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POLLEN AND SPORES FROM THE PRE-VERNE CYCLICAL FORMATION OF THE SAGINAW GROUP, GRAND LEDGE, MICHIGAN, U. S. A.

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POLLEN AND SPORES FROM THE PRE-VERNE CYCLICAL FORMATION OF THE SAGINAW GROUP, GRAND LEDGE, MICHIGAN, U. S. A.

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ABSTRACT—Dispersed spores belonging to 36 genera and 63 species, 9 of which are new, were recovered from shale samples collected below Cycle "A" of the Pre-Verne cyclical formations of the Early Pennsylvanian age Saginaw Group at Grand Ledge, Michigan. All of the major plant groups known to have inhabited the coal swamps are represented. They are arranged according to the system suggested by Bharadwaj & Venkatachala in 1968.

CONTENTS

INTRODUCTION

ARNOLD (1944) described a heterosporous cone, *Bowmanites delectus,* which he later reassigned to Nemejc's genus *Discinites* (Arnold, 1949), from the shale below the lower *Lingula* layer in the quarry of the Grand Ledge Clay Products Company at Grand Ledge, Michigan. This shale lies immediately below Cycle "A" of the Pre-Verne cyclical formation of the Saginaw Group and is of Late Pottsville (Early Pennsylvanian) age.

The present report is concerned with the dispersed spores recovered from the shale bearing the fossilized cones, and enlarges somewhat the picture of the vegetation of the region during Pottsville times. While the shale upon maceration failed to yield any spores that can be positively identified with *Discinites delectus,* four species of *Calamospora,* the dispersed spore genus that embraces those of *D. delectus,* were found. These are *Calamospora perrugosa* (Loose) Schopf, Wilson, & Bentall, 1944, *C. microrugosa* (Ibrahim) S. W. & B, *C. breviradiata* Kosanke, and *C. hartungiana* (Loose) S. W. & B. The two spore types of *D. delectus* differ markedly in size. The microspores measure 75–90 micra in diameter, and the megaspores are 660–750 micra in diameter.

All specimens illustrated herein are catalogued and deposited in the Museum of Paleontology, The University of Michigan.

SYSTEMATIC PALYNOLOGY

The fossils are arranged according to the suggestions of Bharadwaj & Venkatachala (1968). The artificial classification at present used to classify dispersed Palaeozoic spores is an effective method by which spores and pollen

are separated on external characters. This method no doubt is of great help in bringing order to the great amount of data that has accumulated in this field but suffers from a shortcoming because of the arbitrary placement of several taxa. Though we are dealing with organ genera, an inquiry into the phylogenetic significance of the morphological characters is of immediate need. Bharadwaj & Venkatachala (1968) critically examined all available evidence from *in situ* records and provide a workable scheme based on morphology. The scheme put forward by them is no doubt not exhaustive but attempts to give the principle on which a phylogenetic classification can be constructed.

A study of dispersed as well as *in situ* spores of Lycopsida, Sphenopsida, and Pteropsida shows distinct differentiations in spore morphology. The lycopsid spores contain a central inner body which is attached to the main central body with three interradial cushions. These can be clearly seen in *Lycospora, Cirratriradites, Crassispora, Densosporites, Cristatisporites,* and other spores attributed to this group. The spores are also characterized by an equatorial or subequatorial exoexinous extension in the form of a crassitudo, cingulum, zona, or zonisaccus. The equatorial extensions meet the need of effective dispersal.

Sphenopsid spores are simpler in construction, being either bilateral or circular, and possess an inner body loosely enveloped by an outer cover. *Vestispora, Velamisporites, Calamospora,* and others show this type of organization.

Pterospid spores are devoid of an inner body and show an elaborate sculptural pattern on the exoexine. Angular thickenings in the form of auriculae are seen in *Triquitrites* Wilson & Coe (1940).

Cycadofilicalean pollen grains are saccate or asaccate. Specimens with ornamentation and two distinct parallel distal folds are found among pollen grains of *Potoniea, Codonotheca, Waldenburgia, Psaliangium, Telangium, Stephanospermum, Aulacotheca, Boulaya, Dolerotheca, Goldenbergia,* and *Whittleseya.* The dispersed spores of this group are exemplified by *Punctatisporites, Planisporites, Verrucososporites, Schopfipollenites,* and *Cymbospora.* The first three genera also encompass fern spores but the cycadofilicalean prepollen can be distinguished by two parallel folds on the distal face. *Schopfipollenites, Cymbospora,* and other pollen also possess a distinct, but different, fold pattern. Subsaccate pollen, as characterized by *Schulzospora, Wilsonites, Guthoerlisporites, Florinites, Complexisporites,* and *Kosankeisporites,* were also produced by Cycadofilicales (Bharadwaj & Venkatachala, 1968).

Cordaitalean and coniferous pollen show a girdling type of saccus exposing the proximal as well as the distal faces of the spore body, in contrast to the cycadofilicalean saccate pollen, which are distally covered by the saccus leaving only the proximal germinal area. The sulcus differentiation seen in *Complexisporites* and *Kosankeisporites* is not seen in these pollen.

The dispersed pollen recovered here are arranged according to the scheme outlined above.

LYCOPSIDA

Genus LYCOSPORA (Schopf, Wilson, & Bentall) Potonié & Kremp, 1954

Type species. — *Lycospora micropapillata* (Wilson & Coe, 1940) Schopf, Wilson, & Bentall, 1944.

LYCOSPORA PUNCTATA Kosanke, 1950

Pl. 1, fig. 4

Holotype.—Kosanke, 1950; pl. 10, fig. 3.

Description.—Roundly triangular spores, 35–

EXPLANATION OF PLATE 1

All figures × 500

FIGS. *1, 2*—*Spinozonotriletes arnoldii* n. sp.; Slide no. P/6, UMMP 57921.
3—*Lycospora brevijuga* Kosanke, 1950; Slide no. P/7, UMMP 57922.
4—*Lycospora punctata* Kosanke, 1950; Slide no. P/1, UMMP 57916.
5—*Densosporites* cf. *D. annulatus* (Loose) Schopf, Wilson, & Bentall, 1944; Slide no. P/4, UMMP 57919.
6, 11, 15—*Spinozonotriletes michiganensis* n. sp.; Slide no. P/1, UMMP 57916.
7—*Spinozonotriletes* cf. *S. conspicuus* Playford, 1963b; Slide no. P/8, UMMP 57923.
8—*Apiculatisporis* sp.; Slide no. P/5, UMMP 57920.
9—*Grandispora* sp.; Slide no. P/7, UMMP 57922.
10—*Cristatisporites* sp.; Slide no. P/7, UMMP 57922.
12—*Microreticulatisporites* cf. *M. concavus* Butterworth & Williams, 1958; Slide no. P/2, UMMP 57917.
13—*Leiotriletes subadnatoides* Bhardwaj, 1957; Slide no. P/1, UMMP 57916.
14—*Cristatisporites* cf. *C. indignabundus* (Loose) Potonié & Kremp, 1954; Slide no. P/8, UMMP 57923.
16—*Raistrickia* sp.; Slide no. P/1, UMMP 57916.
17—*Cirratriradites annulatus* Kosanke & Brokaw, *in* Kosanke, 1950; Slide no. P/4, UMMP 57919.
18—*Cirratriradites saturnii* (Ibrahim) Schopf, Wilson, & Bentall, 1944; Slide no. P/4, UMMP 57919.

