils are present as molds and casts, and many are coated by iron oxide. The fossils include Pyncnodontes, *Exogyra, Turritella (Bilira),* and some belemnites. According to Sohl (oral commun., Feb. 8, 1977), the age range is about equivalent to the lower and middle parts of the Navesink. Although this bed may be equivalent to coarse sands in the middle of the Red Bank Sand in New Jersey, the "Transitional units" of Minard (1964), correlation with the lower part of the Navesink seems best, both lithically and on age.

The depositional environment for the Severn Formation appears to have been mostly inner shelf, as indicated by its lithology and fossil content. One local distinctive lithologic constituent is the siderite, generally in the upper part of the section. It may occur as spherical concretionary masses or "doughnuts" 1 m in diameter, or as large slabs as much as 40 cm thick and 3.6 m long, these slabs crop out near water level at Rughby Hall. Another horizon of smaller concretions occurs near the top of the formation, about 5.4 m higher, in the same outcrop.

The Severn Formation crops out across the central part of the quadrangle. It forms steep outcrops along the shores of Round Bay and underlies stream-valley bottoms and intermediate slopes back from the water. Locally it underlies isolated flat-topped interfluves.

The Severn is best exposed in the banks along the shores of Round Bay. It crops out at several places, along the south side of the bay and also on the narrow peninsula at the mouth of Brewer Pond where a bed of calcareous shells and siderite concretions are near water level. The age of the Severn in the Round Bay quadrangle is early Maestrichtian.

The Severn equivalent in Delaware, the upper meter of the upper part of the Monmouth, crops out along Drawyers Creek, just west of Odessa, Del. (fig. 1). That part of the Monmouth, above the Mount Laurel and equivalent to the Severn, crops out between this place and Bohemia Mills, Md., 9 km west of Odessa. This part of the Monmouth, about 24 m thick, has a coarse glauconitic sand bed at its base. It is overlain at Drawyers Creek by the glauconitic Hornerstown Sand of Paleocene age. In this area, Osburn and Jordan (1975, p. 162) place the quartz sand, below the typical Hornerstown glauconite sand, in the Hornerstown on the basis of foraminifera. Christopher and May report (oral commun., June 25, 1975) pollen and dinoflagellates from this interval, some of which are restricted to the Cretaceous. For a more detailed discussion, refer to Minard, Owens, and Sohl (1976, p. 42–43).

TERTIARY SEDIMENTARY ROCKS

BRIGHTSEAT FORMATION

The Brightseat Formation mapped on the west side of Chesapeake Bay consists of dark-gray silty and clayey, fine quartz sand. The unit was first proposed as a formation by Bennett and Collins (1952), who reported it to be as much as 15–23 m thick. At its type locality in Maryland, several kilometers northeast of the farthest eastern part of the District of Columbia, it is about 7.5 m thick. The Brightseat is the lowermost Tertiary unit in the area; it occupies the same approximate stratigraphic position here that the Hornerstown Sand does in New Jersey and in the northern part of the Salisbury embayment (at least as far southwest as the Betterton quadrangle). In outcrop in the Round Bay quadrangle, the Brightseat ranges in thickness from 3–6 m near the updip limit of the formation; it is thicker downdip and to the southwest.

According to Hazel (1968, fig. 2, p. 106), the Brightseat is early to middle Danian in age on the basis of ostracods; the Hornerstown is partly equivalent in age, however the uppermost part of the Hornerstown may be late Danian on the basis of foraminifera; therefore, it is younger than the Brightseat.

The Brightseat Formation is medium gray to medium dark gray and dark greenish gray where unweathered, brownish gray where weathered. It is mostly fine-grained, glauconitic micaceous quartz sand. It contains some medium quartz sand and some coarse to very coarse grains and granules scattered throughout, particularly in the base where there also are some pebbles and pieces of lignitized wood. Glauconite is generally more abundant (several percent) in the Brightseat Formation than in the underlying Severn Formation and is more distinct morphologically; a considerable number of accordian or concertina grain forms are present. A distinctive lithic characteristic of the basal meter is the presence of many moderate-green, flat to curved, thin (¼–½ mm) fragments of illite and kaolinite several millimeters across. Mica, more abundant here than in the underlying Severn, is mostly colorless muscovite but with much green chloritized mica.

Many animal borings characterize the formation, particularly near the top. They commonly are filled by cleaner and coarser material than that in the formation surrounding them. Glauconite content usually is considerably higher in these borings; the glauconite being largely derived from the overlying Aquia Formation. Because of the fossils and lithology, it seems likely that the sediments were deposited in a nearshore environment such as estuaries and lagoons. Ostracods in the formation have been discussed in detail by Hazel (1968), foraminifera by Loeblich and Tappan (1957).

Some features of the basal contact of the Brightseat Formation suggest an unconformity. At some places the contact lies about a meter above the gray clay layer near the top of the underlying Severn Formation; at other places, the contact is near the top of the clay layer. Locally there is a considerable amount of lignitic material and pebbles in the base of the Brightseat sediments. The thin green clay fragments in the basal part may partly result from reworking of such material or crusts from dessication polygons. Benson (1975) studied the dinoflagellates in detail across the Cretaceous-Tertiary boundary, he concluded (p. 19) that an "unconformable relationship" was indicated and "a paraconformity exists at the Cretaceous-Tertiary boundary in the Round Bay, Maryland area."

The Brightseat Formation crops out mainly as narrow bands along steep to moderate slopes. The best outcrops can be seen in the bluffs along the shores of Round Bay, particularly on the south and east shores (fig. 10).

FIGURE 10.—Exposure of the Brightseat Formation at Arnold Point. The fragmental clay layer near the top of the Severn Formation is exposed at and just above high-water level.

AQUIA FORMATION

The Aquia Formation is dark-greenish-gray, fine to medium and coarse glauconitic quartz sand. Its type locality is at Aquia Creek in Virginia, where it is reported to be about 30 m thick, about the same thickness as in the Round Bay quadrangle. It occupies about the same stratigraphic position as the Vincentown Formation to the northeast and is lithologically and faunally similar. Minard (1974) mapped the Aquia stratigraphic interval as Vincentown in the Betterton quadrangle on the Eastern Shore of Chesapeake Bay, as did Pickett and Spoljaric (1971) in Delaware.

The Aquia is of Paleocene age and overlies the Brightseat disconformably (Hazel, 1969, p. C64) in the area west of Chesapeake Bay.

The Aquia is medium to dark gray and dark greenish gray where unweathered; where weathered it is various shades of brown and gray, moderate reddish brown, moderate yellowish brown, light greenish gray, grayish orange, moderate brown, light olive gray, and dusky yellow.

It is mostly fine- to medium-grained glauconitic quartz sand containing a few coarse to very coarse grains in the lower part. Average grain size and glauconite content increase upward. Coarse to very coarse quartz grains and granules are abundant in the middle to upper part of the formation and some small (to 20 mm) pebbles are present. Mica generally is sparse but locally is abundant in layers; it is mostly muscovite but it includes considerable green chloritized mica.

Glauconite content ranges from several percent in the basal part to as much as 30 percent in the middle and upper parts. Except for the thin (1 m) glauconite bed in the Matawan, the Aquia is the most glauconitic formation in the quadrangle. Other than the Potomac, it is also the thickest. The glauconite mostly consists of moderate green to greenish black, medium to coarse botryoidal grains and some tabular grains. Some weathered sections of the formation are clean, loose, light-gray to light-greenish-gray quartz sand speckled with green grains of glauconite. Other weathered sections contain reddish-brown sand and thin to thick layers of iron-oxide-cemented sand, commonly resistant, forming vertical outcrops and protruding ledges (fig. 11). Fossil imprints are common in the ironstone layers. Some unweathered sections consist of dark gray to dark-greenish-gray, firm glauconitic, micaceous quartz sand.

The Aquia probably was deposited in an inner shelf to nearshore depositional environment. The coarse-grained nature of the upper part suggests a moderately high energy zone. The Aquia is in general very fossiliferous, both megafossils and microfossils are abundant.

FIGURE 11.—Iron-oxide-cemented layers and ledges in the Aquia Formation. *Ophiomorpha nodosa* burrows of the callianassid shrimp are common in the sand. Extreme southwest part of the quadrangle.

FIGURE 12.—Highest bluff (36 m) in the Round Bay quadrangle. Nearly all the Aquia Formation and about 4.5 m of the Brightseat Formation (base of bluff) is exposed. Much ironstone is in the upper part, including many casts and molds of pelecypod shells and *Ophiomorpha nodosa*. Southeast of Arnold Point.

Exogyra, pectens, *Ostrea*, *Venericardia*, and *Glycymeris* are common megafossils. Foraminifers and ostracods are generally abundant in the unweathered sediment. *Ophiomorpha nodosa*, burrows of the callianassid shrimp are common, particularly in the upper half of the formation. Such burrows indicate a littoral depositional environment.

The Aquia crops out in the southern half of the quadrangle where it forms steep bluffs along the Severn River. Back from the river, it underlies a well-dissected hilly landform with irregular ridge lines and hilltops incised by many erosion gullies. It is well exposed in the high bluffs along the southern part of Round Bay and along the Severn River south of Round Bay. The Aquia forms nearly all of the highest bluff along the Severn river (fig. 12) a 36-m high on the east shore of the river just south of Arnold Point. The basal part of the bluff, approximately 4.5 m, is Brightseat; the rest, Aquia. Prominent ironstone ledges form the base of a nearly vertical section of the upper 12–15 m of the bluff. These ledges contain many oyster shell imprints and *Ophiomorpha nodosa* tubes. The upper 4.5 m is nearly all iron oxide-cemented sand, mostly thin layers.

The face of the upper bluff retreated 1.5 m in the 10 years 1965 to 1975, mainly through frost-riving, root-wedging, and loss of support of fracture blocks by gravity creep and flowing of loose underlying sand.

The soil developed on the Aquia is mostly fairly loose and sandy. Ironstone fragments litter the ground on many steep slopes and narrow ridge tops. A distinctive green clayey glauconite soil forms at some horizons where glauconite content is high. Such a soil can be seen at the top of the highest bare bluff on the south side of Round Bay. It is mostly a mottled blocky green glauconite clay with quartz grains throughout; most grains of glauconite have been weathered to a green clay similar to soils on the Hornerstown Sand in New Jersey.

CALVERT FORMATION

The Calvert Formation in the Round Bay quadrangle typically is yellowish-gray, fine to very fine grained quartz sand. Its type locality is Calvert Cliffs in southern Maryland on the west shore of Chesapeake Bay, where it is about 54 m thick. In the early 1900's (Shattuck, 1904, p. 22–24) divided it into two members: the lower Fairhaven Diatomaceous Earth Member and the upper Plum Point Marl Member. Only the lower 15 m of the formation is present in the Round Bay quadrangle.

The Calvert occupies nearly the same stratigraphic position that the Kirkwood Formation does in New Jersey to the northeast. It is of Miocene age, probably early Miocene. In the Round Bay quadrangle, it unconformably overlies the Aquia Formation.

In the Round Bay quadrangle, the Calvert is highly weathered. It ranges in color from moderate and light brown to yellowish and pale moderate yellowish brown, light gray to yellowish gray and grayish yellow, and very pale orange, grayish orange, and dark yellowish orange. It is fairly uniform texturally and mineralogically, mostly a silty and clayey very fine to fine grained quartz sand; colorless mica, ilmenite, and feldspar are all common. Some medium quartz grains are scattered in the lower meter. Some glauconite is present in the very basal part as a result of reworking from the underlying Aquia Formation. No fossils were found in the formation in the quadrangle, probably because it was highly weathered; where less weathered it is abundantly fossiliferous. Diatomaceous earth, in varying amounts, is a well-known constituent of the lower part of the Calvert in its type area. In appearance, outcrop pattern, age, and lithology, the Calvert is very similar to the Kirkwood Formation of New Jersey.

The Calvert forms isolated caps on more than 60 ridges and small hills in the southern part of the quadrangle. It is best exposed in roadcuts. Several small good exposures of the basal contact are noted on the map (pl. 1) by triangular pointers. The contact relation is sharp; the yellowish-gray to dark-yellowish-orange and light-brown fine quartz sand of the Calvert lies directly on the light-olive-brown to light-olive-gray to olive-gray glauconitic quartz sand of the Aquia. Thin layers of ironstone are common at the contact (fig. 13).

