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ERNST CLOOS, *Acting Director*

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THE SPORES AND POLLEN OF THE POTOMAC GROUP OF MARYLAND

By

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PREFACE

Ever since its founding the Maryland Geological Survey which is now the Department of Geology, Mines and Water Resources, published highly technical scientific works along with topographic and geologic maps, county reports and bulletins of more general interest and application. Maryland is the only state in the Union which is completely covered with data on ground water and has almost complete coverage of geologic maps. Even if some of these data are in need of revision they provide data for many purposes.

This volume is in a new field which has made great progress during the last 15 years and has become an important tool in the correlation of formations where other means have failed. It deals with fossil spores and pollen which occur in the earliest Maryland Coastal Plain sediments, the Potomac Group, which were deposited on the eroded old basement rocks of the Piedmont Province. At that time dense forests existed similar in character to the warm-temperate rain-forests of New Zealand. In the forests grew trees with a luxuriant growth of all types of fern. The deposits were continental and were made up mostly from continental debris. Gradually the sea progressed, however, and the forests gave way to oceanic conditions and deposits which include marine forms.

The work on which the volume is based was done at Pennsylvania State University under the guidance of experts and was offered to us for publication because the material and many of the described localities are in Maryland. It is the first comprehensive publication on Lower Cretaceous spores and pollen published in the United States.

The volume will be helpful in correlating the Cretaceous formations in Maryland and will be used beyond our borders. The interest in the Cretaceous formations is a practical one because half of the state draws its water from these strata and their complete knowledge plays an important part in our economy.

Ernst Cloos

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ACKNOWLEDGMENTS

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Messrs. H. T. Ames and W. L. Riegel, staff members of the Department of Geology, offered their advice on several occasions.

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I. Introduction

GENERAL STATEMENT

The Potomac Group forms the oldest unit of the Maryland Coastal Plain. It consists of a series of interlensing gravels, sands, silts, and clays deposited in a continental environment. The Potomac Group is of extreme interest to paleobotanists, for in the upper part, the Patapsco Formation, the first undoubted remains of angiosperms are found. The introduction of angiosperms in Patapsco time is an important phase in plant evolution, because in the Raritan, which overlies the Potomac Group, the angiosperms have, for the first time, become the dominant group in the vegetation.

In the area between Washington, D. C. and Baltimore, Maryland, the Potomac Group is divided into three formations: the Patuxent, Arundel, and Patapsco. Outcrops of these three formations are recognizable in this area, although mapping the boundaries presents frequent difficulties. To the northeast towards Delaware and to the southwest in Virginia rapid lateral and vertical lithologic changes, so typical of continental sedimentation, make correlation with the Potomac area extremely difficult. The problem is further complicated by the fact that in Delaware and New Jersey the overlying nonmarine Raritan Formation is lithologically indistinguishable from the Patapsco Formation. Although plant megafossils can be used to recognize the formations, they are extremely sparse, and, therefore, not practical as a stratigraphic tool.

In the summer of 1960, the writer examined several samples from the Potomac Group of Maryland for palynological content. The carbonaceous silts and clays scattered throughout the section proved to be highly productive, containing numerous spores and pollen. It then became apparent that the microflora might be used to develop an effective zonation of the Potomac Group, regardless of geographic differences in lithology. It was also believed that a study of the spores and pollen would contribute to an understanding of such topics as the nature and time of the arrival of angiosperms into this region, the age of the sediments, and vegetational changes during Potomac time.

Until now no detailed study of Lower Cretaceous spores has been published in the United States. It was thought, therefore, that a detailed account of the spores and pollen from the Potomac group would be a contribution to the palynology of this part of the geologic column.

HISTORICAL SUMMARY OF THE POTOMAC GROUP

In 1886 the name Potomac Formation was first used by McGee for nonmarine gravels, sands, and clays that form the basal Cretaceous series along the inner margin of the Atlantic Coastal Plain from Delaware to Virginia (McGee, 1886). At that time two distinct units were recognized: (1) a lower member consisting of sands and gravels with minor amounts of clay, and (2) an upper member composed of variegated clays. The age of the Potomac deposits was then considered Jurassic by some, and Early Cretaceous by others. Fontaine (1889) published the first detailed account of the Potomac flora; he considered it to be most comparable to the Neocomian floras of Europe. Owen C. Marsh (1896) studied the reptilian remains from beds chiefly from the Arundel Formation and strongly advocated a Jurassic age for the Potomac Formation.

In 1897 Clark and Bibbins published a paper on the Potomac deposits of Maryland, raising them to group status and dividing them into four formations: the Patuxent, Arundel, Patapsco, and Raritan. The Patuxent and Arundel were assigned to the Jurassic, and the Patapsco and Raritan to the Lower Cretaceous (Clark and Bibbins, 1897). Berry (1910) showed that the Raritan Formation is of Late Cretaceous age, and Clark (1910) removed the Raritan from the Potomac Group. He referred to the Potomac Group as Lower Cretaceous, and the Raritan Formation as Upper Cretaceous. In 1911 Berry published his comprehensive study of the Potomac flora, revising much of the earlier work by Fontaine. In this study he demonstrated the close similarities between the Neocomian floras of Europe (Portugal in particular) and the floras of the Patuxent and Arundel. The overlying Patapsco Formation, which contains the remains of definite angiosperms, was shown to be Albian (Clark, Bibbins, and Berry, 1911).

In 1939 Gilmore (p. 343) expressed the opinion that the Arundel Formation is Upper Cretaceous. He based this on the presence of a reptile belonging to the *Ornithomimidae*, a family known only from the Upper Cretaceous of the North American continent. According to Dorf (1952), Edwin H. Colbert (now vertebrate paleontologist at the American Museum of Natural History) stated (personal communication to Dorf) that Lower Cretaceous dinosaurs are virtually unknown from Western North America, and that the presence of sauropod remains in the Arundel Formation might represent an early appearance in the Lower Cretaceous.

From about 1910 to 1948 an Early Cretaceous age for the Potomac Group was generally accepted (Dorf, 1952). In 1948 Anderson recovered Cenomanian invertebrates from the lower part of the Maryland Esso Well. Although he admitted that the subsurface section is not lithologically identifiable with the Arundel and Patapsco at the surface, he considered the beds correlative with those formations. In 1950 a paper on the geology of the Atlantic Coastal Plain was published by Spangler and Peterson. They were so impressed by the similarity and proximity of the Raritan in New Jersey with the Potomac Group and Raritan Formation in Maryland that they suggested their age equivalence. The Patuxent Formation was correlated with the lower Raritan Formation in New Jersey and referred to the Lower Cretaceous Series, and the

Arundel, Patapsco, and Raritan Formations of Maryland were correlated with the upper part of the Raritan in New Jersey and placed in the Upper Cretaceous (Spangler and Peterson, 1950). Dorf (1952) criticized Spangler and Peterson for disregarding the overwhelming difference between the flora of the Raritan in New Jersey and the Potomac in Maryland. He reasserted that the Raritan Formation of New Jersey, Delaware, and Maryland is of Late Early Cretaceous age and the Potomac Group of Maryland of Lower Cretaceous age.

The Maryland Department of Geology, Mines and Water Resources now considers the Arundel and Patapsco Formations to be Upper Cretaceous in age (Hack, et al., 1950, p. 18), although most paleobotanists refer them to the Lower Cretaceous series.

PREVIOUS LOWER CRETACEOUS PALYNOLOGY

The earliest palynological investigation of Lower Cretaceous coals was done by Miner (1935) from the Kootenai Formation of Montana. This work involved only the description and illustration of a few very simple spore types. No further work was published until 1949 when Thiergart described a number of spores from the Wealden of Germany and Austria.

The first major work on Lower Cretaceous spores was done by Bolkhovitina (1953) in which she described numerous spores and pollen from the Hauterivian to Cenomanian Deposits of Central Russia; on page 133, Figure 8, the stratigraphic range for 59 species is given. Of particular interest is the first occurrence of undoubted angiosperms in the Albian. During the same year Couper described some Lower Cretaceous spores as part of a larger study on the upper Mesozoic and Cenozoic spores and pollen of New Zealand. The first occurrence of angiosperm grains was found in beds thought to be of Late Cretaceous age (Couper, 1953). In 1956 Bolkhovitina published a comprehensive spore study of the Jurassic and Lower Cretaceous (Neocomian) deposits of the Vilyui Basin of Russia. Spores from the Wealden of Belgium were first described in a paper by Delcourt and Sprumont (1955). In 1957 Balme published a long paper on Jurassic and Lower Cretaceous (Neocomian-Aptian) spores from Western Australia.

In 1958 two important papers were published on Lower Cretaceous sporomorphae. Cookson and Dettmann (1958) described 29 trilete microspores from Eastern Australia. Some of the spores appear conspecific with Potomac forms. Couper (1958) published a major work on British Mesozoic microspores and pollen. Sixty-six species of spores and pollen ranging from the Lias to the Lower Greensand (Aptian) are described. The spores and pollen of the Wealden and Lower Greensand described by Couper show a striking resemblance to those from the Potomac Group, although beds equivalent in age to the Patapsco (Albian) are absent. No angiosperms were found in the Aptian. Some additional work was done on the Jurassic and Lower Cretaceous spores of England by Lantz (1958).

In 1960 Couper published another paper on the Mesozoic and Cenozoic microflora of New Zealand. In this work the age of the deposits was ascertained from marine invertebrate fossils; it is of interest to note that the first tricolpate grains were found in sediments of Albian-Cenomanian age (Clarence Series). Groot and Penny (1960) published a small paper describing some spores and pollen from the Cretaceous of Maryland and Delaware. The specimens came from samples believed to range from the Patuxent to the Raritan Formation, but the stratigraphic position of the samples was uncertain.

Except for the small papers by Miner (1935) and by Groot and Penny (1960), no work has been published on Lower Cretaceous spores and pollen from North America.

PURPOSE AND SCOPE OF THE INVESTIGATION

As previously mentioned, the Potomac Group is of interest palynologically both from a botanical and stratigraphic viewpoint. Botanically it involves a section in which the first unequivocal evidence of angiosperms is found. Since the viscissitudes of preservation of spores and pollen grains may differ greatly from that of leaves, the former may contribute additional information on the makeup of the vegetation and the changes in the vegetation with geologic time.

A systematic study of the spores and pollen should provide the information required for a stratigraphic zonation of the section, distinguishing it from the lithologically similar Raritan and Magothy Formations above. A subsequent study of the spores of the Raritan Formation of New Jersey should end the confusion in the literature as to the relationship of these deposits to the Potomac Group of Maryland.

The following list outlines the primary objectives of this investigation:

1. To give an account of all types of spores and pollen common to the Potomac Group of Maryland.
2. To establish the microfloral differences between the formations of the Potomac Group, and, as a result, contribute to a better understanding of age relationships of the sediments from one location to another.
3. To develop a zonation of the Potomac Group.
4. To contribute information on the stratigraphic position of the first angiosperms and the nature of this first appearance.
5. To obtain additional information on the botanical makeup of the vegetation and its change within the span of Potomac time.
6. To find out if the spores and pollen could contribute any additional information as to the age of the deposits.

To achieve these goals 43 surface and subsurface samples were studied in detail. Due to the complexity of the section, core material was used to establish unquestionable vertical control.

II. STRATIGRAPHY OF THE POTOMAC GROUP

GENERAL STATEMENT

The sediments of the Potomac Group form the basal unit of the Coastal Plain of North Carolina, Virginia, Maryland, and Delaware. This Plain is a part of the larger Atlantic Coastal Plain Province that extends from Cape Cod southward through Florida, and is underlain by a wedge-shaped body of unconsolidated nonmarine and marine gravels, sands, and clays of late Mesozoic and Cenozoic age. The Coastal Plain sediments, which were deposited on the eastward sloping margin of the Older Appalachians, dip gently to the east and southeast, 10 to 40 feet to the mile (Hack, et al., 1950).

The Potomac Group consists of approximately 600 feet of continental sediments that can be divided, in the area between Baltimore and Washington, D. C., into three formations: the Patuxent, Arundel, and Patapsco. The rest of the nonmarine Cretaceous consists of the overlying Raritan and Magothy Formations. The Patuxent Formation has its greatest development from Maryland southward into North Carolina. The Arundel Clay attains its maximum thickness in central Maryland, disappearing in northeastern Maryland and in the southern part of the Maryland Coastal Plain near Virginia. The Patapsco is largely developed from Delaware to Virginia, disappearing in the vicinity of Fredericksburg. It is not exposed at the surface in New Jersey.

PATUXENT FORMATION

Name—The Patuxent Formation takes its name from the type area in the valleys of the Little Patuxent and Patuxent Rivers where it forms the basal unit of the Coastal Plain sediments. It was first recognized as a distinct unit in the Potomac Group of Maryland by Clark and Bibbins (1897).

Distribution—The Patuxent deposits outcrop in an irregular belt 1 to 6 miles wide, along the inner margin of the Maryland Coastal Plain from the Delaware line to the Potomac River. Its surface continuity is interrupted by such waterways as Gunpowder Falls, and the Susquehanna, Patapsco, and Potomac Rivers. In its entirety it extends from Delaware to North Carolina.

Lithology—The Patuxent Formation is primarily composed of cross-bedded and lenticular sands and gravels with minor amounts of light gray, brown, and pink clay beds. Some of the sands contain small balls of kaolin. Much of the sand contains disseminated kaolin and mica flakes with some incompletely decomposed feldspar grains. The gravels and sands are predominately of subangular to subrounded milky quartz. The heavy minerals consist primarily of zircon, tourmaline, and staurolite with minor amounts of rutile, sillimanite, and kyanite; the high amount of staurolite characterizes the Patuxent Formation (Bennett and Meyer, 1952). The gravels and sands are usually white to buff and occasionally red and purple. In places, lenses and irregular masses of indurated sandstone form ledges in the deposits; these layers are composed of sand in which the grains have been firmly cemented by iron oxide. Drab carbonaceous clays, although not as common as in the overlying Arundel Clay and Patapsco Formation of Maryland, are occasionally found; such clays are more common in the Patuxent of Virginia.

Attitude and Thickness—In Maryland, the strike of the Patuxent Formation is in a northeast-southwesterly direction with a gentle dip southeastward of 50 to 90 feet to the mile (Clark, Bibbins, and Berry, 1911, p. 61).

The thickness of the Patuxent in Maryland ranges from 150 to 350 feet at the surface, thickening considerably downdip. In a deep well near Ocean City, Maryland, Anderson (1948, p. 93) found 2,310 feet of this formation without having reached the crystalline basement.

Stratigraphic Relations—The Patuxent sediments rest directly on a crystalline basement which is the southeastward-dipping submerged margin of the Piedmont. According to Clark, Bibbins, and Berry (1911), the Patuxent Formation is unconformably overlain by the Arundel Clay. The time lapse represented by this disconformity is not considered very great because of the similarity between the Patuxent and Arundel floras. The disconformable relationship between the Patuxent Formation and Arundel Clay may disappear downdip where the change from a lower sandy formation to a tough clay sequence is not as sudden in some areas.

ARUNDEL CLAY

Name—The Arundel Clay takes its name from the type area in northern Anne Arundel County where it is well developed. It was named by Clark and Bibbins (1897) who were the first to recognize the Arundel Formation (now called the Arundel Clay) as a distinct unit of the Potomac Group.

Distribution—The Arundel Clay forms an irregular belt from Washington, D. C. to the region of the Bush River about 20 miles northeast of Baltimore. North of this area it is not recognizable as a distinct lithologic unit. Its width of outcrop ranges from $\frac{1}{2}$ to a maximum of 7 miles in the northern part of Prince Georges County. Its continuity of outcrop is interrupted by Gunpowder Falls, and the Patapsco and Back Rivers. It is not present in Virginia where the Patuxent Formation is directly overlain by the Patapsco Formation.

Lithology—The Arundel Clay is primarily a clay deposit, in contrast to the more arenaceous deposits of the Patuxent Formation. The clays are relatively pure in comparison to the greater admixtures of silt and sand in the clays of the overlying Patapsco Formation. The colors of the Arundel Clay are commonly dark gray, red, and various shades of brown. The drab clays frequently contain lignite, leaf compressions, siderite, and hydrous iron oxide nodules (Pl. 2, fig. 2). It is in the drab clay lenses that many of the reptilian bones were found. The Arundel Clay is quite plastic and tough, and, as a result, is easily recognized by drillers by an increase in drilling time.

Attitude and Thickness—The strike of the Arundel Clay parallels that of the Patuxent Formation. The beds dip to the southeast at about 50 feet to the mile. The thickness of the Arundel ranges from a few feet to 125 feet (Hack, et al., 1950) in the middle of the belt.

Stratigraphic Relations—When seen in outcrop, the Arundel Clay appears to unconformably overlie the Patuxent, although this relationship is obscure downdip; it is overlain unconformably by the Patapsco Formation. The clays of this formation commonly serve as a stratigraphic marker separating the Patuxent from the Patapsco Formation.

PATAPSCO FORMATION

Name—The Patapsco Formation takes its name from the Patapsco River Valley where it was first recognized as a distinct formation of the Potomac Group by Clark and Bibbins (1897).

Distribution—The Patapsco Formation of Maryland outcrops in an irregular belt, about 5 miles wide, from Delaware southwestward to Washington, D. C.; it then continues on into Virginia disappearing at the surface in the vicinity of Fredericksburg.

Lithology—The sediments of the Patapsco Formation consist of interlensing sands, silts, and clays. The Patapsco Formation differs from the Patuxent Formation by its greater amount of clay. The clay is commonly more highly colored than the Patuxent clays, and variegated red, gray, white, and chocolate clays are typical. The clays grade rapidly in a vertical and horizontal direction into sands and silts that frequently show a marked cross-bedding. Thick lenses of lignitic clay, similar in appearance to the dark gray Arundel clays, have yielded numerous plant fossils. These carbonaceous clays may grade rapidly into the colorful variegated clays mentioned above. The clays, in general, are not as pure as the Arundel clays in the type area, frequently containing admixtures of silt and sand. Iron carbonate nodules occur locally, but are not as abundant as in the Arundel Clay.

The sands occasionally contain disseminated kaolin, but not as frequently as in the Patuxent sands. The heavy-mineral suite in the Baltimore area (Bennett and Meyer, 1954, p. 60) consists primarily of zircon and tourmaline and lesser amounts of garnet and hornblende. It differs significantly from the Patuxent Formation in its low staurolite content.

Attitude and Thickness—The strike of the Patapsco Formation is essentially parallel to that of the two preceding formations; the formation dips to the east about 40 feet to the mile. At the surface the average thickness of the Patapsco deposits is about 200 feet; it thickens rapidly downdip.

Stratigraphic Relations—The Patapsco Formation rests unconformably on the Arundel or on the Patuxent Formation when the former is absent. In places it transgresses the underlying formations, lying directly on the crystalline rocks of the Piedmont. In Maryland the Patapsco is unconformably overlain by the Raritan Formation. In places the Raritan is lithologically indistinguishable from the Patapsco Formation, but, in general, the Raritan clays in Maryland are less colorful and sandier, especially in the upper part of the formation. In Delaware the formations are lithologically inseparable. In the subsurface the Patapsco Formation is often lithologically indistinguishable from the overlying Raritan and Magothy.

An apparent disconformity between the Patapsco and Raritan? Formations was observed by the writer along a railroad track near Hawkins Point, Maryland (Pl. 3, fig. 2).

III. METHODS OF STUDY

SAMPLING PROCEDURES

During the spring and early summer of 1960, several days were spent in the Coastal Plain of Delaware and Maryland in order to become familiar with the stratigraphy of the Potomac Group. One day was spent in Delaware with Dr. Johan Groot, Chief Geologist of Delaware, looking over the section. Dr. Maxwell Knechtel of the U. S. G. S. spent a few days showing the writer the Potomac section of Maryland and discussing some of the fundamental problems involved.

It then became apparent that, although, the Potomac Group could be roughly divided into three formational units in the area between Baltimore and Washington, D. C., the boundaries of these units are extremely difficult to locate in the field. This situation is due to two main factors: (1) the scarcity and limited size of exposures decreases the probability of finding one that contains a formational boundary, and (2) discontinuous development of the typical clays of the Arundel Clay makes it difficult to distinguish the top of the Patuxent Formation from the bottom of the lithologically similar Patapsco Formation. The problem is further complicated by extreme changes in the character of the sediments both in a vertical and horizontal direction, and the possibility that outliers of each formation extend its outcrop further west than its outcrop belt; mapping the boundaries of these formations, then, becomes an extremely difficult task. Outside the type area, in northern Maryland, Delaware, and Virginia, the task of separating the Patuxent from the Patapsco becomes almost impossible˙

In view of the above-mentioned difficulties, the following approach was taken in acquiring samples for this study:

1. Core material was obtained from the type area to insure vertical control.
2. Surface samples were collected in the Potomac Group across the whole length of Maryland and in Virginia as far south as the James River near Richmond.
3. The sampling pattern consisted of stations parallel and perpendicular to the outcrop belts.

Most of the samples collected in Virginia were later found to be barren of spores and pollen; only one sample from Virginia was used in this study. This sample (St. 26) came from the Patuxent Formation exposed along the James River just south of Richmond. The rest of the samples are from Maryland.

Although several samples were collected and macerated from each of approximately 50 surface localities, only one sample from each productive locality was used for a detailed palynological examination. In this way a greater geographic area could be sampled, and any large-scale vertical changes in the spores and pollen could be investigated without getting involved with detailed variations due to ecologic factors.

A total of 21 surface samples, representing 21 stations, and 22 subsurface samples from two probe holes were studied in detail. After processing over 150 samples of various lithologies, it was found that sediments containing gray clay, either as a clay or as the matrix of silts and sands, yielded spores and pollen. The red clays and silts and the very light gray, white, and brown clays, silts, and sands were found to be consistently barren. Detailed descriptions of all the wells, surface localities, and samples are given in the Appendix. The location of the surface localities and wells is shown on Text-Figure 1.

SAMPLE PREPARATION

All samples collected proved unindurated and easily disaggregated by crushing in a mortar and then adding distilled water. The organic matter was separated from the inorganic matter by flotation in a heavy liquid solution of zinc chloride with a specific gravity of 2.0 The organic float (spores, cuticles, woody material, etc.) was then bleached in a 5.25% solution of sodium hypochlorite (Clorox), treated in a 10% solution of ammonium hydroxide, stained, and finally mounted in diaphane. The inorganic residue was examined for organic material and the separation proved complete.

The following is a detailed description of the above procedure:

Disaggregation

1. Using a mortar and pestle crush about 3 tablespoons of a sample down to pieces about 5 mm. in diameter, add distilled water, stir, and continue crushing until all lumps are disaggregated.
2. Let the stirred mixture settle about 30 seconds and pour off mixture into a 50 ml. plastic centrifuge tube.
3. Centrifuge for about 3 minutes and decant water. Continue adding sample-water mixture until there is $\frac{3}{4}$ of an inch of sediment at the bottom of the tube.

Flotation

4. Pour off all water from sediment and add ZnCl heavy liquid solution (S. G. 2.0) to within $\frac{1}{2}$ inch from the top of tube.
5. Using a glass rod, thoroughly mix sediment and ZnCl solution so as to loosen it from the bottom and break up all clumps that float to the top. Pour mixture into a sharp-lipped beaker.
6. Lubricate the inside of two (50 ml.) plastic centrifuge tubes with glycerine and insert a 9-inch piece ($\frac{3}{8}$ inch diam.) of tygon tubing in each centrifuge tube. The tube is bent in half and inserted so that half an inch of tubing projects beyond the centrifuge tube.

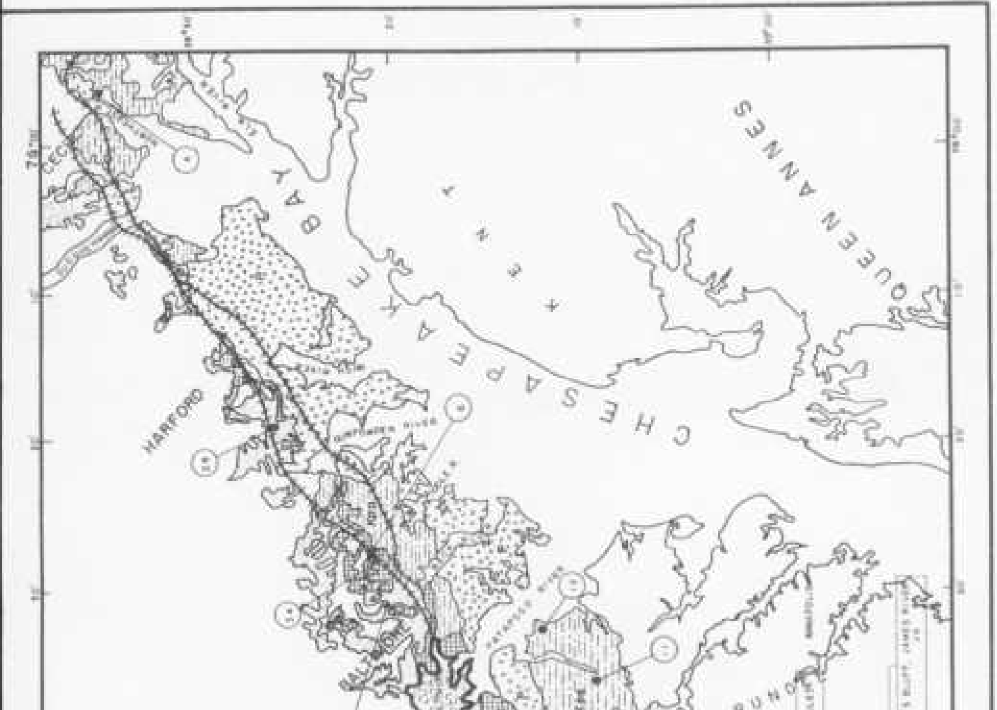


FIGURE 1. Geologic Map of the Potomac Group formations of Maryland with the locations of outcrop and subsurface samples selected for detailed study (Adapted from Geologic Map of Maryland, Clark, Bibbins, and Berry, 1911)

7. Pour ZnCl-sediment mixture into the tygon tubing. The sharp-lipped beaker facilitates accurate pouring.

8. Centrifuge for about 30 minutes (approx. 1500 rpm.).

9. Remove the plastic tubing carefully, hold upright, and pinch the two ends tightly together just under the float.

10. Pour float with a rapid motion into a clean beaker, maintaining the pinched condition on the tygon tubing. Remove the float that adheres to the inside of the plastic tubing by rinsing with 10% HCl.

11. Transfer contents from beaker into two 15 ml. centrifuge tubes with tapered bottoms. Add several drops of 10% HCl. The HCl prevents the precipitation of zinc hydroxide when water is added.

12. Wash twice with distilled water.

13. Add HF and allow to stand for 25 minutes. This step removes any clay that might have floated with the organic material.

14. Wash twice with distilled water.

Oxidation

15. Oxidize with Clorox for 20 minutes. If Clorox does not react with float, add a few drops of 10% HCl.

Base

16. Wash twice with distilled water, then add NH_4OH (10%) and allow to stand 3 minutes.

17. Wash with distilled water twice, half water and alcohol once, and finally in pure alcohol.

Stain

18. Stain with dilute safarrine Y in alcohol from 10 to 20 minutes.

19. Wash out, stain, and mount in diaphane.

ANALYTICAL PROCEDURES

A minimum of two slides were prepared for each of the 43 samples examined. On each slide are printed the sample locality or well number, as well as a letter indicating the slide preparation. For example, the slide designation St. 10B indicates a sample from station 10, and that it is the second slide prepared. L1-22A and L2-49A refers to sample 22, first slide from Probe Hole No. 1, and sample 49, first slide from Probe Hole No. 2, respectively. Two hundred and fifty to 300 specimens were counted for each sample from two slides; 120 to 150 specimens from each slide. When the number of specimens on two slides did not amount to at least 250 specimens then all the specimens encountered on both slides were recorded.

Counting was done with a 100× oil immersion objective. After counting 250

CLASSIFICATION		SPORE BEARING PLANTS																																																																																	GYMNOSPERMAE																																			ANGIOSPERMAE								INCERTAE SEDIS						
SPECIES NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	
POLLEN & SPORES	GENERA	Alsophilidites	Apiculatisporis	"	Appendicisporites	"	"	"	Ceratosporites	Cicatricosisporites	"	"	"	"	"	"	"	Cingulatisporites	"	"	"	"	Cirratriradites	Concavissimisporites	"	Converrucosisporites	"	Cyathidites	"	"	Deltoidospora	Densoisporites	"	Dictyophyllidites	Foveotriletes	Gleicheniidites	"	"	Granulatisporites	Ischyosporites	Klukisporites	"	Kuylisporites	Lycopodiacidites	"	"	"	"	"	"	Lycopodiumsporites	"	Matonisporites	"	Microreticulatisporites	Neoraistrickia	Perotriletes	"	Pilosisporites	"	Psilatriletes	"	Reticulatisporites	Sphagnumsporites	Taurocusporites	"	"	Todisporites	Trilites	Trilobosporites	"	"	"	Undulatisporites	Inaperturopollenites	Reticulatasporites	Laevigatosporites	Monosulcites	Peromonolites	"	"	Decussosporites	Entylissa	Eucommiidites	Monosulcites	"	"	Ephedripites	"	"	Araucariacites	Inaperturopollenites	Laricoidites	"	Tsugaepollenites	Zonalapollenites	"	Exesipollenites	Perinopollenites	Circulina	Classopollis	Spheripollenites	Abietineaepollenites	"	"	Alisporites	Parvisaccites	"	"	Phyllocladidites	Pinuspollenites	Platysaccus	Podocarpidites	"	"	Rugubivesiculites	Vitreisporites	Liliacidites	Retitricolpites	"	"	"	Tricolpopollenites	"	"	Clavatipollenites	"	Monosulcites	"	Schizosporis	"	NO. OF SPECIMENS COUNTED
SAMPLES																																																																																																																																					
NO. 1 PROBE HOLE																																																																																																																																							
SAMPLE	DEPTH																																																																																																																																				
L1-21	212-213.5 ft.	1	x	x	x	1	x	2	x	8	10			10	1	1													7	x	6		x		x			7	3	x	x					1			x	x			4	x		x					1	1	2		3	1	3	x	x								x							x							1	x	1					2	x		8		2			x		x		x						1	x					x		x				1				300
L1-22	222-223.5 ft.	1	2		x	3	x	x	x		9			6	x	x							x	x				x	6		3		2				x	6	2		2			x		x			x				x	x		x	x				5		1		2	x	4	3	x								1						x	2							3	2						4	x		5		3		2	2		2		x		x				3	x	x										3	x			254
L1-39	427-428.0 ft.			x		4		x		2	5			6							x		x	x		x	x		9		1							4			3											x	1							x		1					1	x									x						6	14							9	x									5		5			1				x							x							6	2	5			2			144
L1-41	447-448.5 ft.	x		x		x				x	2			4	x														6		x		x					x	x		x				x					x		x				x			x	x	x	x			x			x											x	x		x	3	7							11	6				x		2	1		9		14	x	2	2		2		x	x		x			x	x				x			8	2	13		x				273
L1-47	507-508.5 ft.	x		3		3		x			9			13	1			x			1		x	x					9		x		x				x	5	x	x										x			1						2	2		x						x									x	x		x		x	2	x				x			x	6						4	3	x	7		3			2		2		x			2		x		2							2		5	x					254
L1-50	532-533.5 ft.	3	x	1		x		x			4			3	x	x				x	x			x	x		x		9				x		x		x	1	1	x					1		x						x		x		x		x						3	x	1	1				x			x		1	x		x			4	3				x			x	5	x					2	x	x	19	2	1		x	6		x			x		x		x		2							[illegible]	[illegible]	[illegible]	[illegible]					278
L1-69	712-713.0 ft.	x				2			x	1	4			4				x			x		x		x	x			13	x	x		x			x	x	x	2	x						x	x		x			x			x			x		1				x						x		x	x				2				x	x	2	2	3							6	x					13	1	x	20	x	x			12		3		x			x	x	x		x	x					x	x		x			x			270
L1-70	722-723.5 ft.	4	x		x	7		2		8	17			14		x				x		x	x	x	2	x	x		6				3				x	3		2	2		x									4		x	x									x													x						x	x								x						1			16		2		2																											250
L1-71	732-733.5 ft.	x				4				3	7			4										x	1				38	x			2					4			1		x						x			2		x						x					x												x						x															x			20	2			6			x	x								x															x		x	250
L1-73	802-803.5 ft.									6	22			6										6					6				6					6			11			6																																								6								6									17																															18
L1-96	1062-1062.5 ft.		x							3	3												x			x			37	3			2		2			4			7																							2					x					5									2	7														3	x		15							x		x							x															104
L1-103	1132-1132.5 ft.	1				5		3		6	9	x		4		2				x				2			x		19		x		2		x	x		x	x		2					10			x													x			4	3		x	x					x	x	x			x	x	x		2									x	x			x		1			9		x		x	x	x	2																								260
NO. 2 PROBE HOLE																																																																																																																																								
SAMPLE	DEPTH																																																																																																																																									
L2-49	473-474.0 ft.	x		x		x		x	x	x	2	x		4	1	x	x	x		x			x	x					5		x		2					x	x	x	x						x		x		x		x			1	x			1	x	x			x	x	x	x				x	x		x	x	1	x						8					x		19	4			x	2		x	1	x	9		28	x	x	1		x			x	x	x	x		1	x															307
L2-53	503-504.0 ft.	x	2					x	x		1			6			x				x			x		x			2				x		x			x	1	x	x																				x		x		x	x	x	3				x			x		2	x				x		14				x				16						2	1		12		2			x				x						x					x			5	x	4						255
L2-58	548-549.5 ft.	x	x	x		x				1	1			9	x	x	x	x		4	x		x	x					19		x	x			x			x	1	x							x		x	x			x			x	x		x						2	2	1	1	x			x			x		2	1		x			x	7				x	x		x	9						1			15		3		x	1		x		x	x		x	x								1		x		x					4	287
L2-61	573-574.0 ft.	x	x	1		x			x	x				7	1	x	x			x	x			2					2		1		1				x	2	2	x	x					x			x				x							x	x	x			x	2	2	x				x			x		3							11					x			8				x		2	x		15		4	x						x			1						x			x		21	2	6	x					255
L2-65	613-614.0 ft.		2	2				2												2									5				2																																2																											2				2		11		x	41		2		2					2								7			5			16	4	3			x			44
L2-74	703-704.0 ft.	1	1			1				2	5		3	6		x				5	1					1			2	1	1							1			1					5			3						1										5	2		1	6								1															1	1					8			6		11			5		3						1			1									5	2					89
L2-84	803-804.0 ft.	2								2	7			3										x					45				2						x		4								x													x							x				2				2						x									x						5			18		2					x									2									1						204
L2-88	843-844.5 ft.	2			2			2		12	6			6						2				3		5			29		4							x			4								x			4																x														x		5														5			6	x	x					x																			2					181
L2-89	853-854.0 ft.	2	x		x	5		2		8				4						3				x		2			31		6					x		2	x		6											2										x															x					2		6										x				2			8	4																								x						134
L2-110	1063-1064.5 ft.									2	2			6										3					2		5																																														2							14															2		65																															65
SURFACE SAMPLES																																																																																																																																										
STATION	FORMATION																																																																																																																																											
St. 40	Patapsco	x	x	x		x	x		x	x	2			3	x	x		x		x	x	x	x					x	6	x	x		x				1	1	4	x	x						x		x		x	x	x		x						x	x			x	x	x				x	x			x		1					1		2	2			x			4	11	x		x			2	1		5		3		x			x		2			x	x		x			x		x		x	22	14	2	x	x		x		281
St. 39	"			x						x	x			2	1	x	1		x					x					3		x	x	x				x		2			x					x						x		x	x					x	x			x	x	x				x				x		x	2			x	x	1	2	x			1			2	4	x			x		2	1	x	52	x	4		1	x		x		x		x	x	x	x		x				x		x	6	x	4	x	x				250
St. 30	"	x	x	x		x		x	x	x	x	x		5	x	x				1	x	x	x	x					7		x	x	x				2	x	2	x							x			x	x		x			x	x				x	x			x	x	x	x			x						2	2				1	x	9	1		x	1	x		2	13						2	4		5	x	15		x	x		1		x	x	x	x	x	x	x					2	x	x	9	2	4	1					299
St. 29	"					x				x	x			2										x					28								x	x																							x															x	x	x		x		x		1	x						2	10		x		x		2			2		3					2				x							2	x	9	x	x	24	5	2	1					250
St. 12	"			1		1			1	1	x			x	x	x	x				x	x	x					x	15		x		x				x	x	x		x						1			x			x		x	x				x	x	x					x				x						x			x	x	x	4	8	x			x	x		5	6	x			x		4	x		1		16		x	x		x		x				x		x	x	x		x		x	2	16	6	2	1					282
St. 11	"			x		x	x		x	2	1	x		3	x	1		x		x	x						x		13		x					x	x	x	1	x						x	x			x			2			x			x		x	x			x	x	x							x	x		x	x					1	3	2			x			2	10	x		x	x		6	x		3		1	x		x		1	x	x				x			x		x	x	2		x	27	9	4			x			254
St. 4	"								x											3									12	1			x			x		x	x							x	3		x											x					x	3		x								x	2	12			x	x	2	x				x			x	4	x								3	x	30			1		3				x	x		x								x	2	x	8	3					251
St. 43	"		x			1				2	2			6				x					x	3		x		x	10	x			x				x	1	x								4	x												x			x		x	x		x			x					x	2	x		1		x	x	6	x		x		x			41	x	x		x		5	x		4	x	3			x					x	x	x	1	x		x			x			x	1	x	1	x		x			265
St. 44	"																			x				2					15				x				4	1	1							x	x														x	x			7	1									x		14	7			x	1	3	x							x	4	1	x				4			5		5		3	2		4		x				x	1		x		x					x		6	4			x		277
St. 17	"		x	x		x	x	x	x	x	1			2		x				x	x		x	x				x	1	x		x	x						1		x	2				x	x						x		x		x			x	x	x	x		1	x											x	x	x		x		x	x		x						3	x					17	1	x	58		2			x		x		x			x	x			x			x			x	x		x						261
St. 38	"					x	x		x	3	2			10		x		x		1	x			x			x	x	7			x	x				x	x	2	x	x	x					x		x				x		x					x	2				x	x		x			x							7			2	x	x	x	2							6	x			x	x	29	x	x	8		3			1		x		2	x		x	x	x		2							x		1	2	x			x	263
St. 10	Arundel	x				x				1	1			3		x			1	x			x	7	x	x			4		x		1			x	x		x		x											x			x			x		x									x	x			x				1		45	x	x	x	x	x	x							4	x			x	x	7	x	x	5	x	4		3	x	x	x	x	2		x		x	x		x									3	x			1	x	264
St. 6	"	x								x	8			3										11			x		10		x						x															x						x		x													x	x			3		46	3		x	x		x			x					x					x			2							x		x				x												12					x	266
St. 34	"	2									x									x				9					26	x	9			1		2	4	11						x																				x					x				18				11			x			4																		x	x	x					1		x				x			x														x	255
St. 16	"	1	x			x				3	3			11		x				4		x		1		x			6		x	x	4			x	x	x	x		x											x			x					x	x							x	1	x			x				1			x		x	3	x	x			x			1	8	x			x	x	24	2	x	12	1	2			x		x		2				x	x		x									1	x					255
St. 15	"	x	x					x		7	2			5						2	x				x				11		x		1				x	2	1	x												x			x			x																			1			x		x	3	3	x							5						6	x		9	1	2		24	x		2		x					x		3									3						256
St. 49	Patuxent		x			x		x		4				2		x					1	x		1	x	x	x	x	16		x	x	x			x		x	x		11	x				x		x				1						x			x	x		x	x							x	x			x	5			x		x		x							1	4	x					16	x	x	18	2	4			x		x	x	2				x	x		x												x			256
St. 35	"	x	x		x	2		x		4	x			1						1									47		x		x			1	x	x			4	2																							x								x				7					x	x	4	1							x						5		x	5	x				x		x		x				x			3									1						276
St. 31	"	x				x				2				x											x				27				x			x			x		x		x												x																		x				x					2	x	16	x			x			x	7				x		24	x		6	4	6		x	x		x				x		x	x												x					275
St. 28	"							x		5	x			3		x				x				x	x				6		x		x			x	x				x											x						x			x												x				x				x	x	x	x				x				x	8						x	x	69	x	x			x		x		x				x			x									x	x					256
St. 26	"	x								2	36	x	x	26		x			x					x	1		x		12		x	x	x										x			x			x									x		x	x				x			x					x				x					x	x	x		x		x		2		x						1		x	9		x					x									x									x					x	250

x = Less than 1. per cent

DISTRIBUTION AND PERCENTAGE OCCURRENCE OF THE SPORE AND POLLEN FROM THE POTOMAC GROUP

TABLE 1

to 300 specimens, two slides were completely scanned under a 45× objective to establish the presence of any rare species. The scanning is a very important part of the procedure, especially in Subzone A of Zone II (lower Patapsco) where the presence or absence of a few small tricolpate grains may be a critical factor in the zonation. The frequency of each species encountered in all 43 samples is recorded on Table 1.

The exact position of all illustrated specimens is indicated by recording first the horizontal and then the vertical coordinates on the mechanical stage. The position of any specimen can be found on another microscope by the use of a key slide. A key slide indicates the coordinates on a slide of an inscribed "X". When transferring this key slide to a mechanical stage other than the one used in this study, the coordinates of the figure "X" are recorded and constant compensating values are calculated. For example: if the coordinates of the inscribed "X" on the key slide are 20.5–110.5, and the coordinates of the "X" on the new stage are 21.5–111.5, then one whole unit is added to the horizontal and vertical scales of a given designation in order to relocate the specimen. In case of possible loss or damage to a key slide others may be available. Three key slides have been prepared:

1. Key slide A, coordinates 28.7–119.4
2. Key slide B, coordinates 28.5–119.3
3. Key slide C, coordinates 32.2–120.1

PHOTOGRAPHY

The localities and specimens illustrated on Plates 1–43 were photographed with Kodak Panatomic X, 35 mm. film and printed on Kodabromide F-2, F-3, and F-4 paper. The photographs were then reproduced as halftones.

The original photographs were taken with a Leica 35 mm. camera mounted on the monocular tube of a Leitz Ortholux microscope. Except for a few, all figures are enlarged 1000 times.

IV. RESULTS OF PALYNOLOGICAL INVESTIGATION

GENERAL METHODS AND APPROACH

The palynological investigation of 21 surface and 22 subsurface samples has yielded 130 distinct sporomorphae. Names are proposed for 65 new species and 1 new genus. Sixty of the 130 species have been previously reported in the literature. The 5 remaining forms are either too simple morphologically or too rare to be named.

Table 1 records palynological data from all of the samples investigated in detail. The 43 samples are listed in the vertical column on the left; the 130 sporomorphae are numbered and listed horizontally at the top. The occurrence of each species in a sample is stated as a percentage of the total spore count, and, since the samples are listed in their relative stratigraphic position, the vertical range of each species is indicated. The stratigraphic position of the surface samples has been inferred from the position of the stations on the Geologic Map of Maryland (see Text-Figure 1). Whenever possible, the position of a sample within a formation was estimated by its proximity to adjacent formations.

In Table 1, no formational names were attached to the subsurface samples; however, in Text-Figures 2–6 the positions of the Patuxent, Arundel, and Patapsco Formations were estimated from lithologic descriptions given in well logs (see Appendix A).

With the information presented on Table 1, Text-Figures 2–7 were constructed. Text-Figures 2 and 3 show the vertical distribution of species with restricted ranges in Probe Hole No. 1 and Probe Hole No. 2. The occurrence of a species is indicated with a bar symbol, and the length of the bar indicates its general frequency. The distribution of several "primary" sporomorphae within the two wells permitted the subdivision of the Potomac deposits into two major zones: Zone I and Zone II. The base of Zone II seems to coincide with what is lithologically equivalent to the Patapsco Formation at the surface. Zone I would then encompass the Patuxent and Arundel Formations. These two formations are, for the most part, palynologically inseparable; however, productive samples from the Patuxent horizon were very scarce, and future investigations may be able to show greater differences between them. Zone II can be subdivided into Subzones A and B. Subzone B can, with some difficulty, be further subdivided into Subzone B-1 and Subzone B-2. The top of Zone II is obscure, because the upper part of the nonmarine section in both wells proved barren. It is believed, however, that all of the samples in Zone II are within the Patapsco horizon, none of them extending into the levels equivalent in age to the Raritan and Magothy Formations. The following reasons seem to support this conclusion:

1. The spores of the Potomac Group form, essentially, a microfloral unit, with the majority of sporomorphae common to both Zone I and Zone II.

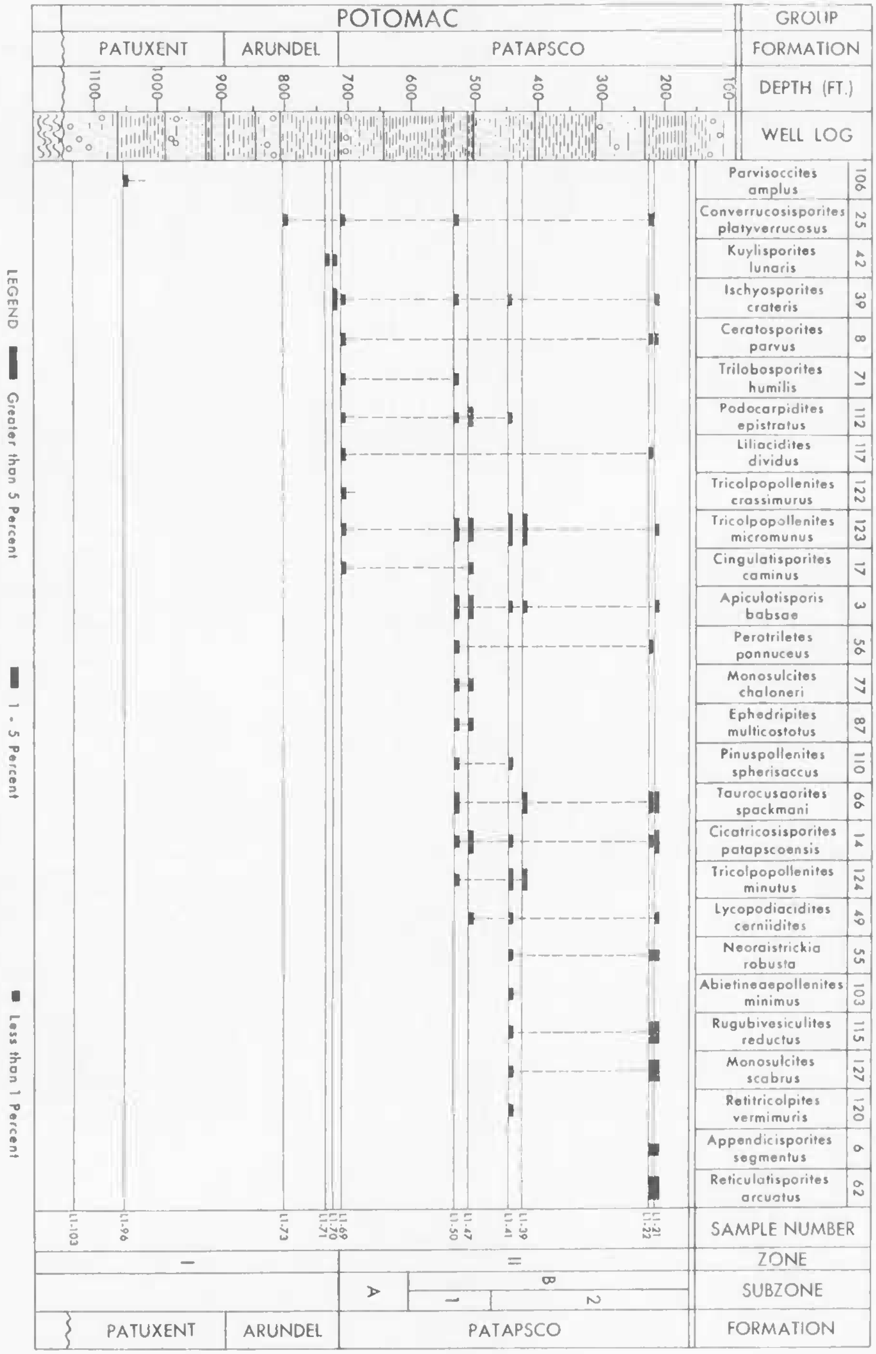


FIGURE 2. Stratigraphic Range of Vertically Restricted Spores and Pollen from Probe Hole No. 1.

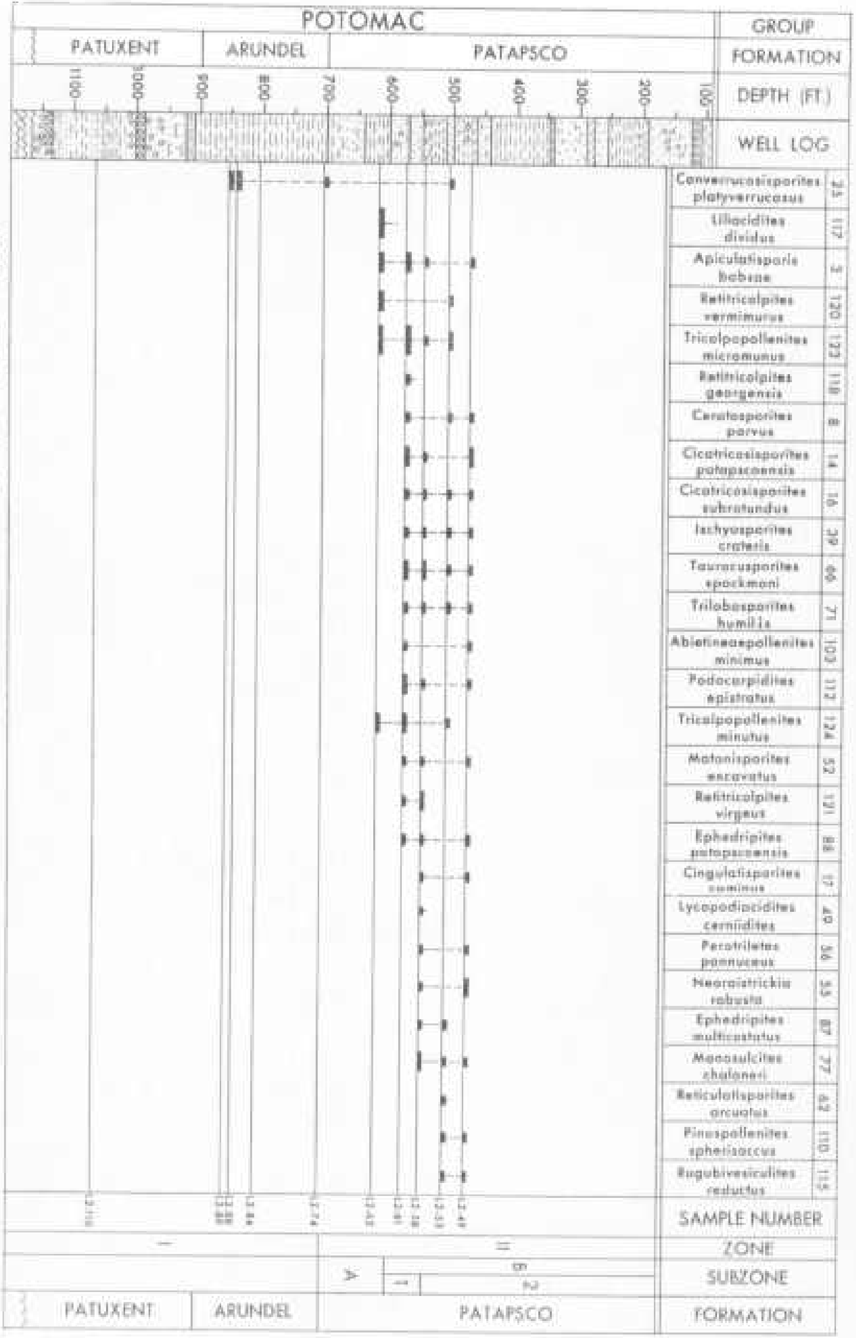


FIGURE 3. Stratigraphic Range of Vertically Restricted Spores and Pollen from Probe Hole No. 2.

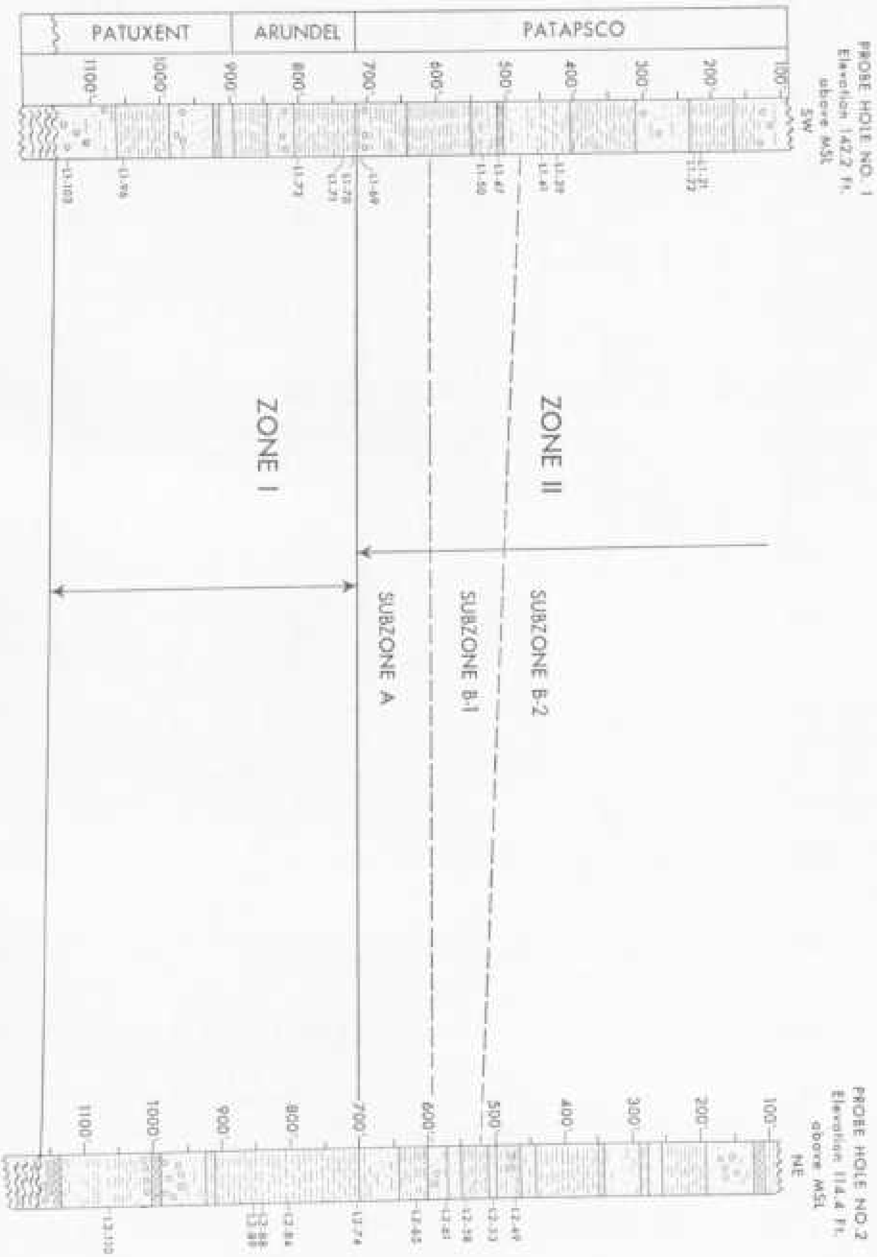


FIGURE 4. Correlation of probe hole 1 and 2 by Palynological zones.

