



OKLAHOMA GEOLOGICAL SURVEY
Charles J. Mankin, *Director*

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**PLANT MICROFOSSILS FROM THE DENTON SHALE
MEMBER OF THE BOKCHITO FORMATION
(LOWER CRETACEOUS, ALBIAN) IN
SOUTHERN OKLAHOMA**

F. H. WINGATE



The University of Oklahoma
Norman
1980

OKLAHOMA GEOLOGICAL SURVEY

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Title Page Illustration

Quadricolpites reticulatus, n. gen., n. sp.; paratype specimens,
×500 (see pl. 16, figs. 13–15).

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PLANT MICROFOSSILS FROM THE DENTON SHALE
MEMBER OF THE BOKCHITO FORMATION
(LOWER CRETACEOUS, ALBIAN) IN
SOUTHERN OKLAHOMA

F. H. WINGATE¹

Abstract—The Denton Shale Member of the Bokchito Formation (Lower Cretaceous) of southern Oklahoma and northern Texas contains a rich and diverse assemblage of pollen, spores, and microplankton. This assemblage is particularly valuable in that it occurs in a sequence of strata well dated as upper Albian by its ammonite fauna. The microfossils include numerous well-preserved representatives of the Lycophyta, Pterophyta, Gymnospermae, and Angiospermae. Organic-walled cysts of dinoflagellates and acritarchs are present in decreasing amounts from the base to the top of the Denton, indicating marine, regressive deposition of the member. Comparisons made between the palynological assemblage of the Denton and those reported from the Potomac Group of the Atlantic Coastal Plain of the United States and from the Albian section of the Peace River area of northwestern Alberta, Canada, indicate that elements of both the Canadian and eastern U.S. assemblages are present in the Denton, which is interpreted as being floristically intermediate between the other two in terms of species composition.

INTRODUCTION

A palynological investigation of the Denton Shale was begun in the summer of 1971 as a dissertation topic for the Ph.D. degree at The University of Oklahoma. The Denton Shale is the basal member of the Bokchito Formation in southern Oklahoma and can be accurately dated as equivalent to the upper Albian part of the Lower Cretaceous on the basis of invertebrate megafossils occurring directly above and below it. This makes the palynological assemblage particularly useful as a reference for other, less accurately dated assemblages. A large number of well-preserved pollen, spores, dinoflagellates, and acritarchs were recovered; the pollen and spores are treated in this study, with results of the marine-microfossil study to be issued at a later date.

Previous palynological investigations of Lower Cretaceous strata in North America were reviewed thoroughly by Brenner (1963) and Singh (1964, 1971). The extent of the reported assemblages and the thorough illustration and description of specimens have made these three studies most useful in the present investigation. Previous palynological works on the southwestern United States include a report by Hedlund and Norris (1968) on an assemblage from the Walnut Clay in the Fredericksburg Group in southern Oklahoma, which is slightly older than the Denton assemblage. In addition, there has been a study of Cenomanian palynomorphs by Hedlund (1966), also from southern Oklahoma, plus a report of a small assemblage from the De Queen Limestone (Albian) in Arkansas by Bond (1972). A report on the palynology of the Paluxy (Albian) and Tuscaloosa (Cenomanian) Formations in southwestern Mississippi and northeastern Louisiana was published by Phillips and

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Felix (1971a and b), and, more recently, Srivastava (1977) produced a comprehensive study of the microspores from the Fredericksburg Group (Albian) in northeastern Texas and southern Oklahoma. As the Denton study was completed prior to publication of Srivastava's work on the Fredericksburg Group, his findings are not incorporated in this manuscript.

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I am indebted to L. R. Wilson, George Lynn Cross Research Professor, Department of Geology, The University of Oklahoma, for his direction of this study and for his warm, personal tutelage during my tenure as his student. Professor G. J. Goodman, as co-director of this study, also earned my gratitude, along with the other members of the faculty of the Department of Botany and Microbiology at The University of Oklahoma. Special thanks are due the Oklahoma Geological Survey for use of its facilities during the course of this study and for its assumption of the financial burden for the publication of this study.

STRATIGRAPHY

Lower Cretaceous rocks of the western Gulf Coast of the United States are referred to collectively as the Comanchean Series, which includes the Trinity, Fredericksburg, and Washita Groups from base to top. These strata crop out from southwestern Arkansas westward to Love County, Oklahoma, then southward to central and southwestern Texas (text-fig. 1). The Washita Group is represented in central Texas primarily by the Georgetown Limestone, which includes several members. These are, from base to top, the Kiamichi Shale, Duck Creek Limestone, Fort Worth Limestone, Denton Shale, Weno Shale, Pawpaw Sandstone, and Main Street Limestone (text-fig. 2). The object of this study, the Denton Shale Member, is exposed intermittently along the Lower Cretaceous outcrop from southeastern Oklahoma to central Texas (text-fig. 1).

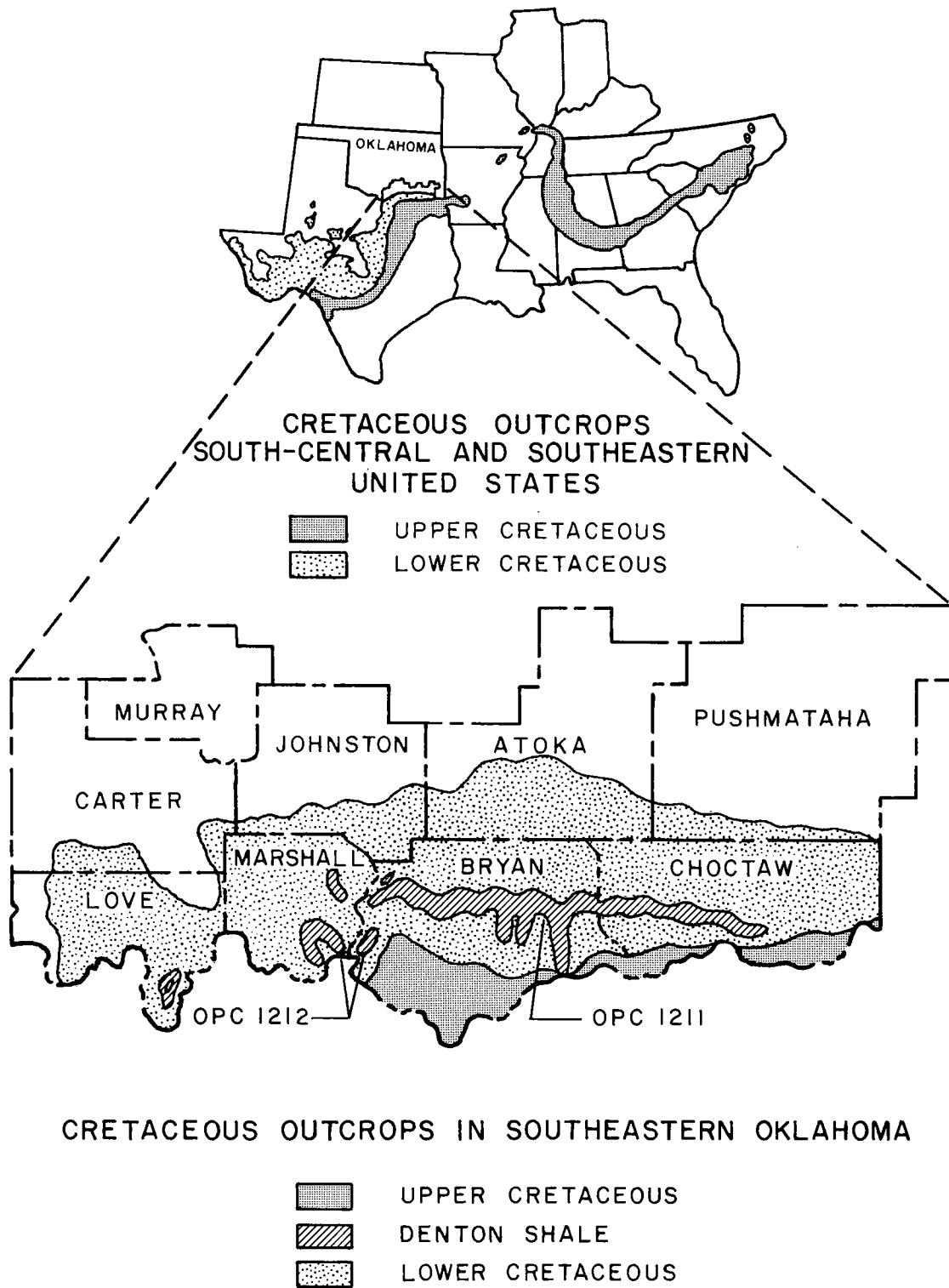
The Denton was named by Taff and Leverett (1893), who established as its type section the 40 feet of clay shales and lime-

stones exposed along Denton Creek between Roanoke and Justin in Denton County, Texas.

As the Texas strata are traced northward into southern Oklahoma, the Duck Creek and Fort Worth Limestones are mapped as a single unit, designated the Caddo Limestone. The Denton, Weno, and Pawpaw units were retained as names of members of the Bokchito Formation of southern Oklahoma by Taff (1902) and Bullard (1926). Hill (1894) used the name Marietta for the Denton interval, with the Fort Worth Limestone below and the North Denison sands above, but the name fell into disuse.

Taff and Leverett (1893) indicated that the Denton overlies the Fort Worth Limestone conformably and is separated from the Weno Shale above by a zone of thin, highly fossiliferous limestones that are referred to as the *Ostrea carinata* beds, after the dominant oyster contained in the beds. This usage was also followed by Hill (1901). The index fossil *Rastellum (Arctostrea) carinatum* (previously *Ostrea carinata*), which is used to identify the top of the Denton Shale Member at the type locality, is replaced northward by *Rastellum (Arctostrea) quadriplicatum* (formerly *Ostrea quadriplicata*), and an associated oyster, *Texigryphaea washitaensis*, becomes dominant (Hart, 1970). In the northeastern area of Denton outcrop, two to three thin limestones, containing *Texigryphaea washitaensis* and fewer *Rastellum (Arctostrea) quadriplicatum*, occur within the top 8–10 feet of the unit and were designated the Soper Limestone by Huffman and others (1975). Mapping of the Denton Shale Member in southern Oklahoma is dependent upon exposure of the underlying Caddo Limestone (Duck Creek and Fort Worth equivalent) and the "Ostrea beds" at the top. The shales of the Denton, Weno, and Pawpaw beds are so similar that distinctions are nearly impossible without the presence of identifiable limestone units, which makes the use of the inclusive Bokchito Formation in place of the three much easier to apply in field investigations.

Young (1959, 1967) placed the Denton Shale Member of north-central Texas in the ammonite zone *Drakeoceras lasswitzii*, which he correlates as being slightly above the middle of the upper Albian division of the Lower Cretaceous. Correlations with units of



Text-figure 1. Index map to Cretaceous outcrops of southeastern Oklahoma, showing collection localities in Denton Shale.

equivalent age to the northwest in New Mexico and Colorado were discussed by Scott (1970), while more regional correlations across the Gulf Coast and along the Atlantic Coastal Plain are given in Stephenson and others (1942).

The Denton Shale Member consists of buff to light-gray shales interbedded with dark-gray to nearly black shales, with a few thin sandstone lentils occurring near the middle of the section in Love County, Oklahoma (Redman, 1964). The entire section has a very high clay content, and it is also highly calcareous in the basal few feet. This shale is weakly indurated and thus easily weathered, resulting in limited exposure owing to extensive development of soil and vegetation. In only one area, along Bokchito Creek in Bryan County, Oklahoma, was there sufficient exposure to collect a composite set of samples. The upper and lower parts of the section are sufficiently exposed for sampling along the shores of Lake Texoma, but the middle one-third is covered in this area.

The Denton Shale ranges from approximately 70 feet in thickness in Love County, Oklahoma (Redman, 1964), to about 50 feet in Bryan County (Hart, 1970; Currier, 1968; Olson, 1965), thinning eastward to the limit of its outcrop in eastern Choctaw County, where it is covered by alluvium and onlapping Upper Cretaceous strata. The very fine-grained size of clastic particles and the abundant invertebrate fauna indicate deposition in a low-energy marine environment. From southern Oklahoma the Denton Shale thins southward to 45 feet in southern Cooke County, Texas, to 25–30 feet in Tarrant County, becoming only 3–5 feet thick in central Texas (Hart, 1970; Wilbert, 1967). This southward thinning is a feature common to all clastic units of the Lower Cretaceous of Texas and Oklahoma and indicates a northern source for the clastic sediments in this region.

Detailed mapping and stratigraphic descriptions of Lower Cretaceous sediments in southern Oklahoma have been accomplished by several University of Oklahoma students in their theses, which are reviewed and referenced by Hart (1970) and are therefore not covered here.

The lower units of the Comanchean Series (Trinity and Fredericksburg Groups)

represent a cycle of marine transgression, interrupted by minor periods of regression, with the seas encroaching progressively northward out of the Gulf of Mexico (Hendricks, 1967). A period of stability then followed during deposition of the lower part of the Washita Group (Kiamichi, Duck Creek, and Fort Worth Members). This was followed by deposition of the Denton Shale Member, which represents shallower water than existed during deposition of the underlying Fort Worth Limestone Member, when there was a cycle of marine regression. Rather than indicating a period of regression, however, the Fort Worth may have been deposited during a time of greater sediment supply and infilling of the depositional basin (Hendricks, 1967). Fluctuations of the shoreline continued until a major transgressive event resulted in the deposition of upper Washita Group carbonates at the close of Early Cretaceous time. The regressive nature of deposition of the Denton Member is also expressed in the distribution of palynomorphs within the unit.

METHOD OF STUDY

Sample Collection

Samples were collected from two groups of exposures of Denton Shale in Bryan and Marshall Counties, Oklahoma, by digging approximately 2 to 2½ feet below the surface to avoid weathered material. Each sample consists of approximately ½ cubic foot of material collected from 2 vertical feet of strata, which was placed in cloth sample bags for storage. Twenty-eight samples representing 56 feet of strata were collected from central Bryan County, Oklahoma, in secs. 3 and 4, T. 6 S., R. 11 E., and sec. 34, T. 5 S., R. 11 E., approximately 3½ to 4 miles north of the town of Bokchito, along and east of Oklahoma State Highway 22. Exposures of Denton Shale in this area are discontinuous, and sampling was accomplished by following the course of Bokchito Creek and two small tributary streams along the west side of the main stream channel. This sample locality is designated Oklahoma Palynology Collection (OPC) 1211, and individual samples are designated A (bottom) through ZB (top). The thickness of the total section in this area was estimated to be 60 feet by Olson (1965) and is

estimated to be 62 feet in this study. Approximately 3 to 5 feet of the section was not sampled because of its being covered. In addition, a 1-foot limestone at the top was not sampled.

Two outcrops of Denton Shale on the shores of Lake Texoma were sampled in the same manner as outlined above and were designated OPC 1212. On the western shore of the Washita arm of the lake, a 25½-foot section at the base of the unit is sufficiently exposed for sample collection. This locality adjoins the property of the Lake Texoma Lodge in sec. 28, T. 6 S., R. 7 E., in southeastern Marshall County, Oklahoma. Eleven samples representing 23½ feet of section (2 feet being covered) were collected and were designated A through K (base of formation to top of exposed section). Directly east of this exposure, on the opposite side of the lake, a 22½-foot section at the top of the Denton was sampled. Seven samples representing 11½ feet of section were collected and were designated L through R (bottom to top). This exposure occurs at the Johnson Creek Picnic Ground, 0.2 mile north of U.S. Highway 70, at a small bank along the water's edge. Only about one-half the section in this locality is exposed sufficiently for sampling (11 feet being deeply weathered and slumped).

All samples collected for this study are permanently stored at the Oklahoma Geological Survey, Norman, Oklahoma.

Sample Preparation

Samples were prepared for study according to the methods used by the Oklahoma Geological Survey Palynology Laboratory. The following steps were taken:

1. Each sample was thoroughly crushed and mixed, and approximately 25 grams transferred to a 600-ml polyethylene beaker.

2. Samples were covered with concentrated HCl acid for 12 to 16 hours to remove calcareous minerals, if any. Highly calcareous samples were treated with additional acid to ensure completion of the reaction.

3. Fluid was decanted from each sample, then HF acid (48 percent) was added slowly until the sample was well covered. This step to remove siliceous minerals must be accomplished slowly in the case of highly siliceous samples by adding very small amounts of acid over a period of 1 to 2 hours, with frequent stirring.

4. Samples were again decanted, then washed four to five times in distilled water, allowing all sediment to settle each time before decanting.

5. Approximately 5 ml of sample suspended in distilled water was placed in a 15-ml conical centrifuge tube and further diluted to 10 to 12 ml, then centrifuged 15 to 20 seconds and decanted to remove colloidal clay material. This short centrifuging is repeated until colloidal matter is no longer visible in the fluid phase. All liquid decanted is saved, later centrifuged, and examined for lost palynomorphs.

6. The thoroughly washed sample residue was then mixed with 3 to 4 ml of ZnBr₂ solution (specific gravity 1.85), using a mechanical (Vortex) agitator or an ultrasonic generator.

7. Samples were then centrifuged 2 minutes at 2,800 r.p.m., and the material suspended in heavy liquid was poured into clean centrifuge tubes, diluted with distilled water, and centrifuged 5 minutes. The residue not suspended in the heavy liquid was examined for lost palynomorphs. If significant numbers of palynomorphs remained, the heavy-liquid separation was repeated.

8. Material removed by heavy liquid was thoroughly washed four to five times in very dilute HCl and then was examined for palynomorphs.

9. Palynomorphs were then oxidized 2 minutes in Schultz solution and washed in distilled water. Then, two or three drops of 30-percent KOH solution were added to the residue suspended in approximately 10 ml of distilled water, mixed rapidly, and the sample was immediately centrifuged 30 seconds and quickly decanted. The residue was then washed several times with very dilute HCl. This step removed much extraneous organic matter and rendered the palynomorphs more transparent. Care must be taken not to damage or destroy the palynomorphs, and therefore speed is of utmost importance.

10. Palynomorph residues were then stained with safranin O and mounted on 24 × 50-mm cover glasses in a water-miscible mounting medium (Wilson, 1968). After drying several hours in a warming oven at 40°C, the cover glasses were permanently sealed to microscope slides with Lakeside 70 dissolved in absolute ethyl alcohol, with each

slide properly labeled. Ten slides per sample were prepared and then dried in the warming oven 10 to 12 hours.

Study Procedure

After studying each microscope slide thoroughly, each specimen deemed worthy of marking for future reference was ringed with permanent slide-marking ink, and each ring was numbered. This makes it possible to record each specimen's location by sample-collection number, level, slide, and ring number. For example, OPC 1211 X-3-15 indicates Oklahoma Palynology Collection 1211, level X of the sample section (lettered from the base, beginning with A), slide 3, and ring 15. These specimens can thus be located rapidly on any microscope at any future date. Specimens to be illustrated were photographed on Kodak Panatomic X film.

Specimens were counted for each level, using a species-stratum curve (Wilson, 1959, 1964) to determine the total count required, which was a maximum of 2,700 specimens for levels of high diversity and a minimum of 900 for levels of lower diversity. Relative percentages of each species were calculated and recorded for each level.

TAXONOMIC APPROACH

The microfossils encountered in this study have been assigned to previously described taxa whenever appropriate, by adhering to the system of priorities and types prescribed in the International Code of Botanical Nomenclature (Stafleu and others, 1972). Taxa are arranged by botanical family or higher category, based on known or probable affinities; specimens are placed under *incertae sedis* where affinities are unknown and cannot be reasonably deduced. Formal descriptions are given only for those forms not assigned to previously described species.

Not all palynomorphs exhibit the necessary qualities to be useful in stratigraphic analysis. Forms with simple structure and ornament reduced or lacking are often very broadly defined. Such fossils frequently have a long range in geologic time, probably as a result of inclusion of two or more genetically unrelated species into a single fossil form-species. Attempts to refine such taxa into more stratigraphically useful entities by

emphasizing small differences in size, shape, or surface ornament are more likely to result in the development of synonyms than in separation of useful species.

By considering small differences in size and surface ornament of spores and pollen to be within the realm of expected variation of form within a species, I have attempted to avoid the creation of new and likely superfluous names. My observations of modern pollen and spores reveal frequent cases of intraspecific variation as well as occasional overlap of form among botanically distinct species; both these factors create problems in interpreting fossil pollen and spores, and it becomes a matter of judgment whether a form should be considered a new species or a variant of a previously described species. To ignore overlap of form among botanically distinct species may lead to broadly defined taxa with no stratigraphic significance, but this is often unavoidable. To ignore intraspecific variation often leads either to the development of synonyms or to taxa that cannot be recognized outside the stratigraphic unit or limited geographic area of occurrence of the holotype. Emphasizing such variations results in morphologically distinct but stratigraphically useless taxa.

Once a taxon is deemed distinct from all others, the decision must be made as to the level of distinction. There are no absolute rules governing when to treat a group of characters as defining a form-species or a form-genus. Whenever two fossils described as species belonging to two different form-genera exhibit strong similarity in structural morphology and only slight differences in size or surface sculpture, I believe they should be differentiated at the species level rather than at the generic level.

Some taxonomic problems are encountered in this study which for resolution require re-examination and re-evaluation of holotypes. Such problems are considered beyond the scope of this present study.

SYSTEMATIC PALYNOLOGY

In the following discussion of individual species, size ranges are given as a sequence of three measurements, such as 10(20)30 microns, denoting the minimum, mean, and maximum sizes, respectively. Relative abundances of species within the Denton

Shale are designated as rare (less than 1 percent), occasional (1–5 percent), common (6–10 percent), and abundant (greater than 10 percent).

DIVISION BRYOPHYTA

Class HEPATICAE?

Genus **Aequitriradites** Delcourt and Sprumont, emend. Cookson and Dettmann, 1961

Type species.—*Aequitriradites dubius* Delcourt and Sprumont, 1955.

See Dettmann (1963, p. 91) for synonymy and discussion of proposed affinity with the Hepaticae.

Aequitriradites ornatus Upshaw, 1963

Pl. 1, fig. 1

1963 *Aequitriradites ornatus* UPSHAW, p. 428.

Dimensions.—Equatorial diameter 64(83)102 microns.

Occurrence.—Rare. Only a single specimen observed.

Aequitriradites spinulosus (Cookson and Dettmann) Cookson and Dettmann, 1961

Pl. 1, fig. 2

See Dettmann (1963, p. 93) for synonymy and description.

Dimensions.—Equatorial diameter 45(63)86 microns.

Occurrence.—Rare. Only two specimens observed.

Genus **Kraeuselisporites** Leschik, emend. Jansonius, 1962

Type species.—*Kraeuselisporites dentatus* Leschik, 1955.

See Dettmann (1963, p. 77) for synonymy.

Remarks.—*Kraeuselisporites* is distinguished from *Aequitriradites* in having the laesurae of the trilete confined to the inner spore body, and not extending onto the zona. There is no evidence that this genus may have affinity with the Hepaticae, but it has been placed here for more convenient comparison with the genus *Aequitriradites*, which it closely resembles.

Kraeuselisporites hastilobatus Playford, 1971

Pl. 1, fig. 3

1971 *Kraeuselisporites hastilobatus* PLAYFORD, p. 448.

Dimensions.—Equatorial diameter 50(69)78 microns.

Occurrence.—Rare.

Genus **Foraminisporis** Krutzsch, 1959

Type species.—*Foraminisporis foraminis* Krutzsch, 1959.

Remarks.—*Foraminisporis* is characterized by small clusters of verrucae in the interradial zones of the proximal surface and by foraminate to verrucate distal sculpture (Singh, 1971). Dettmann (1963) assigned to the genus specimens that have a narrow, sculptured cingulum, noting that this feature is not included in the generic description but does appear to be present on the holotype illustrations. De Jersey and Paten (1964) erected the genus *Nevesisporites* to accommodate cingulate trilete spores with circular amb, proximal verrucae in interradial regions, and smooth distal surface. It was distinguished from *Foraminisporis* by the absence of distal sculpture. Srivastava (1972a) revised the diagnosis of *Nevesisporites* to include forms with thickened exine over the distal pole and distal verrucae arranged in a circumpolar ring but noted significant variation in distal sculpture, with some specimens unsculptured. Since the distinguishing feature between *Foraminisporis* and *Nevesisporites* is arrangement of distal sculpture, which has been noted to be highly variable, it appears that only one genus is involved, and the name *Foraminisporis* takes precedence. *Simeonospora* Balme, 1970, and *Asterisporites* Venkatachala and Rawat, 1971, are treated as synonyms of *Nevesisporites* by Srivastava (1972a) and are therefore synonyms of *Foraminisporis*.

Foraminisporis was placed in the Hepaticae by Dettmann (1963) because of the close similarity of her Australian specimens with spores of the extant hepatic species *Nothylas breutelii* and *Phaeoceros bulbiculosus*.

Foraminisporis dailyi (Cookson and Dettmann) Dettmann, 1963

Pl. 1, fig. 4

1958 *Granulatisporites dailyi* COOKSON and DETTMANN, p. 99.

1963 *Foraminisporis dailyi* (Cookson and Dettmann) DETTMANN, p. 72.

Dimensions.—Equatorial diameter 32(40)45 microns.

Occurrence.—Rare.

Remarks.—The close similarity of *Foraminisporis dailyi*, as described by Dettmann (1963), and *Nevesisporites radiatus* (Chlonova) Srivastava (1972a) suggests that these forms may be conspecific.

Foraminisporis wonthaggiensis (Cookson and Dettmann) Dettmann, 1963

Pl. 1, fig. 5

See Dettmann (1963, p. 71) for synonymy.

Dimensions.—Equatorial diameter 29(31)36 microns.

Occurrence.—Rare.

Genus **Triporoletes** Mtchedlishvili, emend. Playford, 1971

Type species.—*Triporoletes singularis* Mtchedlishvili in Mtchedlishvili and Samoilovitch, 1960.

See Playford (1971, p. 551) for synonymy and emended diagnosis.

Remarks.—*Triporoletes* is placed in the Hepaticae because of the close similarity with spores of extant species of *Riccia*.

Triporoletes reticulatus (Pocock) Playford, 1971

Pl. 1, fig. 6

1962 *Rouseisporites reticulatus* POCOCK, p. 53.

1971 *Triporoletes reticulatus* (Pocock) PLAYFORD, p. 552.

Dimensions.—Equatorial diameter 48(59)76 microns.

Occurrence.—Rare.

Triporoletes singularis Mtchedlishvili, 1960

Pl. 1, fig. 7

1962 *Rouseisporites triangularis* POCOCK, p. 54.

See Playford (1971, p. 553) for description.

Dimensions.—Equatorial diameter 36(41)49 microns.

Occurrence.—Rare.

Triporoletes sp.

Pl. 1, fig. 8

Description.—Spore with well-defined Y-shaped tetrad mark, which may or may not be a functional germinal aperture. Thin ektexinal flanges present at the radial areas of the equator. Amb circular to subcircular. Exine smooth (apparent verrucae around the distal pole seem to be the result of breakdown of the exine through corrosion or over-maceration).