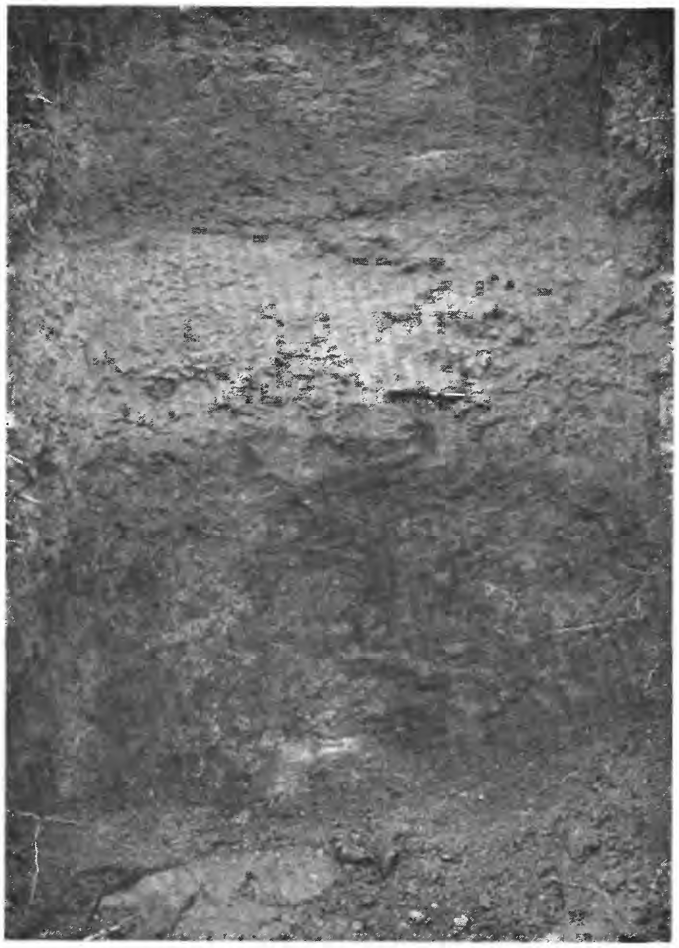


FIGURE 13.—Pen marks typical contact between the Calvert Formation of Miocene age and the underlying Aquia Formation of Paleocene age in the Round Bay quadrangle. The basal part of the Calvert is clayey, very fine grained quartz sand and silt. Colors in the Calvert range from pale brown to yellowish brown and light and moderate brown to yellowish orange, contrasting sharply with the light-olive-brown to grayish-olive-green medium quartz sand of the Aquia below. Thin ironstone layers are common in the upper part of the Aquia. Roadcut northeast of the gatehouse at the entrance to Sherwood Forest (location marked on pl. 1).

The lower contact of the Calvert is the most irregular formational boundary in the quadrangle. In the line of small hills on the blunt-ended peninsula just northwest from Sherwood Forest, the base differs in elevation by as much as 4.5 m nearly along strike. There is no Calvert on hill 211 (elev. ft; 64 m) just northeast from Waterbury, but it caps the upland surface adjacent to the northeast, at an elevation 12 m lower than the top of hill 211. The differences in elevation probably result from deposition of the Calvert sediments in channels or scours in the surface of the underlying Aquia Formation. According to Gibson (1962), the Calvert Formation represents deposition in shallow marine water.

TERTIARY (?) ALLUVIUM

There is very little alluvium mantling the surface in the Round Bay quadrangle as is typical in many of the nearby Coastal Plain areas. In the Betterton quadrangle, on the Eastern Shore of Chesapeake Bay, at least three-fourths of the surface is thickly mantled by alluvium, locally as much as 52 m thick. In the Round Bay quadrangle, there are only a few pre-Holocene alluvial deposits. They may be Pliocene in age, or conceivably, in part, of late Miocene age.

The highest remnant of one of these deposits caps a small hill above 18 m elevation a short distance west of the west shore of Little Round Bay. The material in the deposit, about 1.8 m in maximum thickness, is well weathered, yellowish-brown, loosely to firmly cemented glauconitic quartz sand containing pebbles as large as 2–3 cm; small pebbles, 5–12 mm are common. Clay is present as fragments.

A small alluvial deposit mapped in the west central part of the quadrangle includes a basal quartz-pebble layer underlying a silty glauconitic quartz sand that caps the hilltop and drapes down the slope as a result of creep. The deposit ranges in thickness from 1 m at its periphery to possibly 3–4.5 m at the hilltop.

A third deposit lies against the nose of a ridge along Bacon Ridge Branch in the extreme southwest corner of the quadrangle. The deposit consists of horizontally and cross-bedded, very glauconitic quartz sand with considerable ilmenite. Grain size ranges from very fine sand in thick beds to medium, coarse, and very coarse sand and granules in medium to thin beds. Small pebbles to 16 mm in length are common. The alluvium is light olive gray to moderate and light brown. The deposit is as much as 7.5 m thick.

A fourth deposit mapped as Tertiary alluvium caps the flat-topped peninsula west of Sullivans Cove at the north end of Round Bay. The deposit consists of 3 m of fine-grained, sparsely glauconitic, highly ilmenitic quartz sand overlying the Matawan Formation.

The adjacent quadrangles to the west and southwest contain the broad, thick deposits of the Patuxent River valley. These are clean sands and gravels as much as 9 m thick.

QUATERNARY SEDIMENTS

Sediments of Holocene age in the quadrangle are generally thin and of small areal extent; therefore the different types of deposits are mapped undifferentiated, represented by one symbol. Most of the sediments in the deposits are derived locally, largely from the underlying and adjacent formations.

Deposits included in the Holocene are alluvium along present streams and small tidal deltas and estuarine deposits at the mouths of streams, both tidal and fresh water marsh deposits, and small beach, bar, and spit deposits of sand. Most of these deposits probably are only 1–2 thick; a few, such as the tidal marsh deposits at Maynedier Creek, may be 3–5 m thick. All deposits, except the beach sand, contain much organic matter.

A deposit of clean medium- to coarse-glauconitic quartz sand, mapped as Quaternary sediments (Qs) at South Ferry Point, is possibly as much as 6–9 m thick and probably is the largest and thickest such deposit in the quadrangle. This deposit may be of Pleistocene age.

STRUCTURE

The formations in the quadrangle strike northeasterly, ranging from about N 50°E to N 70°E. The formations of Cretaceous age have the more northerly trend, the younger formations of Tertiary age the more easterly; the Calvert Formation, of Miocene age strikes more easterly than all the underlying formations. No accurate measurements were obtained for the Potomac Group, but it probably dips more steeply than the overlying formations.

The more easterly the strike, the shallower the dip. As basin subsidence progressed, the center of maximum downwarp apparently migrated shoreward or northward with a resultant easterly shift of strike. This same upward shallowing of dip and easterly migration of strike exists in the Coastal Plain in New Jersey.

The Cretaceous formations above the Potomac Group in the Round Bay quadrangle dip about 6.3–7.2 m/km toward the southeast. The lower Tertiary units dip about 5.4–6.3 m/km southeastward. Dips measured on the base of the Calvert Formation (Miocene) are quite irregular, ranging from 0–3.6 m/km toward the southeast. These strikes and dips compare closely with those in the Coastal Plain in New Jersey.

ECONOMIC ASPECTS

Large quantities of ground water are available in the Round Bay quadrangle, particularly in sand beds in the Potomac Group and Magothy Formation.

Good quality mortar sand is dug from the Magothy just south of Sunrise Beach in the west-central part of the quadrangle. A considerable amount of fill material is a byproduct of the mortar sand operation.

Large pits in sands of the Potomac Group in the northwestern part of the quadrangle attest to the extensive previous use of this material and suggest potential for the future (fig.14).

Perhaps one of the most valuable natural resources is the land frontage along the shores of the Severn and Magothy Rivers where lots typically cost as much as the houses built on them.

DINOFLAGELLATE-ACRITARCH PALYNOLOGY

By Fred E. May

Well preserved and diverse dinoflagellate and acritarch assemblages were recovered from all samples (fig. 15) collected at Round Bay localities 6 and 11A. Locality 11A is the type section of the Severn Formation (fig. 8), locality 6 is just north of 11A. Biostratigraphic comparisons of these assemblages with other assemblages reported or observed from the Atlantic Coastal Plain and Europe suggest that the formations studied at Round Bay are of Campanian, Maestrichtian, and Danian Age and that deposition was generally under open marine conditions.

BRIGHTSEAT FORMATION

Benson (1975) reported on the dinoflagellates and acritarchs of the Severn (Monmouth) and Brightseat Formations of Round Bay, concluding that the Brightseat is

FIGURE 14.—Large sandpit in the Potomac Group southeast from Elvaton. The pit floor covers at least 40 hectares.

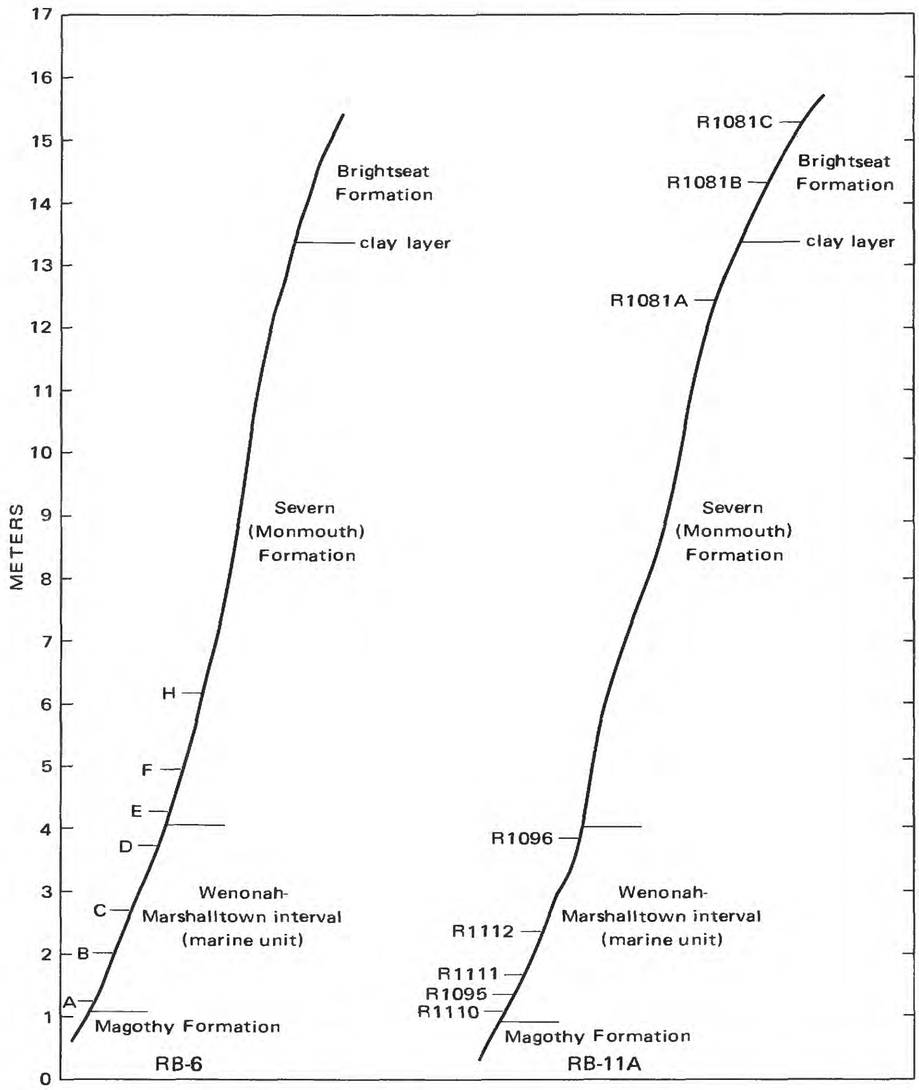


FIGURE 15. — Profiles of bluffs showing locations of samples RB-6 and RB-11A studied by May.

of Paleocene age. Whitney (1976) reaffirmed this age assignment for the Brightseat south of Washington, D.C., suggesting that the dinoflagellates present there are of Danian Age. The Brightseat assemblages observed by May from samples R1081B and C collected at Round Bay locality RB-11A are basically as reported by Benson (1975). They also show strong similarities to Danian-equivalent assemblages from the U.S. Geological Survey's Clubhouse Crossroads core drilled in Dorchester County near Charleston, S.C., (depth 198–244 m). Characteristic species are:

Deflandrea dilwynensis Cookson and Eisenack 1965
D. magnifica Stanley 1965
D. pannucea Stanley 1965
D. phosphoritica Eisenack 1938
D. pulchra Benson 1977
Palaeocystodinium golzowense Alberti 1961
Trichodinium hirsutum Cookson 1965

SEVERN FORMATION

A comparison of Severn Formation assemblages at Round Bay with assemblages of northern New Jersey indicates an age correlation with the middle part of the Navesink Formation (fig. 16). May (1976) reported on the dinoflagellate assemblages from the Monmouth Group, Atlantic Highlands, N.J., correlating the Navesink with the lower type Maestrichtian of Holland (foraminifera zones B and C of Hofker, 1956, 1957, 1962, 1966; *Belemnella* ex gr. *lanceolata* and lower *Belemnitella* ex gr. *junior* zones of Schmid, 1959) (fig. 16*A*). It appears that the Severn Formation of Round Bay (samples E, F, and H of locality RB-6 and sample R1081A of locality RB-11A would correlate with parts of these same zones and that the unit is early Maestrichtian in age (figs. 16B and C). The concurrent ranges of 10 species common at both Round Bay and Atlantic Highlands provide the basis for correlating the Severn of Round Bay with the middle part of the Navesink Formation, in the middle of the Monmouth Group.

