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ABSTRACT

PALYNOLOGY OF THE MONMOUTH GROUP (MAASTRICHTIAN) FROM MONMOUTH COUNTY, NEW JERSEY, U.S.A.

By

Gerald L. Waanders

The Monmouth Group as it occurs in Monmouth County, New Jersey is a marine deposit consisting of 4 formations: The Mount Laurel Sand, Navesink Formation, Red Bank Sand, and Tinton Sand. This group is known elsewhere across the state of New Jersey, and in Delaware and Maryland where it is less complete. The age of the Monmouth Group is considered to be Maastrichtian by most workers, but some believe the lower part to be Campanian in age. In this study, the entire unit is considered Maastrichtian.

Thirty-seven samples from 5 localities were examined for palynomorphs. A microfossil flora consisting of 99 species is described, illustrated, and compared with previous studies. Thirteen of these taxa are new combinations, 1 is a new name, 4 are considered new species, and 3 are left only as informal designations. Several dinoflagellates are illustrated as well, but used only for environmental interpretations.

Certain paleoenvironmental aspects of the sediments are determined from separate taxon counts, land-derived/microplankton ratios, and dinoflagellate associations. The separate taxon counts provide insights into the nature of the terrestrial plant communities represented by the microfossil flora, where swamp and two types of forest habitats are reflected at various localities. L-D/M ratios and dinoflagellate

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associations provide data indicating distance from shore at which deposition occurred. The L-D/M data, however, are unreliable in near shore conditions, whereas dinoflagellate associations are always consistent. Environments of deposition are nearshore for the Mt. Laurel and Red Bank Sands, and offshore for the Navesink Fm. and the Tinton Sand. In one locality (Atlantic Highlands), the offshore flora of the Navesink continues into the basal Red Bank Sand, possibly indicating a more seaward site of deposition than that noted for the other localities containing these units. The interpretation of offshore dinoflagellates in the Tinton Sand favors the opinions of those who believe this unit represents deep water, and contrasts those who suggest shallow water deposition. However, distance from shore as determined here by dinoflagellates is not necessarily comparable to water depth as determined by benthonic organisms or lithology.

Taxonomic data derived from literature studies are summarized into tables that compare the Monmouth Group microfossils both stratigraphically, to those described previously from the Cretaceous and early Tertiary of the Atlantic and Gulf Coastal Plains, and geographically, to described palynofloras from the Late Cretaceous and early Tertiary of Europe, and eastern and western North America. The stratigraphic data is a comparison of the distribution of spores and pollen from this study with those microfossil floras found elsewhere in the Atlantic and Gulf Coast in a time framework. The geographic relationships are suggested by comparison of lists of taxa derived from this study to microfossil floras of comparable age in western North America and Europe. Based on these comparisons, the flora of the Monmouth Group was found to be more similar to those of western North America than to European floras. This is in contras

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contrast to the work of Tschudy (1970) who believes that eastern North American pollen floras are more similar to those of Europe.

PALYNOLOGY OF THE MONMOUTH GROUP
(MAASTRICHTIAN) FROM MONMOUTH CO., NEW JERSEY, U.S.A.

By

Gerald L. Waanders

A THESIS

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INTRODUCTION

Statement of Problem

The following are the goals of this study:

1. Make an in-depth taxonomic study of the spores and pollen found in the late Cretaceous (Maastrichtian) strata represented in Monmouth County, New Jersey.
2. Determine the environments of deposition of the sediments in the sections studied through the analysis of dinoflagellate associations and other palynomorph groups.
3. Compare the Monmouth Group flora with others from eastern North America of Late Cretaceous and Early Tertiary age.
4. Compare more generally the Late Cretaceous floras of eastern North America with some of those described from western North America and Europe.

Previous Work

1. Paleobotanical

The earliest studies of fossil plants in this area were made in the late 1800's and early 1900's by such authors as W. M. Fontaine, A. Hollick, J. S. Newberry, and E. W. Berry. For a review and synthesis of these works see Dorf (1952). The stratigraphic units from which plant remains have been described are the Potomac Group and the Raritan and Magothy formations (see Figure 1). Plant remains other than palynomorphs are not known from younger Cretaceous (Campanian-Maastrichtian) nor from the Early Tertiary formations of the Atlantic Coastal Plain.

2. Palynological

Potomac Group

Of major importance is the work of Brenner (1963) who studied spores and pollen extensively, and was able to subdivide the Potomac Group into several zones. Other works pertaining to this unit are those of Groot and Penny (1960) and Stover (1962 and 1964).

Raritan and Magothy Formations

The original work in these units is that of Steeves (1959) who analyzed spores and pollen from Long Island. All taxa described in that study, however, are related only to modern plant families, and are not treated in the framework of the more conventional palynologic systematics. Other studies on these units include those by Groot, Penny and Groot (1961), Stover (1964), Kimyai (1966 and 1970), and Wolf and Pakiser (1971).

Mattawan and Monmouth Groups

Taxonomic works on spores and pollen from these units are those by Gray and Groot (1966) who described 27 species from 8 localities across New Jersey and Delaware, and Evitt (1973) who recorded 3 specimens representing 3 species of *Aquilapollenites* from the Monmouth Group of both Maryland and New Jersey. A few dinoflagellates have also been described (Evitt, 1961, 1967a & b).

Brightseat Formation

The Brightseat Formation is Paleocene (possibly Danian) and is known only from the southern part of the Mid-Atlantic Coastal Plain. It is equivalent in age to the Hornerstown Formation of New Jersey. A study of the spores and pollen of this formation is that of Groot and Groot (1962b) who described 25 species from this unit.

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One additional palynologic study is that of Doyle (1969). This study is restricted to angiosperm pollen occurring in the Potomac Group, Raritan and Magothy Formations (Barremian-Santonian). It is primarily a treatment of various morphologic types and how they relate to angiosperm evolution.

3. Other Paleontologic Work

Megapaleontologic studies in the northern Atlantic Coastal Plain are numerous. Most significant and recent are those of Richards et. al. (1958 and 1962) and Sohl (in Owens et.al. 1970).

For a history of early foraminiferal studies in the New Jersey Coastal Plain, see Olsson (1960). More recent works on forams are those of Olsson (1960, 1963 and 1964), Jordan (1962) and Mello (in Owens et. al. 1970).

4. Stratigraphic Work

Stratigraphic studies on the New Jersey Coastal Plain began as early as the mid-eighteenth century. Studies pertinent to present interpretations, however, began with those of W. B. Clark and associates in 1894. The first stratigraphic subdivision for this area was from the work of Clark, Bagg and Shattuck (1897). Other sequences to follow were those of Kummel and Knapp (1904), Weller (1907), and Cooke and Stephenson (1928). The presently accepted stratigraphic sequence is that of Weller as modified by Cooke and Stephenson, who showed that certain Upper Cretaceous units of Weller actually belong in the Tertiary. For a more complete review of these works, see Spangler and Peterson (1950) and Owens et al. (1970).

Time-Stratigraphic Units		Rock Stratigraphic Units	
Series	Stages		
Early Tertiary	Eocene	Vincentown Fm.	
	Paleocene	Hornerstown Sand	
Late Cretaceous	Maastrichtian	Monmouth Gp.	Tinton Sand
			Red Bank Sand
			Navesink Fm.
			Mt. Laurel Sand
	Campanian	Mattawan Gp.	Wenonah Fm.
			Marshalltown Fm.
			Englishtown Fm.
			Woodbury Clay
			Merchantville Fm.
	Santonian	Magothy Fm.*	
	Cenomanian	Raritan Fm.*	
	?		
Early Cretaceous	Albian	Potomac Gp.	Patapsco Fm.
	?		
	Aptian-Barremian		Arundel Clay
			Patuxent Fm.

Figure 1. Stratigraphic relations of groups and formations occurring in the Mid-Atlantic Coastal Plain.

* Age and interpretation for the Raritan and Magothy Formations follows Wolfe and Pakiser (1971).

GEOLOGY

Regional and Structural Setting

The Atlantic Coastal Plain as described by Richards (1967) consists of two parts--the emerged and submerged units. The emerged unit consists primarily of unconsolidated Cretaceous and Tertiary sediments, and is the area bordered to the east by the Atlantic shore, and to the west by the Fall Line (a north-south boundary marking the edge of the Appalachian Plateau). The submerged unit is the continental shelf. The widths of these units vary, but in general, they relate inversely to each other so that the total width of the coastal plain is generally uniform. The present study is concerned only with the emerged unit as it occurs in New Jersey.

The New Jersey Coastal Plain is made up of mainly unconsolidated sediments ranging in age from early Late Cretaceous to Quaternary, and rests on a basement feature known as the Cape May Slope, a southeastward dipping structure. Based on only limited information from a few wells and geophysical profiles, basement is believed to occur at depths ranging from about 2000 feet in the vicinity of Raritan Bay to about 6000 feet beneath Cape May in the south.

Sedimentary facies generally thicken and dip to the southeast with the older Cretaceous units dipping at greater angles than the overlying Tertiary formations. According to Minard and Owens (1960), downwarping during deposition explains the thickening of the sediments basinward. In the same study, they suggest that the locus of downwarping migrated westward since successively younger sediments dip more southward. Sediments also tend to thicken along strike from southwest to northeast.

As they are known from outcrops, the entire sequence of formations is relatively thin. Total thickness of the Cretaceous deposits varies from 500 to 1000 feet. The Tertiary deposits range from 150 to 500 feet. Down-dip and offshore sequences, however, are shown to be much thicker, and perhaps total as much as 25,000 feet or more in the offshore areas (Gibson, 1970).

Formations consist of marine, marginal marine, and non-marine units that have resulted from both major and minor sea-level fluctations. In general, the non-marine sequences typify the base and top of the Coastal Plain deposits (early Late Cretaceous and Quaternary). The marine and marginal marine units represent the middle, and were deposited during two distinct sedimentation periods--from Santonian to middle Eocene, and from middle Miocene to probably Pliocene. Deposition of these beds was cyclic in nature, and can be closely related to numerous transgressive and regressive cycles (Owens and Sohl, 1969). More insight into the cyclic nature of the sediments related to this study is provided in the Interpretation of Data section.

The preceding few paragraphs provide only a brief summary of a subject on which much has been written. More complete references are: Spangler and Peterson (1950), Dorf (1952), Dorf and Fox (1957), Le Grande (1961), Murray (1961), Richards (1967), Owens and Sohl (1969), Owens et al. (1970), and Brown et al. (1972).

Local Geology

The segment of the New Jersey Coastal Plain studied here is the

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Monmouth Group as it occurs in five localities from the northern part of Monmouth County (see Figure 3). Elsewhere this unit is known from numerous localities occurring in a narrow belt of outcrops across the state to the southwest. It is most complete and best developed in Monmouth County, and thins to the southwest. In Delaware, it is less complete, and is considered a formation in Maryland.

The Monmouth Group formations are, from oldest to youngest: the Mount Laurel Sand, Navesink Formation, Red Bank Sand, and Tinton Sand. General lithologic and environmental descriptions for these units are here provided, and have been extracted from the following studies: Olsson (1963), Krinsley and Schneck (1964), Owens and Sohl (1969), and Minard (1969).

Mount Laurel Sand

The Mount Laurel Sand is not a single lithofacies as it occurs across New Jersey. In Monmouth County it varies from 20-30 feet, and consists in the lower part of fine to medium-glauconitic quartz sand. Near the top it becomes a thick-bedded medium to coarse glauconitic quartz sand. Where fresh, it varies in color from greenish gray to dark greenish gray. Colors are altered by weathering. Contact of the Mt. Laurel with the underlying Wenonah Formation, a finer textured unit, is conformable.

Numerous fossils are present; especially important is Belemnitella americana in association with Exogyra cancellata, which forms a traceable zone across New Jersey, and on into Maryland. Only a few species of Foraminifera are known from the Mt. Laurel in Monmouth County. A species list is provided by Krinsley and Schneck (1964).

As interpreted by Owens and Sohl (1969), this unit represents a nears

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nearshore gulf deposit. Based on the work of Krinsley and Schneck (1964) crab remains at the top of the Mt. Laurel could indicate water depths as shallow as 30 feet. Sand grain surface texture from this same horizon indicates beach action.

Navesink Formation

In unweathered state, the Navesink is a massive thick-bedded clayey glauconite sand. It is typically about 30% clay and silt and 70% glauconite grains. Thickness in Monmouth County may be as great as 50 feet but is typically about 30 feet. It thins to about 5 feet in the southwestern part of the state. Contact with the underlying Mt. Laurel Sand is unconformable.

Shell beds containing abundant pelecypods are typical of the Navesink. Several species of the genera Gryphaea, Exogyra, and Ostrea occur here along with Belemnitella americana. Marine microfossils also abound; Nine (1954) reported 128 species of foraminifers and 36 species of ostracods.

Based on lithology and glauconite abundance, the Navesink represents a shelf sediment in the framework established by Owens and Sohl (1969). Foraminiferal interpretations suggest a neritic environment with water depths ranging from 120-300 feet. Other significant interpretations provided by Krinsley and Schneck (1964) are the following: 1) The rate of sedimentation was slower than for the Mt. Laurel since absolute frequency of fossils is greater. 2) The nature of certain sponge borings on pelecypods indicate periods of quiescence intermittently distributed between periods of greater turbulence during Navesink time. 3) Waters generally were clear, silt free and of full ocean salinity.

Krinsley and Schneck in their analysis examined the Navesink from three localities in Monmouth County. Two of these, the Marlboro and the Poricy Brook, were also examined and sampled for this study. For this reason, the somewhat localized conditions they apply to this unit are pertinent to this study as well.

Red Bank Sand

This unit occurs only in the northern and west-central parts of the New Jersey Coastal Plain. In Monmouth County it reaches 150 feet in thickness in the bluffs along Raritan Bay. It is composed of two members, the lower Sandy Hook and the upper Shrewsbury. The Red Bank in general is a return to coarse sandy deposition.

The Sandy Hook Member is typically a compact dark-grayish and bluish-black, massive-bedded, feldspathic quartz sand. The sand is clayey and silty and very micaceous. It varies in thickness from 15-30 feet in the study area, and is more restricted in distribution than the upper member. Contact with the Navesink below is conformable and in part gradational.

Typical megafossils from the Sandy Hook member are species of *Trigonia*, *Ostrea*, *Turritella* and *Eutrephoceras*. An abundant foraminiferal assemblage has been described by Olsson (1960).

Based on lithology, the Red Bank as a whole represents inner shelf and nearshore gulf deposits, with the Sandy Hook Member more indicative of the deeper inner shelf facies (Owens and Sohl (1969). According to Olsson (1963), neritic depths of 150-300 feet are representative for deposition of the lower Red Bank sands.

The Shrewsbury Member is composed of massive-bedded, silty, fine to medium feldspathic quartz sand that ranges in color from yellowishgray and grayish-orange-pink to light moderate and moderate reddish-brown. Greatest thickness of about 100 feet is reached in the north along Raritan Bay. Contact with the lower member is gradational.

Fossils from the Shrewsbury are sparse, and only a few poorly preserved pelecypods have been reported (Weller, 1907). According to Olsson (1963), this member is barren of Foraminifera.

This absence of microfossils as suggested by Olsson could indicate a non-marine origin, or be the result of weathering. For this study, samples were collected from the Shrewsbury at 2 localities and all were barren. In the environmental scheme of Owens and Sohl (1969), the Shrewsbury Member is thought to represent a nearshore gulf deposit.

Tinton Sand

The Tinton consists of a gray to olive-drab, argillaceous, medium to coarse grained, glauconite quartz sand. In the type area at Tinton Falls (Pine Brook locality), it is indurated with a siderite cement. Glauconite may constitute from 60-80% of the sand fraction in the upper part of the formation, but decreases downward along with the grain size. Contact with the underlying Red Bank is gradational. The Tinton is limited geographically to the northern part of the New Jersey Coastal Plain.

Numerous fossils are known; some of the more characteristic are species of *Sphenodiscus*, *Cuclaea*, *Exogyra*, *Gryphaea*, *Cardium*, and *Callianassa*. According to Olsson (1963) useful Foraminifera are lacking in the Tinton.

Based on glauconite abundance (Owens and Sohl, 1969) and the *Cucullaea* fauna (Weller, 1907), the Tinton is interpreted as a deeper water sediment (i.e. inner shelf). Olsson, however, suggests water depths similar to or possibly shallower than those for Red Bank deposition. His evidence is based on coarser clastics higher in the section, and remains of the raninid crab, Callianassa. Because of these contrasting phenomena, the depositional environment of the Tinton is problematic.

The nature of the contact of the Tinton with the overlying Hornerstown (Cretaceous-Tertiary boundary) has been interpreted as both conformable and uncomformable, and has been a controversial issue among geologists since the early 1900's. For the most recent arguments in support of a conformable boundary, see Olsson (1963). Minard et al. (1969) presents the most up to date account of evidence suggesting an uncomformable boundary.

Age of the Monmouth Group

As can be seen in Figure 2, most previous workers have agreed on a Maastrichtian age for the Navesink, Red Bank, and Tinton formations. The age of the Mt. Laurel Sand, however, does not show consistent agreement. The basis for the Campanian age by Spangler and Peterson (1950) relates to an opinion that the Mt. Laurel belonged to the Mattawan Formation (Group), and that the Mattawan in general related to the Taylor (Campanian) of the Gulf Coast. In the opinion of Johnson and Richards (1952), this was unfounded since the fossils of the Mt. Laurel could be better correlated to the Navarro (Maastrichtian) of the Gulf Coast.

Arguments of a Campanian age for the Mt. Laurel and Navesink by Sohl, in Owens et al. (1970), are based on a few ammonite specimens identified only to genus and compared to ammonites of the Pierre Shale of the Western Interior, and the presence of the

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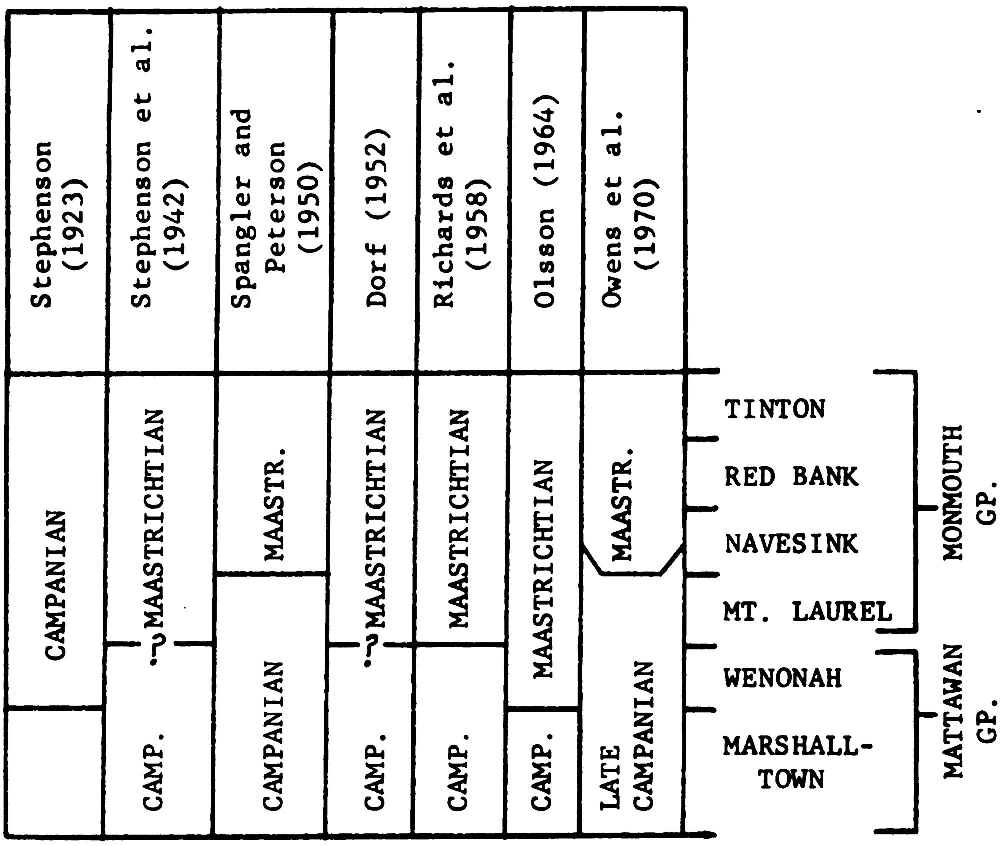

Figure 2. Comparison of stage nomenclature as it has been applied to the Monmouth Gp. in New Jersey.

Exogyra cancellata zone (considered by others to include early Maastrichtian). They also hold to this evidence in their more recent publication (Owens and Sohl, 1973) which acknowledges foram evidence and provides Potassium-Argon dates both of which are contradictory to the age they have assigned. To better accommodate their concept, they suggest changing the absolute age of the Campanian-Maastrichtian boundary from 72 m.y. to 63 m.y.

Another idea relative to the age of the Mt. Laurel, was expressed by Mumby (1961), and later by Richards and Shapiro (1963) and Olsson (1964) who suggest that this unit is older to the south (Delaware and southern New Jersey), and younger to the north (e.g. Monmouth Co.). In comparison, it is interesting that the ammonite specimens on which Sohl bases his late Campanian age are all from collections made in Delaware. From this evidence, it is possible that the Mt. Laurel Sand is late Campanian in Delaware, but it is less possible that the unit represents this age progressively northward in New Jersey.

As indicated earlier, K-Ar dates have been supplied for the Monmouth Gp. by Owens and Sohl (1973), who found reliable ages ranging from about 70 m.y. in the Mt. Laurel to 62-63 m.y. in the Navesink and Red Bank. Ages recorded for the Tinton were unreliable. In another study, Krinsley (1973) indicated K-Ar ages of 63 and 61 m.y. for the Mt. Laurel and Navesink respectively. These ages agree reasonably, but are somewhat younger than those of 72-73 m.y. for the Campanian-Maastrichtian boundary, and 63-64 m.y. for the Cretaceous-Tertiary boundary supplied by Folinsbee et al. (1970).

In summary, a Campanian age for the Mt. Laurel Sand as provided by Spangler and Peterson (1950) is unfounded, and that given in Sohl and Mello (in Owens et al., 1970) is based upon weak ammonite evidence correlated only to the Western Interior. Evidence of a Maastrichtian age is here considered more valid and includes the following:

1. The fossils of the Mt. Laurel Sand can best be correlated to the Navarro Group of Texas, now considered as Maastrichtian in age (see Passagno, 1967).
2. K-Ar age dates better support a Maastrichtian age than a Campanian.
3. The Mt. Laurel Sand as it was sampled for this study represents the youngest phase of this unit.

METHODS OF STUDY

Collection of Samples

Five outcrop localities, all from Monmouth Co., New Jersey, were sampled for this study. Their locations are indicated in Figure 3. The formations exposed and approximate position of samples collected are shown in Figure 4. More specific information on interpretations and collections of the outcrops is supplied in Appendix I.

The samples shown in Figure 4 and Appendix I show only those from which usable palynomorphs could be obtained. All samples collected were productive except for those from the Shrewsbury Member of the Red Bank Formation; this unit was collected from two different localities, but found to be barren in each case. This member also is essentially devoid of other types of fossils.

All collections are spot samples (i.e. collected over an outcrop area of 3-5 inches in diameter) usually collected at two to five foot intervals. The Tinton Formation was indurated and was collected as chunks of rock chiseled off freshly exposed outcrop. Remaining collections are of unconsolidated material, and were taken from 1-2 foot holes dug into the outcrop banks. Samples were placed in cloth bags which were then placed in plastic bags to avoid contamination.

Preparation of Materials

Processing of samples followed routine procedure as described below with only a few exceptions:

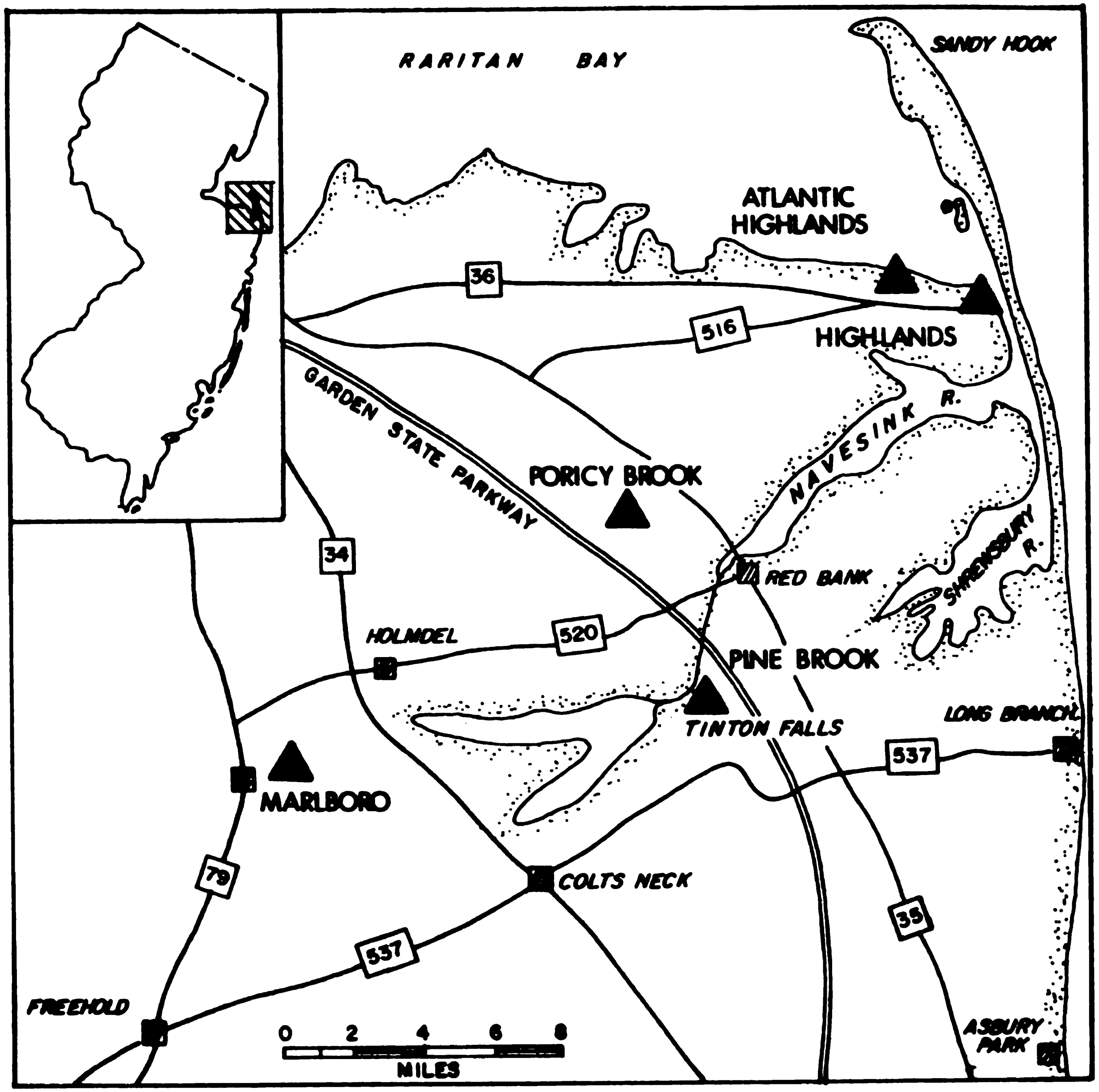

Figure 3: Index map showing locations of sections collected.

▲ indicates localities

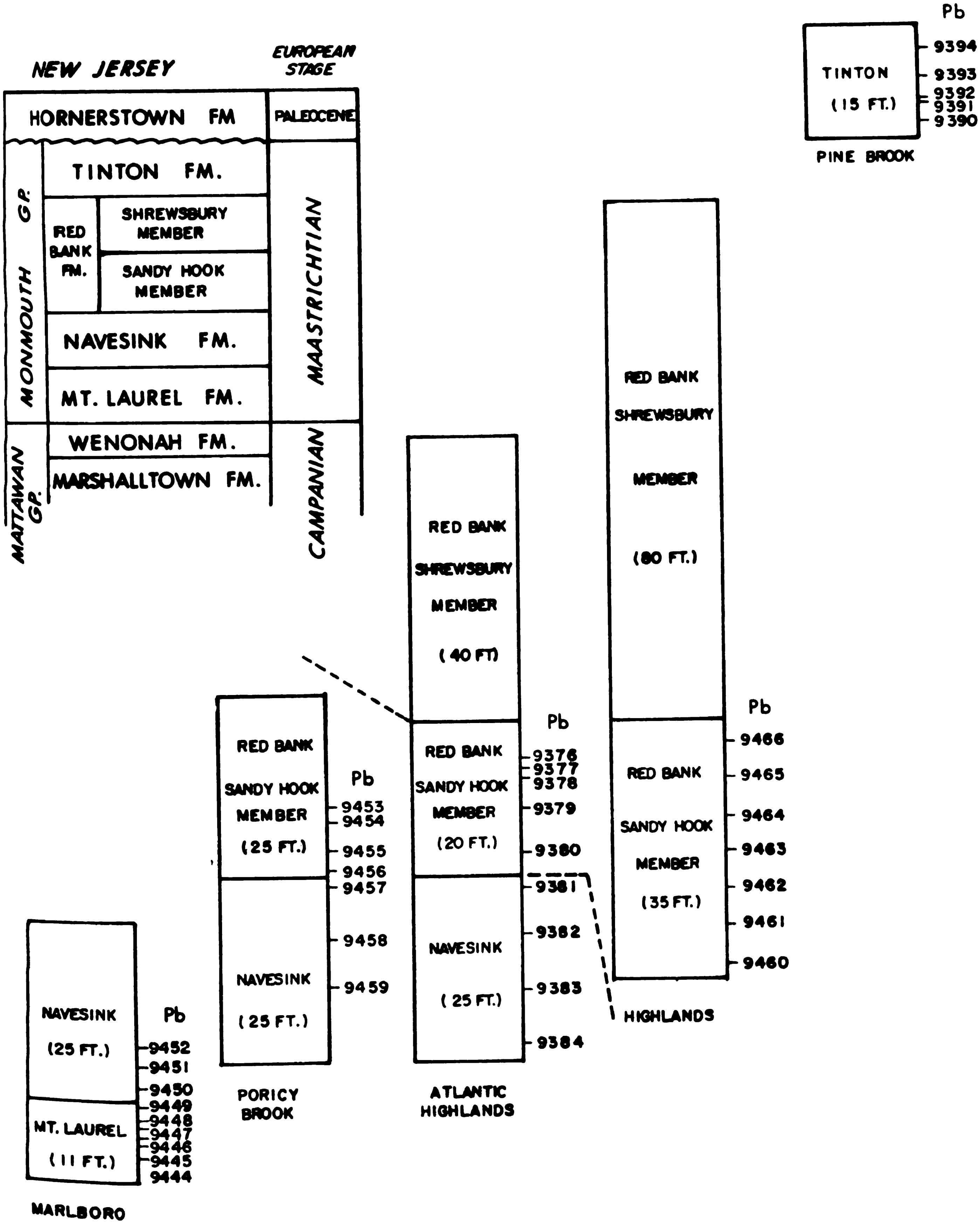

Figure 4: Columnar sections of localities showing approximate positions of samples collected.

Most material was unconsolidated and required little or no crushing. Samples weighing 100 grams were prepared and tested with 10% hydrochloric acid for carbonates. If carbonates were present, as was found in a few cases, samples were immersed in 10% hydrochloric acid for 12-18 hours, or until reaction was complete. Treated samples were then washed.

Samples then were treated with hydrofluoric acid for removal of silicates: Beakers were prepared containing 70% hydrofluoric acid diluted to ½ concentration (c.a. 35%) with either cold water or crushed ice to which samples were carefully added at a rate slow enough to prohibit boiling. It was found early in this study that high temperatures and/or boiling in hydrofluoric acid was detrimental to sample quality. Reactions lasted for 12-18 hours.

Samples were again washed, and then separated in heavy liquid. Separations during the earlier phases of this study were done in bromoform/acetone (specific gravity 2.0); later separations were done in zinc bromide (specific gravity 2.2). The heavier fractions which settled out were all examined for palynomorphs, but found to be barren. Floating fractions containing palynomorphs were saved and washed.

Both whole and sieved fractions of the residue were prepared for this analysis. Whole fractions were used for palynomorph counts, while the sieved fractions were examined for diversity. Sieved parts were made up of -20 micron, +20-120 micron, and +120 micron fractions. In all but a few cases, the +120 micron fractions were barren of palynomorphs.

Slides prepared early in this study from the Atlantic Highlands and Pine Brook localities were mounted in glycerine jelly. Those from

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the remaining localities were made by mounting the residue first to the coverglass in Clearcol, and to the slide in Elvacite 2044 resin.

Oxidizing reactions such as treating with Schulze solution, nitric acid, or potassium hydroxide were not used. They were observed in this study to selectively destroy certain palynomorphs.

All microscope work was done on a Zeiss Photomicroscope equipped with phase contrast and interference contrast (after Nomarski). Photographs were taken on Kodak 35mm Panatomic-X film. Most prints were enlarged to magnifications of 500X and 1000X.

Slides from this study are deposited with the paleobotany section of the Michigan State University Herbarium. Coordinates of the upper left corner of the coverslip centered in the field of view are inscribed on each slide label so that relocating specimens with other microscopes is possible.

Counting Procedure

Relative abundance counts of palynomorphs were made in this analysis. The purpose of these counts is to indicate the following:

1. The simple relationship of taxa as they occur in samples, i.e. to suggest to the reader how prolific a taxon, group of taxa, or association may be in certain samples, formations, or the whole Monmouth Group from the study area.
2. To graphically express relationships of taxa or groups of taxa that attain significant numbers in the samples (these were arbitrarily established by selecting only those occurring in abundances greater that 5% in more than one sample).

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3. To show relationships of land derived vs. marine palynomorphs.
4. To express relations among dinoflagellate associations.

A count of 250 specimens was attempted for all samples. To test whether this number was sufficient, a plot was made of specimen number vs. species encountered (after Wilson, 1959) for the sample deemed most diverse with the least amount of dominance of any one species (Pb-9446). After 200 specimens were counted, no new taxa occurred. A count of 250 is therefore believed adequate to represent the more common taxa.