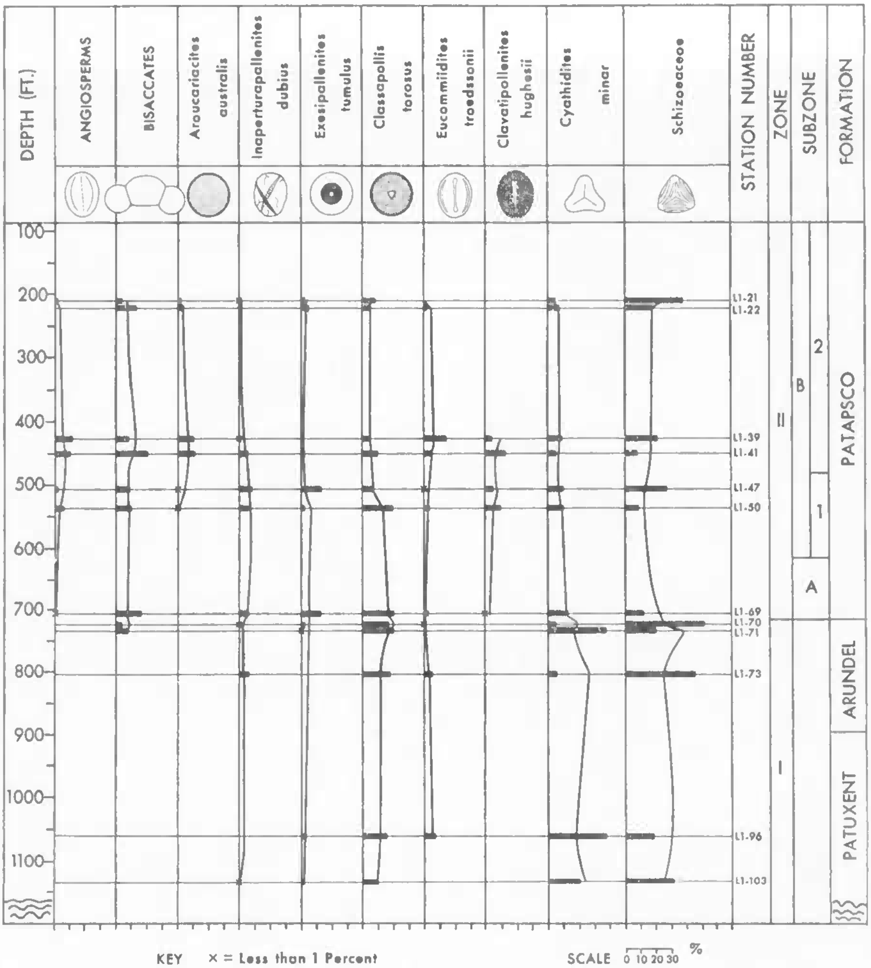


FIGURE 5. Abundance of select species and species groups in probe hole No. 1. Curves based on a three point moving average.

2. The spore and pollen assemblage of the lower part of the Raritan formation in New Jersey (Groot, Penny and Groot, 1961) is quite distinct from any of the surface and subsurface samples from the higher part of Subzone B-2.

In the discussions on zonation and systematics the terms "primary species", "secondary species", "specimen frequency", and "sample frequency" are used. The meaning of such terms are now given:

1. *Primary species*—An important species in the delimitation of a zone of subzone. It usually occurs in at least half the samples in the zone. A rarer species may be considered primary if it is easily identifiable due to certain morphological characteristics.

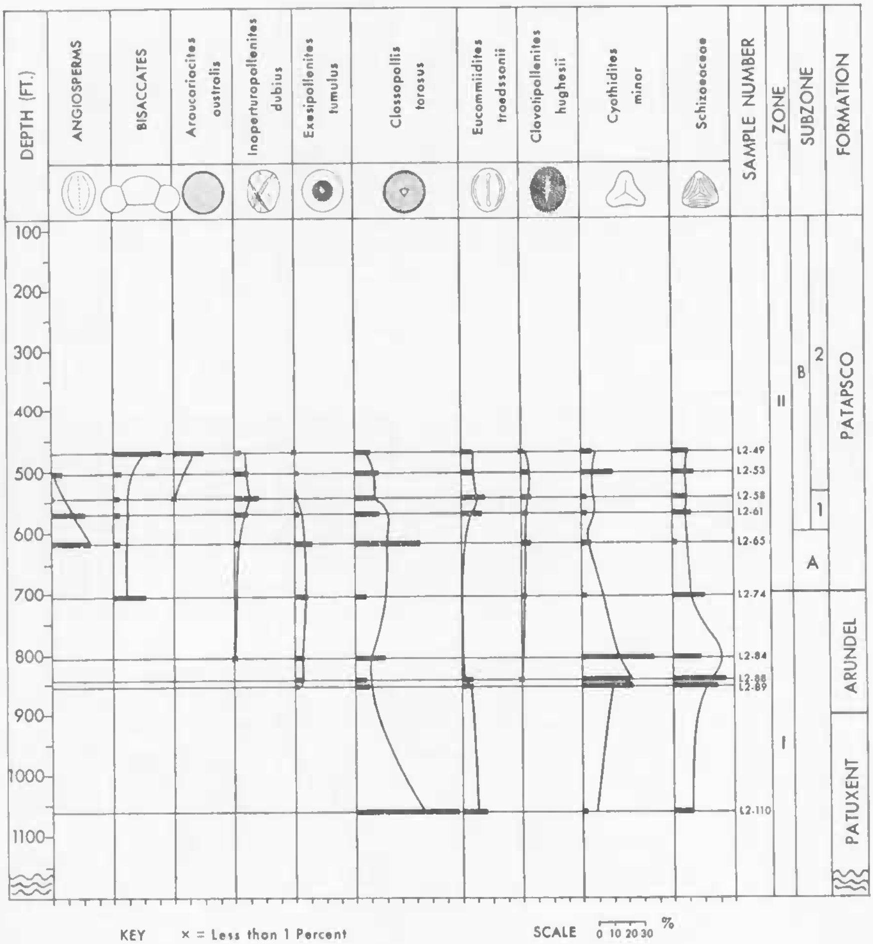


FIGURE 6. Abundance of selected species groups in probe hole No. 2. Curves based on a three point moving average.

2. *Secondary species*—A rarer form found in less than half the samples in a zone or subzone. It usually compliments the primary species in defining the zone. The absence of secondary species, however, is of no significance.

3. *Specimen frequency*—The percentage occurrence of a species in a sample. The following terms are commonly used to express various specimen frequencies:

Term	Value
rare	less than 1 per cent
occasional	1–5 per cent
common	6–10 per cent
abundant	greater than 10 per cent

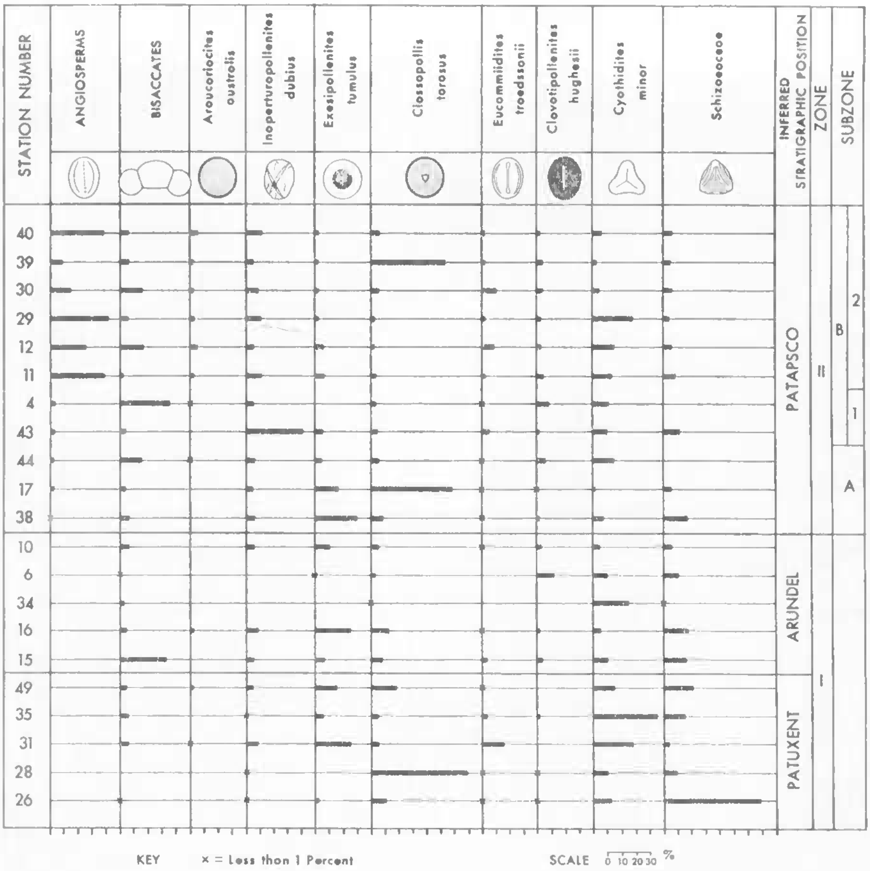


FIGURE 7. Abundance of selected species and species groups from surface samples in the Potomac Group.

4. *Sample frequency*—The percentage of samples in a zone that the species occurs. In this study the following terms are used to express sample frequencies:

Term	Value	Symbol
infrequent	less than 10 per cent	I
low	10–25 per cent	L
moderate	26–50 per cent	M
high	over 50 per cent	H

Text-Figure 4 shows the spore and pollen zonation and correlation of the two wells. The major subdivision of the section is indicated by a solid line; subzones are indicated by broken lines.

Text-Figures 5–7 show the vertical change in the relative abundance of selected species and species groups. These species and species groups are dominant elements of the microflora and large-scale changes in their abundance may reflect important vegetational changes. Such changes may be due to climatic, biologic, or edaphic factors, or the interaction of these factors. This information combined with data from other sources may yield important ecological information. Since vegetational changes take place with passing time, they can be used for correlation and zonation, complementing the standard range method. In a study of this sort, the range method in zonation is more effective than the population approach. By using the range method the position of a single sample may be inferred from the presence or absence of primary index species, whereas with the population approach to zonation more than one sample is usually required to determine its stratigraphic position; since ecologic factors may cause local variation in the relative abundance of the dominant forms, the sequential change in time is of more significance in correlation than the matching of population histograms.

In Text-Figures 5 and 6 trend curves have been drawn. These curves were constructed by taking a three-sample moving average, doubling the top and bottom percentages of each column. Such curves usually subdue the effects of unusual high or low values that may obscure basic trends within the microflora; in diagrams in which the ends of the bars are connected by lines, anomalous values may obscure such trends.

The zonation devised from information in Text-Figures 2 and 3 was then used to deduce the stratigraphic position of the surface samples. The writer was amazed to discover that the stratigraphic sequence of the surface samples as originally inferred from the geologic map and placed on Table 1, was essentially in order. The position of the zones and subzones were then placed on Text-Figure 7.

Because of the rarity of many of the secondary species many are not present in all three sets of samples: the two wells, and the surface samples. Information on their distribution in the Potomac Group is a compilation of all the data, e.g., a species said to be restricted to Subzone B may have been found only in the surface samples.

STRATIGRAPHIC DISTRIBUTION OF THE SPOROMORPHAE

Of the 130 sporomorphae listed on Table 1, 93 range throughout the whole section; only 4 species are restricted to Zone I (Patuxent-Arundel horizons), and 33 species are restricted to Zone II (Patapsco horizon). In discussing the vertical ranges of the various spores and pollen, zone numbers are chiefly used instead of their inferred formational equivalents. This is done because in many subsurface sections the lithologic change downdip does not permit the identification of formations based on surface lithologies. Zone I is equivalent in age to the Patuxent and Arundel Formations combined; Zone II to the Patapsco Formation.

Zone I—Table 2 lists the 4 species restricted to Zone I. The number following the name refers to the species number listed in Table 1. Since the 4 species restricted to this zone have low sample frequencies, they are not very useful as stratigraphic indicators.

Table 3 lists those species that are not restricted to Zone I, but that are more typical of that horizon. The sample frequencies in Zone I of *Cicatricosisporites aralica* and *Cicatricosisporites australiensis* are not much greater than those in Zone II, but the specimen frequencies of these two species are, in general, much higher in Zone I than in Zone II. Four species have much higher sample frequencies in Zone I than in Zone II: *Concavissimisporites variverrucatus*, *Gleicheniidites apilobatus*, *Perotriletes striatus*, and *Trilobosporites marylandensis*. The latter species was found in 9 out of 10 surface samples from Zone I, but in none of the surface samples from Zone II.

Of the 97 species present in Zone I, 96% of them are also found in Zone II. It is then apparent, that the microflora of the lower zone does not differ noticeably from that of Zone II by the presence of any index species; as will be shown later, it is rather the "absence" of a group of sporomorphae that first occur in Zone II that distinguishes Zone I from Zone II.

Zone II—Table 4 lists those species restricted to Zone II. Twenty-two of the

TABLE 2

Sporomorphae Restricted to Zone I

Name	Sample frequency
Cicatricosisporites dorogensis (12)	Low
Ephedripites virginiaensis (89)	Infrequent
Kuylisporites lunaris (42)	Low
Parvisaccites amplus (106)	Low

TABLE 3

Sporomorphae More Common in Zone I

Name	Sample frequency	
	Zone I	Zone II
Alsophilidites pannuceus (1)	H(75%)	H(52%)
Cicatricosisporites aralica (9)	H(95%)	H(70%)
Cicatricosisporites australiensis (10)	H(85%)	H(83%)
Concavissimisporites variverrucatus (24)	M(40%)	I(9%)
Gleicheniidites apilobatus (35)	M(45%)	L(13%)
Klukisporites pseudoreticulatus (40)	H(75%)	M(48%)
Perotriletes striatus (57)	M(30%)	I(4%)
Spheripollenites perinatus (101)	H(55%)	M(26%)
Trilobosporites marylandensis (72)	M(50%)	I(9%)

33 species restricted to this zone were found throughout Zone II; 11 species were found only in Subzone B, and one of them, *Rugubivesiculites reductus* is restricted to Subzone B-2. The 7 species shown in Table 5 have greater sample frequencies in Zone II than Zone I.

TABLE 4

Sporomorphae Restricted to Zone II

Name	Sample frequency
Sporomorphae in Subzone A and B	
Apiculatisporis babsae (3)	H(65%)
Appendicisporites segmentus (6)	M(26%)
Ceratosporites parvus (8)	H(57%)
Cingulatisporites caminus (17)	M(35%)
Liliacidites dividuus (117)	L(17%)
Lycopodiacidites irregularis (46)	H(61%)
Lycopodiumsporites austroclavatidites (50)	L(13%)
Matonisporites excavatus (52)	H(65%)
Monosulcites chaloneri (77)	H(61%)
Monosulcites scabrus (127)	M(26%)
Monosulcites sp. (86)	I(9%)
Perotriletes pannuceus (56)	M(26%)
Pilosisporites brevipapillosus (58)	L(22%)
Podocarpidites epistratus (112)	H(61%)
Reticulatisporites arcuatus (62)	L(22%)
Retitricolpites georgensis (118)	L(22%)
Retitricolpites geranioides (119)	L(22%)
Retitricolpites vermimurus (120)	M(35%)
Tricolpopollenites crassimurus (122)	M(43%)
Tricolpopollenites micromunus (123)	H(91%)
Tricolpopollenites minutus (124)	H(61%)
Tsugaepollenites mesozoicus (94)	L(13%)
Sporomorphae restricted to Subzone B	
Abietineaepollenites minimus (103)	L(22%)
Cicatricosisporites patapscoensis (14)	H(72%)
Cicatricosisporites subrotundus (16)	M(33%)
Ephedripites patapscoensis (88)	M(33%)
Lycopodiacidites cerniidites (49)	M(39%)
Neoraistrickia robusta (55)	M(50%)
Pinuspollenites spherisaccus (110)	M(39%)
Retitricolpites virgeus (121)	M(33%)
Taurocusporites spackmani (66)	H(72%)
Trilobosporites crassus (70)	M(28%)
Sporomorphae restricted to Subzone B-2	
Rugubivesiculites reductus (115)	H(67%)

TABLE 5

Sporomorphae More Frequent in Zone II

Name	Sample frequency	
	I	II
Araucariacites australis (90)	L(15%)	H(70%)
Cirratriradites spinulosus (22)	L(15%)	M(48%)
Clavatipollenites hughesii (125)	M(50%)	H(87%)
Inaperturopollenites pseudoreticulatus (74)	I(5%)	M(39%)
Psilatriletes circumundulatus (60)	L(20%)	H(65%)
Psilatriletes radiatus (61)	L(15%)	H(61%)
Taurocusporites segmentatus (65)	L(10%)	H(70%)

The first appearance of undoubted angiosperm pollen was found in Zone II. They consist of 1 monocolpate and 7 tricolpate forms. These 8 species make up approximately 6% of the 126 sporomorphae found in Zone II. All of them have been found in Subzone A (lower part of Zone II), and there does not seem to have been an increase in the number of angiosperm species during Patapsco time. What does seem to occur is an increase in the specimen frequency of tricolpate grains. Samples from the lower part of Zone II such as L1-69, St. 17, and St. 44 contain tricolpate grains in frequencies of less than 2%, whereas in several samples from the upper part of Zone II frequencies as high as 40 per cent are attained.

Besides the first occurrence of undoubted angiosperm pollen, Zone II is also distinguished from Zone I by the introduction of 33 other sporomorphae.

By virtue of their high sample frequencies the following species are considered "primary species" in the identification of Zone II:

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

....

Cicatricosisporites patapscoensis
Neoraistrickia robusta
Taurocusporites spackmani
Rugubivesiculites reductus

The last 4 species, which have high sample frequencies, are restricted to Subzone B. They are extremely easy to identify because of their unique morphological characteristics, and are the principal species used in the recognition of this subzone. *Rugubivesiculites reductus* first appears in the upper part of Zone II, in Subzone B-2. Although it usually occurs in specimen frequencies of less than 3%, the extremely invaginated surface of its proximal cap makes it easy to locate when scanning. It is of interest to note that this species becomes quite common in the Cenomanian of Minnesota (Pierce, 1961) and the lower Raritan of New Jersey (writer's observations). When it was absent, Subzone B-1 could not be distinguished from Subzone B-2.

The extreme differences between Zone I and Zone II do not commonly become apparent until the horizon of Subzone B. It is in this subzone that the tricolpates commonly attain specimen frequencies in excess of 15%. In addition, certain common species, such as *Araucariacites australis* and *Clavatipollenites hughesii* are generally found in greater specimen frequencies in Subzone B. Subzone A, therefore, often becomes difficult to distinguish from Zone I. With careful scanning, however, tricolpate grains, most commonly *Tricolpopollenites micromunus*, and some of the primary and secondary species can be found. One may then think of Subzone A as a "transitional" zone between the non-angiospermous Zone I (Patuxent-Arundel) and Zone II (Pataspco), which contains a more modernized microflora.

STRATIGRAPHIC DISTRIBUTION OF MICROFLORAL DOMINANTS

The change in the relative abundance of several important microfloral dominants in the samples from this study has been plotted on Text-Figures 5–7. The causes for such changes are extremely difficult to interpret at this time, for practically nothing is known of the habitats of the plants that produced the spores and pollen. Some interpretations based on our knowledge of modern vegetation will be discussed later. Regardless of what factors affected the changes observed on Text-Figures 5–7, the very fact that such changes did take place permits their use in correlation. How widespread such changes were will be known only as more Lower Cretaceous samples are investigated from other areas.

The majority of the 130 sporomorphae are found in infrequent to low specimen frequencies. Several elements so dominate the microflora of both Zone I and Zone II that at first one would consider the whole Potomac Group as a single microfloral unit. A more detailed examination has shown significant changes in the dominants during Potomac sedimentation. The following is a list of species and species groups which formed the major part of the spore and pollen population:

Angiosperms (tricolpates)
Gymnosperms (bisaccates)
Araucariacites australis (*Araucariaceae*)
Inaperturopollenites dubius (*Taxaceae-Cupressaceae*)

Exesipollenites tumulus (gymnosperm)
Classopollis torosus (gymnosperm)
Eucommiidites troedssonii (gymnosperm)
Clavatipollenites hughesii (gymnosperm or angiosperm)
Cyathidites minor (Cyatheaceae)
Schizaeaceae (primarily *Cicatricosisporites*)

One of the most significant changes in the microflora as well as in the macroflora is the introduction of the first undoubted angiosperms at the base of Zone II. In Text-Figure 5 the first angiosperm pollen, which are primarily small tricolpates, occur in low frequency several feet above a predominantly clay unit (L1-69), 185 feet thick, which is considered to be the Arundel Clay. Stations 38, 17, and 44, in Text-Figure 7, contain tricolpate grains in frequencies less than 2%. From a study of their lithologic character and geographic position these stations were considered to be situated in the lower part of the Patapsco formation of Subzone A of Zone II. Towards the top of Subzone A (Text-Figure 6) and in Subzone B tricolpate grains, and in particular *Tricolpopollenites micromunus*, become a dominant member of the microflora.

The abundance of various gymnosperm pollen also changes at approximately the same horizon as the introduction of dicotyledonous pollen. *Araucariacites australis* which is quite rare in Zone I, occurs more frequently in Zone II and becomes a characteristic element of the microflora in Subzone B-2. Bisaccates increase somewhat in abundance above Zone II. Since bisaccate pollen are an important element in almost all Jurassic and Cretaceous horizons, their absence in Zone I of Probe Holes 1 and 2 is probably related to the low pollen content, which may be due to initial conditions of preservation.

Classopollis torosus and *Exesipollenites tumulus* which are commonly found associated with each other have higher specimen frequencies in Zone I than in Zone II. Text-Figures 5–7, suggest a gradual reduction in their abundance near the top of Subzone A, decreasing more rapidly in Subzone B where their specimen frequencies rarely exceed 6% of the population.

Clavatipollenites hughesii is rare to absent in most samples from the lower part of Zone I (Patuxent horizon), and becomes more abundant towards the top of Zone I and in Subzone A. It first becomes a conspicuous part of the microflora in Subzone B.

In most of the samples examined *Cyathidites minor* and schizeaceous spores, primarily *Cicatricosisporites aralica* and *Cicatricosisporites australis*, form the most abundant microfloral elements. Although still a conspicuous element, their importance seems to diminish above Zone I. This situation may be related to the general reduction in the role of the *Schizaeaceae* above the Neocomian stage (Bolkhovitina, 1962).

The following list summarizes the changes in the microflora that may be used to supplement the species-range method in correlation:

Zone I

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

Zone II

1. The first undoubted angiosperms (tricolpates) appear in low frequencies at the base of Subzone A, and become conspicuous members of the microflora towards the top of Subzone A and in Subzone B.
2. *Classopollis torosus* and *Exesipollenites tumulus* are less abundant in Zone II than in Zone I.
3. *Araucariacites australis* and *Clavatipollenites hughesii* become conspicuous members of the microflora in Subzone B.
4. Bisaccate pollen are generally more abundant.
5. *Cyathidites minor* and various schizaeaceous species decrease in abundance.

The above statements are generalized, and it must not be construed that every sample in a zone will follow the patterns described. For example, sample L1-22 in Probe Hole No. 1 (Text-Figure 5) and L2-49 in Probe Hole No. 2 (Text-Figure 6), although they are well within Subzone B-2, do not contain tricolpate grains. Local ecological conditions may not have favored the emplacement or preservation of such grains at those localities; the presence, however, of sporomorphae typical of that zone can be used to place the samples stratigraphically.

BOTANICAL MAKEUP OF THE MICROFLORA

Table 6 shows the abundance of various plant taxa in the micro- and macroflora of the Potomac Group (Clark, Bibbins, and Berry, 1911, pp. 90–95).

Both the micro- and macroflora indicate that the pteridophytes, which are predominantly ferns, and the gymnosperms dominated the vegetation during Potomac time. The angiosperms became part of the vegetation during Patapsco time; the microflora indicate that they gained prominence only at the top of Subzone A and in Subzone B. Notable differences, however, exist between the relative abundance of ferns, gymnosperms, and angiosperms as indicated by the microflora and macroflora. In both the Patuxent-Arundel and Patapsco horizons the microflora indicate about twice as many species of pteridophytes as gymnosperms, while the macroflora show approximately equal numbers of both. In

TABLE 6

Comparison of Microflora and Macroflora

Taxa	Microflora		Macroflora	
	No. of species	Percentage	No. of species	Percentage
Patuxent-Arundel (Zone I)				
Bryophytes	1	1%	0	0%
Pteridophytes	58	60%	42	45%
Gymnosperms	29	30%	45	48%
Angiosperms	0	0%	0	0%
Incertae Sedis	9	9%	7	7%
Palapsco (Zone II)				
Bryophytes	1	1%	0	0%
Pteridophytes	72	57%	23	29%
Gymnosperms	34	27%	27	34%
Angiosperms	8	6%	25	32%
Incertae Sedis	11	9%	3	4%

addition the percentage of angiosperms in the macroflora of the Patapsco horizon is approximately five times that of the microflora.

The higher relative numbers of gymnosperms and angiosperms in the macroflora as compared to the microflora can probably be explained by the different problems inherent in working with plant macroflora as opposed to pollen. In the macroflora the genera are frequently not based on a study of a single organ, as is the case in pollen studies, but on several detached plant parts, such as cones, wood, seeds, and sterile shoots. This inevitably leads to a multiplicity of names, which probably exceeds the true number of species in the fossil assemblage. On the other hand, a study of the pollen of modern gymnosperms has demonstrated the difficulties involved in distinguishing the pollen of many species and even some genera. The pollen of the *Taxaceae* and *Cupressaceae* produce very generalized spherical inaperturate grains, difficult to distinguish from each other. Statistical methods must frequently be used in order to recognize the various species of pine, spruce, and fir. The bisaccate and inaperturate gymnosperm pollen in the Potomac microflora are also extremely difficult to speciate. There is little doubt that such species as *Araucariacites australis* and *Abietineaepollenites microreticulatus* were produced by several plant species, but the generalized morphology of their pollen does not permit further splitting. The same problem exists in the fossil angiosperm pollen in that such form genera as *Tricolpopollenites micromunus* may represent several plant taxa. The polymorphic nature of leaves and the fact that a supposedly simple leaf may be part of a compound leaf favors overspeciation. The tendency towards overspeciation when studying plant macrofossils and underspeciation in pollen work may explain the discrepancies in the macro- and microfloral lists of these two plant groups.

Fontaine (1889) described several leaves from the Patuxent and Arundel Formations as the remains of primitive angiosperms, and assigned them to the genera *Proteaphyllum*, *Ficophyllum*, and *Rogersia*. In a revision of Fontaine's work on the Potomac flora Berry (Clark, Bibbins, and Berry, 1911, p. 503) states that ". . . both *Ficophyllum* and the allied genera *Proteaephyllum* and *Rogersia* are not angiosperms but are related either to ferns of the *Drynaris* type or to the *Gnetales*." The only pollen not accounted for in Zone I is *Clavatipollenites hughesii* which Couper (1958) suggested might be an angiosperm because of its complex retipilate ektexine. This form is found in Zones I and II. Although the writer agrees with Couper in that the retipilate exine is typical of many angiosperm pollen, such an exine structure could have developed in some now extinct group of gymnosperms; pilate structure can also be found in extant pollen of the *Cupressaceae*. The structure of the proximal surface of many bisaccate pollen is certainly no less complex than that of *Clavatipollenites*. Thus, the first definite angiosperms appeared on the scene during Patapsco (Zone II) time, but did not become a major element of the lowland forests until the Cenomanian and Turonian stage.

Table 7 records the pollen morphology of extant genera that Berry suggested as having affinities with the angiosperm leaf genera from the Patapsco Formation (Clark, Bibbins, and Berry, 1911). The left hand column lists the leaf genera; the next column lists the related extant genera. Brief statements then are made on the pollen morphology of the related extant genera and the last column indicates whether comparable pollen types are present in the Patapsco Formation.

TABLE 7

Correlation of Angiosperm Leaf Genera with the Pollen of Equivalent Living Genera

Genus	Modern equivalent	Pollen morphology	Presence
Alismaphyllum	*Sagittaria*	Inaperturate, echinate	
Cyperacites	*Carex*	Monoporate	
Plantaginopsis	*Eriocaulon*	Inaperturate, flecked	×
Populus	*Populus*	Inaperturate, flecked	×
Populophyllum	*Populus*	Inaperturate, flecked	×
Nelumbites	*Nelumbo*	Tricolpate, granular	
Menispermites	*Menispermum*	Tricolpate, 25 μ	
Sapindopsis	*Matayba*	Tricolpate, syncolpate	
Celastrophyllum	*Celastrus*	Tricolpate, retipilate	×
	Euonymus	Tricolpate, retipilate	×
Cissites	*Vitis*	Tricolporate, retipilate	
Sassafras	*Sassafras*	Monocolpate, granular	
Araliaephyllum	*Sassafras*	Monocolpate, granular	

Of the 12 leaf genera listed, only 5 have modern equivalents whose pollen are morphologically comparable to types found in the Patapsco Formation. A similar comparison was made by Pierce (1961, p. 58) using the leaf genera and pollen from the Cenomanian deposits of Minnesota. Pierce found less than a 20% correlation between the leaf and pollen records. Assuming that the plants that left a leaf record were, for the most part, members of the lowland vegetation, the discrepancy between the pollen and leaf record is of interest. It is possible that the affinities suggested for some of the leaf genera may be incorrect. It is also possible that since many genera are eurypalynous, they may have produced pollen types which are now extinct, or which have not been observed by the writer in modern pollen material. Insect pollination and lack of preservation are other factors which may have caused such a discrepancy. It is probable that several of these factors have contributed to the situation.

Several species of *Sapindopsis* make up the bulk of angiosperm leaf impressions in the Patapsco Formation. This genus has been compared most closely by Berry (Clark, Bibbins, and Berry, 1911) with members of the tropical *Sapindaceae* and the genus *Matayba* in particular. Most members of this family including *Matayba* have tricolporate, oblate pollen of types that are distinctly absent from most of the Patapsco Formation. The majority of the angiosperm pollen are made up by the species *Tricolpopollenites micromunus*, a very small tricolpate grain. In the systematic descriptions it has been compared to the pollen of *Tetracentron sinense*, a very primitive member of the Dillenilaes. The leaves of several primitive members of the Ranales, such as *Eupomatia*, have leaves very similar to *Sapindopsis*. Considering the antiquity of this angiosperm flora, the presence of ranalian types would not be surprising. The monocotyledonous genera *Sagittaria* and *Carex* have pollen types which are also not represented in the Patapsco microflora. The absence of certain pollen types, e.g., tricolporates and monoporates, in the Patapsco Formation suggests that some leaf affinities may not have been properly evaluated. However, additional knowledge about Cretaceous angiosperm pollen of North America, and comparisons with their associated leaf remains will be necessary before a proper explanation can be made of the discrepancy between the leaf and pollen records.

PALEOECOLOGICAL INTERPRETATIONS

It has been shown (Muller, 1959; Martin and Gray, 1962) that the spores and pollen that accumulate in continental sediments usually reflect the local vegetation. Spores and pollen from distant upland and lowland areas, although commonly present, are overshadowed by those from the local flora. This may not be the case with marine deposits in which several physical factors, such as wind directions and currents, greatly influence the spore and pollen distribution.

The macroflora as well as the microflora suggest that the forests that existed in the area of the Maryland Coastal Plain during Patuxent and Arundel time were dominated by ferns and gymnosperms. Dicotyledonous plants first appeared in low numbers in the early part of the Patapsco and became a conspicuous element during the middle and later Patapsco horizons. The abundance of *Cyathidites minor* and schizaeaceous spores indicate the importance of the *Cyatheaceae* and *Schizaeaceae* at this time. The gymnosperms of the Potomac forest were chiefly members of the *Podocarpaceae*, *Araucariaceae*, *Taxaceau-Cupressaceae* complex, and *Pinaceae*. The abundance of *Classopollis* suggests the importance of the *Brachyphyllum-Pagiophyllum* type. Other dominant gymnosperms, whose affinities are not yet known, produced such pollen as *Eucommiidites troedssonii*, *Excsipollenites tumulus*, and perhaps *Clavatipollenites hughesii*. The affinity of the dicotyledonous pollen is not known, although types similar to *Tricolpopollenites micromunus* are produced by extant members of the *Tetracentraceae*, *Trochodendraceae*, and *Ranunculaceae*. The *Araucaria-Agathis* type pollen does not become prominent until Subzone B of Zone II.

If one attempts to make a modern analogy with the Potomac macro- and microflora, a striking similarity can be found with plants of some of the warm temperate rainforests of New Zealand.

The rain forests of the North Island are dominated by several broad leaf conifers such as *Agathis australis* (Kauri forest), *Phyllocladus glauca*, *Podocarpus dacrydioides*, and *Dacrydium cupressinum*, etc. The undergrowth supports a luxuriant growth of all varieties of ferns, from epiphytes that clothe the tree trunks to the tall tree ferns of *Cyathea* and *Dicksonia*. *Podocarpus dacrydioides* is a dominant tree of the swampy wet soils of the Kahikatea forests (Schimper, 1930; Campbell, 1923).

The *Cycadaceae* and *Schizaeceae* are almost exclusively tropical in the modern flora. The latter family is well represented in both the micro- and macroflora; the cycadophytes are well represented in the macroflora, but extremely rare in the microflora. Other typically tropical ferns such as *Gleichenia* and *Lygodium* produce spores similar to *Gleicheniidites* and *Concavissimisporites punctatus*, respectively.

Although the ecological requirements of species, genera, and even orders might have been different in the past, the total floral assemblage of the Potomac Group, when compared to the distribution of modern analogous floras, suggests a warm temperate to subtropical rainforest, similar to some of the New Zealand and Australian broadleaf evergreen forests.

It has been pointed out (Scott, et al., 1960) that the most luxuriant and varied angiosperm floras are found today in the tropical rainforest belt. It is possible that during Albian and Late Cretaceous time increasing temperatures (which continued on into the Early Tertiary) favored the rapid development of angiosperms in the lowland flora, so that by late Cenomanian to Turonian time the angiosperms had replaced the conifers and ferns as the dominant vegetation inhabiting the moist lowlands.

PALYNOLOGICAL EVIDENCE RELATING TO THE AGE, CORRELATION, AND STRATIGRAPHY OF THE POTOMAC GROUP

Age and Correlation—Both the age of the Potomac Group in Maryland and its correlation with the Raritan Formation in New Jersey have long been a subject of controversy. Spangler and Peterson considered the Raritan of New Jersey equivalent to the Raritan Formation and Potomac Group in Maryland and Delaware. The Patuxent Formation was referred to the Albian stage and considered equivalent to the lower half of the New Jersey Raritan Formation, whereas the Arundel and Patapsco Formations were placed in the Cenomanian (Upper Cretaceous) and correlated with the upper third of the New Jersey Raritan (Spangler and Peterson, 1950).

The macroflora of the Raritan of New Jersey with 169 species has only 5 species in common with the macroflora of the Potomac Group (Dorf, 1952, p. 2168). Of the 169 species, 131 (77%) of them are angiosperms. The 25 angiosperms recorded by Berry (Clark, Bibbins, and Berry, 1911) from the Patapsco deposits represent only approximately 32% of the flora. Thus, it is quite evident that the Raritan of New Jersey cannot be equivalent in age to any part of the Potomac Group. The microflora also support this conclusion. Groot, Penny, and Groot (1961) listed the spores and pollen in a sample from the South Amboy Fire Clay, the lowest member of the New Jersey Raritan Formation. Of the 18 sporomorphs listed, 11 are the pollen of dicotyledons (61%); the dicotyledonous pollen make up only 6% of the microflora of the Patapsco beds. Only one of the dicotyledonous pollen types in the South Amboy Fire Clay, *Tricolpopollenites micromunis*, is also found in the Patapsco Formation. Tricolporates, which are found in the lower Raritan, are not present in the Patapsco Formation. It appears, then, that the microflora of the Raritan of New Jersey represents the remains of a younger, more modernized flora than that of the Patapsco deposits.

The macroflora of the Raritan of New Jersey and some marine invertebrates discovered in the Woodbridge clay by Richards (1943) suggest a Cenomanian age for the sediments.

Berry (Clark, Bibbins, and Berry, 1911) considered the floras of the Patuxent and Arundel Formations most comparable in age and composition to the Wealden flora of England, which is at present considered Neocomian. The Patuxent and Arundel were referred by Berry to all except possibly the lower Neocomian and all of the Barremian (p. 160). The Aptian was considered missing because of a supposed disconformity between the Arundel Clay and the overlying Patapsco Formation. The geographic extent and time significance of such a disconformable relationship has not been established. Dorf (1952) placed the Patuxent Formation in the Neocomian and the Arundel Clay in the Aptian.

The presence of several species of *Cicatricosisporites* and *Appendicisporites* places the Patuxent Formation safely above the Purbeckian-Neocomian boundary. The microflora of the Patuxent-Arundel Formations is very similar to that of the Wealden as described by Couper (1958) and Lantz (1958b). Of the 43 species listed by Couper from the Wealden and Lower Greensand (Aptian) of England, 26 (60%) are conspecific with Patuxent-Arundel forms.

Hughes (1958) set up a preliminary correlation of the English Lower Cretaceous with the standard European section. This was done by matching the positions of the first occurrence of certain micro- and megaspores in marine sections with their distribution in the English continental deposits. According to Hughes, *Clavatipollenites hughesii* enters the marine sections high in the Barremian. In the Potomac group this species is rare in the Patuxent horizon and becomes more common in the Arundel and Patapsco horizons. If one applies the distribution of this species in England to date the Potomac Group, the Patuxent Formation may be considered upper Barremian or slightly older, and the Arundel Clay high in the Barremian and perhaps even Aptian.

The absence of undoubted angiosperm fossils, both leaves and pollen, indicates a pre-Albian age for the Patuxent and Arundel deposits. No "definite" angiosperm pollen has been found in the Aptian of England (Couper, 1958), the Aptian of Central Russia (Bolkhovitina, 1953) or the Aptian of Portugal (Groot and Groot, unpublished manuscript.) Scott et al. (1960) and Hughes (1961b) have shown that all pre-Albian reports of angiospermous remains have been unconvincing.

The Patapsco flora was considered of Albian age by Berry (Clark, Bibbins, and Berry, 1911). He compared it most closely with the Albian flora of Portugal, which, like that of the Patapsco, contains the first occurrence of dicotyledons. The dicotyledonous pollen of the Patapsco (Zone II) do not contain any tricolporates or porates of any kind, but only tricolpates. Tricolporates and triporates first occur in the overlying Raritan Formation (Groot, Penny, and Groot, 1961).

The Albian age of the Patapsco is further suggested by the fact that the first definite dicotyledonous pollen occur in Central Russia (Bolkhovitina, 1953), New Zealand (Couper, 1960) and Portugal (Groot and Groot, unpublished manuscript) in the Albian stage.

The latter paper described some samples from the Aptian to Cenomanian deposits of Portugal. The section is composed primarily of continental sediments that have been correlated with the European Cretaceous stages by the use of vertebrate remains and invertebrate fossils found in intercalated marine beds. The Aptian sample did not contain any angiosperm pollen. A sample referred to the Albian stage contains a single tricolpate species. Two samples

(samples 50630 and 50628) whose ages were stated as ranging from late Albian to early Cenomanian contain several dicotyledonous pollen. Sample 50630, which was obtained from a stratigraphically lower horizon than sample 50628, contains several tricolpate forms and no triporate pollen. In the other sample (stratigraphically higher) a few triporate forms occur. The lower sample contains the following species whch appear conspecific with forms restricted to Zone II of the Potomac Group:

Portugal species (not published)	Equivalent Potomac species
1. *Tricolpopollenites retiformis*	*Retitricolpites virgeus*
2. *Tricolpopollenites sp. 2*	*Tricolpopollenites crassimurus*
3. *Tricolpopollenites sp. 3*	*Tricolpopollenites geranioides*
4. *Zonalasporites ornatus*	*Perotriletes pannuceus*

The above suggests that the Patapsco Formation is, in part, of late Albian age. Subzone A of Zone II has been considered a transitional horizon in this study and it is possible that it may be of early Albian age.

Stratigraphic Problems—As has been previously mentioned, the rapid change in the character of the sediments of the Potomac group, in both a vertical and a horizontal direction, creates great difficulties in locating the contacts of the three formations. Where the Arundel Clay is missing or not typically developed, it is almost impossible to separate the Patuxent from the Patapsco Formation or the Arundel from the Patapsco. Away from the type area three distinct formations are not developed, and correlation with the type area is difficult.

The general stratigraphic changes in the microflora are believed to reflect temporal changes and not changes due to the vicissitudes of sedimentation or local ecological variation in the vegetation. The palynological zones can then function as a means for correlating Lower Cretaceous beds within and outside the type area, from Maryland to South Carolina, and perhaps even along the Gulf Coast. In wells the zones may be used to correlate sediments with surface formations which are not typically developed downdip.

The significance of any disconformity in continental sediments is extremely difficult to evaluate, since a fluvial system is eroding and depositing simultaneously. If the disconformity represents a long period of regional denudation and subsequent deposition, the microflora may be radically different above and below the erosional surface. This has not proved to be the case between the Patuxent and Arundel Formations. It is possible that the sudden change from the Patuxent, a predominantly sandy unit, to the Arundel, a predominantly clayey unit, was due to a change in the regimen of the drainage system and was not the product of any extensive period of erosion or nondeposition.

The change in the microflora from Zone I to Subzone A of Zone II is represented by 33 new sporomorphae, 8 of which are angiosperms. The sudden introduction of these forms directly above the unit that has been designated as the Arundel Clay, in both the two cores and surface samples, suggests that a disconformity between the Arundel and Patapsco Formations is present. However, since the number of specimens of these new forms is very low in most samples from Subzone A, this subzone is considered "transitional" between the Patuxent-Arundel microflora and the more modernized microflora of Zone II, which does not really become apparent until Subzone B.

The Patapsco-Raritan contact has not been investigated palynologically, although the macroflora indicate a significant lapse of time between the two formations at the surface.

V. SUMMARY AND CONCLUSIONS

A detailed investigation has been made of the spores and pollen from the Potomac Group of Maryland. It was hoped that the microflora could be used to develop a workable zonation of the section and to obtain additional information on such subjects as the composition and change in the vegetation during Potomac time, the stratigraphic position of the first definite angiosperms, and the age of the three formations in the Potomac Group: the Patuxent, Arundel, and Patapsco. It was also thought that the description of the spores and pollen from these sediments would increase our knowledge of Lower Cretaceous systematic palynology.

To achieve these goals the spores and pollen from 21 surface and 22 subsurface samples were examined. The examination yielded 130 distinct sporomorphae assignable to 125 species, and 5 sporomorphs too generalized in form or too rare to be given specific names; 65 of the 125 species are considered new. The 130 sporomorphae are included within 67 genera, of which one, *Decussosporites* is thought to be new. The stratigraphic distribution and relative abundance of the spores and pollen in the samples were recorded. From the information recorded on Table 1, it was possible to achieve the proposed aims of the investigation.

The following paragraphs list the results and conclusions of this study:

1. The distribution of the sporomorphae in the cores and the surface samples indicate that the Potomac Group can be divided into 2 major zones: Zones I and II. Zone I corresponds to the Patuxent and Arundel Formations combined, while Zone II is equivalent to the Patapsco Formation. The microflora of the Patuxent and Arundel Formations are almost identical and could not be used to distinguish the two horizons. Of the 130 sporomorphae, 93 are found in both Zones I and II. Four species are restricted to Zone I and 33 species have been found only in Zone II. The appearance of several distinctive sporomorphae in the upper part of Zone II permitted the further subdivision of this zone into two subzones, Subzone A and B. Subzone B was then further subdivided into Subzones B-1 and B-2 by the appearance of *Rugubivesiculites reductus* in Subzone B-2. This species becomes extremely common in the overlying Raritan Formation.

2. The striking changes between the microflora of Zone I and Zone II do not readily become apparent until Subzone B where several common spores are introduced, and the frequencies of tricolpate pollen commonly exceed 15%. Several species such as *Clavatipollenites hughesii* and *Araucariacites australis* attain their greatest abundance in Subzone B.

3. The first appearance of definite angiosperm pollen was found at the base of Zone II (Subzone A). They consist of 7 tricolpate and 1 monocolpate species;

no triporates or tricolporates have been found. All 8 of them appear in the lowest samples in Subzone A in combined frequencies of less than 2%. Towards the top of Subzone A and in Subzone B the abundance of tricolpate grains increases, and in several samples from Subzone B frequences of 40% are attained.

4. The stratigraphic distribution and relative abundance of ten dominant species or species groups have been determined. Such variation in microfloral dominants are believed to reflect major vegetational changes; these changes may also be used as a supplemental aid in zonation and correlation. *Classopollis torosus* and *Exesipollenites tumulus* (gymnosperms), *Cyathidites minor*, and schizaeaceous trilete spores form the dominant types of Zone I. *Clavatipollenites hughesii* and *Araucariacites australis* are present, but rare, in Zone I. Zone II is marked by the first appearance of definite angiosperm pollen. *Clavatipollenites hughesii* and *Araucariacites australis* become conspicuous members of the sporomorph population in Subzone B along with tricolpate grains (*Tricolpopollenites micromunus* in particular). The dominant types mentioned from Zone I decline in their relative abundance in Zone II.

5. The macroflora and microflora both indicate that the gymnosperms and ferns comprised the dominant plant groups during Potomac time. The angiosperms became part of the vegetation during Patapsco time; the microflora indicate that they gained prominence only at the top of Subzone A and in Subzone B. The gymnosperms of the Potomac forest belonged chiefly to the *Podocarpaceae*, *Araucariaceae*, *Taxaceae-Cupressaceae* complex. Important sporomorphae such as *Classopollis torosus*, *Exesipollenites tumulus*, *Eucommiidites troedssonii* and *Clavatipollenites hughesii* may have belonged to gymnosperm families which are now extinct. The spores of *Cyathadites minor* and trilete schizaeaceous types dominated the spore population.

The forests which existed during Potomac time were probably similar in character to the warm-temperate gymnosperm and fern forests of New Zealand. In these forests, members of the *Podocarpaceae* and *Araucariaceae* are the dominant trees, whereas the lower stories are occupied by a luxuriant growth of all types of ferns, from filmy epiphytes to the tree ferns *Cyathea* and *Dicksonia*. The presence in the micro- and macroflora of remains of Cycads and schizaeaceous plants suggests more tropical conditions than exist in the present New Zealand forests.

6. The presence of several species of *Appendicisporites* and *Cicatricosisporites* in the Patuxent and Arundel Formations places these two formations above the Jurassic-Cretaceous boundary. The microfloras of the Patuxent and Arundel Formations are very similar to those of the Wealden and Lower Greensand of England, which are considered Neocomian and Aptian respectively. Sixty per cent of those forms listed by Couper (1958) from the Wealden and Lower Greensand appear conspecific with forms in the Patuxent and Arundel Forma-

tions. The Arundel is believed to be of upper Barremian to Aptian age because of the frequent occurrence of *Clavatipollenites hughesii*. According to Hughes (1958) the first appearance of *Clavatipollenites hughesii* in England takes place high in the Barremian. Since the Patuxent microflora is so similar to that of the Arundel and because *Clavatipollenites* is present but usually rare, this formation might be upper Barremian or slightly older.

The Patapsco formation is considered Albian in age. It is the oldest formation in the Maryland Coastal Plain that contains definite angiosperm pollen. The pollen are primarily tricolpates, and none of the triporate and tricolporate forms that first occur in the overlying Raritan formation are present. Several species restricted to Zone II have been found in a sample described from the late Albian (?) of Portugal.

A more positive age determination of the Potomac Group will probably be achieved when future studies are made of the spores and pollen from the Lower Cretaceous marine deposits of the Gulf Coast and the standard European section. It is believed that such future studies will not alter the above age determinations radically, but only serve to refine them. Such refinements are important, however, because critical changes in the Earth's vegetation were taking place during late Early Cretaceous time.

7. The stratigraphic range of various sporomorphae has been used to zone the Potomac Group. Since major changes in the microflora are thought to be of temporal significance, it is believed that the zones will prove more useful in subdividing the Lower Cretaceous section than the formational units; the complexity of the sedimentation makes correlation of the units from place to place extremely difficult.

8. The microflora of the Patuxent and Arundel are so similar that the supposed disconformity between them may represent a change in the drainage system rather than a significant hiatus. The change in the microflora from Zone I in the Arundel clay to Subzone A in the Patapsco formation suggests a disconformable contact. The low frequencies of the newly introduced forms in most of the lower part of Subzone A does not indicate any great lapse of time.

9. The macroflora suggest a significant stratigraphic break between the Patapsco and the overlying Raritan Formation. The palynological nature of this boundary has not been investigated and would make an interesting problem for future research.

VI. SYSTEMATIC PALYNOLOGY

INTRODUCTION

In this section, 130 sporomorphae are described from the Potomac Group. Each species has been given a number which refers to the species number listed on Table 1. This number, which is placed in parentheses, follows the specific name in the formal taxonomic heading.

An attempt has been made to arrange the spores and pollen according to some sort of natural classification. Although many of the spores can be grouped into modern families, most of them are listed under Spores-Incertae Sedis and arranged alphabetically. The gymnosperms and angiosperms are listed under the smallest taxonomic headings that seem advisable at this time. In a few cases, e.g. the *Ephedraceae*, the pollen are so distinctive that the fossil forms have been grouped at the family level. The last group listed, Spores and Pollen-Incertae Sedis, is composed of sporomorphae whose affinities are least known.

Although the phylum, class, order, and family names of living plants may be used to group the species into a system of classification, the generic names of extant plants have not been attached to any of the spores and pollen. Most of the species cannot be related to spores or pollen being produced by any genus of living plants, and, therefore, form generic names are used. Some of the form generic names suggest a generic affinity with a living plant, e.g. *Sphagnumsporites*; these are often referred to in the literature as "half-natural" designations. These forms may belong to the genera of extant plants suggested by the designation, but since the spores and pollen are found unassociated with their parent plants and might be produced by plants of other genera, the writer prefers to use form generic names. Within this practice of using only form generic names, the laws of priority, as set up by the International Code of Botanical Nomenclature, are adhered to.

For the most part only the new species are formally described, except when a more satisfactory description of a previously published form is considered desirable. Frequently, dimensions are given in a series of three numbers with the center number enclosed in parentheses: the first number is the minimum value; the second, the arithmetic mean; the third, the maximum value. Under the heading "Occurrence", the first word or phrase usually states the specimen frequency. The specimen frequency denotes the percentage of that form in the total spore count of a sample. If one term is used it refers to the specimen frequency found in most samples; if a frequency range is given, it refers to the range of frequencies found in the zones containing the species.

Specimen frequencies are expressed in the following terms (repeated here for convenience):

rare	less than 1 per cent
occasional	1–5 per cent

common	6–10 per cent
abundant	greater than 10 per cent

The sample frequency expresses the percentage of samples in a zone that the species occurs. The following terms are used to express the sample frequencies (repeated here for convenience):

high	over 50 per cent of the samples
moderate	25–50 per cent of the samples
low	10–25 per cent of the samples
infrequent	less than 10 per cent

The type locality is indicated by the slide designation: e.g.,

St. 10A	station 10 of the surface samples, first slide
L1-21B	sample 21 from Probe Hole No. 1, second slide
L2-29A	sample 49 from Probe Hole No. 2, first slide
D600B	depth of 600 ft. from Delaware City, Del., Core, second slide.

MORPHOLOGICAL TERMS

The following are a list of some important morphological terms used in the systematic descriptions.

Apical areas—Areas surrounding the corners of a triangular spore.

Appendici—Elongate projections at the corners of the spore.

Auriculae—Bulbous or broad processes at the corners of the spore.

Bladder height (*bisaccates*)—The length of the maximum diameter of the bladder parallel to the polar axis, as seen in lateral view.

Bladder length (*bisaccates*)—Maximum diameter of the bladder perpendicular to a line joining the median extremities of the bladders and intersecting the polar axis; seen in polar view.

Bladder width (*bisaccates*)—the line perpendicular to the bladder length; seen in polar view.

Body height (*bisaccates*)—Length of polar axis.

Body length (*bisaccates*)—Maximum diameter of the body parallel to the line connecting the median extremities of both bladders, and passing through the polar axis.

Body width (*bisaccates*)—Diameter perpendicular to the body length and passing through the polar axis.

Total length of grain (*bisaccates*)—Line passing through the polar axis and connecting the median extremities of both bladders.

Canaliculate—Having striate ornamentation in which the width of the muri exceed the width of the canals.

Cicatricose—Having striate ornamentation in which the width of the canals exceed the width of the muri.

Commissure—The line of dehiscence in the tetrad scar.

Echinate—Exine covered with spines.

Foveolate—Exine with pits up to 2 μ in diameter, or too widely separated to form a reticulum.

Gemmae—Subspherical sculptural elements with constricted bases.

Grana—Isodiametric sculptural elements from 1–2 μ in diameter.

Laesurae—Dehiscence scars, including the commissure and margo if present.

Laesurae simple—Commissure without a margo.

Maximum diameter (*triletes spores*)—the longest line connecting a corner to a side of a triangular spore and passing through the polar axis.

Mesocolpium—Area between the furrows, not including the polar area.

Microreticulate—Having lumina of reticulum generally less than 1 μ.

Microrugulate—Having the longest dimension of the rugulae, generally less than 1 μ.

P/E—Ratio of the polar to equatorial axis.

Perine—Noncommittal term for a perisporium-like layer.

Pila—Rod-like elements with swollen distal ends (capita).

Retipilate—Having reticulum formed by the arrangement of pila.

Rugae—Long and narrow elements as seen in surface view; the longest dimension is at least twice the shortest.

Scabrate—Having granular ornamentation in which the projections generally do not exceed 1 μ in diameter.

Sporomorphae—A general term for spore and pollen: commonly used when it is not known if the form is a spore or pollen grain.

Tubercles—Isodiametric sculptural elements with a diameter exceeding 2 μ.

Verrucae—Sculptural elements not isodiametric, broad in surface view, but the longest dimension not greater than twice the shortest.