Deflandrea cordifera May 1977
D. speciosa Alberti 1959
Dinogymnium elongatum May 1977
D. westralium (Cookson and Eisenack) Evitt et al. 1967
Diversispina truncata Benson 1977
Hexagonifera chlamydata Cookson and Eisenack 1962
Ophiobolus lapidaris O. Wetzel 1933
Spongodinium delitiense (Ehrenberg) Deflandre 1936
Trichodinium cf. *T. hirsutum* Cookson 1965
Trithyrodinium pentagonum May 1976 (manuscript species)

MARINE UNITS UNDERLYING THE SEVERN FORMATION

Samples were collected from a 3-m-thick sequence of marine strata between the Severn and Magothy Formations, not previously documented paleontologically, at RB-6 and RB-11A (fig. 15, pl. 1). All samples contained highly diverse dinoflagellate and acritarch assemblages that differ markedly from those seen in the overlying Severn. Of the approximately 60 species observed in the upper part of this marine unit, only about 20 extend upward into the Severn. Species observed in this interval that appear distinctive and may be helpful in differentiating it from the Severn are:

Amphidinium mitratum Vozzhennikova 1967
Deflandrea cf. *D. balcattensis* Cookson and Eisenack 1969
D. ornata May 1977
D. cf. *D. rhombica* Cookson and Eisenack 1974
D. spicata May 1977
D. spicata subsp. 1
D. cf. *D. Sverdrupiana* Manum 1963
D. victoriensis Cookson and Manum 1964
Gillenia hymenophera Cookson and Eisenack 1960
Litosphaeridium siphonophorum (Cookson and Eisenack) Davey and Williams 1966
Odontochitina costata Albert 1961
O. operculata (O. Wetzel) Deflandre and Cookson 1955
Palaeohystrichophora infusorioides Deflandre 1935
Phoberocysta ceratioides (Deflandre) Davey and Verdier 1971
Schizocystia laevigata Cookson and Eisenack 1962
Spinidinium lanternum Cookson and Eisenack 1964
?Svalbardella sp. Wilson 1971

Sample R1112 from RB-11A yielded the most diverse assemblage from the marine unit underlying the Severn Formation, having more than 100 species of dinoflagellates and acritarchs. This sample, about 1.2 m above the Magothy Formation, has an assemblage that is strikingly similar to one observed in the middle part of the Marshalltown Formation of Irish Hill, N.J. Species common to both localities are:

Amphidinium mitratum Vozzhennikova 1967
Deflandrea asymmetrica Wilson 1967
D. cf. *D. balcattensis* Cookson and Eisenack 1969
D. cf. *D. rhombica* Cookson and Eisenack 1974
D. rhombovalis Cookson and Eisenack 1970
D. ornata May 1977
D. spicata May 1977
D. victoriensis Cookson and Manum 1964
Dinogymnium digitus (Deflandre) Evitt et al. 1967
Inversidinium caudatum Benson 1977
Palaeohystrichophora infusorioides Deflandre 1935
? Svalbardella sp. Wilson 1971
Trithyrodinium robustum Benson 1977
New genus A, Benson 1977
New genus B, Benson 1977

Sample C from RB-6 contains many of the same species seen in sample R1112, suggesting a similar correlation.

The presence of *Amphidinium mitratum* and *Deflandrea spicata* subsp. 1 in the upper half of the marine unit (samples C and D of locality RB-6 and samples R1112 and R1096 of locality RB-11A) suggests that the interval could correlate with the Marshalltown-Wenonah interval of Irish Hill, N.J. and the Marshalltown-Wenonah equivalents in the core hole at Clubhouse Crossroads, Dorchester County, near Charleston, S.C. (core depths 310-400 m.) The lower half of the 3-m thick marine unit at RB-6 (samples A and B) and locality RB-11A (samples R1110, R1095, R1111) lacks *A. mitratum* and *D. spicata* subsp. 1 and bears somewhat different peridinioid and gonyaulacoid complexes. Whether this difference reflects a change in environment or time is difficult to determine at present. Some forms restricted to this lower half of the marine unit have been reported in coastal plain sediments considered to be as old as the Merchantville equivalent (lower Campanian). Because of the preliminary state of dinoflagellate-acritarch biostratigraphy in some of the Coastal Plain units, further work is needed before specific conclusions can be made. At this time, it seems reasonable to consider at least the upper 1.8 m of the marine unit underlying the Severn Formation to be Marshalltown through Wenonah equivalent. The possibility that the Mount Laurel equivalent is present cannot be ruled out. Although the dinoflagellate assemblages from the upper part of the Mount Laurel

Sand of northern New Jersey have been documented (May 1976, 1977) and appear distinctively different from these assemblages at Round Bay, the assemblages from the lower part of the Mount Laurel have not been documented.

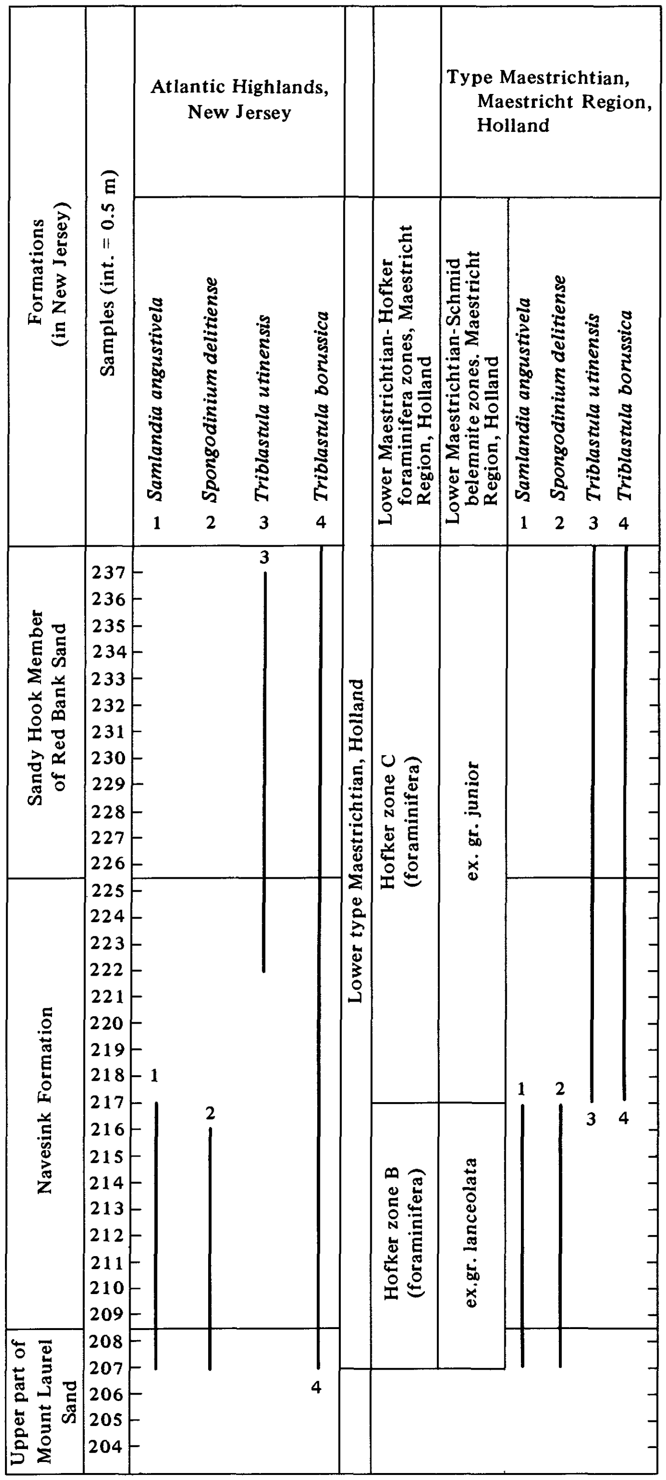
The concurrent ranges of several species noted at Round Bay suggest a general correlation with upper Campanian sedimentary rocks from the Grand Banks of Nova Scotia (Williams and Brideaux, 1975) and the upper Campanian sedimentary rocks of Holland and Denmark (Wilson, 1974). This similarity is best seen in samples from the upper 1.8 m of the Round Bay marine unit beneath the Severn; it is much less striking in the lower 1.2 m. It is hoped that further work will resolve the age relations of the entire unit. Species suggesting a late Campanian Age for the upper part of the unit are:

Amphidinium mitratum Vozzhennikova 1967
Australiella surlyki Wilson 1971 (manuscript species)
Deflandrea victoriensis Cookson and Manum 1964
Eurysphaeridium glabrum Wilson 1971 (manuscript species)
Odontochitina costata Alberti 1961
Palaeohystrichophora infusorioides Deflandre 1935
Phoberocysta ceratioides (Deflandre) Davey and Verdier 1971
? Svalbardella sp. of Wilson 1971
Trichodinium castanea (Deflandre) Clark and Verdier 1967