In nine of the samples studied, 250 specimens could not be found in the slides prepared for counting. In all but one of these, numbers ranging from 100 to 200 were counted and percentages were calculated. For the remaining sample only 21 specimens occurred, and no percentages were calculated.

Determining the reliability of data derived from a 250 count can only be accomplished within certain limits. A pertinent statistical test is that of Faegri and Ottestad (1948) where a method is given for calculating confidence levels in palynomorph counts. By their reasoning, the standard deviation of the percentage number (y) is $\frac{y(100-y)}{n}$ where n=the number of specimens counted. By doubling this value, we have 2 standard deviations or the 95% confidence level. Calculated widths for 2 standard deviations to either side of y and 100-y where n=250, are provided in Table 1 below.

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Table 1. The limits of 2 Standard Deviations either side of y and 100-y for selected values of y in a 250 count (after Faegri and Ottestad, 1948).

y	(100-y)	confidence intervals for y		
1.0	(99.0)	0	2.25	± 1.25
2.0	(98.0)	0.25	3.75	± 1.35
3.0	(97.0)	0.85	5.15	± 2.15
5.0	(95.0)	2.25	7.75	± 2.75
10.0	(90.0)	6.15	13.85	± 3.85
20.0	(80.0)	14.95	25.05	± 5.05
30.0	(70.0)	24.2	35.8	± 5.8
50.0	(50.0)	43.7	56.3	± 6.3

The figures above imply that one can be 95% certain that recorded percentage values would fall within the limits shown above if numerous aliquots of the same processed sample were repeatedly counted in a totally random manner. If all other factors could be considered random, the data from my study as well could be considered with 95% confidence to fall within these intervals. This is not the case, however, because human error and numerous biases cannot be overcome in this type of study. Additional problems of a selective nature are those involved with collecting and handling of samples, and those that can occur naturally such as differential deposition and weathering in sediments.

In conclusion, counts on palynomorphs are used in this study for the purpose of producing various types of useful information. It is also shown here that numerous assumptions are made which may or may not be acceptable, and that caution must be used when interpreting these data.

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SYSTEMATICS

Ninety-nine spore and pollen taxa, all identified to specific rank, are here described. They are placed in the "Englerian" system of classification for the following reasons:

1. The study done here is basically a floristic one, and works of this type are most commonly classified in the Englerian system.
2. All previous works of this type from the Cretaceous and Tertiary of the eastern United States are presented in a classification of this type.
3. Most of the taxa found at least to some extent, lend themselves to this type of classification.

In addition, an alphabetical list by genus with page references is supplied in Appendix II.

Other possible classifications are morphologic systems, and those that simply list taxa alphabetically within higher morphologic or natural categories. The primary weakness of a morphologic classification is that characters used are not always consistent. For example, in previous studies, the presence or absence of a cingulum has been used as a major subdivision for trilete spores, yet this feature is also shown to vary at the generic and interspecific level, e.g. Camarozonosporites and Stereisporites. Pure morphologic systems also force together such high ranking natural categories as divisions (phyla) where bryophytes and pteridophytes are treated inseparably, and classes where many angiosperms are lumped with gymnosperms.

The arranging of taxa alphabetically within larger morphologic categories solves nothing, and the problems of the morphologic system still remain. When the higher categories are natural, the morphologic weaknesses may be solved, yet nomenclatural problems exist. For example, trilete spores with almost certain affinity to the modern genus *Lycopodium* were found in this study to be published under the following valid generic names: *Camarozonosporites*, *Camarozonotriletes*, *Camptotriletes*, *Cingulatisporites*, *Hamulatisporis*, *Inundatisporites*, *Lycopodiacidites*, *Lycopodium*, *Lycopodiumsporites*, *Retitriletes*, *Rugutriletes*, and *Triletes*. Similar examples of chaotic nomenclature also exist for many other taxa, so that arranging taxa alphabetically in a group called pteridophytes for example is of little use to the reader since he may not be familiar with the name used.

As it is used in this study, it is recognized that the "Englerian" system is also imperfect:

1. The arrangement used contains a mixture of form, organ, and "half-natural" genera all placed into the "Englerian" framework.
2. The systematic levels to which taxa can be assigned are variable, i.e. some can be placed in families while others can only be placed in a class or subdivision.
3. Affinities to modern counterparts are often questionable, or suggested on very limited evidence.
4. "Englerian" classifications cannot be used for floras of all ages; they are more easily applied in the Late Tertiary and Quaternary, but become progressively more difficult with older floras.

The classification system followed is that of Engler and Diels (1936). The Engler system is considered outmoded by many, and several other classifications are thought to be superior. However, it was selected since it is complete, i.e. treating all vascular plants on a world-wide basis, and because it is still the most commonly used classification system among the larger American herbaria, and in most regional American floras (Lawrence, 1951).

Taxa as they are reported in this study are shown in Table 2. Provided for each species in the text is a description or literature reference where it is adequately described, a size range, occurrences (summarized both from this study, and all others found in which it was reported), a suggested affinity, and a discussion section for certain ideas or important points not covered in previous headings. Illustrations for all taxa described are provided on plates 1-14; references to figured specimens are given with the plate descriptions.

Illustrations of selected dinoflagellates are provided with identifications only to genus. These forms are included since they have been used to make environmental interpretations. They are not described because an adequate treatment of this group is beyond the scope of this study.

Table 2. Taxonomic placement of taxa.

	Page
Division: Bryophyta	
Class: Anthocertae	
Order: Anthoceratales	
Family: Notothylaceae	
Genus: *Foraminisporis* Krutzsch	
F. dailyi (Cookson & Dettmann) Dettman	29
Class: Musci	
Order: Sphagnales	
Family: Sphagnaceae	
Genus: *Stereisporites* Pflug	
S. australis (Cookson) Krutzsch	30
S. congruens (Pierce) Krutzsch	31
S. cristalloides Krutzsch	32
S. dakotaensis (Stanley) comb. nov.	32
S. regium (Drozhastich) Drugg	33
S. stereoides (Potonie & Venitz) Pflug	34
Division: Pteridophyta	
Class: Lycopodiinae	
Order: Lycopodiales	
Family: Lycopodiaceae	
Genus: *Camarozonosporites* Pant ex Potonie	
C. anulatus (Pierce) comb. nov.	36
C. canaliculatus (Singh) comb. nov.	37
C. caperatus (Singh) comb. nov.	38
C. cerniidites (Ross) Krutzsch	39
C. heskemensis (Pflanzl) Krutzsch	40
C. vermiculaesporites (Rouse) Krutzsch	40
?Genus: *Foveasporis* Krutzsch	
F. triangulus Stanley	41
?Genus: *Foveosporites* Balme	
F. labiosus Singh	42
F. subtriangularis (Brenner) Kemp	42
Genus: *Lycopodiumsporites* Thiergart ex Del. & Spr.	
L. austroclavatidites (Cookson) Potonie	43
?Genus: *Sestrosporites* Dettmann	
S. pseudoalveolatus (Couper) Dettmann	44
Order: Selaginellales	
Family: Selaginellaceae	
Genus: *Densoisporites* Wayland & Krieger emend. Dett.	
D. microrugulatus Brenner	45
Genus: *Lusatisporis* Krutzsch	
L. circumundulatus (Brenner) comb. nov.	46
Class: Filicinae	
Subclass: Leptosporangiatae	
Order: Eufilicales	
Family: Osmundaceae	
Genus: *Osmundacidites* Couper	
O. comaumensis (Cookson) Balme	48

Table 2. (continued) Page

Table 2. (continued) Page

Table 2. (continued) Page

Table 2. (continued) Page

SYSTEMATIC DESCRIPTIONS

Division Bryophyta

Class Anthocerotae

Order Anthocerotales

Family Notothylaceae

Genus Foraminisporis Krutzsch, 1959b

Type species: Foraminisporis foraminis Krutzsch, 1959b

Foraminisporis dailyi (Cookson & Dettmann) Dettmann

Plate 1, Figure 1

1958 Granulatisporites dailyi Cookson & Dettmann, p. 99, pl. 14, figs. 2-4.

1963 Foraminisporis dailyi (Cookson & Dettmann) Dettmann, p. 72, pl. 14, figs. 15-18.

Description: See Cookson & Dettmann (1958) and Dettmann (1963).

Size range: 38 microns; 2 specimens measured. In literature, size ranges from 36-70 microns.

Occurrences: Cretaceous, 2 specimens only, Mt. Laurel and Red Bank Fms. Previous records include the Early Cretaceous of Australia (Cookson & Dettmann, 1958 and Dettmann, 1963), Canada (Playford, 1971), Maryland (Brenner, 1963), northern Germany (Doring, 1966), and the middle Cretaceous of the Horizon Beta outcrop in the Atlantic Ocean (Habib, 1970).

Suggested affinity: According to Dettmann (1963), spores of F. dailyi closely resemble those of two modern hepatic species, Notothylas breutelii and Phaeoceros bulbiculosus (see Appendix I of Dettmann for descriptions and illustrations).

Class Musci

Order Sphagnales

Family Sphagnaceae

Genus *Stereisporites* Pflug, 1953

Type species: *Stereisporites stereoides* (Potonie & Venitz) Pflug, in Thompson & Pflug, 1953.

Comments: The treatment of this genus follows Krutzsch (1959b and 1963b) who expanded it to include forms having either cingula or distal thickenings. Prior treatments only included simpler forms.

Stereisporites australis (Cookson) Krutzsch

Plate 1, Figures 2-4

1947 *Trilites australis* Cookson, p. 136, pl. 15, figs. 58-59.

1949 *Trilites psilatus* Ross, p. 32, pl. 1, fig. 12.

1953 *Sphagnites australis* (Cookson) Cookson, p. 463.

1956 *Sphagnumsporites australis* (Cookson) Potonie, p. 17.

1957 *Sphagnites australis* (Cookson) Cookson, in Balme, p. 15, pl. 1, figs. 1-3.

1958 *Sphagnumsporites psilatus* (Ross) Couper, p. 131, pl. 15, figs. 1-2.

1959b *Stereisporites australis* (Cookson) Krutzsch, p. 71.

1961 *Sphagnum australis* (Cookson) Drozhastchich, in Samoilovitch, et al, p. 14, pl. 1, figs. 2-3.

1965 *Sphagnum australe* (Cookson) Stanley, p. 237, pl. 27, figs. 10-11.

1968a *Sphagnum bujargiensis* (Bolkhovitina, 1956) Elsik, p. 299, pl. 10, fig. 10.

Description: Shape, exine thickness and texture to some extent, nature of the equatorial region as seen in polar view, distal arcuate thickenings, and raised exine folds along the laesurae are all variable features within this taxon. Otherwise description is as given by Cookson (1947) and Stanley (1965).

Size range: 26-40 microns; 14 specimens measured.

Occurrences: A common form known worldwide from the Mesozoic, Tertiary, and on to present time. Here it occurred in greatest abundance in the Mt. Laurel Sand (6.8% in one sample). Although not as common, the distribution pattern of this form is similar to *S. stereoides*, and may be closely associated with it.

Suggested affinity: *Sphagnum*.

Stereisporites congruens (Pierce) Krutzsch

Plate 1, Figures 5-6

1961 *Cingutriletes congruens* Pierce, p. 25, pl. 1, fig. 1.

1963b *Stereisporites congruens* (Pierce) Krutzsch, p. 17, Abb. 8B (p. 18).

Description: Trilete, amb subcircular to rounded triangular. Exine surface smooth to scabrate. Laesurae extend ½ distance to the equator. Equatorial region surrounded by a cingulum that varies both in width (5-10 microns) and depth.

Size range: 38-46 microns (cingulum included); 10 specimens measured.

Occurrences: Cenomanian to Maastrichtian. Found in the 3 lowest samples of the Marlboro locality, all from the Mt. Laurel Sand (1.2% in one of the samples). Previously known from the Cenomanian of Minnesota (Pierce, 1961).

Suggested affinity: *Sphagnum*.

Discussion: *S. congruens* differs from *Cingutriletes clavus* (Balme) Dettmann (1963) by its lack of any thickening on the distal surface.

Stereisporites cristalloides Krutzsch

Plate 1, Figures 7-9

1966 *Stereisporites cristalloides* Krutzsch, in Döring, et al., p. 73-76, pl. 1, figs. 6-8.

Description: As given by Krutzsch, in Döring, et al. (1966).

Size range: 25-30 microns; 8 specimens measured.

Occurrences: Maastrichtian. A rare form with scattered occurrences in the Mt. Laurel, Navesink, and Red Bank Fms. Previously known from the Maastrichtian of central Europe.

Suggested affinity: *Sphagnum*.

Stereisporites dakotaensis (Stanley) comb. nov.

Plate 1, Figures 10-12

1965 *Cingulatisporites dakotaensis* Stanley, p. 243, pl. 30, figs. 1-8.

Description: Cingulum thickness as seen in polar view, varies from 2-6 microns. Thickened folds along the tetrad mark may extend to the cingulum, but the laesurae length is only 1/2 to 2/3 the spore radius. Description otherwise as given in Stanley (1965).

Size range: 26-40 microns (cingulum included), 20 specimens measured.

Occurrences: Maastrichtian to Paleocene. Found in 21 samples, Mt. Laurel, Navesink, and Red Bank Fms. Occurrences reached 2.0% in one Mt. Laurel sample, elsewhere never over 0.8%. Previously this species has been reported from the Late Cretaceous of Montana (Norton & Hall, 1967 and 1969), Alberta (Snead, 1969), Wyoming (Stone, 1973), and the Paleocene of South Dakota (Stanley, 1965).

Suggested affinity: Sphagnaceae?

Discussion: A number of taxa described in Krutzsch (1963b) under *Stereisporites* (Distancoraesporis) are similar to

S. dakotaensis. All forms placed in this subgenus possess the Y-shaped thickened area on the distal surface as described by Stanley (1965), which is the basis for transferring this form to Stereisporites.

Stereisporites regium (Drozhastchich) Drugg

Plate 1, Figures 15-16

1961 Sphagnum regium Drozhastchich, in Samoilovitch, et al. p. 18, pl. 2, figs. 1a and b, 2-3, pl. LXIV, figs. 5-7.

1962 Verrucosisporites pulvinulatus Manum, p. 27, pl. 3, figs. 7-10.

1967 Stereisporites regium (Drozhastchich) Drugg, p. 37, pl. 6, fig. 20.

1968a Sphagnum bimammatus (Naumova ex Bolkhovitina, 1953) Elsik (pars) p. 304, pl. 11, figs. 1-2.

1969 Converrucosisporites sp. Norton & Hall, p. 24, pl. 2, fig. 9.

Description: Trilete spores, amb circular to subcircular. Laesurae extend to about 1/2 the spore radius, although associated folds may extend to the equator. Surface ornamented with verrucae which always occur distally and sometimes proximally (proximal verrucae not found on specimens examined in this study).

Size range: 18-28 microns; 5 specimens measured.

Occurrences: Albian to Paleocene. 3 specimens from the Mt. Laurel and 2 from the Navesink Fms., all occurred as single specimens per sample. Previously reported from Albian-Senonian strata from the Vilyui and Lena River area of Yakutsk, U.S.S.R. (Fradkina, 1967), the Maastrichtian and Paleocene of western Siberia (Samoilovitch et al., 1961), the late Cretaceous of Montana (Norton & Hall, 1969) and Alberta (Snead, 1969), the Danian of California (Drugg, 1967), the Paleocene of South Dakota (Stanley, 1965) and Texas (Elsik, 1968a), and probably Paleocene from Spitzbergen (Manum, 1962).

Suggested affinity: Sphagnum.

Discussion: S. regium is possibly synonymous with two earlier taxa (Stenozonotriletes bimammatus Naumova ex Bolkhovitina, 1953 and Cheiropleuria congregata Bolkhovitina, 1956). These older forms, however, are only briefly described, and poorly illustrated, making them difficult to use with certainty. S. regium is well described and illustrated in a number of publications. Several of the taxa described in Krutzsch (1963b) are also similar to the above.

Stereisporites stereoides (Potonie & Venitz) Pflug

Plate 1, Figures 13-14

1934 Sporites stereoides Potonie & Venitz, p. 11, pl. 1, figs. 4-5.

1937 Sphagnum-sporites stereoides (Potonie & Venitz) forma minor Raatz, p. 9, pl. 1, fig. 5.

1953 Stereisporites stereoides (Potonie & Venitz) Pflug, in Thomson & Pflug, p. 53, pl. 1, figs. 64-73.

1961 Sphagnumsporites psilatus auct. non (Ross) Couper, 1958: Groot, Penny & Groot, p. 127, pl. 24, fig. 1.

1963b Stereisporites minor microstereis Krutzsch & Sontag, in Krutzsch, p. 38, pl. 2, figs. 1-8.

1963b Stereisporites stereoides gracilioides Krutzsch & Sontag, in Krutzsch, p. 44, pl. 3, fig. 34-36.

1963b Stereisporites stereoides leipischensis Krutzsch, p. 44, pl. 4, figs. 1-11.

1963b Stereisporites stereoides stereis (Krutzsch) Krutzsch, p. 42, pl. 3, figs. 31-33.

1963b Stereisporites stereoides stereoides (Potonie & Venitz) Thomson & Pflug subfsp. stereoides Krutzsch, p. 42, pl. 3, figs. 1-30.

1965 Sphagnum antiquasporites auct. non Wilson & Webster, 1946; Stanley, p. 236, pl. 27, figs. 1-2 and 4-5.

1966 Sphagnum stereoides (Potonie & Venitz) Martin & Rouse, p. 184, pl. 1, figs. 1-3.

1968a Sphagnum stereoides (Potonie & Venitz) Martin & Rouse, in Elsik, p. 299, pl. 10, fig. 8.

Description: Trilete spores, amb round to rounded triangular. Exine smooth and uniform, but may thicken slightly at the equator. Laesurae extend to 1/2 the spore radius, but may appear longer due to splitting or folding of the proximal exine along the ray.

Size range: 18-30 microns; 18 specimens measured.

Occurrences: A common form occurring throughout the world in the Mesozoic, Tertiary, and on to present time. Here found in 23 samples over the entire section, but most common where few or no marine forms occurred. Highest recordings were from the Mt. Laurel Fm. (13.2% in one sample). Elsewhere, occurrences never exceeded 3%, and were single and scattered in the more marine samples.

Suggested affinity: *Sphagnum*.

Discussion: The absence of any distal polar thickenings differentiates *S. stereoides* from *S. antiquasporites* (Wilson & Webster) Dettmann, 1963.

Division Pteridophyta

Class Lycopodiinae

Order Lycopodiales

Family Lycopiaceae

Genus *Camarozonosporites* Pant ex Potonie, 1956

Type species: *Camarozonosporites cretaceous* (Weyland & Krieger)
Potonie, 1956

Comments: The treatment used for this genus follows Krutzsch (1963a). In his description, three subgenera are placed within the genus *Camarozonosporites*: Subgenus *Camarozonosporites* comprises the genus *Camarozonosporites* as emended by Klaus (1960), which includes forms with a ± smooth proximal exine, and a differentially thickened spore margin as seen in equatorial view. Subgenus Hamulatisporis is similar, but contains a uniform thickening of the spore margin. Subgenus Inundatisporites differs from the above in having a sculptured proximal exine.

Other accounts for the taxonomy of this complex group are those of Klaus (1960) and Srivastava (1972a). Klaus emended Camarozonosporites, and placed Hamulatisporis Krutzsch, 1959b into Lycopodiacidites (Couper) R. Potonie, 1956. Srivastava simply elevated the rank of Krutzsch's subgenera to genera.

Camarozonosporites anulatus (Pierce) comb. nov.

Plate 1, Figure 17-18, Plate 2, Figure 1

1961 Retitriletes anulatus Pierce, p. 29, pl. 1, fig. 17.

Description: Trilete microspore, amb triangular to rounded triangular. Laesurae simple, extending to 3/4 or more of the spore radius. Proximal face smooth, distal side with sparsely arranged sinuous ridges which may or may not form a loose reticulum (Pierce refers to this pattern as "coarsely reticulate"). The exine thickens equatorially to form a flange, but is always reduced in the radial areas. Thickness of the flange can be as great as 10 microns.

Size range: 36-68 microns; 38 specimens measured. Pierce recorded the size as up to 52 microns.

Occurrences: Cenomanian to Maastrichtian. Found in 24 samples throughout the section. With the exception of two samples (1.6 and 2.0%), occurrences were always less than 1%. This species is previously known from the Cenomanian of Minnesota (Pierce, 1961).

Suggested affinity: ?Lycopodiaceae.

Discussion: Camarozonotriletes farcinarius Martynova (in Pokrovskaya & Stel'mak, 1960) closely resembles the above. However, the size is too small (27-30 microns). A specimen referred to as "Spore Type B" in Stover (1964) is similar, but has a larger size than C. anulatus. This taxon is better placed in the genus Camarozonosporites because it is zonate, and the distal surface is similarly sculptured.

Camarozonosporites canaliculatus (Singh) comb. nov.

Plate 2, Figures 2-4

1971 Camarozonosporites ambigens auct. non Fradkina: Playford, p. 546, pl. 104, figs. 22-23.

1971 Lycopodiacidites canaliculatus Singh, p. 38, pl. 1, fig. 15.

Description: Based on material from this study, the rugulae on the proximal face are reduced in the contact area, which often gives the appearance of ± bordered laesurae. Otherwise as described in Singh (1971).

Size range: 34-64 microns, 28 specimens measured (in literature the size ranges from 36-55 microns).

Occurrences: ?Cretaceous. Found in 30 samples throughout the sections, 0.4-2.0%. Based on the synonymy above, this taxon is known previously only from the Cretaceous of western Canada. However, forms closely resembling C. canaliculatus have been illustrated in a number of Cretaceous reports from around the world. Unfortunately, further synonymies cannot be made with certainty since these taxa have been placed in pre-existing species and/or are inadequately described.

Suggested affinity: Lycopodium.

Discussion: Two previously known taxa which are similar to this species are C. amplus (Stanley) Dettmann & Playford, 1968, and C. rarus (Doktorowicz-Hrebnicka) Krutzsch, 1963a. The laesurae for both of these taxa are longer than those of C. canaliculatus (3/4 or greater vs. 2/3 spore radius). C. amplus differs further in having a larger size, however overall ranges do overlap.

Singh's original assignment of the genus Lycopodiacidites to this taxon follows Klaus (1960). The new combination provided above is sensu Krutzsch (1963a) which was used for this study.

Camarozonosporites caperatus (Singh) comb. nov.

Plate 2, Figures 5-8

1969 Camarozonosporites heskemensis auct. non Krutzsch: Norton & Hall, p. 13, pl. 1, fig. 15.

1971 Lycopodiacidites caperatus Singh, p. 39, pl. 1, figs. 16-17.

Description: Specimens found in the Monmouth Group differ from those of Singh's only in that the exine may appear thickened in the interradial areas on the equator.

Size range: 35-60 microns; 12 specimens measured. Previously published size ranges from 48-63 microns.

Occurrences: Late Albian to Maastrichtian. Found in 12 samples from the Mt. Laurel, Navesink, and Red Bank Fms. A level of 1.2% was attained in one Red Bank sample, otherwise found only as rare single occurrences. Previously known from the late Albian of western Canada (Singh, 1971) and the Late Cretaceous of Montana (Norton & Hall, 1969).

Suggested affinity: Lycopodium.

Discussion: Singh's original assignment of the genus Lycopodiacidites to this taxon follows Klaus (1960). The new combination provided above is sensu Krutzsch (1963a) which was used for this study.

Camarozonosporites cerniidites (Ross) Krutzsch

Plate 1, Figures 19-20, Plate 2, Figures 9-10

1949 Lycopodium cerniidites Ross, p. 30, pl. 1, figs. 1-2.

1955 Lycopodiumsporites cerniidites (Ross) Delcourt & Sprumont, p. 32.

1958 Lycopodiumsporites cerniidites (Ross) Delcourt & Sprumont: in Couper (pars), p. 132, pl. 15, figs. 6-7 only.

1959b Camarozonosporites cerniidites (Ross) Krutzsch, p. 187.

1963 non Lycopodiacidites cerniidites (Ross) Brenner, p. 43, pl. 5, fig. 2.

Description: As given for L. cerniidites Ross with the following exceptions: The proximal face may be lightly sculptured, but never to the extent of the distal surface. Crassitudes may or may not be present.

Size range: 22-27 microns; 5 specimens measured (in literature size ranges from 24-29 microns).

Occurrences: ?Jurassic to Maastrichtian. 5 specimens from 4 samples, Mt. Laurel and Navesink Fms. Known previously from the Senonian of Sweden (Ross, 1949), and possibly the Jurassic and Early Cretaceous of England (Couper, 1958).

Suggested affinity: Lycopodium.

Discussion: C. cerniidites as treated by several authors in Early Cretaceous studies (e.g. Couper (1958) pars, Pocock (1962), Brenner (1963), Singh (1964), von der Brelie (1964)) is not the same as Ross' original taxon. These forms are larger, and have a coarser rugulate sculpture.

Camarozonosporites heskemensis (Pflanzl) Krutzsch

Plate 2, Figures 11-14

1955 Cingulatisporites heskemensis Pflanzl in Murriger & Pflanzl, pp. 83-87, pl. 5, figs. 1-3, pl. 6, fig. 26a and b.

1959b Camarozonosporites heskemensis (Pflanzl) Krutzsch, p. 187, pl. 38, figs. 413-421.

1963a Camarozonosporites heskemensis (Pflanzl) Krutzsch, in Krutzsch, p. 122, pl. 42, figs. 1-14.

1969 Camarozonosporites dakotensis Agasie, p. 19, pl. 2, figs. 9-10.

Description: The specimens here examined have more variable interradial thickenings than those illustrated by Krutzsch (1959b and 1963a). Otherwise as given in Krutzsch (1959b).

Size range: 26-35 microns; 11 specimens measured. Size given by Krutzsch is 30-40 microns.

Occurrences: Cenomanian to Oligocene. Present in 15 samples from the Mt. Laurel, Navesink, and the Red Bank Formations; never greater than 1%. Known also from the Eocene and Oligocene of Europe (Krutzsch, 1963a), and the Cenomanian of northeastern Arizona (Agasie, 1969).

Suggested affinity: Lycopodium.

Camarozonosporites vermiculaesporites (Rouse) Krutzsch

Plate 3, Figures 1-2

1957 Lycopodium vermiculaesporites Rouse, p. 361, pl. 3, figs. 73-74.

1963a Camarozonosporites vermiculaesporis (Rouse) Krutzsch, p. 23.

Description: In the original description of this taxon, the laesurae extend to the periphery of the spore body. In the illustration of Rouse's holotype, however, the laesurae do not appear to reach the equator, but rather extend only about 2/3 of the spore radius. Specimens from the Monmouth group also have shorter laesurae than originally described.

Size range: 38-66 microns; six specimens measured. The size range given by Rouse is 33-38 microns. Most species of Camarozonosporites are more wide-ranging in size and, from the material examined in this study, C. vermiculaesporites is here considered as no exception.

Occurrences: Late Cretaceous. 6 specimens from 5 samples scattered throughout the localities studied. Previously known from the Late Cretaceous of Alberta, Canada (Rouse, 1957).

Suggested affinity: Lycopodium.

Genus Foveasporis Krutzsch, 1959

Type species: Foveasporis fovearis Krutzsch, 1959

Foveasporis triangulus Stanley

Plate 3, Figures 5-6

1965 Foveasporis triangulus Stanley, p. 239, pl. 27, figs. 18-22.

1968 Dictyotriletes pseudoreticulatus auct. non (Couper) Pocock: in McLean, p. 1483, pl. 188, fig. 10.

Description: See Stanley (1965).

Size range: 40 microns; 1 specimen measured.

Occurrences: Maastrichtian to Paleocene. One specimen only from the Red Bank Fm. at the Poricy Brook locality. Previously reported from the Campanian of Wyoming (Stone, 1973), and the Paleocene of South Dakota (Stanley, 1965) and Alabama (McLean, 1968).

Suggested affinity: Stanley suggests a similarity to the Selaginella repanda group.

Discussion: A specimen illustrated in McLean (1968) as *Dictyotriletes pseudoreticulatus* (pl. 188, fig. 10) may be the same as *F. triangulus*.

Genus *Foveosporites* Balme, 1957

Type species: *Foveosporites canalis* Balme, 1957

Foveosporites labiosus Singh

Plate 3, Figures 8-9

1971 *Foveosporites labiosus*, Singh, p. 121, pl. 17, figs. 1-3.

Description: See Singh (1971).

Size range: 36 microns; 2 specimens measured.

Occurrences: Middle Albian to Maastrichtian. 2 specimens only from one sample in the Mt. Laurel Fm. Previously known from the middle and late Albian of Alberta (Singh, 1971).

Suggested affinity: Uncertain.

Foveosporites subtriangularis (Brenner) Kemp

Plate 3, Figure 7

1963 *Foveotriletes subtriangularis* Brenner, p. 62, pl. 16, fig. 2.

1970 *Foveosporites subtriangularis* (Brenner) Kemp, p. 88, pl. 11.

1971 *Foveosporites subtriangularis* (Brenner) Phillips & Felix, p. 318, pl. 7, fig. 2.

Description: See Brenner (1963).

Size range: 42 microns; 1 specimen measured.

Occurrences: Neocomian to Maastrichtian. 1 specimen only from the Navesink Fm. Previous occurrences include the Early Cretaceous of western Canada (Norris, 1967 and Singh, 1971) and Maryland (Brenner, 1963); the Neocomian of Holland (Burger, 1966); the Aptian-

Albian of southern England (Kemp, 1970); and the Cenomanian of Mississippi (Phillips & Felix, 1971a).

Suggested affinity: Uncertain.

Discussion: F. canalis Balme differs from F. subtriangularis in having a more sparsely distributed ornamentation.

Genus Lycopodiumsporites Thiergard ex Delcourt & Sprumont, 1955

Type species: Lycopodiumsporites agathoecus (Potonie, 1934) Thiergart, 1938.

Remarks: The validity of this genus is questionable, and the genus Retitriletes Pierce emend. Dör., W. Kr., Mai, Sch., in Krutzsch, 1963a may be considered as an alternative. Arguments pertaining to these genera are found in Srivastava (1972a), Singh (1971), Potonie (1966), Dettmann (1963), Delcourt, Dettmann, & Hughes (1963), Krutzsch (1959b and 1963a), and Manum (1962). Out of personal preference, Lycopodiumsporites was selected for this study.

Lycopodiumsporites austroclavatidites (Cookson) Potonie, 1956

Plate 3, Figures 10-11

See Dettmann (1963, p. 44) for synonymy and description.

Size range: 30-44 microns; 5 specimens measured.

Occurrences: 5 scattered single occurrences throughout the sections. Previously known from the Jurassic and Cretaceous in various parts of the world.

Suggested affinity: This taxon was closely compared by Cookson (1953), Couper (1958) and Brenner (1963) to the modern species Lycopodium clavatum.

Genus Sestrosporites Dettmann, 1963

Type species: Sestrosporites irregularis (Couper) Dettmann, 1963

Sestrosporites pseudoalveolatus (Couper) Dettmann

Plate 3, Figures 3-4

1958 Cingulatisporites pseudoalveolatus Couper, p. 147, pl. 25, figs. 5-6.

1963 Sestrosporites pseudoalveolatus (Couper) Dettmann, p. 66, pl. 13, figs. 11-16.

1964 Hymenozonotriletes pseudoalveolatus (Couper) Singh, p. 83, pl. 10, figs. 1-3.

1965 Vallizonosporites pseudoalveolatus (Couper) Döring, p. 60.

1968 Foveosporites multifoveolatus auct. non Döring: in McLean, p. 1480, pl. 188, fig. 17.

Description: See Couper (1958) and Dettmann (1963).

Size range: 36-40 microns; 2 specimens measured. Size indicated in literature ranges from 35-65 microns.

Occurrences: 2 specimens only from the Navesink Fm. at the Poricy Brook locality. Previous records of this taxon range from Bajocian to Paleocene. In the Jurassic and Early Cretaceous, it is wide ranging, and reported in numerous studies. Late Cretaceous records include only those of Griggs (1970) from Wyoming (Aequitriradites ornatus), Kidson (1971) from Colorado and Utah, and Gies (1972) from Colorado. Specimens considered as reworked were found by McLean (1968) from the Paleocene of Alabama.

Suggested affinity: Uncertain.

Discussion: Foveosporites cyclicus Stanley (1965), Foveotriletes subtriangularis as shown in Burger (1966), and Vallizonosporites vallifoveatus Döring (1965) all are similar to S. pseudoalveolatus, but cannot be placed in synonymy with certainty.

Order Selaginellales

Family Selaginellaceae

Genus Densoisporites Weyland & Krieger emend. Dettmann, 1963

Type species: Densoisporites velatus Weyland & Krieger emend. Krasnova, in Samoilovitch et al., 1961.

Densoisporites microrugulatus Brenner

Plate 3, Figure 12

1963 Densoisporites microrugulatus Brenner, p. 61, pl. 16, fig. 1.

1964 Lygodiidites laevigatus Pocock, p. 180, pl. 5, fig. 2.

1964 Lygodiidites balmei Pocock, p. 180, pl. 5, figs. 3-4.

1966 Aequitriradites insolitus Kimyai, p. 468, pl. 1, fig. 14.

1970 Densoisporites sp. cf. D. velatus Weyland & Krieger emend. Krasnova sensu Dettmann (pars): in Kemp, p. 110, pl. 21, figs. 9-11.

Description: See Brenner (1963).

Size range: 53 microns; 1 specimen measured.

Occurrences: Late Jurassic to Maastrichtian. 1 specimen only from the Red Bank Fm. at the Poricy Brook locality. Previous records include the Late Jurassic and early Neocomian of Holland (Burger, 1966), the Neocomian of France (Herngreen, 1971), the Aptian-Albian of southern England (Kemp, 1970), the Early Cretaceous of western Canada (Norris, 1967, Pocock, 1964, and Singh, 1971), the Early Cretaceous of Maryland (Brenner, 1963), and the Cenomanian of New Jersey (Kimyai, 1966).

