PALYNOLOGY OF THE SPRINGER FORMATION OF SOUTHERN OKLAHOMA, U.S.A.

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ABSTRACT. Twenty-three surface samples were studied from the Springer formation at its exposure in Johnston County, Oklahoma. The Springer formation is of interest because of the commercial occurrence of oil and gas in its subsurface sandstones, but there has been wide disagreement as to its correct age. The microflora is transitional in character with Mississippian and Pennsylvanian spores represented, and it is regarded as a transgressional facies from the Mississippian Goddard formation to the Pennsylvanian Morrow formation in the area studied. The systematic description of 104 microspore species is included in this paper. Seven new genera and thirty-five new species are proposed. One new name combination is suggested. The new genera represented are *Costatascyclus*, *Cystoptychus*, *Hadrohercos*, *Nexuosisporites*, *Tantillus*, *Trochospora*, and *Scutulum*. The remaining sixty-nine species are referable to previously described taxa and include representatives with ranges from Tournaisian to Westphalian B in terms of European nomenclature. By North American nomenclature the range would be from Kinderhook to Atokan.

THE Springer formation has long been of interest to students of geology, and this has been particularly true in the Ardmore Basin of Oklahoma where the structural instability during Pennsylvanian time has rendered correlations difficult. Each of the sandstones in the Springer contains oil and gas in commercial amounts in areas of southern Oklahoma. Tomlinson and McBee (1959) noted that these sands provided more than half of the new oil reserves discovered in Oklahoma during the 1941–55 period.

This study was originally initiated as a palynological project to determine the plant microfossil assemblages of the Goddard formation at its type section on the Goddard Ranch locality as described by Westheimer (1956) in Sections 18 and 19, T.3S, R.4E, Johnston County, Oklahoma. Inasmuch as the Caney and Springer formations are also well exposed at the Goddard Ranch locality, it was decided to determine whether a separation of the Caney, Goddard, and Springer formations could be made on spore assemblages. The Goddard and Caney phases of this study have been conducted by the Oklahoma Geological Survey under the direction of Dr. L. R. Wilson, and the Goddard formation palynology study is presently available in an unpublished graduate thesis (Wiggins 1962). The actual Goddard Shale exposure in the type section as defined by Westheimer (1956) has been inundated by construction of a reservoir, and Wiggins (1962) made his collections in Section 20 to the east of the flooded area. The surface Springer section treated in this study is considered to include three persistent sandstone members separated by shales (text-fig. 1). These are the Rod Club, Overbrook, and Lake Ardmore sandstones. The Rod Club is the basal unit immediately above the Goddard. The Overbrook sandstone was only 4½ ft. thick at this exposure and was not mapped by Westheimer (1956).

There still exists considerable debate and much disagreement among palaeontologists and geologists as to the age and rank of the Springer. The wide disparity of opinion is demonstrated in its treatment by various workers. Moore *et al.* (1944) included the Springer in the Morrow Series. Dott (1941) assigned the upper Caney to the Springer formation and placed the Springer within the Morrow subseries. Bennison (1956)

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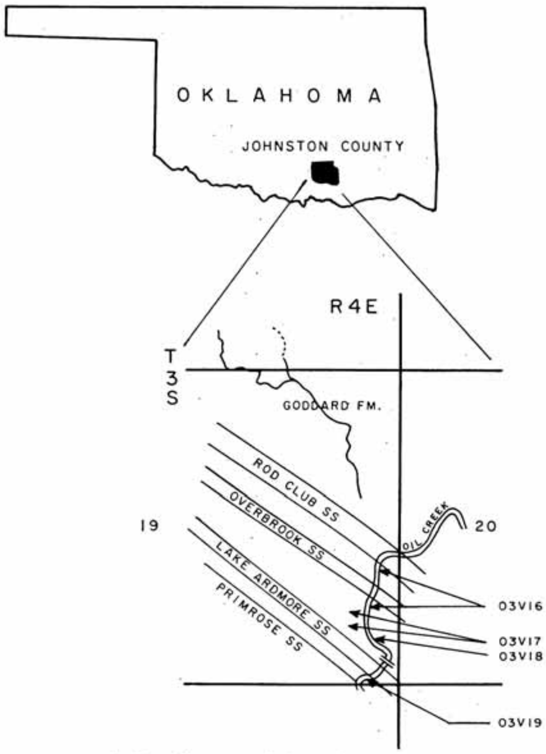
was of the opinion that some of the Morrow sandstone of northwestern Oklahoma probably represents elements of both a Springer and Primose (Pennsylvanian) age. Tomlinson and McBee (1959) have presented an excellent survey of the various viewpoints held by other investigators regarding the age of the Springer. The Editorial Committee of 'Petroleum Geology of Southern Oklahoma' (Hicks *et al.* 1956) defined the Springer as of group rank and included within this definition both the Springer and



TEXT-FIG. 1. Locality map of the Springer collecting area.

Goddard formations. Tomlinson and McBee (1959) likewise defined the 'Springer Group' as including the Goddard formation and the 'Springeran Series'. These authors employed the term 'Springeran Series' in the same sense as did Elias (1956, pp. 70, 89–91), with its upper limit being the base of the Primrose sandstone and the base of the Rod Club sandstone as the lower limit. They excluded the underlying Goddard formation from their 'Springeran Series' on the basis of Elias' (1956) evidence of a Chester age for the Goddard. Peace (1965) has also given an excellent summary of the problems of Springer stratigraphy in which he presents a tentative correlation of Springer outcrops with subsurface units and correlation of locally named subsurface

Springer sandstones of the Anadarko Basin with those of the Ardmore Basin. However, he made no attempt to locate the Mississippian–Pennsylvanian boundary.

Though not the assigned type locality for the Springer, the Goddard Ranch material was chosen for our study because of its excellent exposures of Caney, Goddard, and Springer, thus providing sequential comparative assemblages. In addition, the spore assemblages were quantitatively good and preservation generally superb. The findings and conclusions presented here also incorporate results from other palynological investigations of this laboratory. These include a five-year unpublished study of the subsurface Morrow, Springer, and Chester formations from 48 cored wells in the Anadarko Basin of Texas and Oklahoma. A two-year investigation was made of the microflora from the Atoka, Morrow, and Mississippian in the Morrow type area of western Arkansas; these consisted of 145 collections from 29 localities in Madison, Newton, Searcy, Stone, and Washington counties, Arkansas. In addition to these two major efforts, a number of other areas of investigation have provided accessory information. These are noted throughout the manuscript when spores are encountered common to the Springer. Chief among these are shales and coals associated with fourteen major coals of the lower Pottsville in south-eastern Kentucky and south-western Virginia and shale of surface occurrences from the Johns Valley, Jackfork, and Stanley shales of Oklahoma. Eventual publication of all these data is hoped for and planned.

The samples were also examined by X-ray diffraction techniques to determine mineral constituents and to ascertain whether mineralogical variations existed. This was done in conjunction with studies conducted to attempt correlations from surface to subsurface and to afford accurate identification of the Springer formation from field to field. Two major facies were recognized. One was a low clay, dominantly sand facies and was noted in samples O3V16–1 and O3V19–1. The second facies was a montmorillonite, mixed-layer clay, and the remaining shale samples were of this type.

A total of twenty-three outcrop collections were made and catalogued under four laboratory maceration numbers. The samples were taken as closely as possible in 20 ft. channel samples in order to maintain maximum uniformity (text-fig. 2).

Locality data

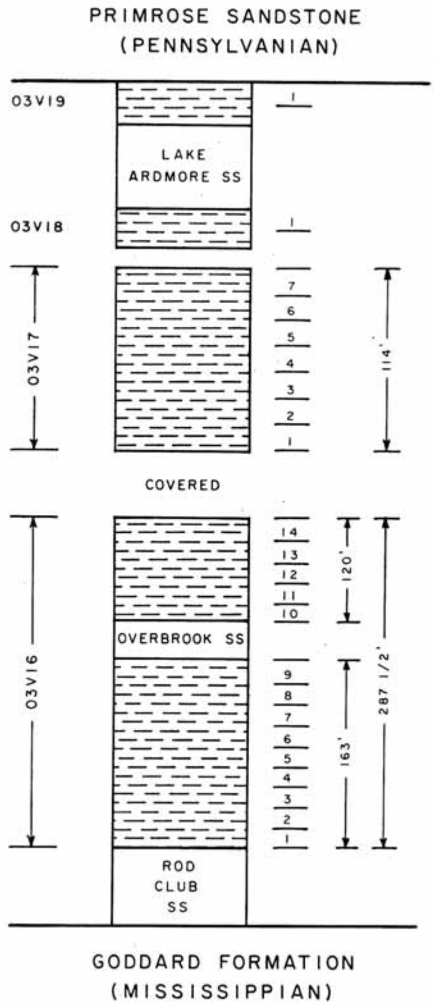
Unit O3V16. NW. ¼ NE. ¼ SE. ¼ Sec. 19, T.3S, R.4E. Johnston County, Oklahoma. Fourteen samples collected in an interval of 287½ ft. Lithology dark grey to buff, laminated shale. Sample no. 1 in the interval is a 'grit' marking the top of the Rod Club sandstone. *Sigillaria* remains were common in the grit.

Unit O3V17. SW. ¼ SE. ¼ SE. ¼ NW. ¼ Sec. 19, T.3S, R.4E. Johnston County, Oklahoma. Seven samples collected in an interval of 114 ft. Lithology dark grey to buff, soft clayey shale.

Unit O3V18. SE. ¼ SW. ¼ SE. ¼ NW. ¼ Sec. 19, T.3S, R.4E. Johnston County, Oklahoma. Single sample collected on east bank of small, meander cut, 50 ft. below the Lake Ardmore sandstone outcrop. Lithology buff, soft, clayey shale.

Unit O3V19. NW. ¼ NW. ¼ NE. ¼ SW. ¼ Sec. 19, T.3S, R.4E. Johnston County, Oklahoma. Single sample collected immediately above the Lake Ardmore sandstone in wind gap gulley dissecting the massive Lake Ardmore sandstone. Lithology buff sandstone with dark, shale streaks.

Maceration techniques. No special problems were experienced in maceration of the Springer shales, and routine laboratory techniques were followed as described by numerous workers, especially Playford (1962, p. 570). Initial treatment consisted of hydrochloric acid, followed by hydrofluoric to digest mineral matter. Oxidation of humic matter was accomplished with Schulze's solution, followed by alkali treatment when required. In some instances ultrasonic generation was effectively utilized. Final



TEXT-FIG. 2. Stratigraphic column of the Springer formation, showing position of sample collections.

separation was achieved with a zinc chloride flotation technique. Clearcol was the permanent mountant used and storage of residues was in Cellosolve.

Classification. The classification system of Potonié and Kremp (1954) is utilized, along with the subsequent treatments by the same authors (Potonié and Kremp 1955, 1956*a*, 1956*b*).

Acknowledgements. The authors wish to acknowledge their indebtedness to Dr. L. R. Wilson of the Oklahoma Geological Survey for graciously withdrawing his staff from the Springer area of study when it became evident that concurrent studies were being undertaken and for his useful assistance and encouragement in this problem and others through the years; to the Arkansas Geological Survey for its very helpful contribution of personnel and other assistance during the Morrow collecting project; to Mr. Virgil Wiggins of the Standard Oil Co. of California, who assisted in collecting the Goddard Ranch samples while a member of the Sun Oil Co. palynology staff, for the use of his unpublished data on the Caney and Goddard formations. Mr. Wiggins also provided comparative material of the subsurface Chainman formation, Mississippian, for which he received the best paper award, west coast AAPG–SEPM, 1960. We are also indebted for comparative reference samples to Mr. M. S. Barss for samples of the Horton coal, to Dr. Geoffrey Playford for Visean and Tournaisian samples of his Spitzbergen material, and Dr. Roger Neves for samples of the material used in his 1958 and 1961 investigations of the Namurian. Thanks are also due to Dr. Russel A. Peppers of the Illinois Geological Survey for the loan of isotype slides from Kosanke's 1950 studies; to Dr. Samine Artüz for her advice and assistance at various times during the course of this work; and to Dr. Herbert Sullivan of the Pan American Petroleum Corporation, who has provided reference material from his several Visean and Tournaisian studies and who has given most generously of his time and advice. We are especially grateful to the Sun Oil Company for granting permission to publish and for financial assistance with illustration costs.

Anteturma SPORONITES (R. Potonié) Ibrahim 1933
Genus CHAETOSPHAERITES Felix 1894

Type species. *C. bilychnis* Felix 1894.

Chaetosphaerites pollenisimilis (Horst) Butterworth and Williams 1958

Plate 53, figs. 1, 2

1955 *Sporonites pollenisimilis* Horst, pp. 150–1, pl. 24, figs. 84–87.
1957 *Sporonites cylindricus* (Horst) Dybová and Jachowicz, pp. 56–57, pl. 1, figs. 1–4.
1958 *Chaetosphaerites pollenisimilis* (Horst) Butterworth and Williams, p. 359, pl. 1, figs. 1–3.
1962 *Chaetosphaerites pollenisimilis* (Horst) Butterworth and Williams; Playford, p. 573, pl. 78, figs. 1–2.

Description. Most of the specimens encountered in the Springer were the bicellular type, which seems to be the usual form. However, three-celled specimens were also common.

Dimensions. (20 specimens.) Diameters range from $14 \times 27\ \mu$ to $16 \times 30\ \mu$.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Anteturma SPORITES H. Potonié 1893
Turma TRILETES (Reinsch) Potonié and Kremp 1954
Subturma AZONOTRILETES Luber 1935
Infraturma LAEVIGATI (Bennie and Kidston) Potonié and Kremp 1954
Genus LEIOTRILETES (Naumova) Potonié and Kremp 1954

Type species. *L. sphaerotriangulus* (Loose) Potonié and Kremp 1954.

Leiotriletes ornatus Ischenko 1956

Plate 53, fig. 3

1956 *Leiotriletes ornatus* Ischenko, p. 22, pl. 2, figs. 18–21.
1960 Spore type 1 of Love, p. 122, pl. 2, fig. 9, text-fig. 12.
1962 *Leiotriletes ornatus* Ischenko; Playford, p. 575, pl. 78, figs. 7–8.

Description. Radial, trilete; subtriangular with sides slightly convex. Laesurae distinct, straight, extending to margins; prominent raised lips 2–3 μ wide. Exine 2–3 μ thick, laevigate.

Dimensions. (10 specimens.) Equatorial diameter 30–42 μ.

Leiotriletes subintortus (Waltz) Ischenko 1952 var. *rotundatus* Waltz 1941

Plate 53, figs. 4, 5

1941 *Azonotriletes subintortus* Waltz var. *rotundatus* Waltz *in* Luber and Waltz, pp. 13–14, pl. 2, fig. 15*b*.

EXPLANATION OF PLATE 53

All figures × 500 unless otherwise indicated.

Figs. 1, 2. *Chaetosphaerites pollenisimilis* (Horst) Butterworth and Williams 1958. 1, Slide O3V16–4 (R-1), location 53·5 × 120·7 (Ref. 32·3 × 118·7). 2, Slide O3V16–4 (R-2), location 37·5 × 123·2 (Ref. 34 × 118).

Fig. 3. *Leiotriletes ornatus* Ischenko 1956. Proximal surface; Slide O3V16–11 (6), location 29 × 110·2 (Ref. 31·7 × 116·9).

Figs. 4, 5. *Leiotriletes subintortus* (Waltz) Ischenko 1952 var. *rotundatus* Waltz 1941. 4, Proximal surface; Slide O3V16–4 (R-1), location 52 × 117·5 (Ref. 32·3 × 118·7). 5, Proximal surface; Slide O3V16–3 (6), location 28·9 × 116·1 (Ref. 33 × 117·9).

Figs. 6, 7. *Leiotriletes tumidus* Butterworth and Williams 1958. 6, Proximal surface; Slide O3V16–13 (A-1), location 9·5 × 122·5 (Ref. 31·1 × 117·9). 7, Proximal surface; Slide O3V16–13 (A-2), location 19·1 × 111·5 (Ref. 32·2 × 117·9).

Fig. 8. *Punctatisporites divaricatus* sp. nov. Holotype. Proximal surface; Slide O3V16–14 (5), location 13 × 124 (Ref. 32·3 × 117·6).

Fig. 9. *Punctatisporites flexuosus* sp. nov. Holotype. Proximal surface; Slide O3V16–11 (1), location 45·5 × 119·8 (Ref. 32 × 118·7).

Figs. 10, 11. *Punctatisporites heterofiliferus* sp. nov. 10, Holotype. Proximal surface; Slide O3V16–3 (6), location 10·2 × 124 (Ref. 33 × 117·9). 11, Trilete split to form triangular opening; Slide O3V16–3 (5), location 54·9 × 115·6 (Ref. 33·7 × 118).

Fig. 12. *Punctatisporites incomptus* sp. nov. Holotype. Proximal surface; Slide O3V16–11 (5), location 38 × 110·8 (Ref. 32·6 × 117·8).

Fig. 13. *Punctatisporites irrasus* Hacquebard 1957. Proximal surface; Slide O3V16–14 (5), location 43·2 × 113·2 (Ref. 32·3 × 117·6).

Fig. 14. *Punctatisporites solidus* Hacquebard 1957. Proximal surface; Slide O3V16–9 (5), location 18·9 × 107·8 (Ref. 32·4 × 118·6).

Fig. 15. *Punctatisporites trifidus* sp. nov. Holotype. Proximal surface; Slide O3V16–3 (5), location 38·5 × 127·5 (Ref. 33·7 × 118).

Fig. 16. *Calamospora* cf. *hartungiana* Schopf 1944. Proximal surface; Slide O3V17–2 (1), location 12 × 125·6 (Ref. 31 × 117·9).

Fig. 17. *Calamospora* cf. *parva* Guennel 1958. Proximal surface; Slide O3V16–11 (1), location 54·5 × 120·5 (Ref. 32 × 118·7).

Fig. 18. *Waltzispora sagittata* Playford 1962. Proximal surface; Slide O3V16–3 (6), location 23 × 110 (Ref. 33 × 117·9).

1952 *Leiotriletes subintortus* (Waltz) Ischenko var. *rotundatus* Waltz; Ischenko, p. 11, pl. 1, fig. 7.