CRETACEOUS POLLEN

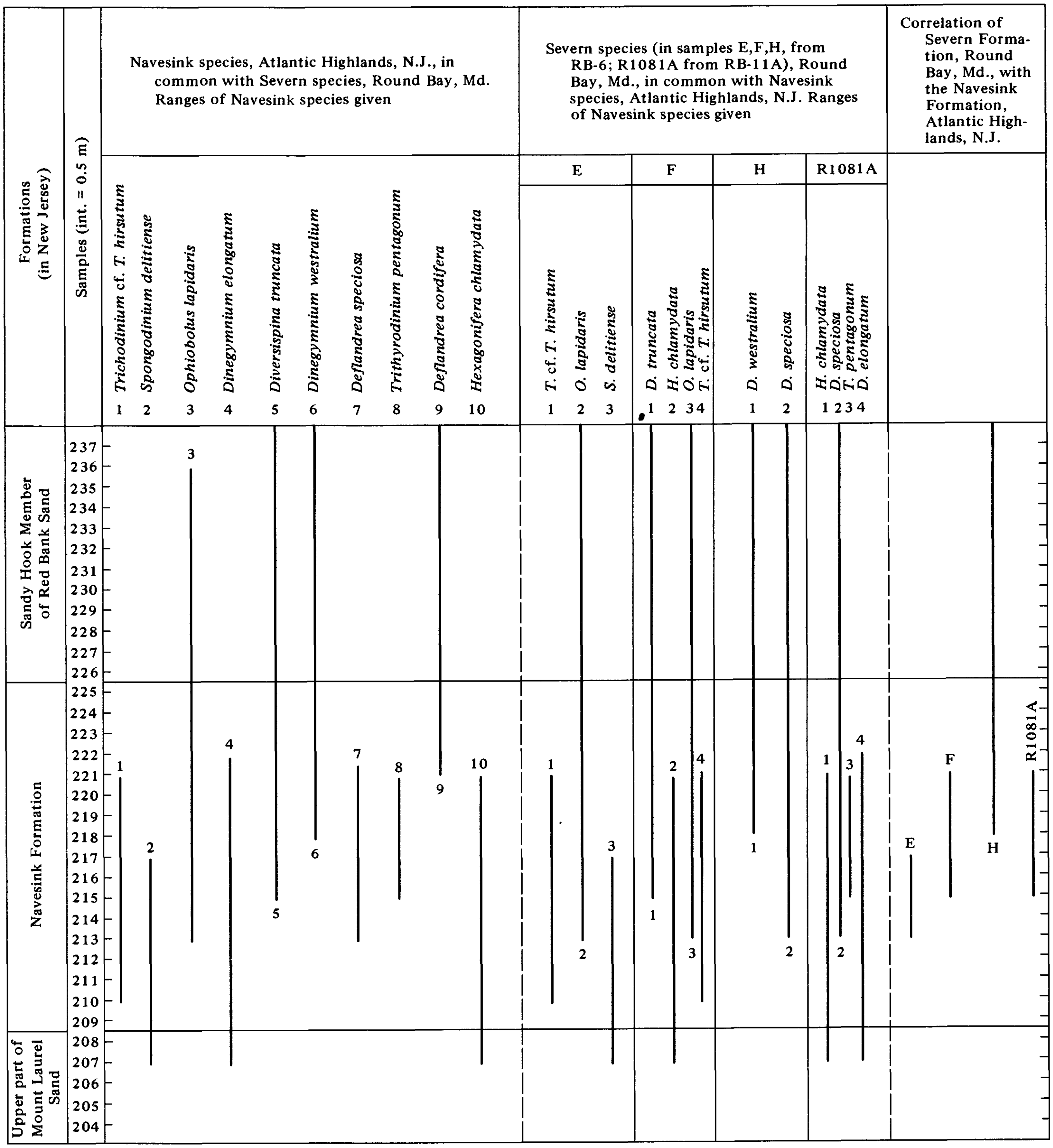
By Raymond A. Christopher

At Round Bay, where the entire post-Magothy Upper Cretaceous section is about 15 m thick (as compared with a thickness of about 143 m for the same section in New Jersey), age determinations are constrained by two factors. First, marine invertebrate megafossils are scarce in many units or absent. Second, as reported by Owens and Sohl (1969), the Cretaceous and Tertiary deposits of the Middle Atlantic Coastal Plain display a cyclic pattern of sedimentation that reflects a series of marine transgressions and regressions. As a result, lithologic units from different cycles, and therefore of different ages, but which represent the same stage in the cycle, commonly display similar mineralogies, textures, and sedimentary structures. Because of poor megafossil control and because many of the post-Magothy Upper Cretaceous beds exhibit similarities in lithology, palynologic examinations were made of three sections in order to compare ages of the post-Magothy Upper Cretaceous lithologic units at Round Bay with



A

FIGURE 16. — A suggested correlation of the Severn Formation at Round Bay, Md., with the Navesink Formation of Atlantic Highlands, N.J. and with the lower type Maestrichtian of the Maestricht Region, Holland, based on dinoflagellates and acritarchs. *A*, A comparison of the ranges of key species common to both the Navesink of New Jersey and the lower type Maestrichtian of Holland.



B C

FIGURE 16. — Continued. General agreement in the pattern of appearance of the four species shown suggests that the Navesink correlates with Hofker's foraminiferal zones B and the lower part of C and Schmid's ex gr. *lanceolata* and lower ex gr. *junior* belemnite zones, suggesting that the Navesink is early Maestrichtian in age. *B* A comparison of the ranges of key species common to both the Navesink of New Jersey and to samples E, F, H, and R1081A of the Severn, Round Bay, Md. The concurrent ranges of the species shown individually for samples E, F, H and R1081A suggest a correlation with the middle Navesink of Atlantic Highlands, N.J. *C*, Probable correlation of samples E, F, H, and R1081A with Navesink of Atlantic Highlands, N.J. By comparison across the chart to the left, it seems that samples E, F, H, and R1081A are correlative with parts of zones A and B of Hofker and ex gr. *lanceolata* and ex gr. *junior* in the lower type Maestrichtian of Holland.

those of New Jersey. Samples were examined from the upper part of the Magothy Formation at Round Bay for the purpose of age correlation with the Magothy of northern New Jersey.

PREVIOUS PALYNOLOGIC INVESTIGATIONS

Although several studies have been made on the spores and pollen of the Magothy and post-Magothy Upper Cretaceous deposits of the Middle Atlantic States (Groot and Penny, 1960; Groot and others, 1961; Kimyai, 1966; Doyle, 1969; Wolfe and Pakiser, 1971), only two, those of Wolfe (1976), and Christopher (1979), present range charts showing the stratigraphic distribution of selected pollen types.

Christopher (1977), in a study of the Raritan and Magothy Formations of northern New Jersey, recognized a three-fold biostratigraphic subdivision of the Magothy based on the distribution of *Normapolles* and triporate pollen types. In ascending stratigraphic order, these subdivisions are referred to as subzones A, B, and C of Sirkin's (1974) informally proposed zone V. Subzone VA includes the South Amboy Fire Clay Member of the Raritan and the lower and middle parts of the Old Bridge Sand Member of the Magothy; the upper part of the Old Bridge Sand and the Amboy Stoneware Clay Members of the Magothy; the "Morgan beds" and the "Cliffwood beds" of the Magothy.

For the post-Magothy Upper Cretaceous units of the Salisbury and Raritan embayments, Wolfe (1976) established six informal palynologic zones based on the distribution of 104 angiosperm pollen types.

Zone CA-1 includes the uppermost beds of the Magothy Formation and therefore overlaps subzone VC of Christopher (1977).

Zone CA-2, which Wolfe (1976) divided into two subzones, encompasses the entire Merchantville Formation of the Raritan embayment and the lower part of the Merchantville of the Salisbury embayment.

Zone CA-3, also divided into two subzones, includes the Woodbury Clay of the Raritan embayment and the upper part of the Merchantville of the Salisbury embayment. Recognition of Zone CA-3 in both embayments led Wolfe (1976) to suggest that the Woodbury Clay changes facies from north to south as indicated by Minard (1974, p. 20), rather than pinch out completely as suggested by J.P. Owens and J. P. Minard (in Owens and others, 1970, p. 10).

Zone CA-4 encompasses the Englishtown Formation of both the Raritan and the Salisbury embayments and includes one of the most distinctive pollen assemblages of the entire section. No subdivision of this zone was made by Wolfe (1976).

The Marshalltown, Wenonah, and Mount Laurel Formations occur in Zone CA-5, which Wolfe (1976) divided into subzones CA-5A and CA-5B.

Zone CA-6/MA-1 includes the Navesink Formation and at least the basal part of the Red Bank Sand in the Raritan embayment. In the Salisbury embayment, the Severn Formation (referred to as the Monmouth Formation by Wolfe, 1976) falls within this zone. Wolfe noted a dissimilarity of samples from the uppermost part of the Navesink and the Red Bank and samples from lower in the Navesink and used this as a basis for a twofold subdivision of zone CA-6/MA-1 in the Raritan embayment. Not noticing this microfloral change in samples from the Salisbury embayment, he included the entire Severn in this subzone. (Wolfe did mention, however, that the marine invertebrate fossils at Round Bay suggest that at least part of the Severn is biostratigraphically equivalent to the upper part of the Navesink and the Red Bank of New Jersey.)

STRATIGRAPHIC PALYNOLOGY AT ROUND BAY

Twenty-two of the species used by Christopher (1977, in press) and 48 of the species used by Wolfe (1976) in formulating their subdivisions of the Upper Cretaceous formations of the Middle Atlantic States were identified in the samples from Round Bay. Because taxonomic studies of these species have yet to be made, many species and some genera are not described. In order to make this report more useful to others and to help in interpreting the data presented here, these species are figured on plates 2–4. The stratigraphic distribution of the 22 species from the Magothy Formation as they occur in northern New Jersey (after Christopher, in press) and of the 48 species from the post-Magothy Upper Cretaceous formations of the Raritan and Salisbury embayments (after Wolfe, 1976) are presented here as figures 17 and 18, respectively. (Because Wolfe used alphanumeric codes to designate his species rather than formal taxonomic binomens, his code designations are presented here in parentheses following the names adopted in this study.)

THE MAGOTHY MICROFLORA

Only two of the samples collected from the Magothy Formation of Round Bay, R1080C and R1094, were palynologically productive. Sample R1080C was obtained from a highly carbonaceous clay lens (0.3 m thick) within a clean crossbedded sand exposed in a sand and gravel pit on the road to Sunrise Beach, west of the Severn River (lat 39°03′45″N, long 76°36′W), sample R1094 from the base of a section located on the east bank of the Severn River, approximatley 0.45 km north of Swan Point. Only the uppermost 0.6 m of the Magothy is exposed in this section; it is overlain by beds of the

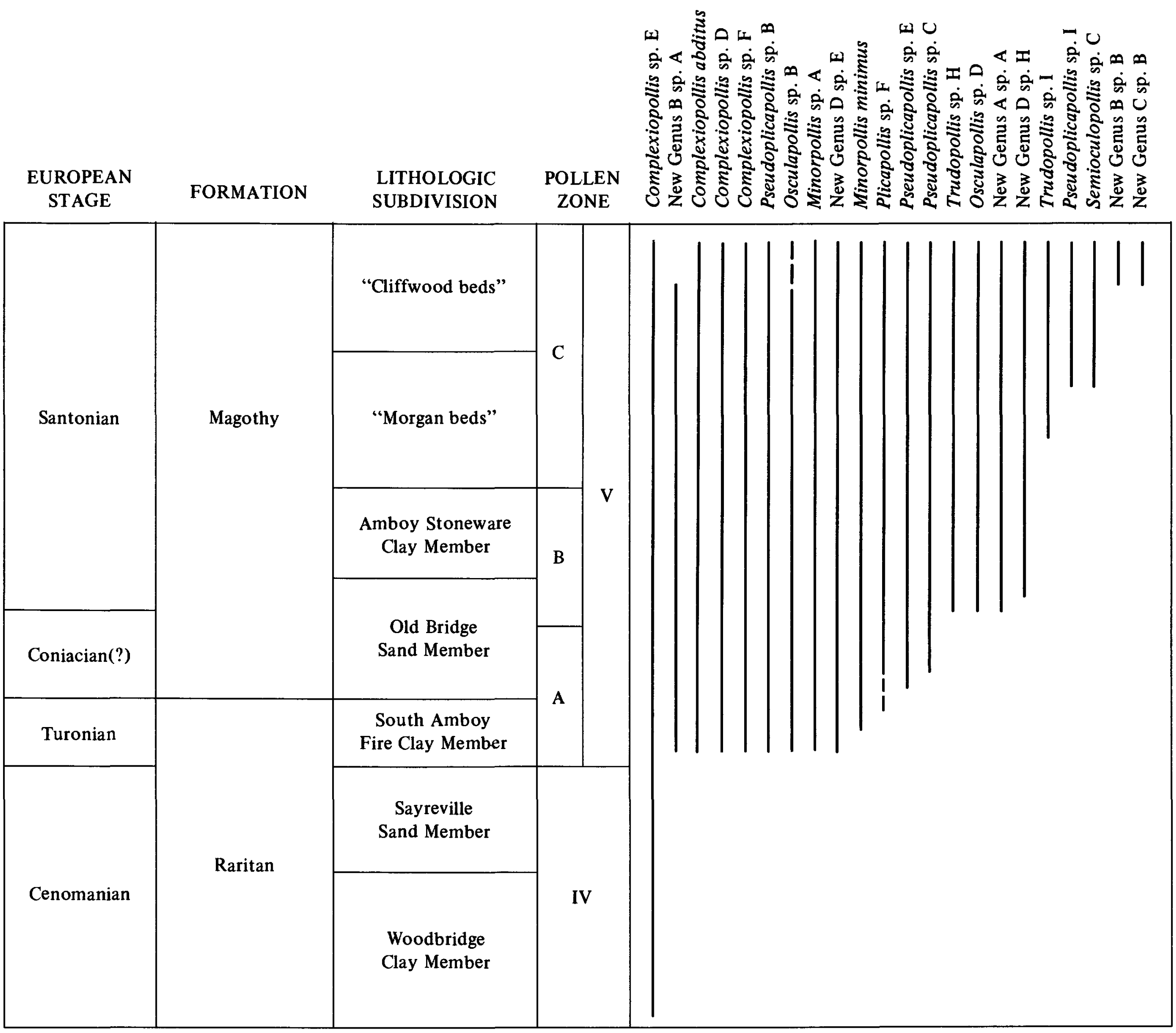


FIGURE 17.—Stratigraphic distribution of the pollen species recovered from the Magothy Formation at Round Bay as they occur in the Magothy of northern New Jersey. After Christopher, (1977,1979).