SYSTEMATIC DESCRIPTIONS

Phylum Bryophyta

Class Musci

Order Sphagnales

Family Sphagnaceae

Genus Sphagnumsporites Raatz, 1937

Sphagnumsporites antiquasporites (Wilson and Webster) Potonié (63)

Plate 4, Figure 1

Sphagnum antiquasporites Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, no. 4, p. 273, fig. 2.

Sphagnumsporites antiquasporites (Wilson and Webster, 1946) Pontonié, 1956, Biehefte Geol. Jahrb., vol. 23, p. 17.

Comments: The maximum diameter of this species ranges from 19–22 μ (5 specimens) with a mean of 21 μ. The exine is ca. 1–1.5 μ thick along the equator. These dimensions are similar to those given in the type description from the Fort Union Coal of Montana (Wilson and Webster, 1946).

An important morphological character, which can be observed on the figure of the holotype and that was not mentioned in the description by the authors, is a differentially thickened area on the distal side directly subtending the proximal pole. This feature may be confused with an arcuate thickening that commonly borders the commissure. Both features darken the exine in the polar regions. If the commissure gapes slightly, the distal thickening, when visible, will pass across the laesurae indicating that its position is distal.

The distal thickening is a feature quite common to many species of *Sphagnum*. It is strongly developed on the spores of the extant species, *Sphagnum cymbifolium* (R-1363 Pennsylvania State University Palynological Collection).

Occurrence: Sphagnumsporites antiquasporites is not restricted to any part of the Potomac Group. It was found in only a few samples and with frequencies of usually less than 1 per cent.

Subphylum Lycopsida

Genus Cingulatisporites Pflug emend. Potonié, 1956

Cingulatisporites reticingulus, new species (20)

Plate 4, Figures 2, 3

Description: Trilete spores; laesurae extending to the inner margin of the cingulum, commissure bordered by narrow lips ca. 0.5 μ wide; outline in polar view triangular with convex to occasionally straight sides, corners rounded to slightly acute.

The exine is two-layered. The endexine is smooth and ca. 0.5 μ thick, ektexine of the central body smooth on the proximal side; distal side ornamented by widely spaced spines. The spines range from 2.5–4 μ in height, and their axes may be straight to strongly curved at the tips; their bases commonly broaden to a width equal to the height of the spine. The nature of the basal broadening is highly variable; it may be so abrupt that the element resembles a tubercle with a spine on it. Between the spines the ektexine is scabrate to microreticulate.

The cingulum is 2.5–4 μ wide, of uniform width, and completely encircles the grain. It has a distinctly microreticulate ornamentation which is coarser than any microreticulum that may develop on the distal side.

Dimensions: Maximum diameter 31(34) 38 μ (12 specimens).

Holotype: Slide St. 11B, coordinates 38.1–118.6; plate 1, fig. 2.

Comments: Spores with stout distal spines and equatorial membranes are common in many species of *Selaginella*. A cingulum is a common feature of Knox's Group I, Sibirica, and distal spines are found in Group XIX, Selaginoides (Knox, 1950).

Occurrence: Rare; sample frequency moderate, not restricted to any zone.

Genus Cirratriradites Wilson and Coe, 1940

Cirratriradites spinulosus Cookson and Dettmann (22)

Plate 4, Figure 4; Plate 5, Figure 1

Cirratriradites spinulosus Cookson and Dettmann, 1958, Proc. Roy. Soc. Victoria, vol. 70, pt. 2, p. 113, pl. 19, fig. 9.

cf. *Aequitriradites inconspicuous* Delcourt and Sprumont, 1952, Mém. Soc. Belge Géol. de Paleont., Sér. in 4, no. 5, p. 45, pl. 2, fig. 6.

Comments: The development of the laesurae, the expression of the fovea, and the nature of the ornamentation are highly variable in this species. The laesurae are frequently absent and polar orientation is determined by the presence of the distal fovea. When the laesurae is developed, it is usually only present on the flange and the outer regions of the central body. The fovea is commonly expressed as a reduction or change in the nature of the distal ornamentation in a small, somewhat circular area situated at the distal pole. The ornamentation is echinate with the spacing of the elements quite variable. The basal cross section of the spines is circular to polygonal. The proximal surface may be densely echinate or devoid of any ornamentation; the distal surface may contain rugae or verrucae along with spines, the verrucae frequently being confined to the foveal area.

Similar spore types are found in the extant *Selaginella megastachys* group of Knox (1950), and, in particular, *Selaginella integerrima*.

Occurrence: Rare; sample frequency moderate, not restricted to any zone but occurs more often in samples from Zone II.

Cirratriradites spinulosus has been reported from several Lower Cretaceous deposits. In the Northern Hemisphere it was found in Neocomian to Albian sediments of the Vilyui depression by Bolkhovitina (1956) and in the upper Neocomian deposits of Western Canada by Pocock (personal communication). Cookson and Dettmann first reported this species in Neocomian to Albian sediments of Eastern Australia.

Genus Lycopodiacidites Couper, 1953

Lycopodiacidites cerniidites (Ross) new combination (49)

Plate 5, Figure 2

Lycopodium cerniidites Ross, 1949, Bull. Geol. Inst. Uppsala, vol. 34, p. 30, pl. 1, figs. 1, 2.

Lycopodiumsporites cerniidites (Ross) Delcourt and Sprumont, 1955, Mém. Soc. Belge de Paleont. Sér. in 4, no. 5, p. 32, pl. 3, fig. 1.

Lycopodiumsporites cerniidites (Ross) Delcourt and Sprumont, 1955. Couper, 1948, Paleontographica, Abt. B 103, p. 132, pl. 15, figs. 6–9.

Comments: Couper's form and the forms found in the Potomac Group are slightly larger than the specimens figured by Ross from the Upper Cretaceous of South Sweden. The diameter of the type specimen from Sweden is 27 μ; Couper's form has a mean diameter of 43 μ, while the maximum diameter of this species in the Potomac Group ranges from 30–45 μ (7 specimens) with a mean of 37 μ.

The smooth contact area and the closely spaced undulating and branching rugulae on the distal surface approximate the condition observed on the spores of the recent plant *Lycopodium cernuum* (R-110, Pennsylvania State University Palynological Collection). The muri on the Potomac forms are broader than on the extant spores, but the distal pattern is very similar.

The genus, *Lycopodiumsporites* is reserved for spores with a distinct reticulum on the distal surface; the writer has, therefore, created a new combination.

Occurrence: Found as a rare form in a few samples from Zone II.

This species was reported from the Wealden of Belgium (Delcourt and Sprumont, 1955), the Jurassic and Lower Cretaceous deposits of England (Couper, 1958), and the Upper Cretaceous deposits of South Sweden (Ross, 1949), the morphographic type extends into the Tertiary and is found in the spores of *Lycopodium cernuum.*

Genus Lycopodiumsporites Thiergart, 1938.

Lycopodiumsporites austroclavatidites (Cookson) Potonié (50)

Plate 5, Figure 3

Lycopodium sp. (fastigiatum-volubile group) Couper, 1953, New Zealand Geol· Surv., Paleont. Bull. 22, p. 19, pl. 1, fig. 2.

Lycopodium austroclavatidites Cookson, 1953, Austr. Jour. Bot., vol. 1, no. 3 p. 469, pl. 2, fig. 35.

Lycopodiumsporites austroclavitidites (Cookson) Potonié, 1956, Beihefte Geol. Jahrb., v. 23, p. 17.

Lycopodiumsporites clavatoides Couper, 1958, Paleontographica, Abt. B 103, pp. 132, 133, pl. 15, figs. 10–13.

Comments: The reduced ornamentation on the proximal surface and the well developed reticulum on the distal surface compares favorably with the spores of *Lycopodium clavatum.*

Occurrence: An extremely rare form found in samples L2-49, St. 30, and St. 40; it probably has no stratigraphic value.

Lycopodiumsporites dentimuratus, new species (51)

Plate 5, Figure 4

Description: Trilete spore; laesurae reaching margin, commissure bordered by a narrow lip ca. 2 μ wide; outline in polar view triangular with slightly convex sides.

Distal surface and outer margin of the proximal surface reticulate, muri high and narrow; 1.5–3.2 μ in height, ca. 1.2 μ wide. At the intersection of the muri a characteristic dentate prolongation is developed, giving the muri an arched appearance. Lumina somewhat polygonal in outline, ca. 4.5–9.5 μ across. Exine of the lumina and smooth area surrounding the proximal pole ca. 1.2 μ thick.

Dimensions: Maximum diameter 27(33)38 μ (8 specimens).

Holotype: Slide St. 26A, coordinates 26–115.8; plate 5, fig. 4.

Comments: This species differs from *Lycopodiumsporites austroclavatides* by the development of dentate projections at the intersection of the muri.

Occurrence: Rare to occasional; sample frequency moderate, not restricted to any zone.

Family Osmundaceae

Genus Todisporites Couper, 1958

Todisporites minor Couper (67)

Plate 6, Figure 1

Todisporites minor Couper, 1958, Paleontographica, Abt. B 103, p. 135, pl. 16, figs. 9–10.

Comments: The maximum diameter of this species in the Potomac Group ranges from 25–40 μ (10 specimens) with a mean of 36 μ. These dimensions would most closely compare with Couper's dimensions for *Todisporites minor*, 32(45)50 μ. Similar morphological types with a diameter greater than 52 μ are placed in the species *Todisporites major*.

According to Couper (1958, p. 134), this genus is reserved for spores of the type found in *Todites williamsonii* and *Todites princeps*.

Occurrence: Rare to occasional; sample frequency moderate, not restricted to any zone.

Family Schizaeaceae

Genus Appendicisporites Weyland and Krieger, 1953

Appendicisporites dentimarginatus, new species (4)

Plate 6, Figures 2, 3

Description: Trilete spore; laesurae reaching the margin, commissure bordered by narrow lips, ca. 1 μ wide and merging at the corners with rod-shaped appendages, ca. 1.3–2.5 μ wide, 1.5–4 μ long; outline in polar view triangular with convex sides.

Distal surface ornamented by narrow muri, ca. 1.5 μ high, 0.5 μ wide and ca. 2.5 μ apart; the muri are parallel to the equator. The proximal surface is smooth.

A translucent equatorial zona with a dentate margin characteristically encircles the spore body. The equatorial teeth are small, ca. 1.2 μ high and 1.5 μ wide at their bases. The zona including the teeth is ca. 2–3.2 μ wide.

Dimensions: Maximum diameter, 22(30)34 μ (8 specimens).

Holotype: Slide L2-89A, coordinates 27–115.8; plate 6, fig. 2.

Comments: This species differs from other species of *Appendicisporites* by its smaller size and dentate equatorial zona. Similar spores are found in the extant species, *Anemia auriculata* Bayrich, *Anemia hirta* Swartz, and *Anemia phyllidiiis* Swartz.

Occurrence: Rare to occasional; sample frequency low, not restricted to any zone.

Appendicisporites potomacensis, new species (5)

Plate 6, Figures 4, 5

Appendicisporites tricornatatus, Couper, pars (non Weyland and Greifeld, 1953) 1958, Paleontographica, Abt. B 103, pp. 135, 136, pl. 17, figs. 8, 9.

Appendicisporites tricornatatus, Groot and Penny (non Weyland and Greifeld), 1960, Micropaleontology, vol. 6, no. 2, p. 230, pl. 1, fig. 4.

Description: Trilete spore; laesurae reaching the margin; commissure bordered by a narrow lip ca. 0.5 μ wide; outline in polar view triangular, sides straight to slightly convex.

Ornamentation distinctly cicatricose; muri parallel to the equator on both the proximal and distal side. The muri merge at the apical areas forming rod-shaped appendages. The appendici range from 2.5–3.8 μ in width and 2.4–9.6 μ in length; muri 2.3 μ wide, 2.5–4 μ apart. The distal muri commonly branch near the region of the distal pole.

Dimensions: Maximum diameter 25(41)54 μ (10 specimens).

Holotype: Slide L2-49A, coordinates 25–112; plate 6, fig. 4.

Comments: This species differs from *Appendicisporites tricornatatus* by its distinctly cicatricose ornamentation and its more elongate appendici. Species that appear conspecific with *A. potomacensis* have been reported from various Lower Cretaceous horizons as *A. tricornatatus*. The latter species is distinctly canaliculate.

Occurrence: Rare to common; sample frequency high, not restricted to any zone.

Appendicisporites segmentus, new species (6)

Plate 7, Figures 1, 2

Description: Trilete spore, laesurae reaching the appendici; commissure may or may not have a thickened border, 3–6 μ wide at the proximal pole and tapering gradually towards the apical areas; outline in polar view triangular, sides slightly concave to convex. Large auriculae are present in each corner, infrequently becoming detached from the central body. The auriculae are 1.5–2 times as broad as they are high, the width ranging from 10–20 μ.

The ornamentation is cicatricose to canaliculate; muri 1–4 μ wide, 0.5–1.5 μ apart. The muri are commonly absent in the contact area; on the proximal side they develop a dentate margin, while on the distal surface the muri lack teeth and characteristically become segmented while maintaining the striate organization. Segmentation may be complete, as in Plate 7, fig. 2, or only partially developed as indentations along the muri.

Dimensions: Maximum diameter excluding the auriculae, 40(48)50 μ (8 specimens).

Holotype: Slide St. 40A, coordinates 24–111; plate 7, fig. 1.

Comments: This species is characterized by its large bulbous appendici and the segmentation of the distal muri.

Occurrence: A rare, but easily identifiable spore that has not been observed below Zone II. In Probe Hole No. 1 it was found in samples L1-21 and L1-22. In the surface samples it was found in Subzones A and B.

Appendicisporites tricornatatus Weyland and Greifeld (7)

Plate 7, Figure 3

Appendicisporites tricornatatus Weyland and Greifeld, 1953, Paleontographica, Abt. B 95, p. 43, pl. 11, fig. 52.

Comments: Weyland and Greifeld described *Appendicisporites tricornatatus* from the lower Senonian of Harz, Germany. The description and illustration of the type specimen shows that the ornamentation is canaliculate and the appendici short and broad. The diameter of the type specimen is 35 μ; the maximum diameter of this species in the Potomac Group is 33(41)46 μ (10 specimens); the muri are 2–3.2 μ wide and are parallel to the equator. The appendici are 5.8 μ long and ca. $\frac{3}{4}$ as wide at their bases. An exinal thickening, ca. 4 μ wide at the proximal pole, borders the commissure. Although the type description does not mention a margo it is apparent on the type illustration.

Occurrence: Rare to occasional; sample frequency moderate, not restricted to any zone.

Genus Cicatricosisporites Potonié and Gelletich, 1932

Cicatricosisporites aralica (Bolkhovitina) new combination (9)

Plate 7, Figures 4, 5

Ruffordia goepperti (Dunk.) Seward, 1913, Quart. Jour. Geol. Soc., vol. 69, text fig. 2a (spores).

Ruffordia goepperti (Dunk.) Seward, 1913. Couper, 1958, Paleontographica, Abt. B 103, pp. 109, 110, pl. 17, figs. 4–6 (spores).

Cicatricosisporites goepperti Groot and Penny, 1960, Micropaleontology, vol. 6, no. 2, p. 230, pl. 2, figs. 20, 22.

Ruffordia aralica Bolkhovitina, 1961, Trans. Inst. Geol. Acad. Sci., U.S.S.R., no. 40, p. 13, pl. 1, figs. 9f–h.

Comments: The proximal side of this species is smooth with muri formed near the equator and onto the distal side. The distal muri are ca. 2 μ wide, 1–2 μ apart, and commonly branching in the region of the distal pole.

This spore seems identical to the spores found associated with *Ruffordia goepperti*. The specific name *goepperti* cannot be combined with the form genus *Cicatricosisporites* and be considered a new combination for a spore, as was done by Groot and Penny (1960), because the species *Ruffordia goepperti* is based on foliage.

Similar spores are produced by extant species of *Anemia*.

Occurrence: Abundant to rare; found throughout the Potomac Group, but most prevalent in Zone I. This form is very common in the Wealden of England.

Cicatricosisporites australiensis (Cookson) Potonié (10)

Plate 8, Figures 1–3

Mohrioisporites australiensis Cookson, 1953, Austr. Jour. Bot., vol. 1, no. 3, p. 470, pl. 2, figs. 31–34.

Cicatricosisporites mohrioides Delcourt and Sprumont, 1955. Lantz, 1958b, Inst. Français du Pétrole, Annales des Combust. Liquides, vol. 13, no. 6, p. 923, pl. 2, figs. 19–23.

Cicatricosisporites australiensis (Cookson) Potonié, 1956, Beihefte Geol. Jahrb., vol. 23, p. 48.

Comments: This specific name has been used for striate spores in which the proximal muri parallel the equator, meeting the laesurae at angles less than 30 degrees; they appear conspecific with the form described by Cookson (1953). Sporangia containing this species were found in sample St. 26 from Virginia. Plate 8, fig. 2a shows a sporangium with a distal annulus so typical of sporangia in the *Schizaeaceae*. Figure 2b shows striate trilete spores within the sporangium.

The nature of the ornamentation and the structure of the sporangium places this form in the *Schizaeaceae* and, in general, suggests this to be the affinity of the form genus *Cicatricosisporites*.

Occurrence: Common to abundant in most samples from the Potomac Group, although generally found in higher frequencies in samples from Zone I.

This species is a very generalized form and has been reported from Cretaceous and Tertiary deposits. It is very common in all Lower Cretaceous deposits as is the *Schizaeaceae* in general.

Cicatricosisporites brevilaesuratus Couper (11)

Plate 9, Figure 1

Cicatricosisporites brevilaesuratus Couper, 1958, Paleontographica, Abt. B 103, p. 136, pl. 18, figs. 1–3.

Comments: Similar to the spores of *Schizaeopsis americana* Berry, from the Patuxent of Maryland.

Occurrence: Rare, not restricted to any zone.

Identical spores reported by Couper (1958) from the English Wealden.

Cicatricosisporites dorogenesis Potonié and Gelletich, emend., Kedves (12)

Plate 8, Figure 4

Cicatricosisporites dorogensis Pontonié and Gelletich, 1933, S.B. Ges. Nat. Freunde, pp. 523–524, pl. 1, figs. 1–5.

Cicatricosisporites sewardi Delcourt and Sprumont 1955, Mém. Soc. Belge Geol. de Paleont., Sér. in 4, no. 5, p. 19, text-fig. 2.

Cicatricosisporites dorogensis Potonié and Gelletich, 1933, emend. subsp. *major* Kedves, 1961, Pollen and Spores, Mus. Nat. Hist. (Paris), vol. 3, no. 1, p. 126; type illustrated in vol. 2, no. 1, pl. 20, fig. 14.

Comments: Kedves (1961) split *C. dorogensis* Potonié and Gelletich into two subformspecies, *C. dorogensis* subfsp. *minor* (40–60 μ) and subfsp. *major* (60–90 μ). The smaller form appears conspecific with *C. hallei* Delcourt and Sprumont from the Wealden of Hainaut, Belgium. *Cicatricosisporites dorogensis*, as described by Potonié and Gelletich, is generally larger than *C. hallei* and falls more into the size range of Kedves' *C. dorogensis* subfs. *major.* In both the type illustrated for *C. dorogensis* and Kedves' two subform-species the proximal muri do not parallel the equatorial outline.

The name *C. dorogensis* has been applied, in this study, to spores between 60–90 μ with more or less canaliculate ornamentation and in which the proximal muri form angles greater than 45 degrees with the equatorial outline.

Occurrence: Rare in St. 26, occasional in L2-74; sample frequency infrequent, found in only Zone I.

Cicatricosisporites hallei Delcourt and Sprumont (13)

Plate 9, Figure 2

Cicatricosisporites hallei Delcourt and Sprumont, 1955, Mém. Soc. Belge Geol. de Paleont., Sér. in 4, no. 5, p. 17, pl. 1, fig. 1, text-fig. 1.

Cicatricosisporites dorogensis, Couper, pars (non Potonié and Gelletich, 1933) 1958, Paleontographica, Abt. B 103, p. 136, pl. 17, figs. 10–11, not 12.

Cicatricosisporites dorogensis subfsp. *minor* Kedves, 1961, Pollen and Spores, Mus. Nat. Hist. (Paris), vol. 3, no. 1, p. 126; type illustrations in vol. 2, no. 1, pl. 20, figs. 1–6.

Comments: The smaller subfsp. of Kedves appears conspecific with *Cicatricosisporites hallei*. In the type description for *C. hallei* the diameter ranges from 35–57 μ with a modal value of 40 μ. In this study this species has a maximum diameter of 24(37)49 μ (24 specimens).

Couper's form designated as *C. dorogensis* (pl. 17, fig. 10) is identical to *C. hallei*. The writer would prefer to restrict *C. dorogensis* to the larger forms previously mentioned.

Occurrence: One of the most abundant species; occurring in almost every sample examined from the Potomac Group.

Cicatricosisporites patapscoensis, new species (14)

Plate 9, Figure 3

Description: Trilete spore; laesure reaching the margin occasionally $\frac{3}{4}$ the radius; outline in polar view triangular with convex sides and moderately acute corners.

Exine canaliculate, ca. 1.5 μ thick including the muri. Muri extremely wide and few in number; on the proximal side canals, parallel to the sides of the spore, connect the ends of the laesurae; on the distal side are four flat-topped muri, ca. 12 μ wide and 0.5 μ apart.

Dimensions: Maximum dimeter 40(49)59 μ (12 specimens).

Holotype: Slide St. 30A, coordinates 26.1–115.8, plate 9, fig. 3.

Comments: This species differs from all other species of *Cicatricosisporites* by its extremely wide muri. The wide muri make this form easily recognizable in any orientation.

Occurrence: Occasional to rare; this species, although low in specimen frequency, is easy to identify morphologically and was found in almost all samples from Subzone B.

Cicatricosisporites potomacensis, new species (15)

Plate 9, Figures 4, 5

Description: Trilete spore; laesurae $\frac{3}{4}$ radius, rarely extending to the margin; outline in polar view triangular with straight to convex sides and moderately rounded corners.

Exine canaliculate; proximal muri parallel to equatorial outline, ca. 1 μ wide, 0.5 μ apart. Exine excluding muri ca. 4 μ thick.

Dimensions: Maximum diameter 44(64)75 μ (12 specimens).

Holotype: Slide L2-49A, coordinates 32.9-112; plate 9, fig. 4.

Comments: Cicatricosisporites potomacensis differs from *C. brevilaesuratus* by its longer laesurae and narrower muri.

Occurrence: Rare to occasional; not restricted to any zone; sample frequency high to moderate.

Cicatricosisporites subrotundus, new species (16)

Plate 10, Figures 1, 2

Description: Trilete spore; laesurae $\frac{1}{2}$–$\frac{3}{4}$ radius; outline in polar view triangular with convex sides and well rounded corners. Exine canaliculate; muri 6–8 μ wide, 0.75 μ apart. Muri on proximal surface intersect the rays; distal muri may be parallel or oblique to the equatorial outline.

Dimensions: Maximum diameter 37(46)55 μ (7 specimens).

Holotype: Slide L2-49A, coordinates 29.1–116; plate 10, fig. 2.

Comments: This species can be distinguished from *Cicatricosisporites patapscoensis* by its narrower and more numerous muri.

Occurrence: Rare, sample frequency moderate to low. This species has only been found in Subzone B.

Genus Ischyosporites Balme, 1957

Ischyosporites crateris Balme (39)

Plate 10, Figures 3, 4

Ischyosporites crateris Balme, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, Chatswood N.S.W., p. 23, pl. 3, fig. 45; pl. 4, figs. 46, 47.

Comments: This species was placed in the *Schizaeaceae* because of its resemblance to *Klukisporites*. *Ischyosporites* differs from *Klukisporites* by its thicker ridges on the distal surface.

Occurrence: Rare; sample frequency moderate; found in the upper part of Zone I and throughout Zone II.

This species was originally reported from Neocomian-Aptian (?) deposits of Western Australia by Balme (1957).

Genus Klukisporites Couper, 1958

Klukisporites pseudoreticulatus Couper (40)

Plate 10, Figure 5

Klukisporites pseudoreticulatus Couper, 1958, Paleontographica, Abt., B 103, p. 138, pl. 19, figs. 8–10.

Comments: This form has been reported by Couper from the Purbeck and Wealden of England.

Occurrence: Rare to abundant; *Klukisporites pseudoreticulatus* is found throughout the Potomac Group; however, its specimen and sample frequency is much higher in Zone I than in Zone II. In the former zone it is found in almost all samples as a dominant form, with frequencies commonly between 5 and 11%.

Klukisporites variegatus Couper (41)

Plate 11, Figure 1

Klukisporites variegatus Couper, 1958, Paleontographica, Abt. B 103, p. 137, p. 19, figs. 6, 7.

Comments: According to Couper (1958) the spores of *Klukisporites variegatus* can be related to spores associated with the schizaeaceous plants *Klukia exilis* and *Stachypteris hallei*, although he does mention that the spores of these plants show a rather variable development of the distal reticulum.

Occurrence: Rare to occasional; sample frequency low. This species was only found in the surface samples in Zones I and II. It was previously reported from the British Middle Jurassic by Couper (1958).

Family Gleicheniaceae

Genus Gleicheniidites (Ross, 1949) Delcourt and Sprumont, 1955

Gleicheniidites apilobatus, new species (35)

Plate 11, Figures 2, 3

Description: Trilete spore; laesurae reaching margin, commissure bordered by a narrow lip ca. 1 μ wide; outline in polar view triangular with strongly concave sides in most specimens; corners abruptly acute.

Exine smooth to finely scabrate, ca. 0.5 μ thick. On the distal side a ridge characteristically crosses the apical lobe at its greatest width; the apical ridge is usually convex toward the proximal pole. The apical ridges may be connected to each other by continued ridge development along the distal side, close to the equator.

Dimensions: Maximum diameter 11(18)24 μ (12 specimens).

Holotype: Slide St. 16B, coordinates 40–121.8; plate 11, fig. 2.

Comments: This species can be distinguished from other species of *Gleicheniidites* by the presence of apical ridges. A similar form from the upper Albian of Western Kazakhstan was described by Bolkhovitina (1953) as *Leiotriletes tricuspidatus*.

This form is larger and has more acute corners than *Gleicheniidites apilobatus*. The abrupt decrease in curvature of the apical outline is a common feature of the spores of *Gleichenia* and, although, one cannot be absolutely sure of its affinities, the writer prefers to keep this species within the *Gleicheniaceae*.

Occurrence: Rare; sample frequency was high in Zone I, low in Zone II.

Gleicheniidites circinidites (Cookson, 1953) new combination (36)

Plate 11, Figures 4, 5

Gleichenia circinidites Cookson, 1953, Austr. Jour. Bot., vol. 1, no. 3, pp. 464–465, pl. 1, figs. 5, 6.

Gleichenia umbonata Bolkhovitina, 1953, Trans. Inst. Geol. Sci., Acad. Sci., U.S.S.R., Rel. 145, Geol. Ser. no. 61, p. 53, pl. 8, figs. 4–7.

Cingutriletes interruptus Pierce, 1961, Univ. of Minn., Minnesota Geol. Surv., Bull. 42, p. 26, pl. 1, fig. 5.

Comments: This form appears to be identical to Cookson's form. It is characterized by its acute corners and a tendency for the equatorial thickening to extend around the apices.

The genus *Gleicheniidites* is preferred to *Gleichenia* for this type of spore because similar types are found in the plant *Hicriopteris.*

Occurrence: Rare to sometimes occasional; sample frequency high except for Probe Hole No. 2. This species is not restricted to any particular zone.

Gleicheniidites senonicus Ross (37)

Plate 11, Figure 6

Gleicheniidites senonicus Ross, 1949, Bull. Geol. Inst. Uppsala, vol. 34, p. 31, pl. 1, fig. 3.

Leiotriletes orientalis Bolkhovitina, 1953, Trans. Inst. Geol. Sci., Acad. Sci. U.S.S.R., Rel. 145, Geol. Ser. no. 61, p. 24, pl. 2, figs. 11–14.

Comments: The figure given by Ross for *Gleicheniidites senonicus* clearly differentiates this species from a similar form *Gleichenia circinidites* Cookson (1953). In the former species the corners have a greater curvature than in *Gleichenia circinidites* and the equatorial thickening is confined to the sides. Although there is much variation in the size and equatorial thickening, specimens found in the Potomac Group seem to group themselves into the two above mentioned species.

Distal folds frequently form in *Gleicheniidites senonicus* that parallel the equatorial outline. These folds may be confused with kyrtomes which are proximal features; infolding of the proximal exine may bring the equatorial thickening into a position also simulating kyrtomes.

Occurrence: Common to rare; sample frequency very high. This species was found in almost all samples from the Potomac Group.

Family Cyatheaceae

Genus Cyathidites Couper, 1953

Cyathidites minor Couper (28)

Plate 11, Figure 7

Cyathidites minor Couper, 1953, New Zealand Geol. Surv., Paleont. Bull. 22, p. 28, pl. 2, fig. 13.

Comments: In the Potomac Group *Cyathidites minor* has a maximum diameter ranging from 23–52 μ with a mean of 38 μ. This closely approximates the dimensions given by Couper for this species. The concave sides and well rounded corners exclude the insertion of this form in the genus *Deltoidospora minor* as emended by Potonié (1956); the genotype of *Deltoidospora hallei* has fairly straight sides and acute corners.

In sample St. 26, from the Patuxent Formation of Virginia, sporangia were found containing the spores designated as *Cyathidites minor* in the dispersed state. Plate 11, fig. 8a shows a sporangium containing *C. minor* (fig. 8b). The indurated cells of the annulus are clearly shown, and the stomial area is suggested by the disappearance of the annulus on the left central side of the sporangium. The insertion of the stalk is at the bottom of the sporangium, and it appears as though the annulus is not interrupted at this point as in the extant fern, *Cheiropleuria*.

There appears to be a greater development of the annulus in this sporangium than is commonly found in extant members of the *Polypodiaceae*, although the small number of spores (less than 80) does suggest a leptosporangiate affinity. The *Cyatheacea*, which are leptosporangiate ferns, have an oblique annulus similar to the one on this sporangium.

Similar spores are also produced by such polypodaceous genera as *Adiantum* and *Microlepia*.

Occurrence: Extremely abundant; sample frequency 100%. This species is one of the most abundant forms in the Potomac Group.

Cyathidites sp. (29)

Plate 11, Figure 9

Description: Trilete spore; laesurae simple, $\frac{1}{2}$–$\frac{3}{4}$ radius; outline in polar view triangular with well rounded corners and convex to concave sides. Exine smooth, ca. 1.5 μ thick.

Dimensions: Maximum diameter, 41(48)63 μ (12 specimens).

Comments: This form has such a generalized morphology that the author preferred not to give it a specific name. Similar spores have been described from the European Jurassic and Cretaceous as *Sporites adriennis* Potonié and Gelletich.

Occurrence: Rare to occasional; sample frequency low to moderate; not restricted to any zone.

Family Matoniaceae

Genus Matonisporites Couper, 1958

Matonisporites excavatus, new species (52)

Plate 12, Figures 2, 3

Description: Trilete spore; laesurae almost reaching the margin, commissure raised several microns above the general surface of the proximal side and bordered by an exinal thickening 5–12 μ wide at the pole. The margo extends to the margin of the spore and surrounds the ends of the commissure, often darkening the exine at the corners. The outline in polar view is triangular with straight to slightly convex sides; the corners are blunt.

Exine thick, ca. 2.5–3.5 μ, varying in thickness along the equator; surface smooth. The distal side characteristically contains a differentially thinned circular to oval area centered at the pole in undeformed specimens. The boundaries of the distal thinning are sharp and appear as a lighter area.

Dimensions: Maximum diameter 47(65)81 μ (14 specimens).

Holotype: Slide L2-49B, coordinates 15–117.5; plate 12, fig. 2.

Comments: This species is easily recognized by the presence of a thin area on the distal side.

Occurrence: Rare to occasional; sample frequency moderate to high. This species is restricted to Zone II and is most common in Subzone B.

Matonisporites phlebopteroides Couper (53)

Plate 12, Figure 1

Matonisporites phlebopteroides Couper, 1958, Paleontographica, Abt. B 103, p. 140, pl. 20, figs. 15–17.

Comments: In size, shape, and in the nature of the equatorial thickening of the exine, the few specimens of this form found in this study appear conspecific with *Matonisporites phlebopteroides* from the British Jurassic and Lower Cretaceous.

According to Couper (1958) this species compares favorably with the spores of *Phlebopteris hirsuta*, *P. muensteri* and *P. indica*.

Occurrence: Rare; found in only a few samples from Zones I and II and in Probe Hole No. 1.

Family Cheiropleuriaceae

Genus Dictyophyllidites Couper, 1958

Dictyophyllidites sp. (33)

Plate 12, Figure 4

Description: Trilete spore; laesurae almost reaching the margin, raised several microns above the general surface and completely surrounded by a margo ca. 5 μ thick at the proximal pole; outline in polar view triangular with straight sides.

Exine smooth, ca. 0.5 μ thick increasing slightly in thickness at the corners where the margo reaches the margin.

Dimensions: Maximum diameter 22.4 μ (one specimen).

Occurrence: One specimen from sample St. 34.

Spores—Incertae Sedis

Genus Alsophilidites Cookson, 1947, ex Potonié, 1956

Alsophilidites pannuceus, new species (1)

Plate 12, Figures 5, 6

Description: Trilete spore; laesurae reaching the margin, commissure bordered by a dark lip 1.4–2.4 μ wide and tapering slightly toward the corners; outline in polar view triangular with straight to slightly convex sides and acute corners; the equatorial outline in the interradial areas are sinuous or indented.

Exine smooth ca. 1.5 μ thick; surface finely wrinkled, the wrinkles showing no preferred orientation.

Dimensions: Maximum diameter 11(24)34 μ (13 specimens).

Holotype: Slide St. 10B, coordinates 21.2–125.5; plate 12, fig. 5.

Comments: Spores of similar morphology are found in members of the *Cyatheaceae*, *Gleicheniaceae*, and *Polypodiaceae.*

Occurrence: Rare to occasional; sample frequency high. This species is found in both Zones I and II, but occurs more often, and in slightly greater specimen frequencies in Zone I.

Genus Apiculatisporis Potonié and Kremp, 1956

Apiculatisporis asymmetricus Cookson and Dettmann (2)

Plate 13, Figure 1

Apiculatisporites asymmetricus Cookson and Dettmann, 1958, Proc. Roy. Soc. Victoria, vol. 70, pt. 2, p. 100, pl. 14, fig. 11.

Comments: This species was originally reported from Albian sediments of Eastern Australia. It is characterized by its subquadrangular shape and closely spaced short and broadly based spines.

Occurrence: Rare to occasional; sample frequency moderate to high; not restricted to any zone.

Apiculatisporis babsae, new species (3)

Plate 13, Figures 2, 3

Description: Trilete spore; laesurae simple, $\frac{3}{4}$ radius; outline in polar view triangular with rounded to moderately acute corners; sides straight to slightly convex.

Exine 1–1.5 μ thick, ornamented by coni 2.4–4.8 μ high, 2–5.6 μ wide at the basal end; conal axis straight to slightly curved at the distal end. The spacing of the cones is rather uniform, 2–3.2 μ apart, except in the contact area where they are either poorly developed or absent.

Dimensions: Maximum diameter 32(39)45 μ (10 specimens).

Holotype: Slide St. 30B, coordinates 24.5–128.8; plate 13, fig. 2.

Comments: Apiculatisporis babsae can be distinguished from other apiculate forms in this study by the presence of uniformly and widely spaced coni. It is more triangular in outline than *A. asymmetricus* and has larger and more widely spaced sculptural elements than *Pilosisporites brevipapillosus.*

Occurrence: Rare to occasional; sample frequency high. Although it is not very abundant in the spore count, its presence appears to be a reliable index to Zone II; it was not found below this zone.

Genus Ceratosporites Cookson and Dettmann, 1958

Ceratosporites parvus, new species (8)

Plate 13, Figure 4

Description: Trilete spore, laesurae reaching the margin, commissure bordered by a narrow lip ca. 1 μ thick. The commissure frequently splits open leaving a triangular gap around the proximal pole; outline in polar view circular to subtriangular.

Exine 1.5–2 μ thick, proximal surface smooth to slightly chagrinate, distal surface ornamented with widely spaced spines 4–6.5 μ long. The length of a spine equal to about twice the base; bases may be abruptly broadened with a basal diameter equal to approximately $\frac{2}{3}$ the length of the spine.

Dimensions: Maximum diameter 22(29)42 μ (10 specimens).

Holotype: Slide St. 30A, coordinates 23.7–127.9; plate 13, fig. 4.

Comments: The almost circular outline and chagrinate surface of the proximal side are the distinguishing characteristics of this species. For a form to be included in the genus *Ceratosporites*, the echinate elements must be restricted to the distal side.

Occurrence: Rare; sample frequency abundant to moderate. This species is restricted to Zone II.

Genus Cingulatisporites Thomson, emend. Potonié, 1956

Cingulatisporites caminus Balme (17)

Plate 13, Figure 5

Cingulatisporites caminus Balme, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, p. 27, pl. 5, figs. 62, 63.

Comments: If these forms in the Potomac Group are the same as those described by Balme from the Upper Jurassic and Lower Cretaceous of Western Australia, then Balme has misinterpreted the morphology of this species. The most prominent feature of this spore is the circular ring on the distal side; the ring encloses a granular area situated in the polar region, ca. 15 μ wide. Midway between the circumpolar ring and the equator is a less distinct ring-like thickening connected to the central ring and the equatorial margin by more or less radial muri. The cingulum described by Balme is probably the area between the middle ring and the margin of the spore.

Occurrence: Rare; sample frequency low; found only in Zone II.

Cingulatisporites cf. eukirchensoides Delcourt and Sprumont (18)

Plate 14, Figure 2

Cingulatisporites eukirchensoides Delcourt and Sprumont, 1955, Mém. Soc. Belge Géol. de Paleont. Sér., in 4, no. 5, p. 38, text-fig. 9.

Comments: The largest dimension of this species in the type description is 50–60 μ. The forms found in the Potomac Group range from 63–81 μ; the flange is also slightly larger than those on the type specimens.

Occurrence: Rare; found in only 3 samples and not restricted to any zone. This species was first described from the Wealden of Belgium by Delcourt and Sprumont; it was subsequently found in Albian deposits of Eastern Australia.

Cingulatisporites distaverrucosus, new species (19)

Plate 13, Figures 6, 7; Plate 14, Figure 1

Description: Trilete spore; laesurae distinct to indistinct in some specimens, reaching the inner margin of the cingulum but not extending onto it, commissure bordered by a narrow lip ca. 0.5 μ wide; outline in polar view triangular to subcircular, sides convex.

Exine consists of two layers, the endexine is ca. 0.5 μ thick; the ektexine is smooth to faintly granular on the proximal surface, the distal surface is covered with numerous verrucae, ca. 2–4 μ across, that fuse with one another at some point along their outline. In some specimens the verrucae remain separate and the spaces between the verrucae are continuous. At the equator the ektexine thickens into an opaque wedge-shaped cingulum. The cingulum is of uniform width, 2.4–3.5 μ, and incompletely segmented in most specimens; in a few specimens the segmentation may develop to such an extent that the cingulum is composed of distinct verrucae.

Dimensions: Maximum diameter 18(31)46 μ (15 specimens).

Holotype: Slide L1-50A, coordinates 24–128.8; plate 13, fig. 6.

Comments: This species can easily be distinguished from *Cingulatisporites sp.* by the presence of distal verrucae and the characteristic segmentation of the cingulum.

Occurrence: Occasional to rare; sample frequency abundant; not restricted to any zone.

Cingulatisporites sp. (21)

Plate 14, Figure 3

Description: Trilete spore; laesurae simple, $\frac{3}{4}$ radius; outline in polar view triangular with straight to convex sides and well rounded corners.

Exine smooth; cingulum ca. 3.2 μ wide, uniform in width; endexine .5–1 μ thick.

Dimensions: Maximum diameter 32(34)40 μ (5 specimens).

Comments: A sporomorph similar to this form was described by Delcourt and Sprumont (1959) from the Wealden of Féron-Glageon as *Sphagnumsporites sp.*

Occurrence: Rare; sample frequency low; not restricted to any zone.

Genus Concavissimisporites Delcourt and Sprumont, 1955

Concavissimisporites punctatus (Del. and Sprum.) new combination (23)

Plate 14, Figure 6

Concavisporites punctatus Delcourt and Sprumont, 1955, Soc. Belge de Géol. de Paleont. Sér. in 4, no. 5, p. 25, pl. 1, fig. 8; pl. 2, fig. 2.

Comments: The ornamentation varies from microrugulate to granular, with both types of sculptural elements commonly found on the same grain. The maximum diameter ranges from 38 to 73 μ with a mean of 54 μ.

Occurrence: Rare to abundant in some samples from Zone I; sample frequency high; not restricted to any zone but more abundant in Zone I.

Concavissimisporites variverrucatus (Couper, 1958) new combination (24)

Plate 14, Figure 4

Concavisporites variverrucatus Couper, 1958, Paleontographica, Abt. B 103, p. 142, pl. 22, figs. 4, 5.

Comments: The genus *Concavisporites* was proposed by Thomson and Pflug (1953, p. 49) for more or less smooth, concave spores with or without kyrtomes. Spores assigned to *Concavisporites variverrucatus* by Couper are strongly verrucate and no kyrtomes are present.

According to Couper similar spores are produced by the extant fern *Dicksonia squarros* Swartz. This type of spore can also be found in some species of *Lygodium*.

Occurrence: Rare; sample frequency low in Zone II, moderate to high in Zone I.

Similar forms have been described as *Lygodium gibberulum* from the Aptian of Kara Mursa by Bolkhovitina (1956, p. 55).

Genus Converrucosisporites Potonié and Kremp, 1954

Converrucosisporites platyverrucosus, new species (25)

Plate 14, Figure 5

Description: Trilete spore; laesurae almost reaching the margin, commissure bordered by a narrow lip ca. 1 μ wide; outline in polar view triangular with convex sides.

Exine ornamented on both sides by flat-topped verrucae. The verrucae are crowded and extremely variable in size, ranging from 1.5 μ to 4 μ wide and 1–1.5 μ high. On the distal surface the verrucae are more crowded than on the proximal surface and they frequently fuse into irregular-shaped masses; the outline is irregular because of the inconstant size of the verrucae.

Dimensions: Maximum diameter 27(30)34 μ (10 specimens).

Holotype: Slide L2-88A, coordinates 36.2–111; plate 14, fig. 5.

Comments: Converrucosisporites platyverrucosus differs from *C. proxigranulatus* by its flatter verrucae and by the presence of a distinct margo.

Occurrence: Rare to occasional in Zone I of Probe Hole No. 2; sample frequency moderate; not restricted to any zone.

Converrucosisporites proxigranulatus, new species (26)

Plate 15, Figures 1–3

Description: Trilete spore; laesurae simple, reaching the margin; outline in polar view triangular with convex sides.

Exine, excluding sculptural elements, ca. 1 μ thick, ornamented on the distal side by large, more or less circular tubercles 3–12 μ across and ca. 5 μ high. The tubercles are closely spaced, occasionally having polygonal outlines; proximal surface covered with densely spaced grana, ca. 1 μ in diameter and becoming verrucate to finely tuberculate in a few specimens.

Dimensions: Maximum diameter 30(35)40 μ (8 specimens).

Holotype: Slide St. 26A, coordinates 34–108.5; plate 15, fig. 1.

Comments: This spore resembles *Leptolepidites verrucatus* Couper from the Jurassic of New Zealand (Couper, 1953) and the Cretaceous of Eastern Australia (Cookson and Dettmann, 1958); it differs from this species, however, by its reduced ornamentation on the proximal surface; in *Leptolepidites* the ornamentation is equally developed on both sides.

Occurrence: Rare; sample frequency low; not restricted to any zone.

Genus Cyathidites Couper, 1953

Cyathidites crassiangulatus Balme (27)

Plate 15, Figure 4

Cyathidites crassiangulatus Balme, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, p. 22, pl. 3, figs. 39–41.

Comments: Similar spores are produced by the living ferns *Dicksonia and Matonia.* The blunted corners and thick exine can be found in the spores of the extant ferns *Dicksonia lanata* and *D. fibrosa.*

Occurrence: Rare; sample frequency low; not restricted to any zone.

Genus Deltoidospora Miner, emend. Potonié, 1956

Deltoidospora hallii Miner (30)

Plate 15, Figure 5

Deltoidospora hallii Miner, 1935, Amer. Midl. Nat., vol. 16, no. 4, p. 618, pl. 24, figs. 7, 8.

Occurrence: Rare to common in a few samples; sample frequency high.

Genus Densoisporites Weyland and Krieger, 1953

Densoisporites microrugulatus, new species (31)

Plate 15, Figure 6; Plate 16, Figure 1

Description: Trilete spore; laesurae simple, $\frac{1}{2}$–$\frac{3}{4}$ radius; outline in polar view subtriangular, sides convex.

Exine two-layered, endexine ca. 1 μ thick, ektexine ornamented by densely spaced microrugulae; cingulum entire, covered with muri forming a fine reticulum whose lumina are lineated in a direction parallel to the equator. The reticulum on the cingulum may frequently migrate onto the central body in the area between the ends of the laesurae and the spore margin.

The area around the proximal pole between the laesurae may be occupied by small dark oval areas. In some grains the endexine is separated slightly from the ektexine in the equatorial region.

Dimensions: Maximum diameter 36(63)77 μ (12 specimens).

Holotype: Slide St. 49A, coordinates 39.1–115.7; plate 15, fig. 6.

Comments: This species differs from *Densoisporites perinatus* Couper by the absence of a wrinkled central body and a finer reticulate pattern on the cingulum.

Occurrence: Rare; sample frequency moderate in the surface samples, found only in L2-58 in the subsurface; not restricted to any zone.

Densoisporites perinatus Couper (32)

Plate 16, Figure 3

Densoisporites perinatus Couper, 1958, Paleontographica, Abt. B 103, p. 148, pl. 23, figs. 6–9.

Comments: This species was first recorded from the Jurassic and Lower Cretaceous deposits of England by Couper (1958). It was also reported from the Potomac Group of Maryland by Groot and Penny (1960).

The type species for *Densoisporites* is *D. velatus*; this species is smaller (25–35 μ) than *D. perinatus* (43–68 μ). The maximum diameter of *D. perinatus* in this study was 34(43)58 μ (12 specimens).

Occurrence: Rare to occasional; sample frequency high; most samples from the Potomac Group contain this species.

Genus Foveotriletes Van der Hammen, 1954, ex. Potonié, 1956

Foveotriletes subtriangularis, new species (34)

Plate 16, Figure 2

Description: Trilete spore; laesurae almost reaching the margin, commissure bordered by a narrow lip ca. 0.5 μ wide; outline in polar view triangular with convex sides.

Exine ca. 1.5 μ thick, foveolate; fovea circular, 1–1.5 μ across, ca. 0.5 μ in depth. The fovea are more closely spaced on the distal than on the proximal surface; on the distal surface they are 1.5–2.5 μ apart, on the proximal surface the fovea are primarily developed near the margin, becoming quite sparse to absent toward the proximal pole.

Dimensions: Maximum diameter 29(38)47 μ (5 specimens).

Holotype: Slide L2-58A, coordinates 22–112.2; plate 16, fig. 2.

Comments: Foveosporites canalis, described from the Neocomian and Aptian of Western Australia by Balme (1957), is similar to *Foveotriletes subtriangularis*; the fovea of the latter species are rounder and do not fuse with each other.

Occurrence: Rare; sample frequency low; found in a few subsurface samples in both Zones I and II.

Genus Granulatisporites (Ibrahim, 1933) Potonié and Kremp, 1954

Granulatisporites dailyi Cookson (38)

Plate 16, Figure 4

Granulatisporites dailyi Cookson, 1958, Proc. Roy. Soc. Victoria, vol. 70, pt. 2, p. 99, pl. 14, figs. 2–4.

Comments: This species is characterized by its finely granular surface and the possession of a large thickened area in the center of the distal surface; the lips bordering the commissure are narrow but well defined.

Occurrence: Occasional to rare; sample frequency high, not restricted to any zone.

This species has been previously reported from Neocomian to Albian sediments of Eastern Australia by Cookson and Dettmann (1958).

Genus Kuylisporites Potonié, 1956

Kuylisporites lunaris Cookson and Dettmann (42)

Plate 16, Figure 5

Kuylisporites lunaris Cookson and Dettmann, 1958, Proc. Roy. Soc. Victoria, vol. 70, pt. 2, p. 103, pl. 14, figs. 21–23.

Comments: This form seems identical to *Kuylisporites lunaris* described by Cookson and Dettmann from Neocomian to Albian deposits of Victoria.

The most outstanding feature of this species is the several lunar-shaped ridges developed on the distal side and, to a lesser extent, on the proximal side near the margin; the ridges are usually convex toward the polar regions.

Occurrence: Rare: sample frequency infrequent. The few samples in which this species has been found are in Zone I, at the position of the Arundel Clay.

Genus Lycopodiacidites Couper, 1953, emend. Potonié, 1956

Lycopodiacidites ambifoveolatus, new species (43)

Plate 17, Figures 1, 2

Description: Trilete spore; laesurae reaching margin, commissure bordered by a narrow lip ca. 0.5 μ wide; outline in polar view triangular with strongly convex sides.

Proximal surface smooth to lightly flecked, becoming verrucose near the margin; distal surface covered with densely spaced flat verrucae 1–5 μ across, highly variable in shape, and frequently fusing with each other forming irregular thickened areas.

Exine is two-layered; ektexine, excluding the height of the verrucae, ca 1.5 μ thick; endexine thin, ca. 1 μ thick. The margin of the spore appears pitted due to the fusion of many of the verrucae at their bases, their uniform height above the endexine, and their flat tops.

Dimensions: Maximum diameter 48–50 μ (3 specimens).

Holotype: Slide L2-58A, coordinates 24–119; plate 17, fig. 1.

Comments: The fusion of the distal verrucae and the pitted appearance of the equatorial margin distinguishes this species from other species of *Lycopodiacidites*.

Occurrence: Rare to common; sample frequency infrequent; not restricted to any zone.

Lycopodiacidites cristatus Couper (44)

Plate 16, Figure 6

Lycopodiacidites cristatus Couper, 1953, New Zealand Geol. Surv., Paleont. Bull. 22, pp. 26, 27, pl. 1, fig. 10.

Occurrence: Rare to occasional; sample frequency infrequent. *Lycopodiacidites cristatus* was first reported by Couper (1953) from the Jurassic of New Zealand.

Lycopodiacidites intraverrucatus, new species (45)

Plate 17, Figure 3

Description: Trilete spore; laesurae reaching the inner margin of a darkened equatorial rim, commissure bordered by a wide lip 1.5–3.5 μ wide; outline in polar view circular to subtriangular.

Exine smooth on the proximal side; distal side contains large vermicular rugulae that branch and fuse with each other forming an irregular reticulum. The bottom of the rugulae have a highly irregular surface and project into the spore body (space between the proximal and distal exine) as verrucae and tubercles.

Dimensions: Maximum diameter 36(43)46 μ (10 specimens).

Holotype: Slide St. 26A, coordinates 20.8–125.9, plate 17, fig. 3.

Comments: This species differs from most species of *Lycopodiacidites* in this study by its large, winding, distal verrucae, its equatorial band, and circular shape; *Lycopodiacidites triangularus* is similar but more triangular in outline, and does not have as many rugulae on the distal surface.

Occurrence: Rare to abundant in some samples; sample frequency moderate; not restricted to any zone.

Lycopodiacidites irregularis, new species (46)

Plate 17, Figures 4, 5

Description: Trilete spore; laesurae usually reaching the margin, commissure bordered by a narrow margo ca. 0.5 μ wide; outline in polar view variable, from triangular with straight sides to subcircular.

Proximal surface usually smooth, although occasionally the distal elements extend slightly onto it; distal surface crowded with numerous gemmae 1–4 μ in diameter. In many grains the gemmae are so crowded that they lie on top of one another; minor elements may be tubercles, verrucae, and bacula; exine excluding sculptural elements 1–1.5 μ thick.

Dimensions: Maximum diameter 30(39)49 μ (12 specimens).

Holotype: Slide St. 43A, coordinates 21.7–108; plate 17, fig. 4.

Comments: The most diagnostic feature of this species is the distal gemmae and the accretionary manner of their emplacement on the grain.

Occurrence: Rare to occasional; sample frequency low in the subsurface samples, high in the surface samples; it appears restricted to Zone II.

Lycopodiacidites tortus, new species (47)

Plate 18, Figure 1

Description: Trilete spore; laesurae reaching the spore margin, commissure bordered by a narrow lip ca. 1 μ wide.

Exine, excluding sculptural elements, ca.1.5 μ thick, covered with numerous closely spaced, blade-like and spinose processes that diminish in number around the proximal pole. The elements are drooped, twisted, and frequently fused at their tips; they are ca. 10 μ in height, 2 μ wide, and 1 μ thick.

Dimensions: Maximum diameter 27–36 μ (2 specimens).

Holotype: Slide St. 49B, coordinates 30.6–125; plate 18, fig. 1.

Comments: This very rare form is characterized by its long, twisted, bladelike processes; these processes are longer than any other sculptural elements on the species assigned to this genus.

Occurrence: Rare, found in sample St. 49 in Zone I and St. 43 in Zone II.

Lycopodiacidites triangularus, new species (48)

Plate 17, Figure 6

Description: Trilete spore, laesurae simple, reaching the inner margin of the darkened equatorial band; outline in polar view triangular with convex sides and well rounded corners.

Exine ca. 1 μ thick, smooth on the proximal side; distal side covered with irregular thickenings ranging from verrucae ca. 5 μ long to long twisting rugulae which may fuse into a thickened mass at the distal pole.

Dimensions: Maximum diameter 36(42)47 μ (8 specimens).

Holotype: Slide D-730A, coordinates 40.6–111.4; plate 17, fig. 6.

Comments: Lycopodiacidites triangularus differs from *L. intraverrucatus* by its more triangular shape and the lesser development of the distal rugulae; it also does not have the well developed margo of *L. intraverrucatus.*

Occurrence: Rare; sample frequency moderate, not restricted to any zone.

Genus Microreticulatisporites (Knox) Potonié and Kremp, 1954

Microreticulatisporites crassiexinous, new species (54)

Plate 18, Figure 2

Description: Trilete spore, laesurae may not develop, $\frac{3}{4}$ to full radius when present; outline in polar view circular to subtriangular.

Exine ca. 4.5 μ thick, foveoreticulate (muri approximately the same width as lumina); fovea circular ca. 1.5 μ in diameter, 1.5–2.5 μ apart. The pits are wider at the surface, tapering downward to about 1 μ.

Dimensions: Maximum diameter 50(67)72 μ (12 specimens).

Holotype: Slide St. 16A, coordinates 42–123.4; plate 18, fig. 2.

Comments: Microreticulatisporites crassiexinous differs from *Foveotriletes subtriangularis* by its larger size, thicker exine, and more circular outline. The thick pitted exine of *M. crassiexinous* superficially resembles the outline of *Lycopodiacidites ambifoveolatus*, but the latter is actually verrucate.

Occurrence: Rare; sample frequency moderate, not restricted to any zone.