Dimensions.—Equatorial diameter 43 to 47 microns, including radial flanges (5 to 7 microns).

Occurrence.—Rare. Only two specimens observed.

Class MUSCI

Family SPHAGNACEAE

Genus **Stereisporites** Pflug, 1953

Type species.—*Stereisporites stereoides* (Potonié and Venitz) Pflug, in Thompson and Pflug, 1953.

Stereisporites sp.

Pl. 1, fig. 9

Dimensions.—Equatorial diameter 25(38)41 microns.

Occurrence.—Rare.

DIVISION LYCOPHYTA

Family LYCOPODIACEAE

Genus **Camarozonosporites** Pant ex Potonié, emend. Klaus, 1960

Type species.—*Camarozonosporites cretaceus* (Weyland and Krieger) Potonié, 1956.

See Srivastava (1972a, p. 6) for synonymy, and Klaus (1960, p. 135) for emended diagnosis.

Remarks.—The proposal by Srivastava (1972a) for treating the various subgenera of *Camarozonosporites* described by Krutzsch (1959) as independent genera is not followed here. Srivastava noted the similarity of spores of *Camarozonosporites* and *Inundatisporis* with those of extant species of *Lycopo-*

dium and suggested a likely affinity with the Lycopodiaceae.

Camarozonosporites ambigens

(Fradkina) Playford, 1971

Pl. 1, fig. 10

See Playford (1971, p. 546) for synonymy and description.

Dimensions.—Equatorial diameter 27(41)54 microns.

Occurrence.—Rare.

Remarks.—Playford noted the presence of reduced ornament on the proximal surface on some specimens, which is the case with specimens in the present study.

Genus **Foveosporites** Balme, 1957

Type species.—*Foveosporites canalis* Balme, 1957.

See Dettmann (1963, p. 42) for synonymy.

Remarks.—Balme (1957) pointed out the similarity of *Foveosporites canalis* to spores of modern *Lycopodium verticillatum*.

Foveosporites labiosus Singh, 1971

Pl. 1, fig. 11

1971 *Foveosporites labiosus* SINGH, p. 121.

Dimensions.—Equatorial diameter 36(40)42 microns.

Occurrence.—Rare.

Remarks.—The wide margo bordering the laesurae distinguishes this species from *Foveosporites canalis*.

Genus **Lycopodiacidites** Couper, emend.
Potonié, 1956

Type species.—*Lycopodiacidites bul-lerensis* Couper, 1953.

Remarks.—*Lycopodiacidites* is here treated as including circular trilete spores with hamulate ornament, often reduced or absent on the proximal surface, and with uniformly thick exine at the equator, distinguishing it from *Camarozonosporites*, which has interrational crassitudes.

Lycopodiacidites ambifoveolatus

Brenner, 1963

Pl. 1, fig. 12

1963 *Lycopodiacidites ambifoveolatus* BRENNER, p. 63.

Dimensions.—Equatorial diameter 39(46)54 microns.

Occurrence.—Rare.

Genus **Lycopodiumsporites** Thiergart ex
Delcourt and Sprumont, 1955

Type species.—*Lycopodiumsporites agathoecus* (Potonié) Thiergart, 1938.

See Singh (1964, p. 39) for synonymy and diagnosis.

Remarks.—*Lycopodiumsporites* includes trilete spores with a smooth proximal surface and reticulate distal surface with rigid, high muri and irregular, deep lumina. *Dictyotriletes* and *Reticulatisporites* have essentially the same features, but in the former the muri of the distal reticulum are broad and flat with very shallow intervening lumina, and in the latter the muri of the reticulum are very thin and project into an outer membrane. Dettmann (1963, p. 43–44) noted that the genus *Lycopodiumsporites* is of insecure validity, with the type species being characterized by foveoreticulate sculpture. Srivastava (1972a, p. 29–30) proposed to restrict the genus *Lycopodiumsporites* to forms having distally foveoreticulate sculpture and transferred several species from *Lycopodiumsporites* to *Retitriletes* Pierce, emended Döring, Krutzsch, Mai, and Schulz in Krutzsch, 1963. *Retitriletes* accommodates trilete, reticulate spores with the reticulum formed by thin, raised muri. No attempt has been made here to resolve this problem, and it is noted that the species listed may be more properly assignable to the genus *Retitriletes*.

Lycopodiumsporites crassimacerius

Hedlund, 1966

Pl. 2, figs. 1, 2

1966 *Lycopodiumsporites crassimacerius* HEDLUND, p. 19.

Dimensions.—Equatorial diameter 41(49)57 microns.

Occurrence.—Rare.

Lycopodiumsporites sp., cf. **L. dentimur-
atus** Brenner, 1963

Pl. 2, figs. 3, 4

1963 *Lycopodiumsporites dentimuratus* BRENNER, p. 44.

Dimensions.—Equatorial diameter (in-

cluding sculpture) 56(65)70 microns.

Occurrence.—Rare.

Remarks.—Specimens from the Denton Shale have slightly coarser sculpture and are larger than the type material of *Lycopodiumsporites dentimuratus* Brenner, 1963. Brenner described the species as having a size range of 27 to 38 microns (although his illustrations on pl. 5, figs. 4a, b, measure 45 microns).

***Lycopodiumsporites marginatus* Singh, 1964**

Pl. 2, figs. 5, 6

See Norris (1967, p. 90) for synonymy and description.

Dimensions.—Equatorial diameter 48(51)54 microns.

Occurrence.—Rare.

Remarks.—Srivastava (1972a) transferred this species to the genus *Retitriletes*, giving it the new specific epithet *singhii* to avoid synonymy with *Retitriletes marginatus* (Kara-Murza) Krutzsch, 1963. This usage has not been followed here (see remarks for the genus).

Family SELAGINELLACEAE

Genus *Apiculatisporis* Potonié and Kremp, 1956

Type species.—*Apiculatisporis aculeatus* (Ibrahim) Potonié and Kremp, 1956.

Remarks.—*Apiculatisporis* accommodates trilete spores with circular amb and echinate sculpture with spines longer than broad.

***Apiculatisporis* sp.**

Pl. 2, fig. 7

See Brenner (1968, p. 350) for description.

Dimensions.—Equatorial diameter 29(34)38 microns.

Occurrence.—Rare.

Remarks.—Specimens from the Denton appear conspecific with the spores reported by Brenner (1968) as *Apiculatisporis* sp., although the specimen illustrated here shows an incomplete reticulation between the spines that is not apparent on Brenner's illustration. Brenner noted the similarity of

this form with spores of the *Selaginella sub-aborescens* group of Knox (1950).

Genus *Ceratosporites* Cookson and Dettmann, 1958

Type species.—*Ceratosporites equalis* Cookson and Dettmann, 1958.

Remarks.—*Ceratosporites* is distinct from *Neoraistrickia* and *Acanthotriletes* in having a smooth proximal surface and was attributed to the Selaginellaceae by Cookson and Dettmann (1958).

***Ceratosporites pocockii* Srivastava, 1972**

Pl. 2, fig. 8

See Srivastava (1972a, p. 8) for synonymy and discussion.

Dimensions.—Equatorial diameter of spore body 31(35)40 microns; spines 4 to 8 microns long.

Occurrence.—Rare.

Remarks.—Srivastava (1972a) transferred *Acanthotriletes varispinosus* Pocock, 1962, to *Ceratosporites* based on the lack of ornament on the proximal surface, proposing the new specific epithet *pocockii* to avoid synonymy with *Ceratosporites varispinosus* Pocock, 1970.

Genus *Densoisporites* Weyland and Krieger, emend. Dettmann, 1963

Type species.—*Densoisporites velatus* Weyland and Krieger, 1953.

See Dettmann (1963, p. 83) for synonymy and emended diagnosis.

Remarks.—*Densoisporites* is characterized by a loosely enveloping outer layer of the sporoderm (cavate), attached to the proximal surface, and small circular thickenings (papillae) in each interradian area near the proximal pole. Dettmann pointed out the similarity between *Densoisporites* and the Paleozoic genus *Endosporites*, which is also cavate with interradian papillae, and that these features are suggestive of affinity with the Selaginellaceae.

***Densoisporites microrugulatus* Brenner, 1963**

Pl. 2, fig. 9

1963 *Densoisporites microrugulatus* BRENNER, p. 61.

Dimensions.—Equatorial diameter 66(85)108 microns.

Occurrence.—Rare.

Remarks.—The microrugulate ornament of the outermost layer of the sporoderm tends to obscure the smaller inner body and the interradiial papillae.

Densoisporites velatus Weyland and Krieger, emend. Krasnova, 1961

Pl. 2, fig. 10

See Dettmann (1963, p. 84) for synonymy and description.

Dimensions.—Equatorial diameter 28(37)44 microns.

Occurrence.—Rare.

Genus Lusatisporis Krutzsch, 1963

Type species.—*Lusatisporis punctatus* Krutzsch, 1963.

See Srivastava (1972a, p. 23) for synonymy and discussion.

Lusatisporis dettmannae (Drugg)

Srivastava, 1972

Pl. 2, fig. 11

See Srivastava (1972a, p. 23) for synonymy and revised description.

Dimensions.—Equatorial diameter 36(40)45 microns.

Occurrence.—Rare.

Genus Heliosporites Schulz, emend.

Srivastava, 1972

1962 *Heliosporites* SCHULZ, p. 311.

1963 *Lundbladispota* BALME, p. 21.

1965 *Lundbladispota* Balme, emend. PLAYFORD, p. 189.

1972 *Heliosporites* Schulz, emend. SRIVASTAVA, p. 18.

Type species.—*Heliosporites altmarkensis* Schulz, 1962.

See Srivastava (1972a, p. 18) for emended diagnosis.

Remarks.—*Heliosporites* as defined by Schulz (1962) accommodates trilete spores having a distal "perispore" (actually cavate) with projecting spines on the distal surface and along the equator. Srivastava (1972a) noted a flattening of the equatorial region of the outer, cavate layer of the exine, pointing out that this sometimes gives the appearance of a zonate structure. Srivastava further noted the finely reticulate (or punctate) nature of the outer layer of the exine as a char-

acteristic feature of the genus. Balme (1963) and Playford (1965) gave essentially the same description for the genus *Lundbladispota*, with the addition of the usual (but not always) occurrence of three thickenings (papillae) in the vicinity of the proximal pole. Comparison of illustrations and descriptions of both genera lead to the conclusion that they are one, and *Lundbladispota* is therefore a later synonym of *Heliosporites*.

Various authors have noted the similarity of spores of *Heliosporites* to those of the extant *Selaginella selaginoides* (Srivastava, 1972a, p. 19). Balme (1963) noted that spores illustrated by Lundblad from the Lower Triassic of Greenland appear conspecific with *Lundbladispota playfordi* and were associated with the selaginellaceous strobilus *Selaginellites polaris* and may represent its microspores.

Heliosporites breviculus (Balme), n. comb.

Pl. 2, figs. 12, 13

1963 *Lundbladispota brevicula* BALME, p. 23.

1963 *Cingulatisporites reticingulus* BRENNER, p. 42.

1971 *Lundbladispota reticingula* (Brenner) PLAYFORD, p. 548.

1972 *Heliosporites kemensis* SRIVASTAVA, p. 19.

See Balme (1963, p. 24) for description.

Dimensions.—Overall equatorial diameter 35(42)48 microns, with inner body diameter 20(28)34 microns. Spines 1 to 6 microns long with diameter at the base approximately 2 microns.

Occurrence.—Rare.

Remarks.—*Cingulatisporites reticingulus* Brenner, 1963, and *Heliosporites kemensis* Srivastava, 1972a, conform in description and size with *Heliosporites brevicula* (Balme), n. comb., and are thus treated here as synonyms.

Genus Minerisporites Potonié, 1956

Type species.—*Minerisporites mirabilis* (Miner) Potonié, 1956.

See Singh (1964, p. 157) for synonymy and description.

Remarks.—Singh (1964) suggested that *Minerisporites* is of probable selaginellaceous affinity.

Minerisporites marginatus (Dijkstra)

Potonié, 1956

Pl. 2, fig. 14

See Singh (1964, p. 158) for synonymy and description.

Dimensions.—Equatorial diameter 244(273)304 microns.

Occurrence.—Rare.

Minerisporites venustus Singh, 1964

Pl. 3, fig. 1

1964 *Minerisporites venustus* SINGH, p. 159.

Dimensions.—Equatorial diameter 176 × 222 microns.

Occurrence.—Rare. A single specimen observed.

Remarks.—This specimen is significantly smaller than the range given by Singh (1964; 320 to 410 microns) for the type material, but it is identical in other respects.

DIVISION PTEROPHYTA

Order MARATTIALES or FILICALES

Genus **Punctatosporites** Ibrahim, 1933

Type species.—*Punctatosporites minutus* Ibrahim, 1933.

See Playford and Dettmann (1965, p. 149) for synonymy.

Remarks.—Scabrate to granulate monolete spores have frequently been reported from Cretaceous strata under the genus *Marattisporites* Couper, 1958, which is, according to Playford and Dettmann (1965), a junior synonym of *Punctatosporites*.

Punctatosporites scabratus (Couper)

Singh, 1971

Pl. 3, fig. 2

1958 *Marattisporites scabratus* COUPER, p. 133.

1971 *Punctatosporites scabratus* (Couper) SINGH, p. 106.

See Couper (1958, p. 133) for description.

Dimensions.—Length 16(21)27 microns; width 13(17)21 microns.

Occurrence.—Rare.

Order FILICALES

Family OSMUNDACEAE

Genus **Baculatisporites** Thompson and

Pflug, 1953

Type species.—*Baculatisporites primarius* (Wolff) Thompson and Pflug, 1953.

See Dettmann (1963, p. 34) for synonymy.

Remarks.—*Baculatisporites* is characterized by a circular amb and baculate sculpture, whereas *Osmundacidites* Couper has granular sculpture and *Conbaculatisporites* Klaus has a triangular amb.

Baculatisporites comaumensis (Cookson)

Potonié, 1956

Pl. 3, fig. 3

See Srivastava (1972a, p. 5) for synonymy, and Dettmann (1963, p. 35) for description.

Dimensions.—Equatorial diameter 30(43)52 microns.

Occurrence.—Rare.

Genus **Conbaculatisporites** Klaus, 1960

Type species.—*Conbaculatisporites mesozoicus* Klaus, 1960.

See Klaus (1960, p. 125) for generic diagnosis.

Remarks.—*Conbaculatisporites* is distinguished from *Baculatisporites* in having a triangular amb. Chaloner (*in* Tschudy and Scott, 1969, p. 297) pointed out that *Conbaculatisporites* is a characteristic Triassic form of limited stratigraphic range. The use of this form-genus for spores found in the Denton Shale is based on morphological grounds and does not propose close biological affinity with Triassic spores of similar form.

Conbaculatisporites sp.

Pl. 3, fig. 4

Dimensions.—Equatorial diameter 28(35)40 microns.

Occurrence.—Rare.

Genus **Biretisporites** Delcourt and

Sprumont, emend.

Delcourt, Dettmann, and Hughes, 1963

Type species.—*Biretisporites potoniaei* Delcourt and Sprumont, 1955.

See Delcourt, Dettmann, and Hughes (1963, p. 283) for synonymy and emended diagnosis.

Biretisporites potoniaei Delcourt and
Sprumont, 1955
Pl. 3, fig. 5

See Delcourt, Dettmann, and Hughes (1963, p. 284) for synonymy and description.

Dimensions.—Equatorial diameter 34(41)50 microns.

Occurrence.—Rare.

Biretisporites dentonensis, n. sp.
Pl. 3, fig. 6

Description.—Trilete spores with laesurae extending nearly to the equator and bordered by wavy, membranous lips. A narrow zone of thickened exine occurs adjacent to the laesurae, forming a narrow margo. Exine smooth to scabrate, 2 to 3 microns thick at the equator. Amb subcircular with strongly convex sides.

Holotype.—OPC 1211 W-15-3; pl. 3, fig. 6; equatorial diameter 52 × 54 microns.

Dimensions.—Equatorial diameter 52(59)67 microns.

Occurrence.—Rare.

Remarks.—The larger size, subcircular amb, and scabrate exine distinguish this species from *Biretisporites potoniaei*.

Genus **Osmundacidites** Couper, 1953

Type species.—*Osmundacidites wellmanii* Couper, 1953.

See Dettmann (1963, p. 31) for synonymy and discussion.

Osmundacidites alpinus Klaus, 1960
Pl. 3, fig. 7

1960 *Osmundacidites alpinus* KLAUS, p. 127.

Dimensions.—Equatorial diameter 20(28)33 microns.

Occurrence.—Rare.

Remarks.—*Osmundacidites alpinus* is distinguished by its small size from *O. wellmanii*. This distinction may be only apparent, however, as Dettmann (1963) noted that the size range of *O. wellmanii* is very broad and distinction of species on this basis is impractical because of the occurrence of all intermediate forms.

Genus **Todisporites** Couper, 1958

Type species.—*Todisporites major* Couper 1958, p. 134.

Todisporites minor Couper, 1958
Pl. 3, fig. 8

See Singh (1964, p. 45) for synonymy and description.

Dimensions.—Equatorial diameter 30(39)50 microns.

Occurrence.—Rare.

Family SCHIZAEACEAE

Spores comparable to those of modern schizaeaceous ferns, particularly the genera *Anemia* and *Mohria*, are very common and characteristic features of most Lower Cretaceous strata. They are, however, one of the most taxonomically confused groups encountered and have been the object of much discussion concerning their systematic treatment and stratigraphic value (Singh, 1971; Hughes, 1969b; Hughes and Moody-Stuart, 1966, 1967, 1969; Pocock, 1964; Bolkhovitina, 1961). The most striking characteristic of spores of the *Anemia* and *Mohria* type is an exine ornamentation of parallel muri that are arranged in various designs upon the spore surfaces. The presence or absence of radial "appendages" (blunt projections from the spore radii) serves to distinguish the two form-genera *Appendicisporites* Weyland and Krieger, 1953, and *Cicatricosisporites* Potonié and Gelletich, 1933, with species of each being defined most commonly on the basis of ornament pattern, size, and shape. Unfortunately, forms intermediate between those used as types for both the two form-genera and their numerous species are common, making the task of assigning these forms to previously described taxa very difficult. For example, spores with slight radial thickenings have been described under the genus *Cicatricosisporites* (see *Cicatricosisporites* sp., cf. *Anemia exilioides*, pl. 6, figs. 6, 7), and spores with a slight "appendage" at one radius and none at the other two radii have been placed in the genus *Appendicisporites* (*Appendicisporites degeneratus*, pl. 3, figs. 9, 10). It should be noted that some work has been published on the spores of *Anemia* and *Mohria* (Selling, 1944; Bolkhovitina, 1961), but in neither case has variation been adequately recorded, leaving doubt as to how to treat the numerous intermediate forms. Spores assignable to *Appendicisporites* and

Cicatricosisporites have been extracted from the sporangia of the schizaeaceous megafossils *Pelletiera*, *Ruffordia*, and *Schizaeopsis* from the Lower Cretaceous (Hughes and Moody-Stuart, 1966).

It is beyond the scope of this study to attempt resolution of this taxonomic problem, which will ultimately require the reexamination of all possible holotypes. In the following presentation of schizaeaceous spores, assignment to taxa is based upon comparison with validly published descriptions and illustrations and are considered tentative pending revision of the group.

Genus **Appendicisporites** Weyland and Krieger, 1953

Type species.—*Appendicisporites tricuspoidatus* Weyland and Krieger, 1953.

See Srivastava (1972a, p. 4) for synonymy, and Pocock (1964, p. 161) for description and discussion.

Remarks.—Singh's (1971) proposal to assign schizaeaceous spores having one or more radial appendages to this form-genus is followed here.

Appendicisporites degeneratus

Thiergart, 1953

Pl. 3, figs. 9–12

See Phillips and Felix (1971a, p. 301) for synonymy and description.

Dimensions.—Equatorial diameter (including radial appendages) 40(54)67 microns.

Occurrence.—Rare.

Remarks.—Forms from the Denton Shale are characterized by only one or two proximal muri which parallel the equator. A simple branching of the innermost proximal rib, forming closed ovals in the middle of each interradiation region, is commonly, but not always, present. Distal muri commonly join and form a circular ring at the distal pole.

Appendicisporites erdtmanii Pocock, 1964

Pl. 3, figs. 13, 14

1964 *Appendicisporites erdtmanii* Pocock, p. 167.

Dimensions.—Equatorial diameter 39(59)74 microns.

Occurrence.—Rare.

Appendicisporites foveolatus (Deák), n. comb.

Pl. 4, figs. 1, 2

1962 *Costatoperforosporites foveolatus* DEÁK, p. 231.

See Singh (1971, p. 87) for description.

Dimensions.—Equatorial diameter 45(51)56 microns.

Occurrence.—Rare.

Remarks.—*Costatoperforosporites* was described by Deák (1962) to accommodate spores essentially the same as *Appendicisporites*, differing only in possessing exclusively canaliculate (broad muri separated by narrower canals) sculpture with rows of perforations occurring along the muri (Singh, 1971). This difference does not appear sufficient for the establishment of a separate genus, and I consider the species to belong to *Appendicisporites*.

Appendicisporites jansonii Pocock, 1962

Pl. 4, figs. 3, 4

See Pocock (1962, p. 37) for description.

Dimensions.—Equatorial diameter 72(76)84 microns.

Occurrence.—Rare.

Appendicisporites potomacensis

Brenner, 1963

Pl. 4, figs. 5, 6

1963 *Appendicisporites potomacensis* BRENNER, p. 46.

See Singh (1971, p. 62) for discussion and comparison to other similar species.

Dimensions.—Equatorial diameter of spore body 44(53)58 microns; radial appendages 3 to 12 microns long.

Occurrence.—Rare.

Appendicisporites problematicus

(Burger) Singh, 1971

Pl. 4, figs. 7, 8

1966 *Plicatella problematica* BURGER, p. 245.

1971 *Appendicisporites problematicus* (Burger) SINGH, p. 63.

See Burger (1966, p. 245) for description, and Singh (1971, p. 63) for discussion.

Dimensions.—Equatorial diameter 46(55)60 microns.

Occurrence.—Rare.

Appendicisporites segmentus Brenner, 1963

Pl. 4, figs. 9–11

1963 *Appendicisporites segmentus* BRENNER, p. 46.*Dimensions*.—Equatorial diameter 36(49)56 microns.*Occurrence*.—Rare. Only seven specimens observed.*Remarks*.—The specimen illustrated by Hughes as *Plicatella* sp. in Tschudy and Scott (1969, pl. 15–2, fig. 13) appears conspecific with *Appendicisporites segmentus*. Hughes' specimen came from depth 1,353 feet in the borehole at Warlingham, Surrey, England, with an estimated age of Early Barremian (Hughes, personal communication).**Appendicisporites tricostatus** (Bolkhovitina) Pocock, 1964

Pl. 4, figs. 13, 14

See Pocock (1964, p. 166) for synonymy and description.

Dimensions.—Equatorial diameter 56(61)64 microns.*Occurrence*.—Rare.**Appendicisporites dentimarginatus**

Brenner, 1963

Pl. 4, fig. 12

1963 *Appendicisporites dentimarginatus* BRENNER, p. 45.1964 *Appendicisporites spinosus* POCKOCK, p. 169.*Dimensions*.—Equatorial diameter (including spines) 30(47)60 microns.*Occurrence*.—Rare.*Remarks*.—Strivastava (1972b, p. 224) suggested that *Appendicisporites spinosus* Pocock, 1964, is a junior synonym of *A. dentimarginatus* Brenner, 1963, which is the usage followed here.**Appendicisporites alatus**, n. sp.

Pl. 5, figs. 1, 2

Description.—Trilete spore with triangular amb. Laesurae extending to the equator, appearing somewhat sinuous in some specimens owing to the presence of raised, membranous lips. Proximal face smooth, except for one set of thin muri paralleling the equator and positioned approximately two-thirds the distance between the

proximal pole and the equator. Stout appendages with rounded tips occur at the radii, usually singly, but in some specimens two or three at one radial position.

A thin, but rigid, extension of ektexine occurs in one or more interradial areas along the equator, forming winglike flanges. These projecting flanges do not extend to the radii and thus do not join one another. Sets of two to four muri occur on each of the three sides of the distal surface, paralleling the equator. Where individual muri join those of another set, blunt, clavate projections often, but not always, form.

Holotype.—OPC 1211 Y-19-10; pl. 5, figs. 1, 2; equatorial diameter of the spore body 49×53 microns, and radial appendages 7 to 9 microns long.*Dimensions*.—Equatorial diameter (including radial appendages) 45(50)59 microns; radial appendages 2 to 9 microns long; equatorial flange 1 to 5 microns wide. Sixteen specimens measured.*Occurrence*.—Rare.**Appendicisporites stellantis**, n. sp.

Pl. 5, figs. 3–7

Description.—Trilete spores with laesurae reaching, or nearly reaching, the equator. The laesurae are bordered by thin, sinuous lips. Rounded triangular amb. Sculpture is canaliculate, with five to six muri on the proximal surface and eight to 10 muri on the distal surface, all paralleling the equator. Ten to 20 stout spines with bluntly rounded tips occur on the distal surface and equatorial zone. The spines are widely and rather equally spaced and are often formed by fused outgrowths of two or more muri. Frequently, two or more spines fuse to form broad, winglike projections, but single spines developed from individual muri are the most common. The spines range in size from 7 to 12 microns long and 2 to 6 microns broad. Projections occur at the radii, as in all species of *Appendicisporites*, and these projections may be identical with others on the spore or may be larger and more tapering, making them distinct from the distal spines.*Holotype*.—OPC 1211 S-15-1; pl. 5, fig. 4; equatorial diameter (without spines) 50×53 microns, and spines 8 to 10 microns long.*Dimensions*.—Equatorial diameter of spore body (less ornament) 50(54)60 microns

and spines 7(9)12 microns long (20 specimens); polar diameter 44(47)50 microns (three specimens).

Occurrence.—Rare.

Remarks.—Canaliculate sculpture with relatively few, large spines, not confined to the crests of single muri, distinguish this species from *Appendicisporites spinosus* Pocock, 1964.

Appendicisporites sp.

Pl. 5, fig. 8

Description.—Trilete spores with subcircular to rounded triangular amb and laesurae nearly reaching the equator. Proximal surface smooth, and distal surface canaliculate, with one set of muri paralleling the equator and the remaining three muri paralleling one side only. Smooth flanges of approximately the same width as the muri circumvent the equator. Short, blunt appendages occur at the radii, where the distal muri and equatorial flanges join.

Dimensions.—Equatorial diameter 56(60)63 microns.

Occurrence.—Rare. Only four specimens observed.

Remarks.—Although the radial appendages are very small, assignment to *Appendicisporites* rather than to *Cicatricosisporites* seems more appropriate.