Matawan Formation. These beds were augered at this location. The sample reported on here came from 1 m below the Magothy-Matawan contact.

Occurrence of the biostratigraphically diagnostic pollen species in both Round Bay samples is presented in table 3. Although the two samples contain somewhat dissimilar microfloras, the presence of certain species in each assemblage suggests that both samples should be placed in subzone VC of Christopher (1977).

Only one species in sample R1094, New Genus C, sp. B, was considered by Christopher (1977) to be biostratigraphically significant within the Magothy Formation. In northern New Jersey, this species is restricted to the "Cliffwood beds" of the Magothy of subzone VC, suggesting a "Cliffwood" age for the sample.

Of the 16 biostratigraphically significant species occurring in sample R1080C, three are restricted to subzone VC: *Trudopollis* sp. I, *Pseudoplicapollis* sp I, and New Genus B sp. B. None of the remaining species have stratigraphic ranges that conflict with an assignment of sample R1080C to subzone VC. The occurrence of New Genus B sp. B suggests a "Cliffwood" age (Magothy) for this sample.

The suggestion that "Cliffwood-equivalent beds" (Magothy) are present in Round Bay conflicts with Wolfe's hypotheses (1976) that the Magothy Formation

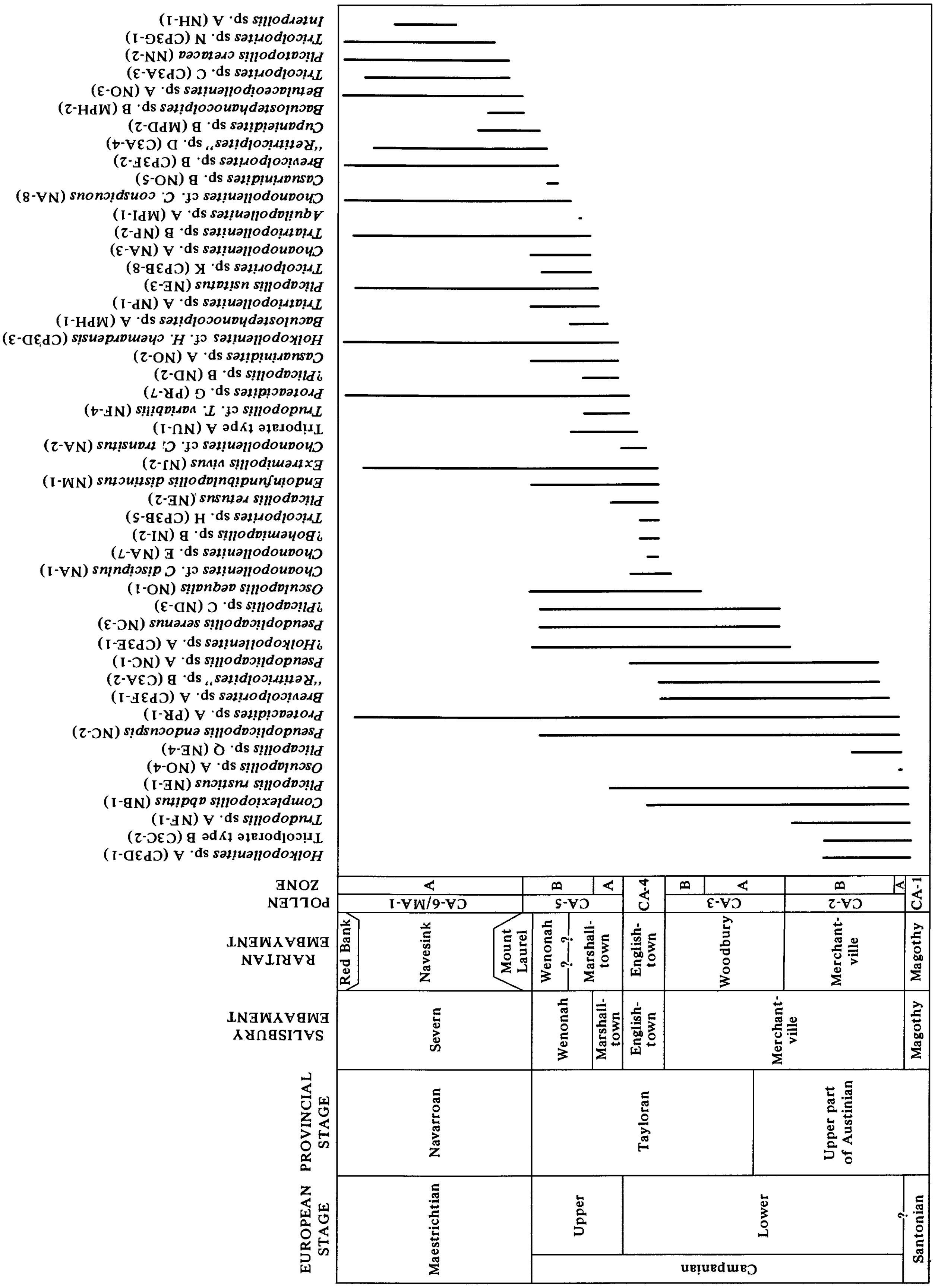


FIGURE 18.—Stratigraphic distribution of the pollen species recovered from the post-Magothy Upper Cretaceous formations at Round Bay as they occur in the Salisbury and Raritan embayments. After Wolfe (1976).

TABLE 3.—*Occurrence of the biostratigraphically diagnostic pollen species in the samples from the Magothy Formation at Round Bay*

Species	Sample No. R1080C from RB-72A3	Sample No. R1094 from RB-11A
Complexiopollis sp. E	×	——
New genus B sp. A[1]	——	——
Complexiopollis abditus	×	×
sp. D	×	——
sp. F	×	——
Pseudoplicapollis sp. B	×	——
Osculapollis sp. B	——	×
Minorpollis sp. A	——	×
New genus D sp. E	×	——
Minorpollis minimus	×	——
Plicapollis sp. F	×	×
Pseudoplicapollis sp. E	×	×
sp. C	×	——
Trudopollis sp. H	×	——
Osculapollis sp. D[1]	——	——
New genus A sp. A[1]	——	——
New genus D sp. H	×	——
Trudopollis sp. I	×	——
Pseudoplicapollis sp. I	×	——
Semioculopollis sp. C	×	——
New genus B sp. B	×	——
New genus C. sp. B	——	×

[1]Recovered only from sample at high-tide watermark at section RB-81A. Considered reworked.

in Round Bay is biostratigraphically equivalent to an interval between the samples he examined from the Old Bridge Sand and the Amboy Stoneware Clay Members of the Magothy in New Jersey. Wolfe based his correlations on broad similarities in assemblages, for example, the diversity of *Normapolles,* tricolpate and tricolporate pollen occurring as common elements rather than on the stratigraphic distribution of species. Christopher (1979) has shown that *Normapolles* diversity is fairly constant throughout the upper part of the Old Bridge Sand and Amboy Stoneware Clay Members and "Morgan beds," and into the middle part of the "Cliffwood Beds" of the Magothy. Higher in the Cliffwood, its diversity declines slightly. Moreover, the histograms presented by Christopher (1979) showing the relative percent of major palynomorph groups throughout the Raritan and Magothy Formations of northern New Jersey indicate a strong similarity in the relative frequency of both tricolpate and tricolporate pollen in the upper part of the Old Bridge Sand and the Amboy Stoneware Clay Members and the "Cliffwood beds." These data might help explain the discrepancy between the age assignments for the Magothy Formation of Round Bay proposed here and that proposed by Wolfe. (Wolfe does mention that some of the tricolpate and tricolporate pollen types observed in his Round Bay samples also occur in samples from the Amboy Stoneware Clay Member of the Magothy, but it has been my experience that most tricolpate and tricolporate species range throughout the Magothy, although their relative abundance fluctuates greatly.)

POST-MAGOTHY LATE CRETACEOUS MICROFLORA

Samples from three post-Magothy Upper Cretaceous sections—RB-6, RB-87a, and RB-79—were collected and examined for palynomorphs. The most thoroughly sampled section is RB-6, exposed along the north shore of the Severn River, approximately 0.6 km southeast of Eaglenest Point. The basal 1.5 m of the section is clean, light-gray, coarse to very coarse quartz sands of the Magothy Formation. These sands are overlain by approximately 2.7 m of dark-green, glauconitic, micaceous, and lignitic clays, silts, and sands assigned to the Matawan Formation on the basis of their lithologic characteristics. These beds are overlain by lighter colored beds, primarily of quartz sand, which generally contain lesser amounts of glauconite, mica, and lignite than the underlying unit. On the basis of lithologic evidence, the upper deposits have been assigned to the Severn Formation.

The stratigraphic position of the seven samples collected at this locality are 0.2 m, 0.6 m, 1.5 m, 2.4 m, 3 m, 3.7 m, and 4.9 m above the high-tide waterline. Occurrence of the biostratigraphically diagnostic pollen types in these seven samples from RB-6 and samples from RB-81a and RB-79 are presented in table 4.

A comparison of the distribution of the species at Round Bay with their stratigraphic ranges as presented by Wolfe (1976) indicates that a distinct microfloral change takes place between the samples at 2.4 and 3 m. This biostratigraphic break coincides with the lithologic break separating the Matawan and Severn Formations. Pollen data from this section suggest that the Matawan can be placed in Wolfe's zone CA-5 (1976), whereas the Severn belongs in his zone CA-6/MA-1.

With the exception of *Betulaceoipollenites* sp. A (NO-3) and *Choanopollenites* cf. *C. discipulus* Tschudy 1973 (NA-1), the 11 biostratigraphically significant species in the basal sample of section RB-6 occur together only in subzone CA-5A in beds of Marshalltown age from the Raritan and Salisbury embayments. *Betulaceoipollenites* sp. A (NO-3) has previously been reported only from younger beds, *Choanopollenites* cf. *C. discipulus* (NA-1) only from older beds (Wolfe, 1976).

The concurrent ranges of all but three species of pollen from the samples at 0.6 m, 1.5 m and 2.4 m suggest that these samples can be placed in subzone CA-5B, making them correlative with the Wenonah and (or) the Mount Laurel to the north. *Tricolporites* sp. K (CP3B-8) and *Casuarinidites* sp. B (NO-5) are restricted to subzone CA-5B in the Raritan and Salisbury embayments. Again, *Betulaceoipollenites* sp. A (NO-3) has previously been reported only from younger beds, whereas *Choanopollenites* cf. *C. transitus* Tschudy 1973 (NA-2) and *C.* sp. E. (NA-7) have been reported only from older beds (Wolfe, 1976).