Suggested affinity: Potonie (1956) compared spores of the type species D. velatus to Selaginellites hallei Lundblad and the recent species Selaginella scandens. Dettmann (1963) suggested a closer relationship to Selaginellites polaris Lundblad. According to

Pocock (1964), spores of this type have a close affinity to Lygodium flexuosum (L.) Swartz.

Discussion: Krasnova (in Samoilovitch et al., 1961) combined D. perinatus Couper (1958) with the type species D. velatus. This also was followed by Dettmann (1963) in her emendation of the genus. Kemp (1970) combined D. microrugulatus with D. velatus, making all three of these taxa synonymous. In the case these new combinations hold, the taxon described above is widespread, and ranges through the Jurassic and Cretaceous. D. microrugulatus was retained in this study since the morphology of the specimen found best fits this taxon, and a range of variation could not be established.

Genus Lusatisporis Krutzsch, 1963b

Type species: Lusatisporis punctatus Krutzsch, 1963b

Lusatisporis circumundulatus (Brenner) comb. nov.

Plate 3, Figures 13-16

1963 Psilatriletes circumundulatus Brenner, p. 67, pl. 20, figs. 4-5.

1970 Endosporites? sp. A Habib, p. 355, pl. 3, fig. 13.

1972a Lusatisporis dettmannae (Drugg) Srivastava (pars), p. 23, pl. 20 figs. 6-8 only.

Revised description: Trilete microspore; amb circular to subtriangular, perinate. Raised laesurae extending to the equator, straight in low focus, and becoming sinuous in raised focal plane; often bordered by lips. Inner body smooth to scabrate, relatively thin; outer body smooth to granulate, about 1 micron thick. Inner and outer layers separated by as much as 6 microns at the equator. Radially arranged folds occur on both surfaces and extend to the equator resulting in an undulating margin.

Size range: 28-40 microns (including perine); 9 specimens measured. According to Brenner (1963) size ranges from 28-41 microns.

Occurrences: Late Albian to Maastrichtian. Most common in the Mt. Laurel Fm. (1.5 and 1.6% in two samples), but also found as rare single occurrences throughout the sections. Previously this taxon has been reported from the late Albian of Maryland (Brenner, 1963), the Albian-Cenomanian of the Horizon Beta outcrop in the North Atlantic Ocean (Habib, 1970), and the Maastrichtian of Alberta (Srivastava, 1972a).

Suggested affinity: Spores of this taxon are similar to modern species of the genus *Selaginella* (see Srivastava, 1972a).

Discussion: *L. perinatus* Krutzsch, 1963b is larger than *L. circumundulatus*. *L. dettmannae* (Drugg) Srivastava, 1972a and *Selaginella sinuites* Martin & Rouse, 1966 have wider "flanges" and are more coarsely granulate.

The genus *Psilatriletes* (Van der Hammen) ex Potonie, 1953 is intended for forms with simple exines. The taxon described above is a double layered form, and therefore a new combination of the species originally diagnosed by Brenner has been provided.

Class Filicinae

Subclass Leptosporangiatae

Order Eufilicales

Family Osmundaceae

Genus *Osmundacidites* Couper, 1953

Type species: *Osmundacidites wellmanii* Couper, 1953

Osmundacidites comaumensis (Cookson) Balme

Plate 4, Figures 1-2

1953 *Triletes comaumensis* Cookson, p. 470, pl. 2, figs. 27-28.

1956 *Baculatisporites comaumensis* (Cookson) Potonie, p. 33.

1957 *Osmundacidites comaumensis* (Cookson) Balme, p. 25, figs. 54-56.

1957 *Osmunda-sporites elongatus* Rouse, p. 362, pl. 3, figs. 59-60.

1962 *Osmundacidites wellmanii* auct. non Couper: Pocock, p. 35, pl. 1.

1963 *Baculatisporites comaumensis* (Cookson) Potonie: Dettmann, p. 35, pl. 3, figs. 22-23, fig. 4k.

1965 *Osmunda comaumensis* (Cookson) Stanley, p. 250, pl. 31, figs. 6-9.

Description: See Cookson (1953) and Dettmann (1963).

Size range: 36-52 microns; 4 specimens measured.

Occurrences: 5 specimens from 5 samples, Mt. Laurel and Navesink fms. *O. comaumensis* is widely known throughout the world from the Mesozoic and Tertiary.

Suggested affinity: Cookson (1953) suggests affinity to two modern osmundaceous genera, *Todea* and *Leptopteris*. In addition, Dettmann (1963) compares *O. comaumensis* with certain species of *Osmunda*, e.g., *O. cinnamomea*.

Discussion: The type species of *Osmundacidites* as described by Couper has "granular-papillate sculpture", which also is a range of variation common at both the generic and specific level in the extant *Osmundaceae* (see Erdtman, 1957). This makes the placement of *O. comaumensis* in the genus *Baculatisporites* by Potonie (1956) and Dettmann (1963) both unacceptable and unnatural.

Genus *Goczanisporis* Krutzsch, 1967

Type species: *Goczanisporis baculatus* Krutzsch, 1967

Goczanisporis baculatus Krutzsch

Plate 4, Figures 3-6

1967b Goczanisporis baculatus Krutzsch, p. 936, pl. 2, figs. 1-19.

Description: Trilete microspore, amb triangular to round, apices well rounded, sides slightly concave to convex. Laesurae simple, extending about 1/2 distance to the equator and commonly split open. Distal surface and equator well ornamented with elements consisting of granulae, baculae, and pilae ranging up to 2 microns in size. Proximal surface steeply sloped, with ornamentation reduced to sparsely scattered granules.

Size range: 26-32 microns, 4 specimens measured.

Occurrences: Maastrichtian. A total of 4 specimens, 1 from the Mt. Laurel Sand and 3 from the Navesink Formation, Marlboro and Poricy Brook localities. Previously known from the Maastrichtian of Europe(Krutzsch, 1967b).

Suggested affinity: ?Osmundaceae.

Genus Todisporites Couper, 1958

Type species: Todisporites major Couper, 1958

Todisporites major Couper

Plate 4, Figure 7

1958 Todisporites major Couper, p. 134, pl. 16, figs. 6-8.

Description: See Couper (1958)

Size range: 62-68 microns; 2 specimens measured.

Occurrences: Middle Jurassic to Paleocene. Single occurrences in 3 samples only, Mt. Laurel and Red Bank fms. Previously recorded from the Early and Middle Jurassic of England (Couper, 1958), the Middle Jurassic of southern Sweden (Tralau, 1968), the Aptian of Portugal (Groot & Groot, 1962a), and the Paleocene of Maryland (Groot & Groot, 1962b).

Suggested affinity: Couper (1958) relates T. major to the fossil fern species Todites williamsonii (Family-Osmundaceae).

Todisporites minor Couper

Plate 4, Figure 8

1958 Todisporites minor Couper, p. 135, pl. 16, figs. 9-10.

1959b Leiotriletes microadriennis Krutzsch, p. 61, pl. 1, figs. 3-7.

Description: See Couper (1958).

Size range: 30-48 microns; 12 specimens measured.

Occurrences: Bajocian to Maastrichtian. Found in 14 samples, Mt. Laurel, Navesink, and Red Bank fms. Youngest occurrences were from the Red Bank locality at Highlands, N. J. as was found for Cyathidites minor. The sample with the most specimens (5.2% T. minor) was also the same for the two taxa. T. minor has previously been reported from the Bajocian to Cenomanian of western Canada (Norris, 1967, Pocock, 1962, and Singh, 1964 and 1971), the Bajocian of England (Couper, 1958), the Middle Jurassic of southern Sweden (Tralau, 1968), the Cenomanian of Oklahoma (Hedlund, 1966), and the Early and Late Cretaceous of the U.S. east coast (Brenner, 1963 and Gray & Groot, 1966).

Suggested affinity: Couper suggests a strong similarity of T. minor to the spores of the fossil fern species Todites princeps (Osmundaceae).

Family Schizaeaceae

Genus Cicatricosisporites Potonie & Gelletich, 1933

Type species: Cicatricosisporites dorogensis Potonie & Gelletich, 1933.

See Dettmann (1963) for synonymy and diagnosis of genus.

Cicatricosisporites dorogensis Potonie & Gelletich

Plate 4, Figure 18

1933 Cicatricosisporites dorogensis Potonie & Gelletich, p. 522, pl. 1, figs. 1-5.

1951 Mohrioisporites dorogensis (Potonie & Gelletich) Potonie, p. 135, pl. 20, fig. 14.

1961 Mohria dorogensis (Potonie & Gelletich) Markova, in Samoilovitch & Mtchedlishvili, p. 86, pl. 22, fig. 4.

1962 Cicatricosisporites intersectus Rouse, p. 197, pl. 3, figs. 30-31.

Description: See Potonie & Gelletich (1933), Potonie (1956), and Srivastava (1972b).

Size range: 34-52 microns; 14 specimens measured.

Occurrences: Found throughout the sections, 1.2% and 2.0% in two samples, elsewhere only in scattered single occurrences.

This species is a common Mesozoic and Tertiary form.

Suggested affinity: Schizaeaceae.

Cicatricosisporites hallei Delcourt & Sprumont

Plate 4, Figures 16-17

1955 Cicatricosisporites hallei Delcourt & Sprumont, p. 17, pl. 1, fig. 1.

Description: See Delcourt & Sprumont (1955), Delcourt, Dettmann & Hughes (1963) and Kemp (1970).

Size range: 36-42 microns; 4 specimens measured.

Occurrences: Cretaceous. 5 specimens from 5 samples, Mt. Laurel and Navesink Fm. Previous records of this taxon range from

Early Cretaceous to Cenomanian in Europe and North America (see Singh, 1971, p. 71 for more extensive account of distribution).

Suggested affinity: Schizaeaceae.

Genus Radialisporis Krutzsch, 1967

Type species: Radialisporis radiatus (Krutzsch) Krutzsch, 1967.

Radialisporis radiatus (Krutzsch) Krutzsch

Plate 4, Figures 12-13

1957 Group 19 Krutzsch, p. 514, pl. 1, figs. 38-42.

1959a Cicatricosisporites radiatus Krutzsch, p. 126.

1962 Cicatricosisporites cf. cicatricosoides auct. non Krutzsch: Manum, p. 22, pl. 1, figs. 10-11.

1965 Anemia radiata (Krutzsch) Stanley, p. 258, pl. 33, figs. 6-7.

1967a Radialisporis radiatus (Krutzsch) Krutzsch, p. 88, pl. 26, figs. 6-18.

Description: See Krutzsch (1967) and Srivastava (1972a).

Size range: 32-48 microns; 6 specimens measured.

Occurrences: Campanian to Pliocene. A total of 9 specimens from 7 samples; Navesink and Red Bank fms. Elsewhere this taxon has been reported from the Campanian of Montana (Tschudy, 1973), the Maastrichtian of Alberta (Srivastava, 1972a), the Paleocene of South Dakota (Stanley, 1965), the Early Tertiary of Spitsbergen (Manum, 1962), and the upper Eocene-Pliocene of central Europe (Krutzsch, 1959a).

Suggested affinity: Stanley (1965) assigned spores of this species to the extant genus Anemia; and according to Srivastava (1972), the cicatricose sculpture of this taxon has affinity with the Schizaeaceae.

Discussion: *Cicatricosisporites coconinoensis* Agasie, 1969 is similar to *R. radiatus*, but has finer ridges.

Family Gleicheniaceae

Genus *Concavisporites* Pflug emend. Delcourt & Sprumont, 1955

Type species: *Concavisporites rugulatus* Pflug, in Thomson & Pflug, 1953.

Concavisporites arugulatus Pflug

Plate 4, Figures 9-11

1953 *Concavisporites arugulatus* Pflug, in Thomson & Pflug, p. 50, pl. 1, figs. 30-32.

Description: Trilete microspores, amb triangular with straight to slightly concave sides. Laesurae extend to the margin, and are paralleled by thick tori that bend inward interradially. Exine surface smooth. Small folds may occur across the radial extensions of the tori.

Size range: 18-33 microns; 9 specimens measured.

Occurrences: Late Cretaceous to Paleocene. A total of 12 specimens seen, 11 Red Bank and 1 from the Navesink Fm. 10 occurrences are from the Highlands locality. Previously reported from the Late Cretaceous to Paleocene of Germany (Thomson & Pflug, 1953). Some forms attributed to this species by Krutzsch (1959b) from the Tertiary of central Europe are of questionable identification.

Suggested affinity: Gleicheniaceae?

Discussion: A number of forms that range throughout the Mesozoic and Tertiary are similar to this species. The following is a list of some of these forms which are comparable, but not necessarily the same as *C. arugulatus*: *Auritulinasporites intrastriatus* Nilsson

(1958), Cibotium gleichenioides and C. junctiformis Argranovskaya, in Pokrovskaya & Stel'mak (1960), Concavisporites jurienensis Balme (1957), Concavisporites spp. Krutzsch (1959b), and Gleicheniidites apilobatus Brenner (1963).

Genus Gleicheniidites Ross emend. Skarby, 1964

1949 Gleicheniidites Ross (nom. nud.) p. 31.

1955 Gleicheniidites Ross ex Delcourt & Sprumont, p. 64.

1963 Gleicheniidites Ross ex Delcourt & Sprumont emend. Dettmann, p. 64.

1964 Gleicheniidites Ross emend. Skarby, p. 62.

Type species: Gleicheniidites senonicus Ross, 1949

Gleicheniidites senonicus Ross

Plate 4, Figures 14-15, Plate 5, Figure 1

1949 Gleicheniidites senonicus Ross, p. 31, pl. 1, fig. 3.

1964 Gleicheniidites senonicus Ross, in Skarby, p. 65, 3 pls., 1 text-fig.

Description: See Skarby (1964).

Size range: 20-38 microns; 43 specimens measured.

Occurrences: Found in all but one sample, ranging from a single occurrence up to 8%. Elsewhere, it has been reported in numerous studies worldwide. Stratigraphically G. senonicus occurs from the Jurassic to Pliocene.

Suggested affinity: According to Skarby (1964) spores of the genus Gleicheniidites probably belong to the Gleicheneaceae, although she could not relate them to any of the extant genera of this family. Cookson (1953) attributed spores of her species G. circinidites (put in synonymy with G. senonicus by Skarby) to Gleichenia circinata Schwartz.

Discussion: Kemp (1970), in her treatment of this group, retained G. circinidites for the most "robust forms" of the group with "steep-sided crassitudes". This treatment is not accepted in this study.

Family Matoniaceae

Genus Dictyophyllidites Couper emend. Dettmann, 1963

Type species: Dictyophyllidites harrisii Couper, 1958

Dictyophyllidites equiexinus (Couper) Dettmann

Plate 5, Figure 5

1958 Matonisporites equiexinus Couper, p. 140, pl. 20, figs. 13-14.

1963 Dictyophyllidites equiexinus (Couper) Dettmann, p. 27.

1965 Hymenophyllumsporites furcosus Stanley, p. 249, pl. 31, figs. 1-5.

1966 Matonisporites globosus Kimyai, p. 467, pl. 1, fig. 9.

1968a Divisisporites enormis auct. non Pflug: Elsik, p. 294, pl. 9, figs. 1-3, pl. 10, figs. 1-5.

1970 Harrisispora equiexina (Couper) Pocock, p. 38, pl. 6, fig. 10 only.

1972b Divisisporites enormis auct. non Pflug: Srivastava, p. 230, pl. 5, figs. 4-6.

Description: Laesurae extend 2/3 distance or more to the equator as mentioned in Groot & Groot (1962a) and Gray & Groot (1966), and may bifurcate at the tips as described by Pocock (1970) in his generic diagnosis. Otherwise as given in Couper (1958).

Size range: 30 to 84 microns; 7 specimens measured.

Occurrences: Jurassic to Paleocene. 7 scattered single occurrences from the Mt. Laurel, Navesink, and Red Bank fms. Previous findings include the Jurassic of western Canada (Pocock, 1970), the Jurassic and Early Cretaceous of England (Couper, 1958 and Lantz, 1958), the Albian and Cenomanian of Oklahoma (Hedlund & Norris, 1968 and Hedlund, 1966), the Cenomanian of Portugal (Groot & Groot, 1962a), the Late Cretaceous of Delaware and New Jersey (Gray & Groot, 1966 and Kimyai, 1966), the Cretaceous-Eocene of Malaysia (Muller, 1968), the Late Cretaceous and Paleocene of South Dakota (Stanley, 1965), and the Paleocene of Texas (Elsik, 1968a), and Alabama (Srivastava, 1972b).

Suggested affinity: Couper (1958) relates *D. equiexinus* to the spores of *Phlebopteris angustiloba* and *Matodinium goepperti*, both fossil fern species of the Matoniaceae. Hedlund (1966) suggests an affinity to the modern schizaeaceous genera *Anemia* and *Lygodium*.

Discussion: Several species assigned to the genera *Leiotriletes* and *Toroisporis* by Krutzsch (1959b and 1962a) are similar to *D. equiexinus*. The genus *Divisisporites* Pflug, 1953 includes only spores that have bifurcating laesura tips, and since this is a variable feature shown in the specimens of Elsik (1968), and Srivastava (1972b), it is more appropriate to include these forms in *D. equiexinus*.

Dictyophyllidites harissii Couper

Plate 5, Figure 6

1958 *Dictyophyllidites harissii* Couper, p. 140, pl. 21, figs. 5-6.

Description: See Couper (1958).

Size range: 32-45 microns; 8 specimens measured.

Occurrences: Jurassic to Maastrichtian. 11 occurrences in 10 samples, Mt. Laurel, Navesink, and Red Bank fms. Previously found in the Jurassic of England (Couper, 1958) and the Cretaceous of Maryland (Groot & Penny, 1960).

Suggested affinity: Couper relates D. harissii to the spores of the Jurassic fern genus Dictyophyllum.

Discussion: Certain of the species of Toroisporis in Krutzsch (1959b and 1962a) are similar to D. harissii. Deltoidospora harissii (Couper) Pocock, 1970 is comparable to neither Couper's nor the specimens found in this study.

Genus Matonisporites Couper emend. Dettmann, 1963

Type species: Matonisporites phlebopteroides Couper, 1958

Matonisporites crassiangulatus (Balme) Dettmann

Plate 5, Figure 17

1957 Cyathidites crassiangulatus Balme, p. 22, pl. 3, figs. 39-41.

1960 Laevigatisporites percrassus Anderson, p. 15, pl. 9, fig. 10.

1963 Matonisporites crassiangulatus (Balme) Dettmann, p. 58.

1971 Matonisporites crassiangulatus (Balme) Dettmann, in Singh, p. 103, pl. 14, fig. 12.

Description: See Balme (1957) and Singh (1971).

Size range: 42-48 microns; 3 specimens measured.

Occurrences: Oxfordian to Maastrichtian. 3 specimens only, from the Mt. Laurel and Navesink fms. Previously recorded from the Oxfordian-Aptian of western Australia (Balme, 1957), the Early Cretaceous of Maryland (Brenner, 1963), the Albian of Alberta (Singh, 1971), and the Maastrichtian of New Mexico (Anderson, 1960).

Suggested affinity: Couper (1958) and Bolkhovitina (1953) relate spores of the genus Matonisporites to the fossil fern genus Phlebopteris. Other writers (see Dettmann, 1963) have related Matonisporites to certain species of the modern fern genus Dicksonia.

Discussion: Based on the original description (Balme, 1957), M.

crassiangulatus has concave sides. Singh (1971) expanded the description to include forms with ± straight to concave sides. Provided Singh's treatment is acceptable, a few of the specimens illustrated as M. phlebopteroides in Srivastava (1972a) should be included with M. crassiangulatus.

Matonisporites excavatus Brenner

Plate 5, Figures 15-16

1963 Matonisporites excavatus Brenner, p. 54, pl. 12, figs. 2-3.

1964 Matonisporites equiexinus auct. non Couper: in Stover, p. 144, pl. 1, fig. 23.

Description: See Brenner (1963).

Size range: 44 microns; 1 specimen.

Occurrences: Neocomian to Maastrichtian. 1 single occurrence from the Mt. Laurel Fm. Previously known from the Aptian and Albian of Maryland (Brenner, 1963 and Stover, 1964), the Neocomian of England (personal work), and the Cenomanian of New York (Kimyai, 1970).

Suggested affinity: As given for M. crassiangulatus.

Family Cyatheaceae

Genus Cyathidites Couper, 1953

Type species: Cyathidites australis Couper, 1953

Cyathidites minor Couper

Plate 5, Figure 9

1953 Cyathidites minor Couper, p. 28, pl. 2, fig. 13.

Description: See Couper (1953 and 1958).

Size range: 23-60 microns; 27 specimens measured.

Occurrences: Found in 31 samples throughout the section. Greatest abundance from the Red Bank locality at Highlands, N. J. (4.4% in one sample). C. minor is a widespread taxon reported from several parts of the world in the Jurassic and Cretaceous.

Suggested affinity: Couper (1958) suggests affinity to the Mesozoic fern species Coniopteris hymenophylloides, and to other fossil cyatheaceous or dicksoniaceous ferns such as Eboracia lobifolia and Dicksonia mariopteris. Hedlund (1966) relates C. minor to the schizaeaceous genus Lygodium.

Genus Kuylisporites Potonie, 1956

Type species: Kuylisporites waterbolki Potonie, 1956 (from Hemitelia-type in Kuyl, Muller & Waterbolk, 1955, pl. 1, fig. 7).

Kuylisporites aduncus (Chlonova) comb. nov.

Plate 5, Figure 2

1961 Camursporis aduncus Chlonova, p. 42, pl. 2, fig. 14.

1964 Spore Type D, Stover, p. 146, pl. 2, figs. 13-14.

1965 Kuylisporites scutatus Newman, p. 9, pl. 1, fig. 1.

1966 Rotaspora rugulatus Gray & Groot (pars), p. 124, pl. 42, fig. 11 only.

Description: Trilete microspore, amb subcircular to subtriangular, laesurae simple, extending 3/4 distance to the equator. Proximal surface smooth, distal surface smooth to rugulate.

Based on the specimens examined in this study, the scutula occur as either of the following two possibilities: In some specimens they are thickened interradial crassitudes with round inner margins that may or may not contain circular depressed areas. They also occur as areas to the outside of an in-curved ridge which delineates the contact area on the proximal face.

Size range: 25-30 microns; 5 specimens measured.

Occurrences: Late Cretaceous. 4 specimens from the Mt. Laurel and 1 from the Navesink Fm. Previous records of this taxon include the Late Cretaceous of western Siberia (Chlonova, 1961), Colorado (Newman, 1964 and 1965), Delaware (Gray & Groot, 1966), and Maryland (Stover, 1964).

Suggested affinity: According to both Potonie (1956) and Chlonova (1961) spores of this type compare most closely with the modern fern genus Hemitelia.

Discussion: K. waterbolki Potonie, 1956 and Hemitelia mirabilis Bolkhovitina, 1953 are both too large to be included with K. aduncus. Hemitelites laevis Romanovskaya (in Pokrovskaya & Stel'mak, 1960) is too poorly illustrated for comparison. The new combination is made here because Kuylisporites is appropriate for this taxon, and has priority over Camursporis.

Family Polypodiaceae

Genus Laevigatosporites Ibrahim, 1933

Type species: Laevigatosporites vulgaris (Ibrahim) Ibrahim, 1933

Laevigatosporites haardti (Potonie & Venitz) Thomson & Pflug

Plate 7, Figures 3-4

1934 Sporites haardti Potonie & Venitz, p. 13, pl. 1, fig. 13.

1953 Laevigatosporites haardti (Potonie & Venitz) Thomson & Pflug, p. 59, pl. 3, figs. 27-38.

For additional synonymy see Krutzsch (1967).

Description: See Potonie & Venitz (1934), Thomson & Pflug (1953), and Krutzsch (1967).

Size range: 30-56 microns; 19 specimens measured.

Occurrences: Found in 26 samples throughout the sections, ranging from single occurrences up to 6.0% in relative abundance. Previous records of this taxon are numerous and, although not restricted, mainly from the Cretaceous and Tertiary (see Krutzsch, 1967).

Suggested affinity: Polypodiaceae.

Genus *Verrucatosporites* Thomson & Pflug, 1953

Type species: *Verrucatosporites alienus* (Potonie) Thomson & Pflug, 1953

Verrucatosporites saalensis Krutzsch

Plate 7, Figures 1-2

1959b *Verrucatosporites saalensis* Krutzsch, p. 209, pl. 41, figs. 457-459.

Description: See Krutzsch (1959b).

Size range: 38-41 microns; 5 specimens measured.

Occurrences: Late Cretaceous. 5 specimens from 3 samples, all from the Red Bank Fm. at the Highlands, N. J. locality. Previously reported from the Late Cretaceous of central Europe (Krutzsch, 1959b).

Suggested affinity: Polypodiaceae.

Discussion: This species differs from others of the genus *Verrucatosporites* in that the sculpture elements are in the shape of flattened cones when seen in optical section.

Filicinae Incertae sedis

Genus *Asbeckiasporites* von der Brelie, 1964

Type species: *Asbeckiasporites wirthi* von der Brelie, 1964

Asbeckiasporites sp.

Plate 5, Figures 12-14

Description: Trilete microspores, amb subtriangular with concave sides. Laesurae distinct, straight, raised, and extending to the spore margin. Equatorial margin surrounded by a cingulum which may vary from 1.5-4.0 microns interradially, and become as thick as 7.0 microns toward the apices. Cingulum is invaginated or truncated directly at the apices. Exine surface smooth both proximally and distally.

Size range: 30-40 microns; 11 specimens measured.

Occurrences: Maastrichtian. 12 specimens in 9 samples, Mt. Laurel, Navesink, and Red Bank fms.

Suggested affinity: Uncertain.

Discussion: Similar forms, although not the same have been reported in various Early Cretaceous studies: *Asbeckiasporites wirthi* von der Brelie, 1964, also in Playford, 1971 and Singh, 1971; *Murospora florida* (Balme) Pocock, 1961; *Gleicheniidites bulbosus* Kemp, 1970.

Genus *Converrucosisporites* Potonie and Kremp, 1954

Type species: *Converrucosisporites triquetrus* (Ibrahim) Potonie & Kremp, 1955

Converrucosisporites proxigranulatus Brenner

Plate 5, Figure 8

1963 *Converrucosisporites proxigranulatus* Brenner, p. 60, pl. 15, figs. 1-3.

Description: See Brenner (1963).

Size range: 35-40 microns; 2 specimens measured.

Occurrences: Late Jurassic to Maastrichtian. 2 specimens only from the Mt. Laurel Fm. Previous records of this taxon include the latest Jurassic and earliest Cretaceous of the Netherlands (Burger, 1966), the Early Cretaceous of Maryland (Brenner, 1963), the Albian-Aptian of Spain (Boulouard & Canerot, 1970), and the Albian of Oklahoma (Hedlund & Norris, 1968).

Suggested affinity: Uncertain.

Genus Distaltriangulisporites Singh, 1971

Type species: Distaltriangulisporites perplexus (Singh) Singh, 1971

Distaltriangulisporites perplexus (Singh) Singh

Plate 5, Figures 10-11

1964 Appendicisporites perplexus Singh, p. 55, pl. 5, figs. 6-9.

1964 Appendicisporites degeneratus auct. non Thiergart, 1953: in Pocock, p. 172, pl. 4, figs. 16-18.

1967 Contignisporites perplexus (Singh) Norris, p. 98, pl. 14, figs. 1-4.

1971 Distaltriangulisporites perplexus (Singh) Singh, p. 89, pl. 12, figs. 1-6.

Description: See Singh (1964 and 1971).

Size range: 36-44 microns, 5 specimens measured. In literature, range extends from 35-63 microns.

Occurrences: Albian to Danian. 7 specimens from 4 samples in the Mt. Laurel Fm., and 1 specimen from the Red Bank Fm. Previously known from the Albian of western Canada (Norris, 1967, Pocock, 1964, and Singh 1964 and 1971), the Maastrichtian-Danian of California (Drugg, 1967), and tentatively reworked from the Paleocene of Alabama (McLean, 1968).

Suggested affinity: Uncertain.

Genus Leptolepidites Couper emend. Norris, 1968

Type species: Leptolepidites verrucatus Couper, 1953

Leptolepidites tenuis Stanley

Plate 5, Figure 7

1965 Leptolepidites tenuis Stanley, p. 255, pl. 32, figs. 7-11.

Description: See Stanley (1965).

Size range: 33-38 microns; 5 specimens measured. Overall size as recorded in the literature is 24-50 microns.

Occurrences: Maastrichtian to Danian. 1 specimen from the Navesink Fm. and 7 specimens from the Red Bank Fm. at the Highlands, N. J. locality; never greater than 0.8%. Previous records are from the Maastrichtian of South Dakota (Stanley, 1965) and Alberta (Snead, 1969 and Srivastava, 1972a), and the Maastrichtian and Danian of California (Drugg, 1967).

Suggested affinity: Uncertain.

Discussion: The genus Leptolepidites as mentioned in Dettmann (1963) and emended by Norris (1968) has a smooth proximal face. Stanley (1965) does not make this clear in his description but, according to both Snead (1969) and Srivastava (1972a), L. tenuis has a smooth proximal face. Specimens examined in this study showed the surface of the proximal side to be either smooth or of reduced ornamentation.

Leptolepidites verrucatus Couper

Plate 5, Figures 3-4

1953 Leptolepidites verrucatus Couper, p. 28, pl. 2, figs. 14-15.

1963 Leptolepidites verrucatus Couper, in Dettmann, p. 29, pl. 3, figs. 6-9.

1964 Trilites pulcher Kedves & Simoncsics, p. 29, pl. 8, figs. 5-6.

1968 Leptolepidites verrucatus Couper, in Norris, p. 316, figs. 12-15.

1972a Leptolepidites bullatus (van Hoeken-Klinkenberg) Srivastava, p. 21, pl. 16, figs. 9-10.

Description: See Dettmann (1963) and Norris (1968).

Size range: 30 microns; 1 specimen measured; in literature, range extends up to 48 microns.

Occurrences: Early Jurassic to Maastrichtian. One specimen only from the Red Bank Fm. Previous records are from the Early Jurassic of Queensland (de Jersey, 1960), the Late Jurassic of England (Lantz, 1958) and New Zealand (Couper, 1953 and Norris, 1968), the Jurassic of Hungary (Kedves & Simoncsics, 1964), the Cretaceous of Australia (Cookson & Dettmann, 1958 and Dettmann, 1963) and the Cretaceous of Alberta (Singh, 1971 and Srivastava, 1972a).

Suggested affinity: Uncertain.

Discussion: Converrucosisporites proxigranulatus Brenner, 1963 is similar, but has a granulate proximal face.

Genus Toripunctisporis Krutzsch, 1959b

Type species: Toripunctisporis granuloides Krutzsch, 1959b

Toripunctisporis granuloides Krutzsch

Plate 6, Figures 1-4

1959b Toripunctisporis granuloides Krutzsch, p. 88, pl. 9, figs. 59-62.

Description: Exine sculpture as found in this study ranges from smooth to granular-punctate. Description otherwise as given in Krutzsch (1959b).

Size range: 26-32 microns; 15 specimens measured.

Occurrences: Maastrichtian to Eocene. Found in 11 samples, Mt. Laurel, Navesink, and Red Bank fms. Most abundant in the Red Bank Sand at the Highlands, N. J. locality (2.8% in one sample). Elsewhere found only as scattered single occurrences. Previously known from the

Eocene of central Europe (Krutzsch, 1959b).

Suggested affinity: Uncertain.

Genus Trizonites Mädler, 1964

Type species: Trizonites cerebralis Mädler, 1964

Trizonites subrugulatus nom. nov.

Plate 6, Figures 5-7

1966 Rotaspora rugulatus Gray & Groot (pars), p. 124, pl. 42, fig. 12 only.

Description: Trilete microspore, amb circular to sub-triangular. In polar view the central body is strongly triangular; apices of central body narrowly coincident with the equator. Equatorial flange (cingulum) coincident with the equatorial plane, thin, and reduced or missing at the radial extensions of the central body, no distinct margo. Distal surface of central body distinctly or indistinctly rugulate with rugae about 2 microns wide and 1 micron apart. Proximal face psilate to sub-granulate.

The above description follows Gray & Groot (1966), but differs where necessary to exclude forms belonging to Kuylisporites aduncus as discussed elsewhere in this work (p. 59).

Size range: 30-36 microns; 12 specimens measured.

Occurrences: Late Cretaceous. A total of 15 specimens from 8 samples, Mt. Laurel, Navesink, and Tinton fms., from the localities at Marlboro, Poricy Brook, and Pine Brook. Previous records of this taxon include the Late Cretaceous of Delaware (Gray & Groot, 1966) and Oklahoma (Morgan, 1967).

Suggested affinity: Uncertain.

Discussion: This taxon is here removed from Rotaspora because the nature of the zone is not the same as originally described for the genus by Schemel (1950) and emended by Potonie & Kremp (1956) or Smith & Butterworth (1967). The genus Trizonites Mädler accomodates this species since the zone is simple and the distal surface ± rugulate.

A new combination of this taxon is here intended, however, the name *T. rugulatus* is preoccupied (see Mädler, 1964). The new specific epithet (*T. subrugulatus*) alludes to the less rugulate distal surface than that found in *T. rugulatus*.

Trilete sp. 1

Plate 6, Figures 11-13

Description: Trilete microspores, amb circular to rounded triangular. Laesurae raised, bordered by thin lips, and extending near or to the spore margin. Spore body surrounded equatorially by a zone 4-9 microns wide. Proximal surface smooth, distal surface covered with a loose reticulum (often broken), with muri extending just on to the edge of the zone. Width of lumina (if enclosed) about 10 microns, height of muri undetermined.

Size range: 35-45 microns; 8 specimens measured.

Occurrences: Maastrichtian. A total of 10 specimens seen in 7 samples, Mt. Laurel, Navesink, and Red Bank fms.

Suggested affinity: Uncertain.

Trilete sp. 2

Plate 6, Figures 8-10

Description: Trilete microspores, amb rounded triangular. Laesurae distinct, raised, thin, extending to the spore margin, and appearing sinuous in raised focal plane. Spore body two-layered; inner layer thicker, with smooth to scabrate sculpture; outer layer membranous, attached to central body over the contact area, and separating toward the equator to form a membranous zone. Outer layer smooth proximally, and varying distally from an incomplete to a complete reticulum with muri not extending on to the zonal area. Width of enclosed luminae vary from 4-9 microns.