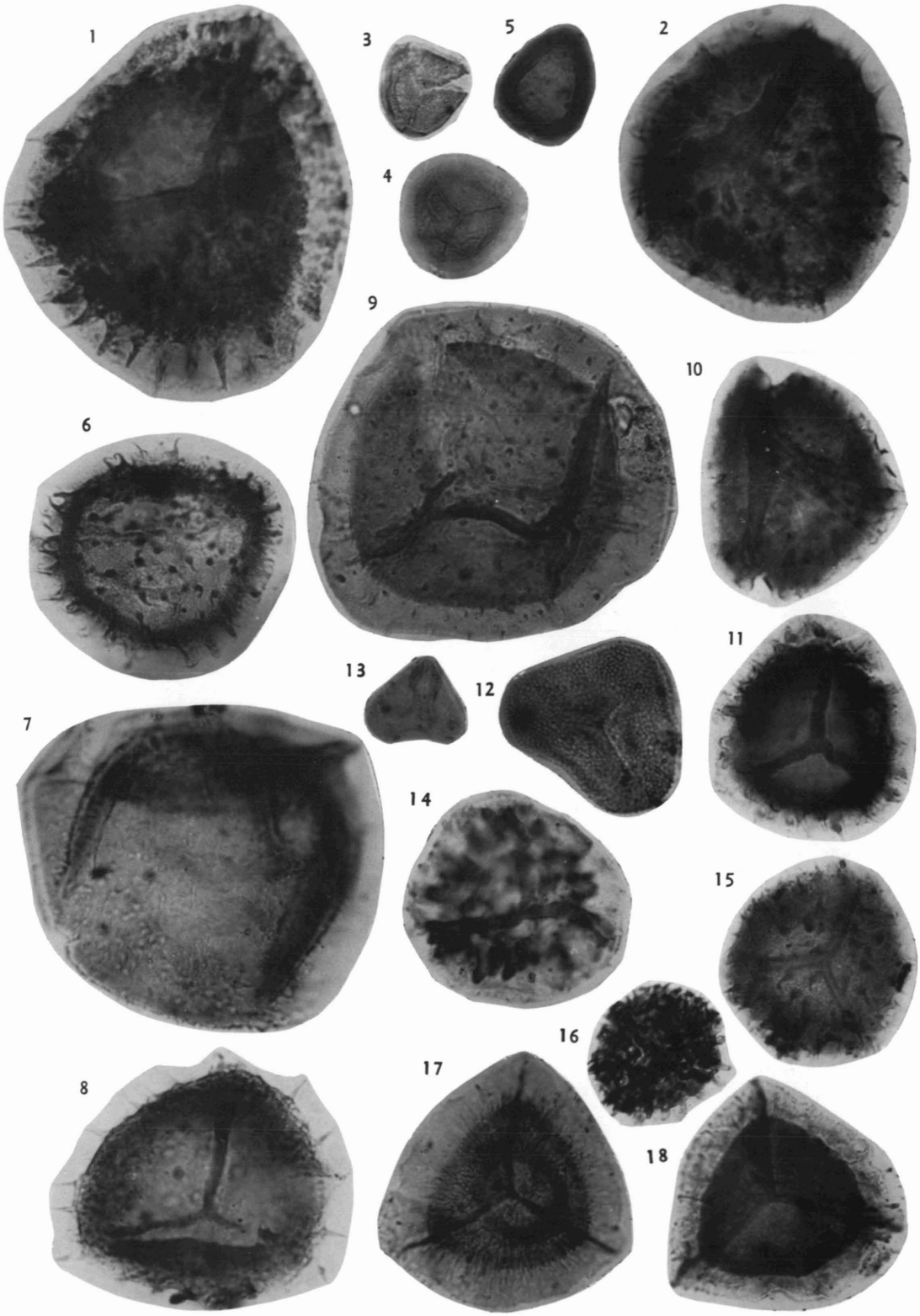

PLATE 1

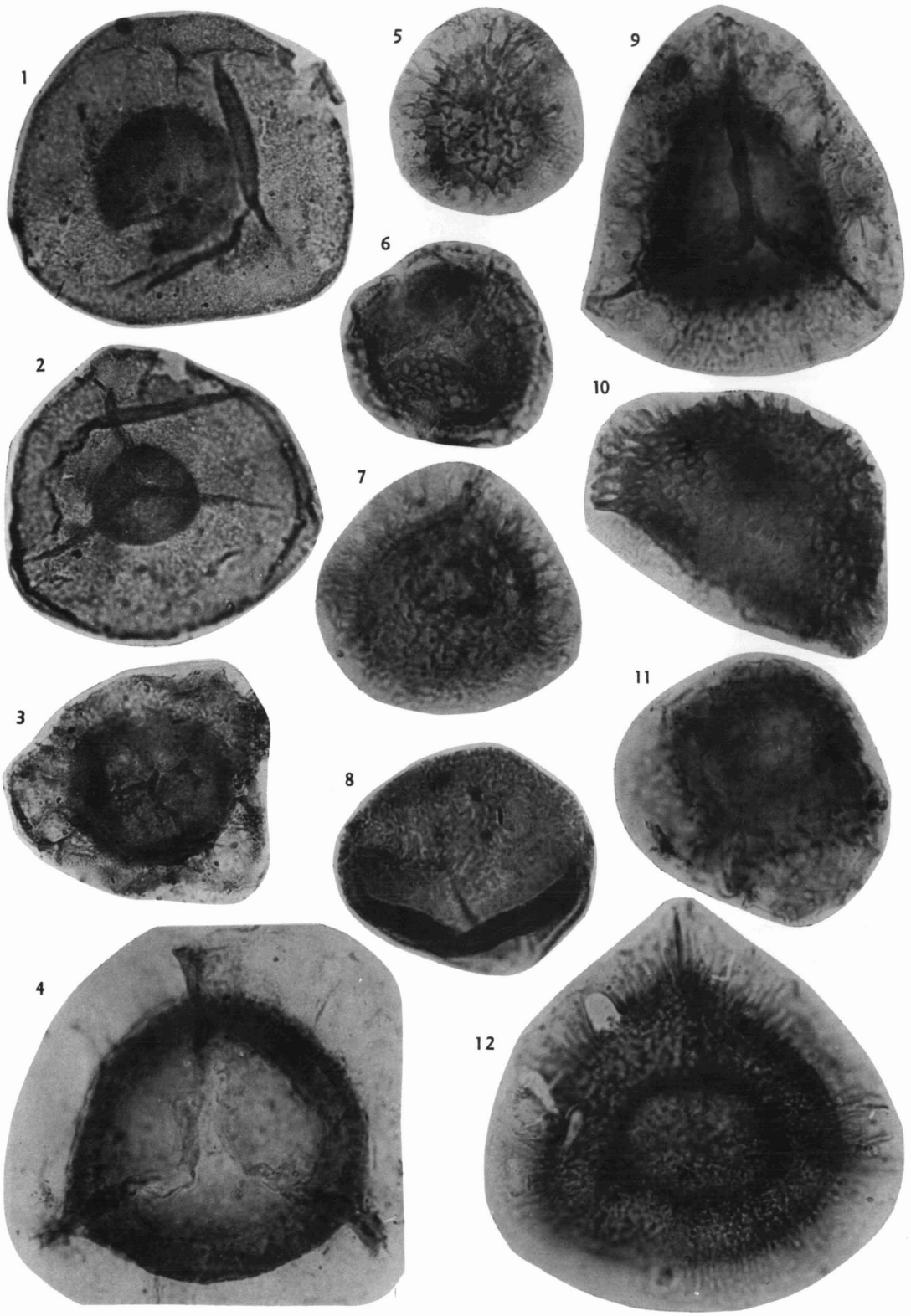

PLATE 2

40 μ. Trilete mark distinct, raised and reaching up to the equatorial cingulum. Cingulum up to 5 μ wide, fimbriate.

LYCOSPORA BREVIJUGA Kosanke, 1950
Pl. 1, fig. 3

Holotype.—Kosanke, 1950, pl. 10, fig. 5.

Description.—Roundly triangular spores, 30 μ. Trilete mark distinct, raised, reaching the narrow, up to 2 μ-wide cingulum.

Comparison.—*L. brevijuga* is distinguished by the presence of a narrow cingulum which is often folded to appear like a crassitudo.

Genus CRISTATISPORITES (Potonié & Kremp, 1954)
Bharadwaj & Venkatachala, 1961

Type species.—*Cristatisporites indignabundus* (Loose) Potonié & Kremp, 1954, 1955.

CRISTATISPORITES cf. C. INDIGNABUNDUS (Loose)
Potonié & Kremp, 1954
Pl. 1, fig. 14

Description.—Roundly triangular miospores, 76 μ. Trilete mark distinct, rays almost reaching up to the margins, raised, tecta and apex high. Exine sculptured with irregular warts, often anastomosing to simulate a reticulate pattern, interspersed with grana.

Comparison.—The spores compared here with *C. indignabundus* differ from the latter in possessing well-defined sculptural elements. They anastomose to form a pseudoreticulate pattern, while in the other the exine is smooth.

CRISTATISPORITES sp.
Pl. 1, fig. 10

Description.—Roundly triangular, 70 μ. Trilete mark present, not perceptible, proximal exine ornamented with grana while the distal has broad-based sharp-tipped spines. Cingulum up to 10 μ wide, dark and spinose.

Comparison.—*C. indignabundus* has more prominent spinous ornamentation. *C. alpernii* Staplin & Jansonius has a well-defined cingulum and thus not comparable.

Genus DENSOSPORITES (Berry)
Potonié & Kremp, 1954

Type species.—*Densosporites covensis* Berry, 1937.

Remarks.—*Densosporites* is distinguished from *Cristatisporites* by the absence of distinguishable sculptural elements on the cingulum as well as the spore body. It is pertinent to reexamine the type of *Densosporites* Berry, which shows distinct sculptural elements for its ornamentation.

DENSOSPORITES cf. D. ANNULATUS (Loose) emend. Schopf, Wilson, & Bentall, 1944
Pl. 1, fig. 5

Description.—Roundly triangular, 23 μ, trilete mark not distinct, cingulum up to 8 μ wide, uniform, smooth. Exine smooth, infrapunctate in the body region.

Comparison.—*D. annulatus* is larger with a distinct trilete mark and vacuolations in the inner margin of the zone.

Genus SPINOZONOTRILETES Hacquebard, 1957

Type species.—*Spinozonotriletes uncatus* Hacquebard, 1957.

SPINOZONOTRILETES ARNOLDII n. sp.
Pl. 1, figs. 1, 2

Holotype.—Pl. 1, fig. 1.