TABLE 4.—*Occurrence of the biostratigraphically diagnostic pollen species in the post-Magothy Upper Cretaceous formations at Round Bay*

Species	Southeast of Eaglenest Point							North of Mathier Point			NW of Long Point	
	Section											
	RB-6							RB-81A			RB-79	
	Meters											
	0.2	0.6	1.5	2.4	3.0	3.7	4.9	0.0	1.5	3.0	2.0	2.9
Holkopollenites sp. A (CP3D-1)	—	—	—	—	—	—	—	—	×	—	—	—
Tricolporate type B (C3C-2)	—	—	—	—	—	—	—	×	—	—	—	—
Trudopollis sp. A (NF-1)	—	—	—	—	—	—	—	×	—	—	×	—
Complexiopollis abditus (NB-1)	—	—	—	—	—	—	—	×	×	—	—	—
Plicapollis rusticus (NE-1)	—	—	—	—	—	—	—	×	×	—	—	—
Osculapollis sp. A (NO-4)	—	—	—	—	—	—	—	×	×	—	—	—
Plicapollis sp. Q (NE-4)	—	—	—	—	—	—	—	—	×	—	—	—
Pseudoplicapollis endocuspis (NC-2)	—	—	×	—	—	—	—	—	×	—	×	—
Protencidites sp. A (PR-1)	—	—	—	—	—	×	—	—	—	×	×	×
Brevicolporites sp. A (CP3F-1)	—	—	—	—	—	—	—	×	—	—	—	—
"*Retitricolpites*" sp. B (C3A-2)	—	—	—	—	—	—	—	×	×	—	—	—
Pseudoplicapollis sp. A (NC-1)	—	—	—	—	—	—	—	×	×	—	—	—
Pseudoplicapollis serenus (NC-3)	—	—	×	—	—	—	—	×	×	—	×	—
?*Holkopollenites* sp. A (CP3E-1)	×	×	—	—	—	—	—	×	×	—	—	—
?*Plicapollis* sp. C (ND-3)	—	×	—	—	—	—	—	×	×	—	—	—
Osculapollis aequalis (NO-1)	×	×	×	×	—	—	—	×	—	—	×	×
Choanopollenites cf. *C. discipulus* (NA-1)	×	—	—	—	—	—	—	—	—	—	—	—
Choanopollenites sp. E (NA-7)	—	×	—	—	—	—	—	—	×	—	×	—
?*Bohemiapollis* sp. B (NI-2)	—	—	—	—	—	—	—	×	×	—	—	—
Tricolporites sp. H (CP3B-5)	—	—	—	—	—	—	—	×	×	—	—	—
Plicapollis retusus (NE-2)	×	—	—	—	—	—	—	×	×	—	—	—
Endoinfundibulapollis distinctus (NM-1)	—	—	—	—	—	—	—	×	×	—	—	—
Extremipollis vivus (NJ-2)	—	—	—	—	—	—	—	—	—	—	—	×
Choanopollenites cf. *C. transitus* (NA-2)	×	—	×	—	—	—	—	×	—	—	×	—
Triporate type A (NU-1)	×	×	×	×	—	—	—	×	—	—	×	×
Trudopollis cf. *T. variabilis* (NF-4)	—	—	—	—	—	—	—	×	×	—	—	—
Proteacidites sp. G (PR-7)	×	×	×	—	×	—	×	—	—	×	×	×
?*Plicapollis* sp. B (ND-2)	—	—	×	—	—	—	—	—	—	—	—	—
Casuarinidites sp. A (NO-2)	—	×	×	×	—	×	×	—	—	—	—	×
Holkopollenites cf. *H. chemardensis* (Cp3D-3)	×	×	×	×	×	×	—	×	×	×	×	—
Baculostephanocolpites sp. A (MPH-1)	×	×	×	×	—	—	—	—	—	—	×	×
Triatriopollenites sp. A (NP-1)	—	—	×	—	×	×	—	—	—	×	×	×
Plicapollis usitatus (NE-3)	×	×	×	×	×	×	×	×	×	×	×	×
Tricolporites sp. K (CP3B-8)	—	×	—	×	—	—	—	—	—	—	—	—
Choanopollenites sp. A (NA-3)	—	×	×	×	—	×	×	—	—	—	—	—
Triatriopollenites sp. B (NF-2)	—	—	—	—	×	×	×	—	—	×	—	—
Aquilapollenites sp. A (MPI-1)	—	—	—	—	×	—	—	—	—	—	—	—
Choanopollenites cf. *C. conspicuous* (NA-8)	—	—	—	—	—	×	×	—	—	×	—	—
Casuarinidites sp. B (NO-5)	—	—	×	—	—	—	—	—	—	—	—	×
"*Retitricolpites*" sp. D (C3A-4)	—	×	—	—	—	—	—	—	—	—	—	—
Cupanicidites sp. B (MPD-2)	—	—	—	—	—	×	—	—	—	—	—	—
Baculostephanocolpites sp. B (MPH-2)	—	—	—	—	×	×	×	—	—	×	—	—
Betulaceoipollenites sp. A (NO-3)	×	×	×	×	×	×	×	—	—	×	×	×
Tricolporites sp. C (CP3A-1)	—	—	—	—	—	—	×	—	—	—	—	—
Plicatopollis cretacea (NN-2)	—	—	—	—	×	×	×	—	—	×	—	—
Brevicolporites sp. B (CP3F-2)	—	—	—	—	×	×	×	—	—	×	—	×
Tricolporites sp N (CP3G-1)	—	—	—	—	—	×	×	—	—	—	—	—
Interpollis sp. A (NH-1)	—	—	—	—	—	×	—	—	—	—	—	—

Samples from above the lithologic break at 2.7 m in section RB-6 contain similar pollen assemblages. Of considerable biostratigraphic significance are the concurrent ranges of *Plicatopollis cretacea* Frederiksen and Christopher, 1978 (NN-2), *Choanopollenites* of *C. conspicuous* (Groot and Groot, 1962) Tschudy 1973 (NA-8), *Tricolporites* sp. C (CP3A-3), T. sp. N (CP3G-1), *Brevicolporites* sp. B (CP3F-2), *Interpollis* sp. A (NH-1), *Baculostephanocolpites* sp. B (MPH-2), and *Cupanieidites* sp. B (MPD-2), all of which indicate an equivalency with Wolfe's subzone CA-6/MA-1A (1976). In the Raritan embayment, this subzone represents all but the upper part of the Navesink Formation. At the RB-6 locality, three species were observed from the Severn Formation that have previously been reported only from older beds: *Triatriopollenites* sp. A (NP-1), *Casuarinidites* sp. A (NO-2), and *Choanopollenites* sp. A (NA-3). Wolfe reported *Aquilapollenites* sp. A (MPI-1) as occurring in only one sample from the Wenonah Formation of the Salisbury embayment, but Evitt (1973) has recovered specimens of *Aquilapollenites* from the "Monmouth" Formation of Charles County, Md, and from the Red Bank Sand of Monmouth County, N.J. The genus is generally considered to be a major constituent in many

Campanian and Maestrichtian assemblages from western North America; its rare occurrence in samples from the Atlantic Coastal Plain is possibly the result of long-distance wind transport; the stratigraphic distribution of this genus in deposits from this area is probably not biostratigraphically significant.

A second section sampled for spores and pollen, RB—81a, is located along the western shore of Little Round Bay approximately 0.5 km north of Mathiers Point, due west of St. Helena Island. Two lithologic units are recognized at this locality. The basal 2 m consists of a black, very lignitic blocky clay with thin layers and laminae of white sand, (fig. 6) lithologically similar to the uppermost regressive phases of the sedimentary cycles described by Owens and Sohl (1969). Resting in sharp contact with the lower unit is 2.1 m of mottled gray, silty, very fine to medium sand containing some glauconite and disseminated organic matter. Two samples were collected from the lower unit: one at the high-tide waterline and one from 1.5 m higher in the section. One sample was collected from the upper unit, 3 m above the high-tide watermark. Occurrence of the biostratigraphically significant pollen types in samples from section RB—81a is presented in table 4. The stratigraphic ranges of species from the lower unit (as reported by Christopher, (in press) and by Wolfe, 1976) suggest that sediments of the Magothy and (or) Merchantville Formations have been reworked into beds equivalent to the Englishtown Formation (zone CA—4). The upper unit can be placed in Wolfe's subzone CA—6/MA—1A and probably represents the Severn Formation at this locality.

Evidence of reworking in the lower unit lies in the disjunct nature of the species ranges in these samples. Five of the species from this unit have previously been reported only from the Magothy Formation of northern New Jersey (Christopher, 1979), and three only from the Merchantville Formation of the Raritan and Salisbury embayments (Wolfe, 1976). Species apparently reworked are indicated as such on table 3.

Except for *Plicapollis usitatus* Tschudy 1975 (NE—3) and *Holkopollenites* cf. *H. chemardensis* Fairchild in Stover, Elsik, and Fairchild (1966) (CP3D—3), previously observed only in younger beds, the concurrent ranges of all other species indicates that the lower unit at RB—81a can be placed in Wolfe's zone CA—4 (1976). Four of these species are considered by Wolfe to be restricted to this zone: *Tricolporites* sp. H (CP3B—5), *?Bohemiapollis* sp. B (NI—2), *Choanopollenites* sp. E (Na—7), and *C.* of *C. transitus* (NA—2). On this basis, it is concluded that the black lignitic blocky clays with thin, white sand partings at the base of section RB—81a represent zone CA—4 and are equivalent to the Englishtown Formation. Sediments for this unit were probably derived from beds of Magothy and (or) Merchantville age.

The pollen assemblage from the upper lithologic unit at Mathiers Point is very similar to the assemblage from the Severn Formation at locality RB—6, all species present in the Mathiers Point sample are present in the Severn at RB—6, including *Plicatopollis cretacea* (NN—2), *Baculostephanocolpites* sp. B (MPH—2), and *Brevicolporites* sp. B CP3F—2). As stated, the concurrence of these species is indicative of subzone CA—6/MA—1A in the Raritan and Salisbury embayments.

Although pollen from the section at Mathiers Point suggest that beds equivalent to the Englishtown Formation are directly overlain by the Severn Formation, with units equivalent to the Marshalltown, Wenonah, and Mount Laurel Formations of Wolfe's zone CA—5 missing, representatives of at least one and possibly two of the units missing at Mathiers Point are present at a section, RB—79, exposed on the north side of Long Point, 0.3 km northwest of the tip of the point. Here, 1.8 m of a medium- to dark-gray, lignitic, compact clayey quartz sand exposed at the base of the section is overlain by approximately 1 m of thinly bedded, glauconitic, dark-greenish-gray to greenish-black clays, silts, and sands. A third lithologic unit at the top of the section consists of 1.8 m of medium-gray to yellow-gray, slightly glauconitic, lignitic quartz sand.

Two samples from the middle lithologic unit were sampled; the palynomorphs recovered from them are listed in table 4.

The concurrent ranges of all species except *Choanopollenites* sp. E (NA—7) and *Betulaceoipollenites* sp. A (NO—3) suggest that the lower sample collected at the base of the middle lithologic unit at Long Point belongs to subzone CA—5A and is equivalent to the Marshalltown Formation in the Salisbury and Raritan embayments. *Choanopollenites* sp. E (NE—7) indicates an older age for this sample, having been previously reported only from the Englishtown Formation by Wolfe (1976), whereas *Betulaceoipollenites* sp. A (NO—3) suggests a younger age. However, *Betulaceoipollenites* sp. A (NO—3) was recovered from all samples at section RB—6, and its presence at Long Point is consistent with its presence in other samples of apparent Marshalltown age at Round Bay.

The second sample from the middle lithologic unit exposed at Long Point was collected 0.9 m stratigraphically higher than the first. The concurrent ranges of all species recovered from this sample, again with the exception of *Betulaceoipollenites* sp. A (NO—3), indicates that this sample belongs in subzone CA—5B, which encompasses the Wenonah and the Mount Laurel in the Raritan and Salisbury embayments.

SUMMARY

Palynologic examinations of samples from five outcrop sections at Round Bay suggest: First, at least part of the Magothy Formation at Round Bay is equivalent to the uppermost units of the Magothy of northern New Jersey (the "Cliffwood" and possibly the "Morgan beds").

Second, the Matawan Formation at Round Bay consists of at least Englishtown, Marshalltown, and Wenonah or Mount Laurel equivalents. These beds may not be continuous throughout the area, because the younger Severn Formation is observed to rest directly on Englishtown equivalents at one locality, but on Wenonah or Mount Laurel equivalents at two others. Further, a reworked microflora within the Englishtown Formation suggests that units equivalent to the Merchantville Formation were present in the area, at least during Englishtown time.