1962 *Leiotriletes subintortus* (Waltz) Ischenko var. *rotundatus* Waltz; Playford, pp. 574–5, pl. 78, figs. 5–6.

Description. Radial, trilete, subtriangular with rounded apices and concave sides. Laesurae distinct, extending nearly to spore margin. Exine 1–2 μ thick. Laevigate.

Dimensions. (25 specimens.) Equatorial diameter 30–45 μ.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Leiotriletes tumidus Butterworth and Williams 1958

Plate 53, figs. 6, 7

Description. Radial, trilete, subtriangular with sides convex to slightly straight. Laesurae distinct, straight, extending nearly to body margin, lips prominent. Body wall thin, approximately 1 μ thick, laevigate.

Dimensions. (25 specimens.) Equatorial diameter 30–45 μ.

Discussion. The Springer specimens do not show the proximal tumidity with the degree of regularity noted by Butterworth and Williams (1958). However, this feature is evident on some specimens, and any further specific separation seems inadvisable.

Genus PUNCTATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. P. punctatus Ibrahim 1933.

Punctatisporites divaricatus sp. nov.

Plate 53, fig. 8

Diagnosis. Radial, trilete, subtriangular. Laesurae slightly sinuous, equal to two-thirds to four-fifths of radius; prominent lips increase in width toward terminal ends, range in width from 2–5 μ at junction area to 5–10 μ terminally; commissure distinct and suture bifurcating terminally with each division 5–10 μ long; lips flare out sharply on either side of suture division. Exine 3–5 μ thick and always well defined, essentially laevigate but sometimes minutely punctate.

Dimensions. (25 specimens.) Equatorial diameter 60–95 μ (average 70–85 μ).

Holotype. Slide O3V16–14 (5). Location 13×124 (Ref. 32·3×117·6).

Description. Holotype subtriangular, diameter 80×85 μ; laesurae slightly sinuous, 26–35 μ in length, four-fifths of spore radius; prominent lips 5 μ wide at junction with rays to 10 μ wide at terminal ends; commissure distinct, ending in divisions of 15 μ in length; exine 5 μ thick, minutely punctate when viewed at high magnification.

Comparison. The conspicuous wall serves to distinguish it from *P. flexuosus*, along with the less sinuous laesurae. It differs from *P. incomptus* by the widely expanded and more sinuous lips, as well as the more pronounced thickened exine.

Punctatisporites flexuosus sp. nov.

Plate 53, fig. 9

Diagnosis. Radial, trilete, subtriangular. Laesurae sinuous to convolute, equal to four-fifths of radius, frequently extending to margin; prominent lips increase in width towards terminal ends, ranging in width from 2–3·5 μ wide at junction area to 5 μ in width terminally; commissure distinct and bifurcating terminally with each division 5–7·5 μ long; lips expand sharply on either side of suture divisions. Exine indistinct but measurable walls 3·5–5 μ thick recorded. Body laevigate.

Dimensions. (25 specimens.) Equatorial diameter 55–80 μ (average 60–75 μ).

Holotype. Slide O3V16–11 (1). Location 45·5×119·8 (Ref. 32×118·7).

Description. Holotype subtriangular, diameter 65×69 μ; laesurae markedly convolute in area of junction of rays, 30 μ in length and equal to over four-fifths of radius; lips 3·5 μ wide in area of convolutions to 5 μ wide at terminal ends; wall not sharply defined but 5 μ in thickness.

Discussion. In several specimens, including the holotype, the commissure was noted to be sinuous also and often followed the twistings of the lips. This indicated that the lips and commissure are not features of different exine structures as was suggested for *P. validus*.

Comparison. The excessive convolutions of the laesurae serve to differentiate the species from *P. incomptus* and *P. divaricatus*, while its rather indistinct exine also differs from the well-defined exine of these two species.

Punctatisporites heterofiliferus sp. nov.

Plate 53, figs. 10, 11

Diagnosis. Radial, trilete, circular. Laesurae well-defined, simple, straight, sometimes indistinct due to ornamentation, extending nearly to body margin, no lip development; trilete frequently split to form a triangular-shaped opening (Pl. 53, fig. 11) ranging from 20×20 μ to 40×45 μ over-all. Wall thick, 5–7 μ. Sculpture finely obervermiculate, composed of short, thread-like markings, often branching but never anastomosing to form a reticulum.

Dimensions. (25 specimens.) Equatorial diameter 48–68 μ (average 55–65 μ).

Holotype. Slide O3V16–3 (6). Location 10·2×124 (Ref. 33×117·9).

Description. Holotype circular, 63·5×66 μ; laesurae straight, simple, 25 μ long and extending nearly to the margin; wall distinct, 6 μ thick. Sculpture minutely obervermiculate, branching slightly, but not reticulate.

Comparison. *P. vermiculatus* Kosanke 1950 (p. 19, pl. 2, fig. 4) is similar, but in addition to the lengthy geological time gap existing, Kosanke's species is described as having a poorly defined trilete and is deeply incised by a well-developed vermiculate sculpture.

The minor sculpture of *P. parvivermiculatus* Playford 1962 (p. 577, pl. 78, fig. 14) is quite similar to that of *P. heterofiliferus*. However, Playford's species has a much thinner exine and is subject to folding. The exine sculpture is also less well defined, since he noted that oil immersion is frequently necessary in studying. The infravermiculate sculpture also differs from *P. heterofiliferus*, which has the vermiform markings definitely positioned upon the exine. The degree of sculpture of *P. heterofiliferus* appears to lie between that for *P. vermiculatus* and *P. parvivermiculatus*. The triangularly split trilete probably does not occur more than 50 per cent. of the time and should not be considered as diagnostic. However, it is frequent enough to warrant attention.

Punctatisporites incomptus sp. nov.

Plate 53, fig. 12

Diagnosis. Radial, trilete, subtriangular. Laesurae straight except for slight undulation of lips, equal to three-fourths to four-fifths of radius; prominent raised lips increase in width towards outer limits, range from 2·5–4·5 μ in width at junction point to 4–6·5 μ terminally; commissure distinct and suture has slight terminal bifurcation, with each division about 5 μ in length, lips tending to flare out noticeably on each side of divided suture, with sutures slightly exceeding the lips in over-all length. Wall distinct, 3–5 μ thick, laevigate.

Dimensions. (25 specimens.) Equatorial diameter 60–90 μ (average 65–80 μ).

Holotype. Slide O3V16–11 (5). Location 38 × 110·8 (Ref. 32·6 × 117·8).

Description. Holotype subtriangular, diameter 74 × 77 μ; laesurae straight, 30–35 μ in length, four-fifths of spore radius; prominent lips from 3·5 μ wide at junction with rays at apex to 6·5 μ wide at terminal ends; commissure distinct, ending in divisions of 5 μ in length; exine 4 μ thick, laevigate.

Comparison. This species is distinguished from *P. validus* by the more pronounced exine, undulation of the lips, and the regular bifurcation of the rays and accompanying expansion of the lips. The lips do not display the prominent height of those in *P. validus*. It may be distinguished from *P. divaricatus* and *P. flexuosus* by differences in exine thickness and a less conspicuous expansion of the rays.

Punctatisporites irrasus Hacquebard 1957

Plate 53, fig. 13

Description. Radial, trilete, circular to oval. Laesurae distinct, simple, straight, one-half to three-quarters of spore radius; germinal sutures commonly gaped open to form triangular opening with darker intertectal area. Body wall distinct, 2–3 μ thick, laevigate to minutely granulose.

Dimensions. (25 specimens.) Equatorial diameter 48–75 μ.

Discussion. There is the possibility that *Leiotriletes microtriangulus* Artüz 1957 is the same, but assignment cannot be definite without reference to Artüz's material.

Hacquebard's (1957) West Gore assemblage was available for comparison, as well as Sullivan's (1964*a*) Plump Hill and Puddlebrook material, and the Springer specimens are indistinguishable from *P. irrasus*. However, it never attained the high percentages recorded by Hacquebard and by Sullivan, where the species composed one-fourth to one-third of the total assemblages. The highest occurrence recorded was in O3V17–5 where it totalled 11 per cent.

Punctatisporites solidus Hacquebard 1957

Plate 53, fig. 14

Description. Radial, trilete, circular to subcircular in outline. Laesurae distinct, simple, straight, length four-fifths spore body radius. Body laevigate. Wall 3–4 μ thick.

Dimensions. (15 specimens.) Equatorial diameter 36–60 μ.

Punctatisporites trifidus sp. nov.

Plate 53, fig. 15

Diagnosis. Radial, trilete, circular. Laesurae straight, equal to one-half to two-thirds of radius; rays bifurcating at their termini with each division frequently continuing a distance equal to their length before division; prominent, highly elevated lip structures originate on either side of suture about one-half the distance from the ray's point of junction to the terminal point of division; lips flare out, accompanying the suture bifurcation on either side. Exine thin, 1·5–2·5 μ thick, laevigate.

Dimensions. (25 specimens.) Equatorial diameter 50–75 μ.

Holotype. Slide O3V16–3 (5). Location 38·5 × 127·5 (Ref. 33·7 × 118).

Description. Holotype circular, diameter 62·5 × 65 μ; laesurae straight, 17–22 μ in length, equal to two-thirds distance of radius; sutures bifurcate about two-thirds their length with divisions accompanied by prominent lips about 5 μ in width; exine 2 μ thick, laevigate.

Discussion. The rays are often accompanied their entire length by slightly developed labial structures, but these are usually very difficult to discern and the prominence of the conspicuous terminal lips serves to overshadow any other features. The divided suture and widely flared lips are reminiscent of the upper Pennsylvanian genus *Cadiospora* but does not reveal any tendency to continue as arcuate thickenings as in *Cadiospora* and various megaspore genera.

Comparison. *Leiotriletes auritus* Ischenko 1956 is probably the same, but again the brevity of description and illustration prevent making an accurate comparison.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Punctatisporites validus sp. nov.

Plate 54, figs. 1, 2

Diagnosis. Radial, trilete, subcircular. Laesurae distinct, straight, equal to over four-fifths of radius, frequently extending to spore margin; prominent raised lips individually 3–5 μ wide and commissure distinct; rays commonly not bifurcated, but in rare instances a slight terminal division is present. Exine 2–3 μ thick, laevigate, body occasionally with one or two minor folds. Spores generally retaining tetrad grouping.

Dimensions. (50 specimens.) Equatorial diameter 60–94 μ (average 70–80 μ).

Holotype. Slide O3V16–11 (5). Location 15·5×123·1 (Ref. 32·6×117·8).

Description. Holotype subcircular, diameter 86 μ; laesurae straight, 40 μ long, extending nearly to spore margin, prominent lips 4·5 μ wide, commissure visible; exine 2·5 μ thick, laevigate.

Discussion. A feature commonly observed in this spore is the difference in length of the actual sutural opening and the lips, as well as the fact that they do not always overlie each other. Staplin and Jansonius (1964) have noted this in their densospore study and regarded the laesura as a structure of the intexine and the sutural ridge to be an exoexine structure. The tetrad character is considered of diagnostic significance since the tetrad grouping appeared to be retained in most instances, even through the maceration process. This feature does serve to increase the difficulty of identification since the laesurae configuration is more or less obscured. The laesurae are one of the more reliable identification features. The prominent lips do not bifurcate as in *P. incomptus* or *P. trifidus*, and they maintain a constant dimension throughout their lengths. The straight laesurae with conspicuous raised lips are also characteristic of the species. Although there is an occasional slight terminal bifurcation of a suture, it is never to the degree noted in the other species of the genus described here and is never accompanied by the pronounced expansion of the lips. The wall is not as distinct as in *P. incomptus* or *P. divaricatus*. It is also the only spore of this group of *Punctatisporites* displaying a tendency, though slight, to folding and plication of the spore wall.

Comparison. Trachytriletes auritus Ischenko 1956 may well be the same. However, Ischenko described the ornamentation in the Russian spore as shagreen to tubercular. The brevity of the description and inadequacy of illustrations prevents any accurate comparison.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Genus CALAMOSPORA Schopf, Wilson, and Bentall 1944

Type species. C. hartungiana Schopf *in* Schopf, Wilson, and Bentall 1944.

Calamospora cf. *hartungiana* Schopf 1944

Plate 53, fig. 16

Description. Radial, trilete, originally spherical, compressed in lenticular outline with numerous folds. Laesurae one-fourth to one-half radius, very thin lip development. Spore coat laevigate, 1–2 μ thick.

Dimensions. (50 specimens.) Equatorial diameter 45–100 μ (average 50–70 μ).

Discussion. Calamospora is very numerous in the Springer formation. However, the taxonomy of this taxon is still so poorly defined as to render definite segregation of species nearly impossible. The Springer specimens are within the size ranges of *C. breviradiata* Kosanke, characterized by short rays and an *area contagionis*, and of *C. liquida* Kosanke, with long rays and the *area contagionis* not present. *C. microrugosa* (Ibrahim) Schopf, Wilson, and Bentall 1944 is very similar to the Springer material and differs from *C. hartungiana* primarily in the lack of the *area contagionis*. These features appear useless diagnostically in view of the present assemblage. Specimens in all phases of the size range have been observed with long rays, with short rays, with and without the *area contagionis*. They could possibly be included in *C. microrugosa*, *C. liquida*, *C. exigua*, or *C. breviradiata*. However, every conceivable combination of diagnostic characters appears to exist in the Springer assemblage and no clearcut division seems possible. Hartung (1933) described degenerate spores from *Macrostachya* cones which fall within the size ranges of the Springer specimens and possess the *area contagionis*. However, he also observed mature spores of larger dimensions and without the *area contagionis* in the same cones. Such morphological development appears to be a factor in the heterogeneity of this Springer taxon.

EXPLANATION OF PLATE 54

All figures × 500 unless otherwise indicated.

Figs. 1, 2. *Punctatisporites validus* sp. nov. 1, Tetrad; Slide O3V16–11 (2), location 33 × 126 (Ref. 32 × 118). 2, Holotype. Proximal surface; Slide O3V16–11 (5), location 15·5 × 123·1 (Ref. 32·6 × 117·8).

Fig. 3. *Gulisporites incomptus* sp. nov. Holotype. Proximal surface; Slide O3V16–9 (A-1), location 27·9 × 119 (Ref. 31 × 116·5).

Fig. 4. Undescribed spore. Proximal surface; Slide O3V16–10 (2), location 39 × 118 (Ref. 53 × 117·7).

Fig. 5. *Cyclogranisporites lasius* (Waltz) Playford 1962. Slide O3V16–3 (6), location 28 × 111·6 (Ref. 33 × 117·9).

Figs. 6, 7. *Granulatisporites* cf. *pallidus* Kosanke 1950. 6, Proximal surface; Slide O3V16–3 (5), location 13·9 × 115·1 (Ref. 33·7 × 118). 7, Proximal surface; Slide O3V16–3 (6), location 23·5 × 123 (Ref. 33 × 117·9).

Figs. 8, 9. *Granulatisporites politus* Hoffmeister, Staplin, and Malloy 1955. 8, Proximal surface; Slide O3V16–3 (5), location 43·7 × 108 (Ref. 33·7 × 118). 9, Proximal surface; Slide O3V16–11 (R-1), location 29 × 93 (Ref. 31·7 × 116·9).

Fig. 10. *Granulatisporites spinosus* Kosanke 1950. Distal surface; Slide O3V16–3 (5), location 24·9 × 128·4 (Ref. 33·7 × 118).

Fig. 11. *Anapiculatisporites concinnus* Playford 1962. Distal surface; Slide O3V16–14 (6), location 10·2 × 108·6 (Ref. 33 × 117).

Figs. 12, 13. *Lophotriletes labiatus* Sullivan 1964. 12, Proximal surface; Slide O3V17–1 (4), location 44 × 117·2 (Ref. 32 × 119·6). 13, Proximal surface; Slide O3V16–3 (A-2), location 25·9 × 125 (Ref. 32·2 × 117·9).

Figs. 14, 15. *Granulatisporites tuberculatus* Hoffmeister, Staplin, and Malloy 1955. 14, Distal surface; Slide O3V16–13 (B-1), location 49·2 × 119·4 (Ref. 31·9 × 117·2). 15, Proximal surface; Slide O3V16–4 (R-1), location 27·5 × 96·6 (Ref. 32·3 × 118·7).

Calamospora cf. *parva* Guennel 1958

Plate 53, fig. 17

Description. Trilete, spherical, with numerous lenticular folds. Laesurae short, 7·5–13 μ in length (average 8–10 μ), no visible lips. Wall laevigate, not exceeding 1 μ in thickness. Well-developed *area contagionis*.

Dimensions. (50 specimens.) Equatorial diameter 25–45 μ (average 35–40 μ).

Discussion. This spore is quite common throughout the Springer section, and its probable assignment to *C. parva* is based on a close comparison but without certainty that they are conspecific. The Springer form could probably be fitted into other specific niches available in the published literature. The presence of the *area contagionis* is of doubtful value, being noted in several other species. A significant clue as to the possible true nature of many small *Calamospora* may again be provided by the results of Hartung (1933) and his description of the numerous degenerate spores from *Macrostachya* cones. There is little doubt in the present authors' opinion but that *C.* cf. *parva* represents such degeneracy or immature developmental stage.

Genus WALTZISPORA Staplin 1960

Type species. W. lobophora (Waltz) Staplin 1960.

Waltzispora sagittata Playford 1962

Plate 53, fig. 18

1960 *Leiotriletes politus* Love, p. 111, pl. 1, fig. 1.
1962 *Waltzispora sagittata* Playford, p. 582, pl. 79, fig. 12, text-fig. 5c.

Description. Radial, trilete, subtriangular with concave interradial margins and convex apices. Laesurae simple, length three-fourths of spore radius, occasionally extending to body margin. Wall about 1 μ thick, laevigate to finely granulose.

Dimensions. (15 specimens.) Equatorial diameter 24–30 μ.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Genus GULISPORITES Imgrund 1960

Type species. G. cochlearius (Imgrund) Imgrund 1960.

Gulisporites incomptus sp. nov.

Plate 54, fig. 3

Diagnosis. Radial, trilete, subtriangular, with slightly convex sides and rounded apices. Laesurae prominent, extending nearly to body margin, lips dark, commissures usually obscured by lips; lips 13–15 μ wide, 5–8 μ high, frequently contorted to appear spirally twisted. Body laevigate, wall indistinct and relatively thin, not exceeding 2·5 μ.