Description.—Spores roundly triangular, 90–120 μ. Trilete, Y-arms almost reaching the equatorial margins, tecta 5–8 μ high, with folded flangelike lips. Exine differentiated into a flangy, thin outer layer and a thick crassitudinous inner layer which encloses a "mesosporoid" inner body. Distal exine and equator covered with spines, 12 μ long and up to 5 μ wide, with pointed, hooked or recurved tips; the spine bases sometimes fuse. Exine between spines granulose.

Comparison.—*S. conspicuus* Playford has broad spines for the ornamentation; *S. tenuispinus* Hacquebard lacks the thin flange at the equator. *S. uncatus* also lacks the flange and has smaller spines for ornamentation. *S. tuber-*

EXPLANATION OF PLATE 2

All figures × 500

FIG. 1—*Endosporites ornatus* Wilson & Coe, 1940; Slide no. P/7, UMMP 57922.
2—*Endosporites globiformis* (Ibrahim) Schopf, Wilson, & Bentall, 1944; Slide no. P/8, UMMP 57923.
3—*Endosporites zonalis* (Loose) Knox, 1950; Slide no. P/8, UMMP 57923.
4, 9—*Cirratriradites* sp.; Slide no. P/8, UMMP 57923.
5, 7, 11—*Cirratriradites rugulatus* n. sp.; Slide nos. P/4, P/6, P/8, UMMP 57919, 57921, 57923.
6, 10—*Cirratriradites foveolatus* n. sp.; Slides nos. P/4 and P/6, UMMP 57919 and 57921.
8—*Velamisporites* sp.; Slide no. P/6, UMMP 57921.
12—*Cirratriradites dialetrus* Venkatachala & Bharadwaj, 1964; Slide no. P/7, UMMP 57922.

culatus Neves & Owens lacks the distinctive trilete mark as found in *S. arnoldii.*

SPINOZONOTRILETES cf. S. CONSPICUUS Playford, 1963b
Pl. 1, fig. 7

Holotype of *S. conspicuus.* — Playford, 1963b; pl. V, fig. 4.

Description.—Roundly triangular, 80 μ. Trilete, tecta straight, distinct with minor lip development, apex high, tecta almost reaching the equatorial margins. Exine differentiated into an outer thicker, sculptured zone and an inner thinner area; ornamented with sharp up to 8 μ-long conical spines distally and with interspersed grana on the equator.

Comparison.—*S. conspicuus* has larger spines and a coarsely punctate proximal face in contrast to the specimen figured here.

SPINOZONOTRILETES MICHIGANENSIS n. sp.
Pl. 1, figs. 6, 11, 15

Holotype.—Pl. 1, fig. 15.

Diagnosis.—Roundly triangular with convex sides and rounded angles, 50–80 μ. Trilete, Y-mark distinct, reaching the margins. Apex and vertex high, labra thick, flexuous up to 6 μ broad. Exine flangy at equator, with an inner equatorial crassitudinous ridge (see illustrated tetrad), ornamented distally with bulbous-based, sharp-tipped, up to 8 μ-long spines, spine bases coalescing at the crassitudinous area and thus contributing to the thick ridge at the equator, spines broader proximally and longer at equator, punctate in between, distally punctate spines. Plate 1, figure 6 illustrates the distal view.

Comparison.—*S. uncatus* Hacquebard lacks the crassitudinous thickening as seen in the species described here as well as the well-developed trilete mark. *S. tenuispinus* Playford has distinct broad spines and does not possess the thick tecta as seen in *S. michiganensis.*

Genus GRANDISPORA Hoffmeister, Staplin, & Malloy, 1955

Type species.—*Grandispora spinosa* Hoffmeister, Staplin, & Malloy, 1955.

GRANDISPORA sp.
Pl. 1, fig. 9

Description.—Circular, trilete mark present, exine folded along the suture of the Y-mark, 104 μ broad, ornamented with 2–3 μ long and up to 2 μ wide sparsely spaced spines; exoexine infragranulose, the central body area darker than the outer exoexine, 86 μ broad. The folds are seen only in the exoexine.

Comparison and remarks. — *G. echinata* Hacquebard is ornamented with larger spines, and *G. spinosa* Hoffmeister, Staplin, & Malloy has long conical spines with a broad base for ornamentation. The spore is interpreted here as possessing an inner body as in other lycopodian spores.

Genus CIRRATRIRADITES Wilson & Coe, 1940

Type species. — *Cirratriradites annulatus* Kosanke & Brokaw, *in* Kosanke, 1950.

CIRRATRIRADITES ANNULATUS Kosanke & Brokaw, *in* Kosanke, 1950
Pl. 1, fig. 17

Holotype.—Kosanke, 1950; pl. 7, fig. 4.

CIRRATRIRADITES SATURNII (Ibrahim) Schopf, Wilson, & Bentall, 1944
Pl. 1, fig. 18

Holotype.—Ibrahim, *in* Potonié, Ibrahim, & Loose, 1932; pl. 15, fig. 14.

CIRRATRIRADITES DIALETRUS Venkatachala & Bharadwaj, 1964
Pl. 2, fig. 12

Holotype.—Venkatachala & Bharadwaj, 1964; pl. 12, fig. 163.

CIRRATRIRADITES RUGULATUS n. sp.
Pl. 2, figs. 5, 7, 11

Holotype.—Pl. 2, fig. 5.

Diagnosis.—Roundly triangular, 60–80 μ, holotype 60 μ. Zona at the angles rounded, sides convex. Trilete mark distinct to indistinct, reaching up to the margin and entering into the zona, commissure reaching only up to the body margin; spore body 44–54 μ broad, zona up to 18 μ broad, continuous, dissected in the

EXPLANATION OF PLATE 3

All figures × 500

FIGS. *1, 2*—*Endosporites magnus* n. sp.; Slides nos. P/6 and P/7, UMMP 57921 and 57922.
3—*Calamospora perrugosa* (Loose) Schopf, Wilson, & Bentall, 1944; Slide no. P/7, UMMP 57922.
4—*Calamospora hartungiana* (Loose) Schopf, Wilson, & Bentall, 1944; Slide no. P/7, UMMP 57922.
5—*Calamospora breviradiata* Kosanke, 1950; Slide no. P/1, UMMP 57916.
6—*Calamospora microrugosa* (Ibrahim) Schopf, Wilson, & Bentall, 1944; Slide no. P/7, UMMP 57922.
7—*Velamisporites rugosus* Bharadwaj & Venkatachala, 1961; Slide no. P/5, UMMP 57920.