Size range: 35-54 microns; 6 specimens measured.

Occurrences: Maastrichtian. 6 specimens from 4 samples, Mt. Laurel Sand only.

Suggested affinity: Uncertain.

Trilete sp. 3

Plate 6, Figures 14-18

Description: Trilete microspores, amb triangular with straight to slightly convex sides. Laesurae distinct, raised, extending to the spore margin and appearing membranous in raised focal plane. Spore body surrounded equatorially by a zone 7-12 microns wide, that reaches maximum width interradially, and is abruptly reduced or missing at the apices. Proximal surface smooth; distal surface reticulate, with strongly developed muri, and rounded lumina (± 8 microns diameter). Distal reticulum clearly a separate feature from the well developed zone.

Size range: 36-48 microns (zone included); 12 specimens measured.

Occurrences: Maastrichtian. A total of 19 occurrences in 11 samples, throughout the sections.

Suggested affinity: Uncertain.

Division Embryophyta

Subdivision Gymnospermae

Order Coniferae

Family Cheirolepidaceae

Genus Classopollis Pflug, 1953 emend. Pocock & Jansonius, 1961

Type species: Classopollis classoides Pflug, 1953 emend. Pocock & Jansonius, 1961

Classopollis classoides Pflug emend. Pocock & Jansonius

Plate 7, Figures 7-8

1950 "Conifer pollen" Reissinger, p. 114, pl. 14, figs. 15-16.

1953 Classopollis classoides Pflug, p. 91, pl. 16, figs. 29-31.

1961 Classopollis classoides Pflug, 1953 emend. Pocock & Jansonius, p. 443, pl. 1, figs. 1-9.

Description: See Pocock & Jansonius (1961).

Size range: 20-23 microns diameter.

Occurrences: Rhaetic to Eocene. 6 specimens from 4 samples, Mt. Laurel, Navesink, and Red Bank fms. Elsewhere this taxon is well known from numerous studies, and is particularly abundant in Jurassic rocks.

Suggested affinity: Classopollis-type pollen as summarized in Pocock & Jansonius (1961, p. 448) may have been produced by any one or combination of 3 extinct gymnospermous genera: Cheirolepis, Brachyphyllum, or Pagiophyllum. They believe the genus Cheirolepis is most likely.

Family Podocarpaceae

Genus Parvisaccites Couper, 1958

Type species: Parvisaccites radiatus Couper, 1958

Parvisaccites radiatus Couper

Plate 8, Figure 1

1958 Parvisaccites radiatus Couper, p. 154, pl. 29, figs. 5-8.

1961 Retibivesiculites parvus Pierce, p. 38, pl. 2, figs. 51-52.

Description: See Couper (1958) and Kemp (1970).

Size range: 35-60 microns total grain diameter.

Occurrences: Late Jurassic to Maastrichtian. Found in 19 samples throughout the sections and varying from single occurrences up to 3%. Elsewhere this taxon has been reported from the uppermost Jurassic to Albian of Holland (Burger, 1966 and Couper & Hughes, 1963), the "Wealden" of France (Levet-Carette, 1966), the Late Jurassic to Albian of England (Couper, 1958; Norris, 1969 and Kemp, 1970), the Early Cretaceous to Cenomanian of western Canada (Pocock, 1962; Singh, 1964 and 1971; and Norris, 1967), the Barremian to Albian of Maryland (Brenner, 1963), the middle Albian to early Cenomanian of Colorado and Nebraska (Pannella, 1966), the Cenomanian of Minnesota (Pierce, 1961) and the middle Cretaceous of the Atlantic Ocean (Habib, 1969 and 1970).

Suggested affinity: Couper (1958) relates this taxon to certain species of the modern genus Dacrydium (e.g. D. elatum).

Genus Phyllocladidites Cookson, 1947 ex Couper, 1953

Type species: Phyllocladidites mawsonii Cookson, 1947

Phyllocladidites inchoatus (Pierce) Norris

Plate 8, Figures 2-4

1961 Bacubivesiculites inchoatus Pierce, p. 34, pl. 2, fig. 34.

1961 Clavabivesiculites inchoatus Pierce, p. 34, pl. 2, fig. 36.

1961 Granabivesiculites inchoatus Pierce, p. 35, pl. 2, fig. 38.

Description: See Norris (1967).

Size range: Corpus length ranges from 29-48 microns.

Occurrences: Middle Albian to Maastrichtian. 13 specimens from 9 samples, Mt. Laurel, Navesink, and Red Bank fms. Previous occurrences include the Albian of Alberta (Norris, 1967 and Singh, 1971) and the Cenomanian of Minnesota (Pierce, 1961), and the Campanian of Montana (Tschudy, 1973).

Suggested affinity: Brenner (1963) relates a similar species (*P. microreticulatus*) to the modern genus *Phyllocladus*, in particular *P. hypophyllus* as figured in Erdtman (1943).

Discussion: With the exception of the rudimentary bladders, the above taxon closely resembles *Monocolpopollenites asymmetricus* (p. 80).

Genus *Podocarpidites* (Cookson, 1947) ex Couper, 1953
non *Podocarpidites* (Cookson) emend. Potonie, 1958

Type species: *Podocarpidites ellipticus* Cookson, 1947

Podocarpidites potomacensis Brenner
Plate 7, Figures 5-6

1963 *Podocarpidites potomacensis* Brenner, p. 82, pl. 32, figs. 1-2.

Description: See Brenner (1963).

Size range: 28-36 microns (corpus diameter only). Specimens found in this study were somewhat smaller than those reported by Brenner.

Occurrences: Late Jurassic to Maastrichtian. 4 specimens from 4 samples, Navesink and Red Bank fms. Previous records include the Late Jurassic and early Neocomian of the Netherlands (Burger, 1966) and the Early Cretaceous of Maryland (Brenner, 1963).

Suggested affinity: Podocarpaceae.

Genus Rugubivesiculites Pierce, 1961

Type species: Rugubivesiculites convolutus Pierce, 1961

See Potonie (1966, p. 126) for generic diagnosis

Remarks: Specimens relating to this genus, as found in this study, are placed in three of the species originally described by Pierce (1961). However, due to extensive ranges of morphologic variation, it is difficult to circumscribe these taxa, and perhaps more or less species of this genus may actually be present. A natural taxonomic treatment for this genus could only be attempted through a detailed numeric analysis, which was not done for this study.

Previous records of this genus include the Early Cretaceous of western Europe (Burger, 1966 and Herngreen, 1971), the late Albian-Maastrichtian of North America, the Senonian of Malaysia (Muller, 1968), and possibly the Cretaceous of Russia (Pinus aralica in Bolkhovitina, 1953 and Chlonova, 1961 and 1971).

Rugubivesiculites convolutus Pierce

Plate 8, Figures 7-8

1961 Rugubivesiculites convolutus Pierce, p. 39, pl. 2, fig. 57.

Description: See Pierce (1961)

Size range: 28-40 microns for central body, full length including bladders up to 67 microns.

Occurrences: Cenomanian to Maastrichtian. Found in 15 samples ranging from single occurrences up to 1.2%, Mt. Laurel, Navesink, and Red Bank fms. Previously recorded only by Pierce (1961) from the Cenomanian of Minnesota.

Suggested affinity: Podocarpaceae according to Pierce (1961) and

Brenner (1963). A close relationship of this genus to the Pinaceae as well was suggested by Muller (1968), e.g. *Pinus khasya* and *P. heterophylla* (both extant species). In my opinion, pollen of the genus *Rugubivesiculites* most closely resembles that of *Podocarpus nubigenus* as illustrated in Erdtman (1957, p. 38 and 1965, p. 64).

Rugubivesiculites reductus Pierce

Plate 8, Figures 9-10

1961 *Rugubivesiculites reductus* Pierce, p. 41, pl. 2, figs. 64-65.

1961 ?*Phyllocladidites*? sp. Groot, Penny & Groot, p. 130, pl. 24, fig. 14.

1964 *Podocarpidites* cf. *P. major* Couper, in Leopold & Pakiser, p. 81, pl. 7, figs. 4-6.

1966 non *Rugubivesiculites reductus* Pierce, in Burger, p. 257, pl. 31, fig. 2, pl. 32, fig. 1.

1969 *Podocarpidites* n. sp. A Lohrengel, p. 134, pl. 8, fig. 3.

1970 non *Rugubivesiculites reductus* Pierce, in Habib, p. 356, pl. 4, fig. 7.

1971 ?*Pinus aralica* Bolkhovitina, in Chlonova, pl. 4, fig. 4.

Description: See Pierce (1961).

Size range: Length of central body 28-44 microns; total length up to 63 microns.

Occurrences: Found in 23 samples throughout the sections ranging in abundance from single occurrences up to 15%. Not found, however, at the Highlands, N. J. locality. Previously reported from the middle Albian-Senonian of North America (Pierce, 1961, Groot, Penny & Groot, 1961, Brenner, 1963, Leopold & Pakiser, 1964, Williams & Brideaux, 1974, Pannella, 1966, Norris, 1967, Lohrengel, 1969, Griggs, 1970, Phillips & Felix, 1971b, and Gies, 1972), the Senonian of Malaysia (Muller, 1968), and possibly the Cretaceous of Siberia (Chlonova, 1971).

Suggested affinity: As given for *R. convolutus*.

Rugubivesiculites rugosus Pierce

Plate 8, Figures 5-6

1961 *Rugubivesiculites rugosus* Pierce, p. 40, pl. 2, figs. 59-60.

1961 ?*Pinus aralica* Bolkhovitina, in Chlonova, p. 61, pl. 10, figs. 1-2.

1964 *Podocarpidites* cf. *P. biformis* Rouse, in Leopold & Pakiser, p. 81, pl. 7, figs. 8-13.

1966 ?*Rugubivesiculites* spp. Gray & Groot, p. 125, fig. 17 only.

1970 *Rugubivesiculites reductus* auct. non Pierce: Habib, p. 356, pl. 4, fig. 7.

Description: See Pierce (1961).

Size range: Length of central body 30-50 microns; total length up to 65 microns.

Occurrences: Present in all but 3 samples throughout the sections, ranging from single occurrences up to 22%. Previous records include the late Albian-Maastrichtian of North America (Pierce, 1961, Davis, 1963, Leopold & Pakiser, 1964, Gray & Groot, 1966, Williams & Brideaux, 1974, Norris, 1967, Habib, 1970, Phillips & Felix, 1971b, Singh, 1971, and Gies, 1972) and possibly the Late Cretaceous of Siberia (Chlonova, 1961).

Suggested affinity: As given for *R. convolutus*.

Family Araucariaceae

Genus *Araucariacites* Cookson, 1947 ex Couper, 1953

Type species: *Araucariacites australis* Cookson, 1947

Araucariacites australis Cookson

Plate 7, Figure 9

1947 *Araucariacites australis* Cookson, p. 130, pl. 13, figs. 1-4.

Description: This species is used broadly to incorporate inaperturate grains that are circular in shape and have a smooth to granular exine surface.

Size range: 30-70 microns.

Occurrences: Jurassic to Cretaceous. Found in 22 samples throughout the sections studied, ranging from single occurrences up to 3.6%. A common form known world-wide from the upper Mesozoic.

Suggested affinity: Couper (1958) relates this species to the Jurassic araucarian *Brachyphyllum mamillare* and to recent species of the Araucariaceae as well.

Family Pinaceae

Genus *Pinuspollenites* Raatz, 1937

Type species: *Pinuspollenites labdacus* (Potonie, 1931) Raatz, 1937

Pinuspollenites spp.

Plate 7, Figures 11-15

1966 *Abietineaepollenites* spp. Gray & Groot, p. 126, pl. 42, fig. 18.

Description: Bisaccate pollen grains, corpus scabrate to microreticulate, bladders reticulate.

Size range: 38-80 microns total length of grain.

Occurrences: Present in all samples ranging in abundance from single occurrences up to 31%. Highest relative percentages generally occurred in the more marine samples.

Suggested affinity: This taxon is intended only as a loose circ

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circumscription for pollen forms that resemble the modern genus Pinus.

Family Taxodiaceae

Genus Taxodiaceaepollenites Kremp, 1949

Type species: Taxodiaceaepollenites hiatus (Potonie) Kremp, 1949

Taxodiaceaepollenites hiatus (Potonie) Kremp

Plate 8, Figure 11

1931 Pollenites hiatus Potonie, p. 5, fig. 27.

1949 Taxodiaceaepollenites hiatus (Potonie) Kremp, p. 59.

1965 Thuja? hiatus (Potonie) Stanley, p. 273, pl. 38, figs. 1-3.

Description: See Stanley (1965) for description and additional synonymy.

Size range: 22-31 microns diameter.

Occurrences: Tertiary, Cretaceous, and probably Jurassic. Found in 22 samples ranging up to 12% in one sample, Mt. Laurel, Navesink, and Red Bank fms. Highest percentages occurred in the Mt. Laurel Fm. which also represents the least marine segment of the section studied.

Restriction of the stratigraphic range to Albian and younger sediments as is done by some authors (e.g. Stanley, 1965 and Singh, 1971) is by name only. Similar taxa, if not identical, do exist from older sediments and are here considered a part of this taxon although not formally treated (e.g. Inaperturopollenites dubius as shown from the Late Jurassic and early Neocomian in Norris, 1969, p. 600).

Suggested affinity: ?Cupressaceae, ?Taxodiaceae; see Stanley (1965).

Genus Perinopollenites Couper, 1958

Type species: Perinopollenites elatoides Couper, 1958

Perinopollenites halonatus Phillips & Felix

Plate 7, Figure 10

1971b Perinopollenites halonatus Phillips & Felix, p. 459, pl. 14, figs. 15-16.

1972 Pterospermopsis sp. Bond, p. 182, pl. 3, fig. 4

Description: Grains inaperturate, consisting of a central body and outer perine; ± sperical in shape, but typically with 1-3 folds in the perine. Central body is smooth, uniform in thickness, and may or may not contain a central depressed area (5-8 microns) where the wall layer is reduced. Perine is smooth to finely scabrate or punctate.

Size range: 22-26 microns diameter for central body; 30-36 microns for outer perine.

Occurrences: Aptian to Maastrichtian. 8 specimens from 6 samples scattered throughout the sections. Elsewhere this taxon is known from the Aptian-Albian of Arkansas (Bond, 1972) and the Albian of Louisiana (Phillips & Felix, 1971b).

Suggested affinity: ?Taxodiaceae.

Discussion: The perine of this form has no pore, and is thus considered distinct from P. elatoides Couper (1958) and as described by Habib (1970, p. 360). Aside from this, P. halonatus compares favorably with Habib's specimens and also to his treatment of Exesipollenites tumulus Balme (1957).

Order Gnetales

Family Uncertain

Genus Eucommiidites Erdtman emend. Hughes, 1961

Type species: Eucommiidites troedssonii Erdtman, 1948

Eucommiidites troedssonii Erdtman

Plate 8, Figures 12-14

1948 Tricolpites (Eucommiidites) troedssonii Erdtman, p. 267, figs. 5-10, 13-15.

1958 Eucommiidites troedssonii Erdtman, in Couper, p. 160, pl. 31, figs. 23-27.

Description: See Erdtman (1948), Couper (1958) and Hughes (1961).

Size range: 24-28 microns diameter.

Occurrences: Jurassic and Cretaceous. 2 specimens from 1 sample, Mt. Laurel Fm. Other accounts of this taxon are widespread in various parts of the world from the Jurassic and Cretaceous.

Suggested affinity: ?Gnetales (Chlamydospermales) as given in Hughes (1961). Erdtman (1948) originally proposed a possible angiospermous affinity for Eucommiidites. However, Couper (1958) and Hughes (1961) suggested a gymnospermous relationship for this genus, which was confirmed by Brenner (1967a) who found Eucommiidites pollen in the micropylar canals and pollen chambers of numerous specimens of a gymnospermous seed species from the Early Cretaceous of Virginia.

Subdivision Angiospermae

Class Monocotyledonae

Order Pandales

Family Sparganiaceae

Genus Sparganiaceaepollenites Thiergart, 1938

Type species: Sparganiaceaepollenites polygonalis Thiergart, 1938

See Krutzsch (1970) also for description of genus.

Sparganiaceaepollenites sp.

Plate 9, Figures 1-4

Description: Ulcerate pollen grains with a ± spheroidal shape. Diameter of aperture ranges from 4 to 8 microns. Endexine thin, ektexine up to 2 microns thick. Ornamentation consists of duplibaculate muri that fuse peripherally into a reticulum. Lumina vary in shape among specimens from polygonal to rounded. Ornamentation is best developed on the proximal face, and is reduced distally toward the ulcus. Grains most often found with folds.

Size range: 28-33 microns diameter; 8 specimens measured.

Occurrences: Maastrichtian. Present in 7 samples, Navesink and Red Bank fms. Found in 5 samples from the Highlands, N. J. locality where abundances varied from 0.8-2.0%. The remaining two sample occurrences were single from the Antlantic Highlands, N. J. section.

Suggested affinity: *Sparganium*.

Discussion: *S. magnoides* Krutzsch (1970) is similar to the taxon described above, but cannot be considered conspecific with certainty.

Monocotyledonae-Incertae sedis

Genus *Clavatipollenites* Couper, 1958

Type species: *Clavatipollenites hughesii* Couper, 1958

Clavatipollenites hughesii Couper emend. Kemp

Plate 10, Figures 1-2

1958 *Clavatipollenites hughesii* Couper, p. 159, pl. 31, figs. 19-22.

1968 *Clavatipollenites hughesii* Couper emend. Kemp, p. 426, pl. 80, figs. 9-19.

1971b Clavatipollenites tenellis Phillips & Felix, p. 466, pl. 15, figs. 19-21.

Description: See Kemp (1968).

Size range: 16-22 microns; 4 specimens measured.

Occurrences: Barremian to Maastrichtian. 4 specimens from 4 samples, Mt. Laurel, Navesink, and Red Bank fms. Found at Marlboro, Poricy Brook, and Highlands localities. Clavatipollenites hughesii is reported in numerous studies throughout the world from Barremian to Albian strata. In the Upper Cretaceous it is only rarely found, e.g., the ?Cenomanian of the North Atlantic Ocean (Habib, 1969 and 1970) and the present study.

Suggested affinity: Probably angiosperm or gymnosperm; see Kemp (1968, p. 429).

Genus Monocolpopollenites Pflug & Thomson, 1953 emend. Nichols, Ames, & Traverse, 1973

Type species: Monocolpopollenites tranquillus (Potonie, 1934) Thomson & Pflug, 1953

Monocolpopollenites asymmetricus (Pierce) comb. nov.

Plate 10, Figures 21-23

1961 Granamonocolpites asymmetricus Pierce, p. 46, pl. 3, fig. 85.

1963 Monosulcites scabrus Brenner, p. 95, pl. 42, fig. 1.

1966 Sabalpollenites dividuus Kimyai, p. 470, pl. 2, fig. 13; see also: Phillips & Felix (1971b), p. 465, pl. 15, fig. 18.

1970 Palmaepollenites asymmetricus (Pierce) Habib, p. 358, pl. 6, fig. 15.

Description: See Pierce (1961), Brenner (1963), and Habib (1970).

Size range: 26-51 microns diameter.

Occurrences: Albian to Maastrichtian. 13 specimens from 8 samples, Mt. Laurel, Navesink, and Red Bank (1 specimen) fms.

Previous occurrences include the Albian of Maryland (Brenner, 1963); Albian-Cenomanian of Delaware (Brenner, 1967) and the Horizon Beta Outcrop of the Atlantic Ocean (Habib, 1970); Cenomanian of Minnesota (Pierce, 1961), New Jersey (Kimyai, 1966), and Louisiana and Mississippi (Phillips & Felix, 1971b).

Suggested affinity: Pierce (1961) relates this species to the Magnoliaceae (e.g. *Magnolia virginiana*). Kimyai (1966) suggests this has a similar morphology to the modern palm genus *Sabal*.

Discussion: Except for the lack of rudimentary bladders *M. asymmetricus* closely resembles *Phyllocladidites inchoatus* (p. 70). *Monosulcites major* Kemp (1970) is similar to the above taxon, but is larger.

Class Dicotyledonae

Order Juglandales

Family Juglandaceae

Genus *Momipites* Wodehouse, 1933 emend. Nichols, 1973

Type species: *Momipites coryloides* Wodehouse, 1933

Momipites inaequalis Anderson

Plate 9, Figures 7-9

1960 *Momipites inaequalis* Anderson, p. 25, pl. 6, figs. 7-10, pl. 7, fig. 13.

1967 *Myricipites cavilloratus* Drugg, p. 56, pl. 8, figs. 20-21, 50.

1968b *Engelhardtia inaequalis* (Anderson) Elsik, p. 602, pl. 16, fig. 17, 19-20.

1969 *Triatriopollenites granilabratus* (auct. non Stanley) Norton: Norton & Hall, p. 40, pl. 5, fig. 18.

1973 *Myricipites cavilloratus* Drugg emend. Chmura, p. 141, pl. 32, fig. 1.

Description: Pores of this taxon are variable in position, as is mentioned in Drugg (1967) and Chmura (1973). Otherwise as given in Anderson (1960).

Size range: 18-28 microns; 35 specimens measured.

Occurrences: Campanian to Paleocene. Present in 19 samples, Mt. Laurel, Navesink, and Red Bank fms. from the localities at Marlboro, Poricy Brook, and Highlands. Abundances ranged from single occurrences up to 5.3%. Elsewhere this taxon is known from the Campanian to Danian of California (Drugg, 1967 and Chmura, 1973), the Maastrichtian of Montana (Norton & Hall, 1969), and the Paleocene of New Mexico (Anderson, 1960) and Texas (Elsik, 1968b).

Suggested affinity: Juglandaceae according to Chmura (1973) and Nichols (1973). Pollen of *M. inaequalis* is also similar to certain species of *Casuarina* (see illustrations of *C. luckmanii* and *C. distyla* in Srivastava, 1972b, p. 238, pl. 8, figs. 7-9).

Momipites microcoryphaeus (Potonie) Nichols

Plate 9, Figures 5-6

1931 *Pollenites microcoryphaeus* Potonie, p. 332, tab. 2, fig. 13.

1950 *Engelhardtioidites microcoryphaeus* (Potonie) Potonie, Thomson & Thiergart, p. 51, pl. B, fig. 8, pl. C, fig. 16.

1953 *Triatriopollenites coryphaeus* subsp. *microcoryphaeus* (Potonie) Thomson & Pflug, p. 81, pl. 8, figs. 38-63.

1973 *Momipites microcoryphaeus* (Potonie) Nichols, p. 107.

Description: See Thomson & Pflug (1953).

Size range: 13-17 microns; 13 specimens measured.

Occurrences: Maastrichtian to Miocene. Present in 18 samples ranging up to 5.2%, Mt. Laurel, Navesink and Red Bank fms. from the localities at Marlboro, Poricy Brook, and Highlands. Previously known from the Tertiary of Europe (Potonie, 1931 and Thomson & Pflug, 1953).

Suggested affinity: Juglandaceae according to Nichols (1973).

Momipites tenuipolus Anderson

Plate 9, Figures 10-15

1960 *Momipites tenuipolus* Anderson, p. 25, pl. 7, fig. 14, pl. 8, figs. 14-15.

1962b *Triatriopollenites marylandicus* Groot & Groot, p. 165, pl. 30, figs. 4-5.

1964 *Engelhardtioidites* cf. *E. microcoryphaeus* auct. non (Potonie) Thiergart: Engelhardt, p. 77, pl. 4, fig. 44.

1965 *Engelhardtia microfoveolata* Stanley, p. 300, pl. 45, figs. 8-13.

1968b *Engelhardtia tenuipolus* (Anderson) Elsik, p. 600, pl. 16, figs. 3-6, 8.

1970 *Maceopolipollenites tenuipolus* (Anderson) Leffingwell, p. 31, pl. 6, fig. 4.

1972b *Engelhardtioidites tenuipolus* (Anderson) Srivastava, p. 248, pl. 11, figs. 7-8.

Description: See Anderson (1960) and comments in Elsik (1968b).

Size range: 10-16 microns; 8 specimens measured.

Occurrences: Maastrichtian to Eocene. Present in 16 samples, Mt. Laurel, Navesink, and Red Bank fms. from the localities at Marlboro, Poricy Brook, and Highlands. Relative abundances ranged up to 2.4%. Previously known from the Maastrichtian to Danian of California (Drugg, 1967), the Paleocene of New Mexico (Anderson, 1960), Texas (Elsik, 1968b), Alabama (Srivastava, 1972b), Maryland (Groot & Groot, 1962b), South Dakota (Stanley, 1965), and Wyoming (Leffingwell, 1970), the Paleocene to Eocene of Mississippi (Nichols & Stewart, 1971 and Engelhardt, 1964), and the Eocene of Alberta and British Columbia (Hopkins, 1969 and Rouse, Hopkins, & Piel, 1970).

Suggested affinity: M. tenuipolus closely resembles the modern genus Engelhardtia (Juglandaceae).

Order Proteales

Family Proteaceae

Genus Proteacidites Cookson, 1950 ex Couper, 1953

Type species: Proteacidites adenanthoides Cookson, 1950

Proteacidites marginus Rouse

Plate 9, Figures 19-20

1962 Proteacidites marginus Rouse, p. 205, pl. 2, fig. 26.

Description: See Rouse (1962).

Size range: 20-34 microns; 6 specimens measured.

Occurrences: Santonian to Paleocene. 12 specimens from 8 samples, Mt. Laurel, Navesink, Red Bank, and Tinton fms. from the localities at Marlboro, Poricy Brook, and Pine Brook. Previously known from the Santonian to Campanian of British Columbia and Alberta (Rouse, 1962 and Rouse, Hopkins, & Piel, 1970), the Late Cretaceous to Eocene of Washington (Griggs, 1970), and the Maastrichtian to Paleocene of Montana (Norton & Hall, 1969 and Oltz, 1969).

Suggested affinity: Proteaceae.

Discussion: Finer ornamentation and more "notch-like" apertures are features which distinguish P. marginus from P. retusus.

Proteacidites retusus Anderson

Plate 9, Figures 16-18

1960 Proteacidites retusus Anderson, p. 21, pl. 2, figs. 5-7.

1967 Proteacidites mollis auct. non Samoilovitch: Drugg, p. 57, pl. 8, fig. 37.

Description: Pores may vary from round to elongated slits, and the size range is here extended up to 30 microns. Otherwise as given in Anderson (1960).

Size range: 22-30 microns; 5 specimens measured.

Occurrences: Maastrichtian to Paleocene. 10 specimens from six samples, Mt. Laurel, Navesink, and Red Bank fms. from the localities at Marlboro and Poricy Brook. Previously known from the Late Cretaceous of Wyoming (Stone, 1973), the Maastrichtian of Montana (Norton & Hall, 1969 and Tschudy, 1970), New Mexico (Anderson, 1960), South Dakota (Stanley, 1965), and Utah (Lohrengel, 1969), and the Maastrichtian to Danian of California (Drugg, 1967).

Suggested affinity: Proteaceae.

Discussion: Coarser ornamentation and more rounded apertures are features which distinguish *P. retusus* from *P. marginus*.

Proteacidites thalmannii Anderson

Plate 9, Figures 21-23

1960 *Proteacidites thalmannii* Anderson, p. 21, pl. 2, figs. 1-4, pl. 10, figs. 9-13.

1965 *Proteacidites retusus* auct. non Anderson: Stanley (pars), p. 307, pl. 46, figs. 4-5 only.

1967 *Proteacidites thalmannii* Anderson: In Drugg, p. 58, pl. 8, fig. 38.

1969c *Proteacidites thalmannii* Anderson: In Srivastava, p. 1575, fig. 13.

Description: See Anderson (1960), Drugg (1967), and Srivastava (1969c).

Size range: 22-28 microns; 5 specimens measured. Overall literature size ranges from 17-41 microns.

Occurrences: Santonian to Eocene. 5 specimens from 5 samples, Mt. Laurel, Navesink, and Red Bank fms. Previously known from the Santonian to Campanian of British Columbia and Alberta (Rouse, Hopkins & Piel, 1970), the Santonian to Maastrichtian of Delaware and New Jersey (Gray & Groot, 1966), the Late Cretaceous of Wyoming (Stone, 1973), the Maastrichtian of Alberta (Srivastava, 1966 and 1969c), New Mexico (Anderson, 1960), South Dakota (Stanley, 1965), Utah (Lohrengel, 1969), and the U.S.S.R. (Bratzeva, 1965), the Maastrichtian to Danian of California (Drugg, 1967), the Maastrichtian to Paleocene of Montana (Oltz, 1969 and Norton & Hall, 1969), and the Eocene of British Columbia (Hopkins, 1969).

Suggested affinity: Proteaceae.

Proteacidites sp.

Plate 9, Figure 24

Description: Triaperturate, apertures large, circular, equatorial, with anulus about 4-5 microns wide, diameter of apertures 8 microns. Amb triangular, sides ± straight, poles flattened, polar axis compressed. Surface ornamentation reticulate, fine at the poles, but becoming abruptly coarse in the inter-apertures toward the equator. Lumina up to 4 microns, height of baculae up to 2.5 microns.

Size range: 30-32 microns; 2 specimens measured.

Occurrences: Maastrichtian. 2 specimens from 2 samples, Red Bank and Tinton fms. from the localities at Highlands and Pine Brook.

Suggested affinity: Proteaceae.

Discussion: The variation of reticulate ornamentation in the above taxon is more pronounced than in *P. thalmannii*. *Proteacidites* sp. Hopkins (1969, p. 1124), a possible Cretaceous reworked specimen in the Eocene of British Columbia may be conspecific with the grains found in this study.

Order Sapindales

Family Sapindaceae

Genus *Cupanieidites* Cookson & Pike, 1954 emend. Chmura , 1973

Type species: *Cupanieidites orthoteichus* Cookson & Pike, 1954

Cupanieidites sp. Chmura

Plate 9, Figures 25-26

1973 *Cupanieidites* sp. Chmura, p. 138, pl. 29, figs. 13-17, pl. 30, figs. 1-3.

Description: See Chmura (1973).

Size range: 26-36 microns; 4 specimens measured.

Occurrences: Campanian to Maastrichtian. 4 specimens from 3 samples, Mt. Laurel and Navesink fms. from the Marlboro locality only. Previously reported from the Campanian-Maastrichtian of California (Chmura, 1973) and the Eocene of Australia (Cookson & Pike, 1954).

Suggested affinity: Cookson & Pike (1954) compare a similar species (C. major) with *Cupaniopsis wadsworthii*, a present day rainforest tree of Queensland and New South Wales. According to Chmura, the above taxon may represent pollen from several cupanieaceous species.

Genus *Insulapollenites* Leffingwell, 1970

Type species: *Insulapollenites rugulatus* Leffingwell, 1970

Insulapollenites rugulatus Leffingwell

Plate 9, Figures 27-28

1962b Unclassified pollen sp. 1 Groot & Groot, p. 170, pl. 31, figs. 10-11.

1970 *Insulapollenites rugulatus* Leffingwell, p. 48, pl. 9, figs. 11-12.

Description: See Leffingwell (1970).

Size range: 24-44 microns; 4 specimens measured.

Occurrences: Maastrichtian-Paleocene. 4 specimens from 4 samples, Mt. Laurel, Navesink, and Red Bank fms. Elsewhere this species has been reported from the Paleocene of Wyoming (Leffingwell, 1970) and Maryland (Groot & Groot, 1962b).

Suggested affinity: Groot & Groot (1962b) suggest the Sapindaceae or Myrtaceae.

Order Myrtiflorae

Family Nyssaceae

Genus *Nyssapollenites* Thiergart, 1937

Type species: *Nyssapollenites pseudocruciatus* (Potonie, 1931) Thiergart, 1937

Nyssapollenites puercoensis (Anderson) Drugg, 1967

Plate 9, Figures 30-32

1960 *Nyssa puercoensis* Anderson, p. 23, pl. 7, fig. 12.

1967 *Nyssapollenites puercoensis* (Anderson) Drugg, p. 52, pl. 8, fig. 4.

Description: See Anderson (1960) and Drugg (1967).

Size range: 26-38 microns; 11 specimens measured.

Occurrences: Campanian to Danian. 11 specimens from 8 samples, Mt. Laurel, Navesink, and Red Bank fms. Found at Highlands, Marlboro, and Poricy Brook localities. Elsewhere this taxon has been reported from Campanian to Danian in California (Drugg, 1967 and Chmura, 1973) and lowermost Paleocene in New Mexico (Anderson, 1960).

Suggested affinity: Nyssa.

Discussion: Taxa which are similar, but not synonymous are: Pollenites kruschi forma accessorius Potonie (1934, p. 65), Fagus granulatus Martin & Rouse (1966, p. 199, also in Hopkins, 1969, p. 1119), cf. Symplocoipollenites sp. Elsik (1968b, p. 636), Symplocoipollenites morrinensis Srivastava (1969b, p. 54), and Tricolporopollenites intergranulatus Norton (1969, p. 51).

Family Haloragaceae

Genus Gunnerites Cookson & Pike, 1954

Type species: Gunnerites reticulatus (Cookson, 1947) Cookson & Pike, 1954

Gunnerites reticulatus (Cookson) Cookson & Pike

Plate 9, Figure 29

1947 Tricolpites reticulata Cookson, p. 134, pl. 15, fig. 45.

1954 Gunnerites reticulatus (Cookson) Cookson & Pike, p. 201, pl. 1, figs. 18-19.

1965 Tricolpites interangulus Newman, p. 10, pl. 1, fig. 3.

Description: See Cookson (1947) and Newman (1965).

Size range: 28-36 microns; 4 specimens measured.

Occurrences: Senonian to Pliocene. 4 specimens from 4 samples, Mt. Laurel and Red Bank fms. Elsewhere this taxon is known from the Late Cretaceous of Colorado (Newman, 1965) and Wyoming (Stone, 1973), Campanian of Montana (Tschudy, 1973), Maastrichtian of Alberta (Srivastava, 1966), Late Cretaceous to Eocene of Washington (Griggs, 1970b, Lower Tertiary of the Kerguelen Archipelago (Cookson, 1947), and the Pliocene of New Guinea (Cookson & Pike, 1954).