Dimensions. (25 specimens.) Equatorial diameter 50–80 μ (average 60–70 μ).

Holotype. Slide O3V16–9 (A–1). Location 27·9×119 (Ref. 31×116·5).

Description. Holotype 60×65 μ, subtriangular with slightly convex sides. Prominent laesurae, non-dehisced; lips 6 μ high and 16 μ wide. Exine laevigate, width indistinct.

Discussion. This species differs relatively little from *G. torpidus* described by Playford (1964) from the Mississippian Horton group. *G. torpidus* was granulose in some instances and possessed conspicuous lips which broadened noticeably towards the equator, while the lips of *G. incomptus* are relatively uniform throughout. *G. torpidus* is also noted as having a thick exine, whereas *G. incomptus* has a rather thin wall which is usually difficult to discern. This spore is almost certainly the same which Love (1960) designated as *Ahrensisporites* type B from the Lower Carboniferous of Scotland. However, the prominent laesurae are not regarded as being comparable to kyrtomes.

Genus HADROHERCOS gen. nov.

Type species. H. stereon sp. nov.

Diagnosis. Radial, trilete, subtriangular with very rounded corners. Laesurae straight with prominent, unornamented lips. The spore wall consists of two layers. The inner layer is formed of closely packed, occasionally fused, verrucae with irregular bases; and the outer layer which is a sheath-like covering resting directly on top of the verrucae. This outer layer of the wall contains canals causing it to be very subject to corrosion. Often large patches of it are gone, revealing the negative reticulum formed by the verrucae beneath. Prominent lips and the unusual wall structure characterize the genus.

Hadrohercos stereon sp. nov.

Plate 65, figs. 1–3

Diagnosis. Radial, trilete, subtriangular with very rounded corners. Laesurae straight, 50–63 μ long, with smooth lips 11–13 μ wide. Pitting usually develops along the edge of the lips. The verrucae composing the inner wall layer are 2–6 μ high and have irregularly shaped bases ranging from somewhat polygonal (2–3 μ across) to slightly elongated (1×4 μ). They are closely packed (1–2 μ between) and occasionally fused. The outer wall layer is 5–6 μ thick and contains canals 1 μ or less in diameter. These canals can be seen easily in side view (Pl. 65, fig. 3) and plan view (Pl. 65, fig. 2). The outer sheathing is often partially corroded revealing the negative reticulum formed by the verrucae beneath.

Dimensions. (7 specimens.) Equatorial diameter 126–50 μ (average 140 μ).

Holotype. Slide O3V16–10 (2). Location 23·5×114 (Ref. 53×117·7).

Description. Holotype 144×144 μ radial, trilete, subtriangular. Laesurae straight, 50–55 μ long. Lips 11 μ wide with pitting on outer edge. Verrucae about 1 μ apart and 6 μ high with irregular bases. Large corroded patches reveal negative reticulum. Wall canals visible about 1 μ wide. Outer layer of wall 5 μ thick.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Infraturma APICULATI (Bennie and Kidston) Potonié and Kremp 1954
Genus CYCLOGRANISPORITES Potonié and Kremp 1954

Type species. C. leopoldi (Kremp) Potonié and Kremp 1954.

Cyclogranisporites lasius (Waltz) Playford 1962

Plate 54, fig. 5

1884 Type 524 of Reinsch, p. 52, pl. 32, fig. 211; pl. 42, fig. 220.
1938 *Azonotriletes lasius* Waltz *in* Luber and Waltz, p. 9, pl. 1, fig. 4; pl. A, fig. 4.
1955 *Filicitriletes lasius* (Waltz) Luber, p. 55, pl. 2, fig. 50.
1962 *Cyclogranisporites lasius* (Waltz) Playford, p. 585, pl. 79, figs. 19, 20.

Description. Radial, trilete. Laesurae simple, up to 24 μ in length, about two-thirds spore radius; often obscured by closely spaced, granulose sculpture elements and difficult to discern. Wall thin, 1–2·5 μ thick, with occasional folds; densely covered by fine granulose elements 1–1·5 μ in height. Sculpture elements variable, with some truncated and others tapered to varying degrees.

Dimensions. (25 specimens.) Equatorial diameter 55–75 μ.

Discussion. It resembles *Cyclobaculisporites grandiverrucosus*, but the sculpture elements are very densely spaced and do not possess the uniformity of *Cyclobaculisporites*. The elements of the same specimen are often truncated as in *Cyclobaculisporites* or tapered in the manner of *Verrucosisporites* as defined by Bhardwaj (1955).

Genus GRANULATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. G. granulatus Ibrahim 1933.

Granulatisporites cf. *pallidus* Kosanke 1950

Plate 54, figs. 6, 7

Description. Radial, trilete, triangular with rounded apices, interradial areas slightly concave. Laesurae distinct, straight, length two-thirds to three-fourths spore radius; no lip development, but a vague proximal contact area sometimes present. Proximal and distal ornamentation of closely spaced, minute granulations, about 1 μ in diameter and usually less than 1 μ in height. Spore wall (excluding granulations) about 1 μ thick.

Dimensions. (25 specimens.) Equatorial diameter 24–42 μ.

Discussion. The Springer specimens have a gradation through specimens closely comparable to *G. commissuralis*, *G. granularis*, and *G. pallidus* Kosanke (1950). A clearcut separation is difficult to make, and the majority appear most closely referable to *G. pallidus* Hoffmeister, Staplin, and Malloy (1955*b*, p. 389) encountered a similar situation. Kosanke separated the species on size and spacing of granulations but gave no precise measurements, using descriptive terms such as *coarsely granulose*, *distinctly granulose*, or *granulations are numerous and closely spaced which gives the spore a rough appearance.* His species were conveniently separated geologically but such is not the case in the Springer.

Granulatisporites politus Hoffmeister, Staplin, and Malloy 1955

Plate 54, figs. 8, 9

Description. Radial, trilete, subtriangular with bluntly rounded apices and concave sides. Laesurae distinct, straight, simple, extending nearly to body margin. Wall 1–2 μ thick, laevigate to minutely punctate.

Dimensions. (20 specimens.) Equatorial diameter 24–36 μ.

Discussion. The lateral projection of the rounded apices to produce an angular junction of the radial and interradial areas as described by Butterworth and Williams (1958) is largely the basis for assignment to this species. This is a constant feature of the Springer specimens.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Granulatisporites spinosus Kosanke 1950

Plate 54, fig. 10

1950 *Granulatisporites spinosus* Kosanke, p. 22, pl. 3, fig. 7.
1955 *Anapiculatisporites spinosus* (Kosanke) Potonié and Kremp, p. 82, pl. 14, figs. 253–5.
1957 *Spinositriletes sentus* Dybová and Jachowicz, pp. 130–1, pl. 32, fig. 3.

Dimensions. (20 specimens.) Equatorial diameter 30–38 μ. Spines acute, 2·5–5 μ long and 1·5 μ wide at bases.

Discussion. Kosanke's (1950) original designation is retained since it most adequately provides for the inclusion of this species, while the revision of Potonié and Kremp (1954) fails to sufficiently establish clear differences for genera such as *Apiculatisporis*, *Acanthotriletes*, *Anapiculatisporites* and *Lophotriletes*. The treatment by Dybová and Jachowicz (1957) is procedurally incorrect, and failure to retain the specific epithet violated the International Rules of Botanical Nomenclature.

Granulatisporites tuberculatus Hoffmeister, Staplin, and Malloy 1955

Plate 54, figs. 14, 15

Description. Radial, trilete, subtriangular with rounded apices and concave sides. Laesurae distinct, straight, simple, extending three-fourths of spore radius. Proximal and distal surfaces ornamented with blunt, conical tuberculae 0·5–2·5 μ in height, 1–3 μ wide at bases and 1–4 μ apart.

Dimensions. (25 specimens.) Equatorial diameter 30–45 μ.

Discussion. The Springer specimens project the size range of the species slightly, and tuberculae dimensions are added.

Genus LOPHOTRILETES (Naumova) Potonié and Kremp 1954

Type species. L. gibbosus (Ibrahim) Potonié and Kremp 1954.

Lophotriletes coniferus Hughes and Playford 1961

Plate 55, figs. 1, 4

Description. Radial, trilete, subtriangular to subcircular. Laesurae distinct, slightly sinuous, three-fourths of spore radius, extending to body margin occasionally. Coni up to 2 μ high and 1–4 μ apart. Body minutely granulose with one or two large folds.

Dimensions. (15 specimens.) Equatorial diameter 83–115 μ.

Discussion. The only noteworthy difference from the description of Hughes and Playford is in the distribution of the coni. The Springer specimens appear to have slightly shorter coni and have them more closely spaced than in the type description.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Lophotriletes labiatus Sullivan 1964

Plate 54, figs. 12, 13

Description. Radial, triangular, with slightly convex sides, apices rounded. Laesurae straight, extending to body margin, prominent lips 4–6 μ wide on either side of laesurae. Proximal and distal surfaces ornamented with blunt cones about 1 μ in height.

Dimensions. (10 specimens.) Equatorial diameter 30–45 μ.

Lophotriletes obtusus sp. nov.

Plate 55, figs. 5–7

Diagnosis. Radial, trilete, subtriangular, margins straight or slightly concave. Laesurae simple, extending three-fourths of radius, usually obscured by ornamentation. Ornamented proximally and distally by prominent projections of variable sizes and shapes; projections 1·5–7·5 μ in length, 1–6 μ in diameter across polygonal bases; apices rounded, bluntly squared, rarely acute; closely spaced, 1–3 μ apart. Projections tend to fuse, especially at spore apices, occasionally forming apical pads to 15 μ in length and 5 μ in width. Spore wall thin, 1–2 μ.

Dimensions. (35 specimens.) Equatorial diameter (including projections) 35–50 μ.

Holotype. Slide O3V16–11 (6). Location 54·5 × 125·2 (Ref. 31·7 × 116·9).

Description. Holotype radial, trilete, sides straight, apices rounded. Equatorial diameter 42 × 42 μ. Laesurae three-fourths of radius, obscured by ornamentation. Spore covered proximally and distally with blunt projections from 1·5–7·5 μ in length (average 3 μ) and 2·5 μ in basal diameter. There is a slight fusion of projections at the apices, one forming a thickened apical pad 10 μ in length and 5 μ wide.

Discussion. The tendency of the projections to fuse is not consistent and varies from specimen to specimen. The greater fusion is at the apices and sometimes presents a superficial resemblance to *Triquitrites*. Some specimens show no fusion and seldom will it concern more than one apex of a specimen; very rarely all three apices will display some thickening. The holotype (Pl. 55, fig. 6) is markedly thickened at one apex.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus ANAPICULATISPORITES Potonié and Kremp 1954

Type species. A. isselburgensis Potonié and Kremp 1954.

Anapiculatisporites concinnus Playford 1962

Plate 54, fig. 11

Description. Radial, trilete, triangular with rounded apices and interradial margins straight to convex. Laesurae distinct, simple, straight, length about four-fifths spore radius. Laevigate proximally; distal surface bearing small, scattered spines about 2 μ in length and 2–3 μ apart.

Dimensions. (10 specimens.) Equatorial diameter 20–43 μ.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Genus RAISTRICKIA (Schopf, Wilson, and Bentall) Potonié and Kremp 1954

Type species. R. grovensis Schopf *in* Schopf, Wilson, and Bentall 1944.

Raistrickia vulgata sp. nov.

Plate 55, figs. 2, 3

Diagnosis. Radial, trilete. Laesurae straight, simple, 20–25 μ in length, extending two-thirds distance of body radius. Body densely covered with blunt spines, 2–5 μ in width

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EXPLANATION OF PLATE 55

All figures $\times$ 500 unless otherwise indicated.

Figs. 1, 4. *Lophotriletes coniferus* Hughes and Playford 1961. 1, Proximal surface; Slide O3V16–14 (6), location 46·8 $\times$ 122·5 (Ref. 33 $\times$ 117). 4, Distal surface; Slide O3V16–14 (6), location 17·4 $\times$ 125·9 (Ref. 33 $\times$ 117).

Figs. 2, 3. *Raistrickia vulgata* sp. nov. 2, Proximal surface; Slide O3V16–11 (6), location 38 $\times$ 119·8 (Ref. 31·7 $\times$ 116·9). 3, Holotype. Slide O3V16–11 (6), location 42 $\times$ 111·5 (Ref. 31·7 $\times$ 116·9).

Figs. 5–7. *Lophotriletes obtusus* sp. nov. 5, Proximal surface; Slide O3V16–3 (5), location 15 $\times$ 116·8. (Ref. 33·7 $\times$ 118). 6, Holotype. Distal surface; Slide O3V16–11 (6), location 54·5 $\times$ 125·2 (Ref. 31·7 $\times$ 116·9). 7, Distal surface; Slide O3V16–5 (3), location 23·4 $\times$ 113·9 (Ref. 33·7 $\times$ 118·2).

Fig. 8. *Ibrahimispores sentus* sp. nov. Holotype. Slide O3V16–3 (1), location 35 $\times$ 117·6 (Ref. 33 $\times$ 117·1).

Figs. 9–12. *Spinozonotriletes procinctus* sp. nov. 9, Holotype. Distal surface; Slide O3V16–11 (7), location 35 $\times$ 112·8 (Ref. 31·9 $\times$ 117·9). 10, Proximal surface; Slide O3V16–3 (5), location 29 $\times$ 122 (Ref. 33·7 $\times$ 118). 11, Distal surface; Slide O3V16–11 (7), location 27·8 $\times$ 128 (Ref. 31·9 $\times$ 117·9). 12, Proximal surface; Slide O3V16–11 (2), location 45·5 $\times$ 121·5 (Ref. 32 $\times$ 118).

and 6–13 μ in length; individual spines are of uniform width and rarely show taper; apex of each spine minutely partite, best seen at high magnification. Spore coat thin, about 1 μ in thickness.

Dimensions. (25 specimens.) Equatorial diameter (including spines) 55–70 μ. Body diameter 40–53 μ.

Holotype. Slide O3V16–11 (6). Location 42 × 111·5 (Ref. 31·7 × 116·9).

Description. Holotype circular, over-all diameter 55 × 60 μ, body 44 × 46 μ. Laesurae two-thirds of radius. Spines uniformly distributed, 2·5–6·5 μ wide and 7·5–15 μ long, minutely partite.

Comparison. There is actually very little to distinguish a number of *Raistrickia* species other than spine characters, and this is an admittedly tenuous feature. *R. vulgata* compares well with *R. saetosa* (Loose) Schopf, Wilson, and Bentall as described by Potonié and Kremp (1955), but it does not have the differential proximal-distal spine distribution noted for *R. saetosa* by Bhardwaj (1957, pl. 23, fig. 20). *R. aculeata* Kosanke has similar dimensions but is described as having tapering or blunt spines. Likewise, *R. crinita* Kosanke has tapering, blunt spines and laesurae somewhat longer than in *R. vulgata*. *R. superba* (Ibrahim) Schopf, Wilson, and Bentall is comparable to the Springer species in size of body and spines but has rays reaching the body margin and truncate spines. There is every likelihood that a thorough, monographic study of the genus would result in conspecificity with some species presently described. However, its relatively stable and easily recognized characters, and its common occurrence in the Springer sediments, warrant recognition of *R. vulgata* at this time.

Genus IBRAHIMISPORES Artüz 1957

Type species. *I. microhorridus* Artüz 1957.

Ibrahimispores sentus sp. nov.

Plate 55, fig. 8

Diagnosis. Radial, trilete, outline circular. Laesurae indistinct, simple, extending nearly to body margin. Ornamentation of hollow spines, up to 18 μ in length and 2–5 μ wide at base, tapering to acute tip; 30–40 spines occur about the equatorial outline; spines rarely recurved at the tips or with hollow, bulbous bases. Wall distinct, laevigate, 3–4 μ thick.

Dimensions. (10 specimens.) Over-all equatorial diameter 70–110 μ.

Holotype. Slide O3V16–3 (1). Location 35 × 117·6 (Ref. 33 × 117·1).

Description. Holotype 73 × 100 μ over-all, irregularly circular. Laesurae obscured by folds of exine, simple, extending nearly to margin. Spines hollow, up to 12 μ in length, 2–4 μ wide at base, tapering to acute tip. About 35 spines occurring about equatorial outline. Wall distinct, laevigate, 3 μ thick.

Comparison. *I. sentus* resembles *I. microhorridus* Artüz 1957. However, the latter appears to have solid spines, and the spines are considerably broader with relationship to length.

Artüz (*personal communication*) in an examination of the Springer material did not consider the specimens referable to her *I. microhorridus*. The only other described species showing any comparison to *I. sentus* is *I. brevispinosus* Neves 1961, but it differs in its stout, hollow spines with solid tips.

Genus SPINOZONOTRILETES Hacquebard 1957

Type species. *S. uncatus* Hacquebard 1957.

Spinozonotriletes procinctus sp. nov.

Plate 55, figs. 9–12

Diagnosis. Radial, trilete, roundly subtriangular. Laesurae obscure to distinct, slightly sinuous, lips to 3·5 μ wide on either side of commissure, rays extending to body margin. Spore differentiated into sculptured outer membrane and an enclosed central 'body'. Outer membrane variable from slight to very thick and extending beyond the body to form a wide flange-like structure. Spinose sculpture restricted to the distal surface and equatorial area, proximal surface very rarely displays vestigal spines. Spines variable in size and structure, 6–18 μ long and 2–4·5 μ wide at the base, densely spaced with 40–60 elements visible at the equatorial outline. Spines vary from acute, hollow to specimens with enlarged, bulbous bases with solid apices appearing as dark terminations. Spines are usually straight but recurved examples are sometimes present. The enlarged, swollen bases are usually associated with elements bearing dark, solid apices. Spines do bifurcate infrequently. Although the specific spine types generally seem to be associated with individual specimens, there are usually a few examples of all on each specimen. There is no clearcut basis for separation on spine morphology, and a gradual gradient exists from the rather simple, hollow, acute spines to the more complex, bulbous-based, solid-pointed spines. Spore size bears no significance to spine patterns as all spine types occur on spores of all dimensions. In an examination of *S. uncatus* Hacquebard, Playford (1963) considered the wide variation in spine dimensions as being between specimens rather than within specimens. Despite the variety of spines noted in the Springer specimens and the appearance of more than one form on a specimen, Playford's findings apply to them. Individual specimens do bear spines of fairly uniform size and structure, and morphological variations on individual specimens are minor and usually obscure.