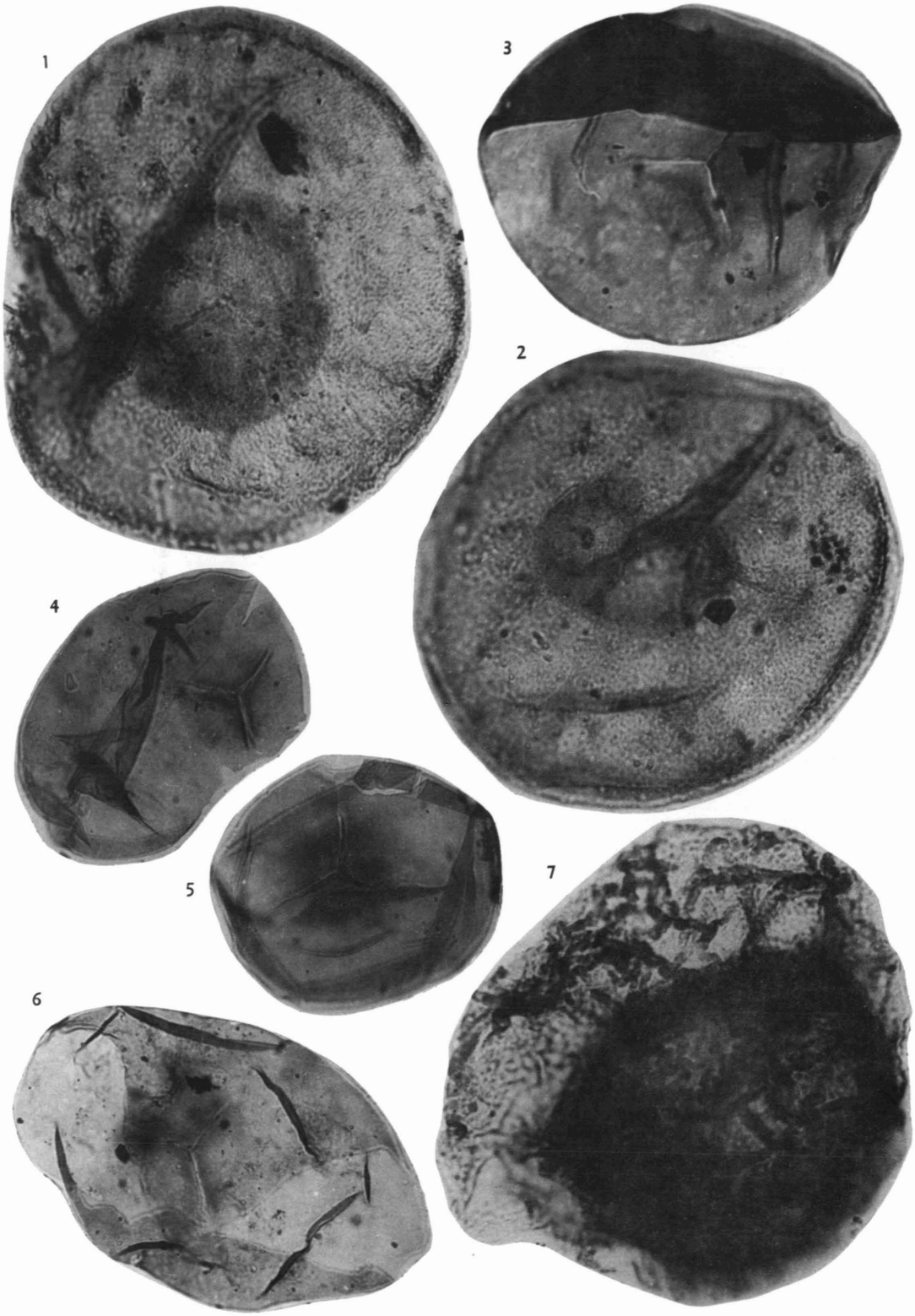

PLATE 3

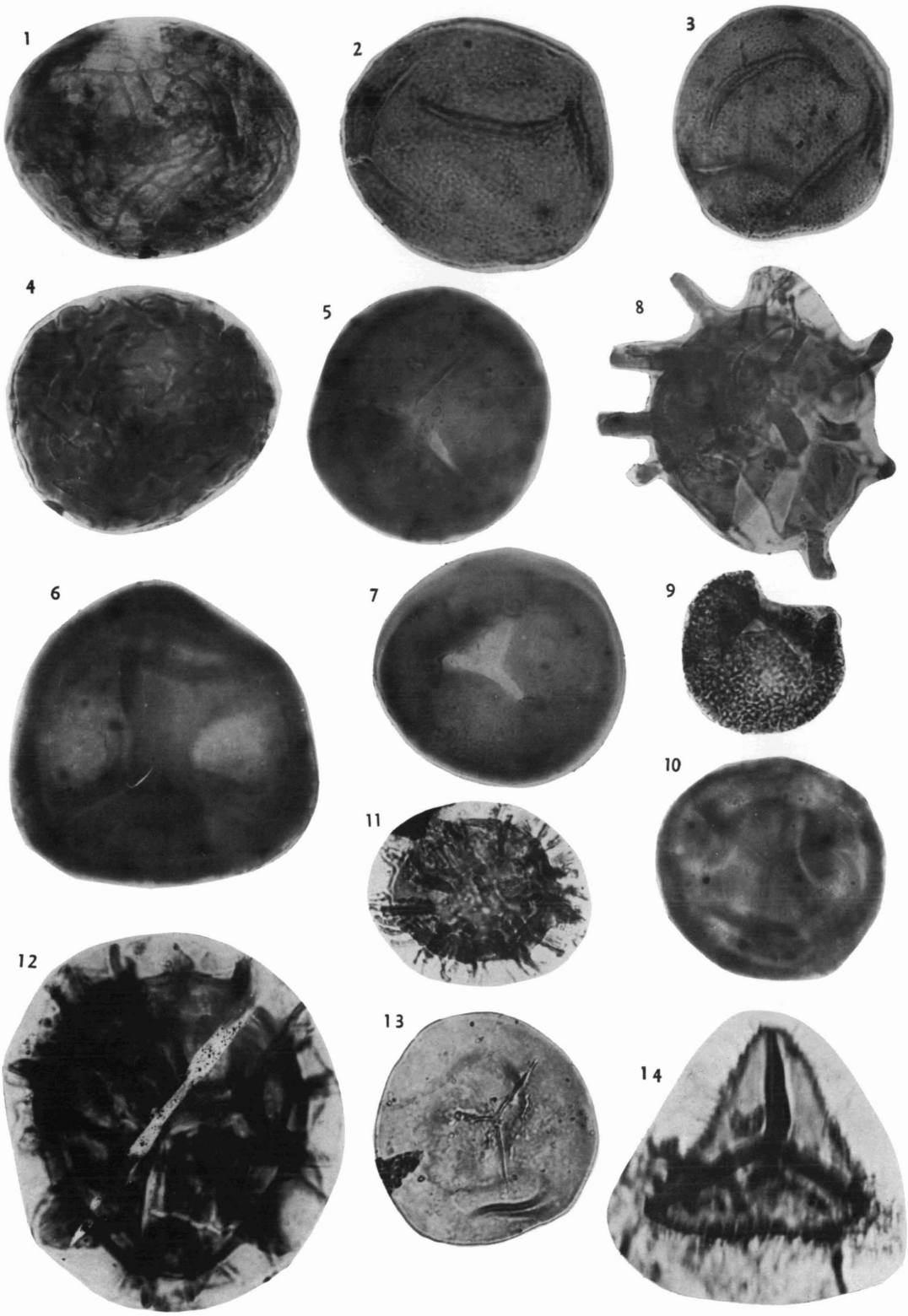

PLATE 4

form of vacuoles. Central body rugulate with muri not forming meshes.

Comparison.—The other species of *Cirratriradites* are ornamented with distinct foveolate pattern. The present species is distinguished by the rugulate ornamentation of the body exine.

CIRRATRIRADITES FOVEOLATUS n. sp.
Pl. 2, figs. 6, 10

Holotype.—Pl. 2, fig. 10.

Diagnosis.—Roundly triangular, 60–80 μ, holotype 106 x 72 μ, zonate. Trilete mark distinct, reaching up to the equator while the commissure reaching only up to the body margin, central body foveolate, muri raised forming up to 6 μ broad, perfect foveola.

Comparison.—*C. annulatus, C. saturnii,* and other species have finer ornamentation of the central body. *C. foveolatus* is distinguished in possessing a broad, foveolate central body.

CIRRATRIRADITES sp.
Pl. 2, figs. 4, 9

Description.—Spores roundly triangular, 110–150 μ. Y-mark distinct, flangy, apex and vertex high, tecta reaching up to the margin, suture restricted up to the body limits. Central body roundly triangular with up to 15 μ-wide crassitudo, laevigate proximally and distally verrucose.

Comparison. — The crassitudinous ridge around the equator of the central body distinguishes these specimens. The earlier recorded species of *Cirratriradites* do not have this thickening.

Genus ENDOSPORITES Wilson & Coe, 1940

Type species.—*Endosporites ornatus* Wilson & Coe, 1940.

ENDOSPORITES ORNATUS Wilson & Coe, 1940
Pl. 2, fig. 1

Holotype.—Wilson & Coe, 1940; pl. 1, fig. 2.

ENDOSPORITES GLOBIFORMIS (Ibrahim) Schopf, Wilson, & Bentall, 1944
Pl. 2, fig. 2

Holotype.—Ibrahim, *in* Potonié, Ibrahim, & Loose, 1932; pl. 14, fig. 5.

ENDOSPORITES ZONALIS (Loose) Knox, 1950
Pl. 2, fig. 3

Holotype.—Loose, 1934; pl. 7, fig. 5.

ENDOSPORITES MAGNUS n. sp.
Pl. 3, figs. 1, 2

Holotype.—Pl. 3, fig. 1.

Diagnosis.—Circular, 150–170 μ, central body of the spore 60–70 μ, circular, Y-mark distinct, rays not very clearly discernible, arcuate ridge (limbus) almost along the equator and distinct, saccus infragranulose to infrarugulate forming canaliculate ridges giving a vermiform appearance.

Comparison.—Such large specimens of *Endosporites* have not been encountered in other Carboniferous sediments so far studied.

SPHENOPSIDA

Genus CALAMOSPORA Schopf, Wilson, & Bentall, 1944

Type species. — Calamospora hartungiana Schopf, Wilson, & Bentall, 1944.

CALAMOSPORA PERRUGOSA (Loose) Schopf, Wilson, & Bentall, 1944
Pl. 3, fig. 3

Holotype.—Loose, 1934; pl. 7, fig. 13.

CALAMOSPORA MICRORUGOSA (Ibrahim) Schopf, Wilson, & Bentall, 1944
Pl. 3, fig. 6

Holotype.—Ibrahim, *in* Potonié, Ibrahim, & Loose, 1932; pl. 14, fig. 9.

EXPLANATION OF PLATE 4

All figures × 500

FIG. *1*—*Vestispora vinculata* (Ibrahim) Bhardwaj, 1957; Slide no. P/4, UMMP 57919.
2—*Planisporites rarus* Venkatachala & Bharadwaj, 1962; Slide no. P/6, UMMP 57921.
3—*Cyclogranisporites aureus* (Loose) Potonié & Kremp, 1955; Slide no. P/1, UMMP 57916.
4—*Convolutispora* cf. *C. mellita* Hoffmeister, Staplin, & Malloy, 1955; Slide no. P/4, UMMP 57919.
5, 7—*Cadiospora arguta* n. sp.; Slide no. P/1, UMMP 57916.
6—*Knoxisporites triradiatus* Hoffmeister, Staplin, & Malloy, 1955; Slide no. P/6, UMMP 57921.
8—*Raistrickia crocea* Kosanke, 1950; Slide no. P/6, UMMP 57921.
9—*Verrucosisporites cerosus* (Hoffmeister, Staplin, & Malloy) Butterworth & Williams, 1958; Slide no. P/1, UMMP 57916.
10—*Knoxisporites rotatus* Hoffmeister, Staplin, & Malloy, 1955; Slide no. P/1, UMMP 57916.
11—*Raistrickia solaria* Wilson & Hoffmeister, 1956; Slide no. P/1, UMMP 57916.
12—*Reticulatisporites ornatus* Ibrahim, 1932; Slide no. P/2, UMMP 57917.
13—*Punctatisporites viriosus* Hacquebard, 1957; Slide no. P/5, UMMP 57920.
14—*Diatomozonotriletes* cf. *D. trilinearis* Playford, 1963a; Slide no. P/5, UMMP 57920.