Genus *Cicatricosisporites* Potonié and Gelletich, 1933

Type species.—*Cicatricosisporites dorogensis* Potonié and Gelletich, 1933.

See Dettmann (1963, p. 52) for synonymy and description.

Remarks.—Spores referred to this genus are closely comparable to those of modern *Anemia*, characterized by surface ornamentation of more or less parallel muroid ridges. Most spores of *Cicatricosisporites* have a circular to subcircular amb and lack the prominent radial appendages characteristic of *Appendicisporites*. As noted previously, however, several forms with small radial thickenings and rounded triangular amb have been assigned to *Cicatricosisporites*, indicating gradation between this genus and *Appendicisporites*.

Cicatricosisporites baconicus Deák, 1963

Pl. 4, figs. 9, 10

See Srivastava (1972a, p. 8) for synonymy and description.

Dimensions.—Equatorial diameter 40(41)44 microns.

Occurrence.—Rare.

Cicatricosisporites claricanalis

Phillips and Felix, 1971

Pl. 5, fig. 11

1971 *Cicatricosisporites claricanalis* PHILLIPS and FELIX, p. 299.

Dimensions.—Equatorial diameter 50(58)70 microns.

Occurrence.—Rare.

Cicatricosisporites hallei Delcourt and Sprumont, 1955

Pl. 5, fig. 12

1963 *Cicatricosisporites hallei* DELCOURT and SPRUMONT, p. 17.

See Singh (1971, p. 71) for discussion.

Dimensions.—Equatorial diameter 41(45)51 microns.

Occurrence.—Rare.

Remarks.—*Cicatricosisporites hallei* is larger and has lower, more rounded muri than *C. venustus*. Differences in distal rib patterns between those two species, discussed by Singh, may not be reliable criteria for distinction. *Cicatricosisporites cuneiformis* Pocock, 1964, differs in being more triangular and having a more canaliculate sculpture, but there does appear to be overlap between the two species.

Cicatricosisporites goniodontos

Phillips and Felix, 1971

Pl. 6, fig. 1

1971 *Cicatricosisporites goniodontos* PHILLIPS and FELIX, p. 297.

Dimensions.—Equatorial diameter 40(47)50 microns.

Occurrence.—Rare.

Cicatricosisporites hughesii

Dettmann, 1963

Pl. 5, figs. 13, 14

1963 *Cicatricosisporites hughesii* DETTMANN, p. 55.

See Dettmann (1963, p. 55) for descrip-

tion, and Singh (1971, p. 72) for discussion and comparisons.

Dimensions.—Equatorial diameter 45(46)48 microns.

Occurrence.—Rare.

***Cicatricosisporites venustus* Deák, 1963**

Pl. 6, fig. 2

1963 *Cicatricosisporites venustus* DEÁK, p. 252.

See Singh (1971, p. 80) for discussion.

Dimensions.—Equatorial diameter 34(35)37 microns.

Occurrence.—Rare to occasional.

***Cicatricosisporites ludbrookii* Dettmann, 1963**

Pl. 6, fig. 4

1963 *Cicatricosisporites ludbrookii* DETTMANN, p. 54.

Dimensions.—Equatorial diameter 59(71)86 microns.

Occurrence.—Rare. Only eight specimens observed.

Cicatricosisporites mediotriatus

(Bolkhovitina) Pocock, 1964

Pl. 6, fig. 3

See Pocock (1964, p. 157) for synonymy and description.

Dimensions.—Equatorial diameter 46(52)59 microns.

Occurrence.—Rare.

Remarks.—Singh (1971) considered this form to be conspecific with *Cicatricosisporites hallei*, which may be the case, although *C. mediotriatus* appears to have a more circular amb and broader muri with a lower, more flat-topped outline. Assignment here of specimens to *C. mediotriatus* is therefore considered tentative.

***Cicatricosisporites* sp., cf.**

***Anemia exilioides* (Maljavkina)**

Bolkhovitina, 1953

Pl. 6, figs. 6, 7

See Singh (1971, p. 70) for synonymy and description.

Dimensions.—Equatorial diameter 55(57)60 microns.

Occurrence.—Rare.

Remarks.—This form is characterized by small radial thickenings that suggest some

transition between the genera *Cicatricosisporites* and *Appendicisporites*.

Cicatricosisporites perforatus

(Baranov, Memkova and Kondratiev)

Singh, 1964

Pl. 6, fig. 5

See Phillips and Felix (1971a, p. 295) for synonymy and description.

Dimensions.—Equatorial diameter 48(55)68 microns.

Occurrence.—Rare.

Cicatricosisporites potomacensis

Brenner, 1963

Pl. 6, figs. 9, 10

1963 *Cicatricosisporites potomacensis* BRENNER, p. 50.

Dimensions.—Equatorial diameter 69(73)74 microns.

Occurrence.—Rare.

***Cicatricosisporites stoveri* Pocock, 1964**

Pl. 6, fig. 8

1964 *Cicatricosisporites stoveri* POCK, p. 161.

Dimensions.—Equatorial diameter 64(71)83 microns.

Occurrence.—Rare.

Cicatricosisporites pseudotripartitus

(Bolkhovitina) Dettmann, 1963

Pl. 6, fig. 11

See Dettmann (1963, p. 54) for synonymy and description.

Dimensions.—Equatorial diameter 38(42)46 microns.

Occurrence.—Rare.

***Cicatricosisporites striatus* Rouse, 1962**

Pl. 7, fig. 1

See Burger (1966, p. 244) for description.

Dimensions.—Equatorial diameter 45(49)51 microns.

Occurrence.—Rare.

Cicatricosisporites brevilaesuratus

Couper, 1958

Pl. 7, fig. 2

1958 *Cicatricosisporites brevilaesuratus* COUPER, p. 136.

Dimensions.—Equatorial diameter 68(72)77 microns.

Occurrence.—Rare.

Cicatricosisporites sp., cf. **C. mohrioides**
Delcourt and Sprumont, 1955

Pl. 7, figs. 4, 5

Dimensions.—Equatorial diameter 46(50)52 microns.

Occurrence.—Rare.

Remarks.—This form is most similar to *Cicatricosisporites mohrioides* Delcourt and Sprumont, 1955 (see Burger, 1966; Singh, 1971), but it differs in having fewer, narrower muri. This difference may be insignificant, however, and the form may be conspecific with *C. mohrioides*. The spore illustrated here appears identical with the one illustrated by Norris (1968, pl. 2, fig. 8) as *Cicatricosisporites* sp.

Cicatricosisporites sp. A

Pl. 7, fig. 3

Description.—Trilete spore with laesurae extending to the equator and triangular amb with rounded sides. Sculpture consists of muri of approximately the same width as intervening spaces, paralleling the equator. The muri do not join at the radii and extend beyond the equator, forming distinct sinuses at the radii. A thin flange occurs along the equatorial plane, interrupted only by the radial sinuses.

Dimensions.—Equatorial diameter 40(42)45 microns.

Occurrence.—Rare.

Cicatricosisporites sp. B

Pl. 7, fig. 6

Description.—Trilete spores with laesurae reaching the equator and bordered by thin, membranous lips. Amb subtriangular with convex sides and broadly rounded radii. Sculpture canaliculate with three sets of muri extending from the proximal surface onto the distal surface obliquely to the equator. The muri of each set meet at a high angle on the distal surface, forming a triangle over the distal pole.

Dimensions.—Equatorial diameter 48 microns.

Occurrence.—Only a single specimen observed.

Cicatricosisporites sp. C

Pl. 7, fig. 9

Description.—Trilete spores with laesurae extending to the equator, bordered by thin

membranous lips. Sculpture cicatricose, with muri only slightly narrower than intervening spaces. Proximal muri parallel to the equator and distal muri subparallel to the equator, with some bifurcating and some discontinuous.

Dimensions.—Equatorial diameter 44(47)50 microns.

Occurrence.—Rare.

Remarks.—This form is similar to *Cicatricosisporites* sp., cf. *C. mohrioides*, differing chiefly in having broader muri that branch and commonly terminate freely.

Cicatricosisporites sp. D

Pl. 7, figs. 7, 8

Description.—Trilete spores with circular to subcircular amb and simple laesurae extending approximately two-thirds to three-fourths the distance to the equator. Sculpture cicatricose, with proximal muri in sets parallel to one laesura and oblique to the other two and the equator. Muri commonly discontinuous (i.e., consisting of short, disconnected segments).

Dimensions.—Equatorial diameter 65(76)80 microns.

Occurrence.—Rare.

Remarks.—*Cicatricosisporites* sp. D differs from *C. hallei* in being cicatricose rather than canaliculate and from *C. venustus* by its larger size.

Genus **Klukisporites** Couper, emend.
Pocock, 1964

Type species.—*Klukisporites variegatus* Couper, 1958.

See Pocock (1964, p. 193) for synonymy and emended diagnosis, and Singh (1964, p. 64) for further description.

Remarks.—Pocock's (1964) emendation of *Klukisporites* expands the genus to include forms with convolute ornament as well as the foveolate sculpture described by Couper (1958) in his generic diagnosis. Singh (1964) essentially did the same but did not treat it as a formal emendation. The genus was established to include dispersed spores of the type produced by the fossil plants *Klukia* and *Stachypteris*, representatives of the Schizaeaceae (Pocock, 1964; Dettmann, 1963). Foveolate forms of *Klukisporites* closely resemble spores included in *Dictyotriletes* (Sri-

vastava, 1972a), and enough overlap occurs to have led Singh (1971) to suggest the necessity for detailed revision.

Klukisporites foveolatus Pocock, 1964

Pl. 7, fig. 12

See Singh (1971, p. 95) for synonymy, and Pocock (1964, p. 194) for description.

Dimensions.—Equatorial diameter 52(61)68 microns.

Occurrence.—Rare.

Klukisporites sp.

Pl. 7, figs. 10, 11

Description.—Trilete spores with laesurae bordered by thin, membranous lips and extending to the equator. Amb subtriangular with convex sides and well rounded radii. Sculpture foveolate to foveo-reticulate on the distal surface and extending onto the proximal surface one-half to two-thirds the distance from the equator to the pole. Proximal sculpture much reduced. The equatorial outline is distinctly dentate.

Dimensions.—Equatorial diameter 44(52)56 microns.

Occurrence.—Rare.

Remarks.—This form is placed in the genus *Klukisporites* because of the foveolate sculpture that occurs on much of the proximal surface as well as all of the distal surface. Argument could be made for placing these specimens in either *Lycopodiumsporites* or *Dictyotriletes*, and they therefore fall into the zone of overlap of these genera and *Klukisporites*, as discussed by Singh (1971).

Genus **Distaltriangulisporites** Singh, 1971

Type species.—*Distaltriangulisporites perplexus* (Singh) Singh, 1971.

See Singh (1971, p. 88) for synonymy and generic diagnosis.

Distaltriangulisporites perplexus (Singh) Singh, 1971

Pl. 7, fig. 13

See Singh (1964, p. 55) for synonymy and description.

Dimensions.—Equatorial diameter 38(44)56 microns.

Occurrence.—Rare.

Distaltriangulisporites mutabilis Singh, 1971

Pl. 7, fig. 14

1971 *Distaltriangulisporites mutabilis* SINGH, p. 94.

Dimensions.—Equatorial diameter 36(44)50 microns.

Occurrence.—Rare.

Genus **Schizaeosporites** Potonié, 1951

Type species.—*Schizaeosporites eocenicus* Potonié, 1956.

See Singh (1964, p. 62) for synonymy.

Remarks.—Krutzsch (1959) considered the type species of *Schizaeosporites* to be alele and proposed an emendation restricting the genus to alele forms. Monoete forms then may be accommodated by the genus *Cicatricosporites* Thompson and Pflug ex Krutzsch, 1959. Potonié (1951) considered *Schizaeosporites* monoete and treated *Cicatricosporites* as a junior synonym. No germinal aperture is visible on specimens of *Schizaeosporites* from the Denton Shale, but the form of the spores suggests monoete dehiscence. If these spores are indeed monoete, it would be most difficult to observe owing to the thick, closely spaced muri of the ektexine, unless dehiscence had occurred prior to preservation. This leads to the conclusion that Potonié's interpretation is probably the correct one and that Krutzsch's emendation is invalid.

Schizaeosporites eocenicus

(Selling) Potonié, 1956

Pl. 8, figs. 1–3

(Synonymy as for genus.)

Dimensions.—Length 43(55)70 microns; width 34(36)40 microns.

Occurrence.—Rare.

Remarks.—Singh (1971, p. 81) erected a new species to accommodate forms having auriculate protrusions at the ends of the elongated spore body, similar to some specimens from the Denton Shale. Since intermediate forms occur between those lacking auriculate protrusions and those having them, it becomes very difficult, if not impossible, to separate the forms into two exclusive species.

?Schizaeoisorites sp.

Pl. 8, fig. 4

Description.—Monolete spores with a longitudinal equatorial axis nearly twice the length of the polar axis. Surface ornament consists of widely spaced spines with rounded tips.

Dimensions.—Length 70 and 72 microns; breadth 40 microns.

Occurrence.—Only two specimens observed.

Remarks.—These spores are tentatively placed in *Schizaeoisorites* primarily because of the structure of the exine ornament, although this feature also occurs in the Polyodiaceae.

Genus Trilobosporites Pant
ex Potonié, 1956

Type species.—*Trilobosporites hannonicus* (Delcourt and Sprumont) Potonié, 1956.

See Delcourt, Dettmann, and Hughes (1963, p. 288) for synonymy and generic diagnosis.

Remarks.—Pocock (1964) proposed a schizaeaceous affinity for *Trilobosporites* based on its close resemblance to spores of some species of modern *Lygodium*, which is the concept followed here.

Trilobosporites canadensis Pocock, 1962

Pl. 8, fig. 5

1962 *Trilobosporites canadensis* POCOCK, p. 44.

Dimensions.—Equatorial diameter 74(80)90 microns.

Occurrence.—Rare.

Trilobosporites humilis
Delcourt and Sprumont, 1959

Pl. 8, figs. 6, 7

See Brenner (1963, p. 71) for synonymy and description.

Dimensions.—Equatorial diameter 28(35)40 microns.

Occurrence.—Rare.

Trilobosporites apiverrucatus Couper, 1958

Pl. 8, fig. 8

1958 *Trilobosporites apiverrucatus* COUPER, p. 142.

Dimensions.—Equatorial diameter 50(64)74 microns.

Occurrence.—Rare.

Trilobosporites minor Pocock, 1962

Pl. 8, fig. 9

1962 *Trilobosporites minor* POCOCK, p. 44.

Dimensions.—Equatorial diameter 34 microns.

Occurrence.—A single specimen observed.

Family GLEICHENIACEAE

Genus **Gleicheniidites** Ross, 1949

Type species.—*Gleicheniidites senonicus* Ross, 1949.

See Srivastava (1972a, p. 14) for synonymy and discussion.

Gleicheniidites senonicus Ross, 1949

Pl. 8, fig. 10

See Singh (1964, p. 69) for synonymy, and Brenner (1963, p. 53) for description.

Dimensions.—Equatorial diameter 24(27)30 microns.

Occurrence.—Rare to occasional.

Genus **Ornamentifera** Bolkhovitina, 1966

Type species.—*Ornamentifera echinata* (Bolkh.) Bolkhovitina, 1966.

See Dettmann and Playford (1968, p. 77) for synonymy and discussion.

Remarks.—The genus *Ornamentifera* is distinguished from other spinose, trilete spores in possessing interradial exinal thickenings. Compression of the spores frequently results in an apparent kytome about the laesurae. The presence of interradial thickenings and general form of *Ornamentifera* strongly suggest affinity with the Gleicheniaceae.

Ornamentifera echinata (Bolkh.)

Bolkhovitina, 1966

Pl. 8, fig. 11

See Singh (1971, p. 98) for synonymy and discussion.

Dimensions.—Equatorial diameter 29(38)44 microns.

Occurrence.—Rare.

Remarks.—According to Singh (1971), the absence of interradial crassitudes in some specimens, as noted by Norris (1967), is likely due to poor preservation or over-maceration. Specimens in this study that appear to lack crassitudes do not show any further signs of alteration, suggesting that there is inherent variation of form involved. When crassitudes are absent, these forms could easily be accommodated in the Paleozoic form-genus *Apiculatisporis* Potonié and Kremp, 1956. Assignment of these forms to *Ornamentifera echinata* in the present study is predicated on the close similarity of other characters with forms having clearly developed interradial crassitudes. Singh (1971) further notes that specimens assigned by Brenner (1963) to *Pilosisporites brevipapillosus* Couper and by Norris (1967) to *Pilosisporites* sp. are probably conspecific with *Ornamentifera echinata*.

Family CYATHEACEAE
or DICKSONIACEAE

Genus **Concavissimisporites**

Delcourt and Sprumont,
emend. Delcourt, Dettmann and Hughes,
1963

Type species.—*Concavissimisporites verrucosus* Delcourt and Sprumont, 1955.

See Singh (1964, p. 76) for synonymy and discussion.

Remarks.—Dettmann (1963) noted the close resemblance of spores of *Concavissimisporites* and those of some species of modern *Cyathea* and *Dicksonia* but also pointed out that some similarity also exists with some modern *Lygodium* spores. The placement of this form-genus in the Cyatheaceae or Dicksoniaceae must therefore be considered tentative.

Concavissimisporites punctatus

(Delcourt and Sprumont) Brenner, 1963
Pl. 8, fig. 12

See Singh (1971, p. 114; 1964, p. 77) for synonymy and description.

Dimensions.—Equatorial diameter 42(58)68 microns.

Occurrence.—Rare.

Concavissimisporites variverrucatus

(Couper) Brenner, 1963

Pl. 8, fig. 13

See Singh (1971, p. 114; 1964, p. 78) for synonymy and description.

Dimensions.—Equatorial diameter 38(54)74 microns.

Occurrence.—Rare.

Genus **Cyathidites** Couper, 1953

Type species.—*Cyathidites australis* Couper, 1953.

See Singh (1964, p. 70) for description and discussion.

Cyathidites minor Couper, 1953

Pl. 8, fig. 14

See Dettmann (1963, p. 22) for synonymy and discussion.

Dimensions.—Equatorial diameter 31(39)46 microns.

Occurrence.—Occasional to common.

Genus **Kuylisporites** Potonié, 1956

Type species.—*Kuylisporites waterbolki* Potonié, 1956.

See Potonié (1956) for generic diagnosis.

Remarks.—Dettmann (1963) discussed the comparison of *Kuylisporites* with other, similar forms, noting that as defined by Potonié (1956) *Kuylisporites* is characterized by distal and equatorial crescent-shaped thickenings or ridges (scutula of Potonié) surrounding shallow lumina. Dettmann further noted the similarity of spores of *Kuylisporites* with certain spores of *Hemitelia* R. Brown, and slight resemblance to some spores of *Alsophila blechnoides* (Rich.), both belonging to the extant Cyatheaceae.

Kuylisporites lunaris Cookson
and Dettmann, 1958

Pl. 9, fig. 1

1958 *Kuylisporites lunaris* COOKSON and DETTMANN, p. 103.

See Dettmann (1963, p. 39) for description and discussion.

Dimensions.—Equatorial diameter 31 x 37 and 44 x 46 microns.

Occurrence.—Only two specimens observed.

Family MARSILIACEAE

Genus *Crybelosporites* Dettmann, 1963

Type species.—*Crybelosporites striatus* (Cookson and Dettmann) Dettmann, 1963.

Remarks.—*Crybelosporites* is characterized by an outer layer of the exine, which is detached from the inner layer in the area of the proximal pole. Dettmann (1963) considered spores of *Crybelosporites* to be analogous with microspores of several species of the modern Marsiliaceae (*Marsilea*, *Pilularia*, and *Regnellidium*).

Crybelosporites brenneri

Playford, 1971

Pl. 9, figs. 2, 3

See Playford (1971, p. 550) for synonymy and description.

Dimensions.—Equatorial diameter 35(40)47 microns; polar diameter 43(51)64 microns.

Occurrence.—Rare to occasional.

Remarks.—Playford (1971) considered this species distinct from *Crybelosporites striatus* and gave it the new name *C. brenneri*, as it included forms identified as *Petrotriletes striatus* by Brenner (1963).

Crybelosporites pannuceus

(Brenner), n. comb.

Pl. 9, figs. 4, 5

1963 *Petrotriletes pannuceus* BRENNER, p. 66.

Dimensions.—Equatorial diameter of spore body 32(51)63 microns; overall diameter with perispore present is 58(67)74 microns.

Occurrence.—Rare to occasional.

Remarks.—This species is characterized by a delicate perispore that is detached from the inner layers of the sporoderm in the area of the proximal pole. This feature indicates that the species belongs in *Crybelosporites*. The perispore is torn away from the inner spore body in varying degrees in several specimens observed. Some smooth-walled, circular spores with a thick exine that lacks a perispore appear identical with the inner spore body of *C. pannuceus* (pl. 9, fig. 4). The specimen illustrated by Kimyai (1964, pl. 9,

fig. 5) as *Trachytriletes*, cf. *T. ancoraeformis* Bolkhovitina, 1953, from the Raritan Formation (Cenomanian) of the eastern United States, appears to be an inner body of *Crybelosporites pannuceus* with the perispore absent.

Family POLYPODIACEAE

Genus *Laevigatosporites* Ibrahim, emend.

Schopf, Wilson, and Bentall, 1944

Type species.—*Laevigatosporites vulgaris* (Ibrahim) Ibrahim, 1933.

See Singh (1964, p. 98) for description.

Laevigatosporites ovatus

Wilson and Webster, 1946

Pl. 9, fig. 6

See Singh (1964, p. 99) for synonymy and description.

Dimensions.—Length 34(43)48 microns; breadth (polar axis) 25(30)35 microns; width 22(29)32 microns.

Occurrence.—Rare.

DIVISION PTEROPHYTA—*INCERTAE SEDIS*Genus *Antulsporites* Archangelsky and Gamarro, 1966

Type species.—*Antulsporites baculatus* (Archangelsky and Gamarro) Archangelsky and Gamarro, 1966.

See Singh (1971, p. 105) for synonymy and description.

Remarks.—Specimens from the Denton Shale assigned to *Antulsporites* have an asymmetric triangular cingulum surrounding a circular to oval central body. In many specimens the trilete is indistinct and where visible is undulate and extends only to the inner margin of the cingulum.

Antulsporites distaverrucosus (Brenner) Archangelsky and Gamarro, 1966

Pl. 9, figs. 7, 8

See Singh (1971, p. 109) for synonymy, and Brenner (1963, p. 58) for description.

Dimensions.—Equatorial diameter 38(48)64.

Occurrence.—Rare.

Genus **Balmeisporites** Cookson
and Dettmann, 1958

Type species.—*Balmeisporites holodictyus* Cookson and Dettmann, 1958.

See Cookson and Dettmann (1958, p. 42) for generic diagnosis, and Singh (1971, p. 215) for additional remarks.

Remarks.—*Balmeisporites* represents a megaspore form-genus with a reported size range from 70 to 220 microns (Singh, 1971; Dettmann, 1963).

Balmeisporites holodictyus
Cookson and Dettmann, 1958

Pl. 9, fig. 9

See Cookson and Dettmann (1958, p. 42) for description, and Dettmann (1963, p. 58) for additional remarks.

Dimensions.—Equatorial diameter of inner spore body 97(111)120 microns; overall diameter 151(172)198 microns.

Occurrence.—Rare.

?**Balmeisporites** sp.

Pl. 9, fig. 10

Description.—Trilete spores with laesurae that are simple slits and commonly indistinct and extend to the equator. The perispore is irregular in shape and, in unaltered specimens, is attached to the inner spore body over its entire surface. The perispore is finely reticulate and is thin and delicate (it is frequently torn partially away from the inner body). The amb is circular, and the wall of the inner body is smooth and thick (4 to 6 microns, measured at the equator).

Dimensions.—Equatorial diameter of inner body 80(89)94 microns; overall diameter 92(102)115 microns.

Occurrence.—Rare.

Remarks.—Spores here treated as ?*Balmeisporites* sp. do not entirely conform to the genus *Balmeisporites*, having a more irregularly developed perine-like outer layer of the sporoderm. Strong superficial resemblance exists between these specimens and speci-

mens of *Dictyotosporites* Cookson and Dettmann, 1958, reported by Dettmann (1963), but the stratified, doubly reticulate nature of the ektexine so characteristic of *Dictyotosporites* is not evident in specimens from the Denton Shale. Some slight resemblance also exists between these specimens and some forms of *Crybelosporites* Dettmann, 1963, but the proximally cavate character of *Crybelosporites* is lacking. The large size of the specimens agrees with *Balmeisporites*, but the placement of Denton specimens in this genus is considered tentative.

Genus **Cingulatisporites** Thompson,
emend. Potonié, 1956

Type species.—*Cingulatisporites levispeciosus* Pflug, in Thompson and Pflug, 1953.

See Potonié (1956, p. 58) for emended diagnosis.

Remarks.—The genus *Cingulatisporites* includes trilete spores with a cingulum, smooth wall, and triangular to convex-triangular amb. Some confusion exists between this genus and *Cingutriteles* Pierce, emend. Dettmann, 1963, which differs only in having a subcircular to circular amb. The distinction between convex-triangular and subcircular is not always clear, and some overlap may occur. Hughes (1969a) suggested that *Cingulatisporites* is best restricted to use with Tertiary material, but this does not deal with the problem. Specimens from the Denton Shale have a nearly circular amb and perhaps best belong in *Cingutriteles*, but they are treated here under *Cingulatisporites* to emphasize their close resemblance to forms previously ascribed to that genus. Pending further evaluation of this group, the botanical affinity is treated as uncertain, although similar forms in the genus *Cingutriteles* are attributed to the Sphagnaceae (Singh, 1971; Dettmann, 1963).

Cingulatisporites levispeciosus Pflug,
in Thompson and Pflug, 1953

Pl. 9, fig. 11

1953 *Cingulatisporites levispeciosus* PFLUG, in Thompson and Pflug, p. 58.

Dimensions.—Equatorial diameter 29(39)54 microns.

Occurrence.—Rare.

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

Type species.—*Concavisporites rugulatus* Pflug, in Thompson and Pflug, 1953.

See Potonié (1956, p. 15) for generic diagnosis, and Singh (1964, p. 76) for additional remarks.

Concavisporites jurienensis Balme, 1957
Pl. 9, fig. 12

See Burger (1966, p. 237) for synonymy and description.

Dimensions.—Equatorial diameter 19(23)26 microns.

Occurrence.—Rare.

Concavisporites sp.
Pl. 9, fig. 13

Description.—Trilete spore with concave sides and laesurae extending over four-fifths the distance from pole to equator. Thickened exine bordering the laesurae usually results in arcuate folds in the interradian regions of the proximal surface. Exine scabrate to smooth, having a mottled appearance.

Dimensions.—Equatorial diameter 26(32)34 microns.

Occurrence.—Rare.