Suggested affinity: Cookson & Pike (1954) relate G. reticulatus to the extant genus Gunnera (Haloragaceae).

Discussion: Gunnera microreticulata (Belsky, Boltenhagen, Potonie, 1965) Leffingwell, 1970 is more finely reticulate than G. reticulatus.

Dicotyledonae-Incertae sedis

Genus Extratriporopollenites Pflug emend. Skarby, 1968

Type species: Extratriporopollenites fractus Pflug, in Thomson & Pflug, 1953

Extratriporopollenites minimus (Krutzsch) comb. nov.

Plate 10, Figures 3-4

1959a Minorpollis minimus Krutzsch, p. 141, pl. 32, fig. 10-14.

1967 Minorpollis minimus Krutzsch, in Goczan et al., p. 478, pl. 11, figs. 1-11.

1970 Triatriopollenites sp. Tschudy, p. 99, pl. 6, fig. 7.

1971 New Genus K, Wolfe & Pakiser, p. 45, fig. 5f.

Description: Specimens from this study are slightly larger; otherwise the same as in Krutzsch (1959a) and Goczan et al. (1967).

Size range: 10-16 microns; 24 specimens measured. Size given in Krutzsch (1959a) is 8-11 microns.

Occurrences: Middle Turonian to Eocene. Present in 13 samples, Mt. Laurel, Navesink, and Red Bank fms. from the localities at Marlboro, Poricy Brook and Highlands. Highest relative abundances occurred in the Mt. Laurel Fm. at Marlboro (up to 7%). Previous occurrences include the middle Turonian to Eocene of central Europe (Krutzsch, 1959a and Goczan et al., 1967), the Santonian of New Jersey (Wolfe & Pakiser, 1971) and the Paleocene of the Mississippi Embayment region (Tschudy, 1970).

Suggested affinity: Uncertain.

Discussion: Other similar taxa are *Pollenites bituitus* (Potonie) Potonie (1934), *Triatriopollenites concavus* Pflug (in Thomson & Pflug, 1953), *Triatriopollenites excelsus* subsp. *microturgidus* Pflug (in Thomson & Pflug, 1953), and *Triatriopollenites excelsus* subsp. *minor* Pflug (in Thomson & Pflug, 1953).

Extratriporopollenites nonperfectus Pflug

Plate 10, Figures 6-9

1953 *Extratriporopollenites nonperfectus* Pflug, in Thomson & Pflug, p. 75, pl. 6, figs. 109-110.

1953 *Trudopollis nonperfectus* (Pflug) Pflug, p. 101, pl. 23, figs. 9-12.

1965 *Betula infrequens* Stanley, p. 290, pl. 43, figs. 7-11.

1966 *Trudopollis acinosus* (auct. non Agranovskaya) Gray & Groot, p. 130, pl. 43, fig. 14.

1968 *Extratriporopollenites nonperfectus* Pflug, in Skarby, p. 37, pl. 15, figs. 1-13, fig. 7: 2.

1971 *Trudopollis* spp. Wolfe & Pakiser, p. 43, fig. 4f-i.

1972b *Extratriporopollenites nonperfectus* Pflug, in Srivastava, p. 252, pl. 13, figs. 5-11, pl. 14, figs. 1-4.

Description: See Skarby (1968) and remarks in Srivastava (1972b).

Size range: 17-27 microns; 15 specimens measured.

Occurrences: Santonian to Paleocene. Present in 11 samples, Navesink, Red Bank and Tinton fms. from the Marlboro, Poricy Brook, Highlands, and Pine Brook localities. Relative abundances were greatest at the Highlands locality (occurrences in 7 samples, up to 2.0%). Previously known from the Campanian of Germany (Pflug, 1953, Weyland & Krieger, 1953 and Skarby, 1968) and Sweden (Skarby, 1968), the Paleocene of Russia (Zaklinskaya, 1963), the Santonian of New Jersey (Wolfe & Pakiser, 1971), the Campanian of New Jersey (Gray & Groot, 1966), and the Paleocene of Alabama (Srivastava, 1972b) and South Dakota (Stanley, 1965).

Suggested affinity: Uncertain.

Discussion: E. firmus Skarby (1968) may be the same as E. nonperfectus (see remarks by Srivastava, 1972b, p. 252).

Extratriporopollenites silicatus (Pflug) Skarby

Plate 10, Figures 10-13

1953 Plicapollis silicatus Pflug, p. 98, pl. 19, figs. 11-17, 21-22.

1965 Sporopollis laqueaeformis auct. non Weyland & Greifeld, 1953: Newman, p. 16, pl. 1, fig. 1.

1966 Triatriopollenites perplexus auct. non Pflug: Gray & Groot, p. 130, pl. 43, fig. 4.

1968 Extratriporopollenites silicatus (Pflug) Skarby, p. 54, pl. 24, figs. 12-16.

1970 Plicapollis sp. Tschudy, p. 99, pl. 6, fig. 27.

1971 Plicapollis sp. Wolfe & Pakiser, p. 45, fig. 5h.

Description: Aperture regions somewhat variable among grains, the annuli may remain thick around a narrow pore canal, or they may be distended forming a vestibulum. For remainder of description, see Skarby (1968).

Size range: 14-20 microns; 9 specimens measured.

Occurrences: Santonian to Paleocene. 9 specimens from 5 samples, Mt. Laurel, Navesink and Red Bank fms. from the localities at Highlands and Marlboro. Previous occurrences include the Campanian of Germany (Weyland & Krieger, 1953, Pflug, 1953 and Skarby, 1968) and Sweden (Skarby, 1968), the Santonian to Maastrichtian of Delaware and New Jersey (Gray & Groot, 1966 and Wolfe & Pakiser, 1971), the Campanian of Maastrichtian of Colorado (Newman, 1965), the Upper Cretaceous and Paleocene of the Mississippi Embayment region (Tschudy, 1970), and the Paleocene of Maryland (Groot & Groot, 1962b).

Suggested affinity: Uncertain.

Discussion: Certain taxa other than *E. silicatus* that may be in part synonymous are: *E. serta* (Pflug) Skarby (1968), *E. peneserta* (Pflug) Skarby (1968), and *E. emaciatus* Skarby (1968).

Extratriporopollenites thornei (Drugg) comb. nov.

Plate 10, Figures 14-15

1967 *Gothanipollis thornei* Drugg, p. 55, pl. 8, figs. 29-30.

1967 *Gothanipollis* sp. Drugg, p. 55, pl. 8, 32.

1968 *Extratriporopollenites tenellus* Skarby, p. 48, pl. 22, figs. 1-8, fig. 10: 3-4.

1971 New Genus D Wolfe & Pakiser, p. 43, fig. 4m.

1973 *Plicapollis thornei* (Drugg) Chmura emend., p. 143, pl. 32, figs. 5-9.

Description: See Skarby (1968) and Chmura (1973).

Size range: 26-28 microns; 5 specimens measured.

Occurrences: Santonian to Danian. 6 specimens from 6 samples, Mt. Laurel and Red Bank fms. from the localities at Marlboro and Poricy Brook. Previously known from the Campanian of Germany and Sweden (Skarby, 1968), the Santonian of New Jersey (Wolfe & Pakiser, 1971), and the Campanian to Danian of California (Drugg, 1967 and Chmura, 1973).

Suggested affinity: Uncertain.

Discussion: Other taxa which are similar, but not the same are: *Plicapollis magnus* Groot, Penny & Groot (1961), *Vacupollis* sp. 2 Groot, Penny & Groot (1961), *Conclavipollis densilatus* Kimyai (1966), and *Complexiopollis* sp. Doyle (1969).

The treatment of taxa representing the Normapolles group in this study has followed Skarby (1968), and to remain consistent, it was necessary to provide a new combination for the above taxon.

Extratriporopollenites sp.

Plate 10, Figure 5

1961 Vacuopollis sp. 1 Groot, Penny & Groot, p. 138, pl. 26, fig. 50.

Description: See Groot, Penny & Groot (1961).

Size range: 14-16 microns; 2 specimens measured.

Occurrences: Santonian to Maastrichtian. 2 specimens from 2 samples, Mt. Laurel and Navesink fms. from the localities at Marlboro and Poricy Brook. Previously known from the Santonian of New Jersey (Groot, Penny & Groot, 1961).

Suggested affinity: Uncertain.

Genus Holkopollenites Fairchild, 1966

Type species: Holkopollenites chemardensis Fairchild, in Stover, Elsik & Fairchild (1966)

Holkopollenites chemardensis Fairchild

Plate 10, Figures 16-20

1966 Holkopollenites chemardensis Fairchild, in Stover, Elsik, & Fairchild, p. 6, pl. 1, fig. 11, pl. 2, figs. 8-9.

Description: See Stover et al. (1966) and Srivastava (1972b)

Size range: 23-34 microns; 17 specimens measured. Total size range reported in literature is 17-40 microns.

Occurrences: Maastrichtian to Paleocene. 17 specimens from 14 samples scattered throughout the sections. Previous occurrences include the Paleocene of the Gulf Coast (Fairchild & Elsik, 1969), Louisiana (Stover et al., 1966), Texas (Elsik, 1968b), Alabama (Srivastava, 1972b), and reworked in the Neogene from the Northern Gulf of Mexico (Elsik, 1969).

Suggested affinity: Uncertain.

Genus Retitricolpites van der Hammen, 1956, ex Pierce, 1961

Type species: Retitricolpites ornatus van der Hammen, 1956

Remarks: See Singh (1971, p. 199) for remarks pertaining to validity of this genus.

Retitricolpites georgensis Brenner

Plate 10, Figures 36-37

1963 Retitricolpites georgensis Brenner, p. 91, pl. 38, figs. 6-7.

1966 Tricolpites cf. T. reticulatus auct. non Cookson, 1947: Hedlund, p. 29, pl. 9, fig. 3.

Description: See Brenner (1963).

Size range: 24-32 microns; 6 specimens measured.

Occurrences: Albian to Maastrichtian. 11 specimens from 10 samples scattered throughout the sections. Previously this taxon has been reported from the Albian of Maryland (Brenner, 1963), and Saskatchewan and Manitoba (Playford, 1971); the Albian-Cenomanian of Alberta (Norris, 1967 and Singh, 1971) and Oklahoma (Hedlund, 1966 and Hedlund & Norris, 1968); and the Cenomanian of Louisiana (Phillips & Felix, 1971b).

Suggested affinity: Uncertain.

Genus Tricolpites Cookson, 1947 ex Couper, 1953 emend. Potonie, 1960

Type species: Tricolpites reticulatus Cookson, 1947

Tricolpites anguloluminosus Anderson

Plate 10, Figures 28-29

1960 *Tricolpites anguloluminosus* Anderson, p. 26, pl. 6, figs. 15-17.

1965 *Tricolpites bathyreticulatus* Stanley, p. 320, pl. 47, figs. 18-23.

1968b *Tricolpopollenites anguloluminosus* (Anderson) Elsik, p. 624, pl. 24, figs. 15-16, pl. 25, fig. 1.

1973 *Tricolpites anguloluminosus* Anderson: In Chmura, p. 108, pl. 22, figs. 13-14.

Description: See Anderson (1960) and Chmura (1973).

Size range: 24-28 microns; 2 specimens measured.

Occurrences: Campanian to Paleocene. 2 specimens from 2 samples, Red Bank Fm. Elsewhere this taxon is known from the Late Cretaceous of Wyoming (Stone, 1973), the Late Campanian of Colorado (Dickinson, Leopold, & Marvin, 1968), the Campanian to Danian of California (Drugg, 1967 and Chmura, 1973), the Paleocene of Texas (Elsik, 1968b), New Mexico (Anderson, 1960), South Dakota (Stanley, 1965) Wyoming (Leffingwell, 1970), and Montana (Oltz, 1969 and Norton & Hall, 1967 and 1969).

Suggested affinity: According to Drugg (1967) *T. anguloluminosus* is similar to pollen of the extant species *Bucklandia populnea* (Hamamelidaceae).

Discussion: *Tricolpopollenites platyreticulatus* Groot, Penny & Groot (1961) is similar but smaller.

Tricolpites parvus Stanley

Plate 10, Figures 24-27

1965 *Tricolpites parvus* Stanley, p. 322, pl. 47, figs. 28-31.

1966 *Tricolpopollenites retiformis* auct. non Pflug & Thomson: Gray & Groot, p. 127, pl. 43, fig. 5.

1968b Tricolpopollenites hians (Stanley) Elsik (pars), p. 622, pl. 23, figs. 17, 19, pl. 24, figs. 1-7.

1973 Tricolpopollenites turonicus (auct. non Mtchedlishvili) Chmura, p. 119, pl. 25, figs. 1-3.

Description: Shape for specimens seen in this study varies from oblate to subprolate, otherwise as given in Stanley (1965) and Srivastava (1972b).

Size range: 16-28 microns; 21 specimens measured.

Occurrences: Campanian to Paleocene. Found in 20 samples varying from single occurrences up to 10%, Mt. Laurel, Navesink, and Red Bank fms. With only one exception, it was found only at the Marlboro, Poricy Brook, and Highlands localities. Elsewhere this taxon is known from the Campanian and Maastrichtian of Delaware and New Jersey (Gray & Groot, 1966) and California (Chmura, 1973), the Maastrichtian to Paleocene of Wyoming (Leffingwell, 1970), and the Paleocene of South Dakota (Stanley, 1965), Texas, (Elsik, 1968b), and Alabama (Srivastava, 1972b).

Suggested affinity: Elsik (1968b) suggests Salix as a probably affinity.

Discussion: Similar taxa are T. hians Stanley (1965) which has a thinner exine and T. sagax Norris (1967) which has finer ornamentation.

All authors who illustrate this taxon, with the exception of Elsik (1968) show the grains in polar view only, and with colpi widely separated. This repeated splitting of the colpi is suggestive of a spheroidal to prolate shape, not oblate as the taxon is usually described.

Genus Tricolpopollenites Pflug & Thomson, 1953

Type species: Tricolpopollenites parmularius (Potonie) Pflug & Thomson in Thomson & Pflug, 1953

Tricolpopollenites micromunus Groot & Penny

Plate 10, Figures 32-35

1960 *Tricolpopollenites micromunus* Groot & Penny, p. 232, pl. 2, figs. 6-7.

1961 *Retitricolpites minutus* Pierce, p. 52, pl. 3, figs. 109-110.

1963 *Tricolpopollenites micromunus* Groot & Penny, in Brenner, p. 93, pl. 39, fig. 7, pl. 40, fig. 1.

1973 *Tricolpopollenites sparsus* forma vescus (auct. non Samoilovitch) Chmura, p. 119, pl. 24, figs. 21-23.

Description: See Brenner (1963) for best description.

Size range: 14-18 microns; 5 specimens measured.

Occurrences: Albian to Danian. 11 specimens from 8 samples, Mt. Laurel, Navesink, and Red Bank fms. from the localities at Highlands, Marlboro, and Poricy Brook. Previously known from the Albian of Maryland (Brenner, 1963, Doyle, 1969 and Groot & Penny, 1960) and Oklahoma (Hedlund & Norris, 1968), the Cenomanian of Delaware (Brenner, 1967) and Minnesota (Pierce, 1961), the Turonian of Peru (Brenner, 1968), the probable late Cenomanian-Santonian (South Amboy Fire Clay-Raritan Fm.) of New Jersey (Groot, Penny & Groot, 1961), and the Campanian to Danian of California (Drugg, 1967 and Chmura, 1973).

Suggested affinity: Brenner (1963) compares *T. micromunus* to pollen of *Tetracentron sinense*, the only living species of the Tetracentraceae, a primitive dicot family, which is presently distributed only in south-central China and adjacent Burma.

Tricolpopollenites micropunctatus Groot, Penny, & Groot

Plate 10, Figures 30-31

1961 *Tricolpopollenites micropunctatus* Groot, Penny & Groot, p. 133, pl. 26, fig. 9.

Description: See Groot, Penny & Groot (1961).

Size range: 11-18 microns; 10 specimens measured.

Occurrences: Cenomanian to Maastrichtian. 19 specimens from 7 samples, Mt. Laurel, Navesink, and Red Bank fms. Found only at the Marlboro and Poricy Brook localities. Previously known from the Cenomanian of Alabama (Groot, Penny & Groot, 1961).

Suggested affinity: ?*Quercus* according to Groot, Penny & Groot (1961).

Tricolpopollenites simplicissimus Groot, Penny & Groot

Plate 10, Figures 38-42

1961 *Tricolpopollenites simplicissimus* Groot, Penny & Groot, p. 132, pl. 26, fig. 6.

1969 *Tricolpopollenites parvulus* auct. non Groot & Penny, 1960: Lohrengel, p. 158, pl. 12, fig. 2.

Description: See Groot, Penny & Groot (1961).

Size range: 15-20 microns; 6 specimens measured.

Occurrences: Cenomanian to Maastrichtian. Found in 17 samples up to 4%, Mt. Laurel, Navesink, and Red Bank fms. Present only at the Highlands, Marlboro and Poricy Brook localities. Previous reports of this taxon include the Cenomanian of Alabama (Groot, Penny & Groot, 1961) and the Maastrichtian of Utah (Lohrengel, 1969).

Suggested affinity: Uncertain.

Genus *Tricolporopollenites* Pflug, 1953

Type species: *Tricolporopollenites dolium* (Potonie, 1931) Thomson & Pflug, 1953

Tricolporopollenites cingulum (Potonie) Thomson & Pflug

Plate 11, Figures 1-5

1931 *Pollenites cingulum* Potonie, p. 26, pl. 1, figs. 45-56, 48, 60-62.

1953 Tricolporopollenites cingulum (Potonie) Thomson & Pflug, p. 100, pl. 12, figs. 15-27.

1972b Rhoipites cingulus (Potonie) Srivastava, p. 268, pl. 20, figs. 7-8.

Description: Total exine thickness up to 1.5 microns; otherwise as described in Srivastava (1972b).

Size range: 12-19 microns; 23 specimens measured.

Occurrences: Maastrichtian to Tertiary. 23 specimens from 8 samples, Mt. Laurel, Navesink, and Red Bank fms. from the localities at Marlboro and Poricy Brook. Previous occurrences include the Paleocene of Alabama (Srivastava, 1972b), and Texas (Elsik, 1968b), and the Tertiary of Europe (Potonie, 1931 and Thomson & Pflug, 1953).

Suggested affinity: According to Potonie (1934) this taxon is similar to modern pollen of Punica granatum and Aesculus glabra. Potonie & Venitz (1934) compare this form to the Puniaceae and Ononis ramosissimus (Leguminosae).

Discussion: T. cingulum differs from T. distinctus in this study by having larger pores and a thicker exine. These characters however, may overlap among these two species.

Similar taxa that cannot here be placed into definite synonymy are: Tricolporites prolata Cookson (1947), and also in Lohrengel (1969), Tricolporites sp. Anderson (1960), and Tricolporopollenites triangulus Groot, Penny & Groot (1961).

Tricolporopollenites cryptoporus (Srivastava) comb. nov.

Plate 11, Figures 6-11

1953 Tricolporopollenites kruschi subsp. pseudolaesus (Potonie) Thomson & Pflug (pars), p. 104, pl. 13, figs. 50, 59-60.

1960 Quercus explanata Anderson (pars), p. 19, pl. 5, fig. 20 only.

1965 Caprifoliipites longus Stanley, p. 295, pl. 44, figs. 10-14.

1966 Tricolpites wilsonii Kimyai, p. 471, pl. 2, fig. 18.

1968b Tricolporopollenites kruschii (Potonie) Thomson & Pflug, in Elsik (pars), p. 628, pl. 31, figs. 2-4, 9, 11-16, pl. 32, figs. 1-3, 6-7, pl. 33, figs. 1-3.

1972b Margocolporites cribellatus Srivastava, p. 260, pl. 19, figs. 1-8, pl. 20, figs. 1-2.

1972b Rhoipites cryptoporus Srivastava, p. 270, pl. 21, figs. 1-11.

Description: The shape of this form varies from sphaeroidal to prolate. Those authors who describe this taxon as oblate only illustrate specimens oriented in polar view with gaping colpi. The state of these forms is here considered the result of mechanical polar compression rather than a natural phenomenon. For remainer of description see Srivastava (1972b) for M. cribellatus and R. cryptoporus.

Size range: 28-42 microns; 16 specimens measured.

Occurrences: Cenomanian to Tertiary. 25 specimens from 15 samples scattered throughout the sections. Previous occurrences include the Cenomanian of New Jersey (Kimyai, 1966), the Paleocene of South Dakota (Stanley, 1965), New Mexico (Anderson, 1960), Texas (Elsik, 1968b), and Alabama (Srivastava, 1972b), and the Tertiary of central Europe (Thomson & Pflug, 1953).

Suggested affinity: Caprifoliaceae according to Stanley (1965).

Discussion: The new combination given above results only from personal preference of the genus Tricolporopollenites over Rhoipites.

Tricolporopollenites distinctus Groot & Penny

Plate 11, Figures 13-16

1960 Tricolporopollenites distinctus Groot & Penny, p. 234, pl. 2, fig. 10.

1961 *Tricolporopollenites subtilis* Groot, Penny & Groot, p. 134, pl. 26, figs. 22-23.

1966 non *Tricolporopollenites distinctus* Groot & Penny: In Burger, p. 268, pl. 37, fig. 2.

Description: Groot, Penny & Groot (1961) separated this taxon into two species based on the nature of the pore. This separation is not apparent in the material examined for this study; the pores simply range from indistinct up to 2 microns in diameter, and the pore shape depends on the state of inflation of the grains and focal plane in the exine at which they are viewed. The exine is two-layered with the tectum in some specimens appearing perforate.

Size range: 8-16 microns; 65 specimens measured.

Occurrences: Cenomanian to Maastrichtian. Present in samples from 3 of the localities studied; Highlands (up to 11%), Marlboro section (5-38%), and the Poricy Brook section (20-64%); Mt. Laurel, Navesink, and Red Bank fms. Absent from the remaining two, more marine localities. Elsewhere this species is known from the Cenomanian to Campanian of the eastern United States (Groot & Penny, 1960 and Groot, Penny & Groot, 1961).

Suggested affinity: ?*Castanea*.

Discussion: Several other taxa closely resemble the above taxon; e.g., *Castanea insleyana* Traverse (1955), *Castanea crenataeformis* Samigulena (in Pokrovskaya & Stel'mak, 1960), *Pollenites exactus* Potonie (1931), *Cupuliferoipollenites pusillus* Potonie (1951), and *Psilatricolporites prolatus* Pierce (1961). These taxa, however, are not placed in synonymy here with *T. distinctus* since they are widely separated both stratigraphically and geographically, and because the small size of the grains limit the precision of the resolution of morphologic features. The tricolporate form refered to this species by Burger (1966) from the Early Cretaceous of the Netherlands is larger than the known size range for this species, and is possibly a contaminant.

Tricolporopollenites granulocuneus Phillips & Felix

Plate 11, Figure 12

1971b *Tricolporopollenites granulocuneus* Phillips & Felix, p. 468, pl. 16, figs. 1-3.

Description: See Phillips & Felix (1971b).

Size range: 31 microns; 1 specimen measured. Size given in Phillips & Felix is 21-31 microns.

Occurrences: Cenomanian to Maastrichtian. 1 specimen only from the Red Bank Fm. at the Atlantic Highlands locality. Previously reported from the Cenomanian of Louisiana (Phillips & Felix, 1971b).

Suggested affinity: Uncertain.

Tricolporopollenites inductorius Chmura

Plate 11, Figures 24-27

1973 *Tricolporopollenites inductorius* Chmura, p. 124, pl. 26, figs. 1-4.

Description: See Chmura (1973).

Size range: 17-22 microns; 6 specimens measured.

Occurrences: Campanian to Maastrichtian. 12 specimens from 8 samples, Mt. Laurel, Navesink and Red Bank fms. from the localities at Highlands, Marlboro, and Poricy Brook. Previously known from the Campanian-Maastrichtian of California (Chmura, 1973).

Suggested affinity: Chmura (1973) compares *T. inductorius* to pollen of the extant species *Ximenia americana* (Olacaceae).

Tricolporopollenites inusitatus Chmura

Plate 11, Figures 17-18

1973 *Tricolporopollenites inusitatus* Chmura, p. 125, pl. 26, figs. 8-11.

Description: Specimens found in this study are confined to the small end of the size range, and are more spheroidal in shape; otherwise as given in Chmura (1973).

Size range: 18-22 microns; 4 specimens measured.

Occurrences: Campanian to Maastrichtian. 4 specimens from 3 samples, Red Bank fm. from the Highlands locality. Previously known from the Campanian to Maastrichtian of California.

Suggested affinity: Chmura (1973) compares this taxon with pollen of modern species of *Gyrostemon* and *Tersonia* (Gyrostemonaceae).

Tricolporopollenites labiatus Gray & Groot

Plate 11, Figures 19-23

1966 *Tricolporopollenites labiatus* Gray & Groot, p. 128, pl. 43, figs. 7-9.

Description: See Gray & Groot (1966).

Size range: 18-36 microns; 18 specimens measured.

Occurrences: Santonian to Maastrichtian. Present in all but two samples from the Highlands, Marlboro, and Poricy Brook localities, Mt. Laurel, Navesink, and Red Bank fms. Previously known from the Santonian to Maastrichtian of Delaware and New Jersey (Gray & Groot, 1966).

Suggested affinity: ?Nyssaceae according to Gray & Groot (1966).

Tricolporopollenites lihokus (Srivastava) comb. nov.

Plate 11, Figures 34-36

1967 *Tricolporopollenites kruschii scutellatus* (Potonie) Krutzsch, in Drugg, p. 50, pl. 7, fig. 43.

1968b *Tricolporopollenites kruschii* (Potonie) Thomson & Pflug, in Elsik (pars), p. 628, pl. 32, figs. 4-5 only.

1972b *Margocolporites lihokus* Srivastava, p. 264, pl. 20, figs. 3-5.

1973 *Tricolporopollenites kruschii* scutellatus (Potonie) Krutzsch, in Chmura, p. 126, pl. 26, figs. 12-16.

Description: The shape varies from spheroidal to prolate; otherwise as given in Srivastava (1972b).

Size range: 42-54 microns; 3 specimens measured.

Occurrences: Campanian to Paleocene. 6 specimens from 6 samples, Mt. Laurel, Navesink and Red Bank fms. Elsewhere this taxon has been reported from the Campanian to Danian of California (Drugg, 1967 and Chmura, 1973) and the Paleocene of Alabama (Srivastava, 1972b) and Texas (Elsik, 1968b).

Suggested affinity: Staphyleaceae according to Chmura (1973).

Tricolporopollenites parvus (Groot & Groot) comb. nov.

Plate 11, Figures 28-33

1962b *Ilexpollenites parvus* Groot & Groot, p. 168, pl. 30, figs. 26-30.

Description: See Groot & Groot (1962).

Size range: 10-21 microns; 12 specimens measured.

Occurrences: Maastrichtian to Paleocene. Found in 13 samples up to 2%, Mt. Laurel, Navesink, and Red Bank fms. from the localities at Highlands, Marlboro, and Poricy Brook. Previously reported from the Paleocene of Maryland (Groot & Groot, 1962b).

Suggested affinity: Dicotyledonae. Groot & Groot (1962b) suggest *Ilex* for an affinity, however, the pollen of that genus does not have reticulate ornamentation. For the same reason the form genus *Ilexpollenites* is not suitable for this taxon.

Tricolporopollenites venustus Chmura

Plate 11, Figures 37-39

1973 *Tricolporopollenites venustus* Chmura, p. 127, pl. 26, figs. 17-18.

Description: See Chmura (1973).

Size range: 13-18 microns; 9 specimens measured.

Occurrences: Campanian to Maastrichtian. 12 specimens from 6 samples, Navesink and Red Bank fms., from the Highlands and Poricy Brook localities. Previously reported from the Campanian-Maastrichtian of California (Chmura, 1973).

Suggested affinity: According to Chmura, *T. venustus* resembles pollen of *Athyana weinmannifolia* and *Sapindus sapinaria* both extant species of the Sapindaceae.

Tricolporopollenites viriosus Chmura

Plate 12, Figures 1-3

1969 Tricolporate type 6 Doyle, p. 19, fig. 5j and k.

1973 *Tricolporopollenites viriosus* Chmura, p. 128, pl. 27, fig. 4-8.

Description: See Chmura (1973).

Size range: 22-28 microns; 5 specimens measured.

Occurrences: Santonian to Maastrichtian. 5 specimens from 4 samples, Mt. Laurel and Navesink fms. Elsewhere this taxon has been reported from the Santonian of New Jersey (Doyle, 1969) and the Campanian to Maastrichtian of California (Chmura, 1973).

Suggested affinity: Nyssaceae or Cornaceae according to Doyle (1969, p. 20).

Genus *Triporopollenites* Pflug in Thomson & Pflug, 1953

Type species: *Triporopollenites coryloides* Pflug, in Thomson & Pflug, 1953

Triporopollenites cf. *T. granifer* (Potonie) comb. nov.

Plate 12, Figures 8-10

1931 *Pollenites granifer* Potonie, p. 332, tab. 1, fig. 18.

Description: Specimens placed in this taxon resemble Potonie's species in all features except for their smaller size. Best descriptions are found in Potonie (1934) and Potonie & Venitz (1934).

Size range: 12-22 microns; 10 specimens measured.

Occurrences: Late Cretaceous and Tertiary. Found in 13 samples, Mt. Laurel, Navesink, and Red Bank fms. Present in all samples from the Highlands locality (0.7-2.4%), 4 samples from the Marlboro locality, and 2 samples from the Poricy Brook locality. Although not well known from the literature, *T. granifer* and numerous similar taxa are found worldwide in late Cretaceous and Cenozoic sediments.

Suggested affinity: Potonie (1934) compares *T. granifer* to extant species of *Carpinus*, *Myrica*, and *Coriaria*.

Discussion: The pore anuli are less developed in cf. *T. granifer* than in cf. *T. robustus* for specimens from this study.

Triporopollenites cf. *T. robustus* Pflug in Thomson & Pflug

Plate 12, Figures 4-7

1953 *Triporopollenites robustus* Pflug in Thomson & Pflug, p. 82, pl. 8, figs. 109-149.

Description: Specimens examined in this study resemble Pflug's in all features except for their smaller size.

Size range: 14-22 microns; 33 specimens measured.

Occurrences: Late Cretaceous and Tertiary. Found in three of the localities studied, Mt. Laurel, Navesink, and Red Bank fms. Samples from the Poricy Brook locality varied from 1.5-6.0%, Highlands locality, 0.8-28.4%, and the Marlboro locality, up to 3.0% (not present in lowest 2 samples). Elsewhere this taxon is known from numerous studies worldwide.

Suggested affinity: ?Betula, ?Corylus.

Discussion: Elsik (1968, p. 610) placed T. robustus into T. bituitus (Potonie) Elsik along with numerous other simple triporate forms. This synonymy is here considered too broad a category.

Division-Incertae sedis

Genus Schizosporis Cookson & Dettmann, 1959

Type species: Schizosporis reticulatus Cookson & Dettmann, 1959

Schizosporis reticulatus Cookson & Dettmann

Plate 12, Figure 11

1959 Schizosporis reticulatus Cookson & Dettmann, p. 213, pl. 1, figs. 1-4.

Description: See Cookson & Dettmann (1959).

Size range: 90-136 microns; 3 specimens measured.

Occurrences: Cretaceous. 3 specimens from 3 samples, Mt. Laurel and Red Bank fms. Elsewhere this taxon is well known from numerous Cretaceous studies (see Singh, 1971, p. 151, for distribution).

Suggested affinity: Uncertain. According to Cookson & Dettmann (1959), spores of the genus Schizosporis have an equatorial line or furrow along which a separation into two approximately equal parts may take place. This same phenomenon occurs in certain angiospermous species, and could suggest a possible affinity. Brenner (1963) proposes an algal affinity for S. reticulatus (e.g. Chlorophyceae).

PALEOENVIRONMENTAL ASPECTS OF THE MONMOUTH GROUP

Presentation of Paleoenvironmental Data

All paleoenvironmental aspects determined from this study have been derived from palynomorph counts. All data obtained from palynomorph counts are presented in Table 3 where relative percents of taxa and taxonomic groups are given for samples organized by localities. Also indicated are those taxa previously known only from older or younger strata (i.e., stratigraphic range extensions), and those considered as possibly reworked. Taxa not counted, but known to occur in samples are indicated by black dots. Occurrences and percentages of spores and pollen are given in Tables 3a and 3b respectively. Data for the gymnosperms and dinoflagellates are provided in Table 3c along with other summary information, including percentages of land derived taxa and microplankton, land derived/microplankton ratios, and the data from separate 100 counts of certain dinoflagellate associations.

Those taxa occurring in relative abundances of 5% or greater in more than two samples were arbitrarily selected from Table 3, and are considered to represent the most dominant forms. Percentages for these taxa are graphically displayed in Figure 5. While certain of these categories represent single species such as *Gleicheniidites senonicus*, *Triporopollenites* cf. *T. robustus*, *Canningia* sp., and *Palaeoperidinium* sp., others consist of multiple species which were combined in order to facilitate identifications or interpretations: *Stereisporites* spp., *Rugubivesiculites* spp., *Pinuspollenites* spp. and the *Deflandrea* assoc. represent all species of the respective genera. *Tricolporopollenites distinctus* may to a minor extent be represented by *Tricolporopollenites cingulum* since these species have overlapping features. The *Areoligera* association comprises species from the genera *Areoligera*, *Cyclonephelium*, and *Systematophora*, and the *Spiniferites* association is composed of species of *Hystrichosphaeridium*, operculodinioid forms, and *Spiniferites* (*Hystrichosphaera*). Illustrated examples of the dinoflagellate genera represented are shown in Plates 12-14.