CALAMOSPORA BREVIRADIATA Kosanke, 1950
Pl. 3, fig. 5

Remarks.—The spores illustrated here as well as those by Bhardwaj (1957) and Venkatachala & Bharadwaj (1964) show a distinct darker *area contagionis* in the proximal polar region. This dark area gets shifted to a side in several specimens studied. This fact suggests that this may be due to a darker inner body. Kosanke's type specimens do not show such a dark area; however, in his description he has mentioned the *area contagionis* in the Y-mark region. Small spores recovered from *Discinites delectus* by Arnold (1944) resemble the specimens described here. The specimen described under *C. perrugosa* (pl. 3, fig. 3) may represent the megaspores recovered from *Discinites delectus* by Arnold (1944).

CALAMOSPORA HARTUNGIANA (Loose) Schopf, Wilson, & Bentall, 1944
Pl. 3, fig. 4

Holotype. — Schopf, Wilson, & Bentall, 1944; text-fig. 1.

General remarks on Calamospora.—The species of *Calamospora* hitherto described by various authors fall into two distinct groups:

a) *C. hartungiana* (Loose) Schopf, Wilson, & Bentall
   C. breviradiata Kosanke
   C. *densa* Bharadwaj & Venkatachala
   C. perrugosa (Loose) Schopf, Wilson, & Bentall
   C. mutabilis (Loose) Schopf, Wilson, & Bentall
   C. microrugosa (Ibrahim) Schopf, Wilson, & Bentall
   C. minuta Bharadwaj
   and other species
b) *C. flexilis* Kosanke
   C. falkenbergensis Venkatachala & Bharadwaj
   C. straminea Wilson & Kosanke
   C. pallidus (Loose) Schopf, Wilson, & Bentall
   and other species

The first group (a) typified by *C. hartungiana* as illustrated and described by Schopf, Wilson, & Bentall (1944) is characterized by a dark area in the proximal polar region near and around the trilete mark, while the second group (b) distinctly lacks an *area contagionis* and has longer Y-mark. These two groups as such show a distinct morphological differentiation which appears to be of importance in considering the parent plants of these species.

Genus VELAMISPORITES Bharadwaj & Venkatachala, 1961

Type Species. — *Velamisporites rugosus* Bharadwaj & Venkatachala, 1961.

VELAMISPORITES RUGOSUS Bharadwaj & Venkatachala, 1961
Pl. 3, fig. 7

VELAMISPORITES sp.
Pl. 2, fig. 8

Description.—Circular, 80 μ, trilete, Y-mark obscured due to perisporal covering. Perisporal coat granulose with wrinkled surface giving a corrugated and pseudoreticulate appearance.

Comparison.—*Velamisporites rugosus* Bharadwaj & Venkatachala is distinctly larger. *V. descretus* Bharadwaj & Venkatachala is distinguished by a transparent perinous coat which lacks the rugose folds present here.

Genus VESTISPORA (Wilson & Hoffmeister) Wilson & Venkatachala, 1963a

Type species.—*Vestispora profunda* Wilson & Hoffmeister, 1956.

VESTISPORA VINCULATA (Ibrahim) Bhardwaj, 1957
Pl. 4, fig. 1

Holotype.—Ibrahim, 1933; pl. 2, fig. 19.

PTEROPSIDA

Genus LEIOTRILETES (Naumova) emend. Potonié & Kremp, 1954

Type species.—*Leiotriletes sphaerotriangulus* (Loose) Potonié & Kremp, 1954.

LEIOTRILETES SUBADNATOIDES Bhardwaj, 1957
Pl. 1, fig. 13

Holotype.—Bhardwaj, 1957; pl. 22, fig. 6.

Remarks.—Specimens observed here show distinct rounded corners and convex sides, with long tapering rays of the Y-mark that almost reach the equator. The gulate structure appearing in some specimens (the one illustrated here on pl. 1, fig. 13) is a characteristic fold that normally develops when roundly triangular and pyramidal spores obliquely flatten during slide preparation.

Genus PUNCTATISPORITES (Ibrahim, 1933) emend. Potonié & Kremp, 1954

Type species.—*Punctatisporites punctatus* Ibrahim, 1933.

PUNCTATISPORITES VIRIOSUS Hacquebard, 1957
Pl. 4, fig. 13

Holotype.—Hacquebard, 1957; pl. 1, fig. 14.

Genus CADIOSPORA (Kosanke, 1950) emend. Venkatachala & Bharadwaj, 1964

Type species.—*Cadiospora magna* Kosanke, 1950.

CADIOSPORA ARGUTA n. sp.
Pl. 4, figs. 5, 7

Holotype.—Pl. 4, fig. 5.

Description.—Circular to roundly triangular 70–80 μ, holotype 76 μ. Y-rays equal, up to ½ the radius of the spore, labra thick, low, tecta ends ending in a raised mond, spore exine 4–6 μ thick, intrapunctate; contact area sometimes differentiated.

Comparison.—*C. aggera* Venkatachala & Bharadwaj, *C. magna* Kosanke, and *C. absoluta* Venkatachala & Bharadwaj (1964) are ornate species with widely distributed irregular monds for their ornamentation. *C. laminata* Venkatachala & Bharadwaj is larger and shows laminations in the exine. The three monds are distinctive in both *C. arguta* and *C. laminata.*

Genus CYCLOGRANISPORITES Potonié & Kremp, 1954

Type species.—*Cyclogranisporites leopoldi* (Kremp, 1952) Potonié & Kremp, 1954.

CYCLOGRANISPORITES AUREUS (Loose) Potonié & Kremp, 1955
Pl. 4, fig. 3

Genus PLANISPORITES (Knox) emend. Potonié & Kremp, 1954

Type species.—*Planisporites granifer* (Ibrahim) Knox, 1950.

PLANISPORITES RARUS Venkatachala & Bharadwaj, 1962
Pl. 4, fig. 2

Holotype.—Bhardwaj, 1957; pl. 23, fig. 13.

Genus APICULATISPORIS Potonié & Kremp, 1956

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

APICULATISPORIS sp.
Pl. 1, fig. 8

Description.—Spore circular, 100 μ, folded, Y-mark present, imperceptible, ornamented by bulbous sparsely spaced coni, 4–6 μ long, sharp-tipped, tips curving in the form of a hook in several cases. Equatorial margin serrate due to ornamentation.

Comparison.—*A. aculeatus* and other species described previously have distinct long coni for ornamentation. *Raistrickia abstrusa* Playford (1963b) has a superficial resemblance to this species, but differs in possessing a roundly triangular shape, a distinct trilete mark, and small but broader spines.

Genus RAISTRICKIA (Schopf, Wilson, & Bentall) Potonié & Kremp, 1954, 1955

Type species.—*Raistrickia grovensis* Schopf, *in* Schopf, Wilson, & Bentall, 1944.

RAISTRICKIA CROCEA Kosanke, 1950
Pl. 4, fig. 8

RAISTRICKIA SOLARIA Wilson & Hoffmeister, 1956
Pl. 4, fig. 11

RAISTRICKIA sp.
Pl. 1, fig. 16

Description.—Circular, 40 μ, Y-mark present, covered over by bacula, bacula up to 8 μ long and 2 μ wide with serrated tips, evenly crowded on the surface of the spore.

Comparison.—*R. crinita* Kosanke and *R. aculeolata* Wilson & Kosanke, have sharp-tipped spines for their ornamentation. *R. solaria* Wilson and Hoffmeister is larger but is closely comparable in the distribution of bacula. *R. crocea* Kosanke has broad, few spines for its ornamentation.

Genus MICRORETICULATISPORITES (Knox) Bhardwaj, 1955

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

MICRORETICULATISPORITES cf. M. CONCAVUS Butterworth & Williams, 1958
Pl. 1, fig. 12

Description.—Triangular, 25–48 μ, apices broadly rounded, margins concave to slightly convex. Y-mark up to ⅔ radius; exine thin, microreticulate, muri up to 2 μ wide with fine meshes, lumina up to 2 μ.

Comparison.—*M. concavus* is larger in size with thick muri, so much so as to form a roughened outline in equatorial flattening.

Genus VERRUCOSISPORITES (Ibrahim) Potonié & Kremp, 1954

Type species.—*Verrucosisporites verrucosus* Ibrahim, 1933.