Dimensions. (100 specimens.) Over-all equatorial diameter 85–140 μ. When distinct, central body diameter 65–75 μ.

Holotype. Slide O3V16–11 (7). Location 35×112·8 (Ref. 31·9×117·9).

Description. Holotype 110×110 μ over-all, roundly subtriangular. Prominent, laevigate, membranous perispore presenting appearance of flange; body distinct and 72×73 μ in diameter. Sinuous rays extending to body margin. Prominent spines distributed equatorially and distally, acute, hollow, up to 10 μ in length and to 4·5 μ wide basally; about 40 spines occurring equatorially.

Discussion. Playford (1963) has discussed the problem of terminology and morphology of the genus to a considerable extent, and he questions whether a true perispore (perine) is present. He recognized an exoexine and intexine in his discussion of *Spinozonotriletes*.

In a later work, Dettmann and Playford (1963) demonstrated that the exoexine in *S. uncatus* Hacquebard has the spinose sculpture and forms the elevated lips of the laesurae.

Comparison. The only previously described species of the genus that is anyway similar to *S. procinctus* is *S. uncatus* Hacquebard 1957. However, *S. uncatus* has a smaller number of body spines and a difference in spine distribution. *S. procinctus* is rather densely ornamented with spines, with 40–60 usually being observed about the equator, whereas Hacquebard (1957) reports about 21 spines occurring equatorially. He also recorded their occurrence both proximally and distally, while in *S. procinctus* they are restricted to the distal side and equatorial area. *S. procinctus* also seems to have a much greater development of the perispore than any other species.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Genus MOOREISPORITES Neves 1958

Type species. M. fustus Neves 1958.

Mooreisporites lucidus (Artüz) comb. nov.

Plate 56, fig. 1

1957 *Tripartites lucidus* Artüz p. 249, pl. 4, fig. 29.
1959 *Tripartites lucidus* Artüz p. 43, pl. 7, fig. 42.

Description. Radial, trilete, concavely subtriangular. Laesurae straight, over one-half of radius, slight lip development; sutures frequently split to form triangular opening with rolled edges giving false impression of thickened lips. Thickened apical pads $10 \times 20\ \mu$ to $15 \times 30\ \mu$, bearing numerous projections, which are often fused basally and branch apically, individual projections 1·5–2·5 μ wide and up to 7 μ in length. Exine thin, not exceeding 1 μ; surface laevigate.

Discussion. The spore described by Artüz (1957, 1959) from the Westphalian A as *Tripartites lucidus* agrees with the Springer representative in every respect, and Sullivan and Neves (1964) have rejected *Tripartites lucidus* from *Tripartites*.

Comparison. M. lucidus differs from previously described species on exine ornamentation features alone. *M. trigallerus* Neves 1961 has numerous scattered coni. *M. bellus* Neves 1961 also possesses scattered coni, as well as large baculae which develop extensively over the distal surface, while *M. fustus* Neves 1958 bears distal, branching baculae.

Mooreisporites trigallerus Neves 1961

Plate 56, fig. 2

Description. The thickened pads at the apices formed by fusion of the baculae range from 19–35 μ in width; they are 7–15 μ high including pad and projections. The individual baculae are 6–9 μ in length.

Dimensions. (10 specimens.) Over-all equatorial diameter 60–75 μ.

Genus CYCLOBACULISPORITES Bhardwaj 1955

Type species. C. grandiverrucosus (Kosanke) Bhardwaj 1955.

Cyclobaculisporites grandiverrucosus (Kosanke) Bhardwaj 1955

Plate 56, fig. 3

1943 *Punctatisporites grandiverrucosus* Kosanke, p. 127, pl. 3, fig. 4.
1955 *Cyclobaculisporites grandiverrucosus* (Kosanke) Bhardwaj, p. 123, pl. 1, fig. 1.

Description. Radial, trilete. Laesurae 18–21 μ in length, not exceeding two-thirds of radius; lips narrow, laesurae sometimes obscured by baculae. Margin of densely spaced baculae 1·5–2 μ high and 0·5–2 μ wide, 75–80 baculae visible about marginal periphery. Baculae of individual specimens of uniform height and of variable shapes in surface view.

Dimensions. (25 specimens.) Equatorial diameter 65–78 μ.

Discussion. A slight adjustment in size range should be noted as Bhardwaj (1955) listed 70 μ as the lowermost limit. In view of the remarkable uniformity of the baculae on Springer specimens, the baculae character to differentiate the genus seems to warrant the significance given to it by Bhardwaj. The minute baculae have uniform truncated apices, and in surface section have the unequal sizes and irregular shapes illustrated in the genotype. It affords a means of removing the spore from the meaningless heterogeneity of *Punctatisporites*.

Genus GRANDISPORA Hoffmeister, Staplin, and Malloy 1955

Type species. G. spinosa Hoffmeister, Staplin, and Malloy 1955

Grandispora echinata Hacquebard 1957

Plate 56, figs. 4, 5

EXPLANATION OF PLATE 56

All figures ×500 unless otherwise indicated.

Fig. 1. *Mooreisporites lucidus* (Artüz) comb. nov. Proximal surface; Slide O3V16–13 (A-2), location 43·8×112·8 (Ref. 32·2×117·9).

Fig. 2. *Mooreisporites trigallerus* Neves 1961. Proximal surface; Slide O3V16–13 (A-1), location 14·5×128 (Ref. 31·1×117·9).

Fig. 3. *Cyclobaculisporites grandiverrucosus* (Kosanke) Bhardwaj 1955. Proximal surface; Slide O3V16–11 (7), location 17·5×100 (Ref. 31·9×117·9).

Figs. 4, 5. *Grandispora echinata* Hacquebard 1957. 4, Tetrad; Slide O3V16–11 (7), location 23·2×125·3 (Ref. 31·9×117·9). 5, Distal surface; Slide O3V16–9 (5), location 51·7×126·9 (Ref. 32·4×118·6).

Fig. 6. *Grandispora spinosa* Hoffmeister, Staplin, and Malloy 1955. Tetrad; Slide O3V16–10 (B-1), location 42×112·5 (Ref. 32·5×117·9).

Fig. 7. *Convolutispora crassa* Playford 1962. Proximal surface; Slide O3V16–10 (A-1), location 46×122 (Ref. 29·5×118·2).

Fig. 8. *Convolutispora florida* Hoffmeister, Staplin, and Malloy 1955. Proximal surface; Slide O3V17–1 (4), location 43·8×103 (Ref. 32×119·6).

Fig. 9. *Convolutispora mellita* Hoffmeister, Staplin, and Malloy 1955. Proximal surface; Slide O3V16–4 (1), location 7·2×110·5 (Ref. 30·3×117·7).

Fig. 10. *Dictyotriletes clatriformis* (Artüz) Sullivan 1964. Slide O3V16–3 (5), location 56·2×127·8 (Ref. 33·7×118).

Description. Radial, trilete; central body enclosed by bladder and not always well defined. Laesurae not always distinct, extending to body margin, up to 38 μ in length; commissure generally visible and lips 3–4 μ wide. Body usually laevigate, rarely minutely granulose. Distal surface of spore and bladder bears small cones and spinose projections of variable dimensions and spacing. The projections in some cases consist of blunt protuberances up to 1 μ in height, 1 μ in basal diameter, and situated 1–6 μ apart. The usual ornamentation consists of tapering spines 1–3 μ long, 1–1·5 μ in basal diameter, and situated 2–6 μ apart. There are infrequent instances of spines exceeding 3 μ in length and with a slight tendency to be falcate. Rare instances existed of specimens bearing scattered spines on the proximal surface. The spores were observed frequently in tetrads, with the entire tetrad diameter ranging from 95–135 μ.

Dimensions. (25 specimens.) Over-all equatorial diameter 60–80 μ; diameter of spore body 54–60 μ.

Discussion. This species is much smaller in over-all size than *G. spinosa*, the only other described species. The body and bladder are more clearly defined in *G. spinosa*, while the laesurae are more distinct in *G. echinata*. The spinose projections of *G. spinosa* are also much larger and situated further apart. Hacquebard (1957) does not mention the distribution of the processes as being limited to the distal side, but neither is this character noted in the genotype description. In all other features it compares closely with *G. echinata*.

Other occurrences. Surface Caney formation, upper Mississippian, Johnston County. Oklahoma.

Grandispora spinosa Hoffmeister, Staplin, and Malloy 1955

Plate 56, fig. 6

Description. Radial, trilete; central body enclosed by bladder, usually well defined; bladder and body wall thin and faintly granulose. Laesurae indistinct, appear to extend to body margin. Spore body and bladder surface bear spinose projections 3–7 μ long, 1–3 μ wide at base, and 6–16 μ apart; spines usually acute but occasionally blunt, usually straight but sometimes curved. Spines are present on both proximal and distal surfaces of body and bladder but are more densely developed on distal surface. Observed more frequently in tetrads, with entire tetrad being 130–60 μ in diameter.

Dimensions. (10 specimens.) Over-all equatorial diameter 90–125 μ; diameter of spore body 70–95 μ.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; subsurface Springer formation, Anadarko Basin; subsurface Chester formation, upper Mississippian, Anadarko Basin; surface Prairie Mountain and Wildhorse Mountain formations, Jackfork group, upper Mississippian, LeFlore County, Oklahoma.

Infraturma MURORNATI Potonié and Kremp 1954
Genus CONVOLUTISPORA Hoffmeister, Staplin, and Malloy 1955

Type species. *C. florida* Hoffmeister, Staplin, and Malloy 1955.

Convolutispora crassa Playford 1962

Plate 56, fig. 7

Description. Radial, trilete, circular. Wall thick, 9–16 μ, including muri. Sculpture of sinuous, flat muri, anastomosing to form imperfect reticulum; muri 3–8 μ long, 1–3 μ high. Laesurae simple, straight, length two-thirds of spore radius.

Dimensions. (15 specimens.) Equatorial diameter 60–110 μ.

Convolutispora florida Hoffmeister, Staplin, and Malloy 1955

Plate 56, fig. 8

Description. Radial, trilete, circular to subcircular. Ornamentation of irregularly arranged, coarsely vermiculate ridges of variable shape; ridges 1–3 μ in height and 3–7 μ in width. Laesurae simple, straight, one-half to three-fourths spore radius, sometimes obscured by ornamentation.

Dimensions. (25 specimens.) Equatorial diameter 38–50 μ.

Discussion. It is admittedly difficult at times to distinguish *C. florida* from species of *Secarisporites*, especially *S. remotus* which has a comparable size range. The pronounced lobation in *Secarisporites* and the presence of a body are the best differentiation features. However, when the body outline is indistinct, identification is difficult. Further study could certainly result in the establishment of a closer relationship between the two.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Convolutispora lepida sp. nov.

Plate 57, fig. 4

Diagnosis. Radial, trilete, circular to subcircular. Laesurae simple, straight, three-fourths of spore radius, usually obscured by sculpture. Wall thick, 7–12 μ, including ridges; sculpture of closely packed, convoluted, freely anastomosing, flattened ridges. Ridges to 8 μ in height and 3–12 μ wide. Lumina irregular, up to 16 μ in length and 1–5 μ wide.

Dimensions. (20 specimens.) Equatorial diameter 50–75 μ.

Holotype. Slide O3V16–11 (6). Location 51×112·5 (Ref. 31·7×116·9).

Description. Holotype 60×60 μ, circular; laesurae approximately three-quarters radius, indistinct due to ornamentation. Wall 12 μ thick; convolute ridges to 8 μ high and 4–9 μ wide, lumina narrow and to 16 μ in length.

Comparison. Some similarity is shown to *C. crassa* Playford 1962 (p. 594, pl. 81, figs. 10–12). However, *C. lepida* does not have the imperfect reticulum characteristic of *C. crassa*, is appreciably smaller, and laesurae features are less pronounced.

Convolutispora mellita Hoffmeister, Staplin, and Malloy 1955

Plate 56, fig. 9

Description. Radial, trilete, circular outline; laesurae simple, straight, 16–25 μ long, three-fourths spore radius, frequently obscured by ornamentation. Exine 3–7 μ thick, uniformly sculptured with broad anastomosing ridges, usually flat surfaced, 2–3 μ high and 2–6 μ wide; interval between convolute ridges about 1 μ.

Dimensions. (50 specimens.) Equatorial diameter 54–80 μ.

Discussion. The only significant departure from the type description is in laesurae length. Hoffmeister, Staplin, and Malloy noted the rays as being 'slightly over one-half spore radius'. The laesurae of the Springer specimens were rather uniformly three-fourths the radius.

Convolutispora sculptilis sp. nov.

Plate 57, fig. 1

Diagnosis. Radial, trilete, circular; laesurae distinct, simple, straight, one-half to two-thirds spore radius, frequently obscured by sculpture. Wall 3–4 μ thick, uniformly sculptured with low, closely spaced, anastomosing ridges; muri not overlapping, 3–6 μ high, 2–9 μ wide. Lumina distinct, irregular in shape, ranging from rounded to elongate 4×4 μ to 3×12 μ. Equatorial margin undulate.

Dimensions. (10 specimens.) Equatorial diameter 55–75 μ.

Holotype. Slide O3V16–3 (6). Location 52·3×108·4 (Ref. 33×117·9).

Description. Holotype circular, 61×70 μ; laesurae two-thirds radius; body wall 3 μ thick; sculpture of anastomosing ridges, proximally and distally; muri 3–5 μ high and 3–9 μ wide. Distinct lumina rounded to elongate, 4×4 μ to 4×10 μ.

Convolutispora superficialis sp. nov.

Plate 57, figs. 2, 3

Diagnosis. Radial, trilete, circular to subcircular, slight marginal undulation. Wall with indistinctly defined sculpture, forming weak convolutions; the elevated portions are broad, weakly developed, with little sinuosity or ramification evident. Weakly delimited lumina usually elongate, 1–5 μ wide and 8–15 μ long; lumina very shallow, not exceeding 2 μ and usually about 1 μ in depth. Laesurae generally distinct, straight, slight lip development, length two-thirds to three-fourths spore radius. Body wall 2–6 μ, well defined.

Dimensions. (50 specimens.) Equatorial diameter 54–80 μ.

Holotype. Slide O3V16–11 (5). Location 40×128 (Ref. 32·6×117·8).

Description. Holotype circular, 78×80 μ. Sculpture of slightly elevated, poorly defined, convolutions. Lumina about 1 μ in depth, ranging from 2·5×15 μ to 5×8 μ in dimensions. Laesurae 25–27 μ in length, over two-thirds radius, slight lip development, commissure distinct. Wall distinct, 6 μ thick.

Discussion. There has been some hesitancy in assignment of this spore to *Convolutispora*. The ornamentation cannot be regarded as ridge-like processes as described by Hoffmeister, Staplin, and Malloy (1955*b*). It is more in the nature of a shallow, irregular, scalloped effect. Nevertheless, the ornamentation pattern is a convolute one. The elevated portion of the wall often covers considerable area, being measured up to sections 17×45 μ in dimension. No real anastomosing or branching occurs.

Convolutispora venusta Hoffmeister, Staplin, and Malloy 1955

Plate 57, fig. 7

Description. Radial, trilete, spherical; laesurae simple, straight, length two-thirds spore radius, occasionally four-fifths; sometimes obscured by sculpture. Wall thick, sculptured with irregular, arete ridges, some anastomosing to form irregular lumina; ridges 1–3 μ high, 2–3 μ wide at their bases.

Dimensions. (15 specimens.) Equatorial diameter 42–70 μ.

Convolutispora vermiformis Hughes and Playford 1961

Plate 57, fig. 5

Description. Radial, trilete. Coarsely rugulate sculpture of sinuous, ramifying muri; muri not intersecting and ridges rounded to flat. Lumina seldom delimited and irregular in size and shape when formed. Muri 2·5–12 μ wide and up to 8 μ in height. Laesurae

EXPLANATION OF PLATE 57

All figures ×500 unless otherwise indicated.

Fig. 1. *Convolutispora sculptilis* sp. nov. Holotype. Proximal surface; Slide O3V16–3 (6), location 52·3×108·4 (Ref. 33×117·9).

Figs. 2, 3. *Convolutispora superficialis* sp. nov. 2, Holotype. Proximal surface; Slide O3V16–11 (5), location 40×128 (Ref. 32·6×117·8). 3, Proximal surface; Slide O3V16–9 (R-2), location 43×110·2 (Ref. 33·9×119·1).

Fig. 4. *Convolutispora lepida* sp. nov. Holotype. Proximal surface; Slide O3V16–11 (6), location 51×112·5 (Ref. 31·7×116·9).

Fig. 5. *Convolutispora vermiformis* Hughes and Playford 1961. Proximal surface; Slide O3V16–9 (A-1), location 44·7×111·3 (Ref. 31×116·5).

Fig. 6. *Reticulatisporites decoratus* Hoffmeister, Staplin, and Malloy 1955. Proximal surface; Slide O3V16–9 (A-1), location 17·5×111·5 (Ref. 31×116·5).

Fig. 7. *Convolutispora venusta* Hoffmeister, Staplin, and Malloy 1955. Proximal surface; Slide O3V16–3 (5), location 43·1×125 (Ref. 33·7×118).

Figs. 8, 9. *Reticulatisporites peltatus* Playford 1962. 8, Reticulum; Slide O3V16–9 (5), location 34×121 (Ref. 32·4×118·6). 9, Proximal surface; Slide O3V17–1 (3), location 35·5×121·9 (Ref. 31×119·5).

Figs. 10, 11. *Dictyotriletes pactilis* Sullivan and Marshall 1966. 10, Proximal surface; Slide O3V16–4 (R-1), location 52·6×107·8 (Ref. 32·2×117·2). 11, Proximal surface; Slide O3V16–3 (6), location 31·1×118·3 (Ref. 33×117·9).

Fig. 12. *Dictyotriletes insculptus* Sullivan and Marshall 1966. Distal surface; Slide O3V16–9 (5), location 26·5×123·8 (Ref. 32·4×118·6).