Figure 6 contains diagrams for the Marlboro, Poricy Brook, Highlands and Pine Brook sections. While relations are not definite, and some duplicate or missing section possibly exists, the three lower outcrops are shown here in a stacked relationship which is only intended as a general fit. Indicated on this figure are plots of percent land derived vs. percent microplankton, land derived/microplankton ratios (after Upshaw, 1964), the dinoflagellate associations related to each other based on the separate 100 counts, and plots derived from values consisting of the percent of the *Areoligera* association subtracted from the *Deflandrea* association. The *Deflandrea* minus *Areoligera* plots are intended to better show transgressive-regressive trends for comparison with the modified examples from Owens and Sohl (1969). Along with a change in vertical scale, their curve is here shown in reversed order to present the trends in their more usual form.

Figure 7 presents the same diagrams given in Figure 6, but for the Atlantic Highlands locality. In addition, the *Deflandrea* minus *Areoligera* plot is compared to that of the Poricy Brook section. These two plots are placed along side the transgressive-regressive trends of Owens and Sohl (1969).

Table 3a: List of occurrences and percentages for the bryophytes and pteridophytes.

▲ TAXON POSSIBLY REWORKED
+ REPORTED PREVIOUSLY ONLY FROM OLDER SEDIMENTS
O REPORTED PREVIOUSLY ONLY FROM YOUNGER SEDIMENTS

LOCALITY	FORMATION	NO. SPECIMENS COUNTED	SAMPLE NO.	FORAMINISPORIS DAILYI	STEREISPORITES AUSTRALIS	STEREISPORITES CONGRUENS	STEREISPORITES CRISTALLOIDES	STEREISPORITES DAKOTAENSIS	STEREISPORITES REGIUM	STEREISPORITES STEREOIDES	CAMAROZONOSPORITES ANULATUS	CAMAROZONOSPORITES CANALICULATUS	CAMAROZONOSPORITES CAPERATUS	CAMAROZONOSPORITES CERNIIDITES	CAMAROZONOSPORITES HESKEMENSIS	CAMAROZONOSPORITES VERMICULAESPORITES	FOVEASPORIS TRIANGULUS	FOVEOSPORITES LABIOSUS	FOVEOSPORITES SUBTRIANGULARIS	LYCOPODIUMSPORITES AUSTROCLAVATIDITES	SESTROSPORITES PSEUDOALVEOLATUS	DENSOISPORITES MICRORUGULATUS	LUSATISPORIS CIRCUMUNDULATUS	OSMUNDACIDITES COMAUMENSIS	GOCZANISPORIS BACULATUS	TODISPORITES MAJOR	TODISPORITES MINOR	CICATRICOSISPORITES DOROGENSIS	CICATRICOSISPORITES HALLEI	RADIALISPORIS RADIATUS	CONCAVISPORITES ARUGULATUS	GLEICHENIIDITES SENONICUS	DICTYOPHYLLIDITES EQUIEXINUS	DICTYOPHYLLIDITES HARRISII	MATONISPORITES CRASSIANGULATUS	MATONISPORITES EXCAVATUS	CYATHIDITES MINOR	KUYLISPORITES ADUNCUS	ASBECKIASPORITES SP.	CONVERRUCOSISPORITES PROXIGRANULATUS	DISTALTRIANGULISPORITES PERPLEXUS	LEPTOLEPIDITES TENUIS	LEPTOLEPIDITES VERRUCATUS	TORIPUNCTISPORIS GRANULOIDES	TRIZONITES SUBRUGULATUS	TRILETE SP. 1	TRILETE SP. 2	TRILETE SP. 3	LAEVIGATOSPORITES HAARDTI	VERRUCATOSPORITES SAALENSIS
				▲+		▲+								+		+	O	+	+		▲+	▲+	+				+		▲+					▲+	▲+	▲+				▲+	▲		▲+	O	+					
PINE BROOK	TINTON	250	Pb-9394							0.4	0.4																	1.2				5.2					0.8											●	0.4	
		250	Pb-9393							0.4	0.4				●				●												0.4					0.4											0.4	●	
		250	Pb-9392								●											●									2.4					●							0.4					
		250	Pb-9391						●		●																				0.8					0.4												
		250	Pb-9390								●																●				0.8																	●	
ATLANTIC HIGHLANDS	RED BANK	100	Pb-9376							5.0	5.0	1.0																			2.0					1.0							2.0						
		21	Pb-9377								●																				●																	
		250	Pb-9378				●			0.4																					1.2					●										●		
		250	Pb-9379							●	0.4															●					0.8	●	●			0.4							0.4				0.4	0.4	
		250	Pb-9380				●			0.4	●																																				
	NAVESINK	250	Pb-9381							0.4																					●					●											0.4	
		250	Pb-9382				●		●	0.8	●	●	●	●									●				2.0		●		0.4					●		●					●					●	
		250	Pb-9383						●	1.6	●																				0.8							●										
		250	Pb-9384		●			0.4	●	●	●	●		●													●	●				0.8					0.8											0.4		
HIGHLANDS	RED BANK	250	Pb-9466					0.8			0.4	1.6	0.4										0.4							●	0.4	8.0		●			3.2							2.8				0.4	3.2	
		250	Pb-9465					●		0.4		0.4											0.4			●	0.4				●	6.8	●				2.8		0.4			0.8		0.8					2.4	
		250	Pb-9464							0.4		●															0.4					5.2		●			2.8							0.4					0.4	●
		250	Pb-9463									0.4	●														●					4.4		●			1.6		0.4			0.4		●					2.0	●
		250	Pb-9462	●						0.4		0.4	0.4														1.2				●	3.2		●			2.0					0.4		0.4					0.8	●
		250	Pb-9461		0.4			0.4		2.8		1.6	1.2		0.4								0.4				5.2				0.4	7.2		0.4			4.4		0.4		●			●					5.6	
		150	Pb-9460					●		1.3		2.7			0.7												5.3				1.3	6.0	0.7	0.7			4.0		0.7			●							4.0	
PORICY BROOK	RED BANK	250	Pb-9453				●	●			●	●	●							●		●										1.2		●			●						●	●						0.4	
		250	Pb-9454					●															●				●	●				2.0					●									●			0.4	
		250	Pb-9455		●					0.8	0.4	0.4	●		0.4		●											●			●	0.8					●												●	
		100	Pb-9456					1.0		5.0	1.0	●																●		●		3.0	●				●								●				1.0	
	NAVESINK	250	Pb-9457				●	0.4		2.0	●	●			0.4	●					●				●		0.8	●	●		0.4	3.6					●								●			0.4	0.8	
		200	Pb-9458				●	0.5		●	0.5	0.5			1.0													●	●	1.0		2.5					0.5	0.5											
		250	Pb-9459		●			1.2		3.6	0.4	0.4	0.4	0.4	0.4				●		●		●				0.4			0.4	0.8	4.4		●			0.4									0.4		●	0.4	
MARLBORO	NAVESINK	250	Pb-9452				●	●		0.4	●	●	●		0.8									●	●				●			0.4	●				●		●										●	
		250	Pb-9451					●	0.4	2.4	●	●			0.4	●								●			●	●		●		0.4														●		0.8		
	MT. LAUREL	250	Pb-9450		0.4			●		1.2	●	●	●		●					●										●		1.2			●		●		●			●			●			●	0.4	
		200	Pb-9449					0.5		2.5	●	●			1.0								0.5									3.5					●				●				0.5	0.5		0.5		
		250	Pb-9448		0.4		●		●	6.0	●				●	●				●								●				1.2	●				0.4	●	●						0.4				1.2	
		200	Pb-9447		0.5			●		4.5	●				●								1.5		●			●				2.5	●					0.5			0.5				0.5		●		1.5	
		250	Pb-9446		6.8	0.8		2.0	●	13.2	0.4	0.4		0.4	0.8			●					1.6	0.4		0.4	1.2	●	●			7.6			●	●	1.2	●		●	0.8				●	0.8	0.8		6.0	
		100	Pb-9445	●	1.0	3.0				13.0			●			●				●			●			●						6.0		●			●	●								●	●		3.0	
		100	Pb-9444		6.0	●		2.0	●	11.0					2.0									●			2.0	●	1.0			2.0					2.0			●	1.0			●		1.0	1.0		3.0	

Table 3b: List of occurrences and percentages for the angiosperms.

▲ TAXON POSSIBLY REWORKED
+ REPORTED PREVIOUSLY ONLY FROM OLDER SEDIMENTS
○ REPORTED PREVIOUSLY ONLY FROM YOUNGER SEDIMENTS

LOCALITY	FORMATION	NO. SPECIMENS COUNTED	SAMPLE NO.	SPARGANIACEAEPOLLENITES SP.	MOMIPITES INAEQUALIS	MOMIPITES MICROCORYPHAEUS	MOMIPITES TENUIPOLUS	PROTEACIDITES MARGINUS	PROTEACIDITES RETUSUS	PROTEACIDITES THALMANNI	PROTEACIDITES SP.	CUPANIEIDITES SP.	INSULAPOLLENITES RUGULATUS	NYSSAPOLLENITES PUERCOENSIS	GUNNERITES RETICULATUS	CLAVATIPOLLENITES HUGHESII	EXTRATRIPOROPOLLENITES MINIMUS	EXTRATRIPOROPOLLENITES NONPERFECTUS	EXTRATRIPOROPOLLENITES SILICATUS	EXTRATRIPOROPOLLENITES THORNEI	EXTRATRIPOROPOLLENITES SP.	HOLKOPOLLENITES CHEMARDENSIS	MONOCOLPOPOLLENITES ASYMMETRICUS	RETITRICOLPITES GEORGENSIS	TRICOLPITES ANGULOLUMINOSUS	TRICOLPITES PARVUS	TRICOLPOPOLLENITES MICROMUNUS	TRICOLPOPOLLENITES MICROPUNCTATUS	TRICOLPOPOLLENITES SIMPLICISSIMUS	TRICOLPOROPOLLENITES CINGULUM	TRICOLPOROPOLLENITES CRYPTOPORUS	TRICOLPOROPOLLENITES DISTINCTUS	TRICOLPOROPOLLENITES GRANULOCUNEUS	TRICOLPOROPOLLENITES INDUCTORIUS	TRICOLPOROPOLLENITES INUSITATUS	TRICOLPOROPOLLENITES LABIATUS	TRICOLPOROPOLLENITES LIHOKUS	TRICOLPOROPOLLENITES PARVUS	TRICOLPOROPOLLENITES VENUSTUS	TRICOLPOROPOLLENITES VIRIOSUS	TRIPOROPOLLENITES CF. T. GRANIFER	TRIPOROPOLLENITES CF. T. ROBUSTUS	SCHIZOSPORIS RETICULATUS
						○							○			▲ +					+	○	▲ +	▲ +				+		○		+	▲ +			+		○					▲ +
PINE BROOK	TINTON	250	Pb-9394					0.4														●									0.4												
		250	Pb-9393																					●																			
		250	Pb-9392					●																							●												
		250	Pb-9391								●							●				●																					
		250	Pb-9390																			●									●												
ATLANTIC HIGHLANDS	RED BANK	100	Pb-9376												1.0							●																					
		21	Pb-9377																																								
		250	Pb-9378										●																		0.4		●										
		250	Pb-9379												●									●														●							
		250	Pb-9380	●																																							
	NAVESINK	250	Pb-9381																																								
		250	Pb-9382	●									●										●			●																	
		250	Pb-9383																																								
		250	Pb-9384							●													●								●									●			
HIGHLANDS	RED BANK	250	Pb-9466	1.2	2.4	2.4	●			●					0.4		●	1.2								10.4	0.4		0.8			2.0				1.2	0.4	2.0	●		2.0	10.0	
		250	Pb-9465		0.8	1.6				●	●							2.0								1.2						●			●	0.4	0.4	0.4			1.2	7.6	
		250	Pb-9464	2.0		0.8												●														●			●	0.4		●			0.8	1.6	0.4
		250	Pb-9463	●	0.8	2.0	0.4							●				0.8								2.4	0.4					0.8						0.4			2.4	10.4	
		250	Pb-9462	0.8	0.8	0.4										●	0.4	●	●							0.4						1.6			●	●		0.4	●		0.8	0.8	
		250	Pb-9461	1.6	2.4	5.2	0.8							●			0.4	0.8		0.4						3.2	0.4		0.8			8.0		●		2.4		2.0	0.4		1.2	26.4	0.4
		150	Pb-9460		5.3	2.0	0.7											1.3							0.7	4.0					0.7	10.7				2.0					0.7	13.3	
PORICY BROOK	RED BANK	250	Pb-9453		1.2	1.6	0.8	0.8						●			1.2					●		●		2.0	0.4	1.6	1.6		●	44.0		0.4		0.8	●	0.4	0.8			1.6	
		250	Pb-9454		0.4		0.4			●						0.4	0.8					●				0.4		1.2	2.8	●	●	37.2				0.4	●				0.4	1.6	
		250	Pb-9455		1.6		2.0	●	●								1.2	●		0.4		●				0.4	0.4	0.4	0.4	●		68.0				0.8					●	2.4	
		100	Pb-9456		2.0			●									1.0				●	●	●		●	1.0		●	1.0			59.0				2.0		2.0	●			6.0	
	NAVESINK	250	Pb-9457		3.6	0.8											1.6	0.4					●	0.4				●	2.0	●		64.0		0.4		1.6		0.8	2.0			2.8	
		200	Pb-9458		3.5	0.5	0.5	0.5	●				0.5											0.5		1.5	1.0		2.0			39.0		0.5		1.0		2.0				1.5	
		250	Pb-9459		2.0	1.2	0.4	0.4	●					●		0.4	1.2					●				0.8	0.4		2.0			19.6				1.2		0.8				2.0	
MARLBORO	NAVESINK	250	Pb-9452		0.4	0.4	0.4						●	●					0.4							0.8			0.4	●	●	5.2					●					0.8	
		250	Pb-9451		0.4									●				●								0.4						14.8				0.4						1.6	
	MT. LAUREL	250	Pb-9450		0.4	0.8	0.4					●										●	●			1.2			●	●		24.4										2.0	
		200	Pb-9449			0.5	1.5							●															4.0		0.5	27.5				1.0	●				0.5	1.0	
		250	Pb-9448		0.4	2.0		0.4	0.4	●			●							●	●		●	0.4		2.8			0.8	●	0.4	34.4		0.8		1.2				●		2.4	
		200	Pb-9447			1.0	0.5		0.5								1.0			●		●	●	0.5		3.0			1.0	●	●	37.5		●		0.5		2.0		●	0.5	3.0	●
		250	Pb-9446		0.8	0.4	2.0		1.2			●		●	0.4		2.0		0.8	●		●		0.4		0.4		●	0.4	●	0.8	10.4		●		3.6		1.2		0.4	1.2	1.2	
		100	Pb-9445		●	1.0	1.0									●	7.0		1.0			●		●		1.0	1.0	2.0	4.0	●	1.0	21.0		1.0		●					2.0		
		100	Pb-9444				1.0					●					2.0		1.0	1.0		●	●	1.0					1.0		1.0	27.0											

Table 3c: List of occurrences and percentages for the gymnosperms and dinoflagellates, the percentages of land-derived and microplankton groups, and percentages for the dinoflagellate associations.

▲ TAXON POSSIBLY REWORKED
+ REPORTED PREVIOUSLY ONLY FROM OLDER SEDIMENTS
○ REPORTED PREVIOUSLY ONLY FROM YOUNGER SEDIMENTS

LOCALITY	FORMATION	NO. SPECIMENS COUNTED	SAMPLE NO.	CLASSOPOLLIS CLASSOIDES	PARVISACCITES RADIATUS	PHYLLOCLADIDITES INCHOATUS	PODOCARPIDITES POTOMACENSIS	RUGUBIVESICULITES CONVOLUTUS	RUGUBIVESICULITES REDUCTUS	RUGUBIVESICULITES RUGOSUS	ARAUCARIACITES AUSTRALIS	PINUSPOLLENITES SPP.	TAXODIACEAEPOLLENITES HIATUS	PERINOPOLLENITES HALONATUS	EUCOMMIIDITES TROEDSSONII	AREOLIGERA-CYCLONEPHELIUM SPP.	CANNINGIA SPP.	DEFLANDREA SPP.	SPINIFERITES SPP.	HYSTRICHOSPHAERIDIUM SPP.	OPERCULODINIOID TAXA	PALAEOPERIDINIUM SP.	SYSTEMATOPHORA SP.	OTHER DINOFLAGELLATE TAXA	TOTAL % SPORES	TOTAL % GYMNOSPERMS	TOTAL % ANGIOSPERMS	TOTAL % LAND-DERIVED	TOTAL % MICROPLANKTON	L-D/M RATIO	NO. SPECIMENS COUNTED	DEFLANDREA ASSOC.	SPINIFERITES ASSOC.	AREOLIGERA ASSOC.	DEFLANREA ASSOC. MINUS AREOLIGERA ASSOC.
				▲+	+	+	▲+	+	+					▲+	▲+																				
PINE BROOK	TINTON	250	Pb-9394		0.4				2.4	4.8	0.4	10.8				11.6	0.4	9.2	10.8	14.8	0.8	3.6	9.2	11.6	8.6	18.8	0.8	28.2	72.0	0.39	100	9	52	39	-30
		250	Pb-9393						0.4	2.4		2.4				14.8	0.4	11.2	9.2	8.0	0.4	24.0	14.4	10.4	2.0	5.2	0.0	7.2	92.8	0.08	100	11	36	53	-42
		250	Pb-9392						2.8	1.2		4.8				19.6	0.8	10.8	4.8	2.4	0.8	16.0	22.0	11.2	2.8	8.8	0.0	11.6	88.4	0.14	100	10	21	69	-59
		250	Pb-9391							2.8		1.6		●		24.0	0.4	10.4	3.2	2.0		17.6	25.2	11.6	1.2	4.4	0.0	5.6	94.4	0.06	100	7	10	83	-76
		250	Pb-9390		0.4				1.2	2.4		2.4				30.4		8.4	6.4	8.0	0.8	8.8	17.6	12.4	0.8	6.4	0.0	7.2	92.8	0.08	100	12	18	70	-58
ATLANTIC HIGHLANDS	RED BANK	100	Pb-9376		3.0	2.0		1.0	15.0	22.0		31.0						3.0						6.0	16.0	74.0	1.0	91.0	9.0	10.0	14	93	7	0	+93
		21	Pb-9377		●				●	●		●								●	●		●	●							0				
		250	Pb-9378		0.8	0.8			1.2	8.0	0.4	11.6	1.2			8.0	2.4	12.0	10.8	3.6	6.0	1.2	12.0	18.0	1.6	24.0	0.4	26.0	74.0	0.35	100	24	39	37	-13
		250	Pb-9379		0.4				1.6	3.2	0.4	8.0	0.8			4.4		8.4	12.0	4.8	24.8	0.4	11.2	16.8	2.8	14.4	0.0	17.2	82.8	0.21	100	17	52	31	-14
		250	Pb-9380		0.4			1.2		0.8	0.4	3.2				57.2		4.4	3.6	2.8	13.6	0.4	4.0	7.6	0.4	6.0	0.0	6.4	93.6	0.07	100	5	21	74	-69
	NAVESINK	250	Pb-9381					●	0.4	2.4	0.4	4.0	0.4			34.0	0.4	8.4	4.8	1.2	19.6	2.4	12.4	8.4	0.8	7.6	0.0	8.4	91.6	0.09	100	3	35	62	-59
		250	Pb-9382		●			●	0.4	1.6		2.4				8.0		8.0	29.2	9.2	14.8		8.4	14.8	3.2	2.4	0.0	5.6	94.4	0.06	100	4	70	26	-22
		250	Pb-9383		●				0.4	2.0		6.8				6.8		18.0	10.4	12.4	17.2	2.0	0.8	20.8	2.4	9.2	0.0	11.6	88.4	0.13	100	13	72	15	-2
		250	Pb-9384		0.4				2.8	3.6		9.2				8.4	0.8	14.8	13.2	8.4	12.8	15.6	0.4	7.2	2.4	16.0	0.0	18.4	81.6	0.22	100	25	56	19	+6
HIGHLANDS	RED BANK	250	Pb-9466			●		0.4		1.6	0.4	2.4	0.8			●		35.6						0.4	21.6	5.6	36.8	64.0	36.0	1.8	100	100	0	0	+100
		250	Pb-9465		0.4					0.4		●	0.4			0.4		66.8						0.4	15.6	1.2	15.6	32.4	67.6	0.5	100	100	0	0	+100
		250	Pb-9464									0.4						82.0						2.0	9.6	0.4	6.0	16.0	84.0	0.2	100	100	0	0	+100
		250	Pb-9463				●	●		●		1.6	0.4					67.6						0.4	9.2	2.0	20.8	32.0	68.0	0.5	100	100	0	0	+100
		250	Pb-9462									●						82.4						2.0	9.2	0.0	6.4	15.6	84.4	0.2	100	100	0	0	+100
		250	Pb-9461							0.4	0.4	1.2						5.6						4.8	30.8	2.0	56.8	89.6	10.4	8.6	100	100	0	0	+100
		150	Pb-9460								0.7	2.7	0.7					20.0						7.3	27.3	4.0	41.3	72.6	27.3	8.6	100	100	0	0	+100
PORICY BROOK	RED BANK	250	Pb-9453		0.4	●		●	0.8	1.2		4.0	0.8				1.6	28.8			1.2			0.4	1.6	7.2	59.2	68.0	32.0	2.1	100	97	3	0	+97
		250	Pb-9454	0.4	0.8		●	●		2.0	●	3.6					2.0	39.2		0.4	1.6	●		1.6	2.4	6.8	46.0	55.2	44.8	1.2	100	93	5	2	+91
		250	Pb-9455		0.4			●		1.6	●	4.0	1.2				1.2	6.8	0.8	●	0.4			2.8	2.8	7.2	78.0	88.0	12.0	7.3	100	64	30	6	+58
		100	Pb-9456					●		1.0	●	1.0	3.0	●		●	2.0	2.0	●	●	●		●	6.0	11.0	5.0	74.0	90.0	10.0	9.0	100	35	53	12	+23
	NAVESINK	250	Pb-9457	0.4		●		●	●	1.2	0.4	1.6	2.8				●	2.4			1.2			0.8	8.8	6.4	80.4	95.6	4.4	21.7	100	52	46	2	+50
		200	Pb-9458						●	6.0	2.5	3.0	2.5			3.5	1.5	7.5	2.5	●	4.5	●	0.5	4.5	7.0	14.0	54.5	75.5	24.5	3.1	100	19	62	19	0
		250	Pb-9459		●	●				0.8	1.6	4.4	3.2			4.4	11.6	6.8	4.8	●	5.6	0.4	1.6	8.4	14.0	10.0	32.4	56.4	43.6	1.3	100	12	68	20	-8
MARLBORO	NAVESINK	250	Pb-9452			●	●		●	4.0	3.6	3.6	0.4			6.4	4.0	1.2	7.2	3.6	10.4	●	2.4	42.8	1.6	11.6	8.8	22.0	78.0	0.28	100	8	52	40	-32
		250	Pb-9451		●	●		●	●	3.2	0.8	3.6	1.2	0.4		20.0	8.4	6.4	7.2	5.2	12.0			9.6	17.6	9.2	4.4	31.2	68.8	0.45	100	6	39	55	-49
		250	Pb-9450	0.4	1.2			●	●	2.4	0.4	5.6	0.8	●		0.8	19.2	11.6	4.0	1.6	3.2	0.4		16.0	29.2	10.8	3.2	43.2	56.8	0.78	100	35	54	11	+24
	MT. LAUREL	200	Pb-9449						●	2.5	1.5	0.5	4.0			6.0	9.5	8.0	7.0	2.5	4.0	●	●	8.5	10.0	8.5	36.5	55.0	45.0	1.2	100	32	57	11	+21
		250	Pb-9448					●		5.6		4.0	7.6	0.8		0.4	6.8	4.4	0.8		0.4	●		13.2	9.6	18.0	46.4	74.0	26.0	2.8	100	93	7	0	+93
		200	Pb-9447	●	●	●		●	●	6.5	1.0	3.0	2.5	●			8.5	4.5	●		0.5	0.5		10.0	12.0	13.0	51.0	76.0	24.0	3.2	100	81	18	1	+80
		250	Pb-9446		1.6		0.4		3.2	9.2	1.6	6.0	4.0		●			0.4	●					0.4	45.6	26.0	27.6	99.2	0.8	124.0	24	67	33	0	+67
		100	Pb-9445						●	8.0	●	7.0	12.0			1.0			1.0					2.0	26.0	27.0	43.0	96.0	4.0	24.0	17	72	22	6	+66
		100	Pb-9444						●	11.0	1.0	11.0	2.0			1.0		●	1.0	2.0				2.0	34.0	25.0	35.0	94.0	6.0	15.7	26	54	42	4	+50

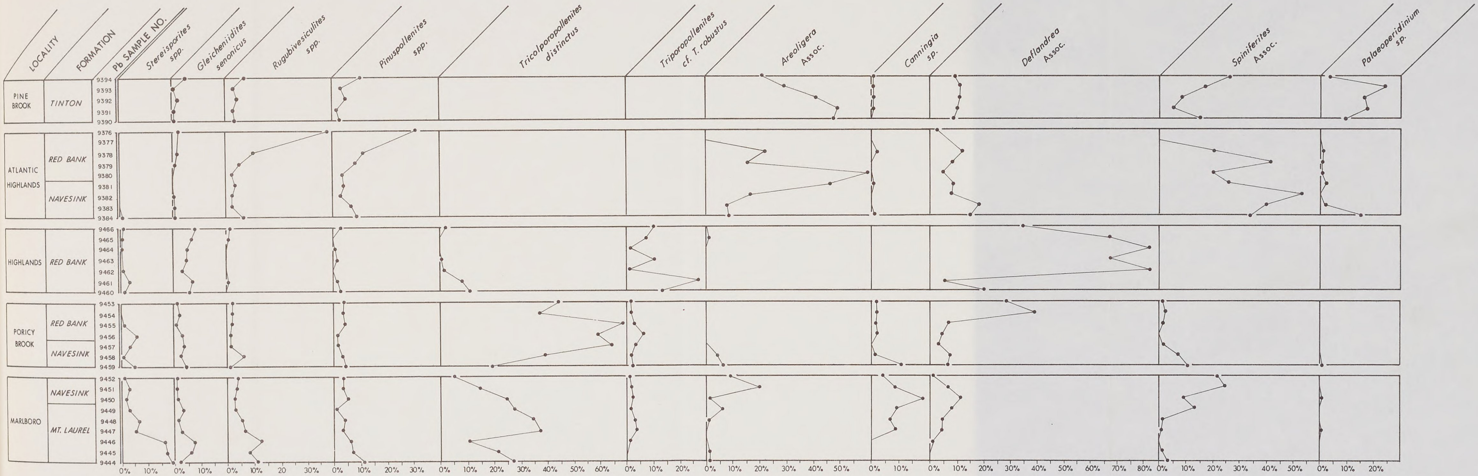

Figure 5: Curves for taxa from the Monmouth Group found in excess of 5% in more than three samples.

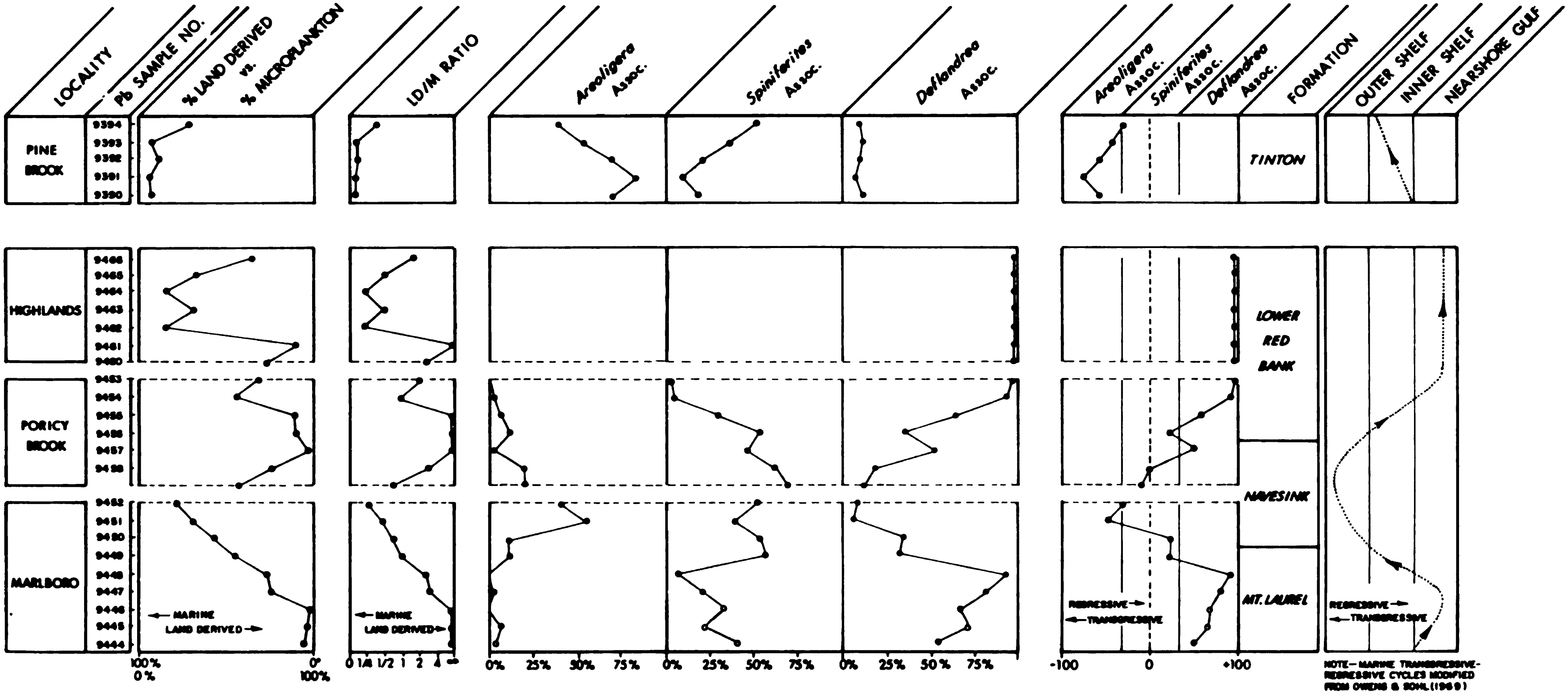

Figure 6: Land-derived/Microplankton curves, dinoflagellate associations, and the Deflandrea minus Areoligera plots for the Marlboro, Poricy Brook, Highlands, and Pine Brook sections.

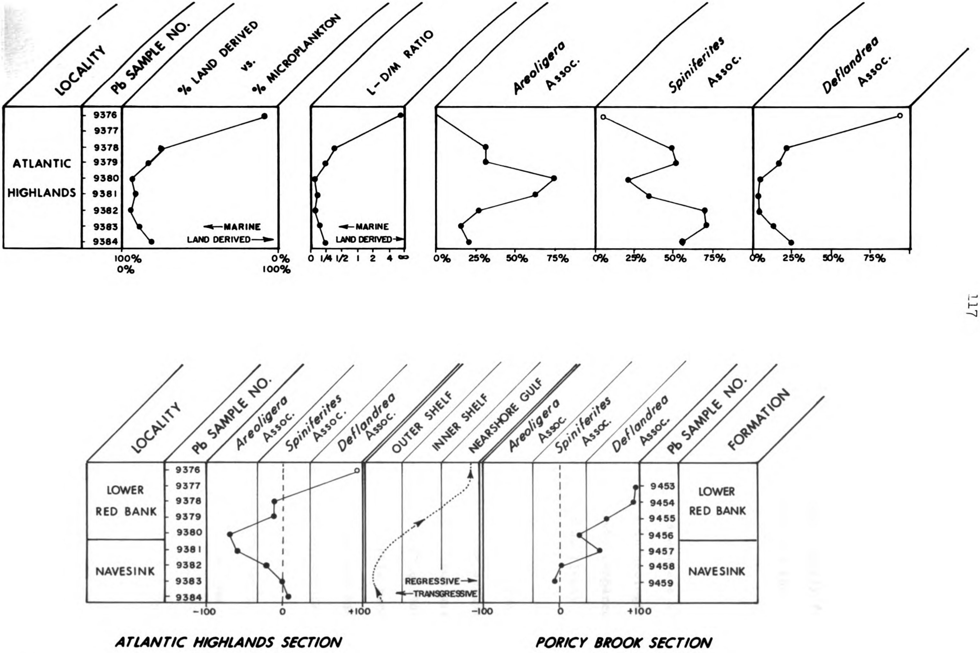

Figure 7: Land-derived/Microplankton curves and dinoflagellate associations for the Atlantic Highlands section, and a comparison of the Deflandrea minus Areoligera plots for both the Atlantic Highlands and the Poricy Brook sections.

Paleoenvironmental Interpretations

Figures 5-7 have been described in the Presentation of Paleoenvironmental Data section. However, to fully understand the interpretations to be made from these diagrams, some explanation is needed, namely for those plots based on land derived and microplankton forms, and the dinoflagellate associations.

Land-Derived vs. Microplankton Curves

Comparisons of this type have previously been used as a means of determining marine transgressive and regressive relations in geologic sections. They were originally used by Sarmiento (1957) who compared hystrichospheres with spores and pollen, and later by Upshaw (1964) whose method was followed in this study.

While these curves have been shown as a part of this study, and they seem to show the desired results from 3 of the 5 sections analyzed, I do not consider them to be good environmental indicators. They are used here only in relation to another technique, namely dinoflagellate associations. The most obvious reason for nonacceptance of this technique is because the two entities compared (i.e. land-derived and microplankton) have no basis for comparison. In other words, the factors involved in the production followed by transport and deposition of spores and pollen into a marine environment are totally different from those involved for the microplankton which are a part of the marine environment. Therefore, results intended to show transgressive-regressive relations could in fact be indicating, e. g., active transport of terrestrial material far out to sea, or on the other hand non-transport of terrestrial material into a near shore environment due to poor water circulation and/or prevailing shoreward winds.

In summary, the factors controlling transport and deposition of land-derived material are diverse and complex. These problems are less confusing for the microplankton since they are indigenous to marine environments. In light of this, an attempt has been made in this study to establish transgressive-regressive relations within the microplankton, and to compare these results with the land-derived/ microplankton data.