Remarks.—Specimens from the Denton Shale appear most similar to the form described by Phillips and Felix (1971a, p. 309, pl. iii, fig. 14) as *Concavisporites* sp. from the Tuscaloosa Formation (Cenomanian) of Louisiana, U.S.A.

Genus **Deltoidospora** Miner,
emend. Potonié, 1956

Type species.—*Deltoidospora hallii* Miner, 1935.

See Singh (1964, p. 80) for synonymy and description.

Deltoidospora hallii Miner, 1935
Pl. 9, fig. 14

See Phillips and Felix (1971a, p. 309) for synonymy and description.

Dimensions.—Equatorial diameter 28(35)40 microns.

Occurrence.—Occasional to abundant.

Genus **Dictyophyllidites** Couper,
emend. Dettmann, 1963

Type species.—*Dictyophyllidites harrisii* Couper, 1958.

See Srivastava (1972a, p. 11) for synonymy, and Dettmann (1963, p. 27) for emended diagnosis.

Dictyophyllidites equixinous
(Couper) Dettmann, 1963

Pl. 9, fig. 15

1958 *Matonisporites equixinous* COUPER, p. 140.

1963 *Dictyophyllidites equixinous* (Couper) DETTMANN, p. 17.

See Couper (1958, p. 140) for description.

Dimensions.—Equatorial diameter 33 × 36 microns.

Occurrence.—Only a single specimen observed.

Dictyophyllidites sp.
Pl. 9, fig. 16

Description.—Spores trilete, rounded triangular to subcircular amb, with scabrate exine. Laesurae nearly reaching the equator, commonly forked at the extremities, and bordered by a zone of thickened exine.

Dimensions.—Equatorial diameter 28(36)56 microns.

Occurrence.—Rare.

Genus **Foveotriletes** van der Hammen
ex Potonié, 1956

Type species.—*Foveotriletes scrobiculatus* (Ross) Potonié, 1956.

See Potonié (1956, p. 43) for synonymy and emended diagnosis, and Singh (1971, p. 121) for additional remarks.

Foveotriletes subtriangularis
Brenner, 1963

Pl. 10, fig. 1

See Brenner (1963, p. 62) for description.

Dimensions.—Equatorial diameter 42(46)51 microns.

Occurrence.—Rare.

Remarks.—The proposed transfer of this species from *Foveotriletes* to *Foveosporites* Balme, 1957, by Phillips and Felix (1971a, p. 318), on the basis of the convexly triangular amb, is not accepted here. Instead, the usage of Singh (1971) is followed.

Genus *Ischyosporites* Balme, 1957

Type species.—*Ischyosporites crateris* Balme, 1957.

See Balme (1957, p. 23) for generic diagnosis.

Remarks.—*Ischyosporites* closely resembles *Klukisporites* Couper, 1958, but is distinguished by equatorial exinal thickenings in the radial areas (valvae), a feature not found in *Klukisporites*.

Ischyosporites disjunctus

Singh, 1971

Pl. 10, fig. 2

1971 *Ischyosporites disjunctus* SINGH, p. 123.

Dimensions.—Equatorial diameter 52(63)70 microns.

Occurrence.—Rare.

Genus *Interulobites* Phillips,
in Phillips and Felix, 1971

Type species.—*Interulobites intraverrucatus* (Brenner) Phillips, in Phillips and Felix, 1971.

See Phillips and Felix (1971a, p. 328) for generic diagnosis.

Remarks.—*Interulobites* is characterized by a broad cingulum and prominent verrucae, rugae, or baculae on the distal surface. Proximal ornament, where present, usually consists of low verrucae or rugae and thickened laesurate margins that are frequently dissected, giving the appearance of rows of rugae oriented perpendicular to the laesurae. *Taurocusporites* Stover, emend. Playford and Dettmann, 1965, is a similar form-genus, differing in having a trizonate distal surface. *Polycingulatisporites* Simoncsics and Kedves, 1961, differs from *Taurocusporites* in being proximally smooth and having three or more zones of sculpture on the distal surface. These three genera may have come from closely related plants.

Interulobites intraverrucatus (Brenner)

Phillips, in Phillips and Felix, 1971

Pl. 10, fig. 3

1963 *Lycopodiacidites intraverrucatus* BRENNER, p. 63.

1971 *Interulobites intraverrucatus* (Brenner) PHILLIPS, in Phillips and Felix, p. 328.

Dimensions.—Equatorial diameter

46(56)62 microns.

Occurrence.—Rare.

Interulobites triangularis (Brenner)

Phillips, in Phillips and Felix, 1971

Pl. 10, fig. 4

1963 *Lycopodiacidites triangularis* BRENNER, p. 65.

1971 *Interulobites triangularis* (Brenner) PHILLIPS, in Phillips and Felix, p. 329.

Dimensions.—Equatorial diameter 38(46)52 microns.

Occurrence.—Rare.

Genus *Leptolepidites* Couper,
emend. Schulz, 1967

Type species.—*Leptolepidites verrucatus* Couper, 1953.

See Schulz (1967, p. 558) for emended diagnosis.

Remarks.—*Leptolepidites*, as emended by Schulz (1967), includes trilete spores with subtriangular to circular amb and coarse, warty sculpture. The sculpture consists of verrucae or gemmae of variable shape, usually domelike with circular outline, which is distributed uniformly over the distal surface of the spore and extends onto the periphery of the proximal surface. The proximal surface is either smooth or has reduced ornament. *Verrucosisporites* Ibrahim, emended Potonié and Kremp, 1954, has very similar morphology, and some overlap between this and *Leptolepidites* may occur. The sculptural elements of *Verrucosisporites* are generally smaller, in relation to the spore size, than those of *Leptolepidites*, and they are not dome-shaped. Also, the ornament on *Verrucosisporites* is equally developed on both proximal and distal surfaces in a pattern that Krutzsch (1959) referred to as "Osmunda-like." *Convrrucosisporites* Potonié and Kremp, 1954, is essentially the same as *Verrucosisporites* but has a generally triangular amb, not approaching subcircular.

Leptolepidites irregularis

(Brenner), n. comb.

Pl. 10, fig. 5

1963 *Lycopodiacidites irregularis* BRENNER, p. 64.

Dimensions.—Equatorial diameter 24(39)54 microns.

Occurrence.—Rare.

Remarks.—*Lycopodiacidites* Couper, emended Potonié, 1956, has a smooth proximal surface and a hamulate distal surface that is the result of convolute folding of what Couper (1953) described as "a hyaline outer coat (?perispore)." The species *irregularis* is coarsely verrucate and therefore would be better accommodated in *Leptolepidites* than in *Lycopodiacidites*.

Leptolepidites proxigranulatus

(Brenner), n. comb.

Pl. 10, fig. 6

1963 *Convruccosporites proxigranulatus* BRENNER, p. 60.

Dimensions.—Equatorial diameter 31(41)48 microns.

Occurrence.—Rare.

Remarks.—The circular amb and reduced proximal ornament on this species is more conformable with *Leptolepidites* than with *Convruccosporites* (see discussion for the genus, above).

Leptolepidites washitaensis, n. sp.

Pl. 10, figs. 7, 8

Description.—Trilete spores with laesurae extending to the equator and bordered by raised, membranous lips. Proximal surface flattened and smooth. Distal surface covered with large, domelike verrucae, extending onto the equatorial plane. Each verruca is circular to polygonal in plan view and has a diameter of 12 to 15 percent of the total diameter of the spore. Amb rounded triangular to subcircular.

Holotype.—OPC 1211 W-13-13; pl. 10, figs. 7, 8; overall equatorial diameter 36 microns.

Dimensions.—Overall equatorial diameter 33(39)44 microns.

Occurrence.—Rare.

Remarks.—*Leptolepidites washitaensis*, n. sp., is distinguished from *L. proxigranulatus* (Brenner), n. comb., by the former's rounded triangular to subcircular amb and smooth proximal surface. The spore illustrated by Kimyai (1964, pl. 5, figs. 7, 8) as *Convruccosporites proxigranulatus* Brenner appears conspecific with *Leptolepidites washitaensis*, n. sp.

Genus **Lophotriletes** Naumova ex Potonié and Kremp, 1954

Type species.—*Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp, 1954.

See Potonié and Kremp (1955, p. 72) for generic diagnosis, and Singh (1971, p. 126) for comparisons with other genera.

Lophotriletes babsae (Brenner) Singh, 1971

Pl. 10, fig. 9

1963 *Apiculatisporis babsae* BRENNER, p. 56.

1971 *Lophotriletes babsae* (Brenner) SINGH, p. 127.

See Brenner (1963, p. 56) for description.

Dimensions.—Equatorial diameter 33 × 36 microns.

Occurrence.—Only a single specimen was observed.

Lophotriletes brevipapillosus

(Couper), n. comb.

Pl. 10, fig. 10

1958 *Pilosisporites brevipapillosus* COUPER, p. 144.

Dimensions.—Equatorial diameter 28(29)32 microns.

Occurrence.—Rare.

Remarks.—*Lophotriletes* is characterized by surface ornament of dispersed conical whose basal diameters are equal to or less than their height (see Singh, 1971), whereas *Pilosisporites* Delcourt and Sprumont, 1955, has surface ornament of closely packed, very thin spines, or capilli (see Singh, 1964). Singh (1971) believed the forms illustrated by Brenner (1963) as *Pilosisporites brevipapillosus* possess interrational crassitudes and therefore belong in *Ornamentifera echinata*. Brenner's illustrations (pl. 20, figs. 2a, 2b) are of a highly compressed specimen, which does not appear to have interrational crassitudes; it appears, rather, that there is a slight thickening of the laesurate borders. Brenner's specimen and specimens from the Denton Shale agree closely with illustration and description of the type species of Couper (1958) and are here treated as conspecific.

?**Lophotriletes** sp.

Pl. 10, fig. 11

Description.—Trilete spores with subtriangular to subcircular amb. Laesurae ex-

tend to the equator. Surface ornament consists of irregularly spaced low conical bluntnly tapered or somewhat rounded at the apices.

Dimensions.—Equatorial diameter 33(40)47 microns.

Occurrence.—Rare.

Genus **Matonisorites** Couper,
emend. Dettmann, 1963

Type species.—*Matonisorites phlebopteroides* Couper, 1958.

See Dettmann (1963, p. 58) for synonymy and emended diagnosis.

Remarks.—The genus *Matonisorites* is characterized by exinal thickenings (valvae) at the equatorial, radial regions and elevated laesurate lips, and has been likened to the spores of several species of the Mesozoic fern *Phlebopteris*, which has been placed in the Matoniaceae (see Dettmann, 1963).

Matonisorites sp.

Pl. 10, fig. 12

Description.—Trilete spore with laesurae reaching the equator. Exine smooth, with equatorial thickenings at the radii.

Dimensions.—Equatorial diameter 63(70)78 microns.

Occurrence.—Rare.

Remarks.—The few specimens of *Matonisorites* sp. observed were compressed to varying degrees, making species identification inconclusive. The size range agrees well with both *M. phlebopteroides* Couper, 1958, and *M. cooksoni* Dettmann, 1963, and the specimens from the Denton Shale possibly belong in one of these species, but definitive characters could not be discerned. *Matonisorites crassiangulatus* (Balme) Dettmann, 1963, is significantly smaller (48 to 51 microns; Singh, 1971).

Genus **Microreticulatisporites** Knox,
emend. Potonié and Kremp, 1954

Type species.—*Microreticulatisporites lacunosus* (Ibrahim) Knox, 1950.

See Singh (1964, p. 97) for synonymy and generic diagnosis.

Remarks.—The emendation of *Microreticulatisporites* by Bharadwaj (Palaeobotanist, v. 4, p. 119–149, 1955) to include only

triangular trilete spores is not followed here.

Microreticulatisporites crassixinuos

Brenner, 1963

Pl. 10, fig. 13

See Brenner (1963, p. 65) for description.

Dimensions.—Equatorial diameter 57(63)66 microns.

Occurrence.—Rare.

Genus **Neoraistrickia** Potonié, 1956

Type species.—*Neoraistrickia truncatus* (Cookson) Potonié, 1956.

See Dettmann (1963, p. 35) for synonymy and description.

Remarks.—Dettmann (1963) noted the similarity between spores of some species assigned to *Neoraistrickia* and those of some modern species of *Selaginella* and *Lycopodium*.

Neoraistrickia robusta Brenner, 1963

Pl. 10, fig. 14

1963 *Neoraistrickia robusta* BRENNER, p. 65.

Dimensions.—Equatorial diameter 60(64)66 microns.

Occurrence.—Rare.

Remarks.—The triangular amb and size and structure of the large, flat-topped bacula suggest that this species may be more akin to the schizeaceous genus *Appendicisporites* than to *Neoraistrickia*, but too few specimens occur within the Denton Shale to enable more critical study.

Neoraistrickia sp.

Pl. 10, fig. 15

Description.—Trilete spores with subtriangular to subcircular amb. Laesurae extend to the equator. Entire surface covered with closely spaced bacula and conical bases about as wide as their height.

Dimensions.—Equatorial diameter 55 × 59 and 58 × 62 microns.

Occurrence.—Only two specimens observed.

Remarks.—These two specimens are most similar to specimens of *Baculatisporites comaumensis* (Cookson) Potonié and may simply represent variants of that species.

The presence of both coni and bacula, however, is suggestive of affinity with *Neoraistrickia* rather than *Baculatisporites*.

Genus Peromonolites
Erdtman ex Couper, 1953

Type species.—*Peromonolites bowenii* Couper, 1953.

See Couper (1953, p. 32) for description.

Peromonolites fragilis Burger, 1966

Pl. 11, fig. 1

1966 *Peromonolites fragilis* BURGER, p. 225.

Dimensions.—Overall length 29(38)44 microns; short equatorial axis 21(29)34 microns; inner spore body length 22(29)32 microns; short equatorial axis of the inner spore body 14(20)24 microns.

Occurrence.—Rare to occasional.

Genus Pilosisporites
Delcourt and Sprumont, 1955

Type species.—*Pilosisporites trichopapillosus* (Thiergart) Delcourt and Sprumont, 1955.

See Singh (1964, p. 75) for synonymy and description.

Remarks.—Dettmann (1963) noted that spores assignable to this genus were proposed to be of schizaeaceous affinity by Bolkhovitina (1961) and Samoilovitch and Mtchedlishvili (1961), but she stated that there is no sound evidence for such a relationship.

Pilosisporites trichopapillosus
(Thiergart) Delcourt and Sprumont, 1955

Pl. 11, fig. 2

See Singh (1964, p. 75) for synonymy and description.

Dimensions.—Equatorial diameter of spore body 48 (60) 68 microns; echini 5 to 9 microns long.

Genus Polycingulatisporites
Simoncsics and Kedves, emend.
Playford and Dettmann, 1965

Type species.—*Polycingulatisporites circumulatus* Simoncsics and Kedves, 1961.

See Srivastava (1972a, p. 27) for synonymy, and Playford and Dettmann (1965, p. 143) for description. See Singh (1971, p. 130) for comparisons to other genera.

Remarks.—*Polycingulatisporites* is characterized by concentrically arranged, thickened rings on the distal surface and a smooth proximal surface.

Polycingulatisporites radiatus

Singh, 1971

Pl. 11, fig. 3

1971 *Polycingulatisporites radiatus* SINGH, p. 130.

Dimensions.—Equatorial diameter 28(32)34 microns.

Occurrence.—Rare.

Polycingulatisporites reduncus

(Bolkhovitina)

Playford and Dettmann, 1965

Pl. 11, fig. 4

See Singh (1971, p. 132) for synonymy, and Singh (1964, p. 86) for description.

Dimensions.—Equatorial diameter 42(46)51 microns.

Occurrence.—Rare to occasional.

Genus Psilatriteles van der Hammen
ex Potonié, 1956

Type species.—*Psilatriteles detortus* (Weyland and Krieger) Potonié, 1956.

See Potonié (1956, p. 18) for generic diagnosis.

Psilatriteles circumundulatus Brenner,
1963

Pl. 11, fig. 5

1963 *Psilatriteles circumundulatus* BRENNER, p. 67.

Dimensions.—Equatorial diameter 31(37)41 microns.

Occurrence.—Rare.

Psilatriteles radiatus Brenner, 1963

Pl. 11, fig. 6

1963 *Psilatriteles radiatus* BRENNER, p. 68.

Dimensions.—Equatorial diameter 40(51)60 microns.

Occurrence.—Rare.

Genus **Staplinisporites**
Pocock, 1962

Type species.—*Staplinisporites caminus* (Balme) Pocock, 1962.

See Singh (1964, p. 84) for synonymy, description, and remarks.

Remarks.—*Staplinisporites* is distinguished from *Cingulatisporites* Thompson, emend. Potonié, 1956, and *Polycingulatisporites* Simoncsics and Kedves, emend. Playford and Dettmann, 1965, in being acingulate. A closely similar genus, *Coronatispora* Dettmann, 1963, differs in having interradial crassitudes.

Staplinisporites caminus
(Balme) Pocock, 1962

Pl. 11, fig. 7

Synonymy as for genus.

See Singh (1964, p. 85) for description.

Dimensions.—Equatorial diameter 48 × 50 microns.

Occurrence.—Only a single specimen observed.

Remarks.—Dettmann (1963, p. 67) erected the genus *Coronatispora* for spores possessing interradial crassitudes but otherwise resembling *Staplinisporites*. She suggested that *S. caminus* is conspecific with *Coronatispora valdensis* (Couper) Dettmann, 1963. If this is indeed the case, *Staplinisporites* is left without a type species and becomes a synonym of *Coronatispora*. The resolution of this problem is beyond the scope of this study.

Genus **Taurocusporites** Stover,
emend. Playford and Dettmann, 1965

Type species.—*Taurocusporites segmentatus* Stover, 1962.

See Playford and Dettmann (1965, p. 146) for synonymy and emended diagnosis.

Taurocusporites segmentatus
Stover, 1962

Pl. 11, fig. 8

1962 *Taurocusporites segmentatus* STOVER, p. 55.

Dimensions.—Equatorial diameter 44(55)65 microns.

Occurrence.—Rare.

Genus **Tigrisporites** Klaus,
emend. Singh, 1971

Type species.—*Tigrisporites halleinis* Klaus, p. 140

Remarks.—Singh (1971) emended this genus to include forms with reticulate or verrucate sculpture around a distal polar thickening, rather than only rugulate forms as originally described by Klaus (1960).

Tigrisporites reticulatus Singh, 1971

Pl. 11, fig. 9

1971 *Tigrisporites reticulatus* SINGH, p. 139.

Dimensions.—Equatorial diameter 32(33)36 microns.

Occurrence.—Only four specimens observed.

Tigrisporites scurrandus Norris, 1967

Pl. 11, fig. 10

1967 *Tigrisporites scurrandus* NORRIS, p. 91.

Dimensions.—Equatorial diameter 43 × 46 and 50 × 52 microns (only two specimens suitable for measuring).

Occurrence.—Rare.

Remarks.—The specimen illustrated here appears to have had a distal polar cap, although it is not now present, and the exine appears torn away in this area. Most other specimens possess a pronounced polar thickening that tends to stain more heavily than the remainder of the exine. Because of breakage and folding, the other specimens were not considered suitable for illustration.

Tigrisporites sp., cf. **Tigrisporites**
sp. B of Singh, 1971

Pl. 11, fig. 11

See Singh (1971, p. 141) for description.

Dimensions.—Equatorial diameter 38 × 40 and 34 × 38 microns.

Occurrence.—Only two specimens observed.

Tigrisporites sp.

Pl. 11, fig. 12

Description.—Trilete spore with triangular amb with sides straight to slightly convex and with rounded corners. Laesurae extend to the equator and are bordered by thin,

membranous lips. Distal surface ornamented with large, low verrucae that are closely spaced and polygonal in outline, giving the appearance of a reverse reticulum. In the region of the distal pole, a large circular area of the exine is uniformly thick and forms a low distal cap, which tends to stain more readily than the remainder of the exine. Proximal surface ornamented by low ridges arranged parallel to each other and perpendicular to the equator.

Dimensions.—Equatorial diameter 46 microns.

Occurrence.—Only a single specimen observed.

Genus **Trilites** Erdtman ex Couper,
emend. Dettmann, 1963

Type species.—*Trilites tuberculiformis* Cookson, emend. Dettmann, 1963.

See Dettmann (1963, p. 61) for synonymy, emended generic diagnosis, and emended description of the type species.

Remarks.—*Trilites* is characterized by radial, equatorial exine thickenings (valvae) and distal verrucae or rugulae that commonly are anastomosing, giving a pseudo-foveolate appearance. Dettmann (1963) considered the spores of modern *Dicksonia squarrosa* (Forst.) to be comparable to *Trilites*.

?**Trilites** sp., cf. **T. tuberculiformis**
Cookson, emend. Dettmann, 1963

Pl. 11, fig. 13

1947 *Trilites tuberculiformis* COOKSON, British, Australian and New Zealand Antarctic Research Expedition 1929–31, Report A2, p. 136, plate 16, figs. 61, 62.

1963 *Trilites tuberculiformis* Cookson, emend. DETTMANN, p. 62.

Dimensions.—Equatorial diameter 44 × 51 microns.

Occurrence.—Only a single specimen observed.

Remarks.—The assignment of this single specimen to a form previously reported only from the Australian Lower Tertiary is considered highly tentative.

Genus **Undulatisporites** Pflug,
in Thompson and Pflug, 1953

Type species.—*Undulatisporites microcutis* Pflug, in Thompson and Pflug, 1953.

See Potonié (1956, p. 19) for diagnosis.

Undulatisporites pannuceus

(Brenner) Singh, 1971

Pl. 11, fig. 14

1963 *Alsophilidites pannuceus* BRENNER, p. 56.

1971 *Undulatisporites pannuceus* (Brenner) SINGH, p. 147.

Dimensions.—Equatorial diameter 39(43)49 microns.

Occurrence.—Rare.

Undulatisporites undulapulus

Brenner, 1963

Pl. 11, fig. 15

See Brenner (1963, p. 72) for description.

Dimensions.—Equatorial diameter 26 and 28 microns.

Occurrence.—Only two specimens observed.

Remarks.—Both specimens observed are slightly corroded, and there is a possibility they are recycled.

Undulatisporites sp.

Pl. 11, fig. 16

Description.—Trilete spore with undulate laesurae extending one-half to two-thirds the distance to the equator and bordered by thin, membranous lips. Exine moderately thick, rigid, and scabrate. Amb subcircular to rounded triangular with convex sides.

Dimensions.—Equatorial diameter 42 microns.

Occurrence.—Only a single specimen observed.

Genus **Verrucosisporites** Ibrahim,
emend. Potonié and Kremp, 1954

Type species.—*Verrucosisporites verrucosus* Ibrahim, emend. Potonié and Kremp, 1954.

Remarks.—*Verrucosisporites* has a circular to subcircular amb, which distinguishes it from *Convrrucosisporites* Potonié and Kremp, 1954. The exine is covered on both proximal and distal surfaces with verrucae that are larger than the grana of *Granulatisporites* Ibrahim, emend. Schopf, Wilson, and Bentall, 1944. *Leptolepidites* Couper, emend. Schulz, 1967, has a proximal surface with reduced or no ornament.

Verrucosiporites dentonianus, n. sp.

Pl. 11, fig. 17

Description.—Trilete spores with subcircular to rounded triangular amb. Laesurae extend approximately two-thirds to three-fourths the distance from pole to equator. Both proximal and distal surfaces are covered with verrucae that range from 0.8 to 1.8 microns in basal diameter and stand 0.2 to 0.5 microns high. The plan-view outline of the verrucae ranges from polygonal with rounded corners to lobate. The verrucae are very closely-spaced, nearly touching one another.

Holotype.—OPC 1211 W-16-4; pl. 11, fig. 17; equatorial diameter 32 microns.

Dimensions.—Equatorial diameter 30(35)38 microns.

Occurrence.—Rare.

Genus Scopusporis, n. gen.

Type species.—*Scopusporis lautus*, n. sp.

Description.—Trilete spores with subtriangular amb and sides straight to slightly convex. The laesurae extend to the equator and are bordered by a broad zone of thickened exine (margo), which is resistant to folding and remains rigid even in compressed specimens. At the extremities of the radii, the termination of the margo is abrupt and results in truncated, or notched, corners on the amb. Each interradial area of the proximal surface is either smooth or contains one or two large, circular verrucae. A narrow cingulum, interrupted at the radii, is present on some, but not all, species. Distal sculpture is quite variable but is arranged concentrically about the distal pole, which is covered in most specimens by a cap (boss) of thickened exine. The sculpture surrounding the polar cap, where present, consists of a ring of smooth exine followed by either a solid ring of thickened exine (circumpolar ridge), a zone of foveolate to reticulate exine that often extends to the equator, or both. The presence or absence of these elements of distal sculpture is useful in distinguishing species.

Remarks.—The spores assigned to *Scopusporis* include three species that have been ascribed previously to three separate form-genera, *Taurocusporites*, *Klukisporites*, and *Matonisporites*. The strong similarity in basic spore morphology among these spores

suggests that they might best be treated as different species of one form-genus, and none of the three previously applied genera properly circumscribes this morphology. For comparisons, see discussions for individual species, following. The botanical affinities of species of *Scopusporis* are as yet unknown.

Scopusporis lautus, n. sp.

Pl. 12, figs. 1-4

Description.—Trilete spores with subtriangular amb and convex to occasionally straight sides. Laesurae extend to the equator and are bordered by a broad zone of thickened exine (a margo). The termination of the margo at the equator makes the amb appear truncated, or flattened, at the radii. A zone of thickened exine, about equal in width to the margo, joins the extremities of the margo along the equator but does not cross the point where the laesurae meet the equator. This ornament has the appearance of a narrow cingulum, interrupted at the radii and crossing the proximal face adjacent to the laesurae in the form of a margo. Each interradial region, between the equator and the proximal pole, is occupied by two large domelike verrucae spaced widely apart. The distal pole is covered by a circular cap of thickened exine, the diameter of which is approximately one-sixth to one-seventh the diameter of the spore. Surrounding this polar cap is a concentric zone of thinner, smooth exine. The width of this thinner zone is approximately equal to the diameter of the polar cap. Outward from this is a concentric ring of thickened exine whose outer border is lobate to scalloped and connects at several points to a coarse reticulum of equally thick exine. This reticulum extends to the equator.

Holotype.—OPC 1211 L-7-1; pl. 12, figs. 1, 2; equatorial diameter 62 × 70 microns.

Paratype.—OPC 1211 Y-13-15; pl. 12, figs. 3, 4; equatorial diameter 64 × 71 microns.

Dimensions.—Equatorial diameter 61(69)73 microns.

Occurrence.—Rare.

Scopusporis excavatus (Brenner), n. comb.

Pl. 12, figs. 5, 6

1963 *Matonisporites excavatus* BRENNER, p. 54.

See Brenner (1963, p. 54) for description.

Dimensions.—Equatorial diameter 48(57)78 microns.

Occurrence.—Rare.