Fig. 13. *Foveosporites futilis* sp. nov. Holotype. Proximal surface; Slide O3V16–11 (6), location 40·2×124 (Ref. 31·7×116·9).

Figs. 14, 15. *Perotriletes perinatus* Hughes and Playford 1961. 14, Proximal surface; Slide O3V17–2 (1), location 51×117·2 (Ref. 31×117.9). 15, Distal surface; Slide O3V16–3 (2), location 45·4×114·7 (Ref. 29×118).

Figs. 16, 17. *Secarisporites remotus* Neves 1961. 16, Proximal surface; Slide O3V16–9 (B-2), location 11·4×126 (Ref. 31·7×118·2). 17, Distal surface; Slide O3V17–1 (3), location 10·8×125 (Ref. 31×119·5).

simple, straight, about two-thirds of radius and usually obscured by the sculpture. Body wall 2·5–5 μ thick, excluding muri. Lumina up to 20 μ in greatest dimension.

Dimensions. (15 specimens.) Equatorial diameter 40–70 μ.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus DICTYOTRILETES (Naumova) Potonié and Kremp 1954

Type species. D. bireticulatus (Ibrahim) Potonié and Kremp 1954.

Dictyotriletes clatriformis (Artüz) Sullivan 1964

Plate 56, fig. 10

1957 *Reticulatisporites clatriformis* Artüz, p. 248, pl. 4, fig. 25*a*, *b*.
1959 *Reticulatisporites clatriformis* Artüz, p. 40, pl. 6, fig. 37*a*, *b*.
1964 *Dictyotriletes* cf. *clatriformis* (Artüz); Sullivan, p. 367, pl. 58, fig. 20; pl. 59, figs. 1, 2.

Description. Oval, trilete, rays difficult to discern. Muri about 1 μ wide and 1–2·5 μ high. Polygonal lumina 4–8·5 μ in maximum dimension.

Dimensions. (25 specimens.) Equatorial diameter 25–30 μ.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Dictyotriletes pactilis Sullivan and Marshall 1966

Plate 57, figs. 10, 11

Description. Radial, trilete, oval. Muri 1–3 μ wide and 5–12 μ high. Lumina irregularly polygonal and 8–14 μ in diameter. Laesurae indistinct, usually obscured by reticulum, simple, and length two-thirds to three-fourths spore radius. Wall, excluding muri, 2 μ thick.

Dimensions. (20 specimens.) Equatorial diameter 44–66 μ.

Discussion. Although Sullivan and Marshall (1966) did not observe trilete rays, they were definitely observed in the Springer specimens. However, measurable laesurae were very rare, and the ornamentation usually covered them.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnson County, Oklahoma.

Dictyotriletes insculptus Sullivan and Marshall 1966

Plate 57, fig. 12

Description. Radial, trilete, spherical. Laesurae indistinct, straight, slightly over one-half spore radius; simple, usually obscured by muri. Sculptured with delicately developed muri 1–2 μ wide enclosing polygonal to irregularly rounded lumina 6–20 μ in greatest diameter. Muri 2–3 μ high, translucent, and projecting in a manner to give the appearance of a narrow, membranous equatorial flange. Spore wall thin, 2 μ (exclusive of muri); laevigate except for rare and scattered granules.

Dimensions. (20 specimens.) Equatorial diameter 39–60 μ.

Discussion. The loose reticulum is usually delimited into six to eight lacunae in each observed plane, and in undistorted specimens orientation results in a central polygonal lacuna with muri radiating outwards towards the spore periphery. There also appears to be a lesser number of lacunae proximally than on the distal side. *R. areolatus* Guennel 1958 is similar in general appearance but has a significantly different size range, as well as much smaller and more numerous lacunae.

Genus RETICULATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. R. reticulatus Ibrahim 1933.

Reticulatisporites decoratus Hoffmeister, Staplin, and Malloy 1955

Plate 57, fig. 6

Description. Radial, trilete, subcircular in outline. Laesurae indistinct, simple, length about two-thirds spore radius, usually obscured by muri. Muri high and membranous, presenting appearance of equatorial flange up to 12 μ in width; muri thin, 1–3·5 μ. Lacunae irregular, 10–20 μ in longest diameter. Exine (excluding muri) 1·5–2·5 μ thick, occasionally with scattered granules.

Dimensions. (10 specimens.) Equatorial diameter 50–70 μ.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Reticulatisporites peltatus Playford 1962

Plate 57, figs. 8, 9

Description. Laesurae distinct, extending almost to body margin, lips thin. Reticulum formed of rounded muri 3–8 μ wide and 3–4 μ high; polygonal lumina irregular and up to 17 μ in longest dimension. Peltate processes originate at junctions of muri; processes are 5–13 μ long and up to 10 μ wide at expanded apices. Body wall 2 μ thick. Reticulum more regular and lumina smaller on distal side, frequently loosely arranged proximally.

Dimensions. (25 specimens.) Equatorial diameter including processes 63–68 μ, excluding processes 45–65 μ.

Discussion. It is quite likely that *Raistrickia boleta* Staplin 1960 and *R. peltatus* are identical. However, the reticulate nature of the spore makes *Reticulatisporites* the more suitable repository, and the excellence of Playford's illustrations and descriptions permits a closer comparison with *R. peltatus*. Neither Staplin nor Playford mention the shape of the peltate processes when the expanded tips were viewed in a plane perpendicular to the body. In the Springer specimens the apices are triangular (Pl. 57, fig. 8), and a similar configuration is evident in Playford's illustrated specimens.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; subsurface Mississippian Chainman formation, Standard Continental Hayden Creek Unit No. 1 well, White Pine County, Nevada.

Genus FOVEOSPORITES Balme 1957

Type species. *F. canalis* Balme 1957.

Foveosporites futilis sp. nov.

Plate 57, fig. 13

Diagnosis. Radial, trilete, roundly triangular. Laesurae distinct, straight, length two-thirds to four-fifths spore radius. Commissure faint, but distinct at proper focus, no lip development. Spore coat densely ornamented with small pits 1–1·5 μ in diameter and spaced 1–3 μ apart. Spore wall distinct, 3 μ thick.

Dimensions. (10 specimens.) Equatorial diameter 42–50 μ.

Holotype. Slide O3V16–11 (6). Location 40·2 × 124 (Ref. 31·7 × 116·9).

Description. Holotype 45 × 46·5 μ, roundly triangular; laesurae 15–21 μ long, three-fourths to four-fifths radius; wall 3 μ thick, covered with closely spaced circular pits 1–1·5 μ in diameter.

Discussion. This genus was established by Balme (1957) for circular or roundly triangular trilete spores with sculpture of pits or short channels irregularly distributed.

Comparison. *F. futilis* bears a decided resemblance to *Converrucosisporites sulcatus* (Wilson and Kosanke) Potonié and Kremp 1955. However, the Springer spore is definitely ornamented with circular, regularly spaced pits. Examination of numerous specimens of *C. sulcatus* from various localities and Pennsylvanian horizons revealed it to be quite verrucose-reticulate. Some conjecture exists over this spore as Guennel (1958, p. 61) has noted, but it is not pitted in the manner of *F. futilis*.

Genus SECARISPORITES Neves 1961

Type species. *S. lobatus* Neves 1961.

Secarisporites remotus Neves 1961

Plate 57, figs. 16, 17

Description. Radial, trilete, circular to subcircular. Ornamentation of irregular ridges. Peripheral lobes of varying dimensions extend to 10 μ beyond body wall and are up to 20 μ in width, lobes sometimes overlapping and deeply incised. Body distinct, 20–30 μ in diameter. Laesurae thin, straight, largely obscured by ornamentation.

Dimensions. (25 specimens.) Equatorial diameter 35–60 μ.

Discussion. The authors are in agreement with Neves' (1961, p. 260) distinction of the genus from *Convolutispora*. The body outline is usually easily discerned in the Springer specimens, and the peripheral rim formed by the lobes is quite distinct from the convolute ornamentation of *Convolutispora*.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus RETICULATASPORITES (Ibrahim) Potonié and Kremp 1954

Type species. *R. facetus* Ibrahim 1933.

Reticulatasporites lacunosus sp. nov.

Plate 58, figs. 1, 2

Diagnosis. Spores radial, laesurae not visible. Sculptured with strongly developed muri 1·5–4·5 μ in width, enclosing polygonal to irregularly shaped lumina ranging from 3·5×3·5 μ to 10×15 μ. Muri 3·5–7 μ high, occasionally muri terminated by slightly peltate enlargement. Spore wall 12–15 μ thick including height of muri.

Dimensions. (15 specimens.) Equatorial diameter 115–65 μ.

Holotype. Slide O3V16–11 (7). Location 48·6×116·2 (Ref. 31·9×117·9).

Description. Holotype spherical, 144×156 μ in diameter; laesurae not evident; deeply

EXPLANATION OF PLATE 58

All figures ×500 unless otherwise indicated.

Figs. 1, 2. *Reticulatasporites lacunosus* sp. nov. 1, Holotype. Slide O3V16–11 (7), location 48·6×116·2 (Ref. 31·9×117·9). 2, Slide O3V16–10 (2), location 36·5×119 (Ref. 53×117·7).

Figs. 3, 4. *Tripartites dubitalis* sp. nov. 3, Holotype. Proximal surface; Slide O3V17–1 (5), location 44·8×127·8 (Ref. 32×119). 4, Proximal surface; Slide O3V17–1 (4), location 16·5×121·2 (Ref. 32×119·6).

Fig. 5. *Tripartites vetustus* Schemel 1950. Proximal surface; Slide O3V16–13 (A-1), location 44·6×114·2 (Ref. 31·1×117·9).

Fig. 6. *Ahrensisporites irroratus* sp. nov. Holotype. Proximal surface; Slide O3V17–1 (3), location 34·5×112 (Ref. 31×119·5).

Fig. 7. *Scutulum pusillum* sp. nov. Holotype. Proximal surface; Slide O3V16–9 (A-1), location 27·5×112 (Ref. 31×116·5).

Fig. 8. *Lycospora brevijuga* Kosanke 1950. Proximal surface; Slide O3V16–3 (1), location 12·2×107·5 (Ref. 33×117·1).

Figs. 9, 10. *Lycospora nitida* (Horst) Potonié and Kremp 1955. 9, Proximal surface; Slide O3V17–1 (4), location 19×126·8 (Ref. 32×119·6). 10, Proximal surface; Slide O3V16–11 (6), location 49·8×120 (Ref. 31·7×116·9).

Figs. 11, 12. *Lycospora noctuina* Butterworth and Williams 1958. 11, Distal surface; Slide O3V16–13 (B-1), location 27·3×119·2 (Ref. 31·9×117·2). 12, Proximal surface; Slide O3V16–13 (B-1), location 48·9×121·5 (Ref. 31·9×117·2).

Fig. 13. *Lycospora pseudoannulata* Kosanke 1950. Proximal surface; Slide O3V16–3 (5), location 55×111·9 (Ref. 33·7×118).

Fig. 14. *Lycospora uber* (Hoffmeister, Staplin, and Malloy) Staplin 1960. Proximal surface; Slide O3V16–13 (B-1), location 42×123·1 (Ref. 31·9×117·2).

Figs. 15, 16. *Rotaspora fracta* Schemel 1950. 15, Proximal surface; Slide O3V16–9 (B-1), location 8·6×111 (Ref. 30·7×116·7). 16, Proximal surface; Slide O3V16–13 (5), location 23·6×116 (Ref. 31·3×118·3).

Fig. 17. *Simozonotriletes intortus* var. *polymorphosus* Sullivan 1958. Proximal surface; Slide O3V16–11 (6), location 33×110·2 (Ref. 31·7×116·9).

sculptured with muri 3–5 μ wide and up to 3·5 μ high, enclosing lumina ranging from 2×3·5 μ to 5·5×7 μ. Wall distinct, 15 μ wide including muri.

Discussion. The meshlike network of the reticulum appears to be more comparable to wall features described for *Reticulatasporites*, rather than the enclosing reticulum characteristic of *Dictyotriletes* and *Reticulatisporites*. The occasional peltate muri terminations are similar to those in *Reticulatisporites peltatus* and *Raistrickia boleta* to a limited degree, but these forms do possess a loosely enclosing reticulum. *Retialetes* of Staplin (1960) is alete but is ellipsoidal, generally ruptured, and with a finer reticulum without the exceedingly thickened exine. *Maculatasporites* (Tiwari 1964) seems to be comparable to *R. lacunosus* in features of reticulum and exine, although its size range is considerably smaller. However, age difference of sediments is great enough to warrant questioning such a comparison, and Tiwari's differentiation from *Reticulatasporites* on muri features does not seem justified in our opinion.

Subturma PERINOTRILETES Erdtman 1947
Genus PEROTRILITES (Erdtman) ex Couper 1953

Type species. *P. granulatus* Couper 1953.

Perotrilites perinatus Hughes and Playford 1961

Plate 57, figs. 14, 15

Description. Radial, trilete, circular. Perispore thin, hyaline, loose about spore body and extending beyond the spore margin 1·5–3 μ. Elements of reticulum not exceeding 1 μ in width.

Dimensions. (25 specimens.) Diameter 42–65 μ.

Discussion. The sporotype was suggested by Erdtman (1947) for fossil trilete spores, less than 200 μ, with a distinct perine or perisporium. Although a form genus and established by Couper for Jurassic spores, Hughes and Playford (1961) made use of it for their assignment of lower Carboniferous spores. Jansonius (1962) suggested *P. perinatus* to be synonymous with *Proprisporites rugosus*. This seems to be a rather vague comparison and without reliable evidence.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Genus VELAMISPORITES Bhardwaj and Venkatachala 1962

Type species. *V. rugosus* Bhardwaj and Venkatachala 1962.

Discussion. Well-preserved, entire specimens of this genus bear a superficial resemblance to *Convolutispora*. However, the sculpture of *Convolutispora* consists of anastomosing rugulae which are a part of the exine, whereas in *Velamisporites* the convolutions are a feature of the perisporal membrane. Due to the loosely enveloping perispore and its characteristic of fragmenting off, the true diameter is often difficult to ascertain. However, the holotype of *V. vermiculatus* (Pl. 59, fig. 1) probably represents an intact specimen. Small specimens such as *V. descretus* (Pl. 59, fig. 3) possibly illustrate a collapsed perispore from which the body has been lost. There is a sizeable variation in the included spore bodies, but they are numerous and the clinging remnants of the membrane and its characteristic convolutions renders identification easy.

Velamisporites descretus Bhardwaj and Venkatachala 1962

Plate 59, figs. 2, 3

Dimensions. (10 specimens.) Equatorial diameter (including perispore) 75–125 μ.

Discussion. This species is relatively rare in the Springer formation. Bhardwaj and Venkatachala (1962) gave a size of 90–110 μ in the original diagnosis. Other than the difference in size range, the Springer specimens compare with their description in all respects. Spore type 4 of Love (1960) is probably this species with much of its perisporal membrane removed.

Velamisporites vermiculatus sp. nov.

Plate 59, fig. 1

Diagnosis. Spore circular, trilete, covered with dense, perisporal membrane which is heavily ornamented with vermiculate thickenings of variable width and length. Spore body wall 2–4 μ thick and laevigate. Laesurae difficult to discern due to perispore but is about two-thirds distance of radius, with little lip development, and without visible commissures. Perisporal membrane generally laevigate although rare specimens possess some granulose ornamentation; convolutions show no regular pattern of development, often intertwining and infrequently forming loosely knit reticulations; convolutions range in width from 2–10 μ (4–6 μ, median).

Dimensions. (25 specimens.) Equatorial diameter (including perispore) 115–200 μ. Spore body 65–140 μ.

Holotype. Slide O3V16–5 (1). Location 9·8 × 107·3 (Ref. 32·5 × 118).

Description. Holotype circular, 180 × 190 μ in diameter. Central body obscured by perispore, trilete indistinct. Laevigate perispore covered with thick irregular convolutions 8–10 μ in width; the rope-like convolutions measure up to 65 μ in length without divisions, but an accurate determination of length is difficult.

Comparison. There is a similarity to *V. rugosus* Bhardwaj and Venkatachala 1962. However, that species possesses a definite and uniform granulose perisporal covering. The perispore in *V. vermiculatus* encloses the spore body more loosely, and the thickened, vermiculate convolutions are decidedly larger and more pronounced. The authors have observed specimens of *V. rugosus* in Caney age strata of Oklahoma, and the distinction between the two species is readily apparent.

Other occurrences. Subsurface Springer formation of the Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; New Livingston Coal, Gizzard formation, lower Pennsylvanian, Rockcastle County, Kentucky; subsurface Hartselle formation, upper Mississippian, Warrior Basin, Alabama. In addition, *V. rugosus* has been observed from the surface Caney formation, upper Mississippian, Johnston County, Oklahoma.

Turma ZONALES (Bennie and Kidston) R. Potonié 1956
Subturma AURITOTRILETES Potonié and Kremp 1954
Infraturma AURICULATI (Schopf 1938) Potonié and Kremp 1954
Genus TRIPARTITES Schemel 1950

Type species. T. vetustus Schemel 1950.

Tripartites dubitalis sp. nov.

Plate 58, figs. 3, 4

Diagnosis. Radial, trilete. Laesurae simple, 12–14 μ long, extending to at least four-fifths body radius. Body punctate proximally and distally; proximal surface marked by rows of coarser punctations bordering laesurae. Outline subtriangular with concave sides and apices with dark, well-defined auriculae. Auriculae appear solid in well preserved specimens, not connected interradially. Auriculae extend 6–11 μ beyond apices, plicated or fluted in weathered specimens, with blunt spines projecting up to 3·5 μ.

Dimensions. (10 specimens.) Equatorial diameter 43–49 μ. Spore body diameter 27–32 μ.

Holotype. Slide O3V17–1 (5). Location 44·8 × 127·8 (Ref. 32 × 119).

Description. Holotype 45 × 45 μ, body 27 × 27·5 μ. Auriculae extending 9–11 μ beyond apices, slightly fluted and projecting rodlets faintly visible. Laesurae 12 μ long, about four-fifths body radius. Wall punctate proximally and distally, punctations dense along laesurae.