Dinoflagellate Associations

In the initial phases of this study, it was noted that different dinoflagellate taxa attained dominance in different samples and localities. In some cases, the marine element consisted almost entirely of one species such as the Highlands locality which was dominated by Deflandrea cf. D. cooksoni. In other instances, samples contained predominately Areoligera cf. A. senonensis such as sample Pb-9380 from the Atlantic Highlands section. Still other samples contained high abundances of Spiniferites spp., Hystrichosphaeridium spp., Systematophora sp. and operculodinioid forms.

Another study where relations of this type were observed is that of Downie, Hussain and Williams (1971) where four microplankton associations were recognized in the Paleogene of England. Their associations are as follows: A Wetzeliella assoc. dominated by species of Wetzeliella and Deflandrea, a Micrhystridium assoc. dominated by several acritarch genera, a Hystrichosphaera assoc. dominated by species of Spiniferites, Hystrichosphaeridium, Achomosphaera, and Cordosphaeridium, and an Areoligera assoc. dominated by the genera Areoligera and Cyclonephelium. These associations were thought to reflect the following environments: The Wetzeliella assoc. was estuarine, the Micrhystridium assoc. marked the initial and closing stages of marine transgression, and the *Hystrichosphaera* and *Areoligera* assocs. indicated open sea environment.

With the exception of the *Micrhystridium* assoc., these same groups are applied here in the following manner: The *Wetzeliella* assoc. is a *Deflandrea* assoc.; *Wetzeliella* had not yet evolved to any significance in the Cretaceous. The *Hystrichosphaera* assoc. is a *Spiniferites* assoc. and is basically unchanged (the name difference here results only from the use of the presently more preferred and valid name for that genus). The *Areoligera* assoc. is the same, but with the inclusion of genus *Systematophora*. The environmental implications suggested by Downie et. al. are applied here as well. In addition, the *Areoligera* assoc. seems to indicate further open marine conditions than does the *Spiniferites* assoc. as will be shown with some comparisons to other studies.

In comparison to modern counterparts, it has been noted by Evitt (special course on dinoflagellates) that a large number of the fossil dinoflagellate cysts have tabulations related to one of three large modern genera--*Peridinium*, *Conyaulax*, or *Ceratium*. From other studies, a few generalized environmental features for these genera can be shown. For example, a survey of these genera in Ferguson Wood (1968) shows that nearly all species of *Ceratium* occur in full ocean environments, where those for *Peridinium* are predominant in fresh, brackish, estuarine, and neritic waters. Species of *Gonyaulax* occur more commonly in open marine waters, but not to the extent of *Ceratium*. One additional important characteristic found in Steidinger and Williams (1970, p. 63-64), Lebour (1925, p. 7) and Wimpenny (1966, p. 64) is that *Ceratium* and *Gonyaulax* are fully photosynthetic, whereas many species of *Peridinium* are saprophytic, and that saprophytic forms more typically inhabit neritic rather than full ocean environments. Tabulations and assumed modern counterparts for the associations of *Deflandrea*, *Spiniferites*, and *Areoligera* from this study correspond respectively to the extant genera *Peridinium*, *Gonyaulax*, and *Ceratium*.

An attempt will be made to relate marine transgressions and regressions to the Monmouth Gp. by using only marine forms. To accomplish this, separate counts were made for the three dinoflagellate associations previously mentioned, and diagrams for their relative percentages are provided in Figures 6 and 7. The curves derived by subtracting the value of the *Areoligera* assoc. from the *Deflandrea* assoc. are given only to express the data more clearly for comparison with transgressive-regressive cycles known from other studies. Note that while parallel relations are evident, the *Deflandrea* minus *Areoligera* curve is not intended to show sea floor conditions as is given in the example from Owens and Sohl (1969). Dinoflagellates are planktonic organisms, and they are not known to vary according to bottom conditions and water depths as do some invertebrate fossils and lithologies.

Marlboro Locality

Spore and pollen taxa (Figure 5) in general decrease up section from the Mt. Laurel to the Navesink as shown in the diagrams for *Stereisporites* spp., *Rugubivesiculites* spp., and *Pinuspollenites* spp. Curves for *Gleicheniidites senonicus* and *Tricolporopollenites distinctus* show this same general decrease higher in the section, but vary in the lower three samples. *Triporopollenites* cf. *T. robustus*, is absent in the lowest two samples and elsewhere in the section is present in small percentage levels.

Dinoflagellates (Figure 5) all are poorly represented or absent low in the section, but with the exception of *Palaeoperidinium* sp., increase upward to the Navesink and then seem to decrease. The greatest percentage occurrences for the dinoflagellates are in the Navesink. The significant abundance of *Canningia* sp. is peculiar, but is not understood.

Plots of percentages of land-derived palynomorphs and percentages of microplankton (Figure 6) indicate nearly all palynomorphs present in the lowest three samples (Mt. Laurel) are terrestrial in origin. From this point upward, the microplankton occur in steadily increasing percentages.

Separate counts of the dinoflagellates show the *Deflandrea* association increasing to near the top of the Mt. Laurel, followed by a decrease on into the Navesink. *Spiniferites* assoc. decreases and is followed by an increase in the Mt. Laurel, and remains stable (ca. 50 percent) in the Navesink. *Areoligera* assoc. remains low in abundance except for the two topmost (Navesink) samples.

The *Deflandrea* minus *Areoligera* plot (Figure 6) as compared with other transgressive-regressive trends shows the same general tendencies. From the base of the section upward, near shore forms (*Deflandrea* assoc.) steadily increase followed by a shift to the more offshore forms (*Spiniferites* and *Areoligera* assocs.) near the top of the Mt. Laurel and into the Navesink. Note that the three lowest samples are marked differently from those above (with an open circle instead of a filled circle). This has been done because the specimens on which these data are based are from counts of only 26, 17 and 24 specimens respectively, upward, and while the expected trends are shown, they are not considered fully reliable.

Added supporting evidence for these relationships is found in the work of Krinsley and Schneck (1964) who state that water depth at the Mt. Laurel-Navesink boundary may have been as shallow as 30 ft. Their evidence was based primarily on crab remains, and sand surface textures that showed signs of beach action and a possible disconformity. From assemblages of forams and certain megafossils, they determined that the overlying Navesink Fm. was deposited in deeper water (120-300 ft.).

Poricy Brook Locality

Tricolporopollenites distinctus (Figure 5) ranges from 19.6%-68.0% in this section with the greatest abundances in the uppermost Navesink and lowermost Red Bank samples. The remaining terrestrial forms are relatively insignificant (in no case above 6%). The dinoflagellates shown in Figure 5 are low to moderate in abundance with the exception of Deflandrea assoc. which is significant in the two highest samples. and Spiniferites which occurred in decreasing abundance up section.

Percent land-derived vs. percent microplankton curves and L-D/M ratios (Figure 6) indicate a section primarily containing land-derived palynomorphs. The point of greatest marine regression occurs at about the Navesink-Red Bank boundary. Note in Figure 5 that these peaks are most influenced by the abundance of one species, Tricolporopollenites distinctus, which is significant in only 2 of the 5 localities examined.

Plots of the separate dinoflagellate counts (Figure 6) indicate an increase for the Deflandrea assoc. up section while both the Spiniferites and Areoligera assocs. decrease. The curves for Spiniferites and Areoligera are parallel, but the abundance of Spiniferites is greater. The Deflandrea minus Areoligera plot (Figure 6) shows a gradual change up section from dominance of Spiniferites to Deflandrea, and compares favorably with the marine regression shown in the cycle taken from Owens and Sohl (1969).

Additional supporting evidence from other studies is as follows: In their description for this locality (p. 274), Owens and Sohl (1969) suggest that the Navesink here is middle to outer shelf, and the Red Bank is an inner shelf deposit. Data from studies of the foraminifera indicate neritic depths of 180-350 feet and 150-300 feet, respectively, for the Navesink and Red Bank formations (Olsson, 1963), and that the Navesink was deposited at a slower rate of deposition than the Red Bank. A study by Weller (1907) on invertebrates showed a deep water Cucullaea fauna vs. a shallower water Lucina fauna for the Navesink and Red Bank respectively. In summary, all previous studies indicate shallowing or regressive trends upward from the Navesink to the Red Bank formations.

Highlands Locality

Relative abundances of terrestrial forms (Figure 5) are low and stable throughout the stratigraphic section at this locality for all taxa except Tricolporopollenites distinctus which is greater in abundance low in the section and Triporopollenites cf. T. robustus which is erratic in distribution. The dinoflagellate taxa are significantly represented only by the Deflandrea assoc. Note that the only other marine form recorded was one specimen of Areoligera in sample Pb-9465.

Percent land-derived vs. percent microplankton and L-D/M ratios (Figure 6) indicate a section with terrestrial forms in greater abundance high and low in the section, but with marine forms dominating the greatest portion. The curves presented here however, are in fact only comparisons of one species of dinoflagellate--*Deflandrea* cf. *D. cooksoni* with two species of angiosperms--*Tricolporopollenites distinctus* and *Triporopollenites* cf. *T. robustus*.

Separate counts for the dinoflagellates show occurrences only of the *Deflandrea* assoc. The *Deflandrea* minus *Areoligera* plot indicates near shore conditions throughout the section which compares favorably with the transgressive-regressive cycles. Environmental data from previous studies of the Red Bank Formation are provided in the last paragraph on the discussion of the Poricy Brook locality (p. 124).

Atlantic Highlands Locality

Significant terrestrial forms from this locality consist only of *Gleicheniidites senonicus*, *Rugubivesiculites* spp., and *Pinuspollenites* spp. (Figure 5). Counts for these taxa show greatest abundances higher in the section, but also significant occurrences in the lower samples. Significant dinoflagellate occurrences (Figure 5) were recorded for *Areoligera* assoc., which was most abundant in the central part of the section, *Spiniferites* assoc., which peaked in abundance both immediately above and below *Areoligera* assoc., and *Deflandrea* assoc., which was lower in abundance, but showed small peaks just above and below those of *Spiniferites* assoc. Counts made for *Canningia* sp. are not considered significant. The recorded values for *Palaeoperidinium* sp. may be important (15.6% in sample no. Pb-9384), but environmental relationships for this taxon are not understood.

The curves for percent land-derived vs. percent marine and the L-D/M ratios (Figure 7) indicate a marine environment with land-derived forms becoming significant in the upper part of the section. It is interesting to note that virtually no angiosperms are recorded as a part of the land-derived element from this locality. Except for the Tinton Sand, this is in contrast to the data from the other localities. Curiously though, these curves compare more favorably with the dinoflagellate associations than do any of the other four localities.

Separate counts for the dinoflagellates (Figure 7) indicate a peak for the *Areoligera* assoc. at about the middle of the section. *Spiniferites* assoc. peaks both above and below that of *Areoligera* assoc., and *Deflandrea* assoc. is most abundant high and to a lesser extent low in the section. Note the similarity of the *Deflandrea* assoc. curve as compared with plots of the percent land-derived vs. microplankton (Figure 7), and *Rugubivesiculites* spp. and *Pinuspollenites* spp. from Figure 5. It should be noted that percentages for the uppermost sample are based on a total count of 14 specimens.

The *Deflandrea* minus *Areoligera* curve (Figure 7) for Atlantic Highlands is compared with the same plot from Poricy Brook and the transgressive-regressive cycles of Owens and Sohl (1969). These diagrams roughly compare two localities over the same stratigraphic section and show a discrepancy as to the nature of the dinoflagellate associations. If the interpretations are in proper perspective, the most marine phase of the Navesink Fm., as seen in the Marlboro and Poricy Brook sections, has been shifted upward to the level of the Navesink-Red Bank contact at Atlantic Highlands. This is possibly explained as one of two alternatives. First of all, the Navesink-Red Bank boundary is gradational, and the contacts as they were recognized in this study could be subject to a different interpretation.

Secondly, the Atlantic Highlands section may represent a farther offshore deposition site so that the event of marine regression was not recorded until higher in the section.

Specific environmental studies for comparison to the Atlantic Highlands section were not found. Environmental events can only be related generally as they have been outlined in the last paragraph of the discussion for the Poricy Brook locality (p. 124).

Pine Brook Locality

Counts of the terrestrial taxa from this locality consist only of *Gleicheniidites senonicus*, *Rugubivesiculites* spp., and *Pinuspollenites* spp. Angiosperm taxa were virtually absent. Dinoflagellate curves shown in Figure 5 indicate the *Areoligera* assoc. decreasing up section while *Spiniferites* assoc. increases, a steady relative abundance for *Deflandrea* assoc. and *Canningia* sp., and a significant, unexplainable, abundance of *Palaeoperidinium* sp.

Curves of percent land-derived vs. percent microplankton and L-D/M ratios (Figure 6) indicate a marine section with a possible regressive trend just beginning with the uppermost sample. Separate counts for the dinoflagellates show a stable abundance for *Deflandrea* assoc. while *Spiniferites* assoc. increases and *Areoligera* assoc. decreases.

The *Deflandrea* minus *Areoligera* plot shows a strong dominance of the *Areoligera* assoc., but proceeding toward the *Spiniferites* assoc. up section. This is in contrast to what is indicated in the transgressive-regressive cycles of Owens and Sohl (1969) who showed the Tinton to represent deeper water up section because of an increase in glauconite. However, grain size also increases up section (Minard, 1969), a tendency usually associated with shallowing water. Weller

(1907) regarded the Tinton as a "deeper water" sediment due to the final recurrence of the *Cucullaea* fauna. Olsson (1963) believed the Tinton to represent water depths similar to or even shallower than the Red Bank based on accumulation of coarse clastics, remains of the raninid crab *Callianassa*, and the gradational relationship with the underlying Red Bank Sand. In summary, several contrasting opinions have been expressed as to the environmental relations of the Tinton Sand. This flora, as it is viewed in this study, is indicative of open marine waters with a possible trend toward shallower conditions up section.

Paleoenvironmental Analysis and Conclusions

The best environmental approach utilizes several methods from which conclusions are drawn. For the Monmouth Gp. in Monmouth Co., New Jersey, several techniques have been applied prior to those used here, and they provide a framework to which these data can be applied. The methods previously used were discussed in the Geology section under the descriptions of the formations and again as they applied to the interpretations of the sections studied. They include the following: paleontology, micropaleontology, paleoecology, textural studies and mineralogy.

As a part of this study, various graphical techniques were applied to the Monmouth Gp. for two purposes: To obtain more understanding of the methods used, and to gain better insights into the environmental relationships of this unit. The three following techniques were used:

1. Curves of Significantly Abundant Taxa

Curves of the terrestrial taxa in Figure 5 show mostly non-comparable results. Consistent trends between taxa exist only for *Rugubivesiculites* spp. and *Pinuspollenites* spp. which in every section have curves similar to each other. Comparisons of the same land-derived taxa between sections produced no usable results. For example, where a significant abundance was noted for *Stereisporites* spp. in the Mt. Laurel Sand, the same condition did not occur higher in the section with the return of near-shore sediments. Angiosperm taxa as well showed peak abundances in unrelated sections.

Little more can be done to further relate the separate terrestrial taxa to environments derived from other studies without counts of absolute percentages. This was not done as a part of this study. However, some speculation is given here pertaining to possible terrestrial habitats from which these forms may have been derived: *Stereisporites* spp., which has affinities to the modern moss genus *Sphagnum*, may indicate a swamp environment. A conifer community is suggested by *Pinuspollenites* and *Rugubivesiculites* which always occur together in a similar relationship. An angiosperm forest may have occurred that was dominated by the plants that produced *Tricolporopollenites distinctus* and *Triporopollenites* cf. *T. robustus* (suggested affinities for these two taxa respectively are *Castanea* and the Betulaceae). The fern species *Gleicheniidites senonicus* seems to be associated with either the conifers or *Stereisporites* spp., but not to the angiosperms.

The taxa mentioned above indicate three possible plant communities because they show apparent unique patterns of distribution. However, it is also possible that the distribution of these forms occurred selectively according to the nature of the transportational and of the depositional environment. Therefore, relations are expressed here suggesting the existence of three terrestrial plant associations, but they represent only a weak concept in need of more study.

The curves presented for the microplankton taxa (Figure 5) showed several significant relationships. For example, high abundances of *Deflandrea* assoc. were found in the Red Bank Sand both at Poricy Brook and Highlands, and the abundances of the *Areoligera* and *Spiniferites* assocs. related inversely to those of *Deflandrea* assoc. Occurrences of *Canningia* sp. and *Palaeoperidinium* sp. were only locally abundant with no repeated trends. Additional relations of the dinoflagellates will be presented later in this study where they were analyzed in separate counts.

2. Land-Derived-Microplankton Curves

The curves presented in Figures 6 and 7 (after Upshaw, 1964) are consistent with other studies in the case of the Pine Brook, Atlantic Highlands, and upper portion of the Marlboro sections. Those for the Highlands, Poricy Brook and lower portion of the Marlboro sections are inconsistent. The most obvious feature of the inconsistent results is that they are related to near-shore environments. Examination of the data show them to be represented by unusually high abundances of either *Tricolporopollenites distinctus* or the *Deflandrea* assoc.

Another technique that has been used to present land-derived vs. marine data is given in Sarmiento (1957). In this study, he compared "hystrichospherids" with spores and pollen, and ignored "dinoflagellates". To state this more correctly, he compared high-spined dinoflagellates (predominantly the *Spiniferites* and *Areoligera* assocs. of this study) to spores and pollen, and ignored the smooth forms (mainly the *Deflandrea* assoc. and *Dinogymnium* spp. of this study). The use of this method would eliminate the poor results obtained in cases of abnormally high percentages of the *Deflandrea* assoc.; however, it would not compensate for the unusual abundances of *Tricolporopollenites distinctus* found in certain sections of this study.

Land-derived/microplankton curves, as they apply to this study, have produced usable results in offshore conditions. However, they are inconsistent when compared in near shore or shallow water environments. For this reason, and for reasons previously given in the *Interpretation of Paleoenvironmental Data*, I do not believe they are good environmental indices.

3. *Dinoflagellate Associations*

The basis for the use of these associations is given in the *Interpretation of Paleoenvironmental Data* where they were shown as equivalent to those of Downie et al. (1971). By the types of tabulation they display, they are related to certain modern genera as suggested by Evitt, where the *Deflandrea*, *Spiniferites*, and *Areoligera* assocs. correspond respectively to the modern genera *Peridinium*, *Gonyaulax*, and *Ceratium*. From a survey of some other studies, the following generalizations are made: 1. Species of *Gonyaulax* and *Ceratium* most commonly occur in open marine waters; *Peridinium* species are more predominant in near shore and brackish water environments. 2. The autotrophic or phototrophic life habit is more characteristic of *Gonyaulax* and *Ceratium*, whereas *Peridinium* is more commonly saprophytic (Lebour, 1925, Steidinger and Williams,1970 and Wimpenny, 1966). Applying these concepts to the fossil dinoflagellate associations provides an assumption that the living forms of the *Deflandrea* association most commonly inhabited near shore and brackish environments where energy conditions of the water were high and organic nutrients were readily available. Those of the *Spiniferites* and *Areoligera* assocs. were more successful at greater distances from the shore or delta where energy conditions were lower and organic nutrients were limiting for the *Deflandrea* assoc. It is also assumed that encystment and burial occurred in the same environment.

Added support is given by Vozzhennikova (1965) who relates forms with thin, delicate membranes and various processes to the open sea (examples of these types from my study are mostly found within the *Spiniferites* and *Areoligera* assocs.); whereas, those with rigid and internal membranes suggest near shore waters (indicative of the *Deflandrea* assoc.). In a study on the Lower Tertiary of the Virginia-Maryland Coastal Plain, McLean (1972) found the genus *Areoligera* predominant in the basal Aquia Formation (Paleocene) which was deposited at a water depth of about 300 ft. Thereafter, normal marine, but progressively shoaling conditions prevailed, and the microplankton assemblage changed.

The dinoflagellate associations as interpreted for the Marlboro, Poricy Brook, and Highlands sections (Figure 6) are consistent with other studies. In general, shallow water deposition is suggested for the Mt. Laurel Sand followed by inner and outer shelf deposition in the Navesink Fm., and again a return to the shallow water environment in the Red Bank Sand. This cycle of deposition is substantiated in several studies and is based on lithologic relations, mineralogy, textural studies, paleoecology, and paleontology (see especially studies by Olsson, 1963, Krinsley and Schneck, 1964, and Owens and Sohl, 1969).

Parallel history is indicated by the dinoflagellates with the dominance of the _Deflandrea_ assoc. in the Mt. Laurel Sand followed by the _Spiniferites_ and _Areoligera_ assocs. in the Navesink Fm., and again returning in reversed sequence back to the _Deflandrea_ assoc. in the Red Bank Fm.

The data from the Atlantic Highlands section as compared with the Poricy Brook section (Figure 7) show an extension of the offshore microflora up into the basal Red Bank Sand before the return to a near shore microflora. As presented more completely in the _Interpretation of Paleoenvironmental Data_, this is believed to indicate either conditions more distant from shore in which the event of marine regression was not recorded until higher in the section, or a poorly defined contact between the Navesink and Red Bank formations.

Environmental relations for the Tinton Sand (Pine Brook Section) are inconsistent among the various studies used here for comparison. Where Olsson (1963) suggests a shallow water environment, others indicate deep water (Owens and Sohl, 1969 and Weller, 1907). A peculiar feature of this unit is that grain size increases up section along with glauconite, a mineral believed by many to form only in deep water. This represents a part of the differing opinions among recent workers. Fossil evidence is provided only by Weller (1907) who reported a deep water fauna from the Tinton. The data from this study (Figure 6) shows dominance of the offshore _Areoligera_ assoc., but with a trend toward the intermediate _Spiniferites_ assoc. up section.

MICROFLORISTIC ASPECTS OF THE MONMOUTH GROUP

Comparison of the Monmouth Group microfossils with others from the Atlantic and Gulf Coastal Plains

A list of the spore and pollen species from the Monmouth Group is provided in Table 4. All other occurrences known for these taxa, as they have been reported from the Cretaceous and Paleocene of the Atlantic Coastal Plain and southeastern United States, have been added to this list. Because the formational units involved are numerous, the occurrences are related to geologic stages. Studies from which these data are derived are the following: Groot and Penny (1960), Groot, Penny and Groot (1961), Groot and Groot (1962b), Brenner (1963 and 1967b), Stevenson and McGregor (1963), Stover (1964), Leopold and Pakiser (1964), Gray and Groot (1966), Kimyai (1966 and 1970), McLean (1968), Doyle (1969), Phillips and Felix (1971a and 1971b), Wolfe and Pakiser (1971), and Srivastava (1972b).

Table 4 is not a range chart. Complete and diagnostic ranges can be established only with additional, more thorough studies of Atlantic and Gulf Coast floras.

Table 4. Known occurrences of Monmouth Gp. taxa from the Cretaceous and Paleocene of the Atlantic and Gulf Coastal Plains.

TAXON	Paleocene	Maastrichtian	Campanian	Santonian	Cenomanian	Early Cretaceous
Foraminisporis dailyi		X			X	X
Stereisporites australis	X	X	X	X	X	X
Stereisporites congruens		X				
Stereisporites cristalloides		X				
Stereisporites dakotaensis		X				
Stereisporites regium		X				
Stereisporites stereoides	X	X	X	X	X	X
Camarozonosporites anulatus		X				
Camarozonosporites canaliculatus		X				
Camarozonosporites caperatus		X				
Camarozonosporites cerniidites		X				
Camarozonosporites heskemensis		X				
Camarozonosporites vermiculaesporites		X				
Foveasporis triangulus	X	X				
Foveosporites labiosus		X				
Foveosporites subtriangularis		X			X	X
Lycopodiumsporites austroclavatidites	X	X	X	X	X	X
Sestrosporites pseudoalveolatus	X	X				
Densoisporites microrugulatus		X			X	X
Lusatisporis circumundulatus		X			X	X
Osmundacidites comaumensis		X				
Goczanisporis baculatus		X				
Todisporites major	X	X				
Todisporites minor		X	X			X
Cicatricosisporites dorogensis	X	X	X	X	X	X
Cicatricosisporites hallei		X				X
Radialisporis radiatus		X				
Concavisporites arugulatus		X				
Gleicheniidites senonicus	X	X	X	X	X	X
Dictyophyllidites equiexinus	X	X	X		X	
Dictyophyllidites harissii		X			X	X
Matonisporites crassiangulatus		X				X
Matonisporites excavatus		X			X	X
Cyathidites minor		X	X	X	X	X
Kuylisporites aduncus		X	X	X		
Laevigatosporites haardti	X	X	X	X	X	X
Verrucatosporites saalensis		X				

Table 4. (Continued)

TAXON	Paleocene	Maastrichtian	Campanian	Santonian	Cenomanian	Early Cretaceous
Asbeckiasporites sp.		X				
Converrucosisporites proxigranulatus		X				X
Distaltriangulisporites perplexus	X	X				
Leptolepidites tenuis		X				
Leptolepidites verrucatus		X				
Toripunctisporis granuloides		X				
Trizonites subrugulatus		X	X			
Trilete sp. 1		X				
Trilete sp. 2		X				
Trilete sp. 3		X				
Classopollis classoides		X		X		X
Parvisaccites radiatus		X			X	X
Phyllocladidites inchoatus		X				
Podocarpidites potomacensis		X				X
Rugubivesiculites convolutus		X	X	X	X	
Rugubivesiculites reductus		X	X	X	X	X
Rugubivesiculites rugosus		X	X	X	X	X
Araucariacites australis		X	X	X	X	X
Pinuspollenites spp.	X	X	X	X	X	X
Taxodiaceaepollenites hiatus	X	X	X	X	X	X
Perinopollenites halonatus		X				X
Eucommiidites troedssonii		X				X
Sparganiaceaepollenites sp.		X				
Clavatipollenites hughesii		X			X	X
Monocolpopollenites asymmetricus		X			X	X
Momipites inaequalis		X				
Momipites microcoryphaeus		X				
Momipites tenuipolus	X	X				
Proteacidites marginus		X				
Proteacidites retusus		X				
Proteacidites thalmannii		X	X	X		
Proteacidites sp.		X				
Cupanieidites sp.		X				
Insulapollenites rugulatus	X	X				
Nyssapollenites puercoensis		X				
Gunnerites reticulatus		X				
Extratriporopollenites minimus		X	X	X		

Table 4. (Continued)

TAXON	Paleocene	Maastrichtian	Campanian	Santonian	Cenomanian	Early Cretaceous
Extratriporopollenites nonperfectus	X	X	X	X		
Extratriporopollenites silicatus	X	X	X	X		
Extratriporopollenites thornei		X		X		
Extratriporopollenites sp.		X		X		
Holkopollenites chemardensis	X	X				
Retitricolpites georgensis		X			X	X
Tricolpites anguloluminosus		X				
Tricolpites parvus	X	X	X			
Tricolpopollenites micromunus		X		X	X	X
Tricolpopollenites micropunctatus		X			X	
Tricolpopollenites simplicissimus		X			X	
Tricolporopollenites cingulum	X	X				
Tricolporopollenites cryptoporus	X	X			X	
Tricolporopollenites distinctus		X	X	X	X	
Tricolporopollenites granulocuneus		X			X	
Tricolporopollenites inductorius		X				
Tricolporopollenites inusitatus		X				
Tricolporopollenites labiatus		X	X	X		
Tricolporopollenites lihokus	X	X				
Tricolporopollenites parvus	X	X				
Tricolporopollenites venustus		X				
Tricolporopollenites viriosus		X	X	X		
Triporopollenites cf. *T. granifer*		X				
Triporopollenites cf. *T. robustus*		X				
Schizosporis reticulatus		X				X

Comparison of the Monmouth Gp. microfossils with those of Europe and western North America

In order to compare the flora of this study with those previously described from eastern and western North America and Europe, several tables based on literature dealing with fossils ranging from Cretaceous to Early Tertiary in age, have been prepared.

Table 5 is a list of the taxa with known occurrences from both eastern and western North America and Europe. Most of the taxa in this list are well known from various other parts of the world.

Table 6 lists those species found with occurrences in eastern North America and Europe, but not western North America.

Table 7 contains those forms known from eastern and western North America, but not Europe. Certain of these taxa have been described from east Asian floras as well which are known to share certain similarities to western North American floras.

Table 8 includes those taxa restricted to eastern North America. Note that the Mississippi Embayment flora shown by Tschudy (1970) and the Cenomanian flora from Minnesota described by Pierce (1961) belong to eastern North America and are distinct from the western floras. The disposition of those described from the Albian (Hedlund and Norris, 1968) and Cenomanian (Hedlund, 1966) of Oklahoma is unclear, i.e., as to whether they should be placed with eastern or western North America or elsewhere.

The purpose of this part of the analysis is only to compare the floras of the eastern United States to those with which they are most closely related. Thus comparisons with Arctic, Asian and southern hemisphere floras is beyond the scope of this study.

Table 5. Monmouth Gp. taxa found also to occur in Europe and western North America during Cretaceous and Early Tertiary time.

Foraminisporis dailyi
Stereisporites australis
Stereisporites regium
Stereisporites stereoides

Camarozonosporites canaliculatus
Camarozonosporites caperatus
Foveosporites subtriangularis
Lycopodiumsporites austroclavatidites
Sestrosporites pseudoalveolatus
Densoisporites microrugulatus
Osmundacidites comaumensis
Todisporites major
Todisporites minor
Cicatricosisporites dorogensis
Cicatricosisporites hallei
Radialisporis radiatus
Concavisporites arugulatus
Gleicheniidites senonicus
Dictyophyllidites equiexinus
Dictyophyllidites harissii
Matonisporites crassiangulatus
Matonisporites excavatus

Cyathidites minor
Laevigatosporites haardti
Verrucatosporites saalensis
Converrucosisporites proxigranulatus
Leptolepidites verrucatus

Classopollis classoides
Parvisaccites radiatus
Podocarpidites potomacansis
Araucariacites australis
Pinuspollenites spp.
Taxodiaceaepollenites hiatus
Perinopollenites halonatus
Eucommiidites troedssonii

Clavatipollenites hughesii
Extratriporopollenites nonperfectus
Extratriporopollenites silicatus
Extratriporopollenites thornei
Tricolporopollenites cryptoporus
Triporopollenites cf. *T. granifer*
Triporopollenites cf. *T. robustus*

Schizosporis reticulatus

Table 6. Monmouth Gp. taxa with previous occurrences only in eastern North America and Europe during Cretaceous and Early Tertiary time.

Stereisporites cristalloides

Camarozonosporites cerniidites
Camarozonosporites heskemensis
Goczanisporis baculatus
Toripunctisporis granuloides

Momipites microcoryphaeus
Extratriporopollenites minimus
Tricolporopollenites cingulum

Table 7. Monmouth Gp. taxa with previous occurrences only in eastern and western North America during Cretaceous and Early Tertiary time.

Stereisporites dakotaensis

Camarozonosporites vermiculaesporites
Foveasporis triangulus
Foveosporites labiosus
Lusatisporis circumundulatus
Kuylisporites aduncus
Distaltriangulisporites perplexus
Leptolepidites tenuis
Trizonites subrugulatus

Phyllocladidites inchoatus
Rugubivesiculites reductus
Rugubivesiculites rugosus

Momipites inaequalis
Momipites tenuipolus

Proteacidites marginus
Proteacidites retusus
Proteacidites thalmannii
?*Proteacidites* sp.
Cupanieidites sp.
Insulapollenites rugulatus
Nyssapollenites puercoensis
Gunnerites reticulatus
Retitricolpites georgensis
Tricolpites anguloluminosus
Tricolpites parvus
Tricolpopollenites micromunus
Tricolpopollenites simplicissimus
Tricolporopollenites inductorius
Tricolporopollenites inusitatus
Tricolporopollenites lihokus
Tricolporopollenites venustus
Tricolporopollenites viriosus

Table 8. Monmouth Gp. taxa known only from eastern North America during Cretaceous and Early Tertiary time.

Stereisporites congruens

Camarozonosporites anulatus
Asbeckiasporites sp.
Trilete sp. 1
Trilete sp. 2
Trilete sp. 3

Rugubivesiculites convolutus

Sparganiaceaepollenites sp.
Monocolpopollenites asymmetricus
Extratriporopollenites sp.
Holkopollenites chemardensis
Tricolpopollenites micropunctatus
Tricolporopollenites distinctus
Tricolporopollenites granulocuneus
Tricolporopollenites labiatus
Tricolporopollenites parvus

Microfloristic Analysis and Conclusions

The spores and pollen of this study are interpreted to represent 99 species from 55 genera, and are described from samples collected at 5 localities of the Monmouth Gp. in Monmouth Co., New Jersey. Further subdivisions of these taxa indicate 2 genera and 7 species of bryophytes, 26 genera and 40 species of pteridophytes, 10 genera and 12 species of gymnosperms, 16 genera and 39 species of angiosperms, and 1 unassignable genus and species. Only 5 of these species are considered as new, and they consist of 4 pteridophytes and 1 angiosperm:

Asbeckiasporites sp.
Trilete sp. 1
Trilete sp. 2
Trilete sp. 3
Sparganiaceaepollenites sp.

A more complete classification for the taxa of this study is provided in Table 2.

Some additional data were assembled from the "Systematics" section and presented in a stratigraphic and geographic framework. Stratigraphically the taxa are compared with those given in several publications on spores and pollen from the Cretaceous and Lower Tertiary of the East and Gulf Coast of the United States (Table 4). Geographic comparisons are made to indicate the relationship of the Monmouth Gp. flora to other floras of Cretaceous and Lower Tertiary age in Europe and western North America (Tables 5-8).

Comparison of the Monmouth Gp. Microflora to Others from the Atlantic and Gulf Coastal Plains

The data used in this comparison (Table 4) is derived from 17 studies of Cretaceous and Lower Tertiary sediments ranging from Nova Scotia to Louisiana. Mention of these papers is provided on page 134 of this work. Table 4 is not a range chart, but rather an up-to-date list of occurrences for certain taxa as they are interpreted in this study. Range charts are of little value until more thorough studies have been made. Most of those presently existing are preliminary surveys that describe only fractions of the floras they represent.