Remarks.—This form differs from other species of *Scopusporis*, n. gen., in having distal sculpture consisting of only a circumpolar ridge. However, this zonate distal sculpture, together with the broad proximal margo, is within the limits of the general morphological definition of *Scopusporis*. *Matonisporites* Couper, emend. Dettmann, 1963, is characterized by strongly developed thickening of the equatorial exine at the radii (valvae) and a smooth, unsculptured exine with no margo.

Scopusporis notabilis

(Srivastava), n. comb.

Pl. 12, figs. 7, 8

1972a *Klukisporites notabilis* SRIVASTAVA, p. 20.

See Srivastava (1972a, p. 20) for description.

Dimensions.—Equatorial diameter 44(59)71 microns.

Occurrence.—Rare.

Remarks.—The zonate distal sculpture with verrucate proximal sculpture and margo relates this species to *Scopusporis*, n. gen. The foveolate nature of the exine and smaller size distinguish *S. notabilis* from other species of *Scopusporis*. This species is transferred from *Klukisporites* Couper, emend. Pocock, 1964, because that form-genus is characterized by a smooth to scabrate proximal surface and convolute, foveolate, or reticulate ornament uniformly distributed over the distal surface.

Scopusporis spackmani

(Brenner), n. comb.

Pl. 12, figs. 9–11

1963 *Taurocusporites spackmani* BRENNER, p. 69.

See Brenner (1963, p. 69) for description.

Dimensions.—Equatorial diameter 34(49)64 microns.

Occurrence.—Rare.

Remarks.—This species is transferred to *Scopusporis*, n. gen., because it lacks the three concentric rings of thickened exine on the distal surface and the numerous small verrucae on the proximal surface that distinguish *Taurocusporites* Stover, emend. Playford and Dettmann, 1965.

?Scopusporis sp.

Pl. 12, fig. 12

Description.—Trilete spore with sub-triangular amb. The sides are convex, and the laesurae extend to the equator. Distal ornament consists of a large polar cap (boss), covering approximately one-third the distal surface, and foveo-reticulate exine extending from the boss to the equator. A narrow cingulum occurs at the equator, interrupted at the radii. The proximal surface is smooth.

Dimensions.—Equatorial diameter 60 × 64 microns.

Occurrence.—Only a single specimen observed.

Remarks.—The zonate distal ornament and interrupted cingulum is suggestive of relationship with *Scopusporis*, n. gen. The lack of proximal ornament, however, makes such a proposed assignment tentative and questionable.

Spore type A

Pl. 12, figs. 13, 14

Description.—Trilete spores with laesurae extending two-thirds to four-fifths the distance from pole to equator. Proximal surface smooth to finely scabrate. A thickening of the exine at the equator and over the distal surface ("patina," as used by Phillips and Felix, 1971a, p. 336) gives the appearance of being cingulate when seen in proximal polar view. Large irregular foveolae are distributed over the distal surface, but they may be the result of corrosion.

Dimensions.—Equatorial diameter 42(49)60 microns.

Occurrence.—Only eight specimens observed.

Spore type B

Pl. 12, fig. 15

Description.—Trilete spores with rounded triangular amb. Laesurae extend approximately one-half the distance from the pole to the equator, with the ends obscured by distal ornament. A zone of thickened exine, 6 to 8 microns wide, borders the laesurae, forming a prominent margo. The exine is thickened in the equatorial region and indented opposite each laesura. Three strongly thickened, arcuate structures occur in the outer radial areas

of the distal surface and appear as prominent folds.

Dimensions.—Equatorial diameter 49 × 56 microns.

Occurrence.—Only a single specimen observed.

Remarks.—It is possible that this single specimen is a recycled spore.

Spore type C

Pl. 12, fig. 16

Description.—Trilete spore with laesurae extending to the equator, bordered by membranous lips. Amb subtriangular with rounded corners. Proximal surface smooth. Long clavate spines are widely dispersed over the distal surface, extending onto the equatorial plane.

Dimensions.—Equatorial diameter of the spore body 23 microns; clavate spines 4 to 5 microns long.

Occurrence.—Only a single specimen observed.

Remarks.—This spore exhibits some corrosion effects and may have been recycled.

Spore type D

Pl. 12, fig. 17

Description.—Trilete spores with laesurae extending to the equator and bordered by arcuate thickenings that protrude slightly beyond the equatorial outline. A single dome-shaped verruca is situated in each interradial area of the proximal face, and a polar cap occupies approximately one-third the distal surface. Amb subcircular with flattened sides and radii, giving the appearance of an almost hexagonal shape.

Dimensions.—Equatorial diameter 40(44)46 microns.

Occurrence.—Only three specimens observed.

Remarks.—These three specimens appear somewhat abraded or corroded and may represent recycled spores.

Spore type E

Pl. 12, fig. 18

Description.—Trilete spores with laesurae extending between one-half and two-thirds the distance from pole to equator. Amb

circular. Exine rugulate with the rugulae appearing as low anastomosing folds, giving the exine the appearance of being highly wrinkled. The exine sculpture covers the distal surface and extends onto the proximal surface approximately one-third to one-half the distance from the equator to the pole. The contact areas between the laesurae are smooth to slightly scabrate.

Dimensions.—Equatorial diameter 37(45)50 microns.

Occurrence.—Rare.

Remarks.—It is possible that spores assigned here to spore type E may be accommodated in the form-genus *Densoisporites*, but insufficient well-preserved specimens were available to evaluate this possibility properly.

DIVISION—*INCERTAE SEDIS*

Genus *Schizosporis*

Cookson and Dettmann, 1959

Type species.—*Schizosporis reticulatus* Cookson and Dettmann, 1959.

See Dettmann (1963, p. 106) for discussion.

Remarks.—The two species assigned to this genus, *S. reticulatus* and *S. parvus*, appear to be similar only in their both possessing a zone of weakness around most of the circumference of the body. This results in common splitting of the body into two saucer-shaped halves. Otherwise, there is no morphological similarity between the two, and they may be totally unrelated.

Schizosporis parvus

Cookson and Dettmann, 1959

Pl. 13, fig. 2

1959 *Schizosporis parvus* COOKSON and DETTMANN, p. 216.

See Dettmann (1963, p. 108) for discussion.

Dimensions.—Length 74(94)108 microns; width (perpendicular to the plane of dehiscence) 39(53)63 microns.

Occurrence.—Rare to occasional.

Remarks.—*Schizosporis parvus* is distinguished by its elliptical shape, its tendency to split into two boat-shaped halves, and large size. It has a smooth wall and is of unknown affinity.

Schizosporis reticulatus
Cookson and Dettmann, 1959
Pl. 13, fig. 1

1959 *Schizosporis reticulatus* COOKSON and DETTMANN, p. 213.

See Brenner (1963, p. 96) and Pierce (1976, p. 25) for discussion.

Dimensions.—Equatorial(?) diameter 98(119)135 microns.

Occurrence.—Rare.

Remarks.—This fossil is characterized by a pseudo-reticulation resulting from close spacing of cell-like capsules that open to the exterior by a small porelike opening (Pierce, 1976). Brenner (1963) suggested an algal affinity, but this is only speculative, and Pierce (1976) noted that the affinity of the species is as yet unknown.

Genus **Echinodiporis**, n. gen.

Type species.—*Echinodiporis minor*, n. sp.

Description.—Same as for the type species, following.

Echinodiporis minor, n. sp.
Pl. 13, figs. 3–6

Description.—Miospores with one or two irregularly developed, porelike apertures that are often obscured by surface ornament, resulting in the grains frequently appearing inaperturate. The porelike apertures usually have a smooth, circular outline but sometimes have a ragged, irregular margin, as if they were formed by tearing of the exine. The diameter of the pores is about one-fourth that of the total grain. The body appears to have been originally spherical but is now flattened into a discoid shape, with exinal folding a common feature. This flattening occurs at various angles to the axis through the porelike openings. The wall is 1 to 1.5 microns thick, and the surface is densely covered with fine hairlike echini 1.5 to 2.5 microns long. Specimens most often occur singly, but they are occasionally found adhering together in twos or threes.

Holotype.—OPC 1211 X-14-14; pl. 13, fig. 3; overall diameter 27 × 30 microns.

Paratypes.—OPC 1211 F-12-20; pl. 13, fig. 4; diameter 25 × 26 microns. OPC W-16-16; pl. 13, fig. 5; diameter 28 × 31 microns.

OPC 1211 G-15-9; pl. 13, fig. 6; diameter 24 × 27 microns. OPC 1211 H-7-1; diameter 27 × 28 microns.

Dimensions.—Overall diameter 22(27)31 microns; diameter of the porelike apertures 6 to 8 microns.

Occurrence.—Occasional to abundant.

Remarks.—The botanical affinity of *Echinodiporis minor*, n. sp., is as yet unknown.

DIVISION SPERMATOPHYTA

Subdivision GYMNOSPERMAE

Family CAYTONIACEAE

Genus **Vitreisporites** Leschik,
emend. Jansonius, 1962

Type species.—*Vitreisporites signatus* Leschik, 1955.

See Singh (1964, p. 102) for synonymy and description.

Vitreisporites pallidus
(Reissinger) Nilsson, 1958
Pl. 13, fig. 7

See Singh (1964, p. 102) for synonymy and description.

Dimensions.—Total breadth 20(28)32 microns; length of sacchi 14(16)19 microns.

Occurrence.—Rare to occasional.

Family CYCADACEAE, GINKGOACEAE,
or BENNETTITACEAE

Genus **Cycadopites** Wodehouse ex
Wilson and Webster, 1946

Type species.—*Cycadopites follicularis* Wilson and Webster ex Potonié, 1958.

See Singh (1964, p. 103) for synonymy and description.

Remarks.—*Cycadopites* is distinguished by having a sulcus that is broader at its extremities than in the middle, while the genus *Monosulcites* Cookson ex Couper, 1958, has a sulcus that is broader at the pole than at the equator. The genus *Ginkgocycadophytus* Samoilovitch, 1953, is most similar to *Cycadopites*, differing chiefly in having a sulcus with broadened extremities that merge with the outline of the grain at the equator.

Cycadopites carpentieri
(Delcourt and Sprumont) Singh, 1964
Pl. 13, fig. 8

1955 *Monosulcites carpentieri* DELCOURT and SPRUMONT, p. 54.

1964 *Cycadopites carpentieri* (Delcourt and Sprumont) SINGH, p. 104.

Dimensions.—Length 70(89)102 microns; width 20(29)35 microns.

Occurrence.—Rare.

Remarks.—Singh (1964) noted that this species is most similar to, and may be conspecific with, *Entylissa deterius* Balme, 1957, and that it also closely resembles the pollen from the megafossil *Williamsonia spectabilis* Nathorst, 1909.

Cycadopites fragilis Singh, 1964
Pl. 13, fig. 9

1964 *Cycadopites fragilis* SINGH, p. 103.

Dimensions.—Length 19(30)38 microns.

Occurrence.—Rare to occasional.

Cycadopites glottus (Brenner),
n. comb.
Pl. 13, fig. 10

1963 *Monosulcites glottus* BRENNER, p. 75.

Dimensions.—Length 22(25)28 microns; width 10(12)15 microns.

Occurrence.—Rare.

Remarks.—Since Brenner's species, *glottus*, has a sulcus that is broader at the extremities than at the pole, it belongs more properly in the genus *Cycadopites* than in *Monosulcites*.

Cycadopites sp.
Pl. 13, fig. 11

Description.—Monosulcate pollen in which the sulcus is narrowest at the distal pole and broadens toward the equatorial extremities. The sulcus is bordered on each side by a fold in the exine. The exine is scabrate to finely granular. The shape is elliptical with bilateral symmetry.

Dimensions.—Length 33(41)46 microns; width 18(27)34 microns.

Occurrence.—Rare (only seven specimens observed).

Remarks.—This species may be conspecific with the form reported as *Monosulcites* sp. by Hedlund (1966, p. 28) from the Woodbine Formation.

Genus **Ginkgocycadophytus**
Samoilovitch, 1953

Type species.—*Ginkgocycadophytus caperatus* (Luber) Samoilovitch, 1953.

See Potonié (1958, p. 93) for description.

Ginkgocycadophytus nitidus
(Balme) de Jersey, 1962
Pl. 13, fig. 12

See Dettmann (1963, p. 104) for synonymy and description.

Dimensions.—Length 25(26)28 microns; width 13(15)21 microns.

Occurrence.—Rare.

Ginkgocycadophytus trapeziformis, n.
sp.
Pl. 13, fig. 13

Description.—Monosulcate pollen with a sulcus that is narrowest at the pole, often obscured by overlapping of the sulcal margins, and widest at the ends. The grains are approximately 50 percent longer than broad. The extremities of the sulcus are delimited by flatly truncated margins at the ends of the grain, and this truncation is set at an acute angle to the longitudinal axis of the grains. The resulting shape is one of an elongated, narrow trapezoid with the longest sides convex and the shortest sides straight. The exine is thin and smooth to slightly scabrate.

Holotype.—OPC 1211 G-12-2; pl. 13, fig. 13; length 58 microns, width 37 microns.

Dimensions.—Length 48(56)60 microns; width 30(36)40 microns.

Occurrence.—Rare.

Remarks.—The merging of the ends of the sulcus with the margin of the grains indicates that this species belongs in *Ginkgocycadophytus* rather than *Cycadopites*.

Order CONIFERALES

Family ARAUCARIACEAE

Genus **Araucariacites**
Cookson ex Couper, 1953

Type species.—*Araucariacites australis* Cookson, 1947.

See Potonié (1958, p. 81) for description.

Remarks.—The type species is considered comparable to pollen of modern Arau-

cariaceae and to pollen of *Brachyphyllum mamillare* Brongn. from the Jurassic of England (Dettmann, 1963).

Araucariacites australis Cookson, 1947
Pl. 13, fig. 14

See Couper (1958, p. 151) for synonymy and description.

Dimensions.—Diameter 44(55)64 microns.

Occurrence.—Rare to occasional.

Remarks.—These pollen grains are of such simple design that they are nearly impossible to separate into more than one species. This undoubtedly explains the long geological range and wide geographical distribution that make them of little stratigraphic value.

Family TAXODIACEAE

Genus **Taxodiaceapollenites**
Kremp, 1949

Type species.—*Taxodiaceapollenites hiatus* (Potonié) Kremp, 1949.

See Potonié (1958, p. 78) for description.

Remarks.—Significant numbers of pollen assignable to the Taxodiaceae, more similar to modern *Taxodium* pollen than to *Sequoia* pollen, have been reported from the Florissant (Oligocene?) beds of Colorado. Megafossils of *Sequoia* are common in these beds, while *Taxodium* has not been found, and pollen extracted from the *Sequoia* megafossils bears a closer resemblance to that of modern *Taxodium* than to *Sequoia* (Penny, in Tschudy and Scott, 1969). In view of this, interpretations of cypress-swamp environments based on dispersed pollen of this type appear open to serious question.

Taxodiaceapollenites hiatus
(Potonié) Kremp, 1949
Pl. 13, fig. 15

See Stanley (1965, p. 273) for synonymy and description.

Dimensions.—Diameter 20(27)35 microns.

Occurrence.—Occasional to abundant.

Taxodiaceapollenites vacuipites

(Wodehouse), n. comb.

Pl. 13, fig. 16

1933 *Glyptostrobus vacuipites* WODEHOUSE, p. 494.

Dimensions.—Length 32(42)58 microns; width 11(21)30 microns.

Occurrence.—Occasional to abundant.

Remarks.—Wodehouse (1933) described *Glyptostrobus vacuipites* from the Green River Shale of Eocene age in Colorado and Utah. The morphology of the pollen is suggestive of *Glyptostrobus*, but there is no evidence to support placing it in this modern genus, so it is here transferred to the form-genus *Taxodiaceapollenites*. Wodehouse (1933) gave only a single dimension for the species (37.6 microns), and it is not clear whether this is an average value or something else. If an average, specimens from the Denton Shale appear to be of similar size (average 42 microns in length). *T. vacuipites* is distinguished from *T. hiatus* by its larger size, fusiform shape, and exinal folds adjacent to the area of common dehiscence. The pollen grain illustrated by Hedlund and Norris (1968, pl. 5, fig. 2) as *T. hiatus* appears to be conspecific with *T. vacuipites*.

Genus **Perinopollenites** Couper, 1958

Type species.—*Perinopollenites elatoides* Couper, 1958.

See Singh (1964, p. 107) for synonymy and generic diagnosis.

Remarks.—Couper (1958) extracted the pollen *Perinopollenites elatoides* from cones of the fossil plant *Elatides williamsonii*, which belongs to the Taxodiaceae.

Perinopollenites elatoides

Couper, 1958

Pl. 14, fig. 1

See Singh (1964, p. 107) for synonymy and description.

Dimensions.—Overall diameter 34(40)44 microns; diameter of inner body 24(32)36 microns.

Occurrence.—Rare.

Family PODOCARPACEAE

Genus **Parvisaccites** Couper, 1958

Type species.—*Parvisaccites radiatus* Couper, 1958.

See Singh (1964, p. 112) for synonymy and description.

Remarks.—Pollen assignable to the form-genus *Parvisaccites* closely resemble those of modern species of *Dacrydium*.

Parvisaccites radiatus

Couper, 1958
Pl. 14, fig. 2

See Singh (1964, p. 107) for synonymy and description.

Dimensions.—Length of body 34(46)62 microns; width of body 26(35)40 microns; breadth of sacci 17(32)42 microns.

Occurrence.—Rare.

Parvisaccites rugulatus

Brenner, 1963
Pl. 14, fig. 3

1963 *Parvisaccites rugulatus* BRENNER, p. 79.

Dimensions.—Length of body 32(39)43 microns; width of body 32(40)44 microns.

Occurrence.—Rare.

Genus Phyllocladidites

Cookson ex Couper, 1953

Type species.—*Phyllocladidites mawsonii* Cookson, 1947.

See Singh (1964, p. 113) for synonymy and description.

Remarks.—The genus *Phyllocladidites* is most similar to *Parvisaccites* but differs in having a smooth to scabrate exine and very small, noninflated sacci that resemble folds in the exine. These forms are most similar to pollen of species of modern *Dacrydium*.

Phyllocladidites inchoatus

(Pierce) Norris, 1967
Pl. 14, figs. 4, 5

See Norris (1967, p. 103) for synonymy and description.

Dimensions.—Overall length 40(49)52 microns; overall width 27(38)45 microns; breadth of sacci 8(27)36 microns.

Occurrence.—Rare to occasional.

Phyllocladidites sp., cf. **P. inchoatus**

(Pierce) Norris, 1967
Pl. 14, fig. 6

Dimensions.—Length of corpus 33(49)60 microns; width of corpus 45(61)73 microns.

Occurrence.—Rare to common.

Remarks.—Numerous specimens of pollen that differ from *Phyllocladidites inchoatus* primarily in their larger size are included here. Although this may suggest the presence of two species, overlap in the size ranges makes separation difficult.

Genus Podocarpidites

Cookson ex Couper, 1953

Type species.—*Podocarpidites ellipticus* Cookson, 1947.

See Singh (1964, p. 115) for synonymy and generic diagnosis.

Podocarpidites multesimus

(Bolkhovitina) Pocock, 1962
Pl. 14, figs. 7, 8

See Singh (1964, p. 116) for synonymy and description.

Dimensions.—Length of sacci 22(30)37 microns; width of sacci 34(44)51 microns; length of corpus 28(34)38 microns; width of corpus 20(29)36 microns.

Occurrence.—Rare to occasional.

Podocarpidites herbstii

Burger, 1966
Pl. 14, fig. 9

1966 *Podocarpidites herbstii* BURGER, p. 260.

Dimensions.—Length of corpus 36(42)50 microns; width of corpus 37(43)52 microns; breadth of sacci 45(59)68 microns.

Occurrence.—Rare to occasional.

Genus Rugubivesiculites Pierce, 1961

Type species.—*Rugubivesiculites convolutus* Pierce, 1961.

See Potonié, R., Beihefte zum Geologischen Jahrbuch, no. 72, p. 126, 1966, for description.

Rugubivesiculites reductus

Pierce, 1961

Pl. 14, fig. 10

1961 *Rugubivesiculites reductus* PIERCE, p. 40.

See Singh (1971, p. 167) for discussion.

Dimensions.—Length of corpus 44(53)59 microns; width of corpus 32(45)55 microns; breadth of sacci 47(57)63 microns.*Occurrence*.—Occasional to abundant.*Remarks*.—Brenner (1963) considered this species an important horizon marker for the upper Patapsco Formation of Maryland.**Rugubivesiculites rugosus**

Pierce, 1961

Pl. 14, figs. 11–14

1961 *Rugubivesiculites rugosus* PIERCE, p. 40.

See Singh (1971, p. 167) for remarks.

Dimensions.—Length of corpus 44(61)72 microns; width of corpus 40(50)58 microns; breadth of sacci 38(44)48 microns.*Occurrence*.—Occasional to abundant.*Remarks*.—Aberrant forms with more than two sacci were rarely observed.

Family PINACEAE

Remarks.—Numerous form-genera have been erected for fossil bisaccate pollen of supposed pinaceous affinity. The distinction of these form-genera is difficult in well-preserved and ideally oriented specimens and is often nearly impossible in poorly preserved or crumpled specimens. In this study, the assignment of pinaceous pollen to form-genera and species is designed to provide easier comparison with other published works, but any such assignment is considered arbitrary, tentative, and inaccurate below the family level. Graham (1972, p. 9) disputed claims of accurate species identification of pollen within the genera *Pinus* and *Abies*, suggesting that critical assessment of palynological literature is required.Genus **Abietinaepollenites**

Potonié ex Potonié, 1958

Type species.—*Abietinaepollenites microalatus* Potonié, 1951.

See Potonié (1958, p. 61) for discussion.

Abietinaepollenites microreticulatus

Groot and Penny, 1960

Pl. 14, fig. 15

See Groot and Penny (1960, p. 231) for description, and Brenner (1963, p. 76) for comments.

Dimensions.—Length of corpus 61 and 67 microns; width of corpus 76 and 72 microns; breadth of sacci 66 and 70 microns.*Occurrence*.—Only two specimens observed.Genus **Alisporites** Daugherty,
emend. Potonié and Kremp, 1956*Type species*.—*Alisporites opii* Daugherty, 1941.

See Singh (1964, p. 107) for synonymy and discussion.

Alisporites grandis

(Cookson) Dettmann, 1963

pl. 15, fig. 1

See Dettmann (1963, p. 102) for synonymy, and Cookson (1947, p. 471) for description.

Dimensions.—Total length 80(101)116 microns; total width 70(85)104 microns.*Occurrence*.—Rare to occasional.**Alisporites validus**

Phillips and Felix, 1971

Pl. 15, fig. 2

1971b *Alisporites validus* PHILLIPS and FELIX, p. 449.*Dimensions*.—Total length 70(79)85 microns; total width 50(56)60 microns.*Occurrence*.—Rare.**Alisporites sp.**

Pl. 15, fig. 3

Description.—Bisaccate pollen with distally pendant, coarsely reticulate sacci. The proximal surface of the corpus is microrugulate, and the distal surface has reduced to scabrate ornament. The distal furrow between the sacci is very straight with parallel sides.*Dimensions*.—Length of corpus 30(41)49 microns; width of corpus 38(52)70 microns; breadth of sacci 43(55)66 microns.*Occurrence*.—Only four specimens observed.

Remarks.—This species is quite similar to, but larger than, *Alisporites thomasii* (Couper) Pocock, 1962, and *Alisporites similis* (Balme) Dettmann, 1963, two species that Singh (1964) considers conspecific.

Genus Cedripites Wodehouse, 1933

Type species.—*Cedripites eocenicus* Wodehouse, 1933.

See Singh (1964, p. 111) for synonymy and generic diagnosis.

Cedripites cretaceus Pocock, 1962

Pl. 15, fig. 4

See Singh (1964, p. 111) for synonymy and description.

Dimensions.—Length of corpus 39(55)66 microns; width of corpus 38(47)54 microns; breadth of sacci 32(42)50 microns.

Occurrence.—Occasional to common.

Genus Cerebropollenites

Nilsson, 1958

Type species.—*Cerebropollenites mesozoicus* (Couper) Nilsson, 1958.

See Nilsson (1958, p. 72) for description, and Singh (1971, p. 172) for discussion.

Cerebropollenites mesozoicus

(Couper) Nilsson, 1958

Pl. 15, fig. 5

See Singh (1971, p. 172) for synonymy, and Burger (1966, p. 261) for description.

Dimensions.—Overall diameter 42(54)64 microns.

Occurrence.—Rare to occasional.

Genus Pinuspollenites

Raatz ex Potonié, 1958

1938 *Pinuspollenites* RAATZ, Abhandl., Preuss. Geol. Landesanst., new series, no. 183, p. 15.

1958 *Pinuspollenites* RAATZ ex Potonié, p. 62.

Type species.—*Pinuspollenites labdacus* (Potonié) Raatz ex Potonié, 1958.

Remarks.—The genus *Pinuspollenites* accommodates bisaccate pollen similar in form to that of modern *Pinus*. Distinctions between this genus and *Abiespollenites* Thiergart, emend. Potonié, 1958, and

Piceapollenites Potonié, 1931, are small and are not attempted here (see remarks for the Family Pinaceae). Numerous pine-like pollen species have been described under the genus *Pityosporites* Seward, emend. Manum, 1960, which is now considered more related to the Podocarpaceae than the Pinaceae (Dettmann, 1963). In this study *Pityosporites* is not used because it may be synonymous with *Podocarpites*.

Pinuspollenites constrictus

(Singh), n. comb.

Pl. 15, figs. 6, 7

1964 *Pityosporites constrictus* SINGH, p. 122.

Dimensions.—Length of corpus 47(61)72 microns; width of corpus 42(54)64 microns; height of corpus 21(22)23 microns; breadth of sacci 44(58)69 microns; height of sacci 28(33)36 microns.

Occurrence.—Occasional to abundant.

Remarks.—The abundance of this species is likely an expression of overrepresentation, considering the frequency of its parent plants in the vegetation, which is typical of coniferous bisaccate pollen.

Order CONIFERALES—*Incertae sedis*

Genus Classopollis Pflug,

emend. Pocock and Jansonius, 1961

Type species.—*Classopollis classoides* Pflug, 1953.

See Singh (1964, p. 124) for synonymy and description.

Remarks.—*Classopollis*-type pollen has been recovered from the fossil male cones of *Cheirolepidium munsteri* Schimper, an upper Mesozoic coniferous species (see Brenner, 1963, p. 85).

Classopollis torosus (Reissinger)

Couper, 1958

Pl. 15, fig. 8, 9

See Brenner (1963, p. 84) for synonymy, and Couper (1958, p. 156) for description.

Dimensions.—Equatorial diameter 22(28)38 microns; polar diameter (one specimen) 20 microns.

Occurrence.—Occasional to abundant.

Remarks.—Disagreement in the litera-

ture as to the distinction of the two species *Classopollis torosus* and *C. classoides* was discussed by Brenner (1963) and Singh (1964).