Genus Neoraistrickia Potonié, 1956

Neoraistrickia robusta, new species (55)

Plate 19, Figure 2

Description: Trilete spore, laesurae simple, $\frac{3}{4}$ radius; outline in polar view triangular with straight to slightly convex sides.

Exine two-layered; endexine thin, ca. 1 μ thick; ektexine ca. 1.5 μ thick between sculptural elements, ornamentation consists of large and uniformly spaced bacula 4–10 μ long; width of bacula approximately equal to length, broadening slightly at their flat, distal ends. In cross section, the shape of the sculptural elements are highly variable, ranging from circular to elliptical, and frequently triangular. The distal bacula are closer together and frequently joined at their distal ends.

Dimensions: Maximum diameter 59(62)69 μ (8 specimens).

Holotype: Slide L1-41B, coordinates 29.8–114; plate 19, fig. 2.

Comments: This species is easily recognized by its distinctive sculptural elements; there is no other spore in the Potomac Group that resembles it.

Occurrence: Rare; sample frequency high, restricted to Subzone B of Zone II.

Genus Perotriletes (Erdtman) ex Couper, 1953

Perotriletes pannuceus, new species (56)

Plate 18, Figure 3; Plate 19, Figure 1

Description: Trilete spore; laesurae $\frac{1}{2}$–$\frac{3}{4}$ radius, difficult to see in most specimens because of a perine which envelopes the whole grain; outline in polar view circular to subtriangular.

Exine of central body smooth, 2.5–4 μ thick; a perine completely envelopes the central body, passes over the laesurae and extends 5–8 μ beyond the central body as observed in optical section; it is a highly wrinkled, invaginated, and transparent layer.

Dimensions: Maximum diameter of the central body 36(48)59 μ (12 specimens).

Holotype: Slide St. 17A, coordinates 42–112.5; plate 18, fig. 3.

Comments: This species is easily recognized by its strongly wrinkled perine that encloses the whole grain.

Occurrence: Rare, sample frequency low; restricted to Zone II.

Perotriletes striatus Cookson and Dettmann (57)

Plate 19, Figure 3; Plate 20, Figure 1

Perotriletes striatus Cookson and Dettmann, 1958, Micropaleontology, vol. 4, no. 1, pp. 43, 44, pl. 1, figs. 8, 9.

Comments: The trilete mark is not seen in most specimens of this form, as it is situated at the apex of the grain where the perine obscures it; in an oblique specimen on Plate 19, Figure 3, the laesurae is clearly visible. The perine is transparent and frequently strongly wrinkled; the exine is characteristically scabrate.

Occurrence: Rare; sample frequency high in Zone I, infrequent in Zone II.

Perotriletes striatus was previously reported from Albian deposits in Eastern Australia; however, in the Potomac Group it is more commonly found in beds considered Neocomian-Aptian.

Genus Pilosisporites Delcourt and Sprumont, 1955

Pilosisporites brevipapillosus Couper (58)

Plate 20, Figure 2

Pilosisporites brevipapillosus Couper, 1958, Paleontographica, Abt. B 103, p. 144, pl. 22, figs. 11, 12.

Occurrence: Rare to occasional in L1-47; sample frequency infrequent; found in Subzone B.

This species has been previously reported from the Middle Jurassic of England by Couper (1958).

Pilosisporites trichopapillosus (Thiergart) Delcourt and Sprumont (59)

Plate 20, Figure 3

Sporites trichopapillosus Thiergart, 1949, Paleontographica, Abt. B 89, p. 22, pls. 4, 5, fig. 18.

Pilosisporites trichopapillosus (Thiergart) Delcourt and Sprumont, 1955, Mém. Soc. Belge Géol. de Paleont. Sér. in 4, no. 5, p. 34, pl. 3, fig. 3.

Comments: The distribution of spines is highly variable in this species; they are more closely spaced in the apical areas than in the contact area, developing inward towards the proximal pole along the borders of the commissure. In some specimens the spines completely cover the exine and no concentration is found in the apical areas.

Occurrence: Rare to occasional; sample frequency moderate; not restricted to any zone.

This species is a very common Lower Cretaceous form. It was first reported from the Wealden of the Hannover district, Germany by Thiergart (1949). Subsequently it was described from the Wealden of Belgium by Delcourt and Sprumont (1955), and from the Purbeck and Wealden of England by Couper (1958).

Genus Psilatriletes (Van der Hammen, 1954) ex Potonié, 1956

Psilatriletes circumundulatus, new species (60)

Plate 20, Figures 4, 5

Description: Trilete spore; laesurae $\frac{3}{4}$ to full radius, commissure bordered by a narrow lip ca. 1 μ wide; outline in polar view triangular with convex sides and acute to fairly rounded corners.

Exine two-layered, ca. 2 μ thick; endexine and ektexine approximately of equal thickness. The endexine is smooth and rigid; the ektexine characteristically separates from the endexine and develops radial folds on both surfaces; the folds make the margin of the spore appear undulate.

Dimensions: Maximum diameter 28(34)41 μ (13 specimens).

Holotype: Slide L1-22B, coordinates 25.2–121.8; plate 20, fig. 4.

Comments: The radial folds and undulate margin are diagnostic properties of *Psilatriletes circumundulatus*; it is smaller in size and has more strongly developed folds than *Psilatriletes radiatus.*

Occurrence: Rare to occasional; sample frequency moderate, not restricted to any zone but more frequently found in samples from Zone II.

Psilatriletes radiatus, new species (61)

Plate 20, Figures 6, 7

Description: Trilete spore; laesurae simple, reaching margin; outline in polar view triangular with convex sides and usually acute corners.

Exine smooth, ca. 1.5 μ thick; exine along the margin of the proximal surface thrown into fine, closely spaced radiating folds; folds may be difficult to see on some specimens.

Dimensions: Maximum diameter 45(46)54 μ (10 specimens).

Holotype: Slide St. 11B, coordinates 35.5–123.4; plate 20, fig. 7.

Comments: The fine, radiating folds on the proximal margin of the exine and the triangular to convex shape with acute corners are diagnostic features of this species. It is similar to *P. circumundulatus*, but is larger and has finer radial folds and a more entire margin.

Occurrence: Rare to occasional in a few samples; sample frequency moderate; not restricted to any zone, but more frequently encountered in samples from Zone II.

Genus Reticulatisporites (Ibrahim) S.W. and B., 1944

Reticulatisporites arcuatus, new species (62)

Plate 21, Figures 2, 3

Description: Trilete spore; laesurae simple, weakly developed or obscured by the ornamentation in most specimens; outline circular.

Exine ornamented by high, narrow muri 3–14 μ high, averaging 8 μ, 1–8 μ wide; muri form an irregular reticulum with muri and lumina of variable size and shape; lumina characteristically circular to arcuate; exine, excluding muri, 1–2 μ thick.

Dimensions: Maximum diameter 32(52)61 μ (8 specimens).

Holotype: Slide L1-22B, coordinates 33.3–109.4; plate 21, fig. 2.

Comments: This species is characterized by the high and narrow muri which form a highly irregular reticulum.

Occurrence: Occasional to rare; sample frequency high in Subzone B-2, rare in Subzone B-1. This species has not been found below Subzone B of Zone II.

Genus Taurocusporites Stover, 1962

Taurocusporites reduncus (Bolkhovitina) Stover (64)

Plate 20, Figure 8; Plate 21, Figure 1

Chomotriletes reduncus Bolkhovitina, 1953, Trans. Inst. Geol. Sci., Acad. Sci. U.S.S.R., ed. 145, Geol. Ser. no. 61, p. 35, pl. 3, figs. 23, 24.

Taurocusporites reduncus (Bolkhovitina) Stover, 1962, Micropaleontology, vol. 8, no. 1, p. 57, pl. 1, figs. 15–21.

Occurrence: Rare to common; sample frequency high, not restricted to any zone.

This species has previously been reported from Aptian to Senonian deposits of Western Kazakhstan and the Middle Jurassic of the Yakutiya region, U.S.S.R. by Bolkhovitina (1953).

Taurocusporites segmentatus Stover (65)

Plate 22, Figure 1

Taurocusporites segmentatus Stover, 1962, Micropaleontology, vol 8, no. 1, p. 56, pl. 1, figs. 1–14, text-fig. 1.

Occurrence: Rare to occasional; sample frequency moderate, not restricted to any zone, but more common in Zone II.

This species was previously reported from the Lower Cretaceous of Maryland by Stover (1962). It has also been found in middle Albian deposits of Western Canada by Pocock (personal communication).

Taurocusporites spackmani, new species (66)

Plate 22, Figures 2, 3

Description: Trilete spore; laesurae reaching the margin, commissure may be bordered by a lip 3–5 μ wide, tapering towards the margin; outline in polar view triangular with slightly convex sides, corners acute to blunted.

The exine is ornamented on the distal side by a ring-like thickening surrounding a centrally located tubercle; proximal side smooth except for 3–10 marginal tubercles 6–8 μ wide, 12–16 μ apart; the central tubercle is usually slightly larger than the proximal tubercles; width of the distal ring 6–8 μ wide; exine, excluding the sculptural elements, 1.5–4 μ thick.

Dimensions: Maximum diameter 38(45)54 μ (11 specimens).

Holotype: Slide L2-61A, coordinates 29.1–109.1; plate 22, fig. 2.

Comments: The distal ring and central tubercles make this species very easy to recognize in almost all orientations. It differs from *Taurocusporites* *reduncus* and *T. segmentatus* by the presence of tubercles on the proximal margin and in the center of the distal side.

Occurrence: Rare to occasional; sample frequency high; restricted to Subzone B of Zone II.

Genus Trilites (Cookson, 1947) ex Couper, 1953

Trilites verrucatus Couper (68)

Plate 22, Figure 4

Trilites verrucatus Couper, 1953, New Zealand Geol. Surv. Paleont. Bull. 22, p. 31, pl. 3, figs. 26, 27.

Occurrence: Rare to occasional; sample frequency low; not restricted to any zone.

Trilites verrucatus was first described by Couper (1953) from Jurassic and Lower Cretaceous beds of New Zealand. It has also been reported by Lantz (1958a) from the Purbeckian of the Island of Oléron. Similar spores have been described as *Dicksonia densa* by Bolkhovitina (1953) from the lower and middle Albian of Western Kazakhstan.

Genus Trilobosporites (Pant, 1954) ex Potonié, 1956

Trilobosporites apibaculatus, new species (69)

Plate 22, Figure 5; Plate 23, Figure 1

Description: Trilete spore; laesure $\frac{1}{2}$–$\frac{3}{4}$, commissure bordered by a lip 2–5 μ wide; outline in polar view triangular with strongly concave sides and well rounded corners.

Exine 1–2 μ thick, slightly thicker halfway between the corners; exine smooth to granular except in the apical areas which bear on both surfaces bacula; bacula approximately three times as long as they are wide, ca. 2.2–6.3 μ long, 2–5 μ apart. On some specimens the bacula develop on or along the margo.

Dimensions: Maximum diameter, excluding bacula, 40(45)53 μ, (8 specimens).

Holotype: Slide St. 10B, coordinates 30.7–126; plate 23, fig. 1.

Comments: Trilobosporites apibaculatus differs from *Trilobosporites marylandensis* and *T. humilis* by the presence of large apical bacula.

Occurrence: Rare; sample frequency infrequent, found in 3 samples, St. 10, St. 16, and L1-69.

Trilobosporites crassus, new species (70)

Plate 23, Figure 2

Description: Trilete spore; laesurae $\frac{3}{4}$ radius; commissure bordered by a lip ca. 3 μ wide; outline in polar view triangular with slightly concave sides and well rounded corners.

Exine thick, 2.5–3.5 μ, variable along the margin; surface of the exine covered with low verrucae and rugulae, which are more strongly developed in the apical areas and distal side than on the rest of the spore body.

Dimensions: Maximum diameter 36(49)59 μ (6 specimens).

Holotype: Slide St. 30A, coordinates 40–108; plate 23, fig. 2.

Comments: The thicker exine and less concave sides on *Trilobosporites crassus* separate this species from other species of *Trilobosporites. T. humilis* is smaller and has finer ornamentation; *T. marylandensis* has smaller and more circular sculptural elements.

Occurrence: Rare; of high frequency in surface samples from Subzone B of Zone II; not found in subsurface samples; restricted to Subzone B.

Trilobosporites humilis Delcourt and Sprumont (71)

Plate 23, Figures 3, 4

Trilobosporites humilis Delcourt and Sprumont, 1959. Extrait des Annales de la Soc. Géol. du Nord T., vol. LXXIX, p. 42, pl. 3, fig. 6.

Comments: The evenly granular surface, triangular shape with more or less straight sides, and the thickened corners developing out of the extension of the margo distinguish this species from other species of *Trilobosporites* in this study; verrucae may develop on the distal side and the margo.

Occurrence: Rare; sample frequency low, not restricted to any zone, but more common in Zone II.

Trilobosporites marylandensis, new species (72)

Plate 23, Figure 5

Description: Trilete spore; laesurae $\frac{3}{4}$ radius, commissure bordered by a strip of densely packed grana 2–3 μ wide; outline in polar view triangular with concave sides and well-rounded corners.

Exine ornamented by grana ranging from 0.75–2 μ in diameter. The sculptural elements increase in size in the apical areas becoming tuberculate to verrucate; if the apical verrucae are crowded an irregular reticulum may develop; exine, excluding sculptural elements, ca. 1.2 μ thick.

Dimensions: Maximum diameter 33(45)54 μ (16 specimens).

Holotype: Slide St. 34A, coordinates 19.6–118.1; plate 23, fig. 5.

Comments: Similar forms have been previously described from Lower Cretaceous deposits; *Trilobosporites apiverrucatus*, described by Couper (1958 from the Wealden of England, is much larger than this species. In *Trilobosporites trioreticulatus* from the Aptian-Albian sediments of Eastern Australia (Cookson, and Dettman 1958) the apical verrucae form a distinct reticulum in the majority of specimens.

Occurrence: Rare to abundant; sample frequency high in Zone I from surface samples, infrequent in Zones I and II from subsurface samples.

Genus Undulatisporites Pflug in Thomson and Pflug, 1953

Undulatisporites undulapolus, new species (73)

Plate 24, Figure 1

Description: Trilete spore; laesurae reaching the margin, commissure bordered by a narrow lip ca. 1.5 μ wide; outline in polar view triangular with straight to slightly convex sides. The laesurae are strongly undulate for about $\frac{1}{3}$ the radius from the proximal pole; exine smooth, ca. 1.5–2 μ thick.

Dimensions: Maximum diameter 23(33)43 μ (3 specimens).

Holotype: Slide St. 11B, coordinates 29.5–112.7; plate 24, fig. 1.

Occurrence: Rare to occasional in L1-96; sample frequency infrequent, found in both Zones I and II.

Genus Inaperturopollenites Thomson and Pflug, 1953

Inaperturopollenites pseudoreticulatus, new species (74)

Plate 24, Figure 2

Description: Inaperturate sporomorphae; outline circular, exine two-layered: endexine 0.5–1 μ thick; ektexine consists of 4–6 sided, flat-topped elements approximately 3–6 μ across, 2–3.5 μ high, and 1 μ apart; canals between polygons form a negative reticulum.

Dimensions: Maximum dimension 20(28)40 μ (5 specimens).

Holotype: Slide L1-103A, coordinates 18.5–120.1, plate 24, fig. 2.

Occurrence: Rare; sample frequency moderate in Zone II, infrequent in Zone I.

Genus Reticulatasporites Ibrahim, 1933, emend. Potonié and Kremp, 1954

Reticulatasporites dupliexinous, new species (75)

Plate 24, Figures 3–5

Description: Inaperturate sporomorphae; circular to broadly oval in outline; exine composed of two layers; endexine smooth ca. 1 μ thick; ektexine broadly reticulate, finely wrinkled between the muri; muri wedge shaped, ca. 1–2 μ wide across the base; the size of the lumina are quite variable from specimen to specimen, 10–17 μ across, 5–6 sided. The muri are formed by both layers of the exine, the outer more translucent layer forming the lumina floor and muri, the endexine wedging up into the surface muri.

Dimensions: Maximum dimension 41(46)72 μ (8 specimens).

Holotype: Slide St. 17A, coordinates 27.2–121.7; plate 24, fig. 4.

Comments: The natural affinity of this form is not known; superficially it resembles certain dinoflagellates, but it does not have a longitudinal or equatorial furrow. In the Bryophyta, certain members of the *Codoniaceae* such as *Fossombronia* produce alete, broadly reticulate spores (Knox, 1939); the spores of *Fossombronia dumortieri* strongly resemble *Reticulatasporites dupliexinous*, but, of course, no identity is suggested.

Occurrence: Rare; sample frequency low; not restricted to any zone.

Genus Laevigatosporites Ibrahim, 1933

Laevigatosporites gracilis Wilson and Webster (76)

Plate 24, Figures 6–8

Laevigatosporites gracilis Wilson and Webster, 1946, Amer. Jour. Bot., vol. 33, no. 4, p. 273, fig. 4.

Description: Monolete spore; laesurae $\frac{1}{2}$–$\frac{3}{4}$ length of proximal face; outline in equatorial view reniform; exine smooth, 1–1.5 μ thick.

Dimensions: Maximum length 23(36)47 μ; polar axis 14(21)30 μ (20 specimens).

Comments: This form is very generalized, and other forms in the literature with the same name may not even have been produced by closely related plants.

Bilateral, monolete spores are, in living plants, produced primarily by members of the *Polypodiaceae.*

Occurrence: Abundant to rare; sample frequency high, not restricted to any zone.

Genus Monosulcites (Cookson) ex Couper, 1953

Monosulcites chaloneri, new species (77)

Plate 24, Figures 9–11

Description: Monosulcate (monolete?); laesurae $\frac{1}{2}$ to $\frac{3}{4}$ length, commissure may be bordered by a lip ca. 1 μ wide, outline in apertural view broadly elliptical to circular with well-rounded ends.

Exine two-layered; endexine smooth, ca. 1 μ thick; ektexine excluding verrucae, 0.5–1 μ thick, covered with closely spaced low verrucae 1.5–4 μ wide, ca. 1.5 μ above the general surface of the ektexine.

Dimensions: Maximum length 18(20)22 μ; width 14(17)22 μ (15 specimens).

Holotype: Slide St. 38B, coordinates 33.9–128.7, plate 24, fig. 9.

Occurrence: Abundant to rare; sample frequency high, restricted to Zone II.

Genus Peromonolites Couper, 1953

Peromonolites allenensis, new species (78)

Plate 24, Figures 12, 13

Description: Monolete spore; laesurae extending the full length of the grain; outline in polar view fusiform with acute ends formed by the extension of the perine.

Exine two-layered; inner layer smooth, ca. 1 μ thick; outer layer extremely wrinkled, 1.5–2 μ thick, forming a thin apertural ridge over the position of the laesurae.

Dimensions: Length 23(32)40 μ; width 15(17)23 μ (15 specimens).

Holotype: Slide St. 6A, coordinates 23–108; plate 24, fig. 13.

Comments: Peromonolites allenensis is easily distinguished from other monolete spores by the development of a highly wrinkled perine.

This perine looks very much like the perisporium found on the spores of living ferns belonging to the subfamilies *Asplenioideae* and *Blechnoideae.*

Occurrence: Usually a rare form, but locally it may be extremely abundant as in samples St. 6 and St. 10; it is not restricted to any particular zone but appears more often in samples from the upper part of Zone I and in Zone II.

Class Gymnospermae

Subclass Cycadophytae

Order Caytoniales

Family Caytoniaceae

Genus Vitreisporites Leschik, 1955

Vitreisporites pallidus (Reissinger) new combination (116)

Plate 25, Figures 1, 2

Pityosporites pallidus Reissinger, 1939, Paleontographica, Abt. B 84, p. 14 (not figured).

Pityopollenites pallidus (Reissinger) Reissinger, 1950, Paleontographica, Abt. B 90, p. 115, pl. 15, figs. 1–5.

Caytonipollenites pallidus (Reissinger) Couper, 1958, Paleontographica, Abt. B 103, p. 150, pl. 26, figs. 7, 8.

Comments: Small bisaccate grains identical to the forms found in this study have been found associated with the microsporophyll, *Caytonanthus*, originally described from Middle Jurassic deposits of the Yorkshire coast.

Leschik (1955) created the genus *Vitreisporites* for small bisaccate grains with a weak triradiate mark on the distal side. The figure of the type specimen shows no such triradiate mark. Until the type specimen is re-examined *Caytonipollenites* Couper, 1958 is regarded as a junior synonym of *Vitreisporites* Leschik, 1955.

Occurrence: Rare to occasional; sample frequency abundant, not restricted to any zone.

Cycadales-Bennettitales-Ginkgoales Complex

Genus Entylissa (Naumova) ex Potonié and Kremp

Entylissa nitidus Balme (82)

Plate 25, Figures 3, 4

Entylissa nitidus Balme, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, p. 30, pl. 6, figs. 78–80.

cf. *Monosulcites minimus*, Couper, 1958, (non Cookson, 1947) Paleontographica, Abt. B 103, p. 137, pl. 26, figs. 23–25.

Comments: Spores identical to *Entylissa nitidus* from the Jurassic and Lower Cretaceous of New Zealand (Balme, 1957) were found throughout the Potomac Group.

They are smooth, elliptical in polar view and monosulcate; the colpus has rounded and slightly expanded ends with sides that may overlap in the polar region. It differs from Cookson's (1947) *Monosulcites minimus* in that this species has a thicker exine (ca. 2 μ) than *E. nitidus*, and its sulcus is wider at the pole than at the ends.

Occurrence: Rare to occasional; sample frequency high, not restricted to any zone.

Genus Monosulcites (Cookson) ex Couper, 1953

Monosulcites epakros, new species (84)

Plate 25, Figures 5, 6

Description: Monosulcate pollen; furrow narrow, extending the length of the whole grain and not expanding at the ends; outline in polar view elliptical with sharply pointed ends.

Exine very thin, ca. 0.5 μ thick, easily wrinkling and forming secondary folds.

Dimensions: Length 26(33)45 μ; width 10(14)18 μ (11 specimens).

Holotype: Slide St. 16A, coordinates 40.4–108.6; plate 25, fig. 5.

Comments: This species differs from the other monosulcate grains in this study by its sharply pointed ends and wrinkled exine.

Occurrence: Rare to occasional; sample frequency infrequent in subsurface samples, abundant in surface samples, not restricted to any zone.

Monosulcites glottus, new species (85)

Plate 25, Figure 7

Description: Monosulcate sporomorphae; furrow narrow and straight, extending ¾ to full length of grain; outline in polar view somewhat rectangular; maximum width at poles.

Sides of grain characteristically folded over about ⅔ the distance to the furrow.

Dimensions: Length 14(17)18 μ; maximum width 9(12)13 μ (15 specimens).

Holotype: Slide St. 26A, coordinates 37.9–118.3; plate 25, fig. 7.

Comments: The small size, rectangular shape, and lateral folds distinguish this species from other monosulcate forms.

Occurrence: Rare; sample frequency infrequent, not restricted to any zone.

Monosulcites sp. (86)

Plate 25, Figure 8

Description: Monosulcate pollen; furrow narrow, extending the full length of the grain; central area of sulcus covered by flap-like extension of the exine; outline in polar view fusiform with acute ends; exine ca. 2 μ thick.

Dimensions: 61 × 18 μ, 58 × 22 μ (2 specimens).

Occurrence: Rare; sample frequency infrequent, found only in Zone II.

Subclass Coniferophytae

Order Coniferales

Family Araucariaceae

Genus Araucariacites (Cookson) ex Couper, 1953

Araucariacites australis Cookson (90)

Plate 25, Figures 9, 10

Araucariacites australis Cookson, 1947, B.A.N.Z., Antarctic Res. Exped. (1929–1931) Rep. A2(Geol.) pt. 8, p. 130, pl. 13, figs. 1–4.

Inaperturopollenites grandis Weyland and Krieger, 1953, Paleontographica, Abt. B 95, p. 14, pl. 4, fig. 25.

Comments: These spores are more or less circular in outline and have a faintly granular to microrugulate sculpture; the exine varies from 1–3 μ in thickness and is commonly thinner in the polar regions. Such grains are comparable to those produced by extant species of *Araucaria* and *Agathis*.

Occurrence: Abundant to rare; sample frequency infrequent in Zone I, high in Subzone B of Zone II.

There is an increase in the pollen of the *Araucariaceae* above Zone I.

In his comprehensive study of the Potomac megaflora, Berry (Clark, Bibbins, and Berry, 1911) lists the only remains attributable to the *Araucariaceae*: *Araucarites aquiensis* and *Araucarites patapscoensis*, in the Patapsco Formation; the increase in the Patapsco Formation (Zone II) of megafossils attributable to the *Araucariaceae* is also duplicated in the microflora, although, in the latter the generalized pollen types produced by this family have not as yet permitted the formation of more than one species.

Coniferae

Families of the Pinaceae-Podocarpaceae Complex

Genus Abietineaepollenites Potonié, 1951

Abietineaepollenites microreticulatus Groot and Penny (102)

Plate 26, Figures 1, 3

Abietineaepollenites microreticulatus Groot and Penny, 1960, Micropaleontology, vol. 6, no. 2, p. 231, pl. 1, fig. 8.

Comments: The total length of this form ranges from 48–117 μ with a mean of 88 μ; this compares favorably with the mean value, 95 μ, given for this species by Groot and Penny. The smaller forms may belong to another species, but they cannot, as yet, be separated out. The bladders are broadly attached to the body and do not form a re-entrant angle where they merge with it; in this respect this species is similar to the pollen of spruce.

The reticulate ornamentation of the bladders gradually merges with the microreticulate to microrugulate ornamentation of the proximal surface.

Occurrence: Rare to abundant; sample frequency high; not restricted to any zone. The specimen frequency of this species increases above Zone 1.

Abietineaepollenites minimus, new species (103)

Plate 26, Figure 2

Description: Bisaccate pollen; central body broadly oval to circular in lateral view; bladders distally disposed with the proximal attachment proximal from the equator; exine of the proximal cap is rugulate, ca. 1.5 μ thick; endexine smooth, exposed on the distal surface between the bladders, ca. 0.5 μ thick; bladders small in relation to central body, attached at their maximum height.

Dimensions: (5 specimens)

Body width	22(25)33 μ
Body height	18(21)24 μ
Bladder length	6–7 μ
Total length of grain	34(36)37 μ

Holotype: Slide L1-41A, coordinates 28.4–113.1; plate 26, fig. 2.

Comments: Abietineaepollenites minimus can be distinguished from other bisaccate pollen by its small size, small sacs in relation to the body, and rugulate proximal cap.

Occurrence: Rare; sample frequency infrequent, has been found only in Subzone B.

Abietineaepollenites sp. (104)

Plate 26, Figure 4; Plate 27, Figure 1

Description: Bisaccate pollen; central body circular to slightly elongate in polar view; bladders large, widely attached, length of bladder greater than width. The bladders are distally pendant, with the proximal roots just proximal to the equator.

Proximal cap microreticulate, ca. 2 μ thick; endexine smooth, ca. 0.5 μ thick; exposed on the distal side of the central body; bladder reticulum loose and often obscure, lumina 1.6–2 μ in the center of the proximal surface of the bladder.

Dimensions: (7 specimens)

Total length of the grain	48(61)72 μ
Body width	38(44)50 μ

Body length	ca. 38 μ
Bladder width	22(26)28 μ
Bladder length	33(41)45 μ

Occurrence: Rare to abundant; sample frequency high, not restricted to any zone.

Genus Alisporites Daugherty, 1941

Alisporites cf. bilateralis Rouse (105)

Plate 27, Figures 3, 4

Alisporites bilateralis Rouse, 1959, Micropaleontology, vol. 5, no. 3, p. 316, pl. 1, figs. 10, 11.

Comments: This species was first reported from the Kootenay of British Columbia by Rouse (1959). The type description gave the length of this form as ranging from 55–72 μ; the Potomac form ranges from 59–86 μ.

Alisporites bilateralis is characterized by the lateral disposition of the bladders, and the manner in which the outline of the bladders, in polar view, is confluent with the body outline. Couper (1958) described a similar type, *Pteruchipollenites thomasii*, from the Lias of England.

Occurrence: Rare to abundant; sample frequency high, not restricted to any zone.

Genus Parvisaccites Couper, 1958

Parvisaccites amplus, new species (106)

Plate 28, Figure 1; Plate 29, Figure 1

Description: Bisaccate pollen; central body broadly oval in polar view; bladders broadly attached, distally pendant. The length of the bladders are approximately two times the width.

Exine of the central body 2–4 μ thick on the proximal surface, thinning toward the distal surface between the bladders; sculpture of the proximal surface microreticulate, structure columellate. Exine of the bladders contain internal radially directed thickenings that form a poorly defined reticulum at the surface.

Dimensions: (6 specimens)

Total length of grain	103(110)117 μ
Body width	81(89)97 μ
Body length	81(87)97 μ
Body height	55–62 μ
Bladder width	25–30 μ
Bladder length	69(74)81 μ

Holotype: Slide St. 10A, coordinates 48.5–128.5; plate 28, fig. 1.

Comments: The large size of the grains and the presence of long, radially directed columellae distinguishes this form from other bisaccate grains found in this study.

Pollen of several species of the extant *Dacrydium* possess bladders with radially directed thickenings; this feature is also found in *Cedrus*.

Occurrence: Rare; sample frequency infrequent, found in two samples from Zone I.

Parvisaccites radiatus Couper (107)

Plate 27, Figure 2

Parvisaccites radiatus Couper, 1958, Paleontographica, Abt. B 103, p. 154, pl. 29, figs. 5–8.

Retibivesiculites parvus Pierce, 1961, Univ. of Minn., Minnesota Geol. Surv., Bull. 42, p. 38, pl. 2, figs. 51, 52.

Occurrence: Rare to occasional; sample frequency high; not restricted to any zone. Although not abundant in number of specimens, this species has been encountered in almost every sample from the Potomac Group; it was previously reported from the Wealden of England by Couper (1958) and the Cenomanian of Minnesota by Pierce (1961).

The spores of some species of *Dacrydium* are very similar to *Parvisaccites radiatus*.

Parvisaccites rugulatus, new species (108)

Plate 30, Figures 1, 2

Description: Bisaccate pollen; central body more or less circular in polar view; bladders attached on the distal side, bladder length much greater than width. Structure of the bladders consists of very fine, radially directed rods that form a microreticulate to scabrate ornamentation near the surface.

Exine of the central body rugulate, becoming characteristically corrugate between the bladders on the distal surface.

Dimensions: (3 specimens)

Diameter of the central body	50–60 μ
Bladder width	14–18 μ
Bladder length	40–44 μ

Holotype: Slide St. 49A, coordinates 39.1–115.7; plate 30, fig. 1.

Comments: This species is easily recognized by its corrugate exine between the bladders.

Occurrence: Rare; sample frequency infrequent, not restricted to any zone.

Genus Phyllocladidites (Cookson, 1947) ex Couper, 1953

Phyllocladidites microreticulatus, new species (109)

Plate 30, Figure 3; Plate 31, Figure 1

Description: Bisaccate pollen, central body circular to broadly elliptical in polar view; bladders rudimentary, not inflated, strongly undulate, and frequently encircling the distal surface by fusing with one another.

Surface of the bladders characteristically scabrate to microreticulate; body ornamentation scabrate; exine of the central body ca. 2 μ thick.

Dimensions: (5 grains)

Body width	34(50)58 μ
Body length	39(43)46 μ
Body height	30–34 μ
Bladder width	4–6 μ
Bladder length	31–35 μ
Bladder height	ca. 18 μ

Holotype: Slide L1-22A, coordinates 32.3–115.9; plate 30, fig. 3.

Comments: The scabrate body sculpture and veil-like rudimentary bladders are diagnostic features of this species.

Although no tubercles are present, the rudimentary veil-like nature of the bladders is highly suggestive of the pollen of *Phyllocladus*, and, in particular, *P. hypophyllus* as figured by Erdtman, 1943 (p. 133, pl. 22, fig. 416).

Occurrence: Rare to occasional; sample frequency high, not restricted to any zone.

Genus Pinuspollenites Raatz, 1937

Pinuspollenites spherisaccus, new species (110)

Plate 31, Figures 2, 3

Description: Bisaccate pollen; central body elliptical in lateral view; exine of the central body scabrate to microreticulate, except for a smooth area on the distal surface between the bladders; bladders of the diploxylon type, more than a hemisphere in lateral view, distally pendant; infrareticulum of the bladders ca. 1.5 μ across; a distinct re-entrant angle is formed where the proximal roots of the bladders merge with the central body.

Dimensions: (7 specimens)

Total length of grain	48(56)64 μ
Body width	29(40)46 μ
Body height	19(24)38 μ
Bladder width	12(18)23 μ
Bladder length	15(21)26 μ

Holotype: Slide L2-58B, coordinates 31–107.8; plate 31, fig. 3.

Comments: The small size of the bladders in relation to the central body and the narrow width of bladder attachment are features of the genus *Pinuspollenites*.

A similar bladder to body relationship is found in the pollen of *Abies*.

Occurrence: Rare; sample frequency moderate to high in Subzone B, found only in Subzone B of Zone I.

Genus Platysaccus (Naumova, 1937) ex Potonié and Klaus, 1954

Platysaccus megasaccus, new species (111)

Plate 31, Figure 4

Description: Bisaccate pollen; central body circular to broadly elliptical in polar view, body length usually greater than body width; exine of the central body scabrate.

Bladders very large, each bladder larger than the central body and attached to it on the distal side near the polar axis. The bladders completely cover the central body when viewed down the distal pole and are in contact with each other, except for a narrow furrow and an indentation along the margin; infrareticulum 2–2.5 μ across, muri ca. 0.5 μ wide.

Dimensions: (6 specimens)

Total length of the grain	80(100)125 μ
Body width	27(40)47 μ
Body length	27(49)68 μ
Bladder width	40(48)63 μ
Bladder length	54(71)93 μ

Holotype: Slide L2-49A, coordinates 22.8–111; plate 31, fig. 4.

Comments: The large bladders that completely cover the body in distal view make this form readily identifiable.

Occurrence: Rare; sample frequency low, not restricted to any zone.

Genus Podocarpidites (Cookson, 1947) ex Couper, 1953

Podocarpidites epistratus, new species (112)

Plate 31, Figure 5

Description: Bisaccate pollen; central body more or less circular in polar view; proximal surface scabrate to microrugulate, distal surface smooth; exine of the central body ca. 1 μ thick.

Bladders broadly attached on the distal side; the attachment is primarily parallel to the length of the bladders; the width being quite narrow.

Infrareticulum of the bladders indistinct, muri radially aligned near the region of attachment to the body.

Dimensions: (8 specimens)

Maximum diameter of the body	25(28)35 μ
Bladder width	10(14)20 μ
Bladder length	26(28)32 μ

Holotype. Slide L1-69A, coordinates 23–124.5; plate 31, fig. 5.

Comments: This form is characterized by its circular, scabrate body, broad bladders with an indistinct infrareticulum, and radially aligned muri in the region where the bladders merge with the body.

The broad bladders with radial muri at their roots is a feature common to the pollen of some species of *Podocarpus*.

Occurrence: Rare to occasional in a few samples; sample frequency high, restricted to subzone B in Zone II.

Podocarpidites potomacensis, new species (113)

Plate 32, Figures 1, 2

Description: Bisaccate pollen; central body elliptical in polar view, with the longest dimension parallel to the length of the bladders; body width approximately equals bladder width. A marginal crest 5–8 μ wide rims the proximal cap, its greatest width is where the proximal roots of the bladder merge with the central body; exine of the proximal side scabrate; distal exine forms a smooth area 4–9 μ wide between the bladders.

Bladders reniform, length approximately 1.5 times the width, broadly attached on the distal surface; infrareticulum coarse, muri ca. 0.5 μ wide, lumina 2.5–4 μ across.

Dimensions: (10 specimens)

Total length of the grain	46(64)88 μ
Body width	27(33)37 μ
Body length	35(37)40 μ
Bladder width	28(32)38 μ
Bladder length	36(40)54 μ

Holotype: Slide L1-50A, coordinates 26.1–111.8; plate 32, fig. 1.

Comments: Podocarpidites potomacensis differs from *P. radiatus* by its lack of radial thickenings in the bladder and by the presence of a marginal crest. Superficially it resembles *Abietineaepollenites sp.* but this species has wider sacs and does not have a marginal crest.

Podocarpidites biformis from the Upper Cretaceous of Western Canada (Rouse, 1957) is a larger form and has a wider and more fully developed marginal crest.

Occurrence: Rare to occasional in a few samples; sample frequency moderate, not restricted to any zone.

Podocarpidites radiatus, new species (114)

Plate 32, Figures 3, 4

Description: Bisaccate pollen; central body more or less circular in polar view; exine 3–6 μ thick, proximal surface scabrate, distal surface between the bladders smooth.

Bladder large, widely attached on the distal side, bladder length approximately 1.5 times the width; infrareticulum distinct, lumina 1.5–2 μ across, muri ca. 0.5 μ wide. Near the inner one-third of the bladder the reticulum breaks up and the muri are radially directed.

Dimensions: (10 specimens)

Total length of grain	57(67)85 μ
Body width	26(34)40 μ
Bladder width	28(30)33 μ
Bladder length	38(44)48 μ

Holotype: Slide St. 10B, coordinates 27.5–114.8; plate 32, fig. 3.

Comments: Podocarpidites radiatus is distinguished from other bisaccates in this study by its strongly pronounced radial thickening on the bladders.

The broad bladders and radial thickenings are common features in some of the pollen of the *Podocarpaceae* such as *Podocarpus wallinchiansus* and *Podocarpus minor.*

Occurrence: Rare; sample frequency moderate, more frequent in the surface samples, not restricted to any zone.

Genus Rugubivesiculites Pierce, 1961

Rugubivesiculites reductus Pierce (115)

Plate 33, Figures 1, 2

Rugubivesiculites reductus Pierce, 1961, Univ. of Minn., Minnesota Geol. Surv., Bull. 42, p. 41, pl. 2, figs. 64, 65.

Comments: Because of its unique morphology this species, although not abundant, is an important horizon marker. The highly corrugated nature of the proximal cap is a distinguishing feature of this form. The corrugations increase in size towards the margin of the cap; the bladders are longer than wide, as is common in the pollen of the *Podocarpaceae.*

Occurrence: Rare to occasional; sample frequency high in Subzone B-2; restricted in the Potomac Group to Subzone B-2 of Zone II.

This form was first reported by Pierce (1961) from the Cenomanian of Minnesota. It first occurs in the upper Patapsco Formation (B-2) and becomes more abundant in the lower Raritan (personally observed), which is *Cenomanian.*

Genus Tsugaepollenites Potonié and Venitz, 1934

Tsugaepollenites mesozoicus Couper (94)

Plate 34, Figure 1

Tsugaepollenites mesozoicus Couper, 1958, Paleontographica, Abt. B 103, pp. 155, 156, pl. 30, figs. 8–10.

Description: Inaperturate pollen; circular to broadly elliptical in polar view. Exine two-layered; endexine ca. 0.75 μ thick, scabrate, exposed on the distal side; ektexine cavate, thrown into a densely rugulate to verrucate surface which forms a velum in the equatorial region. On the distal surface the ektexine is absent; this area is analogous to the distal sulcus of bisaccate grains; the distal side is commonly collapsed inwardly towards the proximal pole.

Dimensions: Maximum diameter 40(47)54 μ (4 specimens).

Occurrence: Rare; sample frequency infrequent, found only in samples from Zone II.

Coniferales-Incertae Sedis

Genus Circulina (Maljawkina, 1949) ex Klaus, 1960

Circulina parva, new species (99)

Plate 34, Figures 2, 3

Description: Monoporate pollen; laesurae in the form of a triangular opening on the proximal side. At the distal pole is a thin, circular area 3–6 μ wide. The grain is divided into two unequal hemispheres by a furrow encircling the smaller distal side; outline in polar view circular to broadly oval.

The exine is smooth and does not have the columellate structure so typical of *Classopollis*; the thickness of the exine at the equator is ca. 1.5 μ. On some specimens there may be faint suggestions of equatorial bands subtending the furrow.

Dimensions: Maximum diameter 13(19)23 μ (15 specimens).

Holotype: Slide St. 17B, coordinates 29.8–110; plate 34, fig. 3.

Comments: The small size and smooth exine distinguishes this species from *Classopollis torosus.*

Occurrence: Rare; sample frequency moderate, not restricted to any zone.

Genus Classopollis Pflug, 1953, emend. Couper, 1958

Classopollis torosus (Reissinger) Couper (100)

Plate 34, Figures 4–6

Pollenites torosus Reissinger, 1950, Paleontographica, Abt. B 90, p. 114, pl. 14, fig. 20.

Classopollis classoides Pflug, 1953, Paleontographica Abt. B 95, p. 91, pl. 16, figs. 20–25, 29–37.

Classopollis torosus (Reissinger) Couper, 1958, Paleontographica, Abt. B 103, pp. 156, 157, pl. 28, figs. 2–7.

Comments: The identity of *Pollenites reclusus* Thiergart, *Pollenites torosus* Reissinger and *Classopollis classoides* Pflug is still in doubt. The holotype of *Pollenites torosus* is lost and the type material has not been critically restudied. Until this problem is resolved, the writer is following Couper's (1958) selection of *Pollenites torosus* as the genotype of *Classopollis* and considering it conspecific with Pflug's species *Classopollis classoides.*

It is now known that *Classopollis* was produced by a group of Jurassic and Cretaceous conifers, such as *Brachyphyllum*, *Pagiophyllum*, and *Cheirolepis*. The pollen described by Hörhammer (1933) from the male cones of *Cheirolepis munsteri* Schimper are identical to *Classopollis*.

Occurrence: Abundant; sample frequency high, found in all samples examined from the Potomac Group.

Genus Decussosporites, new genus

Description: Monosulcate pollen; furrow long; outline in polar view elliptical; exine infragranular to infrareticulate. On the proximal side a furrow, perpendicular to the distal furrow, extends across the grain, passing through the position of the proximal pole; this furrow does not extend onto the distal surface.

Genotype: *Decussosporities microreticulatus*, new species

Decussosporites microreticulatus, new species (81)

Plate 34, Figures 7–9

Description: Monosulcate pollen; furrow almost the length of the grain and completely enclosed by a thickened rim 2.5–3.5 μ wide; furrow ca. 0.5 μ wide at the distal pole, widening greatly at either end. The proximal side has a furrow extending across the whole grain perpendicular to the distal furrow; width of the proximal furrow uniform, 0.5–1 μ wide. Outline in polar view elliptical with rounded ends, the contour of the ends may be interrupted by an outward extension of the margo bordering the distal sulcus. Exine infrareticulate to infrascabrate; lumina less than 1 μ across.

Dimensions: Maximum length 18(24)27 μ; width 11(15)18 μ (10 specimens).

Holotype: Slide St. 31A, coordinates 29.2–115.1; plate 34, fig. 7.

Comments: Several features suggest the gymnosperous affinity of this form. The large longitudinal furrow with widened ends are typical of the pollen of many Cycadophytes and the genus *Eucommiidites*; the infrareticulum is also a common feature of many conifer pollen.

Superficially this form resembles a dinoflagellate; however, the infrareticulum and the fact that the proximal furrow is not connected to the longitudinal furrow, as is the girdle of dinoflagellates, discourages such an interpretation.

Occurrence: Occasional to rare in most samples; sample frequency high, not restricted to any zone.

Genus Eucommiidites (Erdtman) Couper, 1958

Eucommiidites troedssonii Erdtman (83)

Plate 34, Figures 10–12; Plate 35, Figure 1

Tricolpites (*Eucommiidites*) *troedssonii* Erdtman, 1948, Geol. Fören I, Stockholm Förh, Bd. 70, p. 267, figs. 5–10, 13–15.

Protoquercus agdjakendensis Bolkhovitina, 1953, Trans. Inst. Geol. Sci. Acad. Sci. U.S.S.R., ed. 145, Geol. Ser. no. 61, p. 93, pl. 15, figs. 29–32.

Eucommiidites minor Groot and Penny, 1960 (non Hughes, 1961) Micropaleontology, vol. 6, no. 2, p. 234, pl. 2, fig. 14.

Psilatricolpites psilatus Pierce, 1961, Univ. of Minn., Minnesota Geol. Surv., Bull. 42, p. 49, pl. 3, figs. 98–99.

Description: Monosulcate pollen; sulcus extending almost the full length of the grain, 1–3.5 μ in width in the region of the distal pole, uniform for most of its length, ends widen and are rounded. The wide, round ends of the distal sulcus is not an invariable character of the species, and at least 10% of the grains do not possess either or both of these features.

The proximal side has two relatively narrow, lunate sulci near the equatorial margin, the curvature of the proximal sulci more or less approximating the curvature of the equatorial contour. The length of the proximal sulci extends to almost one half the circumference of the grain, and in some specimens the ends of the two sulci may come close enough to develop a zonisulcate condition. Outline in polar view broadly elliptical to nearly circular.

Exine smooth, 1–2.8 μ thick, averaging 1.5 μ in the intersulcate areas, becoming less than 0.5 μ thick in the sulci. Most grains are flattened in the equatorial plane; the proximal surface is usually flatter than the distal surface which tends to bulge outward in the area between the sulci. The fact that the large distal sulcus is so commonly found in a median position suggests that a section perpendicular to the distal sulcus and containing the polar axis was not circular but lens shaped; the sulci, therefore, are not radially distributed about the polar axis as in tricolpate pollen grains.

Dimensions: Maximum length 22(26)31 μ; maximum width 15(23)31 μ (20 specimens).

Comments: Eucommiidites minor was described by Groot and Penny from the Patapsco Formation at Hawkins Point, Maryland. From the description and dimensions given (length 25 μ) it does not seem to differ significantly from *E. troedssonii*. Sample St. 12 is from the same locality that *E. minor* was typified; an examination of the size distribution of the length of 50 specimens of *Eucommiidites* did not reveal any bimodal distribution that might separate out a smaller form. Hughes (1961a) reported *E. minor* from the Wealden of England (length 18–25 μ); this form does differ from *E. troedssonii* by its more circular outline and smaller size, and, therefore, should be renamed.

Hughes (1961a) provided evidence for the gymnospermous affinity of *Eucommiidites*. In the micropyle and pollen chamber of 3 lower Cretaceous seeds, he found several grains of *Eucommiidites delcourtii*. In a clay ball from the Patuxent of Virginia (St. 26), the writer found numerous seeds similar to those found by Hughes. Out of 20 seeds examined 12 contained *Eucommiidites troedssonii* in the micropylar tube of the pollen chamber. The association of

Eucommiidites with gymnosperous seeds in both the Wealden and the Patuxent Formation increases the probability that the physical association of these two organs is a natural and not a coincidental one.

Occurrence: Abundant to occasional in most samples; sample frequency high, not restricted to any zone.

Eucommiidites troedssonii was first reported by Erdtman (1948) from the Lias of Scania. It has since been recorded from numerous Jurassic and Lower Cretaceous deposits from all over the world. Its abundance seems to decline after the Albian, and in Central Europe it has not been found above the Campanian (Krutzsch, 1957).

Genus Exesipollenites Balme, 1957, emend. Brenner

Genotype: Exesipollenites tumulus Balme, 1957

Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, p. 39, pl. 11, figs. 123–125.

Type Locality: G.S. 1. Seismic Shot Hole A 32, 40 feet, Hill River-Jurien Bay area, Perth Basin Western Australia, Cockleshell Gully Sandstone, lower Jurassic.

Description: Outline in polar view circular to subtriangular; exine smooth to granular. Distal exine contains a differentially thickened, dark, circular to subtriangular area enclosing a thin, light, circular depression at the distal pole. The proximal surface does not usually show a dehiscence mark, although, in some specimens, a trilete mark is faintly developed.

Comments: This description is essentially the same as that of Balme's except for the discovery of a trilete mark on some specimens.

Exesipollenites tumulus Balme (97)

Plate 35, Figures 2–4

Exesipollenites tumulus Balme, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, p. 39, pl. 11, figs. 123–125.

Occurrence: Abundant to occasional in most samples; sample frequently high; not restricted to any zone.

This form was first described from the Lower Jurassic of Western Australia (Balme, 1957). A similar looking form was figured by Rouse (1959) from the Kootenay of Western Canada.

Genus Inaperturopollenites Thomson and Pflug, 1953

Inaperturopollenites dubius (Potonié and Venitz) Thomson and Pflug (91)

Plate 35, Figures 5, 6

Pollenites magnus dubius Potonié and Venitz, 1934, Arb. Inst. Paläobot. Petrogr. Brennsteine, vol. 5, p. 17, pl. 2, fig. 21.

Inaperturopollenites dubius (Potonié and Venitz) Thomson and Pflug, 1953, Paleontographica, Abt. B 94, p. 65, figs. 1–13.

Comments: These thin, smooth, and highly wrinkled circular to elliptical grains are quite common in the Potomac Group. Frequently the grains will split, remaining attached at one end.

This spore was probably produced by plants belonging to the *Cupressaceae-Taxodiaceae.*

Occurrence: Abundant to occasional in most samples; sample frequency high, not restricted to any zone.

Genus Laricoidites Potonié, Thomson and Thiergart, 1950

Laricoidites gigantus, new species (93)

Plate 36, Figures 1, 2

Description: Inaperturate pollen; outline broadly elliptical to subcircular depending on compression effects; exine smooth to faintly scabrate, relatively thin (2.5–3 μ thick) in proportion to the large size of the grain.

Dimensions: Maximum length—108(131)156 μ (10 specimens).

Holotype: Slide St. 12A, coordinates 32.2–120.5; plate 36, fig. 1.

Comments: Similar to the pollen produced by the extant conifer *Larix.* It is larger than *Laricoidites magnus.*

Occurrence: Rare; sample frequency infrequent, not restricted to any zone.

Laricoidites magnus (Potonié, 1931) Potonié, Thomson and Thiergart (92)

Plate 37, Figures 1, 2

Sporonites magnus Potonié, 1931, Zur Mikroskopie der Braunkohle, IV.-Z. Braunkohle, vol. 30, p. 556, fig. 6.

Laricoidites magnus (Potonié, 1931) Potonié, Thomson, and Thiergart, 1950, Geol. Jahrb. 65, p. 48.

Comments: Similar to the grains of Larix. This species is similar to *Laricoidites gigantus* but differs from it by its smaller size 58(72)88 μ long.

Occurrence: Rare to occasional; sample frequency moderate.

Genus Perinopollenites Couper, 1958

Perinopollenites elatoides Couper (98)

Plate 35, Figures 7, 8

Perinopollenites elatoides Couper, 1958, Paleontographica, Abt. B 103, p. 152, pl. 27, figs. 9–11.

Occurrence: Rare to occasional; sample frequency high, not restricted to any zone.

This species was previously reported from the Jurassic and Lower Cretaceous deposits of England by Couper (1958).

Genus Spheripollenites Couper, 1958

Spheripollenites perinatus, new species (101)

Plate 37, Figures 3–6

Description: Monoporate pollen; pore barely protruding beyond the contour of the grain; in some specimens a small ligula is present. Outline in polar view circular, in equatorial view circular to pear shaped if a ligula is developed.

Exine consists of two layers: a smooth endexine that contains the pore, ca. 0.75 μ thick; an outer, loosely fitting, wrinkled ektexine, ca. 0.5 μ thick that does not extend onto the distal pore bearing surface; the outer layer may be missing on some specimens.

Dimensions: Maximum diameter 14(16)20 μ; diameter of the grain excluding the ektexine 13(14)16 μ (15 specimens).

Holotype: Slide St. 31B, coordinates 30.4–130; plate 37, fig. 3.

Comments: The weak development of a ligula prevents this form from being included in such genera as *Cryptomeriapollenites* and *Sequoiapollenites.*

The pollen of some extant species of *Cryptomeria* and *Cunninghamia* resemble *Spheripollenites perinatus.*

Occurrence: Rare to occasional; sample frequency moderate, more abundant in Zone I.

Genus Zonalapollenites Pflug, 1953

Zonalapollenites dampieri Balme (95)

Plate 37, Figures 7, 8

Zonalapollenites dampieri Balme, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, p. 32, pl. 8, figs. 88, 89.

Comments: The radial folding of the bladder is quite variable in this species. In most specimens, the outer scabrate layer that forms the bladder has only a suggestion of radial folding. When the folding is intense the contact between the body and bladder is more apparent.

Occurrence: Rare to occasional in a few samples; sample frequency moderate, not restricted to any zone.

This species is a common form in the Jurassic of Australia (Balme, 1957) becoming less abundant in the Lower Cretaceous.

Zonalapollenites trilobatus Balme (96)

Plate 37, Figure 9

Zonalapollenites trilobatus Balme, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T.C. 25, p. 33, pl. 8, figs. 91, 92.

Occurrence: Rare; sample frequency infrequent, found in only 3 samples: St. 10, St. 16, and St. 38.

Zonalapollenites trilobatus was first reported by Balme (1957) from Upper

Jurassic to Aptian deposits of Western Australia. Lantz (1958b) described this species from the Middle Jurassic of Dorset, Great Britain. Its stratigraphic occurrence ranges from Middle Jurassic to Lower Cretaceous.

Order Gnetales

Family Ephedraceae

Genus Ephedripites Bolkhovitina, 1953

Ephedripites multicostatus, new species (87)

Plate 38, Figures 1, 2

Description: Polysulcate pollen; outline elliptical, length approximately twice maximum width; sculpture consists of numerous alternating ridges and furrows converging at the ends of the grain; ridges 18–24 in number, ca. 1–1.5 μ wide, 0.5 μ apart.

Dimensions: Length 22(32)47 μ: maximum width 16(18)20 μ (16 specimens).

Holotype: Slide St. 30A, coordinates 35.6–120.3; plate 38, fig. 2.

Comments: This species is distinguished from other species of *Ephedripites* by its more numerous, narrow, and closely spaced muri.

Occurrence: Rare to occasional in a few samples; sample frequency moderate, not restricted to any zone.

Ephedripites patapscoensis, new species (88)

Plate 38, Figures 4, 5

Description: Polysulcate pollen; outline broadly elliptical; sculpture consists of five narrow ridges 4–6 μ high, 3–5 μ wide at the base, 0.75–1 μ wide at the top, 3–4 μ apart. Muri fused at the ends of the grain, usually forming a knob-like structure. Exine smooth, less than 1 μ between ridges.

Dimensions: Length 31(47)60 μ; maximum width 24(25)26 μ (10 specimens).

Holotype: Slide L2-58A, coordinates 25.5–117; plate 38, fig. 5.

Comments: The five large and widely spaced muri make this form easily distinguishable from other species of *Ephedripites.*

Similar pollen is produced by *Ephedra*, although none of the numerous species of *Ephedra* described by Steeves and Barghoorn (1959) resemble *Ephedripites patapscoensis.*

Occurrence: Rare; sample frequency moderate, restricted to Subzone B of Zone II.

Ephedripites virginiaensis, new species (89)

Plate 38, Figure 3

Description: Polysulcate pollen; outline elliptical with narrow ends; sculpture consisting of 10–14 alternating ridges and furrows, the ridges converging at the ends of the grain; ridges 1.2–1.5 μ wide, ca. 1 μ high and 1–1.5 μ apart. At the ends, where the ridges merge, the exine forms a thickened area, 1.5–2.5 μ thick.