Comparison. This species does resemble *T. vetustus* and is within the prescribed size limits as recognized in the Springer. However, the narrow, almost solid auriculae are distinctive, and the punctations of the spore wall are a constant feature in *T. dubitalis* but not of *T. vetustus*. The markedly coarser rows of punctations along the laesurae are also unique for this species.

Tripartites vetustus Schemel 1950

Plate 58, fig. 5

Description. Radial, trilete. Laesurae simple, length 10–14 μ or two-thirds to three-fourths body radius. Body usually laevigate but sometimes minutely punctate, outline subtriangular with concave sides. Prominent auriculae extend beyond apices 10–13 μ, not connected interradially. Radial portion of auriculae usually fluted or lobed, sometimes appear entire but outer portion usually membranous; in weathered or over-macerated specimens five to six blunt processes are visible.

Dimensions. (25 specimens.) Equatorial diameter 48–60 μ. Spore body diameter 29–34 μ.

Discussion. The described size range of *T. vetustus* is 30–40 μ, but this is the sole difference between the Springer forms and previously described occurrences. In view of the impossibility of making a distinction on any feature other than size, it is felt that they are conspecific and represent an extension of the size limits.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus AHRENSISPORITES Potonié and Kremp 1954

Type species. A. guerickei (Horst) Potonié and Kremp 1954.

Ahrensisporites irroratus sp. nov.

Plate 58, fig. 6

Diagnosis. Radial, trilete, outline triangular. Sides straight or slightly convex. Laesurae simple, extending nearly to body margin. Prominent distal kyrtome nearly continuous. Apical auriculae $6\times15\,\mu$ to $8\times30\,\mu$. Body ornamented proximally and distally with rounded granules 1–2 μ in diameter and 1 μ in height.

Dimensions. (10 specimens.) Equatorial diameter 40–60 μ.

Holotype. Slide O3V17–1 (3). Location $34{\cdot}5\times112$ (Ref. $31\times119{\cdot}5$).

Description. Holotype $44\times45\,\mu$. Auriculae $6\times15\,\mu$ to $7{\cdot}5\times19\,\mu$. Laesurae simple, 18–19 μ long, extending nearly to body margin. Distal kyrtome 6 μ in height, nearly continuous, extending 38 μ in longest dimension. Granulations 1 μ in height and average 1·5 μ in diameter; situated 1–2 μ apart.

Discussion. In a few specimens the concentration of granulations appeared to be slightly more dense along the rays, but this was not a consistent feature. Among previously described species, *A. beeleyensis* Neves 1961 is of similar size but has kyrtomes of blunt cones forming a dentate structure, while *A. guerickei* var. *ornatus* Neves 1961 is considerably larger and ornamented with irregular, wart-like thickenings. Horst's (1955) fig. 61 of *A. guerickei* resembles *A. irroratus* in ornamentation. However, in his specific diagnosis Horst specifies a 'smooth' body for *A. guerickei.*

Genus SCUTULUM gen. nov.

Type species. S. pusillum sp. nov.

Diagnosis. Radial, trilete, convexly subtriangular, laevigate. Bearing subtriangular to rounded platelet on the proximal surface; platelet with three radiating arms or projections, terminating at the apices. Laesurae distinct, oriented on the proximal platelet, extending three-fourths to two-thirds distance of spore radius. Distal surface unornamented. Spore wall thin.

Scutulum pusillum sp. nov.

Plate 58, fig. 7

Diagnosis. Radial, trilete; convexly subtriangular, laevigate. Proximal side bearing subtriangular to rounded platelet with projecting arms terminating at apices. Trilete oriented on the central platelet with laesurae concurrent with platelet arms. Platelet dimensions 16–27 μ; radiating arms 5–10 μ long, 4–7 μ in width. Laesurae 11–15 μ long, extending three-fifths to two-thirds distance of spore radius. Commissure distinct, slight lip development. Distal side unornamented. Spore wall thin, not exceeding 1 μ.

Dimensions. (6 specimens.) Equatorial diameter 31–47 μ.

Holotype. Slide O3V16–9 (A–1). Location $27{\cdot}5\times112$ (Ref. $31\times116{\cdot}5$).

Description. Holotype subtriangular with slightly convex margins and rounded apices. Over-all diameter 31·5×34·5 μ; central platelet 16×19 μ, radiating arms 4–5 μ wide and 9–10 μ long. Laesurae prominent, 9·5–12 μ long, three-fifths of the spore radius.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma. The only additional record of this spore known to the authors is from the subsurface Mississippian Chainman formation in the Standard Continental Hayden Creek Unit No. 1 well, White Pine County, Nevada. The authors are indebted to Mr. Virgil D. Wiggins for this material, which was used by Wiggins for his prize-winning 1960 AAPG–SEPM contribution (Wiggins 1961).

Genus TANTILLUS gen. nov.

Type species. T. triquetrus sp. nov.

Diagnosis. Radial, trilete, triangular with concave sides, laevigate to granulose. Laesurae simple, not always visible, extending two-thirds of spore radius. Radial extremities rounded to gently pointed. Triangular thickening on distal side more concave than spore body. It expands at its apices forming shoulders which spread to equal the width of the body. This thickening is the identifying characteristic of the genus and is often developed to different degrees at the various apices on a single specimen. The apices of the spore body extend past the apices of the distal thickening and give the impression of swollen auriculae. Spore wall very thin.

Tantillus triquetrus sp. nov.

Plate 65, figs. 4, 5

Diagnosis. Radial, trilete, triangular with concave sides, laevigate to minutely granulose. Laesurae 9–12 μ long extending two-thirds spore radius. Radial extremities rounded to gently pointed. Triangular thickening on the distal side more concave than spore body, forming apical shoulders which spread to equal the width of the body. Shoulders are 4–13 μ across and terminate in a peltate, paterate, or T-shaped manner, often displaying this variety on a single specimen.

Dimensions. (35 specimens.) Equatorial diameter 16·5–25 μ.

Holotype. Slide O3V16–11 (6). Location 40·8×110·1 (Ref. 31·7×116·9).

Description. Holotype 18×18 μ, radial, trilete, triangular with concave sides, laevigate. Laesurae 9 μ long, extending two-thirds distance of spore body radius. Radial extremities rounded. The distal thickening expands to 9 μ across with one paterate and two T-shaped apices. Spore wall very thin.

Discussion. The genus bears a resemblance to *Stellisporites* Alpern, Girardeau and Trolard 1958, but their genus evidently did not possess the distal thickening or the distinctive apical terminations.

Other occurrences. Subsurface Springer formation of the Anadarko Basin, blue shale above Lily Coal, Breathitt formation, Whitley County, Kentucky; Barnsley Coal, southern Pennines, England. The Barnsley Coal is an exchange sample received from Dr. Roger Neves; the Barnsley Coal and the Kentucky blue shale are both Westphalian B age.

Subturma ZONOTRILETES Waltz 1935
Infraturma CINGULATI (Potonié and Klaus) Dettmann 1963

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

Type species. L. micropapillata (Wilson and Coe) Schopf, Wilson, and Bentall 1944.

Lycospora brevijuga Kosanke 1950

Plate 58, fig. 8

1950 *Lycospora brevijuga* Kosanke, p. 44, pl. 10, fig. 5.
1957 *Lycospora subjuga* Bhardwaj, p. 127, pl. 25, figs. 84–86.
1962 *Lycospora brevijuga* Kosanke; Piérart, p. 104, pl. F, figs. 32–34.

Description. Radial, trilete, subtriangular. Laesurae straight, distinct, extending to body margin; very slight lip development, commissures distinct. Body minutely punctate, with scattered apical papillae. Very small flange development, not exceeding 1 μ in width.

Dimensions. (20 specimens.) Over-all equatorial diameter 25–40 μ.

Lycospora nitida (Horst) Potonié and Kremp 1955

Plate 58, figs. 9, 10

1955 *Lycospora nitida* (Horst) Potonié and Kremp *in* Horst p. 181, pl. 24, fig. 81.
1956 *Lycospora (Triletes) nitida* (Horst) Potonié and Kremp; Potonié and Kremp, p. 101.
1957 *Simozonotriletes trilinearus* Artüz; Artüz p. 251, pl. 5, fig. 36 *a*, *b*.
1957 *Bellispores bellus* Artüz; Artüz p. 255, pl. 7, fig. 49 *a*, *b*.
1958 *Lycospora nitida* (Horst) Potonié and Kremp; Butterworth and Williams, p. 375, pl. 3, fig. 9.
1959 *Simozonotriletes trilinearus* Artüz; Artüz, p. 46, pl. 8, fig. 51 *a*, *b*.
1959 *Bellispores bellus* Artüz; Artüz p. 52, pl. 10, fig. 64 *a*, *b*.
1962 *Bellispores*; Venkatachala and Beju p. 146, pl. 2, figs. 5–7.

Description. Radial, subtriangular to triangular, margins linear to concave; equatorial flange moderate to strongly dentate and about 4 μ wide. Trilete, laesurae extend to margin of body, lips distinct and 3–7 μ wide; wall thickness 1 μ, minutely reticulate proximally and distally.

Dimensions. (25 specimens.) Over-all equatorial diameter 30–42 μ.

Discussion. Artüz's (1957) establishment of *Lycospora nitida* is invalid, being a later homonym, since Horst (1955) had legitimately applied the name to a morphologically different spore. In addition, Artüz's (1957) application of *L. nitida* was to a spore which appears to be most nearly comparable to *L. noctuina* (*sensu* Butterworth and Williams). On the other hand, her *Bellispores* is rather obviously conspecific with *Lycospora nitida* Horst 1955. Similarly, Venkatachala and Beju (1962, p. 147) also overlooked or ignored Horst's earlier treatment when they identified *Bellispores*. In a more recent publication Sullivan (1964*a*) has described *B. bellus*, distinguishing it from *L. nitida* by the greater concavity of the radial thickenings. However, such a variety of these thickenings appear to be present in the Springer specimens that any such differentiation is impossible.

It is debatable whether this spore actually belongs in *Lycospora*, and Butterworth and Williams (1958) earlier expressed their doubts. It does differ, especially in its labial structure, from the known species definitely associated with the arborescent lycopods. However, much is still unknown about lycopod spore associations and Potonié and Kremp (1956*a*) did include *L. nitida* within the emended generic framework. Though the generic designation may seem inappropriate, its rejection is not advisable until more light can be shed on the spore's affinity.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; Game Refuge Sandstone, upper Jackfork formation, Le Flore County, Oklahoma.

Lycospora noctuina Butterworth and Williams 1958

Plate 58, figs. 11, 12

1957 *Lycospora nitida* Artüz; Artüz p. 250, pl. 5, fig. 34 *a*, *b*.
1958 *Lycospora noctuina* Butterworth and Williams, p. 376, pl. 3, figs. 14, 15.
1959 *Lycospora nitida* Artüz; Artüz p. 45, pl. 7, fig. 48 *a*, *b*.

Description. Radial, trilete, convexly subtriangular. Laesurae distinct, straight, length equal to body radius; distinct lips 1·5–2 μ in width. Cingulum 3–7 μ wide, two zones often evident with inner area solid and outer zone membranous and with minute perforations often present. Central body ornamented with prominent projections of varying sizes and shapes, ranging from large granules to obervermiculate ridges.

Dimensions. (50 specimens.) Over-all diameter 30–40 μ.

Discussion. Butterworth and Williams (1958) noted that the cingulum width roughly equals the radius of the central area. In the Springer specimens the cingulum width more nearly attains about one-half the radius of the spore body, and this actually appears to be the case with specimens figured in the original description by Butterworth and Williams (pl. 3, figs. 14, 15). Our specimens also display a distinct undulation of the outer edge of the cingulum, which seems to be characteristic. There is also considerable variation in the shape and the distribution of the wall ornamentation, which is the chief distinguishing feature of the species. It varies from granules of 1 μ in diameter to oval and rectangular prominences of 4–5 μ dimensions. The obervermiculate ridges are 1–3·5 μ in width and of varying lengths. We have observed them in patterns such as $3{\cdot}5 \times 6{\cdot}5\ \mu$, $1{\cdot}5 \times 8{\cdot}5\ \mu$, $2 \times 9\ \mu$, and $1{\cdot}5 \times 15\ \mu$. Specimens may range from those with little degree of vermiculation to almost dense convolutions, and it was also observed that when there was a difference in distal and proximal ornamentation, the greater degree of ornamentation and vermiculation occurred on the distal surface. This spore is almost certainly the same one that Artüz (1957, 1959) assigned to *L. nitida*. It is quite probable that her *Lycospora paulula* is synonymous with *L. noctuina*. In any case her assignment is not valid as pointed out in our treatment of *L. nitida*. *L. noctuina* is one of the more numerous and easily recognized entities occurring in the Springer assemblages, and it is especially noteworthy in samples O3V16–4 and O3V16–9.

Other occurrences. Subsurface Springer formation, Anadarko Basin; subsurface Chester formation, upper Mississippian, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; surface Prairie Mountain and Wildhorse Mountain formations, Jackfork group, Ouachita Mts., Oklahoma; Livingston Coal, Gizzard formation, Rockcastle County, Kentucky; Stearns #1 Coal, Gizzard formation, McCreary County, Kentucky.

Lycospora pseudoannulata Kosanke 1950

Plate 58, fig. 13

1950 *Lycospora pseudoannulata* Kosanke, p. 45, pl. 10, fig. 7.
1955 *Cirratriradites pseudoannulatus* (Kosanke) Hoffmeister, Staplin, and Malloy, p. 383, pl. 36, fig. 25.
1956 *Lycospora pseudoannulata* Kosanke; Potonié and Kremp, p. 103, pl. 17, figs. 345, 346.

Description. Radial, trilete, subtriangular. Laesurae distinct, straight, length equal to body radius, lips and commissure prominent. Body granulose, wall 2 μ thick. Cingulum up to 5 μ in width, laevigate, with numerous perforations.

Dimensions. (25 specimens.) Equatorial diameter 30–37 μ.

Lycospora uber (Hoffmeister, Staplin, and Malloy) Staplin 1960

Plate 58, fig. 14

1955 *Cirratriradites uber* Hoffmeister, Staplin, and Malloy, p. 383, pl. 36, fig. 24.
1957 *Cirratriradites uber* Hoffmeister, Staplin, and Malloy; Hacquebard and Barss, p. 39, pl. 5, fig. 11.
1960 *Lycospora uber* (Hoffmeister, Staplin, and Malloy) Staplin, p. 20, pl. 4, figs. 13, 17, 18, 20.
1963 *Lycospora uber* (Hoffmeister, Staplin, and Malloy) Staplin; Playford, p. 636, pl. 89, figs. 16, 17.

Description. Radial, trilete, convexly subtriangular. Laesurae straight, distinct, extending to body margin, lips prominent. Body finely granulose to slightly verrucose. Flange 2–5 μ in width, laevigate, usually perforated and ragged in appearance.

Dimensions. (25 specimens.) Equatorial diameter 32–42 μ.

Genus ROTASPORA Schemel 1950

Type species. R. fracta Schemel 1950.

Rotaspora fracta Schemel 1950

Plate 58, fig. 15, 16

Description. Radial, trilete; body subtriangular with interradial margins concave. Cingulum 5–7·5 μ wide interradially and 1–2 μ wide at apices; thickened at periphery to form narrow rim. Laesurae extending nearly to body margin, 12–15 μ long; commissure distinct, lips narrow, not exceeding 1 μ in width. Surface laevigate.

Dimensions. (25 specimens.) Over-all diameter 28–35 μ. Body diameter 25–33 μ.

Discussion. The Springer specimens agree with previous descriptions of the species in all details except cingulum width, where it exceeds most published measurements. However, Butterworth and Williams (1958, fig. 19) indicate an interradial width of about 7 μ, which compares with the Springer spores.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus SIMOZONOTRILETES Potonié and Kremp 1954

Type species. S. intortus (Waltz) Potonié and Kremp 1954.

Simozonotriletes intortus var. *polymorphosus* Sullivan 1958

Plate 58, fig. 17; text-fig. 3

Description. Spores triangular in equatorial plane with sides straight to slightly concave. Apices rounded, thickened, sometimes terminating in minute bosses. Cingulum continuous along sides in interradial region and differentiated into two zones; inner zone dark, thickened, 3–5 μ wide, expanding at the apices into pad-like valvae; outer zone light, membranous in appearance, 2–3 μ in width, restricted largely to interradial region and usually not projecting beyond the apical valvae, rarely the outer zone will encircle the valvae to a width not exceeding 1 μ. Laesurae distinct, length exceeding three-fourths of spore radius, well-developed lips 1·5 μ wide. Body wall 1 μ wide, laevigate to finely punctate, punctations usually restricted to outer margin of laesurae.

TEXT-FIG. 3. *Simozonotriletes intortus* var. *polymorphosus* Sullivan 1958. Proximal surface; slide O3V16–11 (6), location 54·5 × 125 (Ref. 31·7 × 116·9).

Dimensions. (20 specimens.) Equatorial diameter 30–42 μ. Body proper 18–24 μ in diameter.

Discussion. The minute projections of the apices do not exceed 2 μ in length and are not a consistent feature. Very few specimens were observed with all three valvae so ornamented, and perhaps one-half of the specimens observed did not possess them at all. Sullivan (1958) has illustrated a wide variation of differences in *Simozonotriletes*. These would ordinarily result in separation into different genera, were it not for his demonstrating such a continuity in variational patterns that it is impossible to even differentiate species. He noted several infraspecific categories, which possessed an interradial cingulum of two zones. In each instance the bizonate cingulum consisted of an outer dark and an inner light zone. The occurrence of the outer light zone in the Springer specimens is the only significant difference from Sullivan's observations. He established *S. intortus* var. *polymorphosus* to include a very wide variation. Even though the Springer specimens are considerably smaller than the limits he assigned and the cingulum zonation differs, assignment appears most practical since the diversity of morphological types

Sullivan demonstrated for the genus does not allow for confident assignment to new taxon status on the basis of so few dissimilarities.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Genus DENSOSPORITES (Berry) Butterworth, Jansonius, Smith, and Staplin 1964

Type species. D. covensis Berry 1937.