Third, the Severn Formation contains a pollen assemblage similar to that of the Navesink Formation of New Jersey, and one that is quite distinct from assemblages from the underlying Matawan Formation.

If the age assignments and correlations presented here are correct, the stratigraphic ranges of several species used by Wolfe (1976) in formulating his zonation of the post-Magothy Upper Cretaceous formations of the Middle Atlantic States must be extended. *Betulaceoipollenites* sp. A (NO—3) was recovered from samples of apparent Marshalltown and Wenonah or Mount Laurel age, as well as samples from the Severn Formation at Round Bay. Wolfe reported this species as occurring only in the Severn of the Salisbury embayment and in its equivalent Navesink Formation and the overlying Red Bank Sand of the Raritan embayment. The range of *Betulaceoipollenites* sp. A (NO—3) should probably be extended downward to accommodate its occurrences at Round Bay.

Only one specimen of *Choanopollenites* cf. *C. discipulus* Tschudy 1973 (NA—1) was found in the samples from Round Bay which were in beds coeval with the Marshalltown Formation (the basal sample at section RB—6). Wolfe (1976) observed this species in samples from the uppermost part of the Woodbury Clay and throughout the Englishtown Formation. In light of the data presented here, this species apparently extends upward into the Marshalltown.

Wolfe (1976) considered *Choanopollenites* cf. *C. transitus* Tschudy 1973 (NA—2) to be restricted to the Englishtown and the basal part of the Marshalltown, and *C.* sp. E (NA—7) to the Englishtown Formations in the Raritan and Salisbury embayments, respectively. At Round Bay, both species were recovered in samples considered equivalent to the Wenonah and (or) Mount Laurel, which would extend their ranges higher in the section.

Three of the species recovered from samples of the Severn Formation at Round Bay were observed only at lower stratigraphic horizons by Wolfe (1976): the last occurrence of *Triatriopollenites* sp. A (NP—1), *Casuarinidites* sp. A (NO—2), and *Choanopollenites* sp. A (NA—3) all reported from the Mount Laurel Sand. As they are found here to extend up into the Severn Formation, the upper limit of their stratigraphic range should probably be extended.

Aquilapollenites sp. A (MPI—1), observed in one sample of the Severn Formation at Round Bay, was reported only from older beds by Wolfe (1976), but as stated, the occurrence of this genus in the Atlantic Coastal Plain should be treated more as a curiosity than as being biostratigraphically diagnostic.

Plicapollis usitatus Tschudy 1975 (NE—3) and *Holkopollenites* cf. *H. chemardensis* Fairchild in Stover, Elsik, and Fairchild 1966 (CP3D—3) have previously been reported only from the Marshalltown and younger beds (Wolfe, 1976). At Round Bay, both species were observed in samples correlated with the Englishtown Formation, suggesting that their stratigraphic ranges might be extended downward.

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PLATES 2–4

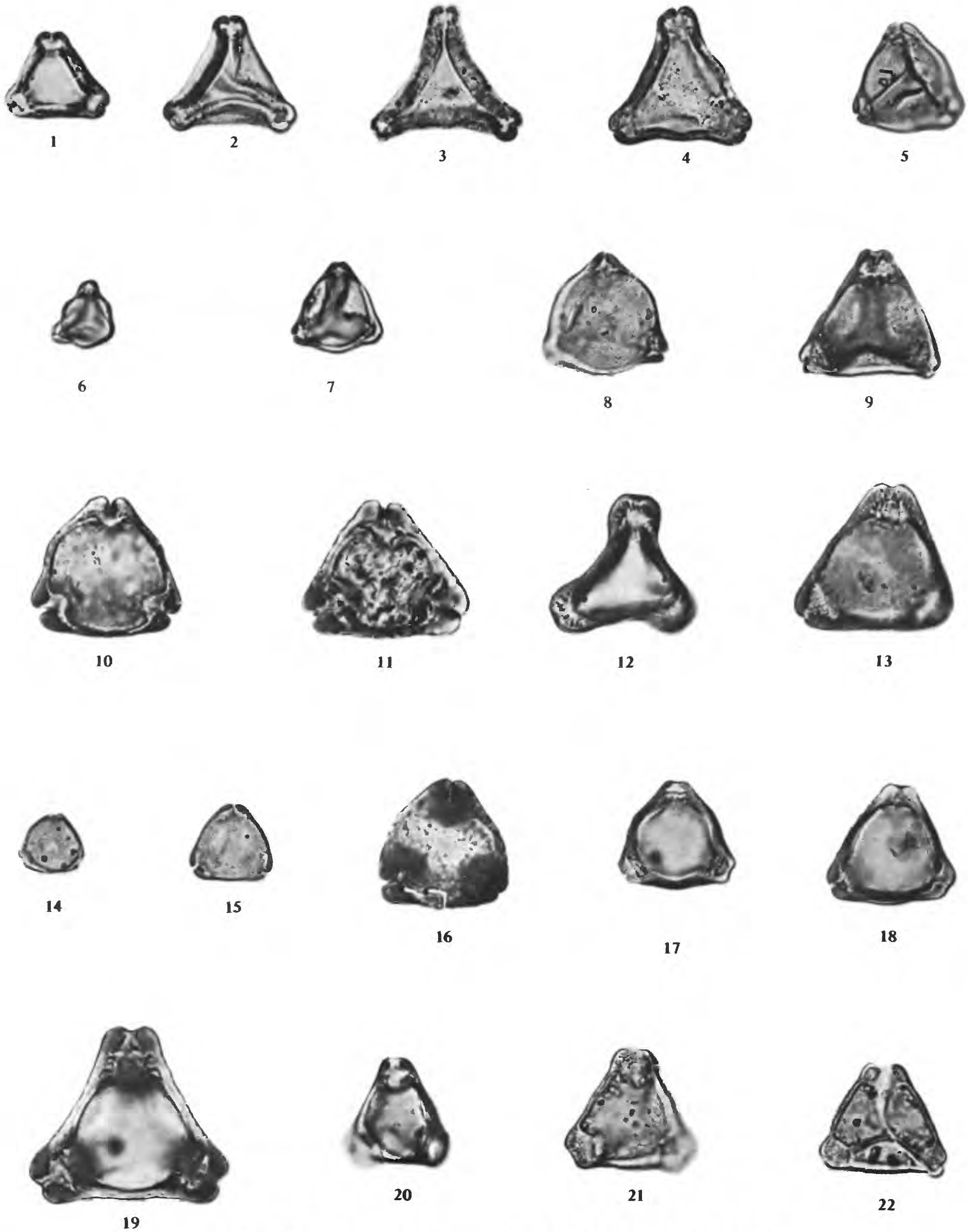
[Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colo. 80225]

PLATE 2

Magothy pollen. All figures ×1000.

FIGURE 1. *Complexiopollis abditus* Tschudy 1973, sample R1080C, slide 2, coor. 17.0 × 107.3 (= NB–1 of Wolfe, 1976).

2. *Complexiopollis* sp. D, sample R1080C, slide 1, coor. 37.2 × 110.7.
3. *Complexiopollis* sp. E, sample R1080C, slide 2, coor. 45.0 × 104.2 (= NB–2 of Wolfe, 1976).
4. *Complexiopollis* sp. F, sample R1080C, slide 2, coor. 23.8 × 98.2.
5. *Pseudoplicapollis* sp. B, sample R1080C, slide 2, coor. 24.9 × 108.6.
6. *Pseudoplicapollis* sp. C, sample R1080C, slide 2, coor. 21.6 × 111.4.
7. *Pseudoplicapollis* sp. E, sample R1080C, slide 2, coor. 24.9 × 108.6.
8. *Pseudoplicapollis* sp. I, sample R1080C, slide 2, coor. 21.7 × 113.4.
9. *Plicapollis* sp. B, from the Matawan Formation (reworked?), sample R1119, slide 6, coor. 45.7 × 105.9.
10. *Trudopollis* sp. H, sample R1080C, slide 2, coor. 22.0 × 111.2.
11. *Trudopollis* sp. I, sample R1080C, slide 2, coor. 42.0 × 103.4.
12. *Osculapollis* sp. B, sample R1094, slide 3, coor. 28.6 × 100.9.
13. *Osculapollis* sp. D, from the Matawan Formation (reworked?), sample R118, slide 6, coor. 47.8 × 112.0.
14. *Minorpollis* sp. A, sample R1094, slide 3, coor. 40.8 × 100.2.
15. *Minorpollis minimus* Krutzsch 1959, sample R1080C, slide 2, coor. 40.8 × 107.4.
16. *Semioculopollis* sp. C, sample R1080C, slide 2, coor. 41.8 × 110.2.
17. New Genus D sp. E, sample R1080C, slide 2, coor. 41.1 × 106.0.
18. New Genus D sp. H, from the Matawan Formation (reworked?), sample R1118, slide 6, coor. 42.1 × 112.6.
19. New Genus B sp. A, from the Matawan Formation (reworked?), sample R1118, slide 6, coor. 21.9 × 101.8.
20. New Genus B sp. B, sample R1080C, slide 2, coor.10.5 × 111.7.
21. New Genus A sp. A, from the Matawan Formation (reworked?), sample R1118, slide 6, coor. 25.0 × 99.3.
22. New Genus C sp. B, from the Matawan Formation (reworked?), sample R1119, slide 6, coor. 28.5 × 101.7.



POLLEN FROM THE MAGOTHY AND MATAWAN FORMATIONS

PLATE 3

Pollen from the Matawan and Severn Formations. All figures ×1000.

FIGURE 1. *Choanopollenites* cf. *C. discipulus* Tschudy 1973 (NA–1), Matawan Formation, sample R1079A, slide 2, coor. 27.0 × 104.4.

2. *Choanopollenites* cf. *C. transitus* Tschudy 1973 (NA–2), Matawan Formation, sample R1079C, slide 1, coor. 36.1 × 102.9.

3. *Choanopollenites* sp. A (NA–3), Matawan Formation, sample R1079B, slide 2, coor. 39.4 × 112.7.

4. *Choanopollenites* sp. E (NA–7), Matawan Formation, sample R1119, slide 6, coor. 32.9 × 104.4.

5. *Choanopollenites* cf. *C. conspicuous* (Groot & Groot 1962) Tschudy 1973 (NA–8), Severn Formation, sample R1120, slide 4, coor. 23.7 × 106.5.

6. *Complexiopollis abditus* Tschudy 1973 (NB–1), Matawan Formation, sample R1119, slide 6, coor. 21.9 × 105.1.

7. *Pseudoplicapollis* sp. A (NC–1), Matawan Formation, sample R1119, slide 6, coor. 13.4 × 107.9.

8. *Pseudoplicapollis endocuspis* Tschudy 1975 (NC–2), Matawan Formation, sample R1103, slide 2, coor. 20.8 × 102.2.

9. *Pseudoplicapollis serenus* Tschudy 1975 (NC–3), Matawan Formation, sample R1079B, slide 2, coor. 18.0 × 110.5.

10. ?*Plicapollis* sp. B (ND–2), Severn Formation, sample R1120, slide 4, coor. 33.0 × 113.4.

11. ?*Plicapollis* sp. C (ND–3), Matawan Formation, sample R1119, slide 6, coor. 41.6 × 99.8.

12. *Plicapollis rusticus* Tschudy 1975 (NE–1), Matawan Formation, sample R1119, slide 6, coor. 38.7 × 105.8.

13. *Plicapollis retusus* Tschudy 1975 (NE–2), Matawan Formation, sample R1119, slide 6, coor. 45.7 × 105.9.

14. *Plicapollis usitatus* Tschudy 1975 (NE–3), Matawan Formation, sample R1102, slide 3, coor. 21.1 × 100.6.

15. *Plicapollis* sp. Q (NE–4), Matawan Formation (reworked?), sample R1119, slide 6, coor. 32.6 × 105.9.

16. *Trudopollis* sp. A (NF–1), Matawan Formation (reworked?) sample R1118, slide 6, coor. 37.4 × 106.4.

17. *Trudopollis* cf. *T. variabilis* Tschudy 195 (NF–4), Matawan Formation, sample R1119, slide 6, coor. 36.2 × 109.9.

18. *Interpollis* sp. A (NH–1), Severn Formation, sample R1079F, slide 1, coor. 11.9 × 103.8.