Dimensions: Length 30(41)52 μ; width 12(21)30 μ (10 specimens).

Holotype: Slide St. 26A, coordinates 39.8–109.1; plate 38, fig. 3.

Comments: Similar to the pollen of *Ephedra* from Group D of Steeves and Barghoorn (1959). This species differs from *E. multicostatus* by its less numerous muri and the presence of a thickened area at the ends.

Occurrence: Found only in sample St. 26.

Angiospermae-Incertae Sedis

Genus Retitricolpites (Van der Hammen) ex Pierce, 1961

Retitricolpites georgensis, new species (118)

Plate 38, Figures 6, 7

Description: Tricolpate pollen; shape subprolate to prolate; colpi long and narrow, extending almost to the poles; endexine ca. 0.5 μ thick, structureless; ektexine composed of closely spaced pila that form a reticulum. Pila ca. 1 μ high, necks 0.75–1.3 μ apart, capita touching; lumina 1–1.5 μ across in the mesocolpium, decreasing in size towards the poles to ca. 0.5 μ across.

Dimensions: Polar axis 18(26)36 μ; equatorial axis 17(22)28 μ, P/E 1.2(1.4)1.8 (10 specimens).

Holotype: Slide St. 29B, coordinates 22.2–116.5; plate 38, fig. 6.

Comments: Retitricolpites georgensis differs from a similar form *R. sphaeroides* described by Pierce from the Cenomanian of Minnesota (1961) by its larger size; *Retitricolpites virgeus* is oblate, while *Tricolpopollenites crassimurus* has a finer reticulum.

Occurrence: Rare to occasional in St. 29; sample frequency low, restricted to Zone II.

Retitricolpites geranioides (Couper, 1960) new combination (119)

Plate 38, Figure 8; Plate 39, Figure 1

Tricolpites geranioides Couper, 1960, New Zealand Geol. Surv., Paleont. Bull. 32, p. 66, pl. 11, figs. 5–8.

Description: Tricolpate pollen; shape prolate to oblate; colpi long and narrow extending almost to the poles. Endexine structureless 0.75–1 μ thick: ektexine 1.5–3.5 μ thick, composed of pila 1–1.6 μ apart, ca. 1 μ wide along the neck, caput extended laterally 1–2 μ and arranged end to end to form a distinct reticulum. The lateral extensions of the capita do not fuse, but remain distinct from each other so that the muri appear segmented when viewed from above. The lumina 4–6 sided, 2–3 μ across in the mesocolpium decreasing to 1–1.5 μ across in the polar regions.

Dimensions: Polar axis 22(48)65 μ; equatorial axis 18(30)40 μ (10 specimens).

Comments: The exine structure and ornamentation of this form is very much like that of the living *Geranium.*

Occurrence: Rare; sample frequency moderate, restricted to Zone II and found only in the surface samples.

This form was first reported from the Miocene deposits of New Zealand by Couper (1960).

Retitricolpites vermimurus, new species (120)

Plate 39, Figures 2, 3

Description: Tricolpate pollen; shape subprolate to oblate; endexine structureless, ca. 0.75 μ thick; ektexine composed of muri 1.5–2 μ high and ca. 0.75 μ wide, forming a loose and winding reticulum. Lumina highly variable in shape and frequently open; muri strongly curved and variably orientated, giving the surface a vermiculate appearance.

Dimensions: Polar axis 16(18)22 μ; equatorial axis 11(15)18 μ; P/E 1.1(1.2)1.4 (15 specimens).

Holotype: Slide St. 29A, coordinates 21.1–112.6; plate 39, fig. 3.

Comments: The small size and vermiculate reticulum distinguishes this species from other small tricolpates.

Occurrence: Common to rare; sample frequency moderate, restricted to Zone II.

Retitricolpites virgeus (Groot, Penny, and Groot) new combination (121)

Plate 39, Figures 4, 5

Tricolpopollenites virgeus Groot, Penny, and Groot, 1961, Paleontographica Abt. B 108, p. 133, pl. 26, figs. 16, 17.

Occurrence: Rare; sample frequency moderate, restricted to Subzone B of Zone II.

This species was first described from the Tuscaloosa formation by Groot, Penny, and Groot (1961). A similar form *Retitricolpites vulgaris* was reported from the Cenomanian of Minnesota by Pierce (1961).

Genus Tricolpopollenites Thomson and Pflug, 1953

Tricolpopollenites crassimurus Groot and Penny (122)

Plate 39, Figure 6

Tricolpopollenites crassimurus Groot and Penny, 1960, Micropaleontology, vol. 6, no. 2, p. 232, pl. 2, figs. 4, 5.

Comments: This form is similar in size to *Retitricolpites georgensis* but its reticulum is much finer. It resembles *Quercus aurita* Bolkhovitina, 1953, from the Albian of Western Kazakhstan; however, this form is scabrate not microreticulate.

Occurrence: Rare; sample frequency moderate, restricted to Zone II.

Tricolpopollenites micromunus Groot and Penny (123)

Plate 39, Figure 7; Plate 40, Figure 1

Tricolpopollenites micromunus Groot and Penny, 1960, Micropaleontology, vol. 6, no. 2, p. 232, pl. 2, figs. 6, 7.

Description: Tricolpate pollen; colpi long and narrow, almost reaching the poles; shape in equatorial view prolate.

Endexine ca. 0.5 μ thick, without structure; ektexine composed of closely spaced bacula ca. 1 μ high, 0.5–0.75 μ wide. At high focus a discontinuous scabrate pattern is seen; at a slightly lower plane of focus, the heads of the bacula touch forming a microreticulum; at a slightly lower level the pattern is again discontinuous; this probably is the level at the base of the bacula.

Dimensions: Polar axis 12(16)19 μ; equatorial axis 10(13)15 μ; P/E 1.1(1.3)1.5 (20 specimens).

Comments: These small, baculate, tricolpate grains are one of the first undoubted angiosperms to appear in the Potomac Group.

The pollen of the extant *Tetracentron sinense* (Pl. 40, figs. 3, 4), a very primitive dicotyledon from the Southern Hemisphere, closely resembles *Tricolpopollenites micromunus*. Bell (1956) placed the leaf species *Populus potomacensis* in the genus *Trochodendroides*. The extant genus *Trochodendron* and *Tetracentron* are very closely related.

Occurrence: Abundant to rare; sample frequency high, restricted to Zone II. One of the first undoubted angiosperms in the microflora of the Potomac Group.

Tricolpopollenites minutus, new species (124)

Plate 40, Figures 5, 6

Description: Tricolpate pollen; colpi long and narrow, extending almost to the poles; shape in equatorial view subprolate. Exine ca. 1 μ thick; structure baculate, sculpture microreticulate.

Dimensions: Polar axis 10(11)13 μ; equatorial axis 6(9)10 μ; P/E 1(1.2)1.5 (15 specimens).

Holotype: Slide St. 11A, coordinates 37.4–120.1; plate 40, fig. 5.

Comments: This species is characterized by its extremely small size and very fine reticulate sculpture; because of its small size, it can be easily missed when scanning.

Occurrence: Abundant to rare; sample frequency high, restricted to Zone II and more frequent in Subzone B.

Genus Liliacidites Couper, 1953

Liliacidites dividuus (Pierce), new combination (117)

Plate 40, Figures 7–10

Retimonocolpites dividuus Pierce, 1961, University of Minn., Minnesota Geol. Surv., Bull. 42, p. 47, pl. 3, fig. 87.

Comments: This species is characterized by the tendency of the outer retipilate ektexine to separate from the smooth endexine. The lumina are larger (greater than 1 μ) than those of *Clavatipollenites* and the furrow is more pronounced.

Occurrence: Rare to common in L2-65; sample frequency low, restricted to Zone II.

Spores and Pollen-Incertae Sedis

Genus Peromonolites Couper, 1953

Peromonolites peroreticulatus, new species (79)

Plate 41, Figures 1, 2

Description: Monosulcate sporomorphae; sulcus extending across the whole length of the grain; outline in polar view fusiform.

Exine of the central body smooth ca. 1 μ thick; perine composed of widely spaced pila, 1.5–2.5 μ high, 1 μ wide, 2.5–4 μ apart; capita connected by "bridges", the upper part of the pila forming a broad reticulum. Reticulum usually not interrupted at the position of the sulcus, but may be split at this position.

Dimensions: Length of central body 12(15)17 μ; maximum width of central body 19(11)12 μ (12 specimens).

Holotype: Slide St. 6A, coordinates 20 μ 128.5; plate 41, fig. 1.

Comments: Peromonolites peroreticulatus differs from *P. reticulatus* by its smaller size and larger reticulum.

Occurrence: Rare to occasional in a few samples; sample frequency moderate, not restricted to any zone.

Peromonolites reticulatus, new species (80)

Plate 41, Figures 3, 4

Description: Monosulcate sporomorphae; sulcus extending the whole length of the grain; outline in polar view fusiform.

Exine of central body smooth, ca. 1 μ thick; perine composed of widely spaced pila, 1.5–2 μ high, 0.75 μ wide along the neck, 1.5–2 μ apart. A reticulum is formed by the connection of the capita by "bridges" 1–2 μ long, and ca. 0.5 μ wide; lumina 3–6 sided, 1–2.5 μ across. The outer layer is considered a perisporium, because, in some specimens, it passes over the sulcus without an interruption. The perisporium has a tendency to rupture and separate from the central body in the region of the sulcus.

Dimensions: Length of central body 17(20)22 μ; width of central body 14(16)17 μ (10 specimens).

Holotype: Slide St. 10A, coordinates 41.5–115.5; plate 41, fig. 3.

Occurrence: Rare in most samples; sample frequency low, not restricted to any zone.

Genus Clavatipollenites Couper, 1958

Clavatipollenites hughesii Couper (125)

Plate 41, Figures 5–7

Clavatipollenites hughesii Couper, 1958, Paleontographica, Abt. B 103, pp. 159, 160, pl. 31, figs. 19–22.

Spheripollenites subgranulatus, Delcourt and Sprumont (non Couper), 1959, Extrait des Annales de la Soc. Géol. du Nord T, vol. 79, p. 47, pl. 6, fig. 25.

Comments: This species was first described by Couper (1958) from the Wealden and Aptian of England. It has also been found in the Upper Jurassic and Neocomian of Western Canada by Pocock (personal communications). Hughes (1958) states that *Clavatipollenites* enters various English sections near the Barremian-Aptian boundary along with a *Pyrobolospora* flora. Couper (1958) suggested that this species may be angiospermous. The evidence for this was the retipilate structure of the ektexine—a common character of angiosperm pollen. He compared the fossil form with the pollen of modern *Ascarina*. The writer feels that this type of exinal organization could have developed in some now extinct gymnosperm group. The exine of many types of gymnosperm pollen is columellate and frequently reticulate.

The double-layered exine with a retipilate ektexine is the outstanding feature of this species. The writer has observed that the sulcus is not always fully developed, and many specimens bear only a faint scar or no furrow at all.

Occurrence: Abundant to rare; sample frequency high, not restricted to any zone.

Clavatipollenites minutus, new species (126)

Plate 41, Figures 8, 9

Description: Monocolpate pollen; furrow extending the whole length of the grain; outline in polar view broadly elliptical to circular in a few specimens.

Exine two-layered; endexine structureless, ektexine retipilate, pila 0.5–1 μ high, capita forming a microreticulum.

Dimensions: Length 13(15)19 μ; width 9(11)14 μ (11 specimens).

Holotype: St. 12A, coordinates 23.5–111.5; plate 41, fig. 8.

Comments: Distinguished from *Clavatipollenites hughesii* by its smaller size.

Occurrence: Rare to occasional; sample frequency moderate, not restricted to any zone.

Genus Monosulcites (Cookson) ex Couper, 1958

Monosulcites scabrus, new species (127)

Plate 42, Figure 1

Description: Monocolpate pollen; furrow long, almost the full length of the grain, and bordered by a narrow lip ca. 1 μ wide; outline in polar view broadly elliptical with rounded ends.

Endexine structureless, 0.5–0.75 μ thick; ektexine scabrate with infragranular structure, ca. 1 μ thick.

Dimensions: Length 34(42)68 μ; width 28(38)43 μ (8 specimens).

Holotype: Slide L1-22B, coordinates 29–111.5, plate 42, fig. 1.

Comments: This species is smaller than a similar form, *Granamonocolpites asymmetricus* Pierce, 1961, from the Cenomanian of Minnesota.

Occurrence: Rare to occasional; sample frequency moderate, found only in Zone II.

Monosulcites spinosus, new species (128)

Plate 41, Figures 10–12

Description: Monosulcate sporomorphae; sulcus $\frac{3}{4}$ length of grain; outline in polar view broadly elliptical.

Exine ca. 1 μ thick, covered with long, widely spaced spines 4(5)8 μ long, 1–2 μ at their bases, 5–10 μ apart; ends of spines commonly bent over.

Dimensions: Length 26(30)35 μ; width 16(19)23 μ (8 specimens).

Holotype: Slide L1-71B, coordinates 42–116.6; plate 41, fig. 11.

Comments: This form is similar to the pollen of some species of *Nymphea* and *Nuphar*. Some ferns, such as *Cystopteris fragilis*, produce echinate, monolete spores similar to *Monosulcites spinosus*.

Occurrence: Rare in most samples; sample frequency low, not restricted to any zone.

Genus Schizosporis Cookson and Dettmann, 1959

Schizosporis microreticulatus, new species (129)

Plate 42, Figures 2, 3

Description: Inaperturate sporomorphae; subequatorial groove divides the spore into two unequal parts; outline circular to broadly elliptical.

Exine microreticulate; muri 4–6 sided, ca. 0.5 μ wide; lumina 1–1.8 μ across.

Dimensions: Maximum diameter 37(42)48 μ; diameter of smaller part 33(39)44 μ (12 specimens).

Holotype: Slide St. 10B, coordinates 24.5–109.5; plate 42, fig. 2.

Occurrence: Rare to moderate; sample frequency infrequent, found only in samples St. 10, St. 44, and St. 40.

Schizosporis reticulatus Cookson and Dettmann (130)

Plate 42, Figure 4; Plate 43, Figures 1, 2

Schizosporis reticulatus Cookson and Dettmann, 1959, Micropaleontology, vol. 5, no. 2, pp. 213, 214, pl. 1, figs. 1–4.

Comments: Sporomorphae identical to forms described by Cookson and Dettmann (1959) from the Lower Cretaceous and Cenomanian deposits of

Australia have been encountered in the Potomac Group. The type description states that the exine is intectate and coarsely reticulate From an examination of the type illustration and specimens found in this study, it appears that the exine is not reticulate but composed of a single layer of isodiametric cells; the cells are thin-walled and closely packed. On some specimens (Pl. 43) the center of the outside surface of each cell contains a circular pore about half the size of the cell diameter; the outline of the pore is well defined.

The cellular organization of this form and the presence of pores suggests an algal affinity. Perhaps, this form is related to some of the colonial *Chlorophyceae*, the pores forming during the production of zoospores.

Occurrence: Rare to occasional; sample frequency low, not restricted to any zone.

This species was first reported from the Lower Cretaceous of Australia by Cookson and Dettmann (1959). It has also been found in the Lower Cretaceous deposits of Western Canada by Pocock (personal communications).

VII. PLATES

PLATE 1

Figure 1. Washington Brick Co. pits at Muirkirk, Md. (St. 16). A close-up of a disconformable contact between the Patuxent Formation (lower sandy beds that appear lighter) and a massive reddish brown clay (upper darker bed). The upper beds may be the Patapsco or Arundel Clay.

Figure 2. In the same pit. This photograph shows the dark gray lignitic beds of the Arundel Clay. It was in this area, and in beds of similar lithology, that J. B. Hatcher (Clark, Bibbins, and Berry, 1911, p. 44) collected a number of sauropod vertebrate bones.

PLATE 1

PLATE 2

Figure 1. United Clay Mine No. 2 at White Marsh, Md. (St. 6). Thirty feet of pure, dark gray clay. Sporomorphae present place this exposure in Zone I. The exposure is probably located in outcrop belt of the Arundel Clay.

Figure 2. William Allen Clay Pit, Prince Georges Co. (St. 10). A close-up of an iron oxide nodule which was one of many embedded in a thick dark gray clay (25 ft.). Sporomorphae and geographic position place this exposure in the Arundel Clay.

PLATE 2

PLATE 3

Figure 1. St. 17, near Bladensburg, Md. Pointer indicates the position of a channel sand which cuts into a dark gray clay bed. The upper gray beds are medium-grained cross-bedded sands. The sporomorphae and geographic location place this exposure in the lower Patapsco Formation.

Figure 2. St. 12, near Hawkins Point, Anne Arundel Co. This photograph shows a fairly well defined disconformable contact between the Patapsco Formation (red and gray mottled clays) below and light, medium-grained, cross-bedded sands above. The contact is sharp and extends down the tracks for several hundred feet. The upper sands probably belong to the Raritan Formation.

PLATE 3

PLATE 4

(All figures × 1000)

Figure 1. *Sphagnumsporites antiquasporites* (Wilson and Webster)

Slide St. 49B, coordinates 31.6–125. la, high focus on proximal surface. Note how the laesurae run over the polar thickening, indicating its distal position. 1b, medium focus on distal surface. Distal polar thickening is now in focus, laesurae pass under it.

Figures 2, 3. *Cingulatisporites reticingulus*, n. sp.

Fig. 2. Holotype, slide St. 11B, coordinates 38.1–118.6. 2a, high focus on the proximal surface. 2b, low focus on the distal surface showing the distal spines with their typically broad bases.

Fig. 3. Slide D725C (well 13), coordinates 25–107.9. Tetrad shows the wedge-shaped character of the cingulum at the juncture of the two spores at the top.

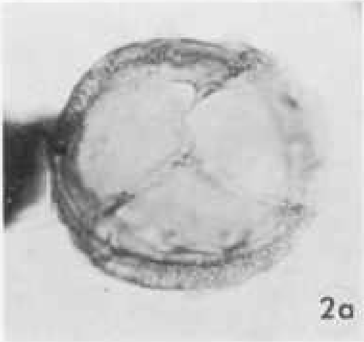
Figure 4. *Cirratriradites spinulosus* Cookson and Dettmann

Slide L1-47A, coordinates 37.4–109.3. 4a, high focus on proximal surface. The proximal surface is ornamented by small closely spaced spines, no trilete is visible. 4b, low focus on the distal surface which is recognized by the possession of a foveal area in the polar region. The distal surface develops rugulae which are reduced in density in the foveal area.

PLATE 4


1a


1b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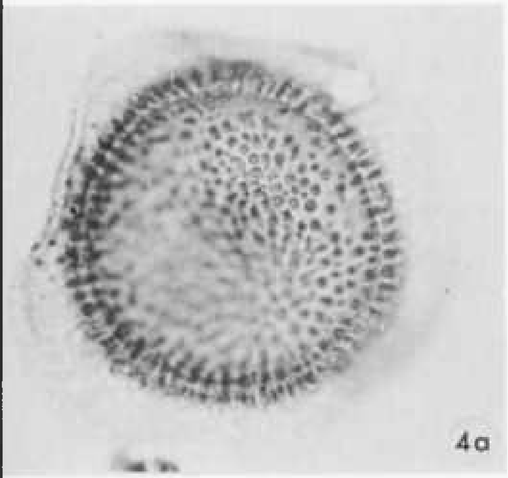
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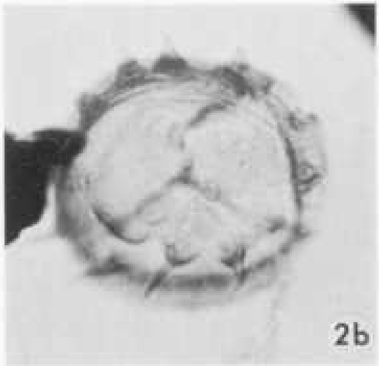
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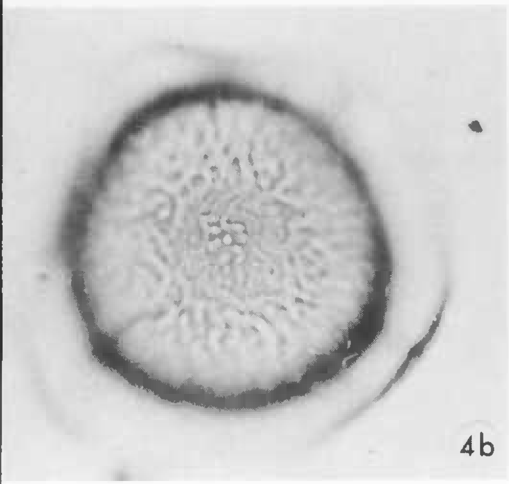
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3

PLATE 5

(All figures × 1000)

Figure 1. *Cirratriradites spinulosus* Cookson and Dettmann

Slide D725B (well 13), coordinates 28.1–126.5. 1a, medium focus showing the development of the laesurae near the equator and on the flange. 1b, low focus on distal surface. Foveal area expressed as a reduction in the rugulate sculpture in the polar region.

Figure 2. *Lycopodiacidites cerniidites* (Ross) nov. comb.

Slide St. 11B, coordinates 29.8–129.6. 2a, high focus on the proximal surface. 2b, low focus on the distal surface.

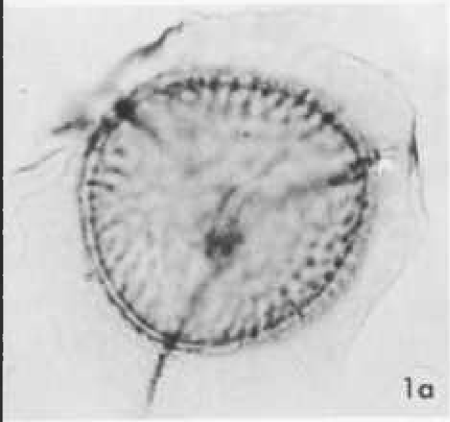
Figure 3. *Lycopodiumsporites austroclavatidites* (Cookson)

Slide St. 30B, coordinates 33.2–113.5. 3a, medium focus showing the high, narrow muri along the margin. Muri are not developed on the proximal surface. 3b, low focus on the distal surface showing the broad reticulum.

Figure 4. *Lycopodiumsporites dentimuratus*, n. sp.

Holotype, slide St. 26A, coordinates 26–115.8. 4a, high focus on proximal surface showing reduced ornamentation in the contact area. 4b, low focus on the distal surface. Notice the high projections at the interesection of the muri.

PLATE 5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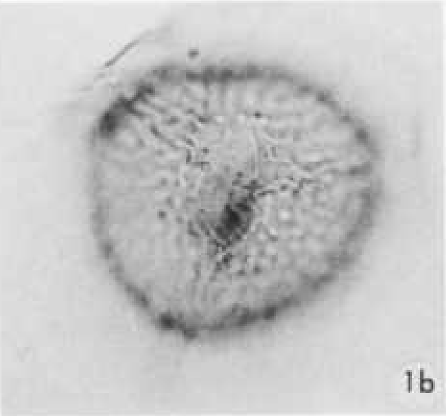
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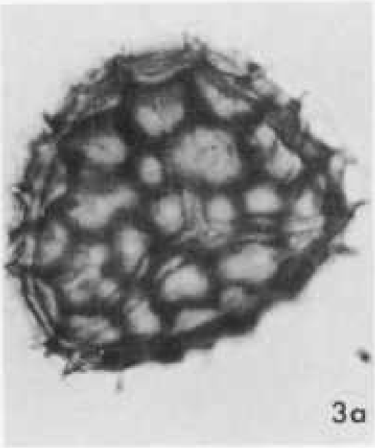
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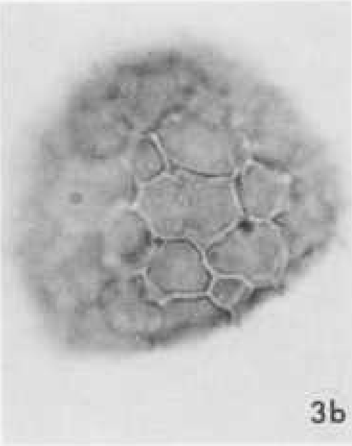
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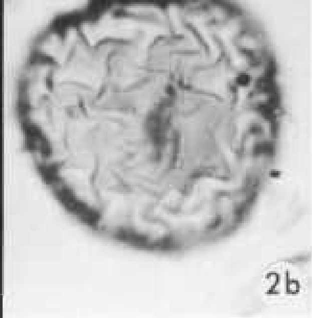
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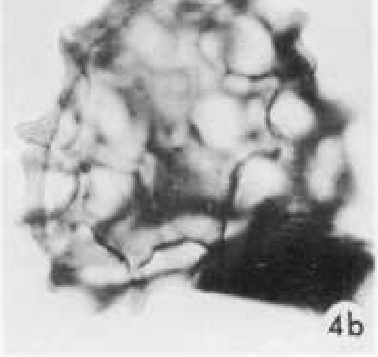
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PLATE 6

(All figures × 1000)

Figure 1. *Todisporites minor* Couper

Slide St. 26A, coordinates 24.3–116.5. High focus on the proximal surface.

Figures 2, 3. *Appendicisporites dentimarginatus*, n. sp.

Fig. 2. Holotype, slide L2-89A, coordinates 27–115.8 High focus on the proximal surface. Notice the strongly dentate margin.

Fig. 3. Slide L2-88A, coordinates 31.7–128. 3a, high focus on the proximal surface. 3b, low focus on the distal surface, a larger specimen.

Figures 4, 5. *Appendicisporites potomacensis* n. sp.

Fig. 4. Holotype, slide L2-49A, coordinates 25–112. 4a, high focus on proximal surface. Muri are more widely spaced than in *A. tricornatatus*. 4b, low focus on distal surface. Muri typically branch in the polar area to form a triangular area.

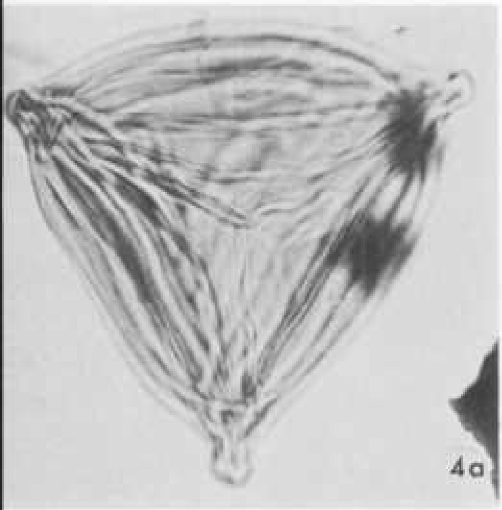
Fig. 5. Slide L1-41A, coordinates 25–112. High focus on the proximal surface of another specimen.

PLATE 6


1


2


3a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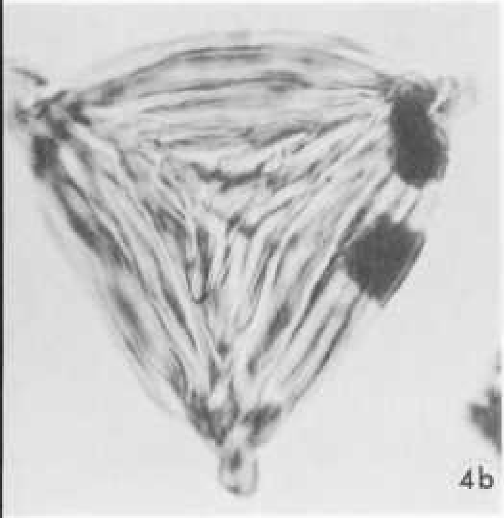
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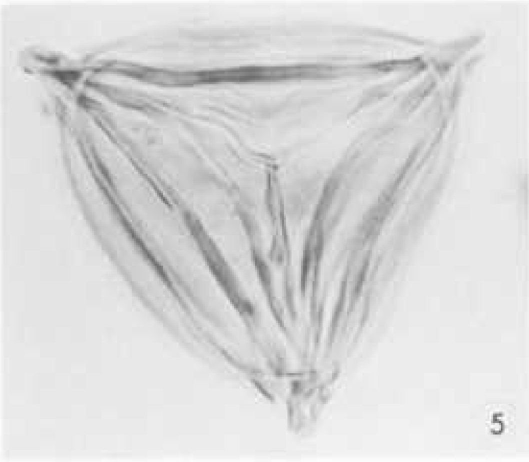
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PLATE 7

(All figures × 1000)

Figures 1, 2. *Appendicisporites segmentus*, n. sp.

Fig. 1. Holotype, slide St. 40A, coordinates 24–111. 1a, high focus on the proximal surface. On the proximal surface the muri typically have a dentate margin. Note the large auriculae at the corners. 1b, low focus on the distal surface. The teeth are not developed on this side and the muri are characteristically segmented.

Fig. 2. Slide L1-22B, coordinates 30.3–126.4. High focus on the distal surface of another specimen, the segmentation of the distal muri is strongly developed.

Figure 3. *Appendicisporites tricornatus* Weyland and Greifeld

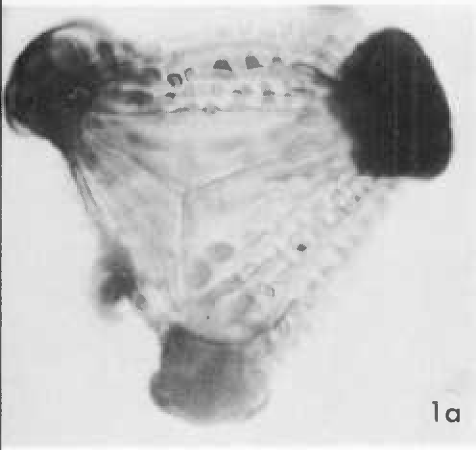
Slide L2-89A, coordinates 29.2–115.4, medium focus. The ornamentation is canaliculate.

Figures 4, 5. *Cicatricosisporites aralica* (Bolkhovitina) nov. comb.

Fig. 4. Slide St. 31A, coordinates 42.4–115.1; high focus on the proximal surface. The ornamentation on the proximal surface is reduced, corners are typically acute.

Fig. 5. Slide St. 28A, coordinates 27.3–122. Medium focus showing the branching of the muri in the polar area of the distal surface.

PLATE 7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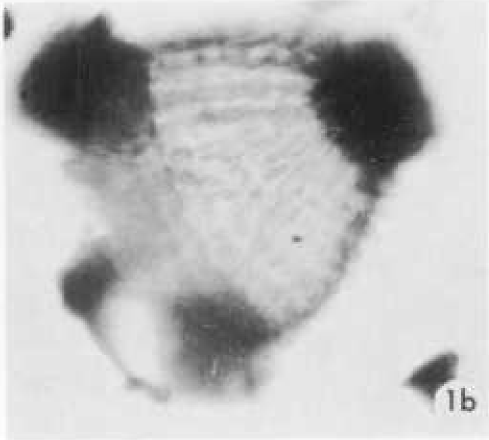
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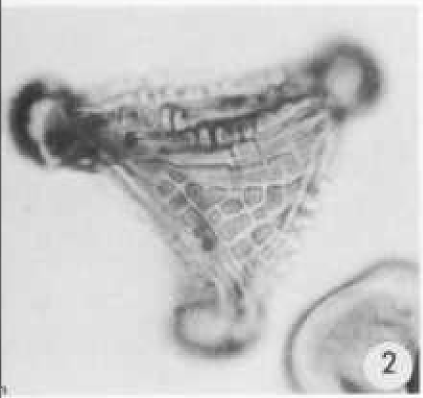
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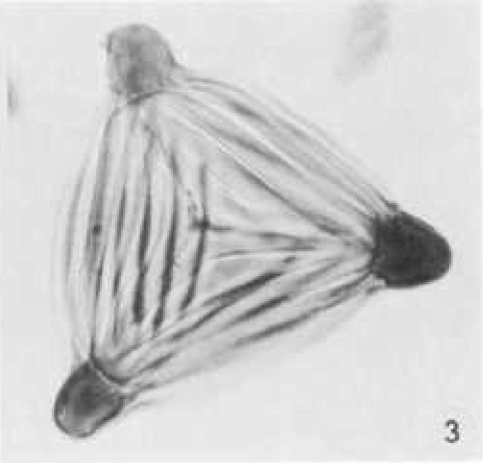
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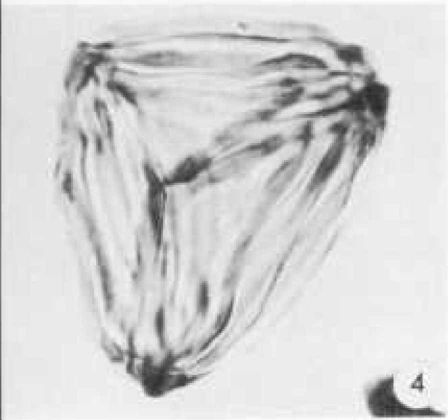
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5

PLATE 8

Figures 1–3. *Cicatricosisporites australiensis* (Cookson)

Fig. 1. Slide St. 26A, coordinates 25.8–115.5. 1a, high focus on the proximal surface, shows muri parallel to equatorial margin. 1b, low focus on the distal surface, × 1000.

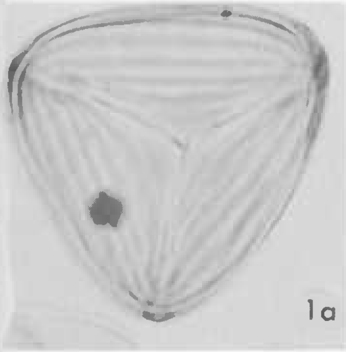
Fig. 2. 2a, sporangium with distal annulus, containing *C. australiensis*, × 111. 2b, shows details of spores within sporangium, × 500, from sample St. 26.

Fig. 3. Slide St. 26A, coordinates 21.5–118.3. Tetrad at medium focus.

Figure 4. *Cicatricosisporites dorogensis* Pontonié and Gelletich

Slide St. 26A, coordinates 26–115.8. 4a, high focus on proximal surface. The muri characteristically meet the laesurae at angles greater than 45 degrees. 4b, low focus, distal view.

PLATE 8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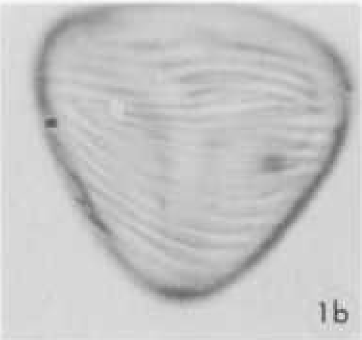
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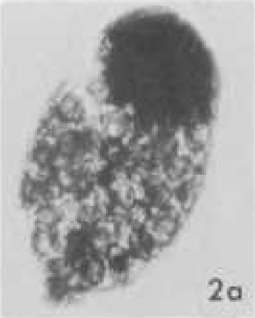
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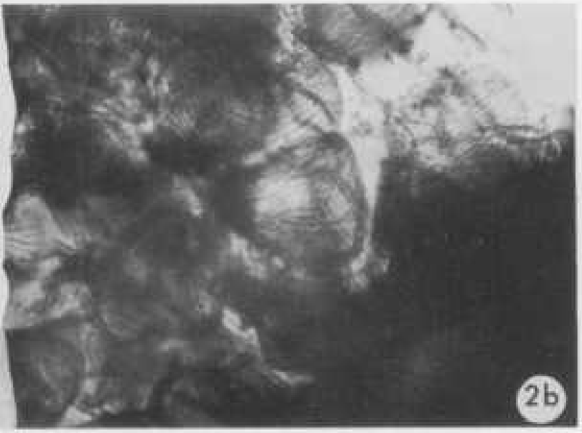
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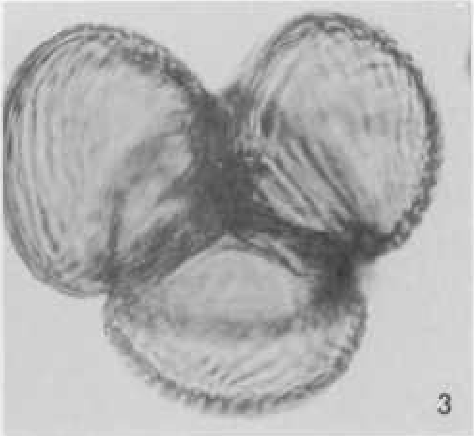
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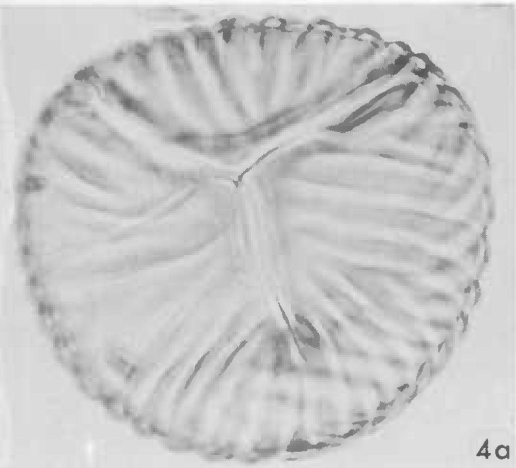
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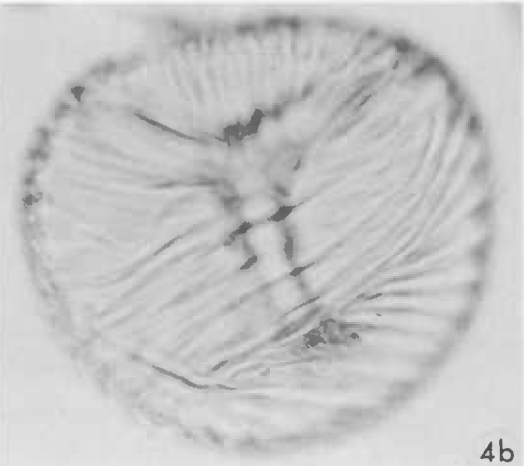

4b

PLATE 9

(All figures × 1000)

Figure 1. *Cicatricosisporites brevilaesuratus* Couper

Slide St. 11A, coordinates 24–116.2, medium focus.

Figure 2. *Cicatricosisporites hallei* Delcourt and Sprumont

Slide St. 11B, coordinates 30.4–116.9, high focus on the proximal surface. Muri meet the laesurae at angles greater than 45 degrees. This species is smaller than *C. dorogensis*.

Figure 3. *Cicatricosisporites patapscoensis*, n. sp.

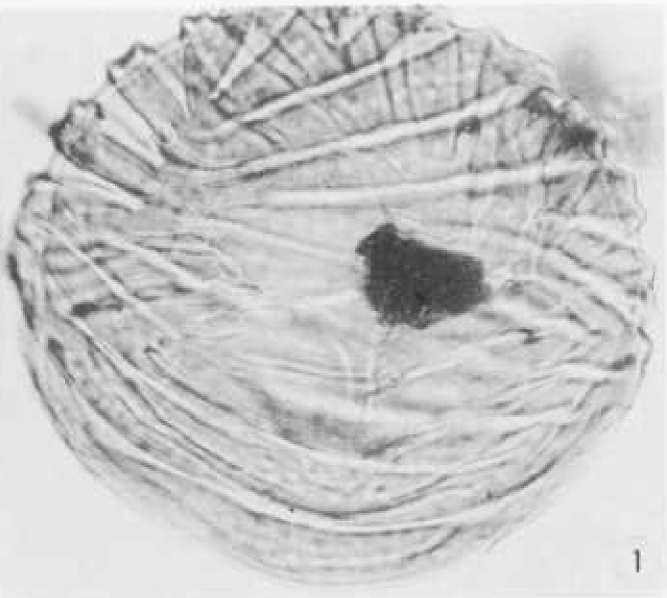
Holotype, slide St. 30A, coordinates 26.1–115.8. 3a, low focus on proximal surface shows the canals connecting the ends of the laesurae. 3b, high focus on distal side shows the typically wide muri and narrow canals.

Figures 4, 5. *Cicatricosisporites potomacensis*, n. sp.

Fig. 4. Holotype, slide L2-49A, coordinates 32.9–112. 4a, high focus on proximal side. 4b, low focus on distal side.

Fig. 5. Slide 11A, coordinates 34.8–110.3, smaller specimen; notice the thick exine of both specimens.

PLATE 9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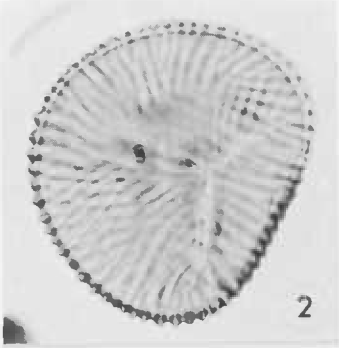
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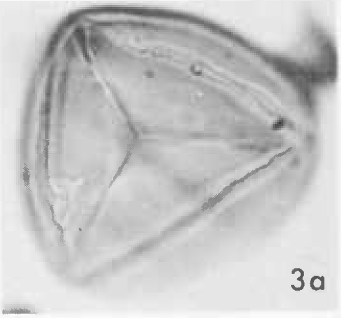
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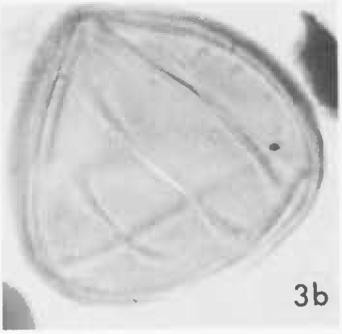
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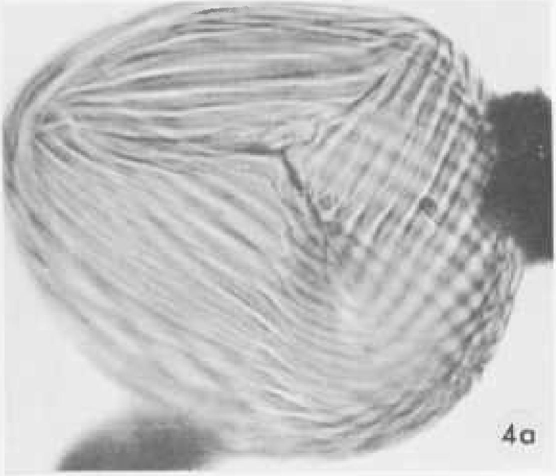
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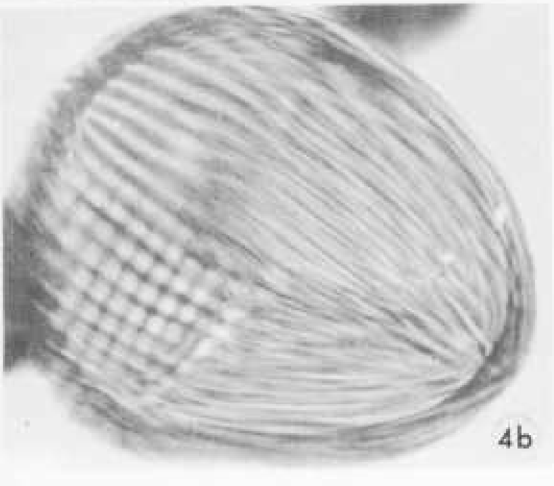
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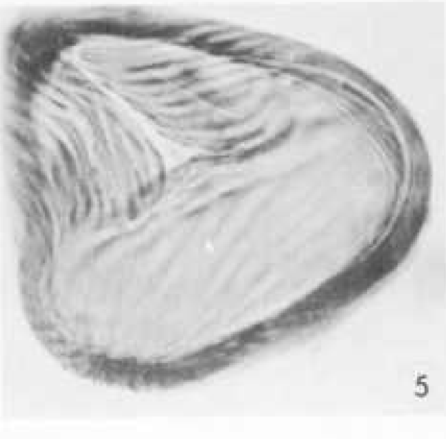
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PLATE 10

(All figures × 1000)

Figures 1, 2. *Cicatricosisporites subrotundus*, n. sp.

Fig. 1. Slide L2-49A, coordinates 39–109.5. 1a, low focus on proximal surface showing the wide flat-topped muri and narrow canals. 1b, high focus on distal surface.

Fig. 2. Holotype, slide L2-49A, coordinates 29.1–116. 2a, high focus on proximal surface. 2b, low focus on distal surface.

Figures 3, 4. *Ischyosporites crateris* Balme

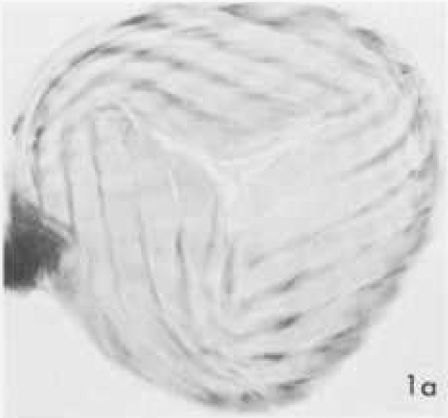
Fig. 3. Slide St. L2-61A, coordinates 21.9–118.9. 3a, high focus on proximal surface; muri not developed on this side. 3b, medium focus showing the wide muri along the margin and on the distal surface.

Fig. 4. Slide St. 11B, coordinates 34.8–122.1, medium focus showing smooth proximal surface and the thick distal muri of the reticulum.

Figure 5. *Klukisporites pseudoreticulatus* Couper

Slide St. 28A, coordinates 28.1–110.1. 5a, high focus on proximal surface; this surface is smooth. 5b, medium focus showing distal reticulum with approximately circular lumina.

PLATE 10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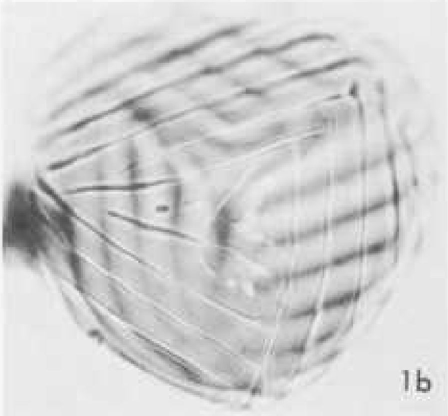
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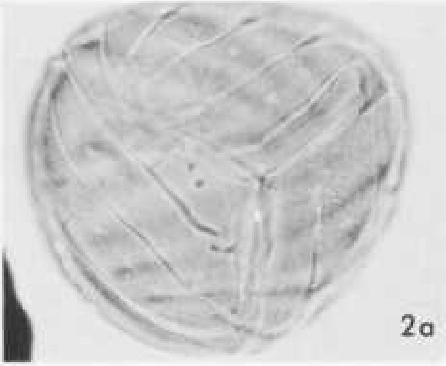
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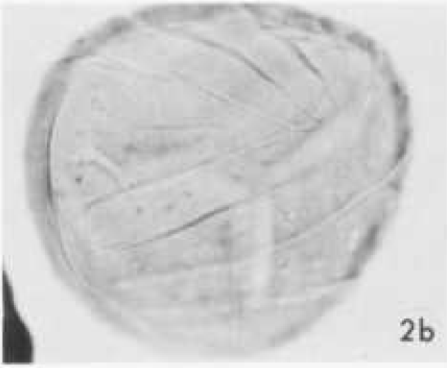
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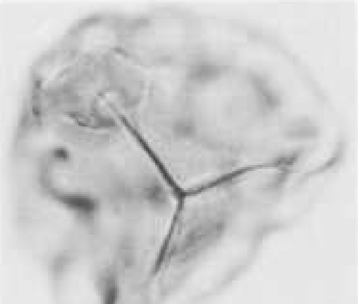
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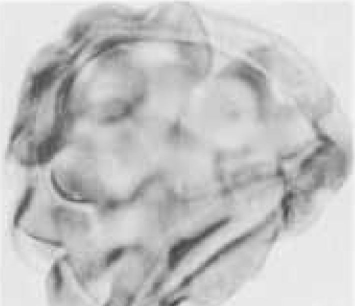
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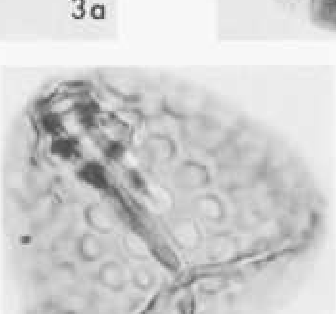
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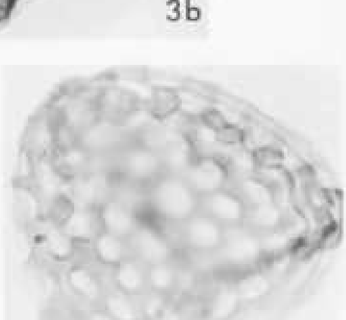
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PLATE 11

Figure 1. *Klukisporites variegatus* Couper

Slide St. 49A, coordinates 23–125. 1a, high focus on proximal surface, smooth. 1b, low focus showing distal reticulum; lumina variable in shape, × 1000.

Figures 2, 3. *Gleicheniidites apilobatus*, n. sp.

Fig. 2. Holotype, slide St. 16B, coordinates 40–121.8. 2a, high focus on proximal surface. 2b, medium focus, distal muri just coming into view. 2c, medium focus, distal muri just coming into view. 2c, low focus on distal surface show the apical muri connected by marginal muri, × 1000.

Fig. 3. Slide St. 35A, coordinates 26.2–122. 3a, high focus on proximal surface. This specimen is less lobate than the holotype and does not have marginal muri, × 1000. 3b, low focus on distal surface.

Figures 4, 5. *Gleicheniidites circinidites* (Cookson) nov. comb.

Fig. 4. Slide St. 16A, coordinates 29.6–112.1, medium focus. Notice the acute corners which are one of the typical features of this species, × 1000.

Fig. 5. Slide 15B, coordinates 35.1–115.6, medium focus; note the acute corners and the way the equatorial thickenings continue around the corners, × 1000.

Figure 6. *Gleicheniidites senonicus* Ross

Slide St. 35A, coordinates 24.1–121.9. 6a, low focus on proximal side; marginal thickening does not extend around corners. 6b, high focus on distal side; dark bands caused by arcuate folds, × 1000.

Figures 7, 8. *Cyathidites minor* Couper

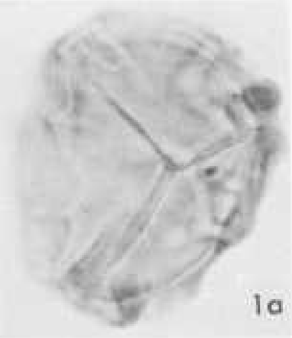
Fig. 7. Slide St. 31B, coordinates 32.2–114.1, medium focus.

Fig. 8. 8a, sporangium containing *C. minor*. The annulus appears oblique as in the *Cyatheaceae*, × 111. 8b, greater magnification showing the smooth trilete spores within, × 484.

Figure 9. *Cyathidites* sp.

Slide L1-69A, coordinates 29–116.2, medium focus, × 1000.

PLATE 11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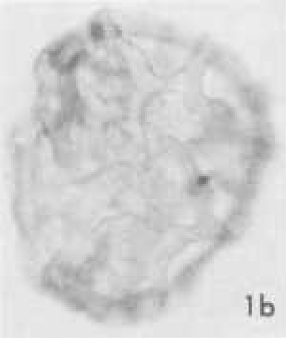
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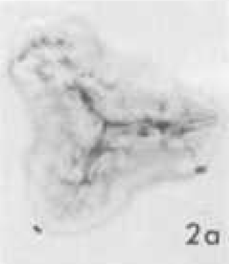
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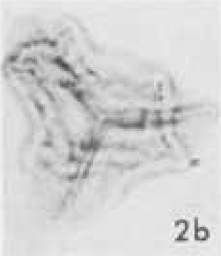
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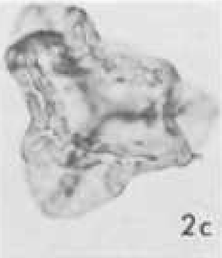
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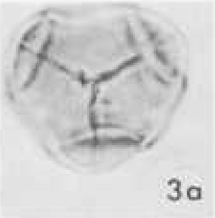
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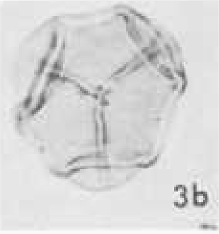
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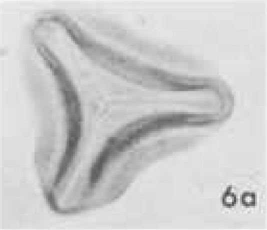
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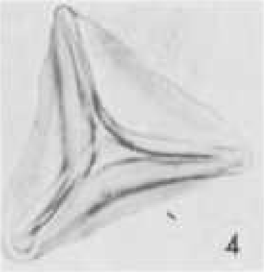
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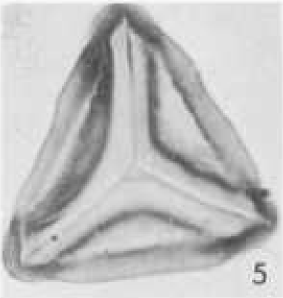
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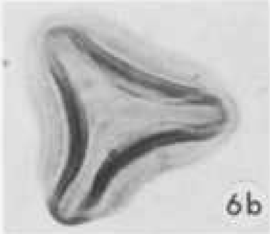
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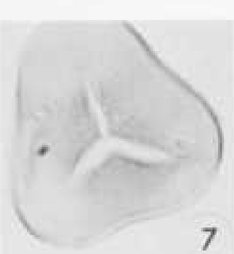
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8b


8a

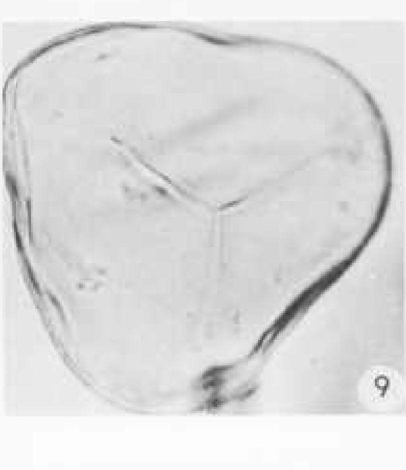
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PLATE 12

(All figures × 1000)

Figure 1. *Matonisporites phlebopteroides* Couper

Slide St. 10B, coordinates 21.2–125.5, high focus on the proximal surface.

Figures 2, 3. *Matonisporites excavatus*, n. sp.

Fig. 2. Holotype, slide L2-49B, coordinates 15–117.5. 2a, high focus on the distal surface showing the thinner area in the region of the distal pole. 2b, low focus on the proximal surface showing an exinal thickening bordering the raised commissure.

Fig. 3. Slide L2-49B, coordinates 14.9–124.3. A specimen with slightly more convex sides. Thinned area on the distal surface more circular than in the holotype.