Remarks. The morphologic spore types included within the 'densospores' contain a number of perplexing problems. Playford (1962) recognized *Anulatisporites* as distinct from *Densosporites*, but he seemed to base much of his opinion on the uncompleted appraisal the densospores were receiving by the International Commission for the Microflora of the Palaeozoic. The subsequent opinion of the C.I.M.P. working group No. 2 (Butterworth *et al.* 1964) and of Staplin and Jansonius (1964) resulted in an emendation of *Densosporites* and rejection of *Anulatisporites*. This interpretation is accepted and is utilized in the assignment of *Densosporites velatus* sp. nov.

Densosporites velatus sp. nov.

Plate 59, figs. 4, 5

Diagnosis. Spores radial, subtriangular to circular. Laesurae distinct, straight, extending three-fourths of body radius; commissure distinct, very slight lip development. Body minutely granulose proximally and distally at high magnification. Cingulum undifferentiated, laevigate. Spore originally enclosed within perisporal membrane, fragments of the perispore adhering to specimens.

Dimensions. (25 specimens.) Over-all diameter 65–75 μ. Diameter of body 36–50 μ. Cingulum 8–16 μ wide.

EXPLANATION OF PLATE 59

All figures ×500 unless otherwise indicated.

Fig. 1. *Velamisporites vermiculatus* sp. nov. Holotype. Slide O3V16–5 (1), location 9·8×107·3 (Ref. 32·5×118).

Figs. 2, 3. *Velamisporites descretus* Bhardwaj and Venkatachala 1962. 2, Slide O3V16–10 (B-2), location 13×107·5 (Ref. 32×117·3). 3, Perispore; Slide O3V16–5 (1), location 43·4×107 (Ref. 32·5×118).

Figs. 4, 5. *Densosporites velatus* sp. nov. 4, Holotype. Proximal surface; Slide O3V17–2 (1), location 48×115·9 (Ref. 31×117·9). 5, With perispore; Slide O3V17–1 (4), location 19·5×115 (Ref. 32×119·6).

Fig. 6. *Densosporites aculeatus* Playford 1963. Proximal surface; Slide O3V16–3 (1), location 25×113 (Ref. 33×117·1).

Fig. 7. *Densosporites irregularis* Hacquebard and Barss 1957. Proximal surface; Slide O3V16–13 (A-1), location 50·4×109·5 (Ref. 31·1×117·9).

Fig. 8. *Densosporites rarispinosus* Playford 1963. Proximal surface; Slide O3V16–3 (6), location 18·8×125·1 (Ref. 33×117·9).

Fig. 9. *Densosporites hispidus* sp. nov. Holotype. Proximal surface; Slide O3V17–1 (4), location 11×114·4 (Ref. 32×119·6).

Figs. 10, 11. *Densosporites variabilis* (Waltz) Potonié and Kremp 1956. 10, Showing pyriform pits; Slide O3V16–13 (6), location 47×121·5 (Ref. 32·8×119·5). 11, Slide O3V16–14 (5), location 29×113·5 (Ref. 32·3×117·6).

Holotype. Slide O3V17–2 (1). Location 48 × 115·9 (Ref. 31 × 117·9).

Description. Holotype 65 × 70 μ over-all. Body diameter 36 × 40 μ. Cingulum 14–16 μ wide, laesurae extending four-fifths distance of body radius, commissure distinct, lips narrow; perispore remnants forming reticulum over entire specimen.

Discussion. The presence of a perispore or perine in mature spores is characteristic of a number of species. It is admittedly questionable as a safe criterion for comparative purposes due to uncertainty of its presence in some genera, while closely related representatives may possess it; it may be a feature present only at maturity, and in fossil ferns the structure may be lost in preservation or through maceration. In *D. velatus* a thick perispore must have been present at maturity, and some specimens possess a membranaceous sheath extending as much as 15 μ beyond the spore's margin (Pl. 59, fig. 5). The enclosing perispore consists of a loosely reticulate structure, the elements being 1–2 μ in thickness. Portions of this reticulum are always present, even though the membrane may be absent. It is conjectural whether the species could be identified without any of the perispore remaining. However, the species is abundant in this study and scores of specimens observed, but at no time were representatives encountered which appeared to be *D. velatus* without the perispore.

Densosporites aculeatus Playford 1963

Plate 59, fig. 6

Description. Radial, trilete; equatorial margin and distal surface bearing simple spines, rounded at base, with basal diameter 2–3·5 μ; length 2–4·5 μ. Laesurae straight to sinuous, frequently extending slightly beyond body margin; rays 10–15 μ in length, commissure distinct and lips up to 2 μ in height on well preserved specimens. Spore body laevigate and wall 1·5 μ thick.

Dimensions. (25 specimens.) Equatorial diameter, exclusive of spinose projections, 35–45 μ. Body 17–22·5 μ in diameter.

Discussion. The Springer specimens are in the lower limits of Playford's (1963) size range, but agreement is very close on every morphological detail.

Other occurrences. Surface Goddard formation, upper Mississippian.

Densosporites hispidus sp. nov.

Plate 59, fig. 9

Diagnosis. Radial, trilete, roundly subtriangular. Laesurae distinct, simple, usually straight but sometimes slightly sinuous; 10–14 μ long, usually extending only to body margin, occasionally extending on to cingulum. Body laevigate proximally; distal surface conspicuously ornamented with small granules approximately 1 μ in diameter and spaced 1 μ apart. Cingulum of uniform width, 10–17 μ wide, laevigate proximally; distal surface with minute spines projecting; spines acute, seldom exceeding 1 μ in length, and spaced 1–2 μ apart; on corroded specimens the cingulum spines are more prominent and visible about outer periphery of spore.

Dimensions. (25 specimens.) Over-all diameter 41–60 μ. Body 20–29 μ in diameter.

Holotype. Slide O3V17–1 (4). Location 11 × 114·4 (Ref. 32 × 119·6).

Description. Holotype convexly subtriangular. Over-all diameter 49 × 51·5 μ; body 20 × 29 μ. Laesurae 12–13 μ long, slightly sinuous, extending slightly on to cingulum, commissure not visible. Cingulum 13–15 μ wide, uniform; laevigate proximally and with numerous minute spines projecting from the distal surface. Body laevigate proximally and with numerous, closely spaced granules on distal surface.

Discussion. The cingulum in *D. hispidus* is very uniform and shows little tendency to break down into more than one zone as is characteristic of several species of the genus. There does not appear to be any internal system of struts or bars, and the minute spines of the distal side are the only ornamentation features. They present a bristle-like appearance and are readily discernible only at high magnifications.

Comparison. *D. hispidus* shows some resemblance to a number of previously described species but cannot be properly assigned to any of these. *D. spitsbergensis* (Playford 1963) has spines on the distal body surface rather than granules, and they are quite large, being 1·5–5 μ in length. *D. rarispinosus* (Playford 1963) has a conspicuous distal sculpture of sizeable spines and small verrucae. *D. spinosus* of Dybová and Jachowicz (1957) is described as being spinose distally and granulose proximally. *D. faunus* Ibrahim as figured by Dybová and Jachowicz (pl. 52, figs. 1, 2) bears some resemblance to *D. hispidus*, but their description makes no mention of ornamentation types or distribution other than being rugose. *D. spongeosus* Butterworth and Williams (1958, p. 380) has a body with typically minute perforations and sometimes granular or finely vermiculate. This species has subsequently been reduced to synonymy with *D. triangularis* Kosanke by Butterworth *et al*. (1964).

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Densosporites irregularis Hacquebard and Barss 1957

Plate 59, fig. 7

Diagnosis. Radial, trilete, rays usually difficult to discern but visible on well-preserved specimens, reaching to body margin. Cingulum thick and opaque adjacent to spore body, becoming translucent and membranous towards the periphery; opaque portion lobed and extending toward the outer margin of the cingulum in the manner of wheel spokes.

Dimensions. (20 specimens.) Over-all diameter 40–48 μ. Body 20–24 μ in diameter.

Discussion. Except for size, the Springer material compares with the species description of Hacquebard and Barss (1957). The Springer spores are smaller than the range of 58–75 μ given for the species. Variations do exist in the arrangement of the opaque portion of the cingulum, but preservation and maceration appear to be responsible.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; Livingston Coal, Gizzard formation, Rock Castle County, Kentucky; Stearns #1 Coal, Gizzard formation, McCreary County, Kentucky.

Densosporites rarispinosus Playford 1963

Plate 59, fig. 8

Diagnosis. Radial, trilete. Laesurae distinct, sinuous, extending beyond the body margin; commissure distinct and prominent lips up to 2·5 μ in height. Distal surface of body and cingulum bearing sparsely distributed simple spines, which project slightly from the equatorial margin (up to 3·5 μ). Body spines average 1·5 μ in diameter and are scattered 1–3 μ apart. There are rare distal verrucae up to 2·5×4·5 μ. Body wall conspicuous, 1·5 μ thick.

Dimensions. (25 specimens.) Equatorial diameter, exclusive of spinose projections, 40–50 μ. Body 20–23 μ in diameter.

Discussion. It is best distinguished from the closely allied *D. aculeatus* by the more prominent laesurae. The laesurae appear to always extend well beyond the body margin, frequently entirely across the cingulum. In *D. aculeatus* this extension beyond the body margin is not a regular feature. The spinose distal sculpture is much more conspicuous in *D. aculeatus*.

Densosporites variabilis (Waltz) Potonié and Kremp 1956

Plate 59, figs. 10, 11

1938 *Zonotriletes variabilis* Waltz *in* Luber and Waltz, pp. 20–21, pl. 4, figs. 44–46, and pl. A, fig. 16.
1941 *Zonotriletes variabilis* Waltz var. *foveolatus* Waltz *in* Luber and Waltz, p. 26, pl. 5, fig. 66*a*.
1941 *Zonotriletes variabilis* Waltz var. *fossulatus* Waltz *in* Luber and Waltz, p. 26, pl. 5, fig. 66*b*.
1941 *Zonotriletes variabilis* Waltz var. *valleculosus* Waltz *in* Luber and Waltz, p. 27, pl. 5 fig. 66*c*.
1956 *Densosporites variabilis* (Waltz) Potonié and Kremp, p. 116.
1956 *Trematozonotriletes variabilis* (Waltz) Ishchenko var. *foveolatus* Waltz; Ishchenko, pp. 102–3, pl. 22, fig. 248.
1963 *Densosporites variabilis* (Waltz) Potonié and Kremp; Playford, pp. 625–6, pl. 88, figs. 19–22.

Description. Radial, trilete, subtriangular. Uniform cingulum 10–12 μ in width with ring of shallow, pyriform pits radially oriented about inner edge of cingulum; pits average 1·5 μ in longest dimension, rarely extend beyond centre of cingulum; occasional pit on outer edge and appears to be beginning point of corrosive deterioration of the cingulum; largest such pit noted measured 2·5 μ in width by 4 μ in length. The cingulum is thick and without any diagnostic interior features; in corroded or oxidized specimens cingulum breakdown does not reveal a system of supporting rodlets or struts such as occurs in many species. Laesurae indistinct, sinuous.

Dimensions. (25 specimens.) Over-all equatorial diameter 35–50 μ. Body 21–25 μ in diameter.

Comparison. A row of pits near the inner margin of the equatorial portion is characteristic of *Vallatisporites*, and Hacquebard (1957) considered a marginal groove and single row of pits as sufficiently diagnostic to separate *Vallatisporites* from *Densosporites*. Although *Vallatisporites* is easily distinguished from *D. variabilis* on ornamentation and cingulum features, there is little difference in pit characters. This reflects some doubt on the accuracy of the pits as features of generic distinction. Similar pits have been noted in other *Densosporites* as corrosion products, but the well developed and uniform arrangement noted on even the best preserved specimens of *D. variabilis* from the Springer lends confidence in their taxonomic value.

Densosporites dissimilis sp. nov.

Plate 60, fig. 1

Diagnosis. Radial, trilete, subtriangular. Laesurae distinct, straight, simple with only slight lip development, extending to body margin. Body ornamented proximally with irregular granules up to $1\times3\ \mu$ and distally with blunt coni. Cingulum 13–17 μ in width, consisting of an inner opaque zone 6–8·5 μ in width and an outer translucent zone 6–10 μ in width. Numerous blunt spines project from proximal and distal surfaces, being most conspicuous on weathered specimens. Body wall distinct, 1·5 μ thick.

Dimensions. (10 specimens.) Over-all diameter 45–55 μ. Body 23–27 μ in diameter.

Holotype. Slide O3V16–3 (6). Location 38 × 119·2 (Ref. 33 × 117·9).

Description. Holotype-subtriangular. Over-all diameter $53\times53\ \mu$; body $25\times27\ \mu$. Laesurae straight, 14 μ in length, extending to body margin, commissure visible.

EXPLANATION OF PLATE 60

All figures × 500 unless otherwise indicated.

Fig. 1. *Densosporites dissimilis* sp. nov. Holotype. Proximal surface; Slide O3V16–3 (6), location 38 × 119·2 (Ref. 33 × 117·9).

Fig. 2. *Knoxisporites corporeus* (Loose) Potonié and Kremp 1955. Distal surface; Slide O3V16–10 (A-1), location 15 × 119 (Ref. 29·5 × 118·2).

Fig. 3. *Knoxisporites dissidius* Neves 1961. Distal surface; Slide O3V16–13 (B-1), location 53·2 × 124 (Ref. 31·9 × 117·2).

Figs. 4, 5. *Knoxisporites hederatus* (Ishchenko) Playford 1963. 4, Distal surface; Slide O3V16–11 (6), location 46·8 × 116 (Ref. 31·7 × 116·9). 5, Proximal surface; Slide O3V16–11 (6), location 34 × 113·5 (Ref. 31·7 × 116·9).

Figs. 6, 7. *Knoxisporites triradiatus* Hoffmeister, Staplin, and Malloy 1955. 6, Proximal surface; Slide O3V16–3 (5), location 38 × 111·2 (Ref. 33·7 × 118). 7, Proximal surface; Slide O3V16–11 (7), location 25 × 115·7 (Ref. 31·9 × 117·9).

Figs. 8, 9. *Knoxisporites inconspicuus* sp. nov. 8, Distal surface; Slide O3V16–11 (7), location 29 × 122·1 (Ref. 31·9 × 117·9). 9, Holotype. Proximal surface; Slide O3V16–9 (A-1), location 47 × 125 (Ref. 31 × 116·5).

Figs. 10–14. *Knoxisporites stephanephorus* Love 1960. 10, Proximal surface; Slide O3V16–13 (A-2), location 51 × 122·3 (Ref. 32·2 × 117·9). 11, Distal surface; Slide O3V17·1 (5), location 39·5 × 114·2 (Ref. 32 × 119). 12, Proximal surface; Slide O3V16–11 (2), location 51·6 × 119·3 (Ref. 32 × 118). 13, Proximal surface; Slide O3V16–3 (1), location 34·8 × 120·1 (Ref. 33 × 117·1). 14, Proximal surface; O3V16–9 (A-1), location 9·8 × 120 (Ref. 31 × 116·5).

Cingulum consisting of two sharply contrasting zones, an outer translucent area 6·5–8 μ wide and an inner opaque zone 7–8·5 μ wide; small blunt spines project from cingulum of weathered specimens. Proximal body surface ornamented with irregular granules, distal side with blunt coni.

Comparison. A number of species have been described with a somewhat similar zonation of the cingulum, but *D. sphaerotriangularis* Kosanke 1950 is probably most closely comparable and differs largely only in ornamentation and ray features. *D. cuneiformis* Hacquebard 1957 has a like difference in ornamentation and rays, although comparable in size and cingulum morphology. The *Densosporites* figured by Venkatachala and Beju (1962, pl. 2, figs. 15, 17) appears comparable to *D. dissimilis*, but they do not provide any comparative data to accompany their illustrations.

Genus KNOXISPORITES (Potonié and Kremp) Neves 1961

Type species. K. hageni Potonié and Kremp 1954.

Knoxisporites corporeus (Loose) Potonié and Kremp 1955

Plate 60, fig. 2

1934 *Reticulati-sporites corporeus* Loose, p. 155, pl. 7, fig. 7.
1955 *Knoxisporites corporeus* (Loose) Potonié and Kremp, p. 116, pl. 16, fig. 317.

Description. Radial, trilete, circular. Distinct cingulum not evident, although weakly defined one present occasionally. Laesurae straight, about 20 μ in length, two-thirds to three-fourths the spore radius, occasional rays extending nearly to margin. Lips 2–3 μ wide. Distal muri 4–7 μ wide.

Dimensions. (10 specimens.) Over-all diameter 60–90 μ.

Discussion. Size range of the Springer specimens is greater than the maximum of 70 μ noted by Potonié and Kremp (1955), and the laesurae are slightly longer than in their description. The prominent lips were not commented on in the original description. This species was transferred to *Reticulatisporites* by Neves (1964) on the basis of possession of a differentially thickened cingulum. We have chosen retention in *Knoxisporites* and regard Neves's generic distinctions as insufficient. He has also retained *K. stephanephorus* in *Knoxisporites*, but we have observed in our study of this species a gradation from simple, non-zoned cingulum to a differentially thickened cingulum. Neves's treatment also leaves no repository for our species classified as *Reticulatisporites*. It appears that a much more thorough reappraisal of several cingulate genera is necessary before valid emendations may be made.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Knoxisporites dissidius Neves 1961

Plate 60, fig. 3

Description. Radial, trilete, outline rounded hexagonal. Distal surface with three radial bars uniting to enclose a triangular area at the distal pole. Laesurae three-fourths body radius. Exine laevigate.

Dimensions. (15 specimens.) Diameter 30–55 μ.

Discussion. The lower limits of the size are considerably below that reported by Neves (1961), who gave a size range of 50–80 μ. However, except for the generally smaller size, the spores correspond very well with Neves's description.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; subsurface Springer of the Anadarko Basin.

Knoxisporites hederatus (Ischenko) Playford 1963

Plate 60, figs. 4, 5

1956 *Euryzonotriletes hederatus* Ischenko, pp. 58–59, pl. 10, fig. 121.
1963 *Knoxisporites hederatus* Ischenko; Playford, pp. 634–5, pl. 90, figs. 9–12; text-fig. 10*a*.

Description. Radial, trilete, circular to subcircular. Cingulum distinct, 6–12 μ wide. Laesurae simple, straight, 12–18 μ long and usually three-fourths of spore body radius, occasionally extending to body margin. Body distinct, exine laevigate. Muri sinuous, 4–12 μ wide, 3–6 μ high.