VERRUCOSISPORITES CEROSUS (Hoffmeister, Staplin, & Malloy) Butterworth & Williams, 1958
Pl. 4, fig. 9

Genus CONVOLUTISPORA Hoffmeister, Staplin, & Malloy, 1955

Type species.—*Convolutispora florida* Hoffmeister, Staplin, & Malloy, 1955.

CONVOLUTISPORA cf. C. MELLITA Hoffmeister, Staplin, & Malloy, 1955
Pl. 4, fig. 4

Description.—Circular to roundly triangular, 70–80 μ, Y-mark distinct, sometimes obscured by the ornamentation. Exine up to 6 μ thick, ornamented with low anastomosing ridges giving a convolute appearance, the ridges up to 6 μ high, separated by canaliculate depressions.

Comparison.—*Convolutispora mellita* differs in possessing closer meshwork with high ridges. The 8 specimens observed in this assemblage are smaller but otherwise closely comparable to those figured by Hoffmeister, Staplin, & Malloy (1955).

Genus RETICULATISPORITES (Ibrahim) Potonié & Kremp, 1954

Type species.—*Reticulatisporites reticulatus* Ibrahim, 1933.

Remarks.—In a review of the genera *Knoxisporites* and *Reticulatisporites,* Neves (1961) emended *Reticulatisporites* to include only cingulate spores and distinguished them from *Dictyotriletes* (Naumova) Potonié & Kremp. The muri in *Dictyotriletes* are confined only to the distal surface and are azonate as compared to *Reticulatisporites.*

RETICULATISPORITES ORNATUS Ibrahim, 1932, 1933
Pl. 4, fig. 12

Genus KNOXISPORITES (Potonié & Kremp) emend. Neves, 1961

Type species.—*Knoxisporites hageni* Potonié & Kremp, 1954.

KNOXISPORITES ROTATUS Hoffmeister, Staplin, & Malloy, 1955
Pl. 4, fig. 10

KNOXISPORITES TRIRADIATUS Hoffmeister, Staplin, & Malloy, 1955
Pl. 4, fig. 6

Genus DIATOMOZONOTRILETES (Naumova) emend. Playford, 1963a

Type species.—*Diatomozonotriletes saetosus* (Hacquebard & Barss, 1957) emend. Hughes & Playford, 1961.

DIATOMOZONOTRILETES cf. D. TRILINEARIS Playford, 1963a
Pl. 4, fig. 14

Description.—Spore radial, trilete, subtriangular with slightly concave sides and rounded apices. Y-mark distinct, labra thick, reaching up to the equatorial margin. Corona composed of up to 12 μ long, pointed saetae.

Comparison and remarks.—The specimen figured here is the only one recovered, and is not sufficiently well oriented for detailed study. It is close to *D. trilinearis* Playford (1963a) but is larger and is distinguished in possessing interradial spines along the Y-mark.

CYCADOFILICALES

Genus SCHOPFIPOLLENITES Potonié & Kremp, 1954

Type species.—*Schopfipollenites ellipsoides* (Ibrahim) Potonié & Kremp, 1954; pl. 5, fig. 91.

SCHOPFIPOLLENITES sp.

Remarks.—A few poorly preserved fragments were found but they are neither illustrated nor described here.

Genus SCHULZOSPORA Kosanke, 1950

Type species.—*Schulzospora rara* Kosanke, 1950.

SCHULZOSPORA OCELLATA (Horst) emend. Potonié & Kremp, 1956
Pl. 5, fig. 5

Holotype.—Horst, 1955; pl. 21, fig. 40.

SCHULZOSPORA MICHIGANENSIS n. sp.
Pl. 5, fig. 9; pl. 7, fig. 4

Holotype.—Pl. 5, fig. 9

EXPLANATION OF PLATE 5

All figures × 500

FIGS. *1, 2*—*Candidispora marginata* n. sp.; Slides nos. P/1 and P/3, UMMP 57916 and 57918.
3—*Guthoerlisporites* cf. *G. densus* Venkatachala & Bharadwaj; Slide no. P/7, UMMP 57922.
4—*Vesicaspora* sp; Slide no. P/8, UMMP 57923.
5—*Schulzospora ocellata* (Horst) Potonié & Kremp, 1956; Slide no. P/8, UMMP 57923.
6—*Tasmanites* sp; Slide no. P/6, UMMP 57921.
7—*Alatisporites hoffmeisterii* Morgan, 1955; Slide no. P/3, UMMP 57918.
8—*Alatisporites punctatus* Kosanke, 1950; Slide no. P/1, UMMP 57916.
9—*Schulzospora michiganensis* n. sp.; Slide no. P/7, UMMP 57922.