Figure 4. *Dictyophyllidites sp.*

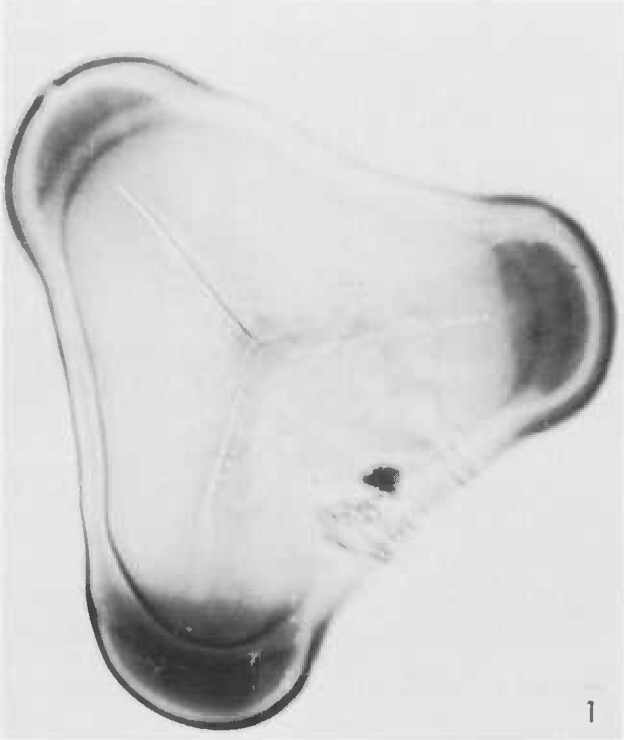
Slide St. 34A, coordinates 30.3–110.2, medium focus. The commissure is raised several microns above the general surface of the spore.

Figures 5, 6. *Alsophilidites pannuceus*, n. sp.

Fig. 5. Holotype, slide St. 10B, coordinates 21.2–125.5. 5a, high focus on the proximal surface. 5b, low focus on the distal surface. The finely wrinkled surface is characteristic of this species.

Fig. 6. Slide L2-58A, coordinates 38.2–108.2, medium focus, a slightly larger specimen with a more strongly developed margo.

PLATE 12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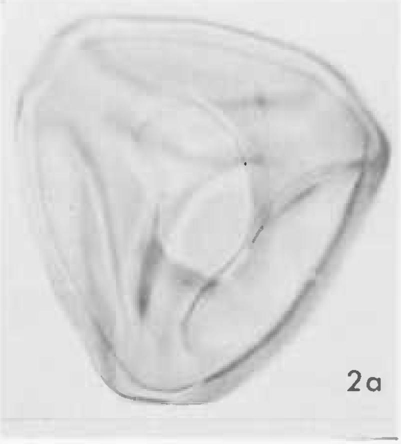
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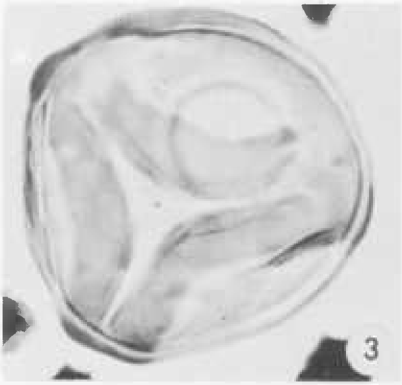
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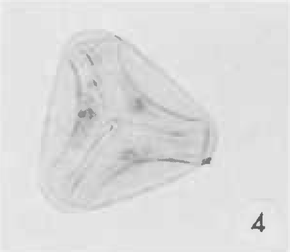
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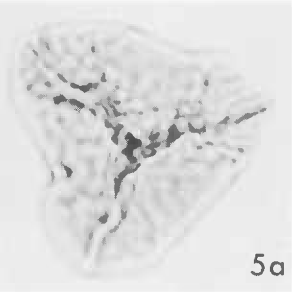
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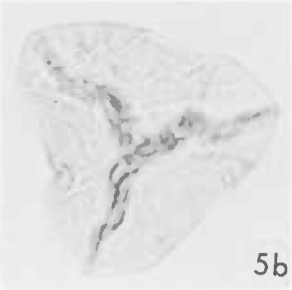
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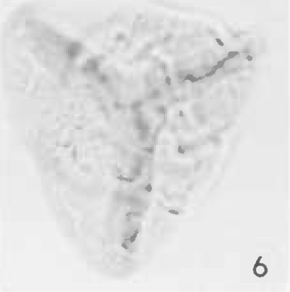
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PLATE 13

(All figures × 1000)

Figure 1. *Apiculatisporis asymmetricus* Cookson and Dettmann

Slide St. 30B, coordinates 25–129. 1a, high focus on the proximal surface, faintly developed trilete mark. 1b, low focus on the distal surface.

Figures 2, 3. *Apiculatisporis babsae*, n. sp.

Fig. 2. Holotype, Slide St. 30B, coordinates 24.5–128.8. 2a high focus on the proximal surface, coni poorly developed in the interray areas. 2b, low focus on the distal surface, coni well developed.

Fig. 3. Slide D600, coordinates 26.4–110.3 (well 13), high focus on the proximal surface. Cones are better developed in the interray areas on this specimen than in the holotype.

Figure 4. *Ceratosporites parvus*, n. sp.

Holotype, Slide St. 30A, coordinates 23.7–127.9. 4a, high focus on the proximal surface. 4b, medium focus showing spines developed on the distal surface.

Figure 5. *Cingulatisporites caminus* Balme

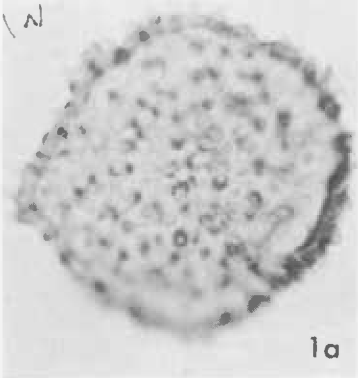
Slide St. 38A, coordinates 23.9–123.2. 5a, low focus on the proximal surface. 5b, high focus on the distal surface. Circular ring encloses a granular area in the region of the distal pole. Notice a more obscure ring is developed between the polar ring and the margin.

Figures 6, 7. *Cingulatisporites distaverrucosus*, n. sp.

Fig. 6. Holotype, Slide L1-50A, coordinates 24–128.8. 6a, high focus on the proximal surface, no ornamentation is present. 6b, medium focus showing distal verrucae.

Fig. 7. Slide St. 10A, coordinates 29.5–129.7, tetrad showing the wedge-shaped nature of the cingulum.

PLATE 13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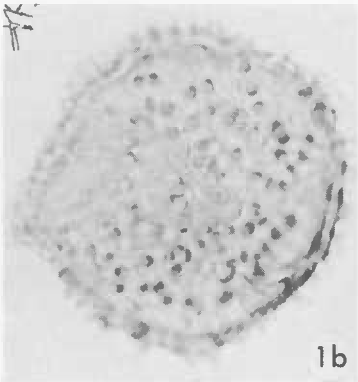
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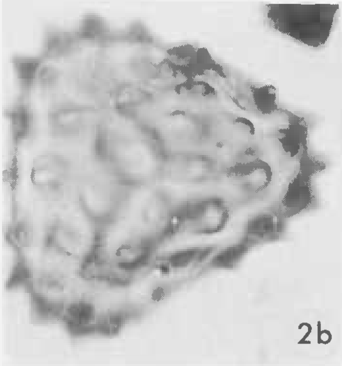
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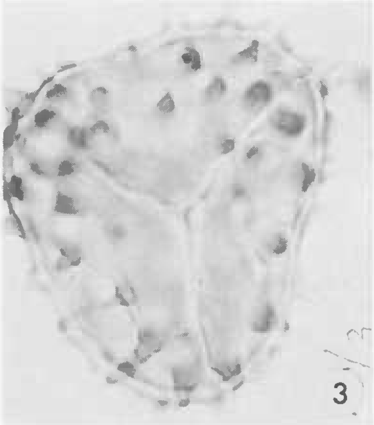
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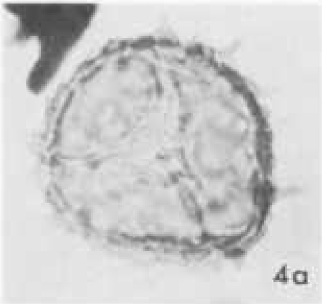
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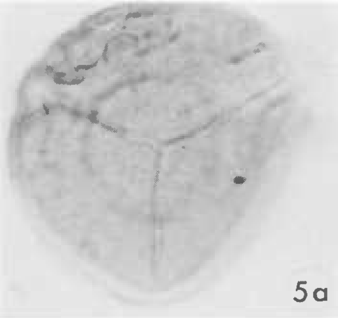
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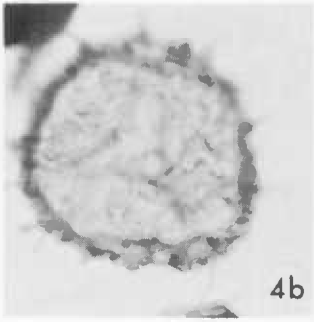
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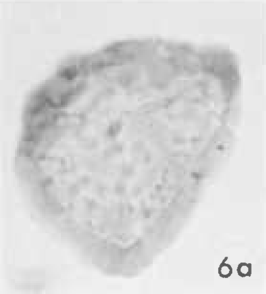
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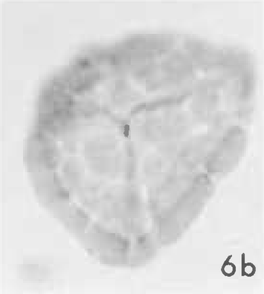
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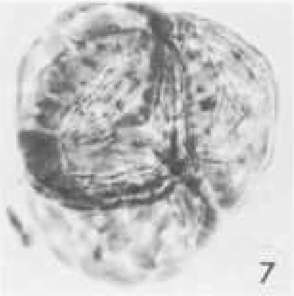
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PLATE 14

(All figures × 1000)

Figure 1. *Cingulatisporites distaverrucosus*, n. sp.
Slide L2-58B, coordinates 25.2–110. 1a, low focus on the proximal surface, cingulum strongly segmented on the left side of the specimen. 1b, high focus on the distal surface.

Figure 2. *Cingulatisporites* cf. *eukirchensoides* Delcourt and Sprumont.
Slide St. 26A, coordinates 20.1–121.8, medium focus.

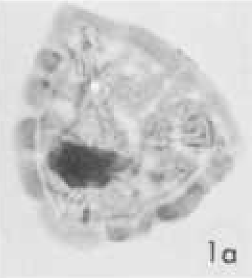
Figure 3. *Cingulatisporites sp.*
Slide St. 49A, coordinates 23.6–126. 3a, medium focus showing the proximal surface. 3b, high focus on distal surface.

Figure 4. *Concavissimisporites variverrucatus* (Couper), nov. comb.
Slide St. 26A, coordinates 39–114.5. 4a, low focus on the proximal surface, note variation in the size of the sculptural elements. 4b, high focus on the distal surface.

Figure 5. *Converrucosisporites platyverrucosus*, n. sp.
Holotype, Slide L2-88A, coordinates 36.2–111. 5a, low focus on the proximal side, large flat-topped verrucae cover the surface. 5b, high focus on the distal surface, the size of the verrucae are extremely variable.

Figure 6. *Concavissimisporites punctatus* (Delcourt and Sprumont), nov. comb.
Slide St. 6A, coordinates 37–128, medium focus.

PLATE 14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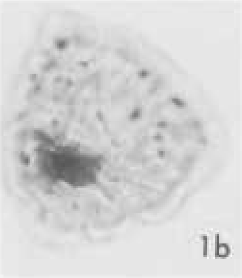
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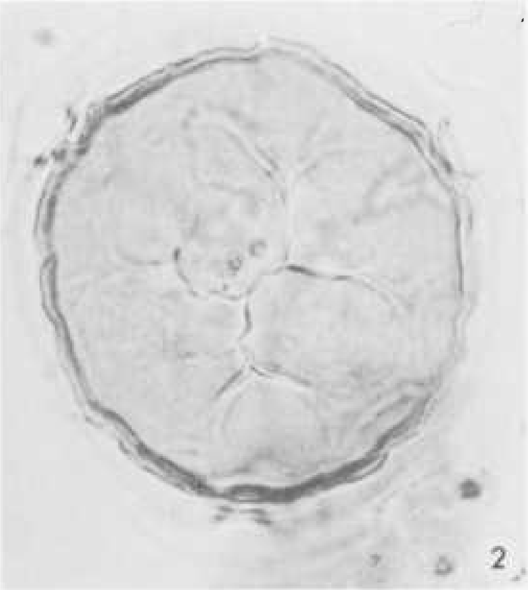
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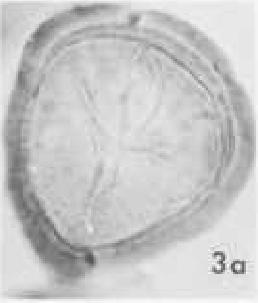
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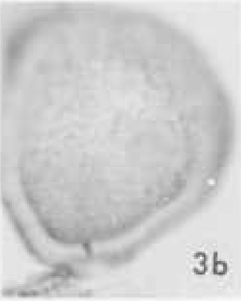
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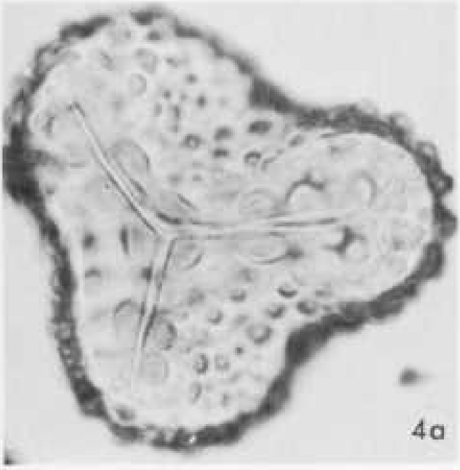
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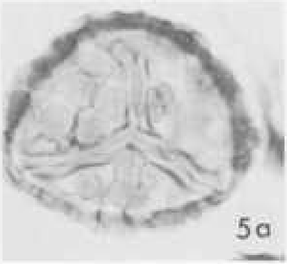
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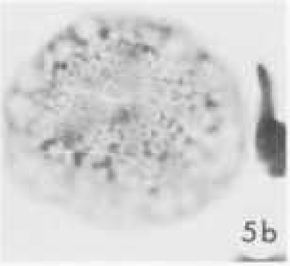
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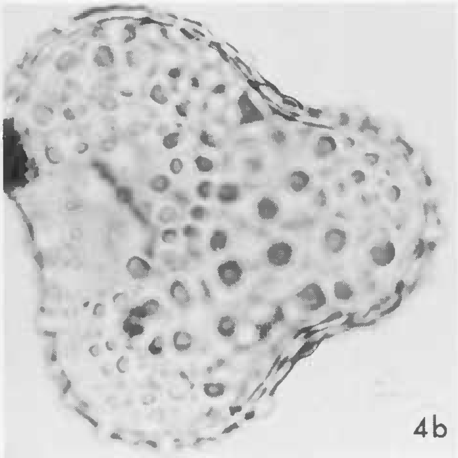
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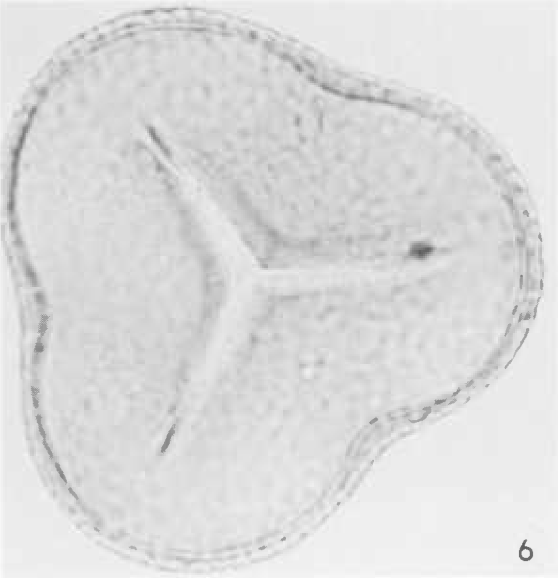
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PLATE 15

(All figures × 1000)

Figures 1–3. *Converrucosisporites proxigranulatus*, n. sp.

Fig. 1. Holotype, slide St. 26A, coordinates 34–108.5. 1a, medium focus shows the granular nature of the proximal surface. 1b, high focus on the distal surface shows the large distal tubercles.

Fig. 2. Slide St. 11A, coordinates 37.9–108. 2a, high focus on the proximal surface, ornamentation coarser than in the holotype. 2b, medium focus. 2c, low focus on the distal surface, tubercles closely spaced on this specimen.

Fig. 3. Slide St. 26A, coordinates 36–110.2, high focus on the proximal surface.

Figure 4. *Cyathidites crassiangulatus* Balme

Slide St. 38B, coordinates 28.8–129.5, 4a, high focus on the proximal surface, exine thickening slightly at the corners. 4b, medium focus, commissure located in a groove.

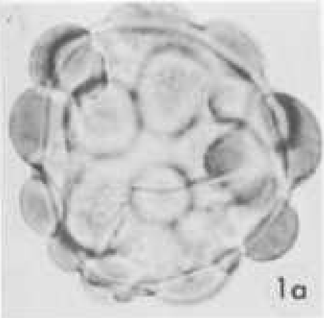
Figure 5. *Deltoidospora hallii* Miner

Slide L1-69B, coordinates 19.3–108.9, medium focus.

Figure 6. *Densoisporites microrugulatus*, n. sp.

Holotype, slide St. 49A, coordinates 39.1–115.7. 6a, high focus on the proximal surface. Three oval-shaped bodies are situated at the proximal pole in the interray areas. 6b, low focus on the distal surface.

PLATE 15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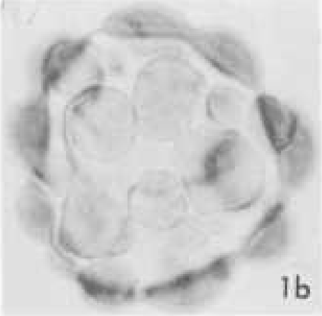
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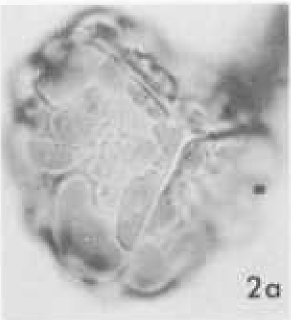
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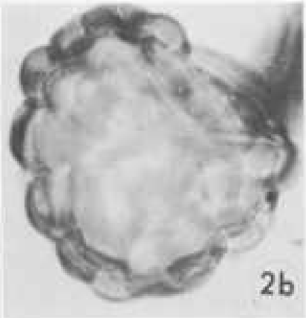
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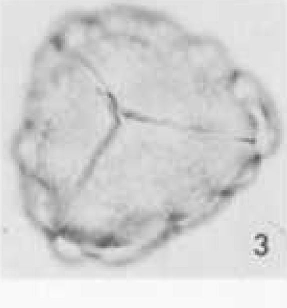
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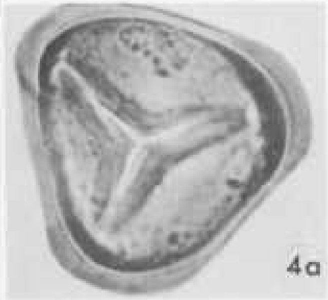
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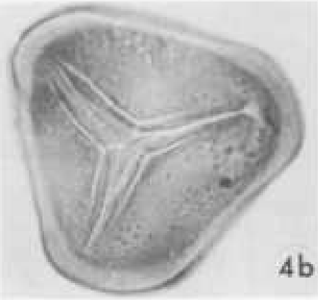
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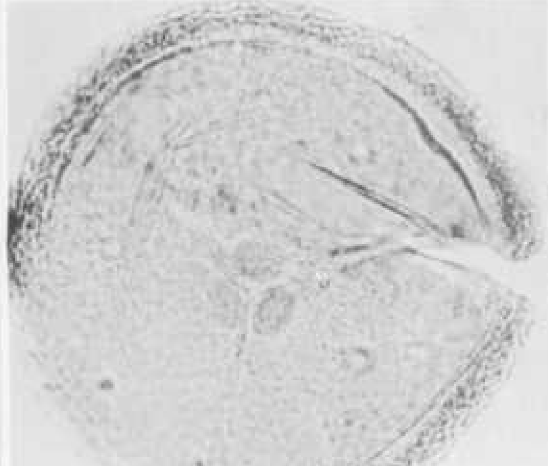

6a


6b

PLATE 16

(All figures × 1000)

Figure 1. *Densoisporites microrugulatus*, n. sp.
Slide L2-58A, coordinates 28.5–129.5, smaller specimen than the holotype, high focus on the proximal surface.

Figure 2. *Foveotriletes subtriangularis*, n. sp.
Holotype, slide L2-58A, coordinates 22–112.2. 2a, low focus on the proximal surface. 2b, high focus on the distal surface.

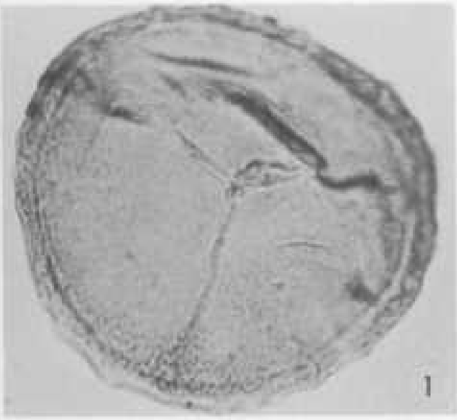
Figure 3. *Densoisporites perinatus* Couper
Slide St. 16B, coordinates 32.3–117.8. 3a, high focus on the distal surface, exine highly wrinkled. 3b, low focus on the proximal surface, shows equatorial thickenings.

Figure 4. *Granulatisporites dailyi* Cookson
Slide St. 11B, coordinates 37–128.6. 4a, high focus in the distal surface, shows thickenings in the polar region. 4b, low focus on the proximal surface.

Figure 5. *Kuylisporites lunaris* Cookson and Dettmann
Slide L1-70A, coordinates 22.5–129.2. 5a, medium focus, lunate ridges absent. 5b, high focus on the distal surface shows the lunate ridges typical of this species.

Figure 6. *Lycopodiacidites cristatus* Couper
Slide L1-41A, coordinates 28.6–121.1. 6a, oblique view, showing the sharply demarcated proximal surface and heavily ornamented distal side. 6b, low focus on distal surface.

PLATE 16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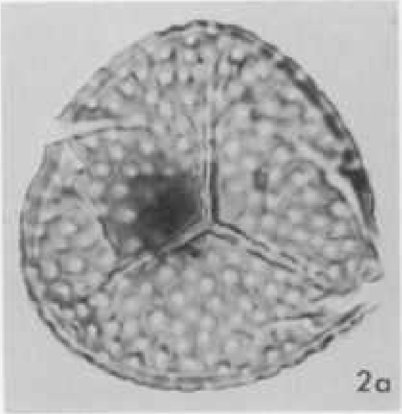
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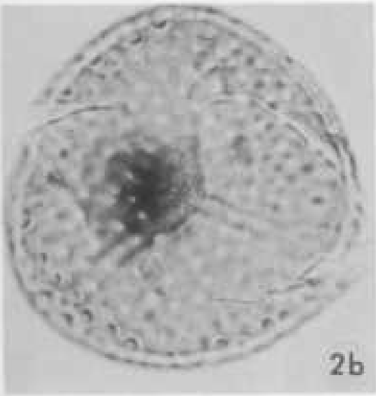
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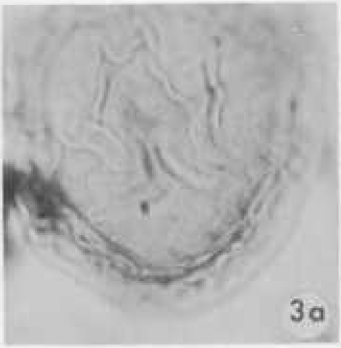
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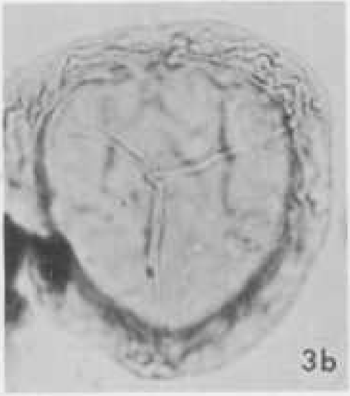
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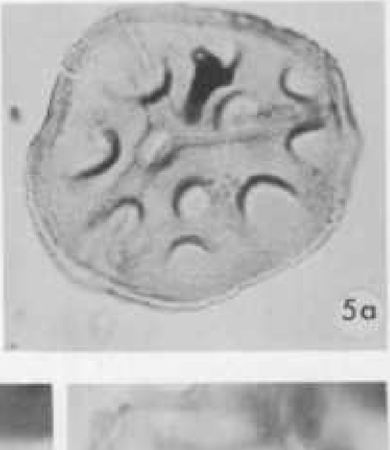
4b


5a


5b


6a


6b

PLATE 17

(All figures × 1000)

Figures 1, 2. *Lycopodiacidites ambifoveolatus*, n. sp.

Fig. 1. Holotype, Slide L2-58A, coordinates 24–119. 1a. medium focus, proximal surface is smooth. 1b, high focus on the distal surface, verrucae variable in shape and frequently fusing.

Fig. 2. Slide L1-22A, coordinates 20.5–127, medium focus showing pseudo-foveolate margin.

Figure 3. *Lycopodiacidites intraverrucatus*, n. sp.

Holotype, slide St. 26A, coordinates 20.8–125.9. 3a, medium focus, proximal side smooth; verrucae seen are the inner projections of the distal rugulae. 3b, high focus on the distal surface, rugulae in focus.

Figures 4, 5. *Lycopodiacidites irregularis*, n. sp.

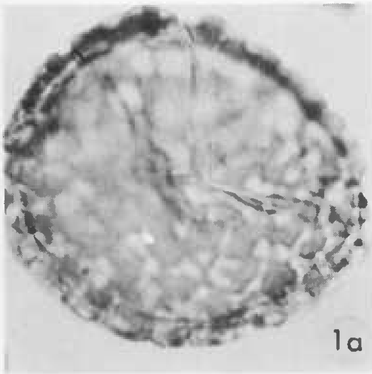
Fig. 4. Holotype, slide St. 43A, coordinates 21.7–108. 4a, high focus on the proximal surface. 4b, low focus on the distal surface.

Fig. 5. Slide St. 43A, coordinates 22.8–110.1. 5a, high focus on the distal surface. Note the irregular distribution of the gemmae. 5b, medium focus showing smooth proximal surface.

Figure 6. *Lycopodiacidites triangularis*, n. sp.

Holotype, slide D-730A (well 13) coordinates 40.6–111.4. 6a, high focus on the proximal surface. 6b, low focus on the distal side showing irregular thickenings clustering around the distal pole.

PLATE 17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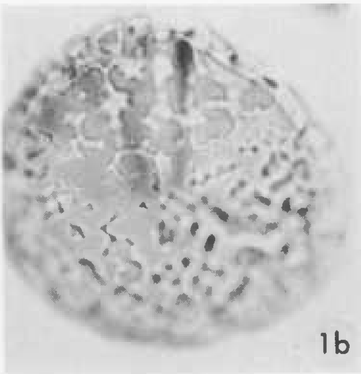
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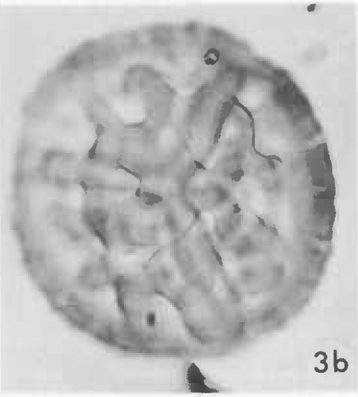
2


3a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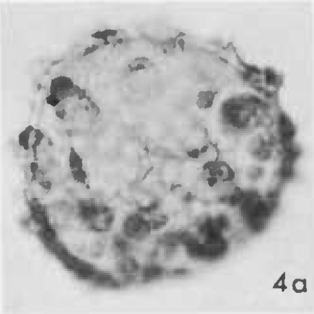
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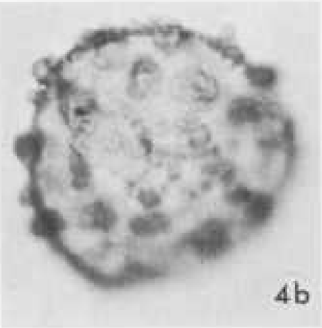
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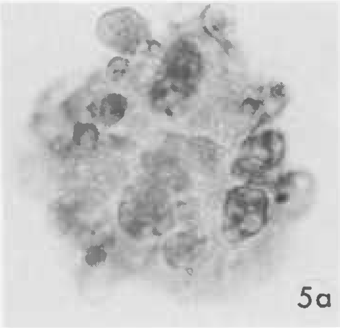
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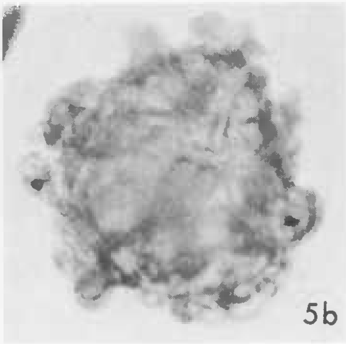
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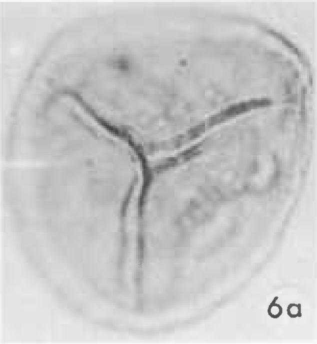
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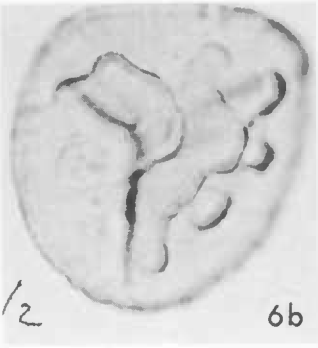


6b

PLATE 18

(All figures × 1000)

Figure 1. *Lycopodiacidites tortus*, n. sp.

Holotype, slide St. 49B, coordinates 30.6–125. 1a, high focus on the proximal surface shows twisted blade-like processes forming near the equator and onto the distal surface. 1b, low focus on the distal surface.

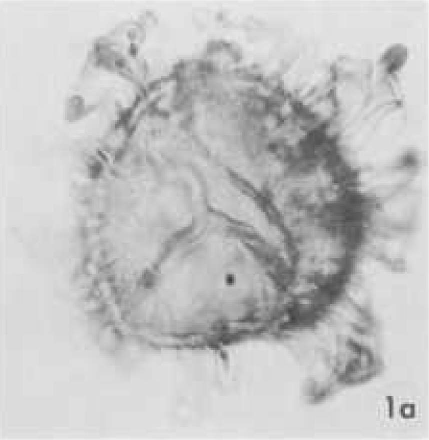
Figure 2. *Microreticulatisporites crassiexinous*, n. sp.

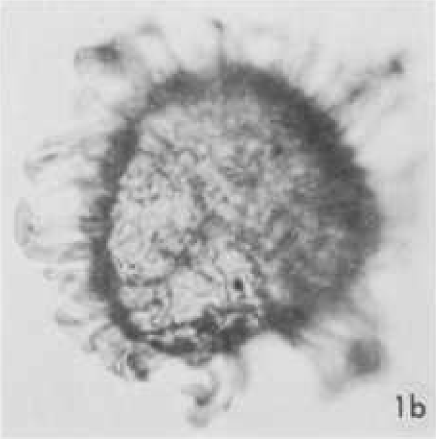
Holotype, slide St. 16A, coordinates 42–123.4. 2a, high focus on the proximal surface. 2b, medium focus showing the thick exine and longitudinal section of the fovea. 2c, low focus on the distal surface.

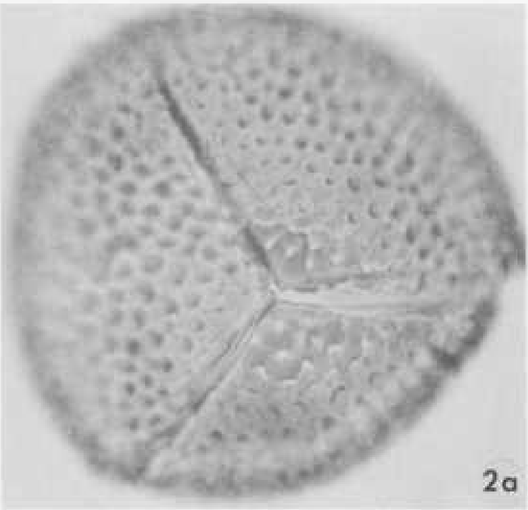
Figure 3. *Perotriletes pannuceus*, n. sp.

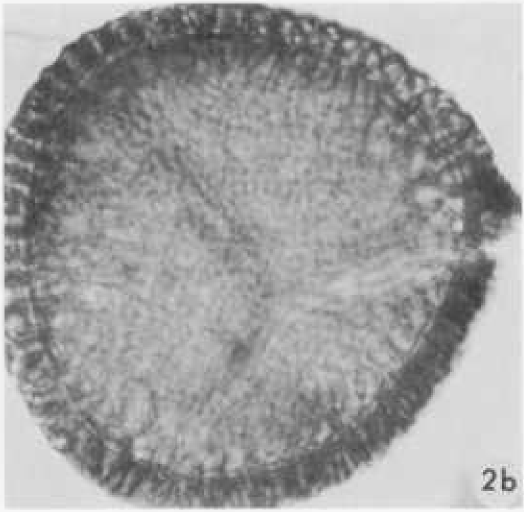
Holotype, slide St. 17A, coordinates 42–122.5, medium focus, perine completely envelops the central body, laesurae obscured.

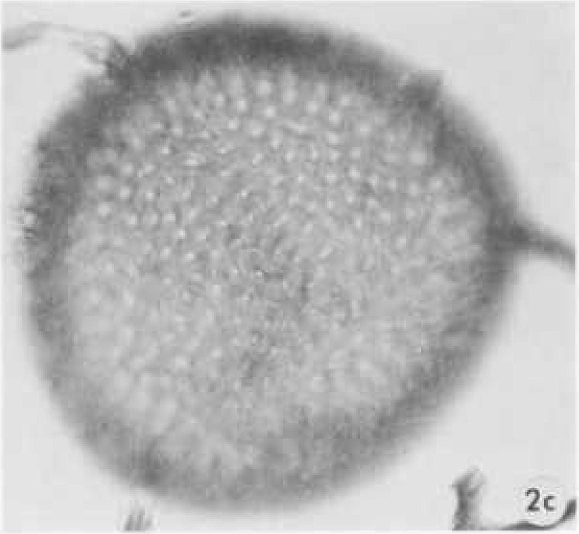
PLATE 18











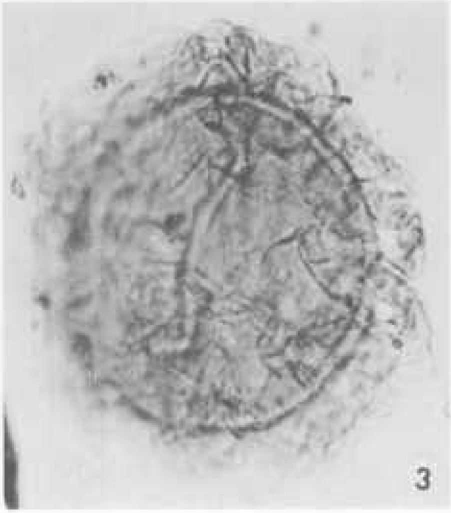


PLATE 19

(All figures × 1000)

Figure 1. *Perotriletes pannuceus*, n. sp.

Slide D600 (well 13), coordinates 14.5–109.8. 1a, high focus. 1b, medium focus showing central body and highly invaginated perine.

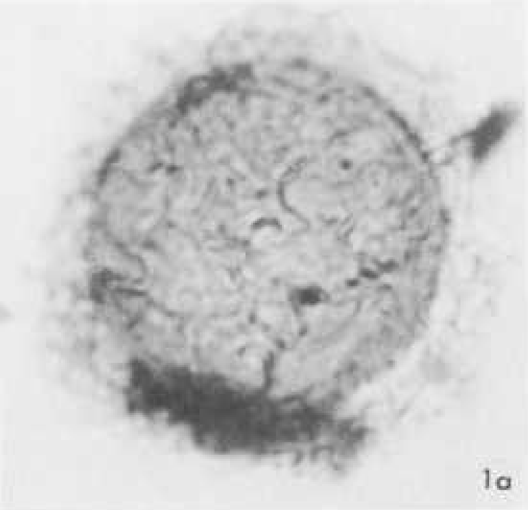
Figure 2. *Neoraistrickia robusta*, n. sp.

Holotype, slide L1-41B, coordinates 29.8–114. 2a, high focus on the proximal surface, cross sections of the bacula are shown. 2b, medium focus shows the expanded distal ends of the bacula. 2c, low focus on the distal surface, distal ends are commonly fused.

Figure 3. *Perotriletes striatus* Cookson and Dettmann

Slide St. 26A, coordinates 21.2–124.4, high focus showing the infrequently seen trilete mark.

PLATE 19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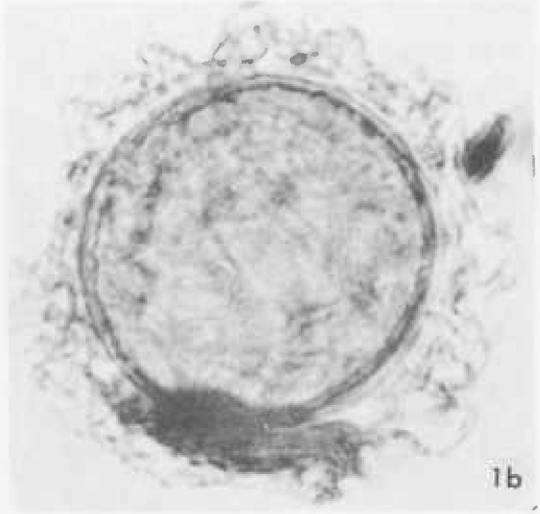
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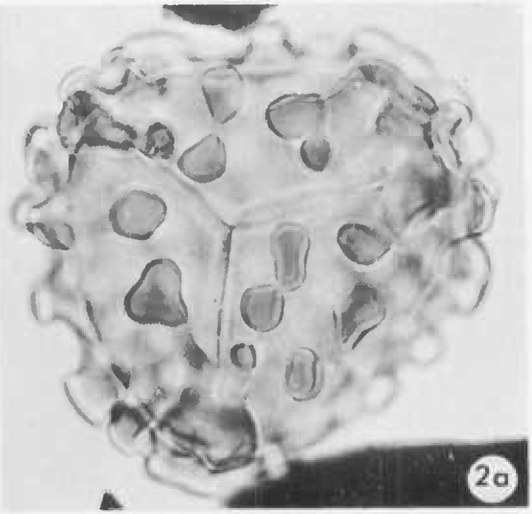
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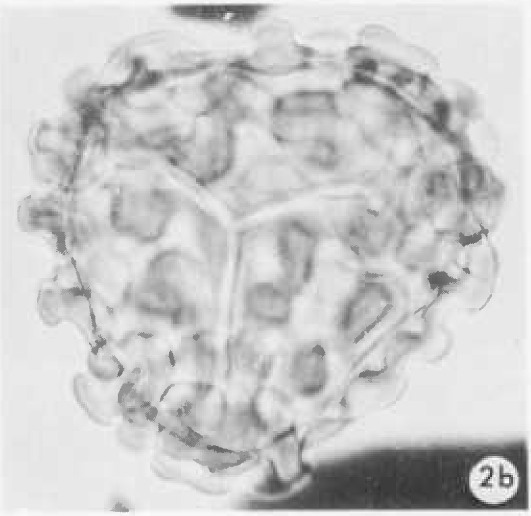
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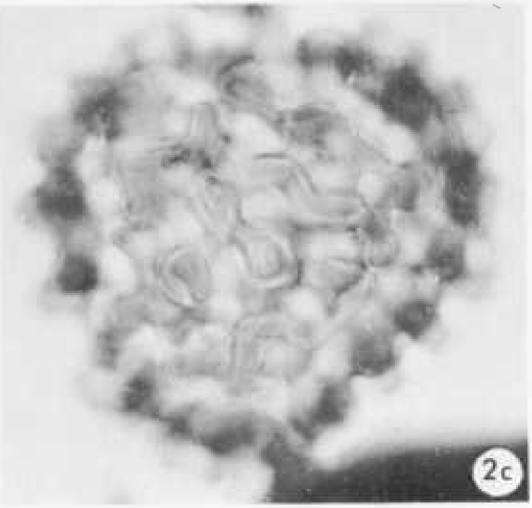
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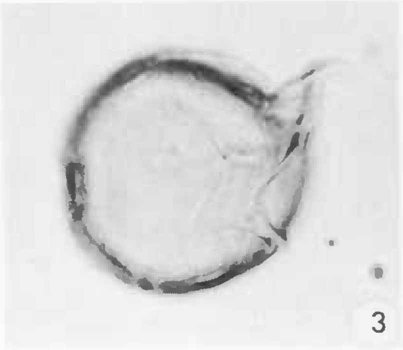
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PLATE 20

(All figures × 1000)

Figure 1. *Perotriletes striatus* Cookson and Dettmann

Slide St. 26A, coordinates 41–108.6. 1a, medium focus of equatorial view, perine completely encloses central body projecting outwards from the proximal surface. 1b, high focus showing the granular nature of the inner layer.

Figure 2. *Pilosisporites brevipapillosus* Couper

Slide L1-41A, coordinates 29.2–119.2. 2a, high focus on proximal surface. 2b, low focus on distal surface.

Figure 3. *Pilosisporites trichopapillosus* (Thiergart)

Slide L2-58B, coordinates 21.7–118.8, high focus on proximal surface, spines denser in the apical areas.

Figures 4, 5. *Psilatriletes circumundulatus*, n. sp.

Fig. 4. Holotype, slide L1-22B, coordinates 25.2–121.8. 4a, high focus on proximal surface. 4b, medium focus showing fine radiating folds and undulating margin. Notice how the ektexine tends to separate from the endexine along the margin. 4c, low focus on distal surface.

Fig. 5. Slide D480A (well 13), coordinates 26–120.2, medium focus. Another specimen in which separation of the two layers is more complete.

Figures 6, 7. *Psilatriletes radiatus*, n. sp.

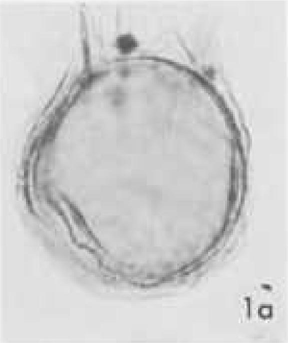
Fig. 6. Slide St. 12A, coordinates 38.5–110.1, high focus on proximal surface.

Fig. 7. Holotype, slide St. 11B, coordinates 35.5–123.4, high focus on proximal surface, fine radiating folds can be seen near the margin.

Figure 8. *Taurocusporites reduncus* (Bolkhovitina)

Slide St. 26A, coordinates 27.2–114.5, high focus on proximal surface; exine of the proximal surface smooth and relatively thin; polar thickening intact.

PLATE 20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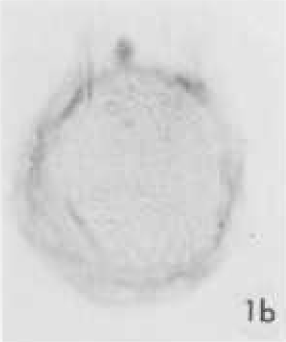
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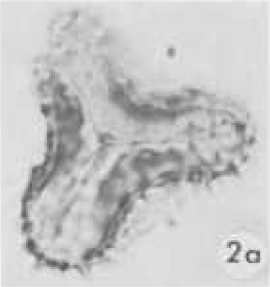
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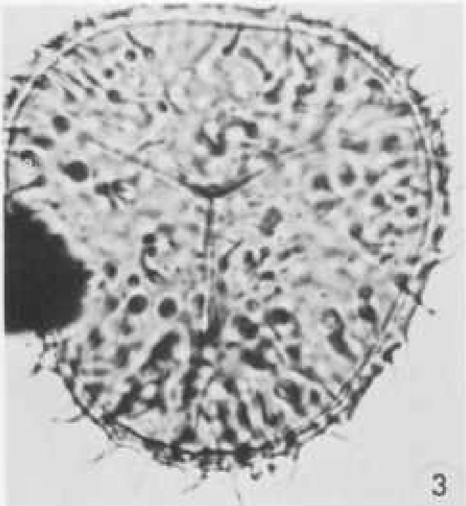
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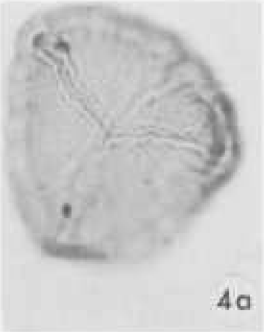
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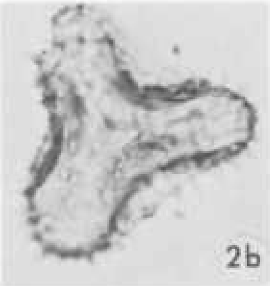
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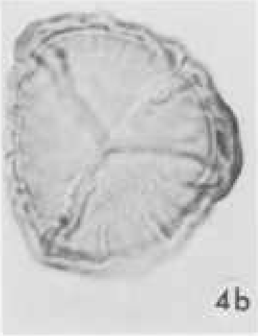
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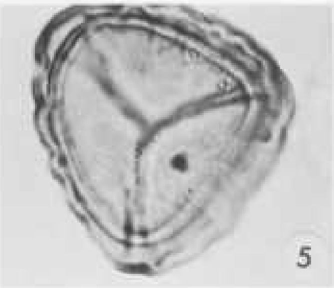
4c


5


6


7


8

PLATE 21

(All figures × 1000)

Figure 1. *Taurocusporites reduncus* (Bolkhovitina)

Slide L2-74A, coordinates 16.4–123.6. 1a, low focus on proximal surface. 1b, high focus on distal surface, central thickening composed of three distinct bodies.

Figures 2, 3. *Reticulatisporites arcuatus*, n. sp.

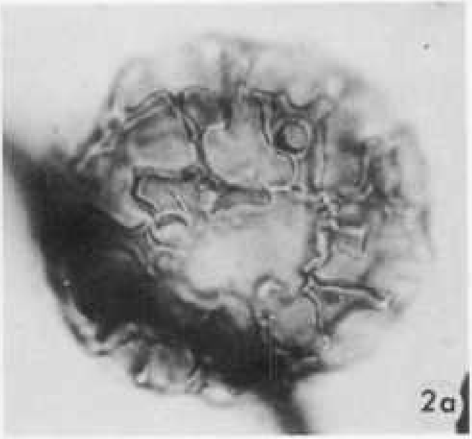
Fig. 2. Holotype, L1-22B, coordinates 33.3–109.4. 2a, high focus showing variable thickness of the muri and shape of the lumina. 2b, medium focus, trilete mark obscure.

Fig. 3. Slide L1-22B, coordinates 18.9–128.1. 3a, high focus, another specimen with slightly thinner muri. 3b, medium focus.

PLATE 21


1a


1b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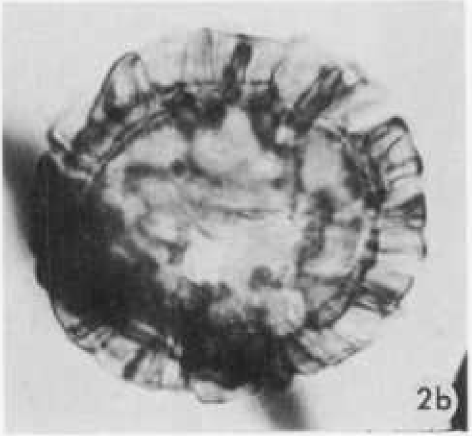
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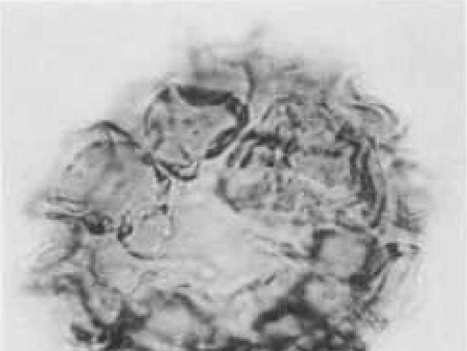
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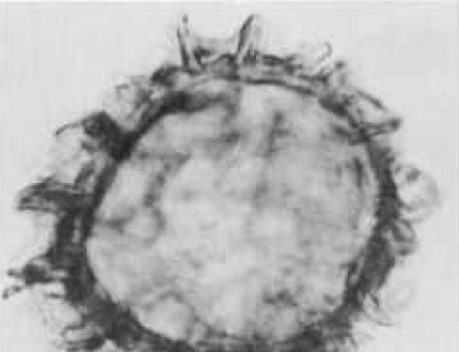

3b

PLATE 22

(All figures × 1000)

Figure 1. *Taurocusporites segmentatus* Stover

Slide L1-103A, coordinates 19.2–124.6. 1a, low focus on proximal surface. 1b, high focus on distal surface.

Figures 2, 3. *Taurocusporites spackmani*, n. sp.

Fig. 2. Holotype, slide L2-61A, coordinates 29.1–109.1. 2a, high focus on distal surface, large polar tubercle clearly seen, distally placed marginal tubercles slightly out of focus. 2b, medium focus showing gaping trilete mark.

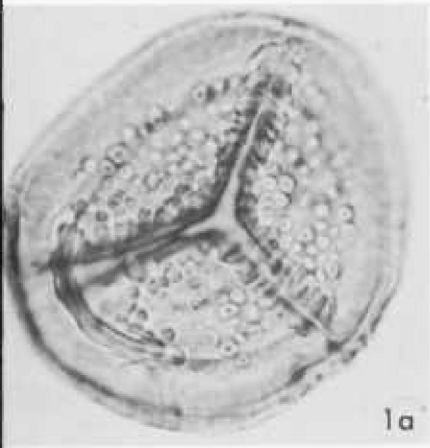
Fig. 3. Slide L2-58B, coordinates 34.8–113.6, medium focus of slightly oblique specimen.

Figure 4. *Trilites verrucatus* Couper

Slide L2-74A, coordinates 38–125, low focus on proximal surface.

Figure 5. *Trilobosporites apibaculatus*, n. sp.

Slide St. 10B, coordinates 20–113.2, high focus on proximal surface.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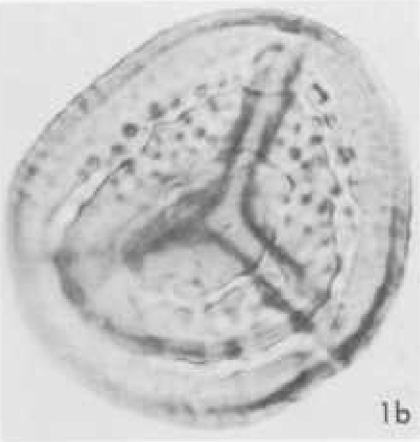
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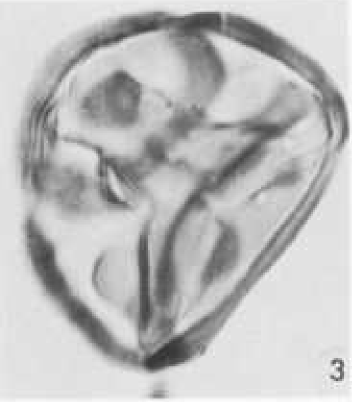
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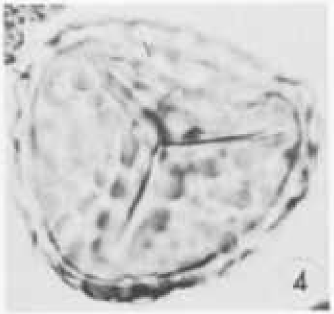
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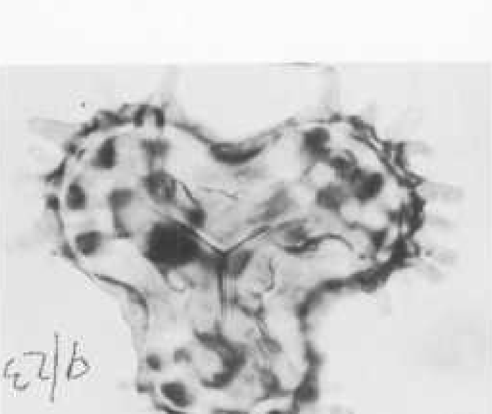
2b



5

PLATE 23

(All figures × 1000)

Figure 1. *Trilobosporites apibaculatus*, n. sp.

Holotype, slide St. 10B, coordinates 30.7–126. 1a, high focus on proximal surface, bacula more numerous in the apical areas both on the proximal and distal surface. 1b, low focus on distal surface.

Figure 2. *Trilobosporites crassus*, n. sp.

Holotype, slide St. 30A, coordinates 40–108. 2a, high focus on proximal surface. Notice the variable thickness of the exine along the equator and the concentration of sculptural elements in the apical areas. 2b, low focus on distal surface.

Figures 3, 4. *Trilobosporites humilis* Delcourt and Sprumont

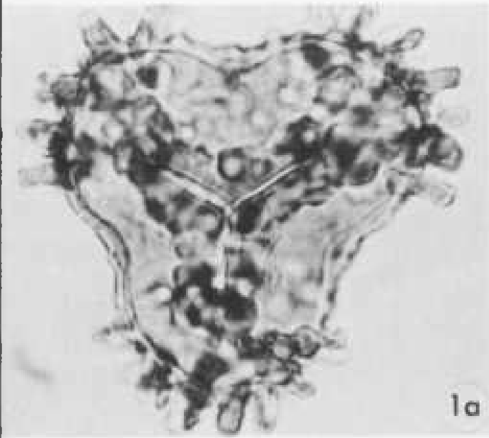
Fig. 3. Slide L1-69A, coordinates 24.2–113.5, high focus on proximal surface. Notice the uniformly granular ornamentation.

Fig. 4. Slide L2-49A, coordinates 26.8–128.4. 4a, high focus on distal surface; crowded verrucae almost cover the distal surface. 4b, low focus on proximal surface, margo composed of verrucae.

Figure 5. *Trilobosporites marylandensis*, n. sp.

Holotype, slide St. 34A, coordinates 19.6–118.1. 5a, high focus on proximal surface. 5b, low focus on distal surface.