Genus **Decussosporites** Brenner, 1963

Type species.—*Decussosporites microreticulatus* Brenner, 1963.

See Brenner (1963, p. 85) for description.

Remarks.—The affinity of this palynomorph is probably with the gymnosperms, but this cannot be determined with certainty. The single sulcus with broadened ends is similar to the cycads, and the "infrareticulate to infrascabrate exine" (Brenner, 1963) is suggestive of the conifers.

Decussosporites microreticulatus
Brenner, 1963

Pl. 15, fig. 10

1963 *Decussosporites microreticulatus* BRENNER, p. 85.

Dimensions.—Length 20(24)26 microns; width 13(15)16 microns.

Occurrence.—Rare (only six specimens observed).

Genus **Eucommiidites** Erdtman,
emend. Hughes, 1961

Type species.—*Eucommiidites troedssonii* Erdtman, 1948.

See Singh (1964, p. 127) for synonymy and description.

Eucommiidites troedssonii
Erdtman, 1948

Pl. 15, fig. 11

See Brenner (1963, p. 85) for synonymy and description.

Dimensions.—Length 28(31)33 microns; width 20(22)24 microns.

Occurrence.—Rare.

Eucommiidites minor
Groot and Penny, 1960

Pl. 15, fig. 12

1960 *Eucommiidites minor* GROOT and PENNY, p. 234.

Dimensions.—Equatorial diameter 20(27)30 microns.

Occurrence.—Rare.

Genus **Exesipollenites** Balme, 1957

Type species.—*Exesipollenites tumulus* Balme, 1957.

See Singh (1964, p. 126) for synonymy and description.

Remarks.—Singh (1964) suggested that this form-genus is probably related to the Taxodiaceae or Cupressaceae.

Exesipollenites tumulus Balme, 1957

Pl. 15, fig. 13

See Singh (1964, p. 126) for synonymy and description.

Dimensions.—Equatorial diameter 23(26)32 microns.

Occurrence.—Rare to occasional.

Genus **Inaperturopollenites** Pflug ex
Thompson and Pflug,
emend. Potonié, 1958

Type species.—*Inaperturopollenites dubius* (Potonié and Venitz) Thompson and Pflug, 1953.

See Potonié (1958, p. 77) for synonymy and emended diagnosis.

Remarks.—*Inaperturopollenites* most likely represents a pollen grain, a conclusion based on its thin wall and smooth to finely scabrate or gemmate ornament. These inaperturate grains are morphologically similar to pollen of some modern conifers, particularly in the family Cupressaceae, or possibly Taxodiaceae.

Inaperturopollenites sp.

Pl. 15, fig. 14

Description.—Inaperturate pollen with a thin wall, scabrate to finely gemmate sculpture, and spherical form. The size range of specimens is quite variable, with such continuous overlap in size as to make subdivision into species on this basis impractical and meaningless.

Dimensions.—Diameter 18(33)42 microns.

Occurrence.—Common to abundant.

Order GNETALES

Family EPHEDRACEAE

Genus *Equisetosporites* Daugherty,
emend. Singh, 1964

Type species.—*Equisetosporites chinleana* Daugherty, 1941.

See Singh (1964, p. 129) for synonymy and emended diagnosis.

Remarks.—Daugherty (1941) misinterpreted a folded, broken ephedraceous pollen grain as being an elater-bearing spore and established the form-genus *Equisetosporites* to indicate affinity with modern *Equisetum*. Scott (1960) reexamined the type material and reported the ephedraceous nature of the specimens. Even though the name *Equisetosporites* seems inappropriate, it is still a validly published genus and must be accepted. Another commonly used form-genus for palynomorphs of this type is *Ephedripites* Bolkhovitina, 1953. Bolkhovitina later concluded that the type material for *Ephedripites* was actually schizaeaceous in affinity and transferred this material to the genus *Schizaea*. See Singh (1964, p. 129) for a more complete discussion of the nomenclatural problems involved.

Equisetosporites concinnus

Singh, 1964

Pl. 16, fig. 1

1964 *Equisetosporites concinnus* SINGH, p. 132.

Dimensions.—Length 76(92)102 microns; width 28(42)52 microns.

Occurrence.—Rare.

Equisetosporites costaliferous

(Brenner), n. comb.

Pl. 16, fig. 2

1968 *Ephedripites costaliferous* BRENNER, p. 362.

Dimensions.—Length 24(31)36 microns; width 12(16)18 microns.

Occurrence.—Rare.

Remarks.—This species is characterized by a noticeable sulcus extending almost to the ends of the grain.

Equisetosporites multicostatus

(Brenner) Norris, 1967

Pl. 16, fig. 3

1963 *Ephedripites multicostatus* BRENNER, p. 90.1967 *Equisetosporites multicostatus* (Brenner) NORRIS, p. 105.

Dimensions.—Length 30(38)42 microns; width 18(23)26 microns.

Occurrence.—Rare.

Equisetosporites multistriatus

Pocock, 1964

Pl. 16, fig. 4

1964 *Equisetosporites multistriatus* POCOCK, p. 146.

Dimensions.—Length 36 microns; width 23 microns.

Occurrence.—Only a single specimen observed.

Equisetosporites patapscoensis

(Brenner), n. comb.

Pl. 16, fig. 5

1963 *Ephedripites patapscoensis* BRENNER, p. 90.

Dimensions.—Length 42(45)47 microns; width 20(23)25 microns.

Occurrence.—Only four specimens observed.

Equisetosporites pentacostatus

(Brenner), n. comb.

Pl. 16, fig. 6

1968 *Ephedripites pentacostatus* BRENNER, p. 363.

Dimensions.—Length 16(18)22 microns; width 8(10)13 microns.

Occurrence.—Rare.

Subdivision—*Incertae sedis*Genus *Sabalpollenites*

Thiergart, 1938

Type species.—*Sabalpollenites convexus* Thiergart, 1938.

See Thiergart (1938, p. 308) for generic diagnosis.

Sabalpollenites scabrus

(Brenner), n. comb.

Pl. 16, fig. 7

1963 *Monosulcites scabrus* BRENNER, p. 95.

Dimensions.—Length 34(43)48 microns; width 31(37)44 microns.

Occurrence.—Rare to occasional.

Remarks.—*Monosulcites* Cookson ex Couper, 1958, accommodates small, smooth monosulcate pollen similar to that of modern *Ginkgo*. The large, microrugulate forms described by Brenner (1963) as *Monosulcites scabrus* seem better accommodated in the genus *Sabalpollenites* Thiergart, 1938.

Subdivision ANGIOSPERMAE

Class—*Incertae sedis*

Genus *Liliacidites* Couper, 1953

Type species.—*Liliacidites kaitangataensis* Couper, 1953.

See Couper (1953, p. 56) for description, and Singh (1971, p. 182) for additional comments.

Liliacidites dividuus
(Pierce) Brenner, 1963

Pl. 16, fig. 8

See Singh (1971, p. 185) for synonymy, and Brenner (1963, p. 93) for comments.

Dimensions.—Equatorial diameter 20(26)35 microns.

Occurrence.—Rare.

Remarks.—Singh (1971) listed *Clavatipollenites rotundus* Kemp, 1968, as a synonym of *Liliacidites dividuus*. Doyle (1969) compared *Clavatipollenites rotundus* with *C. hughesii* and suggested that they may be conspecific. Doyle further compared *C. hughesii* with *Liliacidites dividuus* and from this comparison suggested that Kemp's (1968) treatment of *Clavatipollenites* and *Liliacidites* as one genus may be correct.

Liliacidites* sp., cf. *L. reticulatus
(Brenner) Singh, 1971

Pl. 16, fig. 9

1963 *Peromonolites reticulatus* BRENNER, p. 94.

1971 *Liliacidites reticulatus* (Brenner) SINGH, p. 189.

Dimensions.—Overall length 19(30)37 microns; overall width 16(27)34 microns.

Occurrence.—Rare.

Remarks.—The pollen included here are larger than the specimens discussed and illustrated by Brenner (1963) and Singh (1971), but they agree in all other respects.

Liliacidites textus Norris, 1967

Pl. 16, fig. 10

1967 *Liliacidites textus* NORRIS, p. 106.

Dimensions.—Diameter 30(35)38 microns.

Occurrence.—Rare.

Remarks.—These palynomorphs are distinguished from *Liliacidites* sp., cf. *L. reticulatus* by their consistent spherical shape and absence of the inner layers of the sporoderm. The forms appear as hollow, reticulate spheres with no sulcus visible and compare closely with illustrations of *Liliacidites textus* by Norris (1967).

Liliacidites variegatus Couper, 1953

Pl. 16, fig. 11

1953 *Liliacidites variegatus* COUPER, p. 56.

Dimensions.—Length 28(35)38 microns; width 15(20)24 microns.

Occurrence.—Rare.

Class DICOTYLEDONAE—
Incertae sedis

The Denton Shale contains several colpate pollen, one possible tricolporate type, and one irregularly aperturate form, all of which may be attributed to the Dicotyledonae. Representative pollen of this class of flowering plants are considered by many authors to make their first appearance in rocks of Albian age (Doyle, 1969; Brenner, 1963).

Reports of Aptian occurrences are not uncommon, but these Aptian assignments may or may not be accurate. Reports of older occurrences are as yet unverified or are in dispute (Doyle, 1969).

Because of the morphologic simplicity of these early colpate pollen, comparison with the highly numerous forms of colpate pollen from extant plants is inconclusive and makes assignment of the fossils to extant families or even orders very precarious. An artificial system of nomenclature based on morphological features is thus most widely used in treating these fossil pollen, and this is the approach used in this study.

Quadricolpites, n. gen.

Type species.—*Quadricolpites reticulatus*, n. sp.

Description.—Prolate pollen grains with four colpi that nearly reach both poles. The colpi may be obscured by surface ornament, particularly when viewed indirectly. Longitudinal folds occasionally appear as additional colpi in equatorial views. Polar or oblique views clearly reveal the tetracolpate nature of the grains. The exine is sculptured with retipilate to microrugulate ornament. The shape of the elongate grains varies from terete, with bluntly rounded poles, to a spindle shape resulting from a pronounced tapering from the equator to each well-rounded polar area.

Remarks.—The prolate form and larger size distinguishes *Quadricolpites*, n. gen., from *Tetracolpites* Vimal ex Srivastava, 1966.

***Quadricolpites reticulatus*, n. sp.**

Pl. 16, figs. 12–16

Description.—Same as for the genus, with the added notation that the ektexine is retipilate with the lumina of the reticulum in the equatorial region being larger than near the poles. The size of the lumina reduces gradually from the equator to the polar areas.

Holotype.—OPC 1211 Y-19-2; pl. 16, fig. 12; polar diameter 63 microns, equatorial diameter 43 microns.

Paratypes.—OPC 1211 X-18-15; pl. 16, fig. 15; equatorial diameter (expanded through polar compression) 54×56 microns. OPC 1211 V-8-9; pl. 16, fig. 14; polar diameter 62 microns, equatorial diameter 54 microns. OPC 1211 S-12-2; pl. 16, fig. 13; polar diameter 68 microns, equatorial diameter 50 microns. OPC 1211 T-19-3; pl. 16, fig. 16; equatorial diameter (expanded) 66 microns.

Dimensions.—Polar diameter 58(65)68 microns; equatorial diameter (unexpanded) 33(44)54 microns.

Occurrence.—Rare.

Remarks.—Specimens similar to *Quadricolpites reticulatus*, but differing in being microrugulate rather than retipilate, have been observed in the Lytle Member of the Dakota Group (Lower Cretaceous) by L. R. Wilson (personal communication). Hedlund (1966) described a new species, *Stephanocolpites tectorius*, as a polycolpate pollen grain,

but the species appears to be tetracolpate and is nearly identical with the tetracolpate forms in the Lytle Member. Since specimens of *Stephanocolpites tectorius* have not been examined in this study and thus have not been conclusively demonstrated to be tetracolpate, formal transfer to the new genus *Quadricolpites* is not proposed at this time. Questions as to the distinctions between *Quadricolpites*, n. gen., and *Stephanocolpites* van der Hammen, emended Potonié, 1960, are not elaborated on because the validity of the genus *Stephanocolpites* is in question (see below).

Genus ***Tricolpites*** Cookson
ex Couper, emend. Belsky,
Boltenhagen, and Potonié, 1965

Type species.—*Tricolpites reticulatus* Cookson, 1947.

Remarks.—Great confusion exists as to the status of the numerous form-genera erected to accommodate tricolpate pollen with reticulate exines. The problem stems primarily from the usage of the form-genus *Tricolpites*, which, as emended by Belsky, Boltenhagen, and Potonié (1965), includes all tricolpate grains with reticulate exine. Such a broad circumscription limits the value of the genus, and several authors have therefore attempted to restrict the genus in several ways (Potonié, 1960; Srivastava, 1969; Singh, 1971). This has led to the rather common usage of the genus *Retitricolpites* van der Hammen ex Pierce, 1961 (Brenner, 1963; Singh, 1971), which is untenable since the type species of *Retitricolpites* is a pollen grain of the extant species *Neea macrophylla* and thus is invalid for fossil specimens (Srivastava, 1969). Potonié (1966) attempted to validate the genus *Retitricolpites* by designating *R. vulgaris* Pierce, 1961, as the type but succeeded only in creating an additional junior homonym (Jansonius and Hills, 1976).

The treatment of tricolpate palynomorphs here is entirely arbitrary and tentative, assigning all forms to the genus *Tricolpites*, with indications of placement by other authors into various other form-genera. Formal transfer of species to *Tricolpites* is not proposed, since undoubtedly all these genera involved will undergo revision in description and usage at some future date.

Tricolpites sp., cf. **Foveotricolpites concinnus** Singh, 1971

Pl. 17, fig. 1

1971 *Foveotricolpites concinnus* SINGH, p. 195.*Dimensions*.—Polar diameter 29(33)36 microns; equatorial diameter 16(23)27 microns.*Occurrence*.—Rare.**Tricolpites crassimurus** (Groot and Penny) Singh, 1971

Pl. 17, fig. 2

1960 *Tricolpopollenites crassimurus* GROOT and PENNY, p. 232.1971 *Tricolpites crassimurus* (Groot and Penny) SINGH, p. 207.*Dimensions*.—Equatorial diameter 28(39)46 microns; polar diameter not observed.*Occurrence*.—Rare.**Tricolpites** sp., cf. "**Retitricolpites**" **georgensis** Brenner, 1963

Pl. 17, figs. 3, 4

1963 *Retitricolpites georgensis* BRENNER, p. 91.*Dimensions*.—Polar diameter 19(20)23 microns; equatorial diameter 14(19)22 microns.*Occurrence*.—Rare.**Tricolpites micromunus** (Groot and Penny) Singh, 1971

Pl. 17, fig. 5

1960 *Tricolpopollenites micromunus* GROOT and PENNY, p. 232.1971 *Tricolpites micromunus* (Groot and Penny) SINGH, p. 209.*Dimensions*.—Polar diameter 13(16)18 microns; equatorial diameter 12(13)14 microns.*Occurrence*.—Rare to occasional.**Tricolpites** sp., cf. "**Retitricolpites**" **prosimilis** Norris, 1967

Pl. 17, figs 6, 7

1967 *Retitricolpites prosimilis* NORRIS, p. 108.

See Singh (1971, p. 202) for comments.

Dimensions.—Polar diameter 9(13)15 microns; equatorial diameter 8(10)14 microns.*Occurrence*.—Rare to occasional.**Tricolpites** sp., cf. **Fraxinoipollenites venustus** Singh, 1971

Pl. 17, fig. 8

1971 *Fraxinoipollenites venustus* SINGH, p. 196.*Dimensions*.—Polar diameter 31(47)56 microns; equatorial diameter 21(25)28 microns.*Occurrence*.—Rare.**Tricolpites** sp., cf. "**Retitricolpites**" **virgeus**

(Groot, Penny, and Groot) Brenner, 1963

Pl. 17, figs. 9, 10

1961 *Tricolpopollenites virgeus* GROOT, PENNY, and GROOT, p. 133.1963 *Retitricolpites virgeus* (Groot, Penny, and Groot) BRENNER, p. 92.

See Singh (1971, p. 203) for description and remarks.

Dimensions.—Polar diameter 19(24)26 microns; equatorial diameter 16(19)23 microns.**?Tricolpites** sp.

Pl. 17, fig. 11

Description.—Pollen grains with three regions of thinned exine along the equator approximately 120° apart and extending one-fourth to one-third the distance from the equator to the poles. These three regions of thinning may or may not represent colpi. Ektexine granular to microrugulate over the entire surface, but much less dense over the ?colpi.*Dimensions*.—Equatorial diameter 24(28)30 microns; polar diameter not observed.*Occurrence*.—Rare.*Remarks*.—This form has the appearance of approaching, but not quite attaining, a tricolpate condition and may be closely related to the irregularly aperturate pollen referred to *Penetetrapites* by Hedlund and Norris (1968). The few specimens observed could represent teratological forms.Genus **Striatopollis** Krutzsch, 1959*Type species*.—*Striatopollis sarstedtensis* Krutzsch, 1959.

See Krutzsch (1959, p. 142) for description.

Remarks.—The striate ornamentation of the exine distinguishes this genus from other tricolpate pollen. Pollen of modern *Acer* and several genera of the Rosaceae commonly possess a finely striate exine, superficially similar to *Striatopollis*, but they differ in several other respects so that no affinity is proposed.

Striatopollis paraneus
(Norris) Singh, 1971

Pl. 17, fig. 12

1967 *Retitricolpites paraneus* NORRIS, p. 109.

1971 *Striatopollis paraneus* (NORRIS) SINGH, p. 206.

See Singh (1971, p. 206) for discussion.

Dimensions.—Polar diameter 18(27)31 microns; equatorial diameter 16(20)26 microns.

Occurrence.—Rare.

Tricolporate or Tricolpate sp.

Pl. 17, fig. 13

Description.—Small, oblate pollen grains with colpi extending to near the poles and expanding to the equator. The thin endexine covering the colpi tends to part at the equator, leaving an opening with ragged margins. These openings may represent pores, in which case the species would be tricolporate, or they may represent ruptures of the endexine, possibly as a result of compression along the polar axis. If the latter is the case, the species should be considered tricolpate. All specimens were observed in polar view only and were strongly compressed. The amb is triangular with straight sides and truncated to indented radii, as a result of pore development or parting of the endexine. The ektexine is microrugulate and is absent over the colpi.

Dimensions.—Equatorial diameter 14(18)20 microns.

Occurrence.—Only four specimens observed.

Remarks.—In each of the four specimens observed, the irregular "pores" were present and lead to the suspicion that this is indeed an early tricolporate form. This cannot be stated with certainty, however, in view of the limited number of specimens available for study, and all being in the same view (polar).

Pollen Tetrad Type 1

Pl. 17, fig. 14

Description.—A tetrahedral tetrad of small grains with smooth to granular exine. Germinal apertures, if present, are not clearly exhibited. Two thin areas in the exine are evident when focusing through the tetrad, and these are suggestive of apertures, but this cannot be determined with certainty.

Dimensions.—Overall diameter of the tetrad is 20 microns.

Occurrence.—Only a single specimen observed.

Remarks.—This tetrad appears essentially identical with Tetrad Type 2 of Doyle (1969, p. 14, figs. 3l, m; overall diameter 22 microns) from the Woodbridge Clay Member of the Raritan Formation (Upper Cretaceous) in New Jersey.

Genus **Asteropollis**

Hedlund and Norris, 1968

Type species.—*Asteropollis asteroides* Hedlund and Norris, 1968.

See Hedlund and Norris (1968, p. 152) for generic diagnosis.

Remarks.—This genus is described as being tetra- or pentachotomosulcate, with the number of branches and clarity of the sulcus being variable. Doyle (1969, p. 6) suggested that these pollen are "essentially identical to the irregular-aperturate specimens of *Clavatipollenites* Couper, 1958, from the Potomac Group (Lower Cretaceous) but they show much more complete intergradation from sulcoidate to colpoidate."

Asteropollis asteroides

Hedlund and Norris, 1968

Pl. 17, fig. 15

1968 *Asteropollis asteroides* HEDLUND and NORRIS, p. 153.

1971b *Porotrichotomosulcus clavatus* PHILLIPS, in Phillips and Felix, p. 471.

Dimensions.—Equatorial diameter 23(29)34 microns.

Occurrence.—Rare.

Remarks.—Several specimens from the Denton Shale are trichotomosulcate but are identical in all other respects with tetra- and pentachotomosulcate forms. Phillips and Felix (1971b) described essentially identical

trichotomosulcate forms, with incompletely developed "pores" at the ends of the sulcal branches, under the new genus *Porotrichotomosulcus* Phillips. These forms are here treated as variants of *Asteropollis asteroides* and are placed in synonymy.

Genus Penetrapites
Hedlund and Norris, 1968

Type species.—*Penetrapites mollis* Hedlund and Norris, 1968.

Remarks.—This genus is characterized by three large exinal openings at the equator and occasionally a fourth opening at one pole. These openings are generally bordered by somewhat ragged exine and are difficult to interpret as either true pores or possibly short, broad colpi.

Penetrapites mollis
Hedlund and Norris, 1968
Pl. 17, fig. 16

1968 *Penetrapites mollis* HEDLUND and NORRIS, p. 152.

Dimensions.—Equatorial diameter 27(30)32 microns.

Occurrence.—Rare to occasional.

Genus Stephanocolpites van der Hammen,
emend. Potonié, 1960

Type species.—*Stephanocolpites costatus* van der Hammen, 1954.

See Hedlund and Norris (1968, p. 150) for synonymy.

Remarks.—The form-genus *Stephanocolpites* may be invalid if the first designated species, *S. communis*, is interpreted as the holotype, since the specimen used to designate *S. communis* is a recent pollen grain. The selection of another species, *S. costatus*, as type by Potonié (1960) would then be contrary to the Code of Nomenclature (see Jansonius and Hills, 1976, for discussion of this problem). The use of this form-genus is therefore considered tentative in this study, and the possibility of its being invalid is duly noted.

Stephanocolpites fredericksburgensis
Hedlund and Norris, 1968
Pl. 17, fig. 17

1968 *Stephanocolpites fredericksburgensis* HEDLUND and NORRIS, p. 152.

Dimensions.—Equatorial diameter 24(29)31 microns.

Occurrence.—Rare.

Remarks.—Doyle (1969) suggested a possibly close relationship between *Stephanocolpites fredericksburgensis*, *Asteropollis asteroides*, and *Clavatipollenites*.

RESULTS AND DISCUSSION

The Denton Shale Member of the Bokchito Formation contains a large and diverse assemblage of palynomorphs, including 193 species of pollen and spores. Newly proposed in this study are three new form-genera, eight new form-species, and 11 new combinations. The large number of species and their excellent state of preservation make this fossil assemblage one of the more useful Cretaceous assemblages in North America. Ammonite studies by Young (1959, 1967) in northern Texas indicate that the Denton Shale Member falls within the *Drakeoceras lasswitzii* zone and is therefore of late Albian age. This accurate dating of the stratigraphic unit greatly enhances the value of the plant microfossils as a reference assemblage for other palynological studies in less surely dated rocks. The fossil assemblage also includes numerous forms of microplankton which are not treated in this study and will be the subject of a subsequent report.

Gymnosperms, particularly conifers, dominate the assemblage in terms of relative abundance. This undoubtedly is due to the very high rate of production by the conifers of anemophilous pollen, which is usually subjected to long-distance transport, generally resulting in over-representation of coniferous pollen at many depositional sites. That is, the relative abundance of coniferous pollen in a microfossil assemblage is usually higher than the frequency of the parent plants in the regional vegetation. Other important constituents of the assemblage are monosulcate pollen having possible affinities with the Cycadales, Ginkgoales, or Bennettitales, and polyplicate pollen typical of the Ephedraceae. Pteridophyte spores are abundant, and the forms assignable to the Schizaeaceae are notably diverse and abundant within the Denton Shale Member. These are accompanied by several representatives of the Osmund-

aceae, Gleicheniaceae, and Cyatheaceae or Dicksoniaceae.

Angiospermous pollen constitutes a rather small (10.6 percent), but important, fraction of the assemblage. The group is represented primarily by retipilate tricolpate and monosulcate forms, along with infrequent representatives of irregularly aperturate forms. These morphological types are characteristic of the earliest angiospermous pollen records from the middle and late Albian of North America (Doyle, 1969; Singh, 1975). Comparison with the angiospermous components of the stratigraphically lower Walnut Clay in southern Oklahoma and northern Texas (Hedlund and Norris, 1968) suggests that little evolutionary change and diversification of the angiosperms occurred from middle Albian time (Walnut Clay) through late late Albian time (Denton Shale Member). One notable exception to this is the occurrence of an angiospermous tetrad in the Denton assemblage that is most similar to a form noted by Doyle (1969) in the upper Patapsco Formation and Woodbridge Clay Member of the Raritan Formation in the eastern United States. Singh (1975) considered the first appearance of such tetrads, together with primitive tricolporate types, to mark the Albian-Cenomanian boundary in western Canada. Even though only a single specimen was observed in the Denton assemblage, this suggests that the permanent tetrad form was introduced slightly earlier (late late Albian) in the southwestern United States than in Canada. A possible tricolporate form occurs in the Denton assemblage, suggesting that the earliest appearance of this morphological type in the southwestern United States may be the same as in western Canada (latest Albian: Singh, 1975).

A moderate degree of similarity exists between the palynological assemblages from the Denton Shale Member and the Patapsco Formation of the eastern United States (Brenner, 1963; Doyle, 1969) and the Peace River Formation of northwest Alberta, Canada (Singh, 1971). Of the 130 species discussed by Brenner (1963) from Maryland, 63 appear to be common with species found in the Denton Shale Member. The majority of the species in common are found in the upper part of the Patapsco Formation (Zone II B of Bren-

ner, 1963), including the only form designated by Brenner as being restricted to the highest zone (II B 2), *Rugubivesiculites reductus*. This comparison, together with the occurrence of an angiospermous tetrad and possible tricolporate form in the Denton assemblage, suggests that the Patapsco Formation is slightly older than the Denton Shale Member. Brenner (1963) considered the Patapsco Formation to be partly of late Albian age with possibly some strata of early Albian age in the lower part. The moderate degree of similarity, with regard to species composition, between the Denton Shale Member and the Patapsco Formation may be a reflection of geographic differences in late Albian floras as well as an age difference. The number of pollen and spore species in common between the Denton Shale Member and the Loon River, Peace River, and Shaftesbury Formations of northwest Alberta, Canada (Singh, 1971), is 85. This is also indicative of only a moderate degree of similarity, but it is greater than that found by comparing the Patapsco Formation with the northwest Alberta strata (52 pollen and spore species in common). Since the Loon River, Peace River, and Shaftesbury Formations encompass all of the middle and late Albian (Singh, 1971, 1975), the differences in composition of pollen and spores between those formations and the Denton Shale Member and Patapsco Formation cannot be entirely explained as a difference in age. It appears that floristic differences occurred across North America in middle and late Albian time and that the flora of the Oklahoma-north Texas area, as evidenced through dispersed pollen and spores, was intermediate, or transitional, between the floras of the Atlantic Coastal Plain and the western interior of Canada.