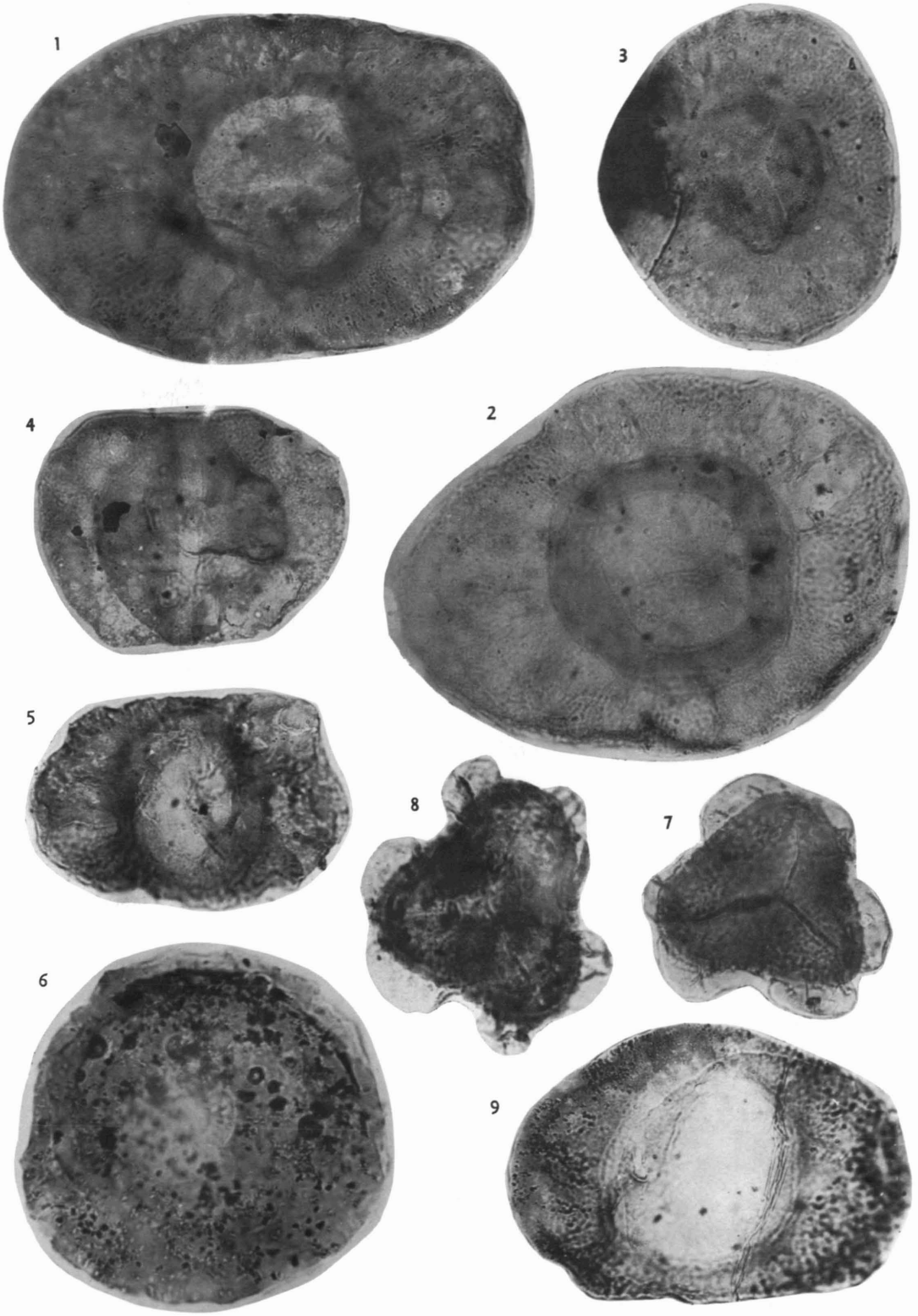

PLATE 5

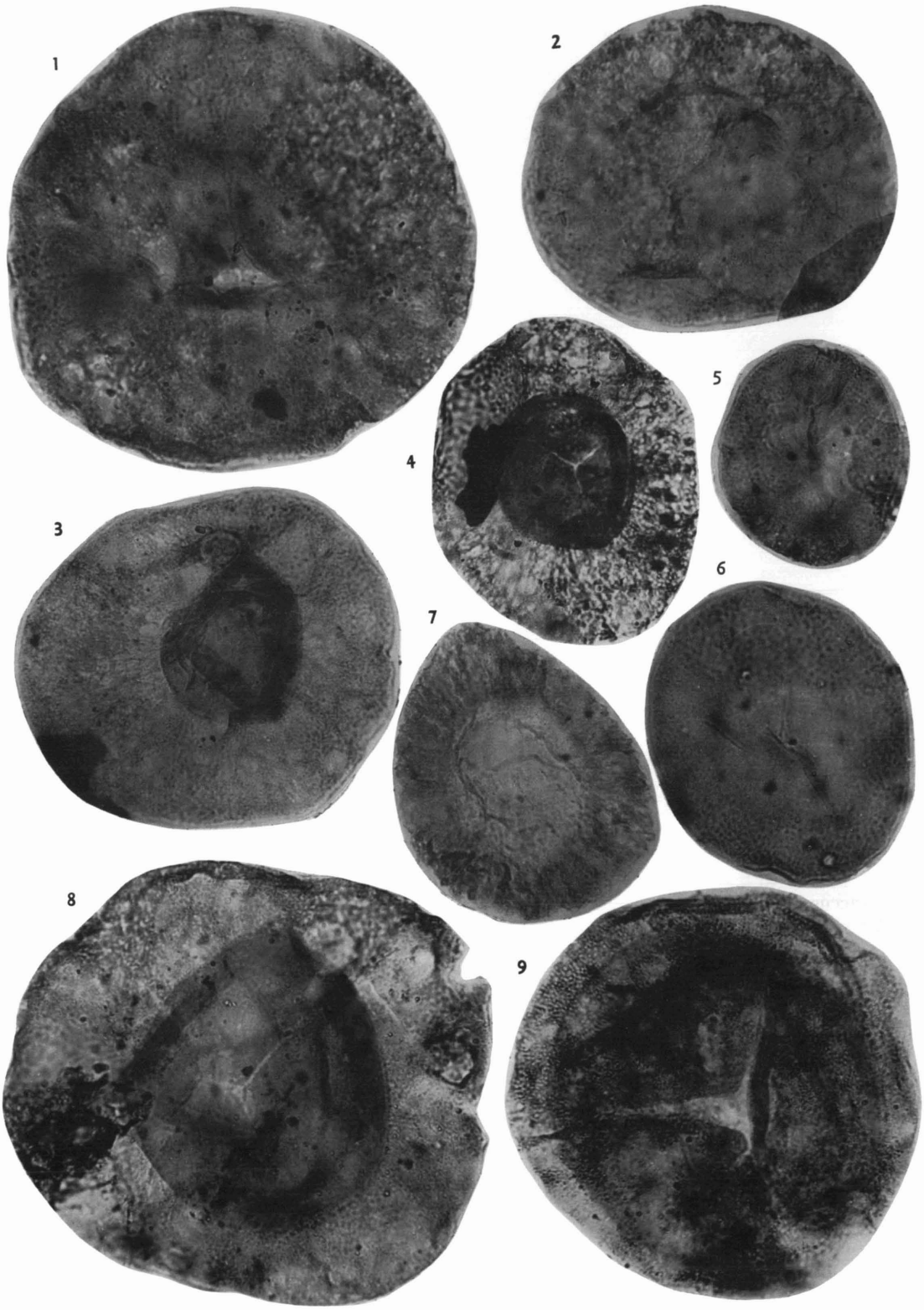

PLATE 6

Description.—Broadly oval, 110–150 μ, central body ellipsoidal, bearing a faint trilete mark. Saccus infrareticulate.

Comparison.—*S. ocellata* has distinct central body and a prominent trilete mark.

Genus WILSONITES (Kosanke, 1950) emend. Kosanke, 1959

Type species.—*Wilsonites vesicatus* Kosanke, 1959.

WILSONITES VESICATUS (Kosanke, 1950) Kosanke, 1959
Pl. 6, fig. 6

Holotype.—Kosanke, 1950; pl. 14, figs. 1–3.

WILSONITES DELICATUS (Kosanke) Kosanke, 1959
Pl. 6, fig. 5

Holotype.—Kosanke, 1950; pl. 14, fig. 4.

Genus GUTHOERLISPORITES Bhardwaj, 1954

Type species.—*Guthoerlisporites magnificus* Bhardwaj, 1954.

GUTHOERLISPORITES MAGNIFICUS Bhardwaj, 1954
Pl. 6, fig. 4

Holotype.—Bhardwaj, 1954; pl. 2, fig. 12.

GUTHOERLISPORITES cf. G. DENSUS Venkatachala & Bharadwaj, 1964
Pl. 5, fig. 3

Holotype. — Venkatachala & Bharadwaj, 1964; pl. 16, fig. 229.

Description.—Circular, 90–105 μ, central body distinct, without any folds, dense, Y-mark distinct, arms going up to the equatorial margin of the central body, central body infrapunctate, saccus finely infrareticulate.

Comparison.—The central body in *G. magnificus* has distinct peripheral folds. *G. densus* has a dark central body. The specimens are comparable to over-macerated specimens of *G. densus* described by Venkatachala & Bharadwaj (1964).

GUTHOERLISPORITES GRANDIS n. sp.
Pl. 6, fig. 8; pl. 7, fig. 2

Holotype.—Pl. 7, fig. 2.

Description.—Circular, 120–160 μ, holotype 150 μ, central body distinct with folds, 60–85 μ, circular. Y-mark distinct, almost reaching up to the margin, bladder infrareticulate.

Comparison.—*G. magnificus* is smaller in size. *G. densus* has dark central body without any associated folds.

Genus KOSANKEISPORITES Bhardwaj, 1955

Type species. — *Kosankeisporites elegans* (Kosanke) emend. Bhardwaj, 1955.

cf. KOSANKEISPORITES sp.
Pl. 7, fig. 3

Description.—Oval, 140 μ, central body faintly discernible, spindle oval, 90 x 70 μ, faint horizontal striations present, mud crack-like marks distinct. Sulcus traversing the whole length of the body.

Comparison and remarks.—The faint horizontal striations on the central body allow the specimens to be placed under *Kosankeisporites*. *Complexisporites* Jizba differs in possessing a distinct central rimlike area and prominent striations. *Vesicaspora* (Schemel) Wilson & Venkatachala and other saccate genera lack the striations on the central body.

Genus VESICASPORA (Schemel) emend. Wilson & Venkatachala, 1963b

Type species.—*Vesicaspora wilsonii* Schemel, 1951.

VESICASPORA sp.
Pl. 5, fig. 4

Description.—Pollen grains bilateral, oval in polar view; 96 x 72 μ, central body spindle oval with a longer vertical axis and a broad saccus-free sulcus running along the whole length of the pollen, 6–8 μ broad. Saccus equatorial, with bladder-free distal sulcus area, infrareticulate with distinct meshes.

EXPLANATION OF PLATE 6

All figures × 500

FIG. 1—*Florinites visendus* (Ibrahim) Schopf, Wilson, & Bentall, 1944; Slide no. P/7, UMMP 57922.
2—*Florinites similis* Kosanke, 1950; Slide no. P/4, UMMP 57919.
3—*Florinites antiquus* Schopf, 1944; Slide no. P/3, UMMP 57918.
4—*Guthoerlisporites magnificus* Bhardwaj, 1954; Slide no. P/1, UMMP 57916.
5—*Wilsonites delicatus* (Kosanke) Kosanke, 1959; Slide no. P/8, UMMP 57923.
6—*Wilsonites vesicatus* (Kosanke) Kosanke, 1959; Slide no. P/7, UMMP 57922.
7—*Latensina* sp.; Slide no. P/3, UMMP 57918.
8—*Guthoerlisporites grandis* n. sp.; Slide no. P/7, UMMP 57922.
9—*Remysporites* sp.; Slide no. P/6, UMMP 57921.

Comparison.—*V. wilsonii* is smaller and has a smaller less well-defined sulcus. *V. schaubergeri* is large, and *V. ovata* from the Permian of Australia is also distinguished by a larger size.

Genus LATENSINA Luber, 1955

Type species.—*Latensina uralensis* Luber, 1955.

cf. LATENSINA sp.
Pl. 6, fig. 7

Description.—Circular to oval, 94 μ, central body circular, not discernible, saccus proximally equatorially attached and distally subequatorially attached to the central body, with the result a distinct circular area along the body margin is seen, saccus radially folded.

Comparison.—*Virkkipollenites* and *Plicatipollenites* described from the Permian of India have comparable morphology. *Latensina* is known from the Upper Carboniferous sediments of Saar-Lothringen Coalfield (Alpern, 1958; Venkatachala & Bharadwaj, 1964). The similarity between these genera is striking; however, according to rules of priority (Int. Bot. Code. Art. 11), the correct name can be established only when the type of *Latensina* is studied and compared with other genera.

Genus PARVESICASPORA Klaus, 1963

Type species. — *Parvesicaspora splendens* (Leschik, 1956) emend. Klaus, 1963.

PARVESICASPORA sp.
Pl. 7, figs. 1, 6

Description.—Bisaccate, haploxylonoid, 130 x 160 μ, central body spindle oval, as long as the pollen. Sulcus up to 14 μ broad with funneled tips.

Comparison.—*P. splendens,* the type species, is larger and is from the Permian sediments.