PLATE 23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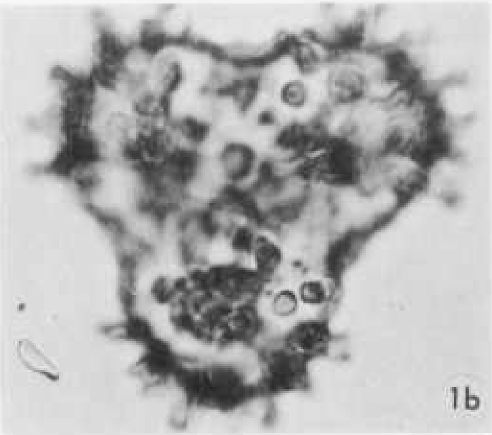
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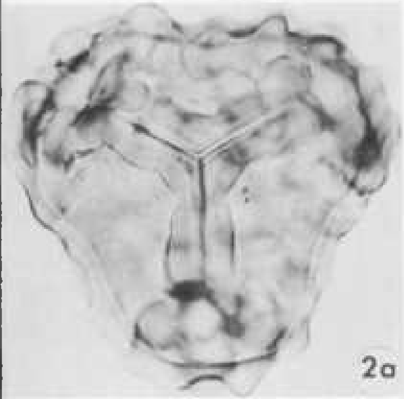
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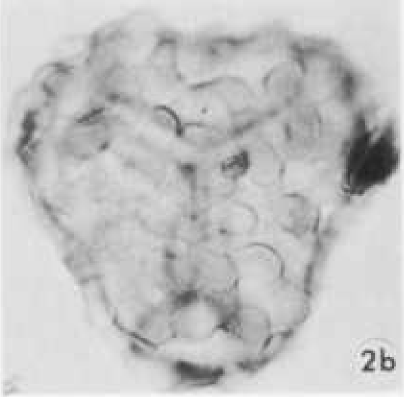
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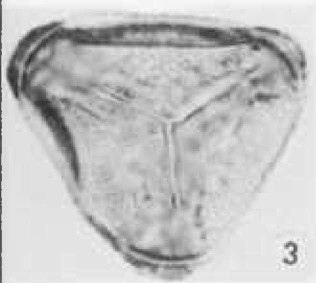
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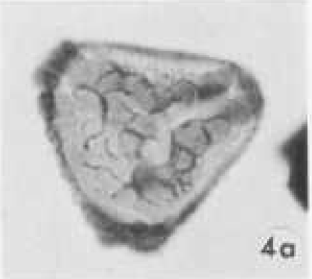
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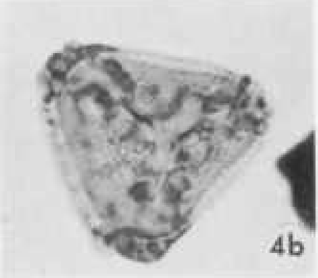
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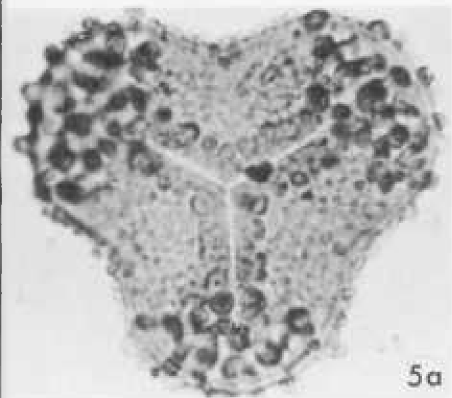
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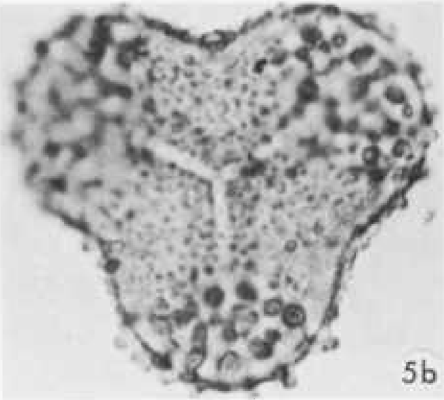
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PLATE 24

(All figures × 1000)

Figure 1. *Undulatisporites undulapolus*, n. sp.

Holotype, slide St. 11B, coordinates 29.5–112.7, medium focus.

Figure 2. *Inaperturopollenites pseudoreticulatus*, n. sp.

Holotype, slide L1-103A, coordinates 18.5–120.1, high focus, negative reticulum formed by interconnected canals.

Figures 3–5. *Reticulatasporites dupliexinous* n. sp.

Fig. 3. Slide St. 49A, coordinates 33.8–127, low focus, small specimen.

Fig. 4. Holotype, slide St. 17A, coordinates 27.2–121.7, medium focus.

Fig. 5. Slide L1-103A, coordinates 20.3–124.1, high focus; wrinkled nature of the ektexine is shown.

Figures 6–8. *Laevigatosporites gracilis* Wilson and Webster

Fig. 6. Slide St. 44B, coordinates 32.6–118.5, medium focus slightly oblique specimen.

Fig. 7. Slide St. 44B, coordinates 34–118.2, medium focus, equatorial view.

Fig. 8. Slide St. 12A, coordinates 20–122, medium focus of larger specimen.

Figures 9–11. *Monosulcites chaloneri*, n. sp.

Fig. 9. Holotype, slide St. 38B, coordinates 33.9–128.7, medium focus, narrow lips border the sulcus.

Fig. 10. Slide St. 38A, coordinates 26.8–115.2, medium focus.

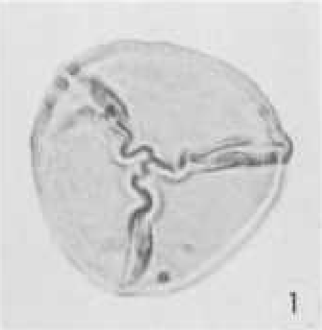
Fig. 11. Slide St. 38A, coordinates 21.1–113.1, medium focus, slightly larger and more circular specimen than the holotype.

Figures 12, 13. *Peromonolites allensis*, n. sp.

Fig. 12. Slide St. 10B, coordinates 30.1–108.5, high focus on proximal surface, polar view, ektexine extremely wrinkled and covering the monolete mark.

Fig. 13. Holotype, slide St. 6A, coordinates 23–108. 13a, high focus, proximal-oblique view. 13b, low focus, distal-oblique view.

PLATE 24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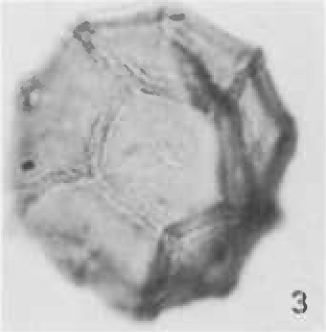
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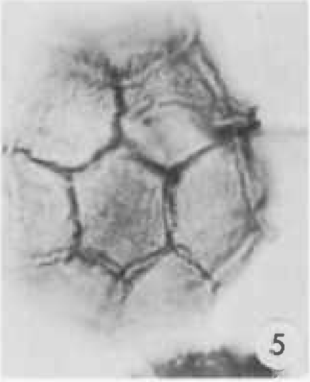
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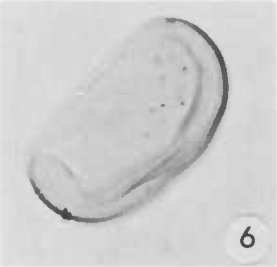
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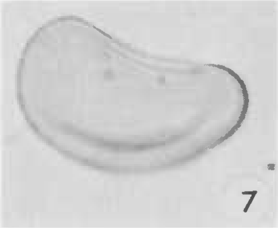
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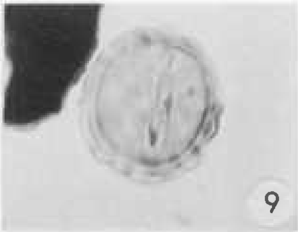
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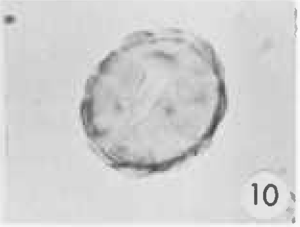
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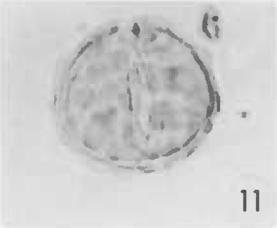
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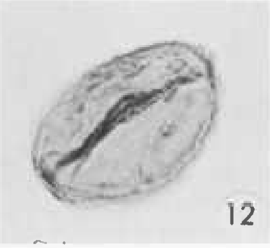
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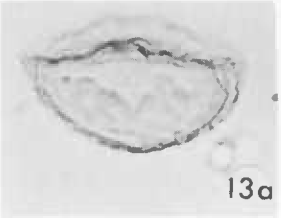
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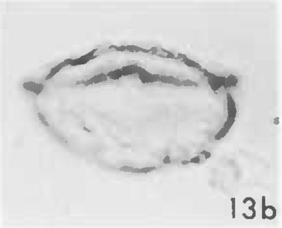
13b

PLATE 25

(All figures × 1000)

Figures 1, 2. *Vitreisporites pallidus* (Reissinger), nov. comb.

Fig. 1. Slide St. 11B, coordinates 26.1–124.2, polar view, note the reduced ornamentation of the central body.

Fig. 2. Slide St. 35A, coordinates 29.4–117, slightly larger specimen.

Figures 3, 4. *Entylissa nitidus* Balme

Fig. 3. Slide St. 11B, coordinates 32–115.1, this specimen shows the widening of the sulcus at the ends.

Fig. 4. Slide St. 34A, coordinates 19.4–108.6, in this specimen the sides of the sulcus have been pushed over each other.

Figures 5, 6. *Monosulcites epakros*, n. sp.

Fig. 5. Holotype, slide St. 16A, coordinates 40.4–108.6, pointed ends are typical for this species.

Fig. 6. Slide St. 39A, coordinates 45.3–112, a smaller specimen than the holotype.

Figure 7. *Monosulcites glottus*, n. sp.

Holotype, slide St. 26A, coordinates 37.9–118.3, distal polar view, sides of the grain are characteristically folded over.

Figure 8. *Monosulcites sp.*

Slide St. 43A, coordinates 23.6–111.2, distal polar view; note the flap-like extension of one side of the sulcus near the pole.

Figures 9, 10. *Araucariacites australis* Cookson

Fig. 9. Slide St. 12A, coordinates 26.5–114.2, medium focus; note the thinner exine in the polar region which shows up as a lighter area.

Fig. 10. Slide L2-49A, coordinates 17.5–118.4, smaller specimen.

PLATE 25


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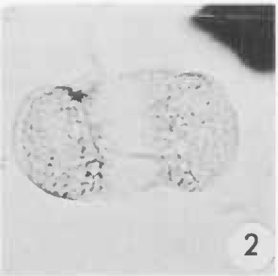
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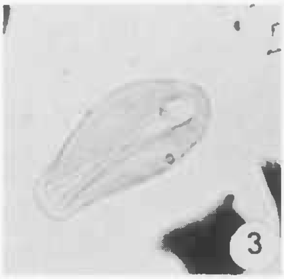
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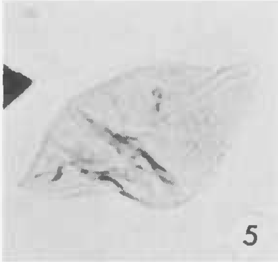
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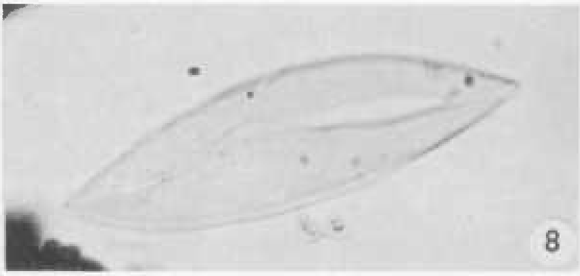
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9


10

PLATE 26

(All figures × 1000)

Figures 1, 3. *Abietineaepollenites microreticulatus* Groot and Penny

Fig. 1. Slide St. 12A, coordinates 25.6–115.2, lateral view, outline of the bladders blends into that of the body.

Fig. 3. Slide St. 26A, coordinates 27.1–121.8, high focus on distal surface.

Figure 2. *Abietineaepollenites minimus*, n. sp.

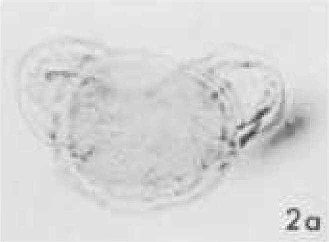
Holotype, slide L1-41A, coordinates 28.4–113.1, lateral view. 2a, low focus. 2b, medium focus, showing the ektexine absent on the distal surface between the bladders. 2c, high focus shows the finely rugulate nature of the proximal cap.

Figure 4. *Abietineaepollenites sp.*

Slide St. 12A, coordinates 24–114.5, lateral view.

PLATE 26

1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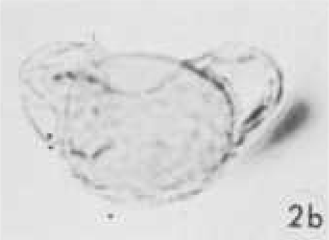
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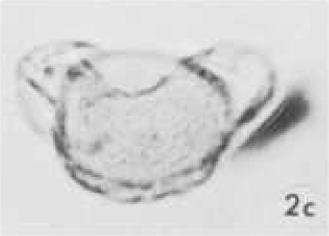
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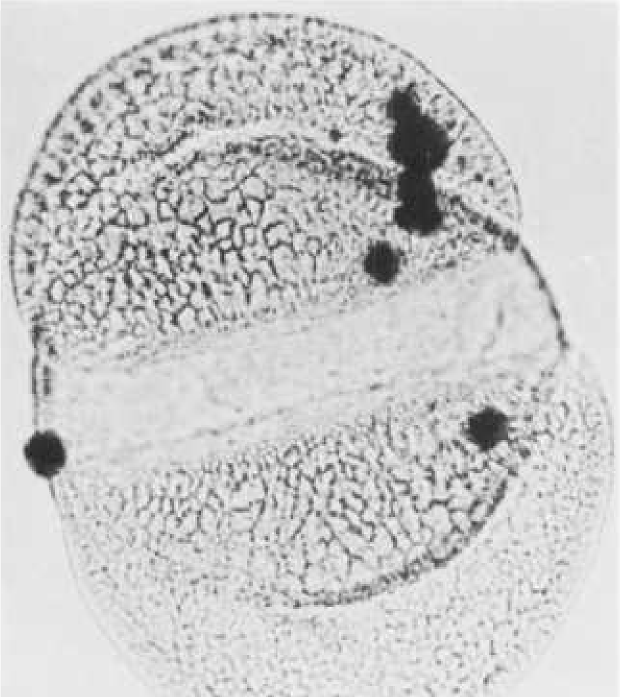
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4

PLATE 27

(All figures × 1000)

Figure 1. *Abietineaepollenites sp.*

Slide St. 12A, coordinates 25.9–113. 1a, high focus showing the ornamentation of the bladders. 1b, medium focus, finely reticulate ornamentation of the proximal cap.

Figure 2. *Parvisaccites radiatus* Couper

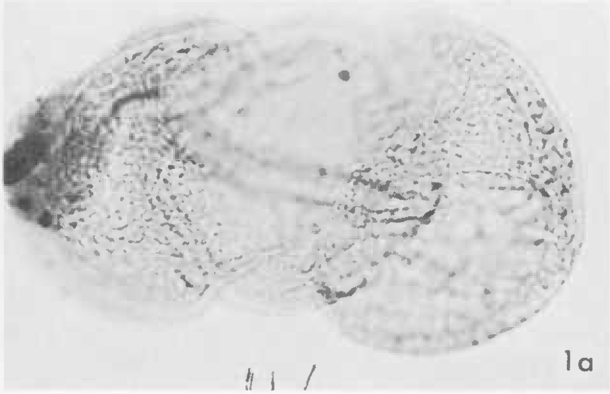
Slide L2-49B, coordinates 26.2–129.2. 2a, medium focus showing the finely rugulate ornamentation of the central body. 2b, high focus, distal, showing the radial thickenings of the bladders.

Figures 3, 4. *Alisporites* cf. *bilateralis* Rouse

Fig. 3. Slide St. 43A, coordinates 27.2–108, polar view, medium focus, bladders laterally disposed.

Fig. 4. Slide L1-69A, coordinates 27.2–111.8, another specimen.

PLATE 27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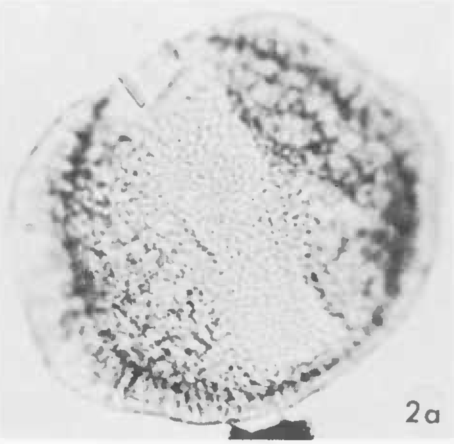
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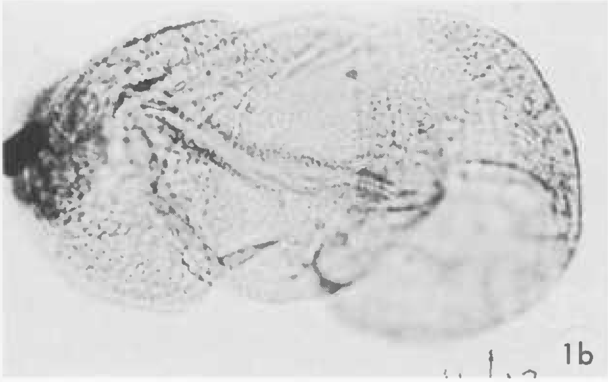
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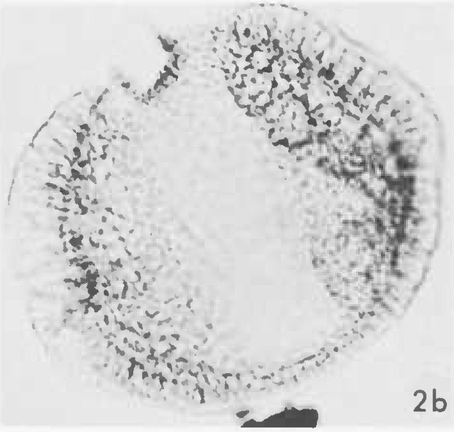
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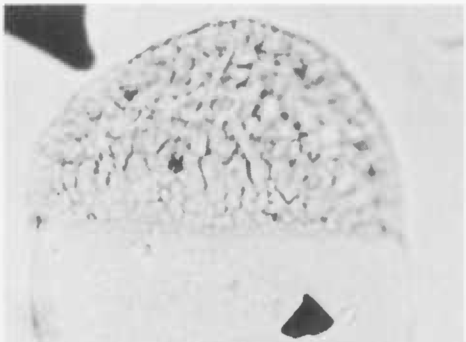
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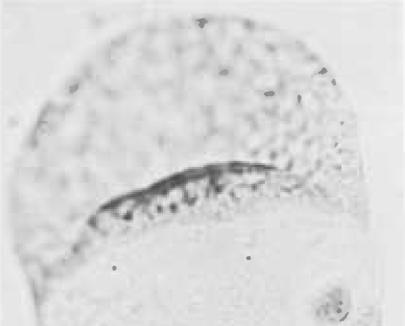
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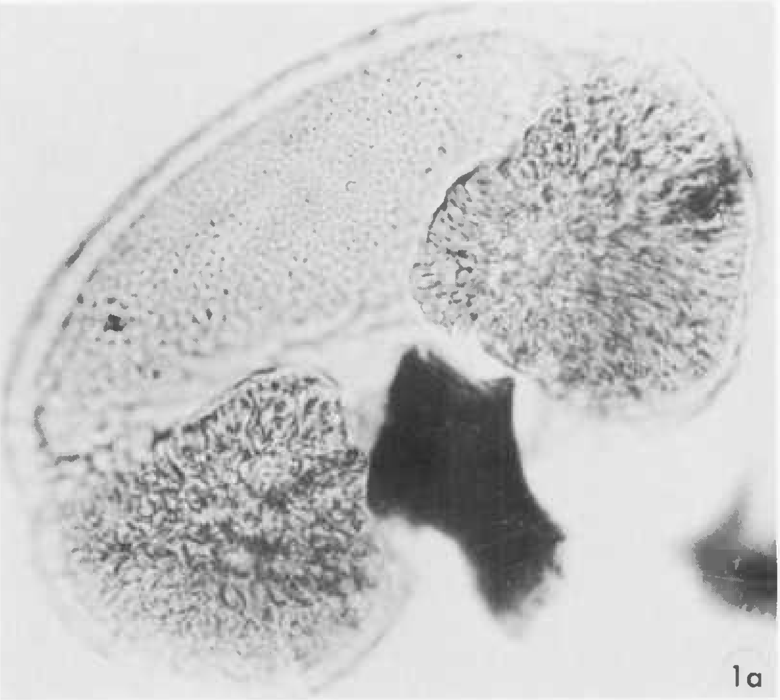
PLATE 28

(All figures × 1000)

Figure 1. *Parvisaccites amplus*, n. sp.

Holotype, slide St. 10A, coordinates 48.5–128.5, lateral view. 1a, high focus, looking down on the radial projections; microrugulate character of the central body can be seen. 1b, medium focus showing radial thickenings of the bladders and columellate structure of the proximal exine.



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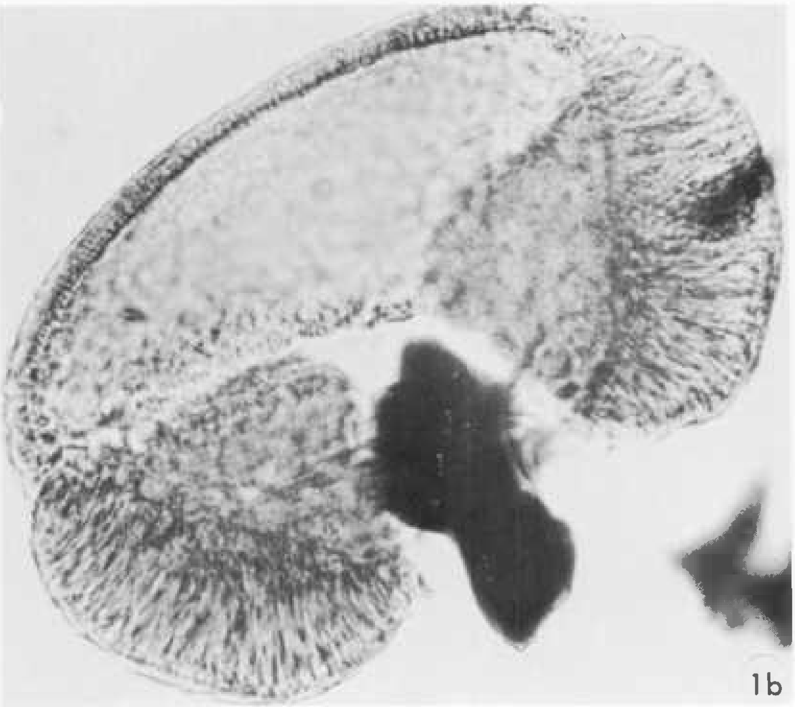


1b

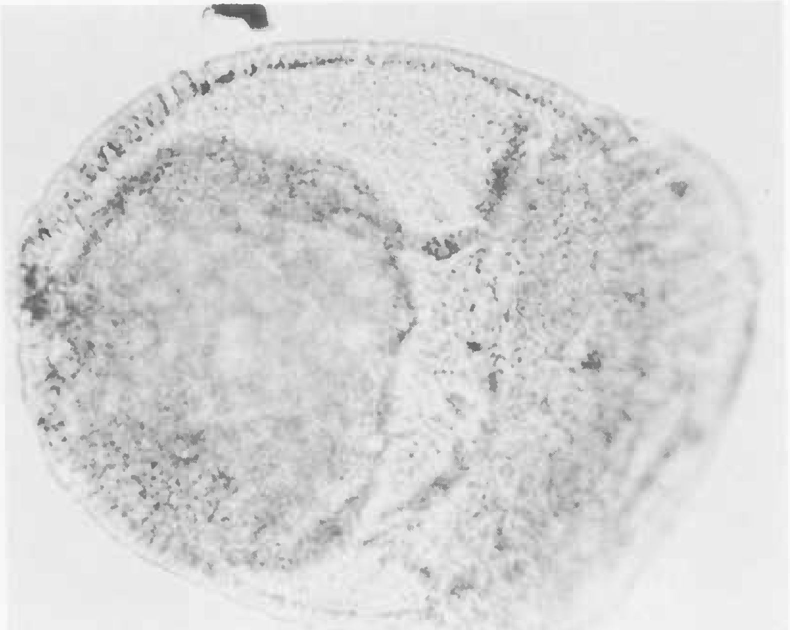
PLATE 29

(All figures × 1000)

Figure 1. *Parvisaccites amplus*, n. sp.

Slide St. 10B, coordinates 21.9–114.5, distal polar view. 1a, high focus on the surface of the bladders. 1b, medium focus showing the ornamentation of the central body.

1a



1b

PLATE 30

(All figures × 1000)

Figures 1, 2. *Parvisaccites rugulatus*, n. sp.

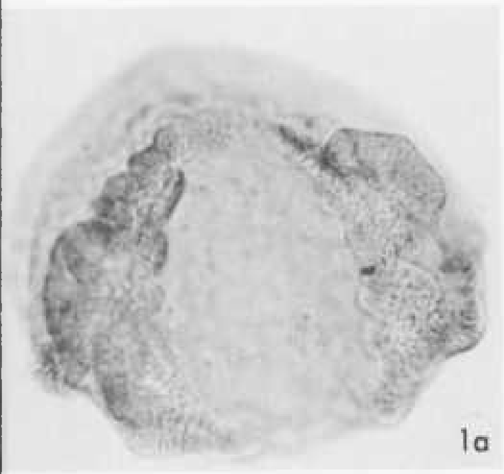
Fig. 1. Holotype, slide St. 41A, coordinates 39.1–115.7, distal polar view. 1a, high focus showing the structure of the bladders. 1b, medium focus, distal surface of the central body characteristically corrugated.

Fig. 2. Slide St. 11B, coordinates 37.5–123.9, distal polar view. 2a, high focus on the bladders. 2b, low focus on the central body shows the rugulate nature of the exine.

Figure 3. *Phyllocladidites microreticulatus*, n. sp.

Holotype, slide L1-22A, coordinates 32.3–115.9, lateral view. 3a, medium focus. 3b, high focus shows the scabrate ornamentation of the bladders and central body. Note the rudimentary veil-like nature of the bladders.

PLATE 30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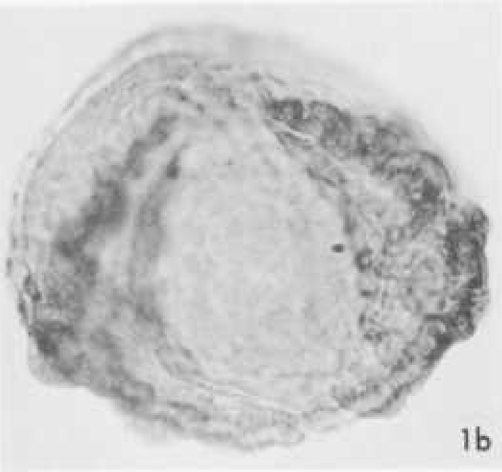
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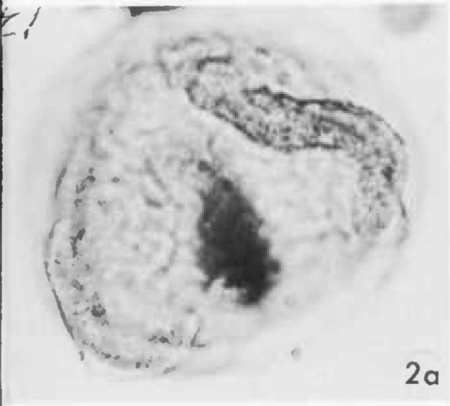
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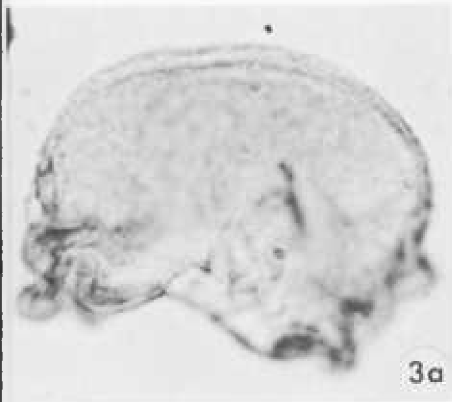

3a


3b

PLATE 31

(All figures × 1000)

Figure 1. *Phyllocladidites microreticulatus*, n. sp.

Slide St. 38B, coordinates 37.8–111.5, distal polar view of a smaller specimen. 1a, high focus on the bladders. 1b, medium focus showing the ornamentation of the central body.

Figures 2, 3. *Pinuspollenites spherisaccus*, n. sp.

Fig. 2. Slide L1-50B, coordinates 35.5–110.4, lateral view. Note the strong re-entrant angle where the proximal roots of the bladders merge with the central body.

Fig. 3. Holotype, slide L2-58B, coordinates 31–107.8, lateral view. 3a, high focus on the bladder showing the coarse infrareticulate ornamentation. 3b, medium focus showing the finer reticulum of the central body.

Figure 4. *Platysaccus megasaccus*, n. sp.

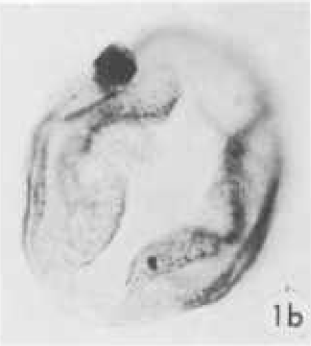
Holotype, slide L2-49A, coordinates 22.8–111, distal polar view.

Figure 5. *Podocarpidites epistratus*, n. sp.

Holotype, slide L1-69A, coordinates 23–124.5, distal polar view. 5a, high focus on the bladders. Note obscure infrareticulum and radial orientation of the muri near the attachment to the central body. 5b, low focus showing the microrugulate sculpture of the proximal cap.

PLATE 31


1a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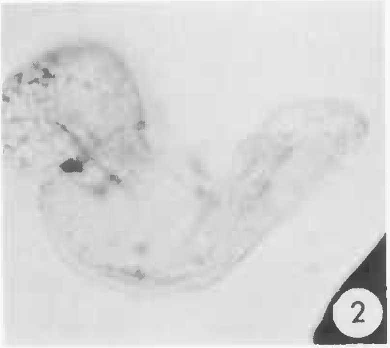

2


3a


3b


4


5a

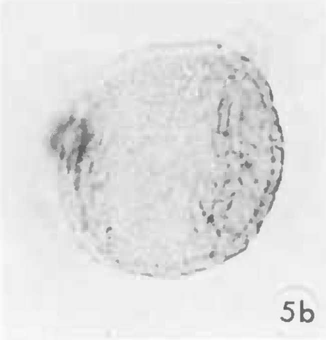

5b

PLATE 32

(All figures × 1000)

Figures 1, 2. *Podocarpidites potomacensis*, n. sp.

Fig. 1. Holotype, slide L1-50A, coordinates 26.1–111.8, distal polar view. 1a, high focus on the coarse infrareticulum of the bladders. 1b, medium focus. Note the presence of a marginal crest.

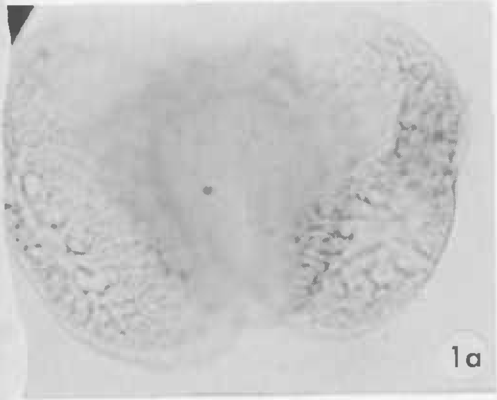
Fig. 2. Slide L2-49A, coordinates 18.5–115, distal polar view. 2a, high focus on the bladders, infrareticulum finer than in the holotype, 2b, medium focus showing the marginal crest.

Figures 3, 4. *Podocarpidites radiatus*, n. sp.

Fig. 3. Holotype, slide St. 10B, coordinates 27.5–114.8, distal polar view. Note strong radial alignment of the bladder thickenings near their attachment to the body.

Fig. 4. Slide St. 10A, coordinates 37–112.6, distal polar view. 4a, high focus on bladder ornamentation. 4b, medium focus showing the radially aligned bladder thickenings.

PLATE 32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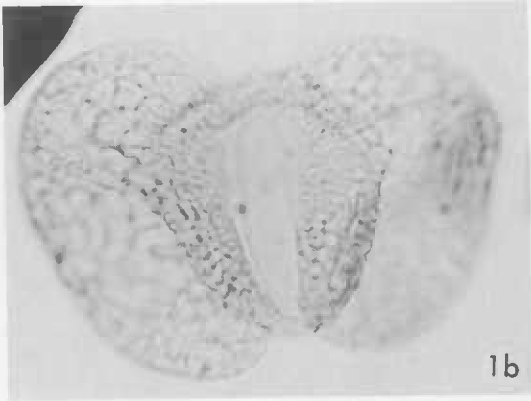
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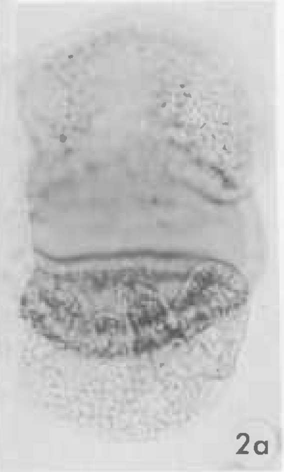
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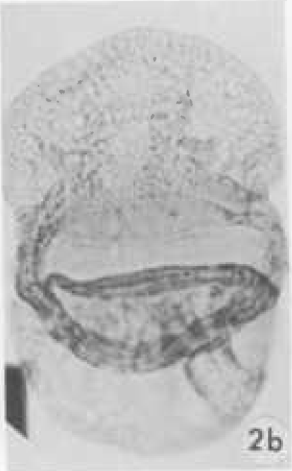
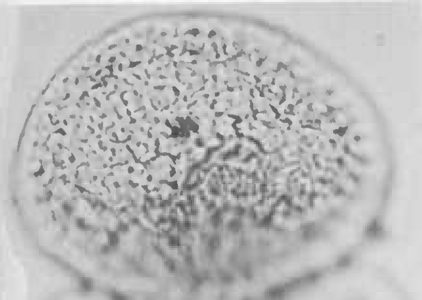

2b


3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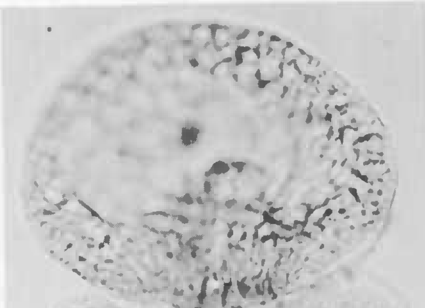
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PLATE 33

(All figures × 1000)

Figures 1, 2. *Rugubivesiculites reductus* Pierce

Fig. 1. Slide L2-49A, coordinates 31.7–110, proximal polar view. 1a, high focus on the surface of the polar cap; note the strongly corrugated character of the proximal cap. 1b, medium focus showing the ornamentation of the bladders.

Fig. 2. Slide L2-49B, coordinates 28–111.2, lateral view. 2a, high focus on the proximal cap. 2b, medium focus. Note that the corrugations on the proximal cap become more intense towards the margins; this is a typical characteristic of this species.

PLATE 33


1a


2a


2b

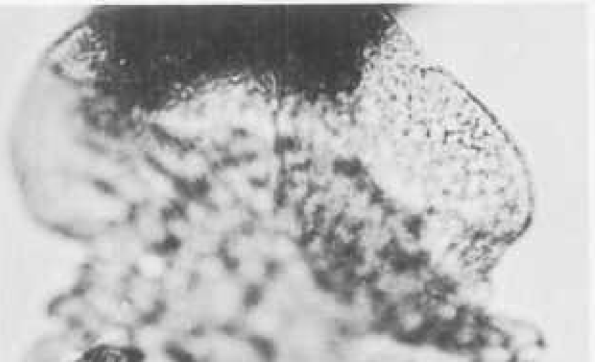

1b

PLATE 34

(All figures × 1000)

Figure 1. *Tsugaepollenites mesozoicus* Couper

Slide St. 11B, coordinates 38.1–112.4, proximal polar view. 1a, high focus, proximal surface depressed. 1b, medium focus, shows the corrugate nature of the ektexine.

Figures 2, 3. *Circulina parva*, n. sp.

Fig. 2. Slide St. 34A, coordinates 40.8–115, distal polar view, exine smooth; note slight suggestion of equatorial striations subtending the furrow.

Fig. 3. Holotype, slide St. 17B, coordinates 29.8–110, distal polar view; note triangular opening on proximal side.

Figures 4–6. *Classopollis torosus* (Reissinger)

Fig. 4. Slide St. 30A, coordinates 36.9–119.1, oblique view showing circum-equatorial striations and distal pore.

Fig. 5. Slide St. 11B, coordinates 20.7–122.7, proximal polar view. 5a, high focus on proximal surface; rare specimen showing a trilete mark. 5b, medium focus.

Fig. 6. Slide D 710A (well 13), coordinates 36.5–129.4; tetrad shows the distal position of the pore.

Figures 7–9. *Decussosporites microreticulatus*, n. sp.

Fig. 7. Holotype, slide St. 31A, coordinates 29.2–115.1, proximal polar view. 7a, high focus showing the proximal furrow extending the whole width of the grain. 7b, low focus on the distal surface, longitudinal sulcus visible.

Fig. 8. Slide St. 28A, coordinates 23–121.5, proximal view showing the rim enclosing the sulcus; note the widening of the sulcus at the ends. Smooth outline indicates the reticulation is formed below the surface as in other gymnosperms.

Fig. 9. Slide St. 31A, coordinates 32.8–120.3, distal view of another specimen.

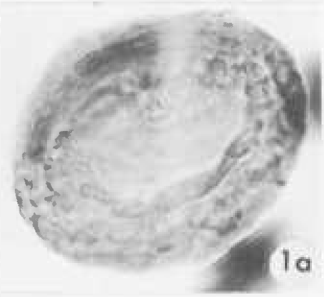
Figures 10–12. *Eucommiidites troedssonii* Erdtman

Fig. 10. Slide St. 31A, coordinates 21.5–110.7, polar view.

Fig. 11. Slide St. 36A, coordinates 26.3–130.9, proximal polar view. 11a, high focus on proximal surface showing the two marginal furrows. 11b, low focus on the distal surface showing the single distal sulcus.

Fig. 12. Slide L2-49B, coordinates 34–108.4, equatorial view showing the disposition of three furrows around the equator. Note the thinning of the exine in the furrows.

PLATE 34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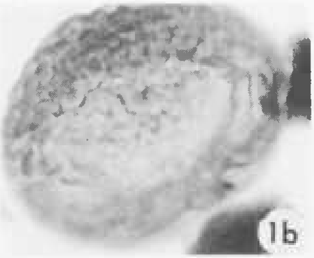
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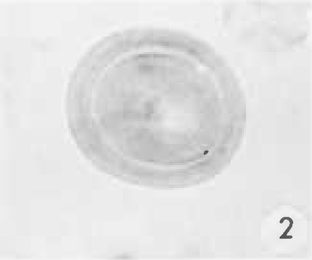
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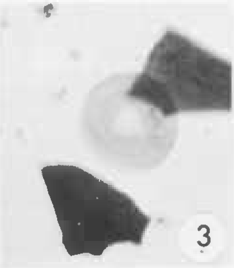
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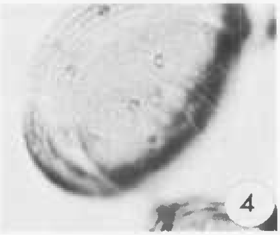
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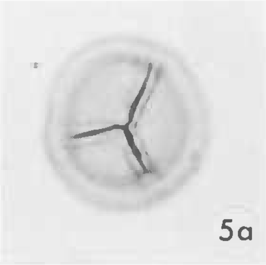
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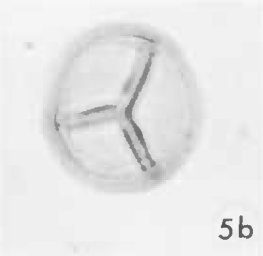
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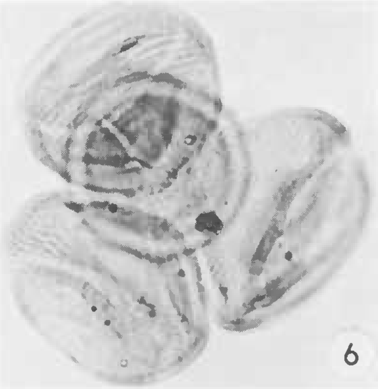
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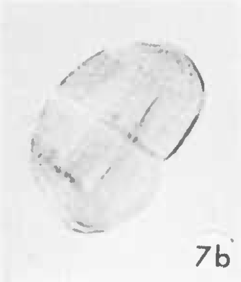
7a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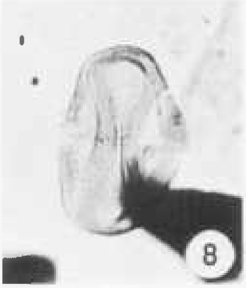
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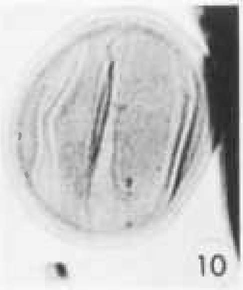
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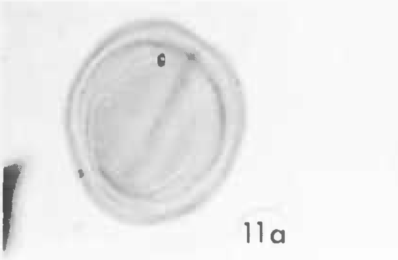
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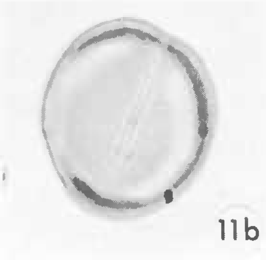
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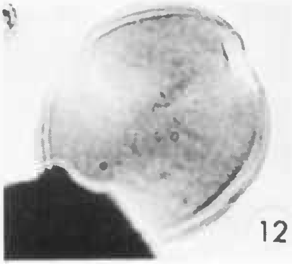

12

PLATE 35

Figure 1. *Eucommiidites troedssonii* Erdtman

1a, Seed containing pollen in the micropylar canal, × 40. 1b, higher magnification; the pollen is in the micropylar canal and pollen chamber; rectangular cells are formed by the outer cuticular layer, × 551. 1c, close-up showing *E. troedssonii*, × 1136.

Figures 2–4. *Exesipollenites tumulus* Balme

Fig. 2. Slide St. 31B, coordinates 34.6–128, typical specimen. × 1000.

Fig. 3. Slide St. 28A, coordinates 40.5–117.5, proximal view showing a triradiate scar, × 1000.

Fig. 4. Slide St. 28A, coordinates 22.6–124.9, × 1000. 4a, high focus on the proximal surface showing a triradiate scar. 4b, medium focus on the distal pore.

Figures 5, 6. *Inaperturopollenites dubius* (Potonié and Venitz)

Fig. 5. Slide D 730A (well 13), coordinates 29.7–130.2, exine thin and characteristically wrinkled, × 1000.

Fig. 6. Slide L1-69B, coordinates 30.2–110.5, specimen is split, × 1000.

Figures 7, 8. *Perinopollenites elatoides* Couper

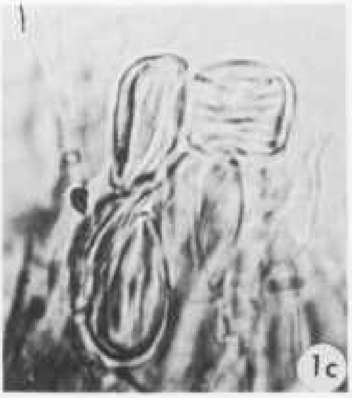
Fig. 7. Slide St. 11B, coordinates 38.2–119, medium focus, note the finely scabrate character of the outer layer that forms the zone, × 1000.

Fig. 8. Slide St. 43A, coordinates 19.5–116, perine is highly folded, × 1000.

PLATE 35


1a


1b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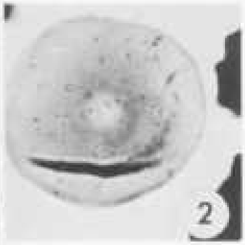
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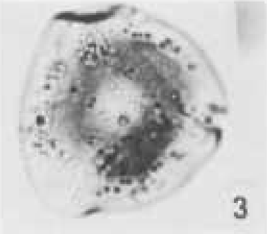
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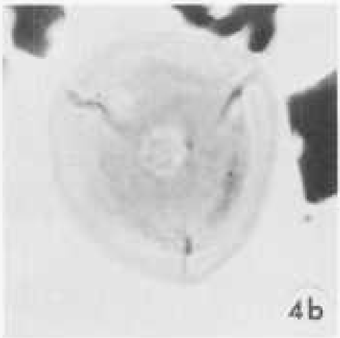
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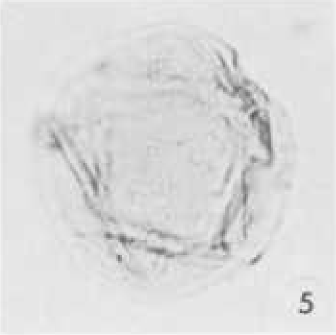
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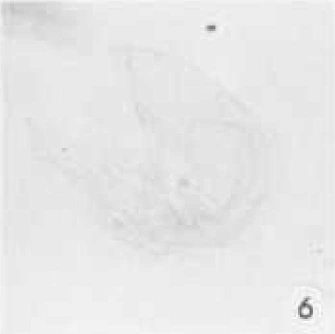

6


7


8

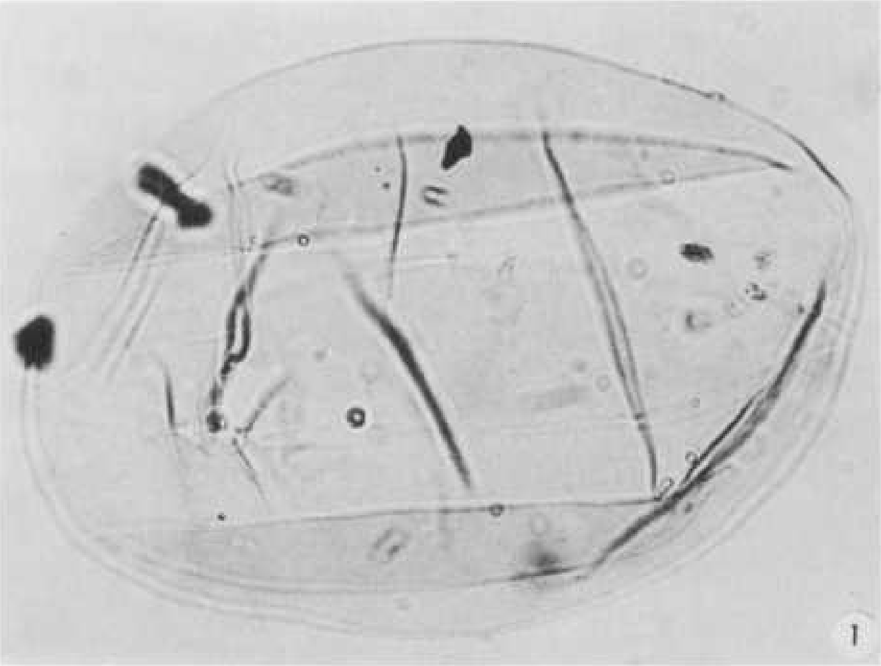
PLATE 36

(All figures × 1000)

Figures 1, 2. *Laricoidites gigantus*, n. sp.

Fig. 1. Holotype, slide St. 12A, coordinates 32.2–120.5, similar to the pollen of *Larix*.

Fig. 2. Slide St. 43A, coordinates 35–112.5, larger specimen than the holotype.



1

2

PLATE 37

(All figures × 1000)

Figures 1, 2. *Laricoidites magnus* (Potonié)

Fig. 1. Slide St. 12A, coordinates 33–114.3, exine thin and easily folded.

Fig. 2. Slide St. 6A, coordinates 23.2–121.2; this specimen is circular and not folded.

Figures 3–6. *Spheripollenites perinatus*, n. sp.

Fig. 3. Holotype, slide St. 31B, coordinates 30.4–130, equatorial view which shows the ektexine covering the lower two-thirds of the grain; the ektexine is absent on the distal surface which contains a slightly protruding ligula.

Fig. 4. Slide St. 31A, coordinates 41.3–111, polar view; ektexine loosely fitting, pore visible.

Fig. 5. Slide St. 10A, coordinates 42–111, specimen which does not have the outer layer, equatorial view.

Fig. 6. Slide St. 30A, coordinates 32.5–119.1, pore expressed as an indentation, outer layer missing.

Figures 7, 8. *Zonalapollenites dampieri* Balme

Fig. 7. Slide L2-49A, coordinates 29.8–121.5, typical specimen with a slightly undulating margin.

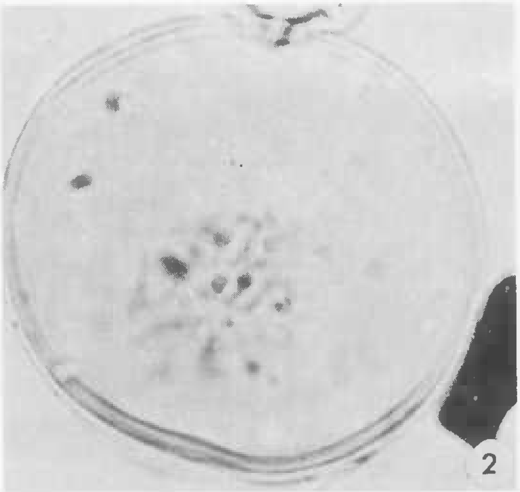
Fig. 8. Slide St. 30B, coordinates 33.1–113.8, marginal undulations on this specimen are pronounced.

Figure 9. *Zonalapollenites trilobatus* Balme

Slide St. 38A, coordinates 40.6–119.5. 9a, high focus, outer layer has formed three distinct bladders along the margin. 9b, medium focus showing the surface of the central body.

PLATE 37


1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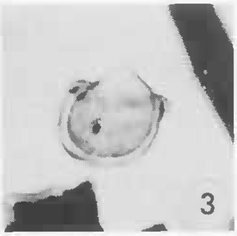
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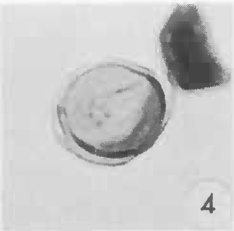
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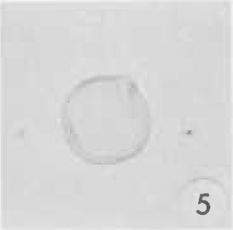
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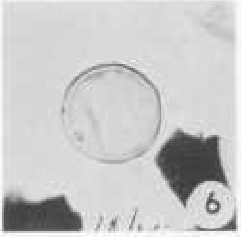
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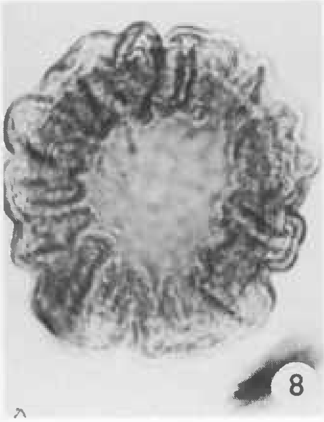

8


9a


9b

PLATE 38

(All figures × 1000)

Figures 1, 2. *Ephedripites multicostatus*, n. sp.

Fig. 1. Slide St. 26A, coordinates 24.1–110.1, specimen slightly smaller than the holotype.

Fig. 2. Holotype, slide St. 30A, coordinates 35.6–120.3, numerous narrow and closely spaced muri are typical of this species.

Figure 3. *Ephedripites virginiaensis*, n. sp.

Holotype, slide St. 26A, coordinates 39.8–109.1, note thickening at the ends.

Figures 4, 5. *Ephedripites patapscoensis*, n. sp.

Fig. 4. Slide St. 30B, coordinates 26.5–118.6, specimen slightly smaller than the holotype, muri fused at the ends.

Fig. 5. Holotype, slide L2-58A, coordinates 25.5–117; notice knob-like structure showing at one end.

Figures 6, 7. *Retitricolpites georgensis*, n. sp.

Fig. 6. Holotype, slide St. 29B, coordinates 22.2–116.5, equatorial view. 6a, high focus. 6b, medium focus; note reduction in the size of the lumina towards the poles.

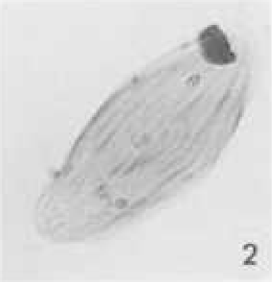
Fig. 7. Slide L1-61B, coordinates 16.6–125.2, larger specimen than the holotype.

Figure 8. *Retitricolpites geranioides* (Couper), nov. comb.

Slide St. 29B, coordinates 20.9–123.8, equatorial view. 8a, high focus, muri pilate. 8b, medium focus.

PLATE 38


1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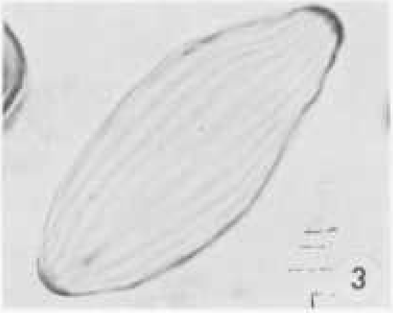
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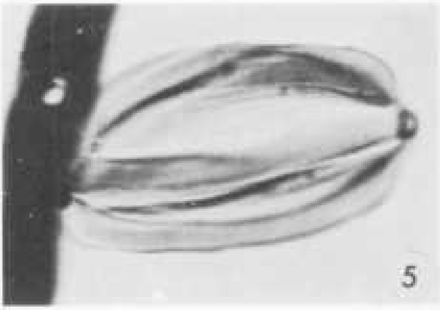

5


6a


7


6b


8a

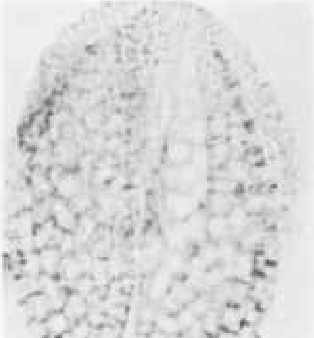

8b

PLATE 39

(All figures × 1000)

Figure 1. *Retitricolpites geranioides* (Couper), nov. comb.

Slide St. 17A, coordinates 22.3–111.8, polar view. 1a, medium focus; notice bridges connecting the pila. 1b, high focus; size of lumina decrease towards the poles.

Figures 2, 3. *Retitricolpites vermimurus*, n. sp.

Fig. 2. Slide St. 29A, coordinates 21.6–113.1, equatorial view. 2a, medium focus. 2b, low focus shows winding character of the muri.

Fig. 3. Holotype, slide St. 29A, coordinates 21.1–112.6, polar view. 3a, medium focus. 3b, high focus showing vermicular muri.

Figures 4, 5. *Retitricolpites virgeus* (Groot, Penny and Groot), nov. comb.