The Denton Shale Member is part of a large sequence of marine clastic and carbonate rocks deposited in northern Texas and southern Oklahoma during Cretaceous time. Fossil microplankton form an important part of the microfossil assemblages in the Denton Shale Member, attaining their highest relative abundance in the lower beds and decreasing gradually upwards in the section. This indicates that deposition of the Denton Shale Member occurred during a period of marine regression, with sediments in the lower beds accumulating at a greater dis-

tance from the ancient shoreline than those in the upper beds. With increasing distance from shore, there is also an increase in the relative abundance of coniferous pollen. This increase is relative, not absolute, and represents the increased importance of regional pollen rain, of which coniferous pollen is often a major constituent, over other pollen types less subject to long-distance transport (Wilson, 1971; Chaloner, 1968). Conversely, the higher relative abundance of dicotyledonous pollen in the upper, more nearshore, levels of the section suggests that the early angiosperms represented by this pollen grew in proximity to the strand. It is imprudent to speculate further as to the phytogeography of Denton time, as the important factors affecting the distribution of the dispersed fossils, such as anemophily versus entomophily and direction and force of air and water currents, are not known.

The palynological assemblages of the Denton Shale Member are characterized by pollen and spores, which, for the most part, can be assigned with reasonable certainty to extant families or orders of plants. What cannot be determined with any reasonable certainty, however, is what these plant groups represent in terms of paleoenvironments and paleoclimates during late late Albian time. Most of the families represented are non-angiospermous, with the angiosperms constituting a relatively minor fraction of the assemblages. The ecological adaptations and geographic distributions of modern plants are undoubtedly very different from past times when the angiosperms were minor constituents of the vegetation and other plant groups were dominant. That is to say, the modern phytogeography of most non-angiospermous plants is highly restricted, as a result of displacement by the angiosperms during their rise to dominance. Therefore, paleoecological and paleoclimatological interpretations based on fossil pollen and spores become increasingly difficult as we attempt to extend them back in time, becoming essentially untenable when that time is earlier than the dominance by angiosperms (Chaloner, 1968; Chaloner and Muir, 1968; Kräusel, 1961). Thus, interpretation of the regional vegetation of Denton time in terms of modern plant groups and their climatic implications would most likely be subject to serious error and is therefore here excluded.

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APPENDIX
Measured Sections and Samples

| <i>Sample level</i> | <i>Description</i> | <i>Feet</i> | <i>Sample level</i> | <i>Description</i> | <i>Feet</i> |
|---|--|-------------|--|--|-------------|
| <i>Bokchito Creek Section</i> | | | | | |
| <i>Bryan County, Oklahoma</i> | | | | | |
| Oklahoma Palynology Collection (OPC) 1211 | | | | | |
| Composite section of Denton Shale, collected from SW ¼ NW ¼ SW ¼ and SW ¼ NE ¼ sec. 3, and SE ¼ NE ¼ SE ¼ sec. 4, T. 6 S., R. 11 E., and SW ¼ SW ¼ sec. 34, T. 5 S., R. 11 E., along Bokchito Creek and its tributaries. Area is approximately 3 miles north of town of Bokchito along Oklahoma State Highway 22. | | | | | |
| WENO SHALE | | | | | |
| | Limestone, hard, well-indurated, very fossiliferous (<i>Texigryphaea washitaensis</i> , <i>Rastellum (Arctostrea) quadriplicatum</i> , <i>Rastellum</i> sp., and echinoid plates and spines most common); weathered surface reddish to yellowish brown, fresh surface gray to brownish gray. | 1 | L | Same as above. | 2 |
| ZB | Limestone, argillaceous, soft and friable, very fossiliferous (mostly <i>Texigryphaea</i> and echinoids, with a few <i>Rastellum</i>); weathered and fresh surface yellowish tan with abundant limonite stain. | 2 | K | Shale, very high clay content, soft; slightly calcareous; thick bedded; breaks into rectangular blocks; weathered surface dark bluish gray to black; fresh surface dark gray with waxy luster; small flattened ironstone concretions occur along bedding planes. | 2 |
| ZA | Limestone, very fine-grained, argillaceous (clay-sized particles), soft, very fossiliferous; gray brown, less iron staining than level ZB. | 1 | J | Same as above. | 2 |
| Z | Limestone, argillaceous, well-indurated, very fossiliferous (coquina-like); weathered surface gray, mottled with white. | 1 | I | Same as above. | 2 |
| Y | Shale, high clay content, thick-bedded; breaks into rectangular blocks; moderately calcareous; very slightly fossiliferous; weathers very dark gray to black with thin dark-reddish-brown iron staining along bedding planes; fresh surface dark gray with waxy luster. | 2 | H | Same as above. | 2 |
| X | Same as above. | 2 | G | Same as above. | 2 |
| W | Same as above. | 1 | F | Covered slope; thickness estimated. | 1 |
| V | Same as above. | 2 | E | Shale, very high clay content; very slightly calcareous, becoming moderately calcareous near base of unit; a 2-3-inch hard finely crystalline limestone lentil occurs approximately 8 inches above base of unit; thick bedded; breaks into rectangular blocks; a few small fossil shell fragments scattered throughout; fresh surface dark gray with waxy luster and limonite staining along bedding planes. | 2 |
| U | Same as above. | 2 | D | Limestone, very argillaceous (or very calcareous shale), soft but moderately well indurated; breaks into rectangular blocks; fresh surface alternating gray and yellowish-brown laminae. | 2 |
| T | Same as above. | 3 | C | Shale, slightly calcareous, slightly fossiliferous, well-indurated; breaks into rectangular blocks; dark gray streaked with yellowish gray. | 2 |
| S | Same as above. | 2 | B | Limestone, very finely crystalline, very argillaceous, thin-bedded, well-indurated; dark gray with limonite stain along bedding and fracture planes. | 2 |
| R | Same as above. | 2 | A | Covered slope; thickness estimated. | 1 |
| Q | Shale, very high clay content, with a few very slightly calcareous and very slightly arenaceous laminae; soft, poorly indurated; thick bedded; breaks into rectangular blocks, breaking most readily perpendicular to bedding planes; small flattened ironstone concretions occur along bedding planes; a few small fossil fragments scattered throughout unit, weathered slope light gray to tan with thin yellowish-brown laminae. | 2 | | Shale, moderately calcareous, very slightly arenaceous; a few fossil fragments; poorly indurated, soft; breaks into rectangular blocks; thin bedded; light gray to tan. | 4 |
| P | Same as above. | 2 | CADDO LIMESTONE | | |
| O | Same as above. | 2 | Total thickness 62 | | |
| N | Same as above. | 2 | <i>Lake Texoma Section</i> | | |
| M | Same as above. | 2 | <i>Marshall County, Oklahoma</i> | | |
| | | | Oklahoma Palynology Collection (OPC) 1212 | | |
| | | | Upper one-third of section sampled from east side of Lake Texoma at Johnson Creek picnic grounds (NE ¼ NE ¼ SE ¼ SE ¼ sec. 28, T. 6 S., R. 7 E.), approximately 0.2 mile north of U.S. Highway 70. | | |
| <i>Sample level</i> | <i>Description</i> | <i>Feet</i> | | | |
| | WENO SHALE | | | | |
| | Limestone, very hard, very fossiliferous, with abundant <i>Rastellum</i> plus <i>Pecten</i> and <i>Texigryphaea</i> and echinoid spines; dark red brown. | 0.3 | | | |

| | | | | | |
|---------------------|---|-------------|---|--|------|
| | Shale, very calcareous, fossiliferous, poorly exposed. | 0.7 | | bedded; breaks into rectangular blocks; scattered fossil-shell fragments; light gray. | 2 |
| | Limestone, fine- to medium-grained, very fossiliferous, with abundant <i>Texigryphaea</i> and some <i>Pecten</i> , <i>Rastellum</i> , and echinoid plates and spines; well indurated; yellow brown. | 2 | J | Shale, very calcareous (or very argillaceous limestone), well-indurated, thin-bedded; breaks into equidimensional blocks; a few scattered fossil-shell fragments; gray to gray brown with limonite stains common. | 3 |
| R | Limestone, very argillaceous (may be a very calcareous shale), poorly indurated; breaks into rectangular blocks; abundant fossil-shell fragments; gray brown, with limonite stain along bedding planes. | 1.5 | I | Shale, calcareous, well-indurated, thin-bedded; breaks into rectangular blocks; a few fossil-shell fragments and casts; gray brown. | 2 |
| Q | Limestone, medium-grained, clastic, argillaceous, thin-bedded, fissile; scattered fossil-shell fragments; light gray with limonite stain along bedding planes. | 0.7 | H | Covered slope. Shale, very calcareous, poorly indurated, thin-bedded; a few scattered fossil-shell fragments; light gray to yellowish brown. | 2 |
| | Covered slope with abundant <i>Texigryphaea</i> in float. | 5 | F | Shale, very calcareous, moderately well-indurated, thin-bedded; breaks into equidimensional plates; dark gray; weathered slope blue gray to black; near middle a thin (2-4 inches) limestone bed occurs (very finely crystalline, sparsely fossiliferous, a few <i>Pecten</i>); very dark gray to black. | 4 |
| P | Shale with very high clay content, slightly calcareous, poorly indurated; breaks into equidimensional blocks; slightly fossiliferous; light gray with red-brown limonite stain in scattered patches throughout. | 2 | | | 2 |
| O | Same as above. | 2.5 | | | |
| N | Same as above. | 2 | E | Shale as above, except darker gray and more fissile (breaks into small thin plates). | 2 |
| M | Same as above. | 2 | | | |
| | Covered slope with float of blue-gray shale and ironstone concretions. | 2.8 | D | Same as above. | 2 |
| L | Shale, very slightly calcareous, well-indurated, thin-bedded; breaks into irregularly shaped plates; slightly fossiliferous; dark gray with limonite stains common. | 0.8 | C | Same as above plus a few very thin discontinuous lentils of dark-gray siltstone. | 2 |
| | Total thickness | 22.3 | B | Shale, moderately calcareous, moderately well indurated; breaks into rectangular and equidimensional blocks; sparsely fossiliferous; medium to dark gray; weathers very dark gray to black; scattered shell casts with limonite encrustations and filled with limonite-rich clay; scattered very thin (less than 1 inch) lentils of dark-gray siltstone. | 2 |
| | Lower one-third of section sampled from west side of Lake Texoma at lake boundary of Texoma Lodge property in NW¼NW¼NE¼ sec. 36, T. 6 S., R. 6 E., Marshall County, Oklahoma. | | A | Same as above. | |
| <i>Sample level</i> | <i>Description</i> | <i>Feet</i> | | | |
| K | Limestone, very argillaceous (or very calcareous shale), well-indurated, thin- | | | | |
| | | | | CADDO LIMESTONE | |
| | | | | Total thickness | 25.5 |

PLATES

Plate 1

(All figures $\times 500$, unless otherwise noted)

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|--|-------------|
| 1. <i>Aequitriradites ornatus</i> Upshaw, 1963; OPC 1212 J-4-2; 91×90 microns (zona 12 microns) ... | 8 |
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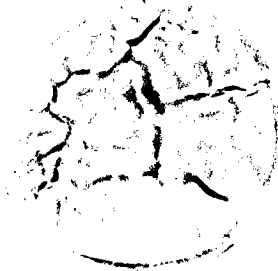
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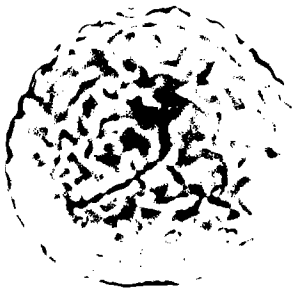
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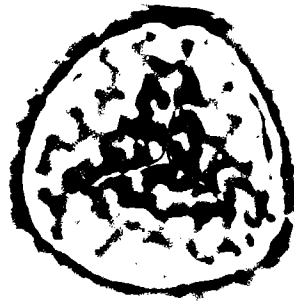
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12

Plate 2

(All figures $\times 500$, unless otherwise noted)

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|---|-------------|
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| 2. Distal view, same specimen. | |
| 3, 4. <i>Lycopodiumsporites</i> sp., cf. <i>L. dentimuratus</i> Brenner, 1963..... | 10 |
| 3. OPC 1211 W-19-25; 56 microns; proximal view. | |
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| 5, 6. <i>Lycopodiumsporites marginatus</i> Singh, 1964 | 11 |
| 5. OPC 1211 Y-20-3; 44 microns; proximal view. | |
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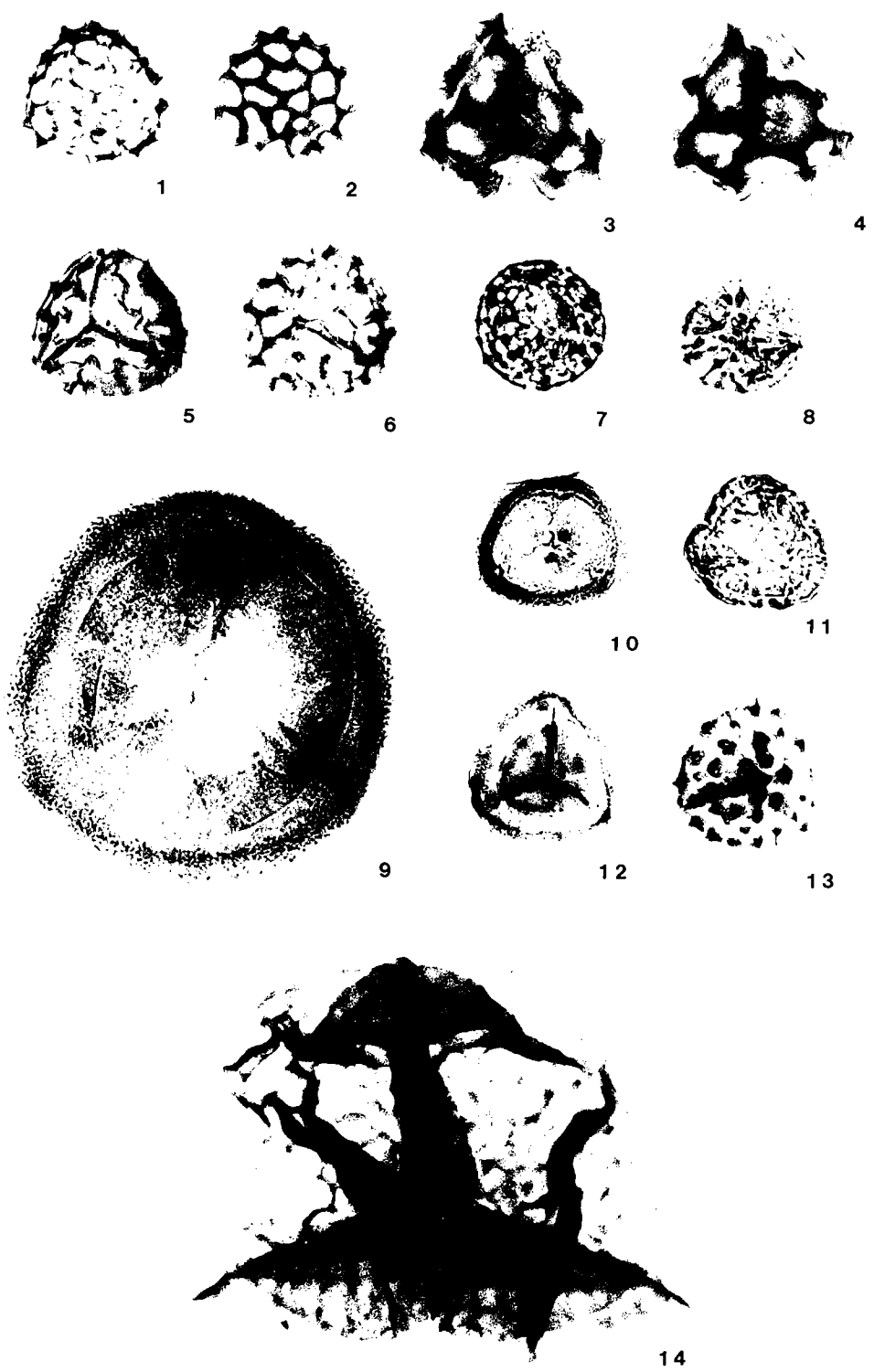


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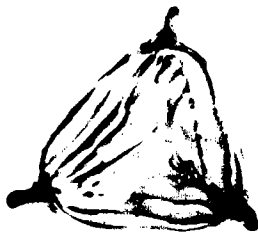
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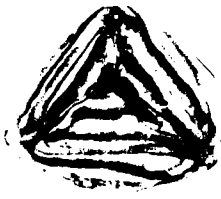


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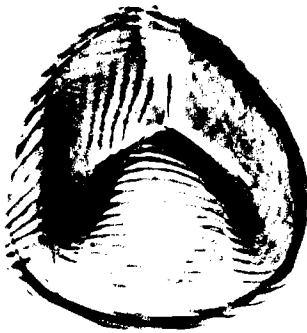
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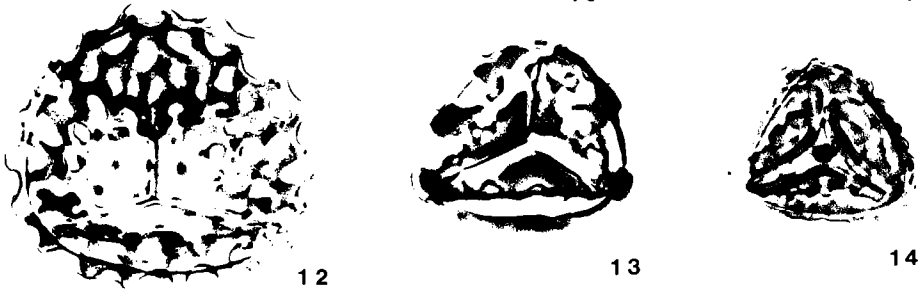
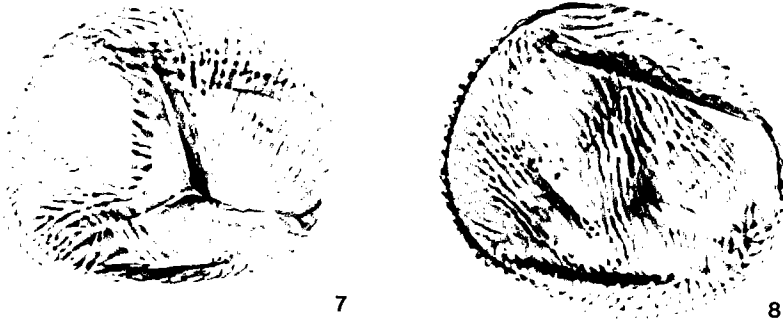
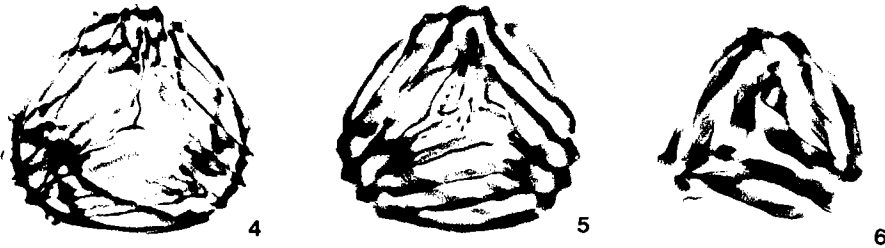


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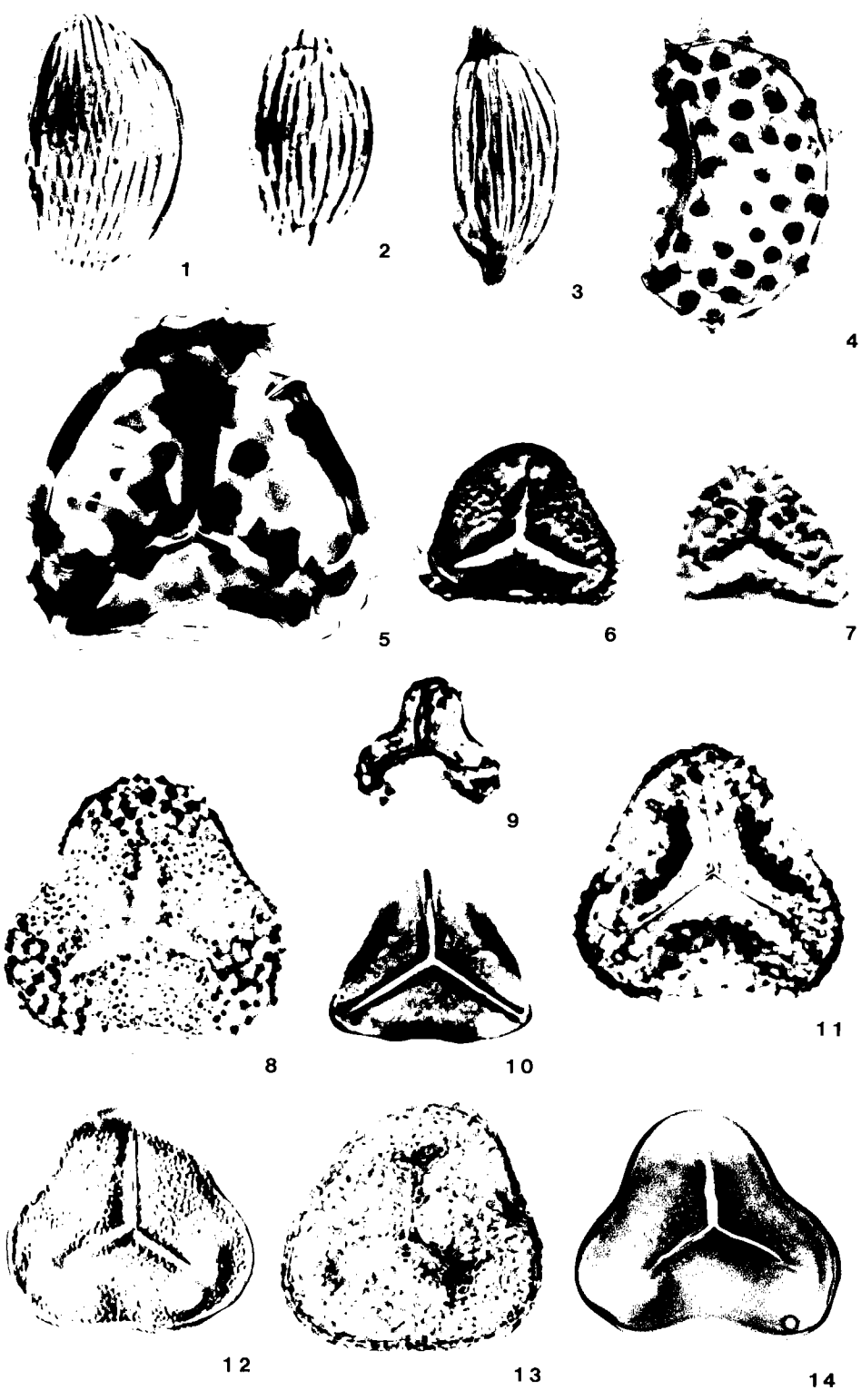
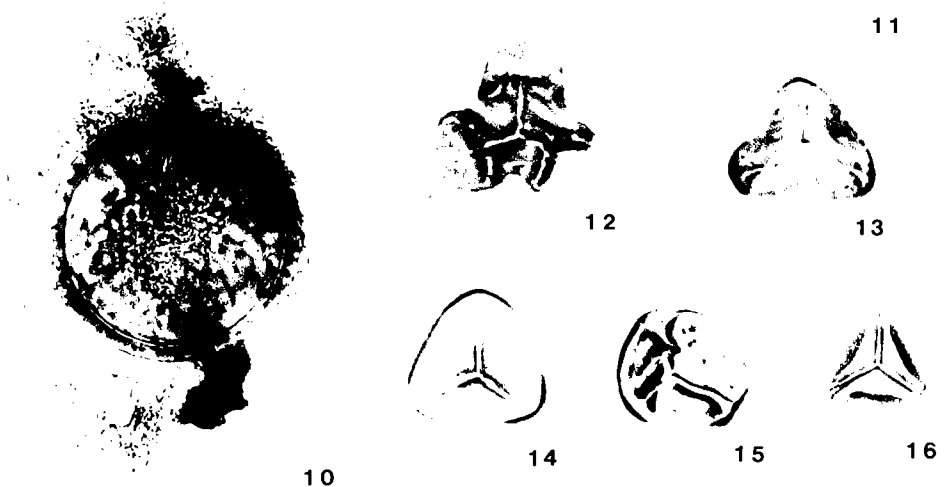
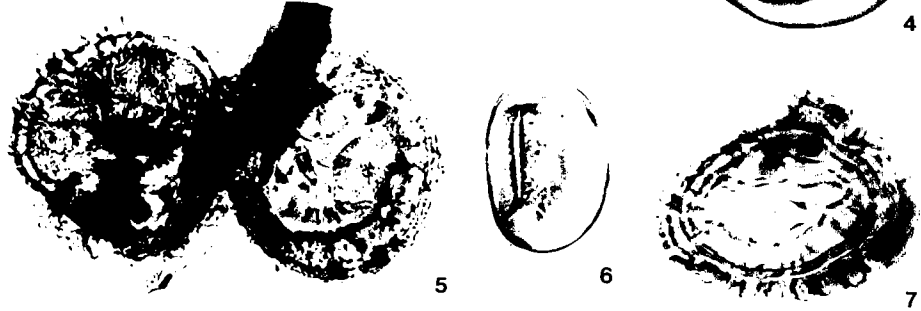
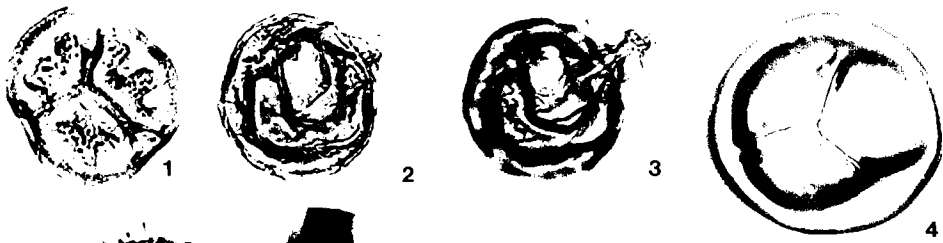