Genus ALATISPORITES Ibrahim, 1933

Type species. — *Alatisporites pustulatus* Ibrahim, *in* Potonié, Ibrahim, & Loose, 1932.

ALATISPORITES INFLATUS Kosanke, 1950
Pl. 7, fig. 5

Holotype.—Kosanke, 1950; pl. 4, fig. 2.

ALATISPORITES PUNCTATUS Kosanke, 1950
Pl. 5, fig. 8

Holotype.—Kosanke, 1950; pl. 4, fig. 4.

ALATISPORITES HOFFMEISTERII Morgan, 1955
Pl. 5, fig. 7

Holotype.—Morgan, 1955; pl. 2, fig. 1.

Genus REMYSPORITES Butterworth & Williams, 1958

Type species. — *Remysporites magnificus* (Horst) Butterworth & Williams, 1958.

REMYSPORITES sp.
Pl. 6, fig. 9

Description.—Circular, 125 μ, central body laevigate, outer cover punctate.

Comparison.—*R. magnificus* is larger in size.

CORDAITALES or ?CONIFERALES

Genus FLORINITES Schopf, Wilson, & Bentall, 1944

Type species.—*Florinites antiquus* Schopf, *in* Schopf, Wilson, & Bentall, 1944.

FLORINITES VISENDUS (Ibrahim) emend. Schopf, Wilson, & Bentall, 1944
Pl. 6, fig. 1

Holotype.—Ibrahim 1933; pl. 8, fig. 66.

FLORINITES SIMILIS Kosanke, 1950
Pl. 6, fig. 2

Holotype.—Kosanke, 1950; pl. 12, fig. 2.

FLORINITES ANTIQUUS Schopf, *in* Schopf, Wilson, & Bentall, 1944
Pl. 6, fig. 3

Holotype. — Schopf, Wilson, & Bentall, 1944; text-fig. 4.

Genus CANDIDISPORA Venkatachala, 1963

Type species.—*Candidispora candida* Venkatachala, 1963.

CANDIDISPORA MARGINATA n. sp.
Pl. 5, figs. 1, 2

Holotype.—Pl. 5, fig. 2.

Description.—Broadly oval, 150–170 μ, holotype 165 μ, central body circular associated

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EXPLANATION OF PLATE 7

All figures × 500

FIGS. *1, 6*—*Parvesicaspora* sp.; Slides nos. P/6 and P/7, UMMP 57921 and 57922.
2—*Guthoerlisporites grandis* n. sp.; Slide no. P/7, UMMP 57922.
3—cf. *Kosankeisporites* sp.; Slide no. P/2, UMMP 57917.
4—*Schulzospora michiganensis* n. sp.; Slide no. P/6, UMMP 57921.
5—*Alatisporites inflatus* Kosanke, 1950; Slide no. P/5, UMMP 57920.

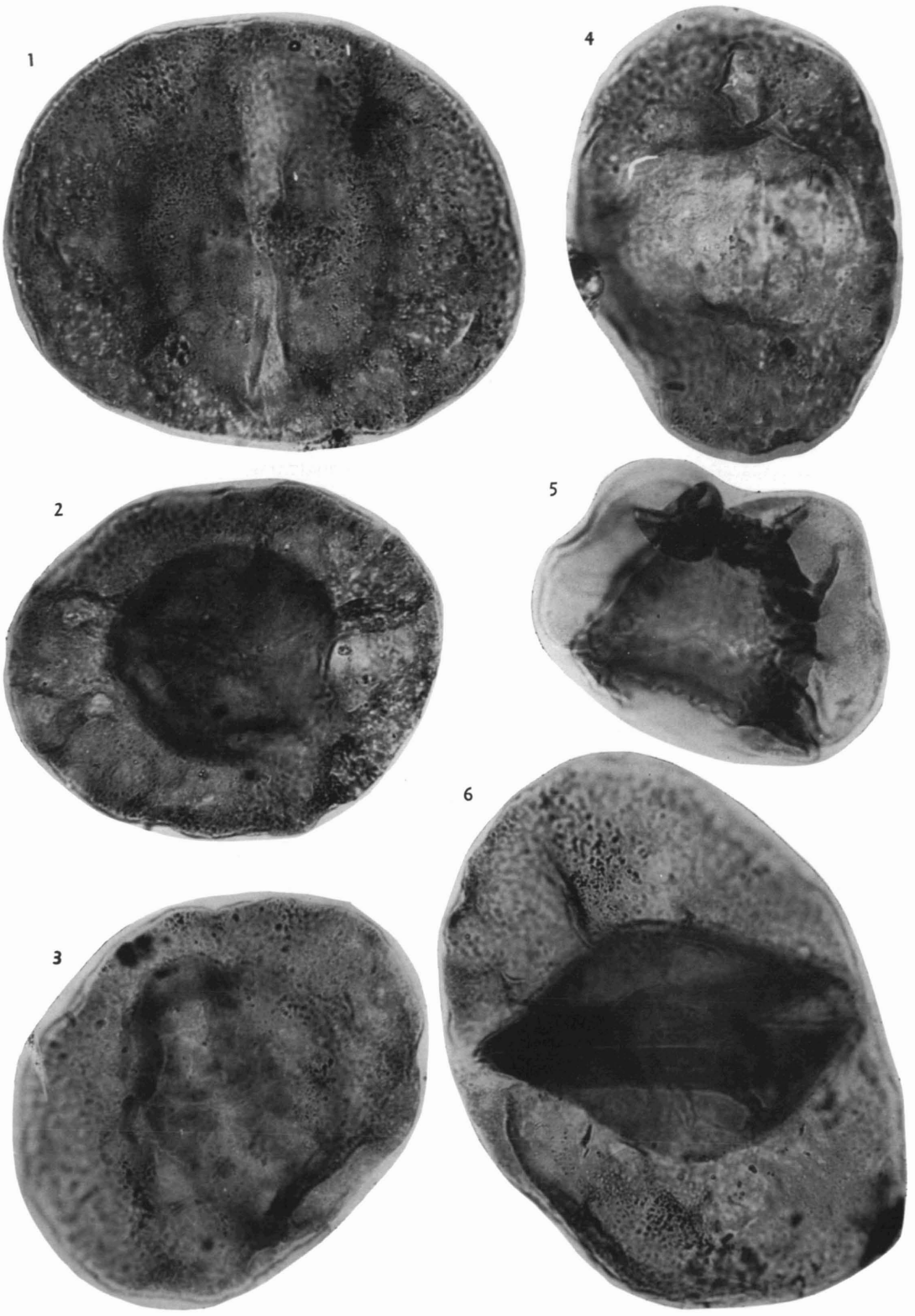

PLATE 7

with peripheral folds running along the periphery of the body. Y-mark distinct; two arms long, forming an obtuse angle and often appearing like a monolete mark; the third arm short. Saccus infrareticulate.

Comparison.—*C. candida* and *C. aequabilis* described by Venkatachala & Bharadwaj have smaller well-defined central bodies.

ALGAL SPOROMORPH

Genus TASMANITES Newton, 1875

TASMANITES sp.

Pl. 5, fig. 6

Description.—Sphaeroid, 112 μ. Pores not uniformly distributed, margin uneven due to pores.

PALYNOLOGICAL COMPOSITION

The spore flora is composed of 36 genera and 63 species of dispersed spores of lycopods, sphenopsids, and pteropsids, and pollen of cycadofilicalian and gymnospermous affinities. It is dominated by the saccate cycadofilicalian and gymnospermous pollen. *Florinites* is the dominant genus with a representation of over 50 per cent of the total assemblage. *Wilsonites, Candidispora,* and *Parvesicaspora* constitute 5, 3 and 1 per cent each. *Endosporites,* a zonisaccate lycopod spore, is represented by 17 per cent; and *Cirratriradites* and *Lycospora,* both zonate spore genera, are 2 per cent each. The only sphenopsid spore genus represented in the counts (12 per cent) is *Calamospora,* and the only fern spore is the schizeaceous spore *Raistrickia* (1 per cent).

It is of interest to note that in a random count of 200 specimens only 9 genera of a total of 36 were included. Most of the genera forming the bulk of this assemblage are saccate gymnospermous or cycadofilicalian pollen. The lycopodian spores are also represented by zonate types. The only other genera represented are *Calamospora* (12 per cent) and *Raistrickia* (1 per cent).

The major component of the spore flora is contributed by wind-blown saccate pollen. The calamarian spores (*Calamospora*) and the schizeaceous spores (*Raistrickia*), possibly representing the local swamp element in the assemblage, occupy only a secondary position. The present study is confined to shales only and, as such, the assemblage recovered is not indigenous to the swamp or areas around the depositional basin but represents material from the surrounding regions brought into the depositional site along with the sediments during deposition.

SUMMARY

Dispersed spores and pollen from the Early Pennsylvanian Pre-Verne cyclical formations of the Saginaw Group at Grand Ledge, Michigan, are described and classified according to the natural system. The taxa are referred to 36 genera and 63 species of which 9 species are new. Quantitative study of the assemblage indicates that the major component of the microflora of the shale unit consists of wind-blown saccate pollen, while spores of indigenous swamp plants of calamarian and schizeaceous affinities are secondary in percentage counts.

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