Fig. 4. Slide St. 11A, coordinates 41.1–110.7, polar view, colpi gaping widely. 4a, medium focus. 4b, high focus.

Fig. 5. Slide St. 29C, coordinates 35.6–110, polar view. 5a, high focus. 5b, medium focus.

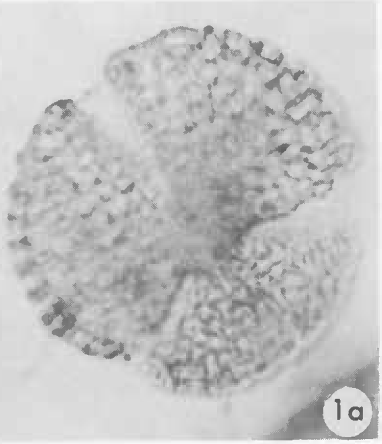
Figure 6. *Tricolpopollenites crassimurus* Groot and Penny

Slide St. 43A, coordinates 23.4–123.5, equatorial view. 6a, medium focus. 6b, high focus shows very fine reticulum.

Figure 7. *Tricolpopollenites micromunus* Groot and Penny

Slide St. 29B, coordinates 20.9–123, polar view. 7a, medium focus; note double-layered exine. 7b, high focus showing retipilate ornamentation.

PLATE 39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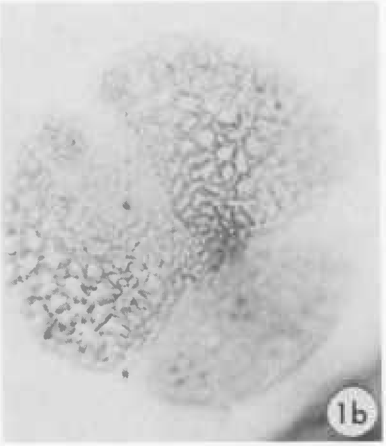
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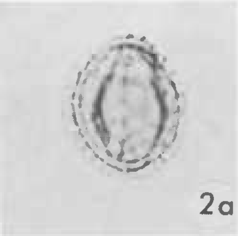
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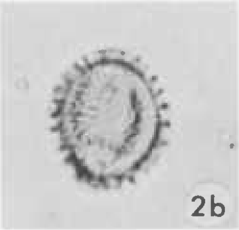
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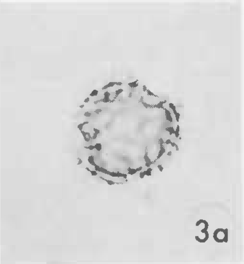
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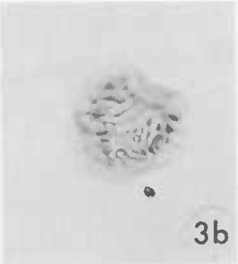
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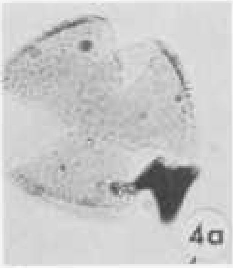
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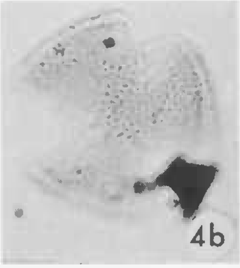
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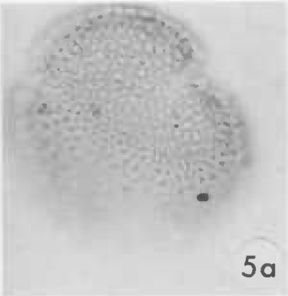
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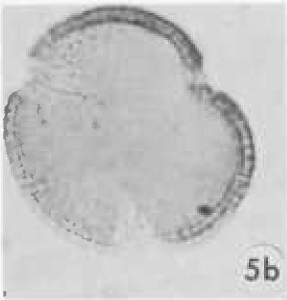
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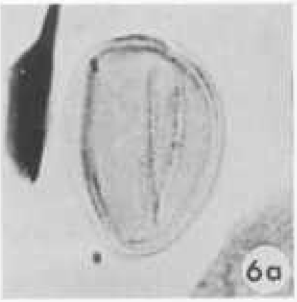
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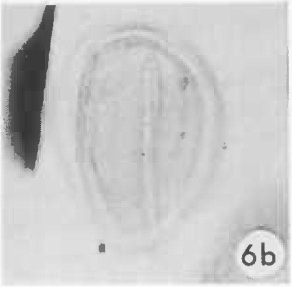
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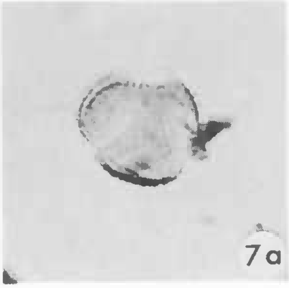
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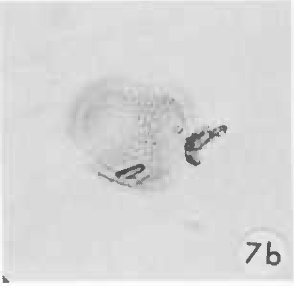

7b

PLATE 40

(All figures × 1000)

Figures 1, 2. *Tricolpopollenites micromunus* Groot and Penny

Fig. 1. Slide L2-58A, coordinates 29.8–116.2, equatorial view. 1a, medium focus; note pilate structure of ektexine. 1b, high focus showing retipilate ornamentation.

Fig. 2. L2-58B, coordinates 14–122.5, polar view, medium focus.

Figures 3, 4. *Tetracentron sinense* Oliv.

Fig. 3. Equatorial view of pollen of the extant plant. Pollen similar in size and exine characteristics to *Tricolpopollenites micromunus.* 3a, medium focus. 3b, high focus.

Fig. 4. Polar view.

Figures 5, 6. *Tricolpopollenites minutus*, n. sp.

Fig. 5. Holotype, slide St. 11A, coordinates 37.4–120.1, equatorial view, note the columellate organization of the ektexine.

Fig. 6. Slide St. 11A, coordinates 37.4–120.1, several grains in various orientations.

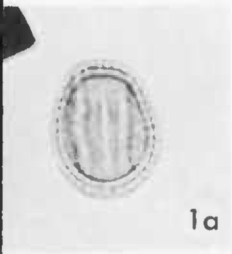
Figures 7–10. *Liliacidites dividuus* (Pierce), nov. comb.

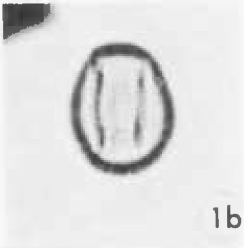
Fig. 7. Slide L2-65A, coordinates 27.9–119.7. 7a, high focus showing retipilate organization of the ektexine. 7b, medium focus; note the partial separation of the ektexine from the structureless endexine.

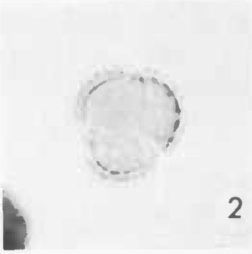
Fig. 8. Slide D 525II (well 13), coordinates 24.5–127.5, proximal polar view. 8a, medium focus, note pilate structure along the equator. 8b, high focus shows reticulate organization of the pila.

Fig. 9. Slide D 525II (well 13), coordinates 25.1–120.1, grain has split along the furrow; ektexine slightly loosened from the endexine.

Fig. 10. Slide D 525II (well 13), coordinates 28.9–113.8, ektexine missing; endexinal body smooth and structureless.


1a


1b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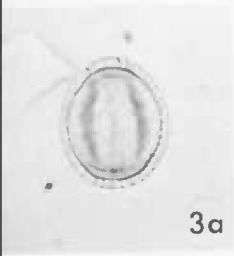
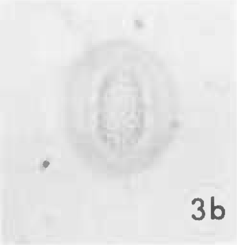
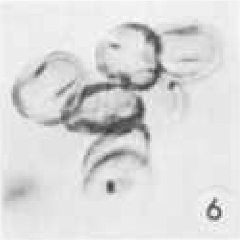

3a


3b


4


5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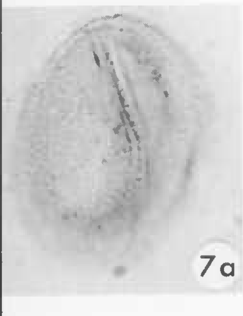
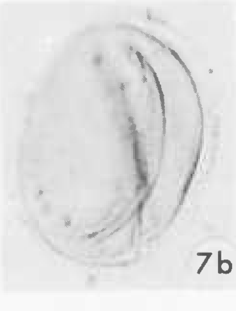
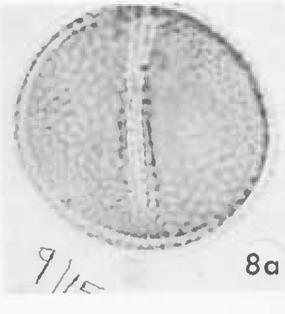
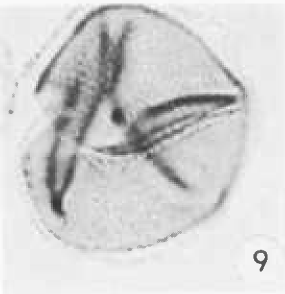

7a


7b



8a


8b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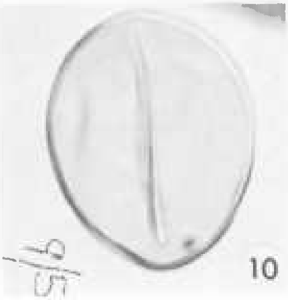

10

PLATE 41

(All figures × 1000)

Figures 1, 2. *Peromonolites peroreticulatus*, n. sp.

Fig. 1. Holotype, slide St. 6A, coordinates 20.8–128.5, proximal view. 1a, high focus on proximal surface showing coarse reticulum. 1b, medium focus; the capita of the pila are connected by bridges. 1c, low focus.

Fig. 2. Slide St. 6A, coordinates 39.3–121.2, proximal view, slightly larger specimen. 2a, medium focus. 2b, high focus.

Figures 3, 4. *Peromonolites reticulatus*, n. sp.

Fig. 3. Holotype, slide St. 10A, coordinates 41.5–115.5, distal polar view. 3a, high focus; ektexinal reticulum broken along the furrow. 3b, medium focus showing reticulate ektexine on proximal side.

Fig. 4. Slide L2-84A, coordinates 35–120.8, two additional specimens, ektexine missing on some parts of the grains.

Figures 5–7. *Clavatipollenites hughesii* Couper

Fig. 5. Slide St. 11B, coordinates 32.5–114.5, sulcus not developed.

Fig. 6. Slide L2-49A, coordinates 17.2–108.4, distal view, position of the sulcus indicated by a reduced development in the ektexine.

Fig. 7. Slide L2-65A, coordinates, 39.5–120.5, sulcus well developed, margins rough.

Figures 8, 9. *Clavatipollenites minutus*, n. sp.

Fig. 8. Holotype, slide St. 12A, coordinates 23.5–111.5, medium focus; note pilate ektexine and narrow furrow.

Fig. 9. Slide St. 30A, coordinates 24.8–111, slightly more elongate specimen.

Figures 10–12. *Monosulcites spinosus*, n. sp.

Fig. 10. Slide L1-71B, coordinates 42.2–116.8, note large widely spaced spines and sulcus.

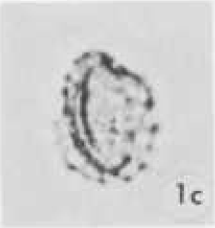
Fig. 11. Holotype, slide L1-71B, coordinates 42–116.6, medium focus.

Fig. 12. Slide L2-61B, coordinates 35.4–128.6, larger specimen.

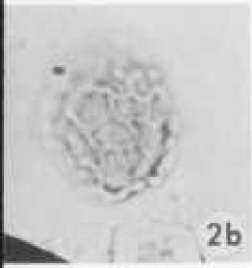
PLATE 41

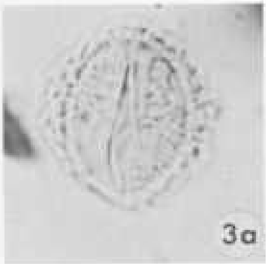

1a

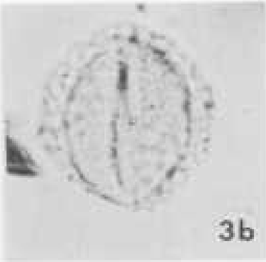

1b


1c

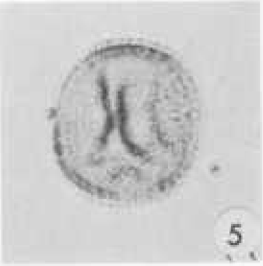

2a

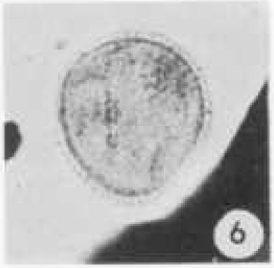

2b

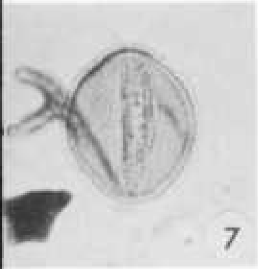

3a


3b


4


5


6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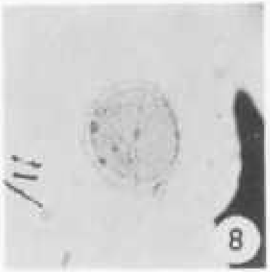
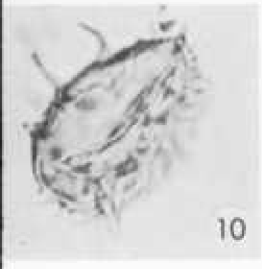

8


9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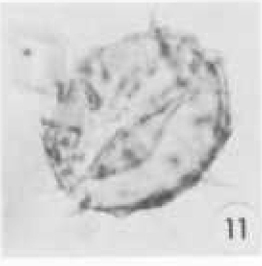

11

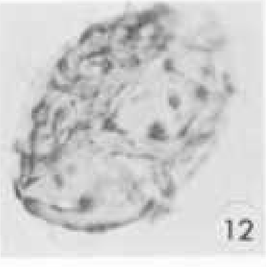

12

PLATE 42

Figure 1. *Monosulcites scabrus*, n. sp.

Holotype, slide L1-22B, coordinates 29–111.5, medium focus, × 1000.

Figures 2, 3. *Schizosporis microreticulatus*, n. sp.

Fig. 2. Holotype, slide St. 10B, coordinates 24.5–109.5, × 1000. 2a, high focus on side opposite subequatorial groove; note microreticulum. 2b, medium focus, subequatorial groove.

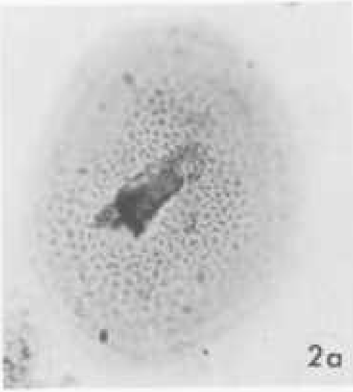
Fig. 3. Slide St. 10B, coordinates 39.8–124.3, another specimen with groove visible, × 1000.

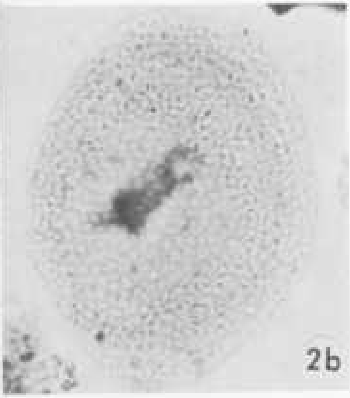
Figure 4. *Schizosporis reticulatus* Cookson and Dettmann

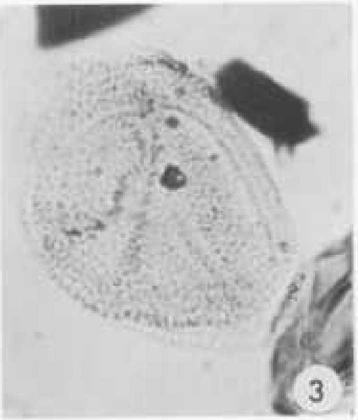
Slide St. 28B, coordinates 21.4–117.4, composed of a single layer of isodiametric chambers, × 500.

PLATE 42


1


2a


2b


3


4

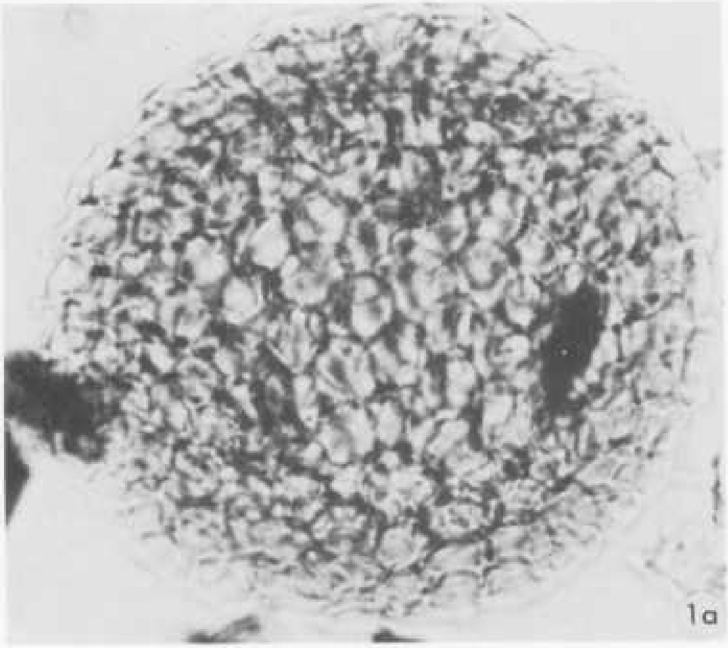
PLATE 43

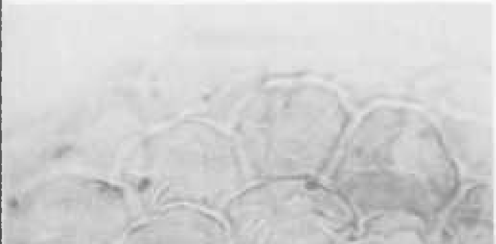
Figures 1, 2. *Schizosporis reticulatus* Cookson and Dettmann

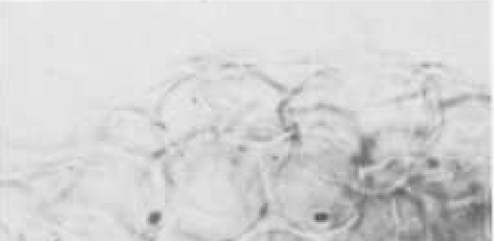
Fig. 1. Slide St. 10A, coordinates 37.8–124.2. 1a, view of the whole grain, × 500. 1b, higher magnification, high focus; note the circular pore on each chamber, × 1000. 1c, low focus showing chambers on other side of grain; these chambers also contain pores, × 1000.

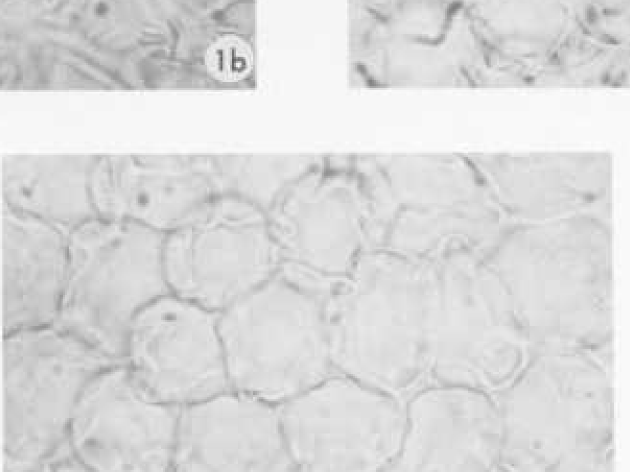
Fig. 2. Same specimen, view of chambers near the center of the grain; each chamber has a pore, × 1000.

PLATE 43









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APPENDIX A
WELL LOGS AND SAMPLES

The well logs and core samples were obtained from C. W. Lauman and Co. of Bethpage, Long Island, New York. In the summer of 1958, two test wells were drilled to bedrock for Levitt and Sons at the Belair Estate, about 15 miles east of Washington, D. C. Forty-six samples from the two cores were studied for spores and pollen. Twenty-two of them were productive; the rest (except for the marine greensands, which were not processed) proved barren.

This section gives the well logs, and then describes the core samples from each probe hole. The samples which yielded spores and pollen and which were used in this study are indicated.

WELL LOGS

Probe Hole No. 1

Company: Sydnor Pump and Well Co.
Well No: Probe Hole No. 1, completed September 3, 1958
Location: Belair Estate, Prince Georges County, Md., Army co-ordinates, 411.3 North, 871.9 East
Owner: Levitt and Sons
Elevation: 142.2 feet above mean sea level
Drilling Method: Standard 6″ rotary hole
Depth: 1165 feet

Lithologic description	Thickness (ft.)	Depth (ft.)
Aquia Greensand		
Sand, fine, orange, glauconitic, micaceous, and orange weathered clay	11.0	11.0
Sand, fine to very fine, greenish gray, glauconitic, micaceous; silt and some black clay	33.0	44.0
Sand, medium to coarse, gray; some glauconite	15.0	59.0
Monmouth Formation		
Clay, greenish black; silt and very fine micaceous glauconitic sand	19.0	78.0
Magothy Formation		
Sand, medium to coarse, and fine gravel	11.0	89.0
Patapsco Formation		
Clay, white; silt and a little very fine sand	10.0	99.0
Sand, coarse to very coarse, white; a little fine gravel and a very little white clay	8.0	107.0

Lithologic description	Thickness (ft.)	Depth (ft.)
Sand, very coarse to coarse with a little medium, white; coarse to fine gravel and a little white clay	17.0	124.0
Clay and silt, white	10.0	134.0
Sand, coarse, and some very coarse, light gray, and some gravel	10.0	144.0
Sand, very fine, white, and white silt	6.5	150.5
Sand, medium, white, and a little white clay	10.5	161.0
Clay, light gray; silt, micaceous, and fine sand; some gravel	8.0	169.0
Clay, gray, brick red, and brown; very little micaceous silt and very little lignite in spots	56.0	225.0
Clay, mottled brick red and gray, and some medium sand	2.5	227.5
Sand, fine to medium, light yellow, and a little silt and clay	7.5	235.0
Sand, fine, white, and a very little white clay. Small streaks of coarse sand and gravel starting at 238 feet	7.0	242.0
Sand, fine, white, and white clay; lenses of light gray silty clay interspersed	15.0	257.0
Sand, fine with some medium, tan and orange and a little clay and silt	15.0	272.0
Sand, fine to medium, and tan clay interlensed with red and gray silty clay, and tan coarse sand	10.0	282.0
Sand, medium with some fine and coarse, and very little clay and gravel	10.0	292.0
Sand, fine to medium, red, and red clay. Streaks of medium to coarse sand in lower part	12.0	304.0
Sand, fine to very fine, white, and a little white and mustard colored clay	10.0	314.0
Clay, mottled brick red, gray, and mustard colored, and a trace of gravel, sand, and silt	96.0	410.0
Sand, very fine to fine, and gray micaceous silt interlensed with maroon silty clay	9.0	419.0
Clay and silt, dark brownish, gray, micaceous; a little lignite and very fine sand in streaks	33.0	452.0
Sand, fine to very fine, white, and some white clay	5.5	457.5
Sand, fine to medium becoming medium to coarse at 468 feet, white, and very little white and yellow clay	16.5	474.0
Clay and silt, reddish brown and white, and lenses of white, silty fine to very fine sand	11.0	485.0
Sand, very fine to fine, and white silt	7.0	492.0
Sand, fine, and clay, mustard colored. Indurated in places to a hard sandstone	12.0	504.0
Clay and silt, black; trace of lignite	5.0	509.0
Sand, medium to fine with some coarse at 512 feet, white, and a very little light yellow clay	11.0	520.0
Clay, mottled, gray, brick red, mustard colored, purple, and black. A few streaks of sandstone below 524 feet	11.0	531.0
Sand, very fine and gray silt. Charcoal streaks in upper part	16.0	547.0
Clay and silt, mottled gray, brown, brick red, and mustard colored.	20.5	567.5

Lithologic description	Thickness (ft.)	Depth (ft.)
Sandstone, pyritized	2.5	570.0
Clay and silt, brownish red, and a little very fine sand at the top	67.0	637.0
Sand, medium to fine; silt and brown clay	8.0	645.0
Silt and clay, brown, slightly micaceous	4.0	649.0
Sand, medium to fine with some coarse, brown, and considerable brown clay	3.0	652.0
Silt and clay, brown, slightly micaceous	6.0	658.0
Clay, brown, white, and brick red, and medium sand	3.5	661.5
Sand, medium to fine and considerable brownish red clay	1.5	663.0
Clay and silt, mustard colored and brown, and a little very fine sand, slightly micaceous	19.0	682.0
Sand, medium with some fine, white, and some white clay	1.0	683.0
Sand, coarse to medium with some very coarse, varicolored; considerable fine gravel and a little white clay. Material is predominantly medium sand in middle of unit	29.0	712.0
Clay, gray, and small lenses of coarse to medium sand, gray silt and lignite. Lignite pyritized in places	1.0	713.0
Arundel Clay		
Clay and silt, gray and brownish red, slightly lignitic at the top	91.0	804.0
Sand, medium to coarse, gray and a little gray clay, slightly lignitic. Mostly coarse sand with a little very coarse sand and fine gravel from 812 to 822 feet	18.0	822.0
Sand, fine becoming mostly medium at the bottom, and some gray clay. Some lignite at the bottom	20.5	842.5
Clay, brown, gray, brick red, and mustard colored, and very little sand, silt, and lignite in places	55.5	898.0
Patuxent Formation		
Sand, fine to very fine; silt and some brownish red and tan clay. Micaceous at the top	14.5	912.5
Clay and silt, brownish red, micaceous	5.5	918.0
Sand, fine with some very fine, white, and a little white clay	9.0	927.0
Sand, medium to fine, white, and a little white clay. Sand becomes medium to coarse in lower part	24.0	951.0
Sand, coarse to medium with some fine and some very coarse; gravel; pebbles, and a little white clay	6.0	957.0
Sand, medium with some fine at the top and some coarse at the bottom; a little white clay, and a little gravel in places	20.0	977.0
Clay and a little silt, brownish red, heliotrope, brick red, and gray	93.0	1070.0
Sand, medium with some fine at the bottom, and some white clay	17.0	1087.0
Sand, coarse with some very coarse and some medium, white; some white clay and a little fine gravel	19.0	1106.0

Lithologic description	Thickness (ft.)	Depth (ft.)
Clay	1.0	1107.0
Sand, medium to fine becoming coarse at 1122 feet; white clay and some silt. Clay lenses interspersed from 1118 to 1122 feet.	24.0	1131.0
Clay, gray, and gravel	3.0	1134.0
Clay, white; silt and medium sand, slightly lignitic	18.0	1152.0
Bedrock		
Schist, weathered, contains quartz, muscovite, garnet, feldspar, biotite, and dark minerals. Solid rock at 1162.5 feet	13.0	1165.0

Probe Hole No. 2

Company: Sydnor Pump and Well Co.

Well No.: Probe Hole No. 2, completed July 31, 1958

Location: Belair Estate, Prince Georges County, Md. Army co-ordinates 413.1 North, 875.6 East.

Owner: Levitt and Sons

Elevation: 114.4 feet above mean sea level

Drilling Method: Standard 6″ rotary drill

Depth: 1178 feet

Aquia Greensand		
Loam, reddish brown	4.0	4.0
Sand, very fine to fine, greenish gray, very micaceous, glauconitic and gray clay. Indurated from 15 to 18 feet and from 26 to 26.5 feet. Some medium sand from 26.5 to 27.5 feet.	23.5	27.5
Sand, medium to coarse, some very coarse, gray, glauconitic, micaceous, and some green and gray clay. Contains shark teeth and bits of shells. Becomes very coarse to coarse at 33 feet. Flowing water at 5 gpm.	7.5	35.0
Monmouth Formation		
Clay, dark gray to black; sand, very fine, micaceous, and silt. Glauconite and pebbles below 53 feet. Large pieces of wood at 63 feet.	32.0	67.0
Gravel, rounded, and coarse sand	.5	67.5
Magothy Formation		
Sand, medium, white, and white clay. Becomes more clayey with depth and at 83 feet clay predominates and occurs in clay balls. Some pebbles at 83 feet	23.5	91.0
Patapsco Formation		
Clay, white, and a little very fine sand and micaceous silt	9.0	100.0
Sand, fine, white, and white clay	11.0	111.0

Lithologic description	Thickness (ft.)	Depth (ft.)
Pebbles and coarse gravel, rounded; coarse to medium white sand and considerable white clay	4.0	115.0
Sand, very coarse to very fine, light gray; considerable white clay, pebbles, and gravel. Materials of different textures occur in numerous lenses	35.0	150.0
Sand, fine to very fine with some medium, and considerable white clay	25.0	175.0
Sand, medium to fine, light gray, slightly micaceous, and a little clay	16.0	191.0
Clay, white; micaceous silt and a little fine sand	30.0	221.0
Clay, mottled gray and brick red	23.0	244.0
Clay, gray, and a little micaceous silt	10.0	254.0
Sand, fine to very fine, white, and white clay	27.0	281.0
Sand, fine to very fine and considerable clay, peach colored	2.5	283.5
Clay, brick red; silt and very fine sand	4.5	288.0
Sand, medium to fine, and considerable clay, mustard colored	14.0	302.0
Sand, fine to very fine; clay and silt, varicolored. Less clay at 323 feet	27.0	329.0
Sand, medium to fine, some coarse, and considerable red and mustard colored clay	10.0	339.0
Sand, coarse to medium, and clay, mustard colored	2.0	341.0
Sand, very coarse to medium; some gray clay and a little gravel. Much lignite and some pyrite	3.0	344.0
Clay, gray, and silt	4.0	348.0
Clay, mottled gray and brick red, and some micaceous silt	60.0	408.0
Clay, mottled gray, brick red, and mustard colored, and a little coarse sand	10.0	418.0
Clay, gray and brown; silt and fine sand. Mica and lignite at 434 feet	24.0	442.0
Clay, gray; considerable very fine to fine sand and micaceous silt	4.0	446.0
Sand, very fine to fine; yellow clay and silt, micaceous	8.0	454.0
Sand, medium, yellow, and a little yellow clay. Some coarse sand at 468 feet	18.5	472.5
Clay, dark brownish gray, and some silt, micaceous	4.5	477.0
Sand, fine, yellow, slightly micaceous, and some yellow clay and silt	6.0	483.0
Sand, coarse to fine, gray; gray clay; some fine gravel; silt and a little lignite	7.0	490.0
Clay, dark gray	4.0	494.0
Sand, coarse to medium, gray, and gray clay. Much lignite	1.0	495.0
Clay	3.0	498.0
Sand, medium, some coarse, yellow to red, and some small streaks of gray clay	16.0	514.0
Clay, brown	15.0	529.0
Clay, brick red; gray silty and very fine sandy clay, mottled	14.0	543.0

Lithologic description	Thickness (ft.)	Dept (ft.)
Clay and silt, micaceous, black to dark gray. "Charcoal" at 548 feet	8.0	551.0
Sand, fine, white and a little white clay. "Charcoal" at 563 feet	27.0	578.0
Sand, very coarse to very fine, white; rounded gravel and a little light gray clay. A little "charcoal" at 583 feet	10.0	588.0
Sand, medium, a little coarse and a little fine; white and a little gray clay	11.0	599.0
Clay, brownish gray; silt and very fine sand, micaceous, slightly lignitic	14.0	613.0
Sand, fine, white, and considerable light gray clay	6.0	619.0
Clay, brownish red, tough, and a little silt	23.0	642.0
Sand, fine, and clay, reddish brown	26.0	668.0
Sand, medium to fine, white; a little white clay and a little micaceous silt. Some coarse sand at and below 683 feet. Very little clay at 693 feet	31.0	699.0
Sand, very coarse, some coarse and medium and a little fine	3.0	702.0
Sand, very coarse to very fine; fine gravel; silt and considerable gray clay. Lignite and mica at 703 feet	1.0	703.0
Arundel Clay		
Clay, tough, brownish red, gray, mustard, and black. A little silt in places	208.5	911.5
Patuxent Formation		
Clay, reddish brown, and fine micaceous sand	11.0	922.5
Sand, medium to fine with some coarse at the bottom, and a little white clay	36.5	959.0
Sand, medium to coarse, gray; gravel and some silt	19.0	978.0
Sand, medium to very coarse, gray; silt and a little medium to coarse gravel	15.0	993.0
Sand, fine, gray, and silt	7.0	1000.0
Gravel	1.0	1001.0
Sand, medium; a little gray silt and clay	6.0	1007.0
Sand and clay streaks. Gravel at 1012 feet	6.0	1013.0
Silt, light gray; fine sand and clay	2.0	1015.0
Clay, gray, red, and tan, mottled	28.0	1043.0
Clay, gray, and silt	5.0	1048.0
Clay, mottled brown, red, and gray	7.0	1055.0
Clay and sand streaks	2.0	1057.0
Sand, medium to very coarse, blue gray, angular	6.0	1063.0
Clay, blue gray; silt and fine sand, slightly micaceous	8.0	1071.0
Sand, fine to very coarse, light gray, some silt. Much lignite, a little pyrite, and a little gravel	9.0	1080.0
Sand and clay	3.0	1083.0
Clay, purple, tough	7.0	1090.0
Sand, fine to medium, and silt, slightly micaceous	3.5	1093.5
Clay, gray, and silt	1.0	1094.5

Lithologic description	Thickness (ft.)	Depth (ft.)
Clay, brownish purple	6.5	1101.0
Sandstone	.5	1101.5
Clay, light gray, and fine sand, micaceous	15.0	1116.5
Sand, coarse to medium, and gray clay, lignitic, pyritic	9.5	1126.0
Clay, bluish gray, interlensed with micaceous brownish gray silty clay	10.0	1136.0
Sand, coarse to very coarse, with some medium; gravel and considerable white soapy clay	11.0	1147.0
Gravel, medium to coarse, subrounded, very clean	10.0	1157.0
Sand, very coarse, angular to subangular	4.0	1161.0
Boulders, probably residual from bedrock	10.0	1171.0
Bedrock		
Gneiss or vein quartz. Ditch sample shows very angular pieces of quartz	7.0	1178.0

WELL SAMPLE DESCRIPTIONS

Probe Hole No. 1

Core sample	Lithologic description	Depth (ft.)	Spores
L1-3	Sand, fine-grained, dark greenish gray, micaceous, glauconitic	32.0–33.5	not processed
L1-6	Sand, fine-grained, dark greenish gray, micaceous, glauconitic	62.0–63.5	not processed
L1-7	Sand, fine-grained, dark greenish gray, micaceous, glauconitic	72.0–73.5	not processed
L1-9	Clay, white, silty	92.0–93.5	barren
L1-14	Clay, white, silty	144.0–145.5	barren
L1-15	Sand, medium-grained, clayey, very light gray	152.0–153.5	barren
L1-16	Silt, clayey, yellowish gray	162.0–162.5	barren
L1-17	Clay, yellowish gray, plastic	172.0–173.5	barren
L1-21	Clay, medium light gray	212.0–213.5	productive
L1-22	Clay, medium light gray	222.0–223.5	productive
L1-25	Sand, very fine-grained, white, clayey	247.0–248.5	barren
L1-38	Sand, medium-grained, yellow gray, clayey	417.0–418.0	barren
L1-39	Clay, medium light gray, silty, micaceous	427.0–428.5	productive
L1-41	Clay, medium gray	447.0–448.5	productive
L1-44	Sand, medium-grained, clayey, very light gray	477.0–478.5	barren
L1-47	Clay, medium light gray	507.0–508.5	productive
L1-50	Clay, medium gray, silty, micaceous with fragments of carbonized plant material	532.0–533.5	productive
L1-51	Clay, light brownish gray, silty	542.0–543.5	barren
L1-69	Silt, clayey, medium light gray, lignitic	712.0–713.0	productive
L1-70	Clay, pale yellowish brown and medium gray, plastic	722.0–722.5	productive

Core sample	Lithologic description	Depth (ft.)	Spores
L1-71	Clay, medium gray	732.0–733.5	productive
L1-73	Sand, very fine-grained, clayey, micaceous, light gray	802.0–803.5	productive
L1-76	Sand, medium-grained, yellowish gray, feldspathic	832.0–832.5	barren
L1-90	Sand, medium to coarse-grained, very light gray	972.0–973.0	barren
L1-96	Silt, clayey, medium light gray	1062.0–1062.5	productive
L1-101	Sand, medium- to coarse-grained, white, feldspathic, clayey	1112.0–1112.5	barren
L1-103	Clay, medium light gray, plastic	1132.0–1132.5	productive
L1-104	Sand, coarse-grained, very light gray, feldspathic, feldspar highly weathered	1137.0–1137.5	barren
L1-105	Sand, fine-grained, clayey, very light gray	1147.0–1147.5	barren

Probe Hole No. 2

Core sample	Lithologic description	Depth (ft.)	Spores
L2-10	Clay, white, silty	93.0–94.0	barren
L2-46	Sand, very fine-grained, clayey, very pale orange	443.0–444.5	barren
L2-49	Clay, medium light gray	473.0–474.0	productive
L2-51	Sand, medium-grained, clayey, very light gray	488.0–489.5	barren
L2-52	Clay, very light gray	493.0–494.0	barren
L2-53	Clay, medium light gray, received as a powder	503.0–504.0	productive
L2-58	Clay, medium gray, lignite present	548.0–549.5	productive
L2-61	Clay, silty, medium gray, received as a powder	573.0–574.0	productive
L2-65	Clay, silt, medium light gray	613.0–614.0	productive
L2-74	Clay, silty, medium light gray, micaceous	703.0–704.0	productive
L2-84	Clay, pale yellowish brown, plastic	803.0–804.0	productive
L2-85	Clay, pale yellowish brown, plastic	813.0–814.5	barren
L2-86	Clay, dark yellowish brown, plastic	823.0–824.0	barren
L2-88	Clay, silty, medium light gray	843.0–844.0	productive
L2-89	Clay, silty, pale yellowish brown	853.0–854.0	productive
L2-90	Clay, grayish yellow green	863.0–864.5	barren
L2-110	Sand, light gray, clayey	1063.0–1064.5	productive

APPENDIX B

SURFACE LOCALITIES AND SAMPLES

Samples were collected in the Potomac Group from over 50 surface exposures in Maryland and Virginia. Only those localities that yielded sporomorphae were used in this study, and, although, several samples were collected and examined from each of the productive exposures, only one sample was thoroughly studied for spores and pollen. By selecting one sample to represent each locality, more exposures covering a wider geographic area could be studied. In this way an attempt to unravel a vertical change in the microflora was more effective.

Most of the localities used in this study are places in which the sediments have recently been exposed due to cultural activities, e.g. highway construction, excavations for buildings, and mining operations for refractory clay and road fill. Very few of the old localities described in the literature have been relocated by the writer, for most of them have been removed by building activities or overgrown by vegetation.

The sediments are extremely variable in lithology both vertically and laterally. Extreme lensing and rapid change in color and texture is a characteristic of the Potomac Group, so that the units listed for any station may not apply to exposures at that station several feet away. This problem is not unique to the Potomac Group, as rapid facies change is a feature common to continental sediments.

Station 4—Just South of North East, Cecil County, Md.

Exposure a road cut, one mile south of intersection of MD. 272 and MD. 7 The cut is on the east side of the road.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Clay, medium gray	3.0
	2. Silt, clayey, light gray, micaceous	1.5
	3. Clay, medium gray	2.0
	Total	6.5

Sample St. 4 was taken from unit 1, 1 ft. above the base. The sporomorphae present place this sample in Subzone B-1 of Zone II. This location is mapped as the Patapsco Formation in the Elkton-Wilmington Folio No. 211, 1920.

Station 6—United Clay Mine No. 2, Baltimore County, Md.

Clay mine at White Marsh, Md., situated on the south side of U.S. 40 about 0.8 mile northeast of intersection of U.S. 40 and MD. 700.

Formation	Lithologic description	Unit thickness (ft.)
Arundel	1. Clay, light gray and pink, variegated	7
	2. Clay, medium gray, plastic and tough. Some red streaks near the middle of the unit	30
	Total	37

Sample St. 6 was taken 20 ft. above the base of unit 2. The sporomorphae present place this sample in Zone I. This locality is situated in the Arundel Clay as determined from the Maryland Geological Survey's geologic map of Maryland (1933).

Station 10—William Allen Clay Mine, Prince Georges County, Md.

Clay mine, about 1 mile southeast of Contee, Md., 0.1 mile just off the south side of Furnace Road, 0.3 mile west of MD. 197. The pit cannot be seen from the road. It is located off the road about 0.1 mile down a dirt road. The thick dark gray clay is very pure and is mined for the manufacture of white brick. It contains large, dark red iron oxide nodules characteristic of the Arundel Clay (Pl. 2, fig. 2).

Formation	Lithologic description	Unit thickness (ft.)
Arundel	1. Silt and clay, yellow, with pebble streaks	6
	2. Clay, red, silty	4
	3. Clay, dark gray, pure, tough and plastic, large iron oxide nodules imbedded in the clay	25
	Total	35

Sample St. 10 was taken from near the base of unit 3. The sporomorphae present place this sample in Zone I. This exposure is located in the Arundel Clay according to the Geologic Map of Maryland (1933).

Station 11—Severn Clay Co., Anne Arundel County, Md.

Clay pit on the north side of the road that connects the Governor Ritchie Highway and MD. 648. The pit is about 1.5 miles southeast of Glen Burnie, Md. and about halfway between the two highways. Numerous fragments of dicotyledonous leaves were found in the gray clay unit at the bottom of the pit.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Clay, brick red, with thin lenses of medium-gray clay	11
	2. Clay, variegated red and light gray	8
	3. Clay, dark gray, with numerous fragments of dicotyledonous leaves	8
	Total	27

Sample St. 11 was taken from the base of unit 3. The sporomorphae present place this sample in Subzone B-2 of Zone II. Mapped as Patapsco on the Geologic Map of Maryland (1933).

Station 12—About 1 mile Southwest of Hawkins Point, Anne Arundel County, Md.

Exposure along a railroad track situated 1 mile southwest of Hawkins Point and just off a road 1.25 miles southeast of Arundel Church. Section consists of about 35 feet of variegated red and white clay disconformably overlain by clean cross-bedded quartz sands. The clays are mapped as the Patapsco Formation on the Geologic Map of Maryland (1933); the sands are probably the Raritan Formation (see Pl. 3, fig. 2).

Formation	Lithologic description	Unit thickness (ft.)
Raritan	1. Sand, medium-grained, cross-bedded, grains primarily quartz. Sharp contact at the base with unit 2	35
Patapsco	2. Clay, variegated red and white, with small medium gray lenses towards base	35
	Total	70

Sample St. 12 was taken from the small gray lenses near the bottom of the exposed clay in unit 2. The sporomorphae present place this sample in Subzone B of Zone II.

Station 15—Public Roads Pit, Southeast of Elkridge, Anne Arundel County, Md.

This exposure is on a hill about 0.5 mile southeast of Elkridge, at an elevation of approximately 120 feet. Section consists of about 10 feet of medium gray clay at the base, overlain by 150 feet of interbedded brick red and buff clay. Slabs of sandstone cemented by iron oxide are dispersed throughout the red clay and silt. The gray clays at the base have been mapped as the Arundel

Clay on the Geologic Map of Maryland (1933); upper silts and clay may be Patapsco.

Formation	Lithologic description	Unit thickness (ft.)
?	1. Interbedded clay and silt, red and buff, numerous iron cemented sandstone slabs	150
Arundel	2. Clay, medium gray, changes laterally into red clay	10
	Total	160

Sample St. 15 was taken from unit 2. The sporomorphae present place this sample in Zone I.

Station 16—Washington Brick Co., Muirkirk, Prince Georges County, Md.

The pit is located on south side of B & O tracks in Muirkirk. A carbonaceous gray clay lens is overlain by about 30 ft. of tough red and chocolate brown clays. The Patuxent Formation can be seen in contact (disconformably) with red clays. The thick gray clay lens has been mapped as Arundel on the Geologic Map of Maryland (1933). Sauropod remains have been found in similar lenses near here.

Formation	Lithologic description	Unit thickness (ft.)
?	1. Clay, red and chocolate brown, very tough. Can be seen to disconformably overlie the Patuxent Formation.	30
Arundel	2. Clay, medium gray, carbonaceous	8
Patuxent	3. Sand, coarse, pebbly, disconformably overlain by red clay	8
	Total	46

Sample St. 16 was taken from unit 2. The sporomorphae present place this sample in Zone I.

Station 17—Section Near Bladensburg, Prince Georges County, Md.

This exposure is located about 1 mile south of Bladensburg and 1 mile northwest of Tuxedo, just off MD. 201, on the east side of the road, and about 0.5 mile north of its intersection with the Defense Highway (U.S. 50). On the west side of the exposure a dark gray silty clay lens is cut into by a channel sand (see Pl. 3, fig. 1). Above the channel sands, the section consists of approximately 11 feet of light gray cross-bedded sands. On the east side at an elevation above the light gray sand, there are about 60 feet of red and gray clays and silts. This section is located in the Patapsco Formation.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Sand, buff and yellow, silty, cross-bedded	15
	2. Silt, medium gray with some red and gray lenses	20
	3. Clay, variegated red and light gray with some indurated sandstone slabs.	20
	4. Silt, medium gray	2
	5. Sand, medium-grained, light gray, cross-bedded	11
	6. Clay, silty, dark gray	7
	Total	75

Sample St. 17 is from unit 6; sporomorphae present place this sample in Subzone A of Zone II. On the Geologic Map of Maryland this locality is mapped as the Patapsco Formation.

Station 26—Drewrys Bluff, James River, Virginia

This exposure is located along the left bank of the James River about 4.5 miles south of Richmond. The sediments are exposed in bluffs near the water level. The exact sampling site can be reached by taking the Bellwood Road 0.8 mile east of its intersection with the Richmond-Petersburg Turnpike. A small road then leads northwest to a gasoline pumping station. A stairway leads down to a loading platform near the water level. The sample is a carbonaceous clay ball found imbedded in cross-bedded sands at the base of the exposure. This locality is one that Berry described in 1914 (Clark, Miller, and Berry, 1914, p. 75). The description of the section is taken from this work.

Formation	Lithologic description	Unit thickness (ft.)
Pleistocene	1. Argillaceous, ferruginous sand	6
	2. Gravel bed	5
Patuxent	3. Light gray coarse, arkosic sand	5–20
	4. Similar materials, much cross-bedded and carrying gravel, cobbles and clay balls	5–15
	5. Dark drab clay lenses in sand	5–10
	6. Indurated arkosic sand	12
	7. Coarse, arkosic, cross-bedded sand with clay balls and cobbles	15
	Total	53–83

Sample St. 26 was taken from a gray clay ball imbedded in unit 7. The sample is silty and contains a large amount of plant material. The sporomorphae present place this sample in Zone I. Berry (Clark, Miller, and Berry, 1914) referred these beds to the Patuxent Formation.

Station 28—On U.S. 40, Near Edgewood, Harford County, Md.

This exposure is located in a cut just off the south side of U.S. 40, 0.5 mile west of the intersection of U.S. 40 and MD. 24. On the east and west side of the cut there are approximately 5 ft. of carbonaceous gray clay containing ironstone fragments. On the south side the gray clay is 15 ft. thick and overlain by fine-grained white sands.

Formation	Lithologic Description	Unit thickness (ft.)
?	1. Sand, fine-grained, white	15
Patuxent-Arundel	2. Clay, medium gray, carbonaceous, containing ironstone fragments.	5–15
	Total	20–30

This locality is mapped as Patuxent on the Geological Map of Maryland; however, it is very close to the Arundel contact and may belong to this formation. The sample was taken from unit 2; the sporomorphae present place this sample in Zone I.

Station 29—West Bros. Brick Co., Prince Georges County, Md.

This exposure is found on the property of the West Bros. Brick Co. It is situated on the north side of Sheriff Road, just west of Cabin Branch Creek, and about 0.5 mile west of Highland Park. Most of the section consists of reddish brown and light gray and red variegated clays. At the top a medium gray clay lens (unit 1) yielded abundant sporomorphae.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Clay, medium gray lens	8
	2. Clay, reddish brown	30
	3. Clay, variegated, red and light gray	25
	Total	63

The sporomorphae present place this locality in Subzone B-2 of Zone II. The locality is mapped as Patapsco on the Geologic Map of Maryland.

Station 30—Addison Road, Prince Georges County, Md.

This exposure is on the north side of Addison Road about 0.5 mile south of Tuxedo and opposite the Fairmont Heights Jr. High School. Sample St. 30 was taken from a thick, dark gray, silty clay at the level of Addison Road.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Sand, fine-grained, buff and yellow	2
	2. Clay, dark gray, silty, with slabs of ironstone	25–30
	3. Sand and gravel, buff, with occasional gray clayey sand lenses	20
	4. Clay, brick red, with occasional light gray lenses	25
	Total	72–77

The sample was taken from unit 2; the sporomorphae present place this sample in Subzone B-2 of Zone II. The locality is mapped as the Patapsco on the Geologic Map of Maryland.

Station 31—Pit South of Sulphur Spring Rd., Baltimore County, Md.

This exposure is in a large pit just south of Sulphur Spring Road between Arbutus and Halethorpe. The sediments change rapidly in both a vertical and horizontal direction. The sample was taken from a dark gray lens, 65 feet thick, containing large amounts of fragmented lignite. The lens rapidly changes laterally into interbedded red and buff clays, sands, and silts.

The sporomorphae place this sample in Zone I. It is mapped as Patuxent on the Geologic Map of Maryland.

Station 34—Baltimore Brick Co., Baltimore County, Md.

In the fields on the east side of the Baltimore Brick Co. a dark gray clay lens, 10–15 ft. thick, is exposed. The Baltimore Brick Co. is located on the west side of U.S. 40, 0.3 mile southwest of the United Clay Mine (St. 6).

The sporomorphae in a sample from the gray clay place this bed in Zone I. It has been mapped as the Arundel Clay on the Geologic Map of Maryland.

Station 35—Near Patapsco, Anne Arundel County, Md.

Sample taken from bank of small stream at the entrance to a newly opened pit of the Arundel Corp. The pit is located about 2 miles northwest of Linthicum about 1.5 miles along a road leading southwest out of Raynor Heights towards Patapsco. The pit is on the north side of the road 0.2 mile east of the Pennsylvania Railroad tracks and 0.4 mile north of Patapsco. The stream cut exposes a few feet of medium gray clay which changes within a few feet into very dark red clay. The sporomorphae in the gray clay place this sample in Zone I. On the Geologic Map of Maryland this locality is in the Patuxent Formation, but very close to the contact with the Arundel Clay.

Station 38—Along Baltimore and Washington Expressway, Prince Georges County, Md.

The sediments are exposed along the east side of the Baltimore and Washington Expressway, 0.5 mile southwest of the Anne Arundel County line, and 0.1 mile northwest of where MD. 197 meets the Expressway. The section consists of approximately 30 feet of brick red silty clay with some small silty carbonaceous clay lenses near the top. The sporomorphae in a sample from the carbonaceous material places this section in Subzone A of Zone II. On the Geologic Map of Maryland this locality is situated near the contact of the Arundel Clay and Patapsco Formation; on the county geologic map it is placed in the Arundel-Patapsco formations combined.

Station 39— Landover, Prince Georges County, Md.

The sediments were exposed along the north side of MD. 202 just west of where it meets the Pennsylvania R.R.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Clay, light brown, plastic	10
	2. Clay, medium gray, lignitic, changing laterally into sands	5
	3. Sand, fine-grained, buff	5
	Total	20

This station is located in the Patapsco Formation on the Geologic Map of Maryland. The sample was taken from unit 2; sporomorphae present place this sample in Subzone B-2 of Zone II.

Station 40—Dodge Park, Prince Georges County, Md.

The exposure is on the surface of an area levelled for construction at the intersection of MD. 202 and MD. 704 behind a Shell gasoline station at Dodge Park. The sample came from some dark gray clay lenses in a brick red clay. This locality is situated in the Patapsco Formation according to the Geologic Map of Maryland. The sporomorphae place this sample in Subzone B-2 of Zone II.

Station 43—Baltimore and Washington Expressway, Prince Georges County, Md.

Approximately 19 feet of sediments are exposed along the west side of the Baltimore and Washington Expressway just east of Greenbelt and 3.7 miles north of the Riverdale Heights overpass.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Clay, variegated red and white	4.0
	2. Clay, dark gray, silty, with abundant pieces of lignite	5.0
	3. Clay, light gray, becoming silty towards top	1.5
	4. Clay, brick red	8.5
	Total	19.0

Sample St. 43 was taken from unit 2; sporomorphae present place this section in Subzone B-1 or Zone II. On the Geologic Map of Maryland this locality falls on the contact between the Arundel and Patapsco Formations.

Station 44—Baltimore and Washington Expressway, Prince Georges County, Md.

Ten feet of sediments are exposed on the east side of the Baltimore and Washington Expressway, a few feet north of its intersection with the Glen Dale Road.

Formation	Lithologic description	Unit thickness (ft.)
Patapsco	1. Clay, brick red, silty	6
	2. Clay, dark gray	4
	Total	10

This station falls just about at the contact between the Arundel and Patapsco Formations on the Geologic Map of Maryland. The sporomorphae in a sample from unit 2 place this section in Subzone A of Zone II.

Station 49—Baltimore Harbor Tunnel Highway, Baltimore County, Md.

About 30 feet of sediments are exposed along the north side of the Baltimore Harbor Tunnel Highway 0.2 mile southwest of where Hazelwood Avenue crosses the highway.

Formation	Lithologic description	Unit thickness (ft.)
Patuxent-Arundel	1. Clay, medium light gray	5.0
	2. Clay, purple	2.5
	3. Silt, buff, clayey	2.0
	4. Clay, dark gray	20.0
	Total	29.5

This exposure is situated right on the Patuxent-Arundel contact; the lithology suggests the Arundel Clay. The sporomorphae in a sample from unit 4 place this section in Zone I. On the county geologic map this locality is in the Patuxent Formation.

APPENDIX C

LIST OF SPOROMORPHAE

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14	*Cicatricosisporites patapscoensis*, n. sp.	50
15	*Cicatricosisporites potomacensis*, n. sp.	50
16	*Cicatricosisporites subrotundus* n. sp.	51
17	*Cingulatisporites caminus* Balme	57
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19	*Cingulatisporites distaverrucosus*, n. sp.	58
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21	*Cingulatisporites sp.*	58
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25	*Converrucosisporites platyverrucosus*, n. sp.	59
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27	*Cyathidites crassiangulatus* Balme	60
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55	*Neoraistrickia robusta*, n. sp.	65
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