To briefly summarize Table 4, the following relations are made for the 99 taxa listed: 13 have previous occurrences both in older Cretaceous and the Lower Tertiary; 37 are known only from older sediments (note that several of these are possibly reworked as is indicated in Table 3); 10 are previously recorded only from younger strata; and 39 are unique to the Monmouth Gp. Only 6 of these unique taxa are new species. The remaining 33 taxa known from studies elsewhere are found only in the Monmouth Gp. in the eastern United States. Additional studies most certainly will reduce this number.

Comparison of the Monmouth Microfossilflora with those from Europe and western North America

Table 5 indicates those taxa recorded in this study that are also known from the Cretaceous and Lower Tertiary rocks of Europe and western North America. Many of these forms are known throughout the world from sediments of equivalent age. In general, these taxa are considered here as cosmopolitan in distribution, and of little value toward establishing a geographic framework.

The taxa shown (Table 5) include species of 4 bryophytes, 23 pteridophytes, 8 gymnosperms, 7 angiosperms, and 1 unassigned species. As compared with the total number of taxa from this study, those given here represent a majority of the bryophytes, pteridophytes, and gymnosperms, but only a few of the angiosperms. These numbers may be due in part to the nature of available literature and communication among palynologists, but they may also be some indication of the state of terrestrial plant evolution. It is well known that the bryophytes, pteridophytes and gymnosperms had been established for a considerable period of geological time. The angiosperms, however, do not have an indisputable fossil record prior to Early Cretaceous. They become quite diverse and prolific in the Late Cretaceous, but because of the separating continents, and short time of establishment they were not as well represented by species with worldwide distribution.

Table 6 shows the taxa from this study that have known occurrences only in eastern North America and Europe. These taxa are not known from western North America. The number of specimens listed are few, and consist only of 1 bryophyte, 4 pteridophytes and 3 angiosperms. Four of the taxa from this list, (*Stereisporites cristalloides*, *Goczanisporis baculatus*, *Toripunctisporis granuloides*, and *Extratriporopollenites minimus*) possess unique features by which they are easily distinguished. The remaining taxa are not as clearly defined, and may, in part, be synonymous with forms from western North America. For example, *Hamulatisporis hamulatus* as it is shown from South Dakota in Stanley (1965) is similar to and possibly synonymous with *Camarozonosporites cerniidites* or *C. heskemensis*. *Momipites microcoryphaeus* and *Tricolporopollenites cingulum* as well have not been clearly distinguished from certain taxa recorded in western North American deposits.

In addition to the similar forms, there are those that distinguish European from eastern North American floras. For example, the Late

Cretaceous and Early Tertiary rocks of Europe are represented by a much higher diversity of the Normapolles group than is known anywhere in North America (Tschudy, 1970). The Normapolles type of pollen are a group of angiosperm genera established by Pflug (1953) that possess unusual structural elements. They had their origin in the Late Cretaceous and became extinct in mid-Tertiary time. From present information, this group is very significant in Europe, and much less important in western North America. In this study, this group is represented by 5 species.

Table 7 shows the taxa found in this study that have known occurrences in North America, but not in Europe. These taxa include 1 bryophyte, 8 pteridophytes, 3 gymnosperms and 20 angiosperms. As stated previously, several of the species represented here are lacking in good diagnostic features, and must be regarded as having ranges of questionable distribution of uncertain extent. Those considered as most important are species of *Cupanieidites*, *Proteacidites*, and *Rugubivesiculites*. *Cupanieidites*, and *Proteacidites* are apparently restricted to North America, Siberia and Australia in the Late Cretaceous. However, forms resembling these genera are known from the Tertiary of Europe (see *Cupanieidites eucalyptoides* Krutzsch, 1962b, and *Symplocoipollenites vestibulum* Potonie, 1951). *Rugubivesiculites* is especially abundant in the Late Cretaceous of eastern North America, but in Europe is only known from the Early Cretaceous (see Burger, 1966 and Herngreen, 1971). Other taxa from Table 7 considered as distinctive are the following: *Kuylisporites aduncus*, *Trizonites subrugulatus*, *Momipites tenuipolus*, and *Insulapollenites rugulatus*. These forms, however, are known as rare occurrences from only a few studies.

Some other taxa known primarily from western North America and Siberia that are distinctive to these floral provinces are: *Aquilapollenites*, *Erdtmanipollis*, *Mancicorpus*, *Pemphixipollenites*, and *Wodehouseia*. One peculiar taxon in this group is *Aquilapollenites* which is commonly known from the Late Cretaceous and Early Tertiary of western North America and Siberia, but it has been reported elsewhere in a few scattered occurrences. Simpson (1961) and Martin (1968) reported some specimens of *Aquilapollenites* from the Tertiary of Scotland, and Evitt (1973) found 3 specimens in the Maastrichtian of Maryland and New Jersey.

Table 8 includes the species found in this study for which only eastern North American occurrences could be found. The list given comprises 1 bryophyte, 5 pteridophytes, 1 gymnsperm, and 9 angiosperms. Those taxa considered significant include the following: *Stereisporites congruens*, *Camarozonosporites anulatus*, *Asbeckiasporites* sp., Trilete sp. 1, Trilete sp. 3, and *Holkopollenites chemardensis*. The forms listed here are distinct and can be easily identified. The remaining taxa were found rarely and/or are difficult to distinguish from similar taxa known elsewhere.

Of those taxa listed above, *Asbeckiasporites* sp., Trilete sp. 1, and Trilete sp. 3 are new species. *Stereisporites congruens*, and *Camarozonosporites anulatus* are known previously only from the Cenomanian of Minnesota (Pierce, 1961), and *Holkopollenites chemardensis* is known only from the Gulf Coast Paleocene and New Jersey Maastrichtian.

Only one species of *Rugubivesiculites* is given in Table 8 that is restricted to eastern North America. However, I believe this group is more prolific in the Cretaceous of eastern North America than elsewhere as is shown in part by the diversity of forms presented in Pierce (1961), Leopold and Pakiser (1964), Brenner (1963), Gray and Groot (1966), and the present study. *Rugubivesiculites* is also an abundant floral element in the Monmouth Group (Figure 5) and in other samples that I have examined from the Cretaceous of New Jersey, Maryland, and in sediments from offshore Nova Scotia and Newfoundland. While this taxon is known from western North America, Asia, and Europe, it is never as abundant in those floras.

It is peculiar that there are no known occurrences for *Rugubivesiculites* in the Tertiary of North America since it was represented by relative abundances in excess of 7% in the Tinton Sand of this study. This unit, one of several, represents the youngest Cretaceous occurring in North America (Late Maastrichtian), and while unconformities are usually apparent, Cretaceous-Tertiary boundaries do occur where the breaks in time are minimal. In most other cases of which I am aware, an extinction usually occurs long after the period in which a taxon reaches its peak in both diversity and abundance. The well established nature at the top of the Cretaceous, and total absence in the earliest Tertiary suggests some sort of catastrophic event which resulted in the extinction of the plant which produced *Rugubivesiculites*.

To summarize the data presented in Tables 5-8 for the purpose of floral comparisons, only 8 species from the Monmouth Group were found to have distributions restricted to eastern North America and Europe, whereas 43 have distributions restricted to eastern and western North America. From this it is concluded that the microflora of the Monmouth Group is more similar to other floras from both eastern and western North America, than to Europe. These findings differ from those of

Tschudy (1970), who based on the presence of the Normapolles Group compared his microflora from eastern North America more closely with Europe.

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APPENDICES

Appendix I

The localities studied were collected during two field trips to the area. The first was in October of 1969, when I had the opporutnity to join Drs. W. W. Brideaux and G. L. Williams (then from Amoco Production Company). During this trip, collections were made from the Highlands, Atlantic Highlands, and the Pine Brook sections which included samples from the Navesink Formation, Sandy Hook Member of the Red Bank Sand, and the Tinton Sand. The second trip was made alone in October, 1971. At that time the Marlboro and Poricy Brook localities were collected and included additional samples from the Navesink and Sandy Hook Member of the Red Bank Sand, and also the Mt. Laurel Sand.

Collections from the Shrewsbury Member of the Red Bank Formation were made during the first trip at Highlands, New Jersey and from some large pits between Atlantic Highlands, N. J., and Highlands. Samples from both localities were barren.

Marlboro Locality

1.2 miles east of Marlboro, New Jersey on south bank of Big
Brook just west of secondary road, Lat. $40^{\circ}19'18''$N.,
Long. $74^{\circ}13'28''$W.

This locality, with the exception of being collected to the west rather than east of the secondary road, is the same as Locality 651 (p. 43) of Spangler and Peterson (1950), Stop 6 (p. 20) of Dorf and Fox (1957), NJK 106 (p. 660) of Olsson (1963 and 1964), and the

Marlboro section described by Krinsley and Schneck (1964). There is a difference of opinion among these workers as to how much of the Mt. Laurel Formation is exposed. For this study, the interpretation by Olsson is accepted. All other interpretations are really one, that of Spangler and Peterson (1950), who, according to Johnson and Richards (1952, p. 2157), misinterpreted the lower part of the Mt. Laurel Formation as the Wenonah.

The section collected here is about 150 yards upstream from that of Olsson's, and was interpreted to contain about 8½ feet of the Mt. Laurel Fm. overlain by 25 feet of Navesink. Lithologies of the two sections are the same. Spot samples (i.e. from an area of outcrop ranging from 3-5" in diameter) were collected as follows.

Pb-9452-16'	above	base	Navesink Fm.
Pb-9451-14	"	"	
Pb-9450-10	"	"	
Pb-9449-8½	"	"	Mt. Laurel Fm.
Pb-9448-6	"	"	
Pb-9447-5	"	"	
Pb-9446-3	"	"	
Pb-9445-1½	"	"	
Pb-9444-Base of section, at stream level.			

Poricy Brook Locality

½ mile south of Oak Hill and about 1¼ miles south of Middletown, 500 feet east of road in south bluff of Poricy Brook, Lat. 40°21'55"N., Long. 74°7'0"W.

The above is Locality 654 (p. 42) of Spangler and Peterson (1950), Stop 6 (p. 47) of Owens, Minard and Sohl (1968), Stop 6 (p. 274) of Owens and Sohl (1969), and the Poricy Brook section of Krinsley and Schneck (1964). The section exposed consists of about 25 feet of Navesink overlain by 25 feet of the lower Red Bank (Sandy Hook Member) as interpreted by Owens, Minard and Sohl (1968). The section suitable for collection was limited to the portion 10' to 32' above the base due to some slumping at the base, and weathering toward the top. Seven spot samples were collected as follows:

Pb-9453-32	feet	above	base	Red Bank Formation
Pb-9454-30	"	"	"	
Pb-9455-27	"	"	"	
Pb-9456-25	"	"	"	
Pb-9457-24	"	"	"	Navesink Formation
Pb-9458-16	"	"	"	
Pb-9459-10	"	"	"	

Base=stream level

Atlantic Highlands Locality

East of Atlantic Highlands Yacht Harbor in bluffs along
Raritan Bay, Lat. 40°24'45"N., Long. 74°1'35"W.

The bluffs along Raritan Bay extend for several miles so that exact correlation with localities reported in other studies is difficult. However, the section collected here is approximately the same as Locality 652 (p. 41) of Spangler and Peterson (1950) and NJK-107 (p. 660) of Olsson (1963). The section as recognized by Olsson contains about 25 feet of the Navesink Formation, overlain by 20 feet of the

Sandy Hook and 40 feet of the Shrewsbury Member of the Red Bank Formation.

About 70 feet of this section was exposed for study at the time collections at this site were made. However, only the interval from 7' to 46' above the base was suitable for collecting. Lithologic interpretations follow Olsson (1963). Spot samples were collected as follows:

Pb-9376-46 feet from base of bluff	Red Bank Formation (Sandy Hook Member)
Pb-9377-44 " " " " "	
Pb-9378-43 " " " " "	
Pb-9379-38 " " " " "	
Pb-9380-33 " " " " "	
Pb-9381-28 " " " " "	Navesink Formation
Pb-9382-22 " " " " "	
Pb-9383-14 " " " " "	
Pb-9384-7 " " " " "	

Highlands Locality

One mile west of Highlands Railroad Station at base of Atlantic Highlands Bluff; cut on south side of road parallel with Bay Avenue, Lat. $40^{\circ}24'23''$N., Long. $73^{\circ}59'56''$W.

The above locality is the same as NJK-103 (p. 660) of Olsson (1963, and also 1960 and 1964), and Stop No. 4 (p. 17) of Dorf and Fox (1957). The section as described by Olsson consists of 35 feet of the lower Sandy Hook and 80 feet of the upper Shrewsbury Member of the Red Bank Formation.

On the original trip to this locality, only fresh exposures of the upper member could be collected. These were later found to be barren. The lower part was found only in slumped condition and covered with undergrowth. However, samples from the lower member were supplied to me by Dr. W. R. Evitt, Stanford University, who had made collections from this locality during the G. S. A. Field Trip led by Dorf and Fox (1957).

Seven spot samples were collected at successively higher intervals from base to top (35 ft.). Respective sample numbers assigned are Pb-9460-9466. Exact footage intervals are not known but assumed to be spaced about 5 feet apart.

Pine Brook Locality

At Tinton Falls, at falls of Pine Brook north of bridge at the old mill (art museum). Lat. 40°18'21"N., Long. 74°5'56"W.

The above locality is the type section for the Tinton Formation. It is described in Spangler and Peterson (1950) as Locality 672 (p. 51), and as NJK-168 (p. 661) by Olsson (1963). As interpreted by Olsson, this unit is about 22 feet thick.

Spot samples were collected over about 15 feet of section in this study as follows:

Pb-9394-12 feet above base of falls
Pb-9393-8 " " " " " in water
Pb-9392-5 " " " " " in water
Pb-9391-5 " " " " "
Pb-9390-2 " " " " "

Tinton Formation

Appendix II

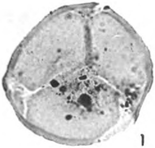
Alphabetical listing by genus of the Monmouth Group taxa

PLATES

PLATE 1

Figure	All Figures X1000	Page
1.	*Foraminisporis dailyi* (Cookson & Dettmann) Dettman, . . . 1963, Pb-9462-1, 119.1 x 15.6, 38u.	29
2-4.	*Stereisporites australis* (Cookson) Krutzsch, 1959b, . . . 2. Pb-9444-3, 110.6 x 3.5, 34u, distal arcuate thickening reduced; 3-4. Pb-9446-8, 103.7 x 10.9, 30u, proximal and distal views, distal arcuate thickening well developed.	30
5-6.	*Stereisporites congruens* (Pierce) Krutzsch, 1963b,. . . . 5. Pb-9446-7, 106.6 x 16.1, 40u, thick zona; 6. Pb-9445-8, 90.2 x 22.6, 44u, thin zona.	31
7-9.	*Stereisporites cristalloides* Krutzsch . . . . 7. Pb-9458-3, 107.5 x 19.8, 32u, round shape; 8-9. Pb-9448-5, 102.7 x 22.3, 30u, subtriangular shape, proximal and distal views.	32
10-12.	*Stereisporites dakotaensis* (Stanley) comb. nov. . . . . . 10. Pb-9446.8, 92.3 x 17.1, 26u, reduced zona; 11-12. Pb-9452-8, 96.4 x 17.7, 36u, proximal and distal views.	32
13-14.	*Stereisporites stereoides* (Potonie & Venitz) Pflug, . . . 1953, 13. Pb-9451-7, 90.0 x 21.0, 30u, 14. Pb-9452-3, 74.1 x 11.4 18u.	34
15-16.	*Stereisporites regium* (Drozhastchich) Drugg . . . . Pb-9451-9, 83.1 x 16.2, 20u, proximal and distal views.	33
17-18.	*Camarozonosporites anulatus* (Pierce) comb. nov. . . . . . Pb-9382-2, 92.3 x 4.8, 60u, proximal and distal views.	36
19-20.	*Camarozonosporites cerniidites* (Ross) Krutzsch, 1959b, . Pb-9446-4, 102.1 x 23.3, 26u, proximal and distal views, note that proximal surface is lightly sculptured, and that interradial crassitudes are missing.	39

PLATE 1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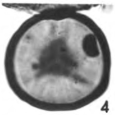
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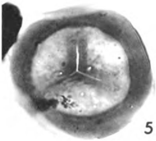
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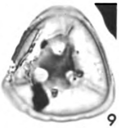
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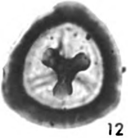
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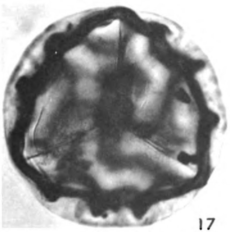
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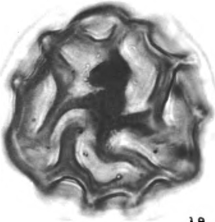
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PLATE 2

Figure	All Figures X1000	Page
1.	*Camarozonosporites anulatus* (Pierce) comb. nov. Pb-9450-1, 105.7 x 21.7, 50u.	36
2-4.	*Camarozonosporites canaliculatus* (Singh) comb. nov. 2. Pb-9450-8, 105.7 x 16.0, 58u, note contact area. 3-4. Pb-9463-1, 105.3 x 12.0, 62u, proximal and distal views.	37
5-8.	*Camarozonosporites caperatus* (Singh) comb. nov. 5-6. Pb-9452-8, 102.4 x 16.1, 38u, proximal and distal views, exine thickened interradially; 7-8. Pb-9463-3, 118.0 x 5.8, 52u, proximal and distal views, exine uniform in thickness.	38
9-10.	*Camarozonosporites cerniidites* (Ross) Krutzsch, 1959b, Pb-9384-4, 107.8 x 2.7, 24u, proximal and distal views, interradial crassitudes present.	39
11-14.	*Camarozonosporites heskemensis* (Pflanzl) Krutzsch, 1959b, 11-12. Pb-9444-8, 106.8 x 7.2, 26u, proximal and distal views. 13-14. Pb-9447-5, 93.2 x 7.5, 26u, proximal and distal views. Note variation of interradial crassitudes for these two specimens.	40

PLATE 2


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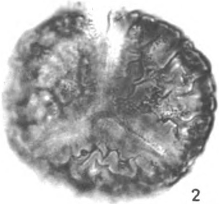
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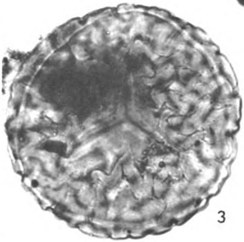
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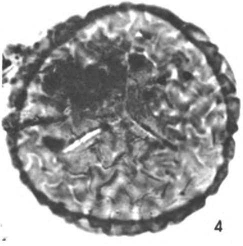
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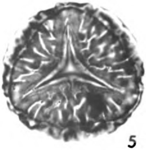
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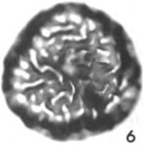
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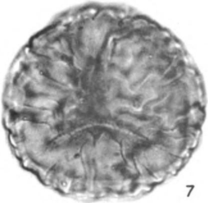
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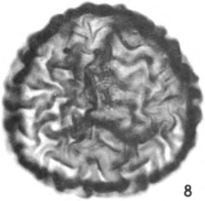
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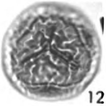
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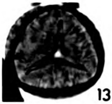
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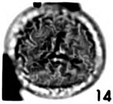
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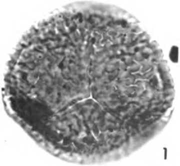
PLATE 3

All Figures X1000

Figure		Page
1-2.	*Camarozonosporites vermiculaesporites* (Rouse) Krutzsch, 1963a, Pb-9457-1, 111.8 x 14.3, 43u, proximal and distal views.	40
3-4.	*Sestrosporites pseudoalveolatus* (Couper) Dettmann, 1963. Pb-9457-1, 105-0 x 16.4, 40u, proximal and distal views.	44
5-6.	*Foveasporis triangulus* (Stanley) 1965 Pb-9455-3, 104.0 x 12.1, 40u, proximal and distal views.	41
7.	*Foveosporites subtriangularis* (Brenner) Kemp, 1970. Pb-9459-3, 118.8 x 12.9, 42u.	42
8-9.	*Foveosporites labiosus* Singh, 1971. Pb-9446-7, 93.4 x 16.8, 36u, proximal and distal views.	42
10-11.	*Lycopodiumsporites austroclavatidites* (Cookson) Potonie 1956, Pb-9445-7, 108.3 x 13.8, 36u, proximal and distal views.	43
12.	*Densoisporites microrugulatus* Brenner, 1963 Pb-9453-3, 113.2 x 15.0, 53u.	45
13-16.	*Lusatisporis circumundulatus* (Brenner) comb. nov. 13-14. Pb-9459-1, 108.7 x 2.6, 30u, proximal and midfocus views, note radially arranged folds on proximal face. 15-16. Pb-9447-6, 103.4 x 17.8, 38u, proximal and distal views, note the raised and sinuous laesurae.	46

PLATE 3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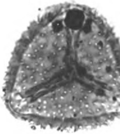
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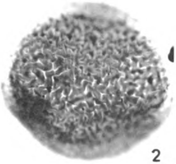
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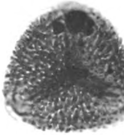
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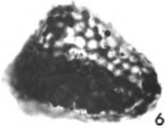
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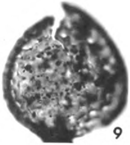
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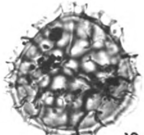
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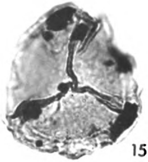
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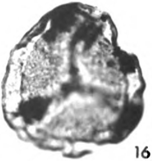
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PLATE 4


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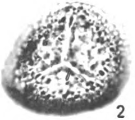
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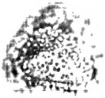
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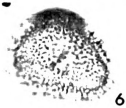
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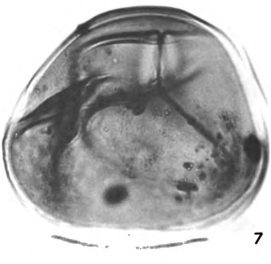
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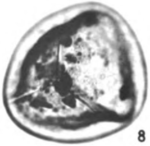
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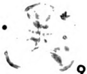
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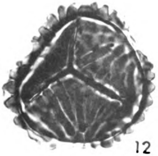
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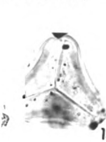
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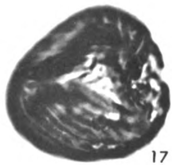
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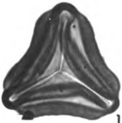
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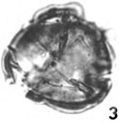
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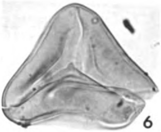
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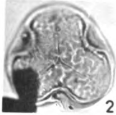
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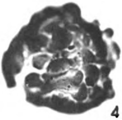
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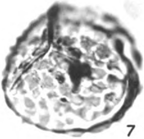
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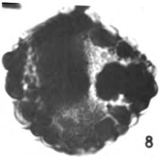
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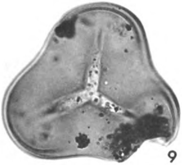
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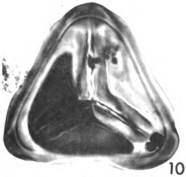
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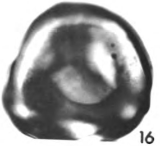
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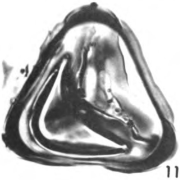
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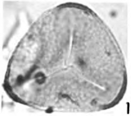
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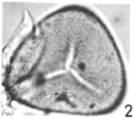
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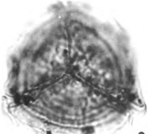
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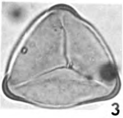
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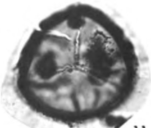
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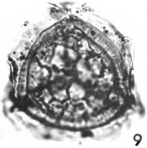
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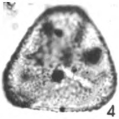
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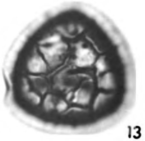
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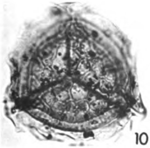
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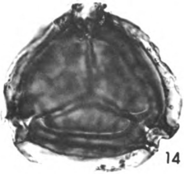
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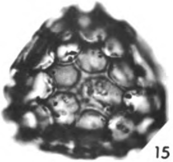
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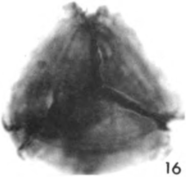
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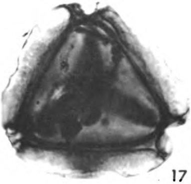
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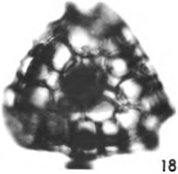
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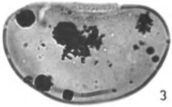
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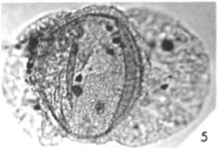
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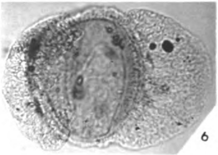
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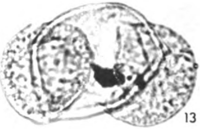
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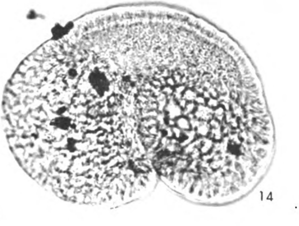
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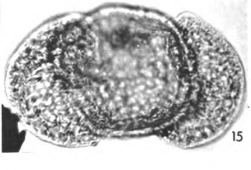
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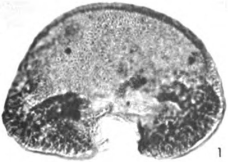
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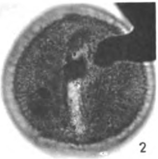
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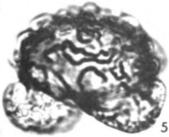
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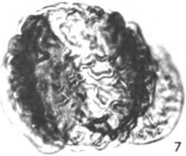
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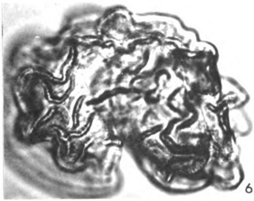
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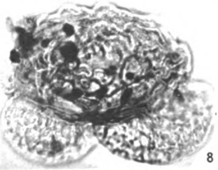
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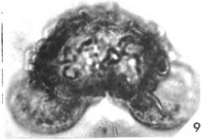
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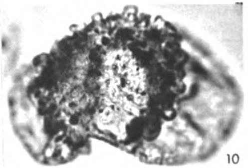
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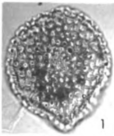
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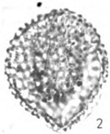
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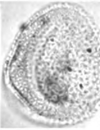
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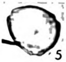
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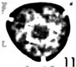
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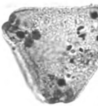
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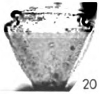
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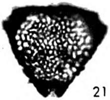
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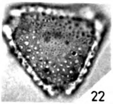
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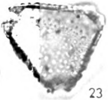
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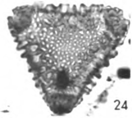
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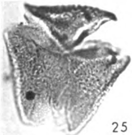
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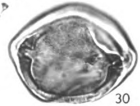
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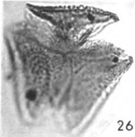
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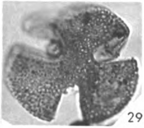
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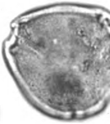
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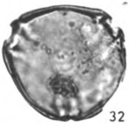
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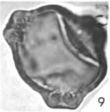
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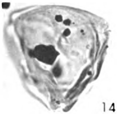
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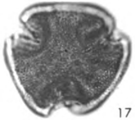
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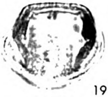
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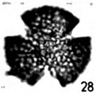
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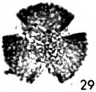
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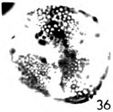
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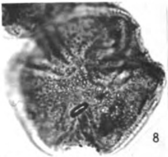
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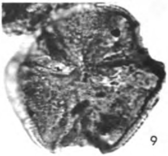
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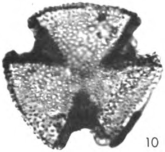
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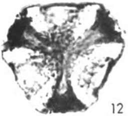
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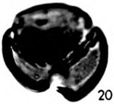
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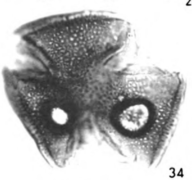
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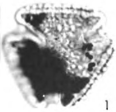
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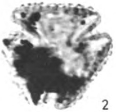
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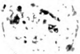
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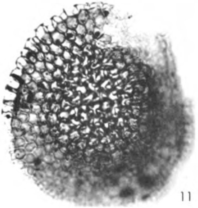
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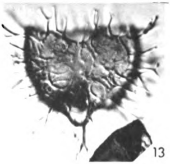
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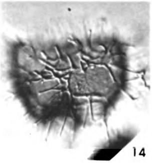
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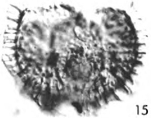
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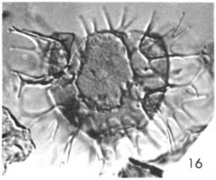
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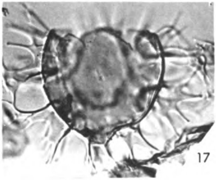
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PLATE 13

Figure All Figures X500

1-7. *Deflandrea* spp.
1-6. *Deflandrea* cf. *D*. *cooksoni* Alberti
1. Pb-9462-3, 103.1 x 6.9, 104u; 2. Pb-9465-3, 105.4 x 11.7, 103u; 3. Pb-9383-3, 92.9 x 24.1, 76u; 4. Pb-9454-1, 105.2 x 3.3, 112u; 5. Pb-9454-1, 99.6 x 19.8, 100u; 6. Pb-9463-3, 111.9 x 9.1, 90u; 7. *Deflandrea* sp., Pb-9447-2, 119.0 x 4.0, 168u. All figures shown in interference contrast.

8-13. *Spiniferites* spp.
8. Pb-9384-4, 74.1 x 18.4, 64u; 9-10. Pb-9390-4, 94.9 x 20.0, 62u; 11. Pb-9384-4, 99.5 x 9.2, 80u; 12-13. Pb-9384-4, 86.7 x 3.4, 88u. Figures 9-13 shown in interference contrast.

14-17. *Hystrichosphaeridium* spp.
14. *Polysphaeridium* sp., Pb-9384-4, 77.0 x 16.2, 64u; 15. *Oligosphaeridium* sp., Pb-9390-1, 82.0 x 13.7, 90u; 16. *Hystrichosphaeridium* *tubiferum* (Ehrenberg), Pb-9394-1, 94.1 x 14.8, 84u. All figures in interference contrast.

PLATE 13


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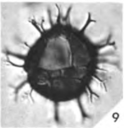
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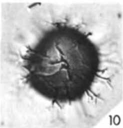
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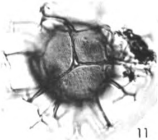
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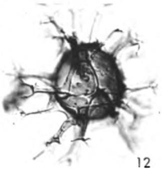
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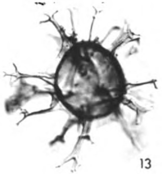
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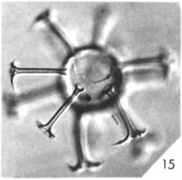
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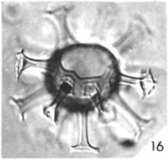
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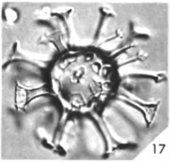
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PLATE 14

Figure All Figures X500 unless specified

1-2. Operculodinioid taxa
1. *Cordosphaeridium* sp., Pb-9452-5, 106.4 x 18.6, 108u, X400; 2. *Operculodinium* sp., Pb-9452-4, 106.0 x 24.1, 66u. All figures shown in interference contrast.

3. *Palaeoperidinium* sp.
Palaeoperidinium cf. *P. basilium* (Drugg), Pb-9393-4, 77.0 x 16.0, 108u, interference contrast.

4-6. *Systematophora* sp.
4. Pb-9393-4, 76.4 x 24.0, 98u; 5-6. Pb-9452-3, 108.7 x 6.8, 88u. All figures shown in interference contrast.

7. *Coronifera oceanica* Cookson & Eisenack, Pb-9382-2, 109.9 x 8.0, 94u, interference contrast.

8-10. *Dinogymnium* spp.
8. Pb-9447-2, 90.7 x 17.7, 34u; 9. Pb-9378-1, 95.2 x 7.7, 47u; 10. Pb-9450-8, 93.1 x 6.0, 80u. All figures shown in interference contrast.

11. ?*Xenikoon* sp.
Pb-9452-8, 106.8 x 16.9, 86u.

12. *Prolixosphaeridium* sp.
Pb-9390-1, 84.1 x 23.5, 34u, interference contrast.

13. *Tanyosphaeridium* sp.
Pb-9379-1, 95.0 x 23.8, 47u, interference contrast.

14. ?*Fromea* sp.
Pb-9459-1, 115.8 x 11.9, 84u.

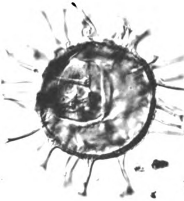
15. Forma A
Pb-9452-8, 101.3 x 6.6, 26u, X1000

16. *Spinidinium* sp.
Pb-9384-4, 74.9 x 18.6, 62u, interference contrast.

17-18. *Microdinium* sp.
Pb-9384-4, 74.1 x 12.8, 30u, dorsal and ventral views.

19. *Svalbardella* sp.
Pb-9451-6, 95.3 x 9.4, 195u.

PLATE 14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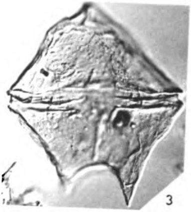
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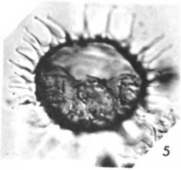
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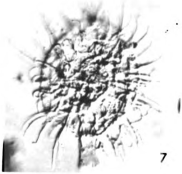
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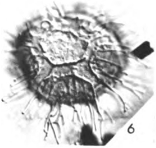
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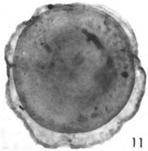
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