19. ?*Bohemiapollis* sp. B (NI–2), Matawan Formation, sample R1119, slide 6, coor. 26.4 × 110.0.

20. *Extremipollis vivus* Tschudy 1975 (NJ–2), Matawan Formation, sample R1102, slide 3, coor. 29.8 × 97.6.

21. *Endoinfundibulapollis distinctus* Tschudy 1975 (NM–1), Matawan Formation, sample R1118, slide 6, coor. 42.2 × 108.2.

22. *Plicatopollis cretacea* Frederiksen & Christopher 1977 (NN–2), Severn Formation, sample R1079H, slide 1, coor. 45.9 × 103.6.

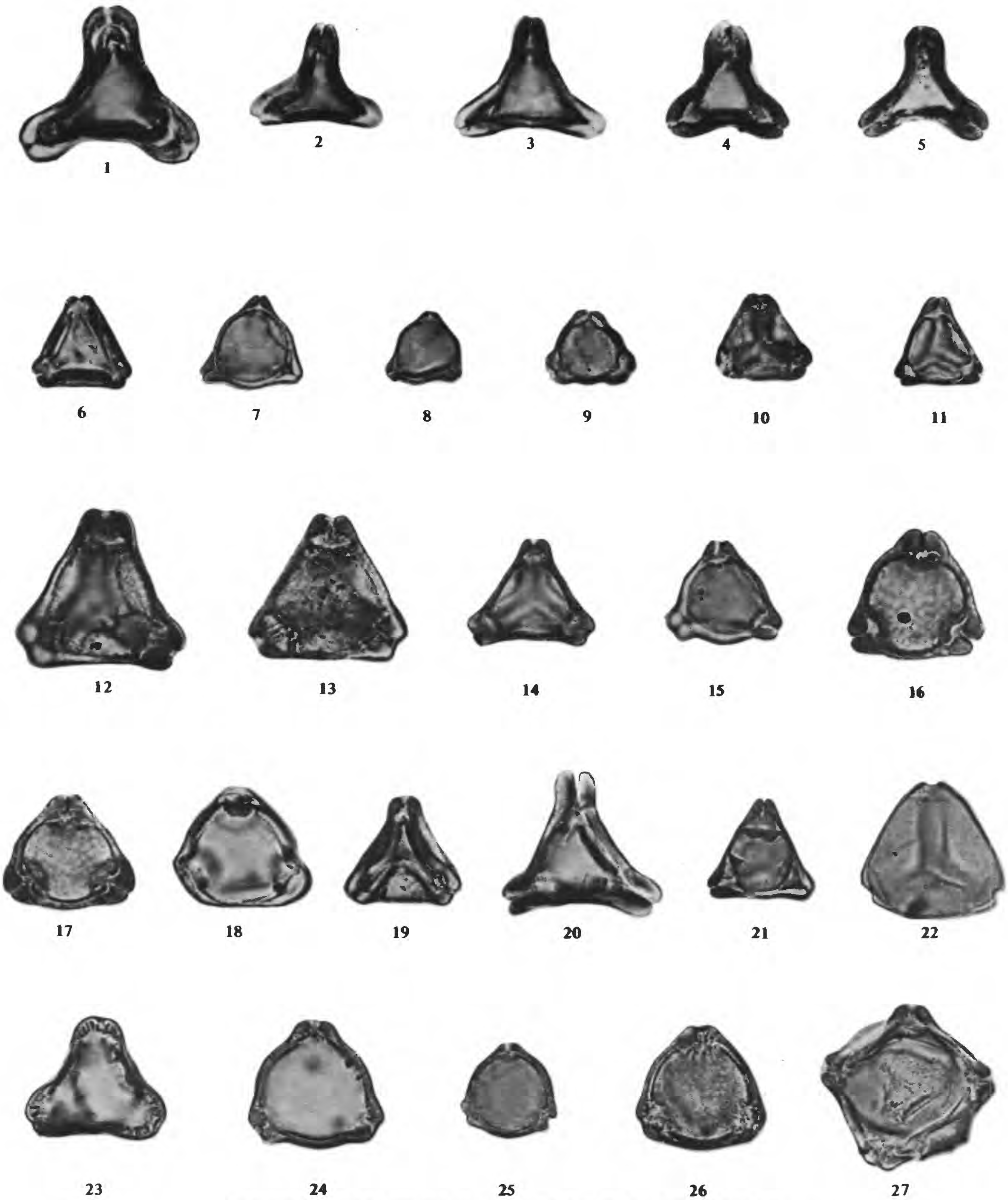
23. *Osculapollis aequalis* Tschudy 1975 (NO–1), Matawan Formation, sample R1079A, slide 2, coor. 19.7 × 107.7.

24. *Casuarinidites* sp. A (NO–2), Severn Formation, sample R1079H, slide 2, coor. 24.2 × 111.5.

25. *Betulaceoipollenites* sp. A (NO–3), Severn Formation, sample R1120, slide 4, coor. 21.9 × 98.0.

26. *Osculapollis* sp. A (NO–4), Matawan Formation (reworked?), sample R1118, slide 6, coor. 38.7 × 114.3.

27. *Casuarinidites* sp. B (NO–5), Matawan Formation, sample R1102, slide 3, coor. 42.0 × 102.7.



POLLEN FROM THE MATAWAN AND SEVERN FORMATIONS

PLATE 4

Pollen from the Matawan and Severn Formations. All figures × 1000.

FIGURE 1. *Triatriopollenites* sp. A (NP–1), Matawan Formation, sample R1079B, slide 2, coor. 38.2 × 113.2.

2. *Triatriopollenites* sp. B (NP–2), Severn Formation, sample R1079E, slide 2, coor. 16.3 × 110.4.

3. Triporate type A (NU–1), Matawan Formation, sample Rk079A, slide 2, coor. 16.7 × 107.3.

4. *Proteacidites* sp. A (PR–1), Severn Formation, sample R1079F, slide 1, coor. 29.9 × 97.5.

5, 10. *Proteacidites* sp. G (PR–7), Matawan Formation, sample R1079B,

6. "*Retitricolpites*" sp. B (C3A–2), Magothy Formation, sample R1080C, slide 2, coor. 15.1 × 99.9.

7. "*Retitricolpites*" sp. D (C3A–4), Matawan Formation, sample R1079B, slide 2, coor. 40.8 × 109.8.

8. Tricolporate type B (C3C–2), Matawan Formation, sample R1118, slide 6, coor. 30.4 × 110.7.

9. *Tricolporites* sp. C (CP3A–3), Severn Formation, sample R1079H, slide 1, coor. 20.8 × 102.8.

11, 12. *Tricolporites* sp. H (CP3B–5), Matawan Formation, sample R1118, slide 6, coor. 22.3 × 112.7.

13. *Tricolporites* sp. K (CP3B–8), Matawan Formation, sample R1079B, slide 2, coor. 33.7 × 101.9.

14. *Tricolporites* sp. N (CP3G–1), Severn Formation, sample R1079F, slide 1, coor. 30.0 × 104.0

15. *Holkopollenites* sp. A (CP3D–1), Matawan Formation (reworked?), sample R1119, slide 6, coor. 18.9 × 106.0.

16, 17. *Holkopollenites* cf. *H. chemardensis* Fairchild *in* Stover and others 1966 (CP3D–3), Matawan Formation, sample R1079A, slide 2, coor. 18.6 × 110.0.

19. ?*Holkopollenites* sp. A (CP3E–1), Matawan Formation, sample R1119, slide 6, coor. 37.0 × 105.8.

20. *Brevicolporites* sp. A (CP3F–1), Matawan Formation (reworked?), sample R1118, slide 6, coor. 46.8 × 103.5.

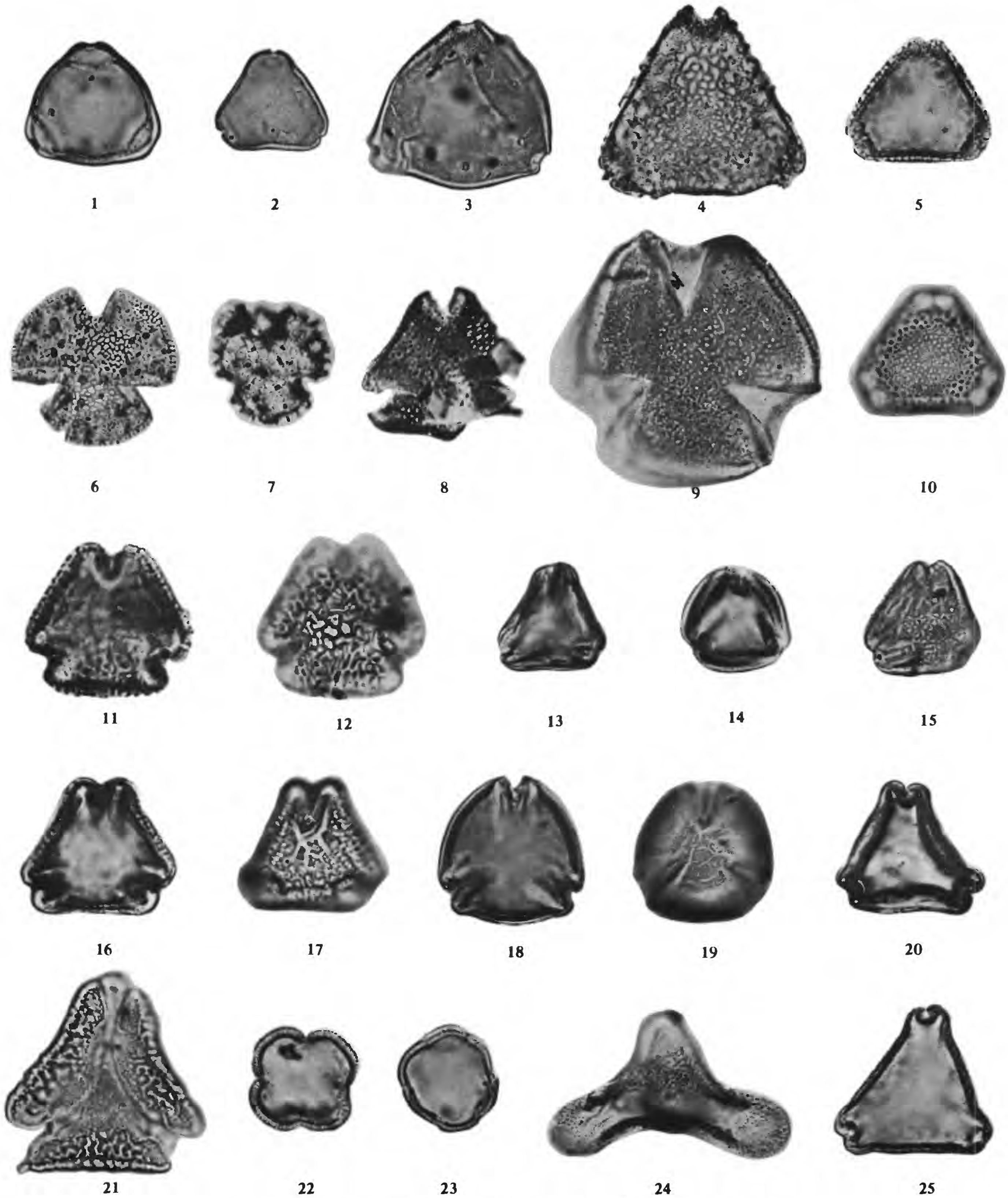
21. *Cupanieidites* sp. B (MPD–2), Severn Formation, sample R1079F, slide 1, coor. 16.1 × 97.0.

22. *Baculostephanocolpites* sp. A (MPH–1), Matawan Formation, sample R1102, slide 3, coor. 13.4 × 109.6.

23. *Baculostephanocolpites* sp. B (MPH–2), Severn Formation, sample R1120, slide 4, coor. 30.9 × 98.5.

24. *Aquilapollenites* sp. A (MPI–1), Severn Formation, sample R1079E, slide 2, coor. 36.4 × 105.4.

25. *Brevicolporites* sp. B (CP3F–2), Severn Formation, sample R1079H, slide 1, coor. 32.4 × 105.1.



POLLEN FROM THE MATAWAN AND SEVERN FORMATIONS