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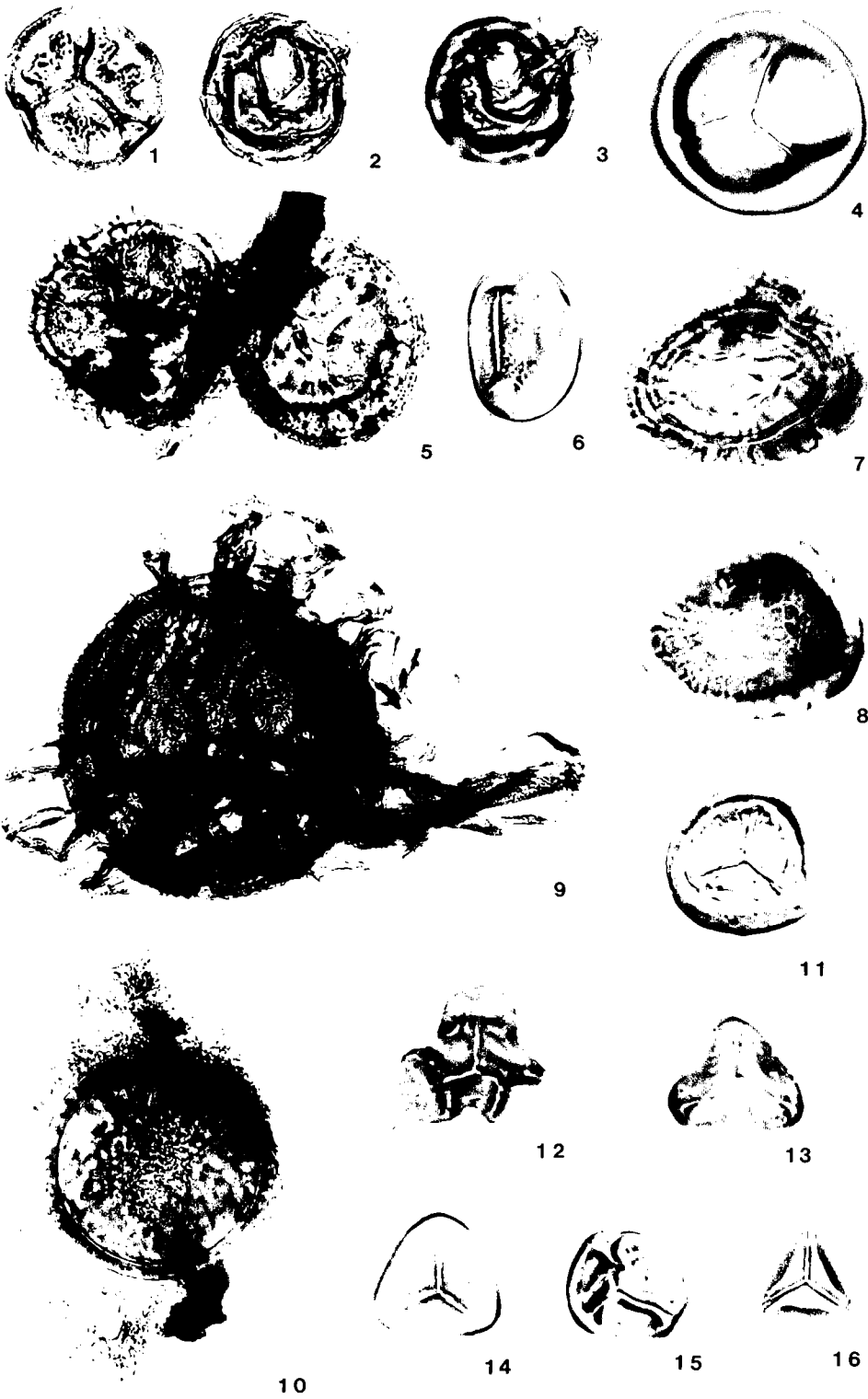


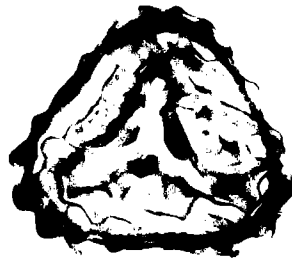
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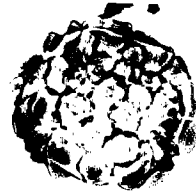
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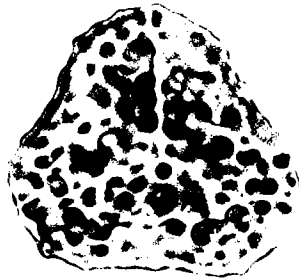
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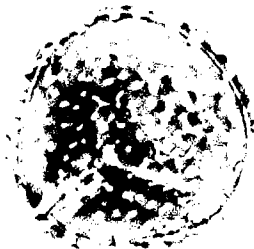
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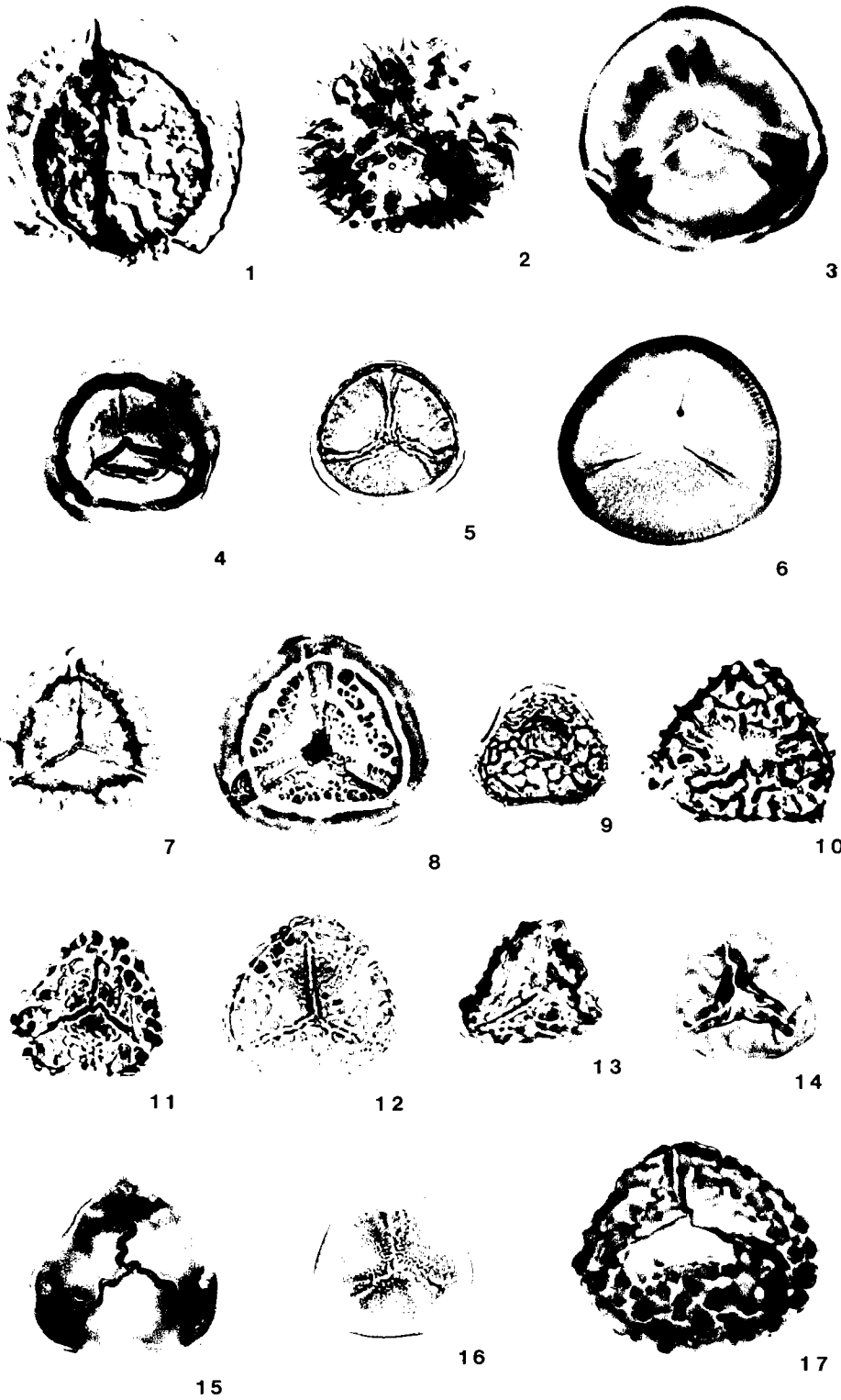


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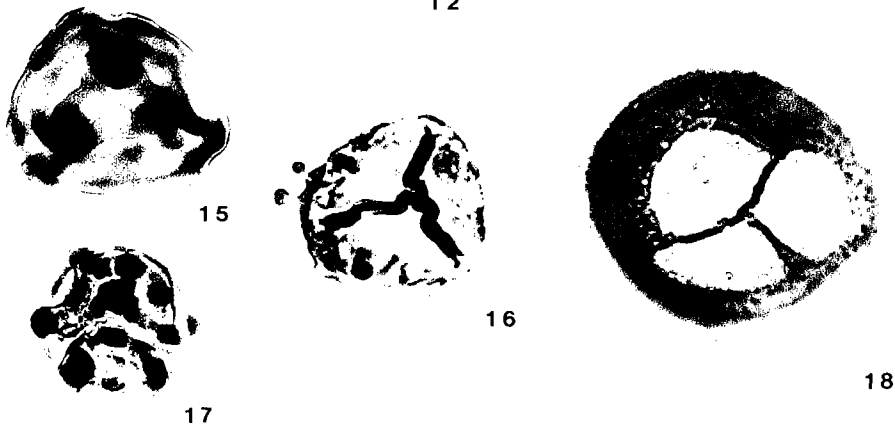
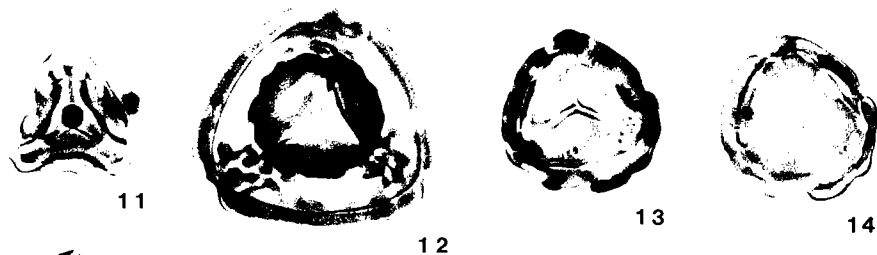
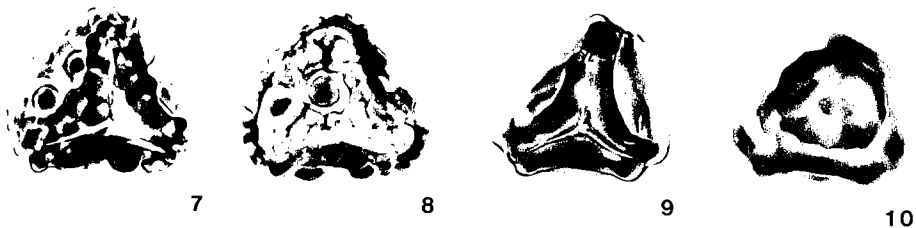
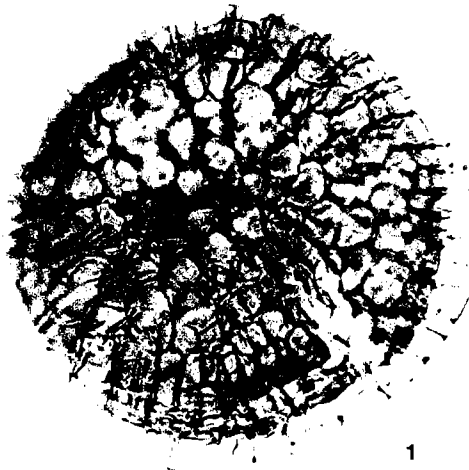


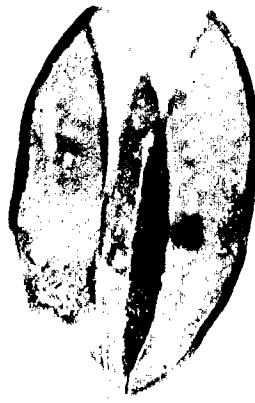
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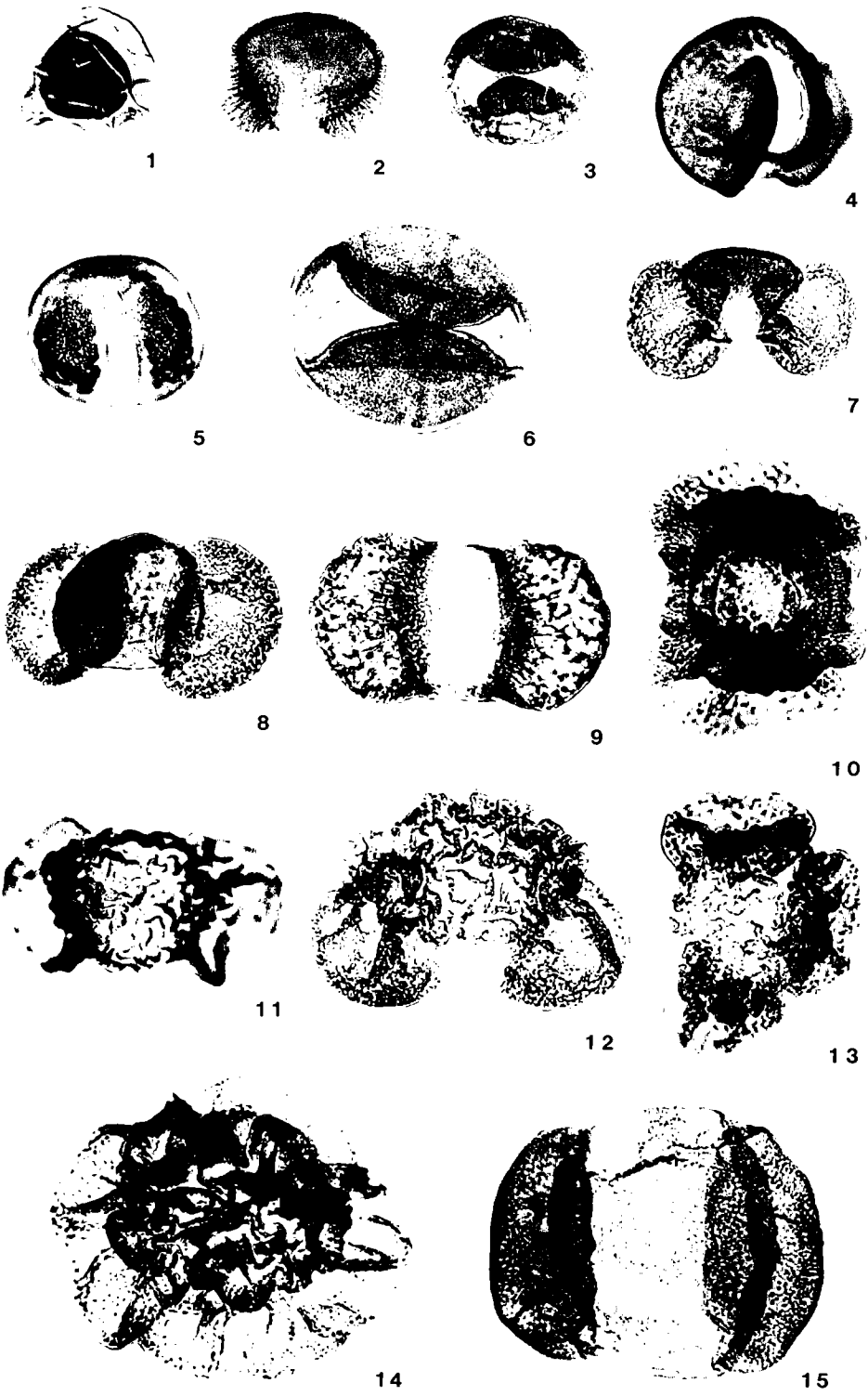


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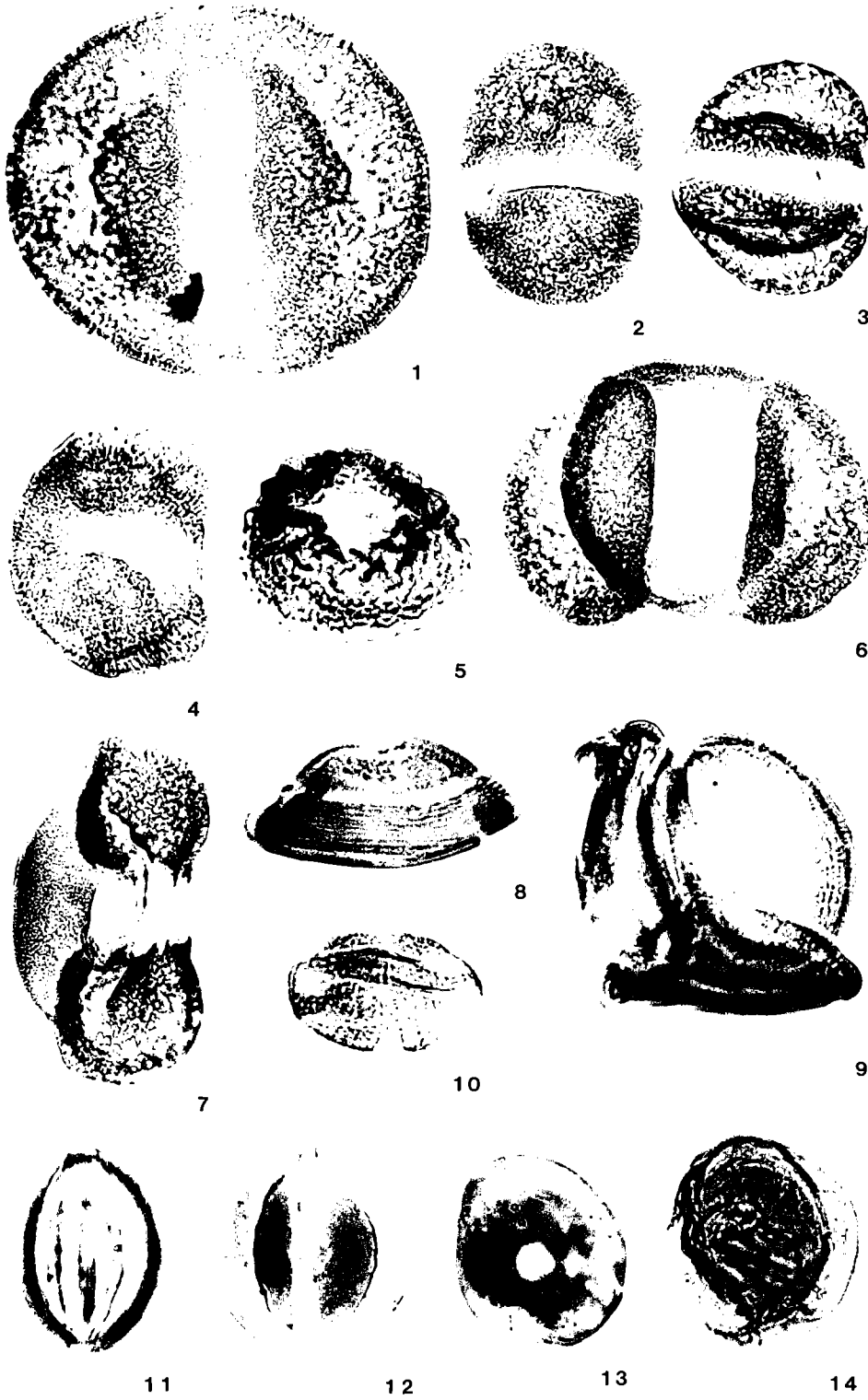


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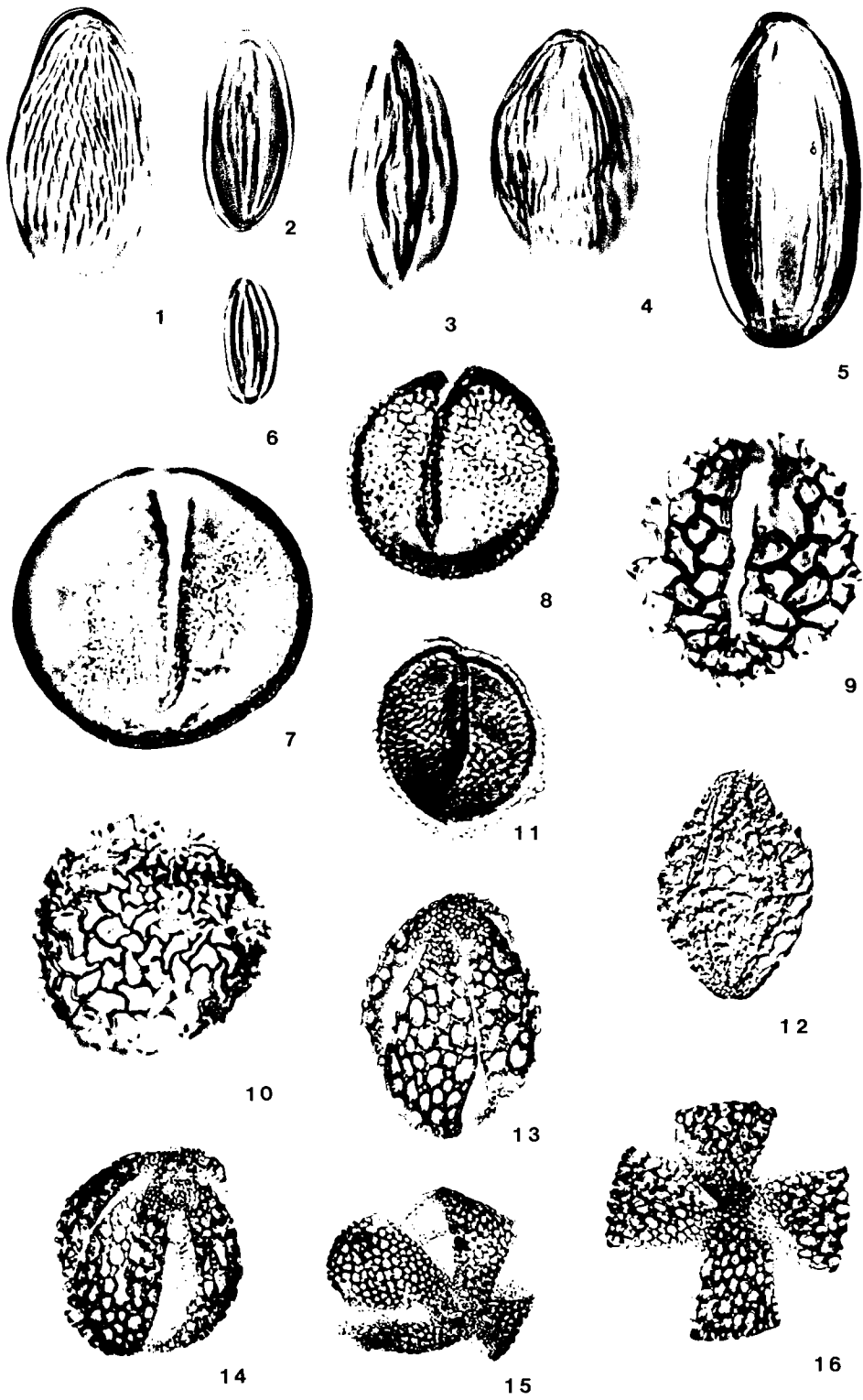
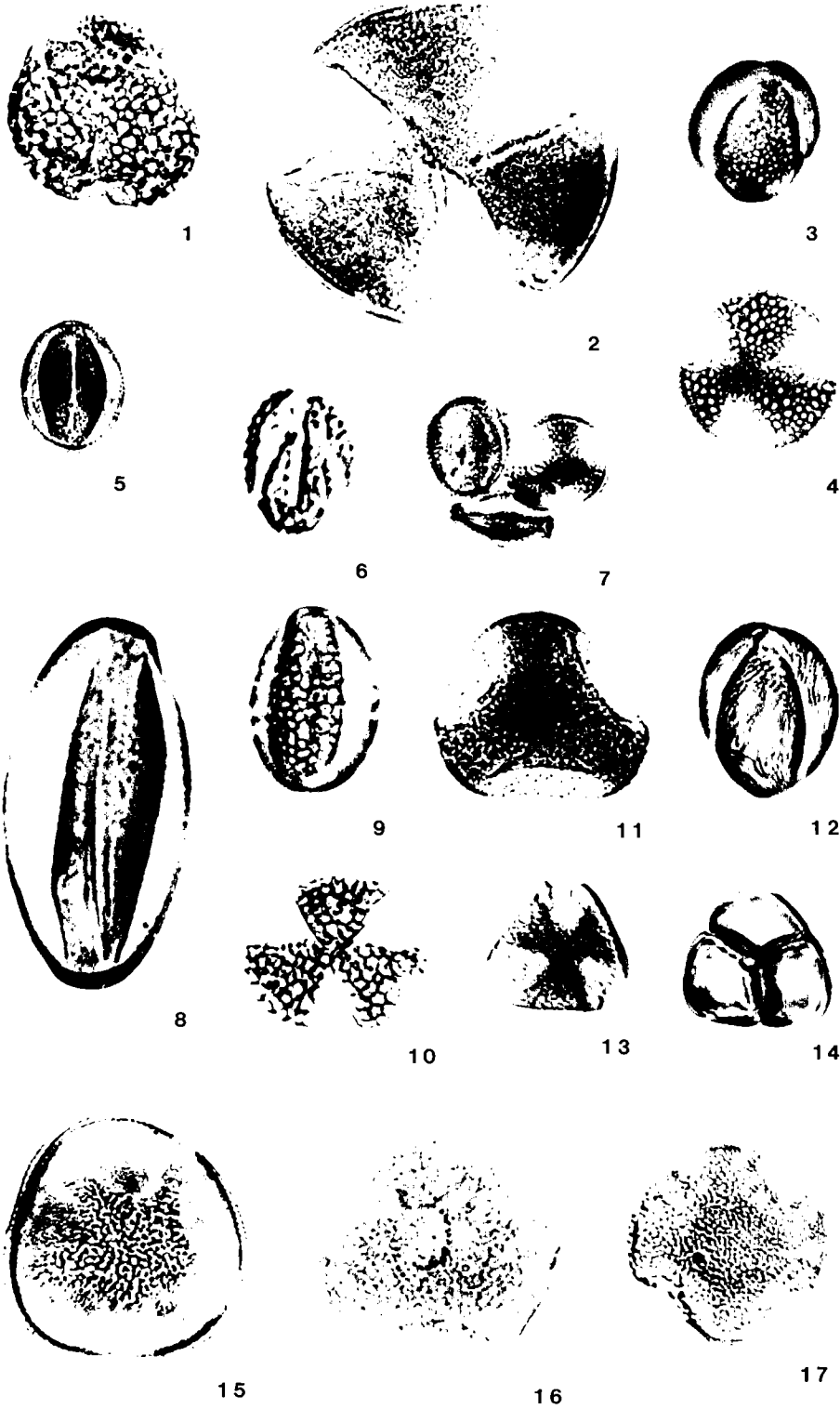


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