Dimensions. (25 specimens.) Over-all diameter 54–70 μ. Body diameter 42–50 μ.

Knoxisporites inconspicuus sp. nov.

Plate 60, figs. 8, 9

Diagnosis. Radial, trilete, subtriangular. Laesurae straight, three-fourths body radius, lips thin, about 1 μ in width, trilete fissures frequently gaped open. Spore subtriangular with convex sides, apices rounded. Cingulum laevigate, 6–12 μ wide; dark thickened inner ridge 1–3 μ wide and an outer, thinner zone of greater width. Distal surface has characteristic sculpture of small, irregularly arranged muri 2–3 μ wide, seldom connecting, infrequently small lobes project at cingulum's periphery.

Dimensions. (20 specimens.) Over-all diameter 33–55 μ. Body diameter 18–30 μ.

Holotype. Slide O3V16–9 (A–1). Location 47×125 (Ref. 31×116·5).

Description. Holotype 44×48 μ over-all, body 30×30 μ. Cingulum laevigate, 8–10 μ wide, inner dark ridge 2 μ wide. Laesurae three-fourths of radius, lips 1 μ wide, trilete open. Distal muri 2 μ wide, irregularly arranged.

Discussion. The species generally resembles spores of the arborescent lycopods. However, the distal hemisphere consistently bears a few muri-like thickenings, some of which terminate in enlarged knobs at the cingulum's outer margin. The muri have no particular arrangement, seldom connect, and are few in number and difficult to discern. On the basis of Neves's (1961) characterization of *Knoxisporites* on the presence of an equatorial cingulum and distal muri, the spore is tentatively assigned to that genus.

Knoxisporites triradiatus Hoffmeister, Staplin, and Malloy 1955

Plate 60, figs. 6, 7

Description. Radial, trilete, circular outline. Prominent cingulum is regular on individual specimens, 6–11 μ in width. Distal muri 6–10 μ in width. Laesurae distinct, straight, extending almost to cingulum; lip development of about 1 μ on either side of commissure in some specimens but is not a consistent feature. Proximal and distal surfaces smooth.

Dimensions. (25 specimens.) Over-all diameter 48–78 μ.

Discussion. There appears to be some variation in the species, but most of this is only superficial and due largely to difference in specimen size and degree of distortion in preservation.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; Kentucky 'A' Seam coal, Kanawha formation, lower Pottsville, Harlan County, Kentucky.

Knoxisporites stephanephorus Love 1960

Plate 60, figs. 10–14

Description. Proximal ring 6–10 μ wide; distal equatorial ring 5–7 μ wide; distal polar boss 7–15 μ in diameter.

Dimensions. (50 specimens.) Over-all diameter 30–60 μ.

Discussion. Love (1960) differentiated this species from *K. rotatus* primarily on the basis of the thickening at the distal pole. In addition he considered the interradial thickening joining the rings to be more strongly developed in *K. rotatus*, while the lip structures in *K. stephanephorus* were more prominent than in *K. rotatus*. He noted some variation in the equatorial thickenings in his specimens. However, such a transition of developmental characters is present in the Springer specimens as to suggest the impossibility of distinguishing between these two species. Plate 60, fig. 11 presents a distinct distal platelet or boss, but it lacks interradial connexions between the equatorial rings. Plate 60, fig. 12 has well-defined interradial connexions but the outer or proximal ring is indistinct. Similarly the thickened lip structures lack consistency, although Love (1960) cited them as being present and narrowing to a point proximally. In Plate 60, figs. 12, 13 these are present the length of the rays, in Plate 60, fig. 14 they accompany the rays no more than one-third their length, and in Plate 60, fig. 10 they are completely lacking. In this study, specimens have been noted with all the characteristics of *K. stephanephorus* except for the distal boss (Pl. 60, fig. 10); others with boss present have no other features of the species. The species, *sensu* Love, is represented in the Springer. However, it is evident that these are developmental transitions which include more than one species, but as the genus is presently being studied by a working group of C.I.M.P. a redefinition is not undertaken here.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus NEXUOSISPORITES gen. nov.

Type species. *N. comtus* sp. nov.

Diagnosis. Radial, trilete, subcircular to subtriangular, margin slightly undulating. Laesurae simple, extending one-half to two-thirds radius. Spore body covered distally by tightly packed convolutions. An unornamented cingulum is attached to the spore, although it often appears zonate because of the convolutions pushed on to it. An irregular, thickened ring rests on the distal surface. Its width varies considerably on a single specimen. Though not always completely developed, portions of the ring are always present.

Nexuosisporites comtus sp. nov.

Plate 65, figs. 6–8

Diagnosis. Radial, trilete, subcircular to subtriangular, margin slightly undulating. Laesurae simple, 9–18 μ long, extending one-half to two-thirds radius. Spore body covered distally by tightly packed convolutions, 3 μ high, 2–3 μ wide, with less than 1 μ between; some minor ornamentation occasionally developed proximally. An unornamented cingulum 5–12 μ thick (width remains constant on individual specimens) is attached to spore. Frequently there is a row of pits at the line of attachment, and the cingulum occasionally appears zonate because of the convolutions pushed on to it. A thickened ring rests on the distal surface. Though probably centred originally, it is often pushed to one side as an effect of compression. This ring is very irregular and its width varies considerably on individual specimens, ranging from 3 to 10 μ, 6 to 16 μ, to 6 to 12 μ. It sometimes appears to consist of connected globules. Ring diameters range from 24 μ to 34 μ, centre diameters from 3 μ to 10 μ. Though not always completely developed, recognizable portions of the ring are always present.

Dimensions. (25 specimens.) Over-all diameter 42–60 μ.

Holotype. Slide O3V16–11 (6). Location 48·5 × 125·5 (Ref. 31·7 × 116·9).

Description. Holotype 48 × 54 μ. Radial, trilete, subcircular, margin slightly undulating. Convolutions quite distinct and well defined, 2 μ wide, 3 μ high, 1 μ apart. Cingulum 12 μ wide, smooth. Trilete 12–16 μ long, extends to body margin. Distal ring well-formed, outline irregular, 10 μ across centre, 30 μ diameter, and ranging from 6 μ to 11 μ in width. Spore wall thin.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus STENOZONOTRILETES (Naumova) Hacquebard 1957

Type species. *S. conformis* Naumova 1953.

Stenozonotriletes cf. *spetcandus* Naumova 1953

Plate 61, fig. 1

Description. Radial, trilete, roundly subtriangular. Laesurae distinct, straight, extending nearly to body margin, commissure distinct; lips smooth, elevated, 4–6 μ wide. Wall distinct, 7–10 μ wide. Body laevigate.

Dimensions. (15 specimens.) Over-all diameter 55–78 μ.

Discussion. There is no definite assurance that this is the spore described by Naumova

(1953), and the assignment is based upon a comparison with the probable assignment by Playford (1962).

Genus CRASSISPORA Bhardwaj 1957

Type species. Crassispora (Planisporites) ovalis Bhardwaj 1957.

Crassispora (Planisporites) kosankei (Potonié and Kremp) Bhardwaj 1957

Plate 61, fig. 10

1955 *Planisporites kosankei* Potonié and Kremp, p. 71, pl. 13, figs. 208–13.
1957 *Apiculatisporis apiculatus* Dybová and Jachowicz, pp. 87–89, pl. 15, figs. 1–4.
1964 *Crassispora kosankei* (Potonié and Kremp) Bhardwaj; Sullivan, p. 376, pl. 60, figs. 13–15.

Description. Spores spheroidal to elliptical, trilete. Rays simple and difficult to discern, extending two-thirds distance of spore radius, rarely intact, usually split open to form characteristic triangular opening; triangular aperture ranging from 30×30 μ to 40×45 μ, size of opening appearing to have no relationship to size of spore. Exine covered with closely spaced coni situated 1·5–4·5 μ apart, 2–3 μ wide at their bases, and averaging 1·5 μ in length. Spores variously plicate, usually with thickened equatorial zone (*crassitudo* of Bhardwaj) 7–10 μ wide about entire spore margin. Wall distinct, 3–6·5 μ thick.

Dimensions. (25 specimens.) Diameter 56–72 μ, characteristic coni are variable in size; some specimens do not have them exceeding 1 μ in length, while on others they measure up to 2 μ. The majority of coni are about 1·5 μ in length.

Discussion. Dybová and Jachowicz (1957) established three forms in the species. The Springer spores compare most closely with their form *media*, but there is a sufficient gradient in over-all size and coni characters in the Springer specimens to prevent definite assignment to any of the forms. They did not note the rather striking triangular gap resulting from the rupture of the trilete suture. It is of such usual occurrence that it seems to be a useful diagnostic feature; it is evident in all of their illustrations. Bhardwaj (1957) described the triangular slit and considered it to be a diagnostic feature.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; Livingston and New Livingston Coals, Gizzard formation, lower Pennsylvanian, Rockcastle County, Kentucky; Lily Coal, Breathitt formation, lower Pennsylvanian, Laurel County, Kentucky.

Genus CRISTATISPORITES (Potonié and Kremp) Butterworth, Jansonius, Smith, and Staplin 1964

Type species. C. indignabundus (Loose) Potonié and Kremp 1954.

Cristatisporites indignabundus (Loose) Butterworth *et al.* 1964

Plate 61, fig. 2

1932 *Sporonites indignabundus* Loose *in* Potonié, Ibrahim, and Loose, p. 451, pl. 19, fig. 51.
1954 *Cristatisporites indignabundus* (Loose) Potonié and Kremp, p. 142, pl. 20, fig. 100 (8).
1964 *Cristatisporites indignabundus* (Loose) Potonié and Kremp; Staplin and Jansonius, p. 108, pl. 19, figs. 7, 9, 12, 14, 20; text-fig. 2*c*.

Description. Radial, trilete, roundly subtriangular. Proximal area finely granulose. Distal surface with prominent protuberances (warts of Staplin), frequently united at bases, up to 8·5 μ in length and 5 μ wide; protuberances usually with setose apices; smaller and more widely separated towards outer margin. Zona not clearly defined. Laesurae usually pronounced, slightly raised, lips 1·5 μ wide; rays reaching to body margin, occasionally appear to extend on zona.

Dimensions. (25 specimens.) Equatorial diameter 45–60 μ. Diameter of body approximately 20–23 μ.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Genus CINCTURASPORITES (Hacquebard and Barss) Bhardwaj and Venkatachala 1962

Type species. C. altilis Hacquebard and Barss 1957.

Cincturasporites minimus sp. nov.

Plate 61, fig. 3

Diagnosis. Spore spherical, trilete, cingulum present 6–9 μ wide, but not pronounced. Distal muri forming loose reticulum, muri 7–11 μ wide.

Dimensions. (5 specimens.) Over-all diameter 65–86 μ.

Holotype. Slide O3V16–10 (B–1). Location 50×111 (Ref. 32·5×117·9).

Description. Holotype 84×86 μ. Cingulum indistinct but attains measurable width of 9 μ. Distal surface with muri 7–8·5 μ in width, radiating to form loose reticulum with

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EXPLANATION OF PLATE 61

All figures ×500 unless otherwise indicated.

Fig. 1. *Stenozonotriletes* cf. *spetcandus* Naumova 1953. Proximal surface; Slide O3V17–7 (1), location 45·2×112 (Ref. 31·3×117·7).

Fig. 2. *Cristatisporites indignabundus* (Loose) Butterworth *et al.* 1964. Distal surface; Slide O3V16–9 (B-2), location 41·8×107·6 (Ref. 31·7×118·2).

Fig. 3. *Cincturasporites minimus* sp. nov. Holotype. Slide O3V16–10 (B-1), location 50×111 (Ref. 32·5×117·9).

Fig. 4. *Cincturasporites magnus* sp. nov. Holotype. Proximal surface; Slide O3V16–14 (6), location 17×119 (Ref. 33×117).

Fig. 5. *Trochospora mastospinosa* sp. nov. Holotype. Proximal surface; Slide O3V16–9 (A-1), location 12·4×124·3 (Ref. 31×116·5).

Figs. 6, 7. *Cirratriradites rusticus* sp. nov. 6, Proximal surface; Slide O3V16–4 (1), location 8×125·5 (Ref. 30·3×117·7). 7, Holotype. Proximal surface; Slide O3V16–9 (6), location 21·2×118 (Ref. 33·9×119·1).

Fig. 8. *Laevigatosporites ovalis* Kosanke 1950. Proximal surface; Slide O3V16–11 (6), location 33·5×124 (Ref. 31·7×116·9).

Fig. 9. *Cirratriradites leptomarginatus* sp. nov. Holotype. Proximal surface; Slide O3V17–1 (3), location 11·6×107·6 (Ref. 31×119·5).

Fig. 10. *Crassispora* (*Planisporites*) *kosankei* (Potonié and Kremp) Bhardwaj 1957. Proximal surface; Slide O3V16–13 (1), location 18·6×114 (Ref. 39·7×118·2).

Fig. 11. *Savitrisporites nux* (Butterworth and Williams) Sullivan 1964. Distal surface; Slide O3V16–11 (6), location 18·2×108 (Ref. 31·7×116·9).

lacunae up to 10×23 μ. Oval, knob-like protuberances 4–7 μ in diameter are a prominent distal wall feature. No discernible ornamentation on wall. Laesurae indistinct, limited to central body.

Discussion. The species is distinguished by elaborate thickenings on the distal side which extend on to the cingulum, obscuring it and rendering accurate measurements difficult. The rays are thin, and the heavy muri obscure them. Usually three or four loosely knit lacunae are formed, but no consistent ornamentation pattern is evident.

Comparison. Among described species only *C. radialis* Bhardwaj and Venkatachala 1962 possesses as elaborate distal ornamentation. However, their species differs greatly in its larger size, well-defined cingulum and laesurae, and in the presence of characteristic radiating thickenings in the cingulum. A slight resemblance to *Convolutispora* may be suggested by the irregular thickenings, but the resemblance is only superficial and the presence of a cingulum in *C. minimus* suffices to distinguish it from the convolute spores.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Cincturasporites magnus sp. nov.

Plate 61, fig. 4

Diagnosis. Spherical, trilete with prominent labial ornamentation. Cingulum distinct 8–17 μ wide. Distal muri irregularly distributed, up to 12 μ wide.

Dimensions. (10 specimens.) Over-all diameter 90–125 μ.

Holotype. Slide O3V16–14 (6). Location 17×119 (Ref. 33×117).

Description. Holotype 112×121 μ. Cingulum distinct, laevigate, undulating to give a variable width of 8–12 μ. Distal surface with muri 6–12 μ wide, forming irregular convolutions but not reticulate. Rounded protuberances averaging 10 μ in diameter scattered about distal surface. No discernible wall ornamentation. Laesurae distinct, 35 μ long, extending three-fourths distance to body margin, and with ray muri 7·5–10 μ wide.

Comparison. The larger size, well-defined cingulum, and laesurae, distinguish this species from *C. minimus*. The muri do not form a loose reticulum, although there is occasional slight branching. The muri lie in loose convolutions, and in the holotype one nearly encircles the entire distal periphery. The lip and cingulum features compare with *C. literatus* (Waltz) Hacquebard and Barss, but *C. magnus* is considerably larger, has a greater degree of muri ornamentation, and does not possess the row of punctations characteristic of the lips of *C. literatus*.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Discussion. Some disagreement already exists as to the proper limits of this genus, and the original designation by Hacquebard and Barss (1957) is certainly too wide. Moreover, Bhardwaj and Venkatachala (1962) pointed out in their emendation that the diplotype possessed distal ornamentation not included in the original description. The specimens described here are considered to fall within the limits of the Bhardwaj and Venkatachala emendation or of Hacquebard and Barss (*sensu C. literatus*). We reject such species as *C. sulcatus*, *C. altilis*, *C. irregularis*, and *C. stenozonalis*. It is also our opinion that the broad labra are not sufficient reason for transfer to *Labiadensites* as suggested by Bhardwaj and Venkatachala (1962). It also seems quite certain that Winslow's (1962) *Reticulatisporites crassus* should be included within *Cincturasporites*.

Genus TROCHOSPORA gen. nov.

Type species. T. mastospinosa sp. nov.

Diagnosis. Spores radial, trilete; convexly subtriangular. Laesurae distinct, lips prominent, sinuous, extending to body margin. Narrow, thickened cingulum present. Distal surface conspicuously sculptured with large mammoid spinose processes, which are more numerous in the equatorial region than in the distal polar area.

Trochospora mastospinosa sp. nov.

Plate 61, fig. 5; text-fig. 4

Diagnosis. Spores radial, trilete, convexly subtriangular. Spore body wall distinct, 2–3 μ thick, laevigate. Laesurae sinuous, lips prominent, 35–40 μ long, length equal to body radius. Cingulum narrow, 4–6 μ wide. Prominent spines restricted to distal side, proximal surface unornamented. Spines 15–30 μ in length, enlarged basal portion up to 8·5 μ in width, apices setose to mammoid.

Dimensions. (5 specimens.) Over-all diameter 90–125 μ. Body diameter 65–80 μ.

Holotype. Slide O3V16–9 (A–1). Location 12·4 × 124·3 (Ref. 31 × 116·5).

Description. Holotype 120 × 122 μ, subtriangular; laesurae 35–37 μ long, extending to body margin, sinuous and with prominent labial structure to 7 μ in height. Cingulum 5–6 μ wide with irregular margin. Prominent spines 15–30 μ long on distal surface and more closely spaced towards equatorial region; processes have enlarged, often bulbous bases, which are up to 8·5 μ in width. Apices of processes of various types, but generally mammoid; however, apices are sometimes falcate, setose, or bulbous (text-fig. 4).

Discussion. This genus bears considerable resemblance to the densospores, but the thickened darkened area encircling the body appears to be a relatively narrow cingulum and not a zona. An appearance of having a zona or wide rim is further produced by the extension of the processes. There is some similarity to *Cristatisporites* which is described as having mammoid or setose small granules or apiculae. It also resembles *Spinozonotriletes* Hacquebard in the spines and their distribution, but *Trochospora* lacks the enveloping exine layer (perispore?).

Genus SAVITRISPORITES Bhardwaj 1955

Type species. S. triangulus Bhardwaj 1955.

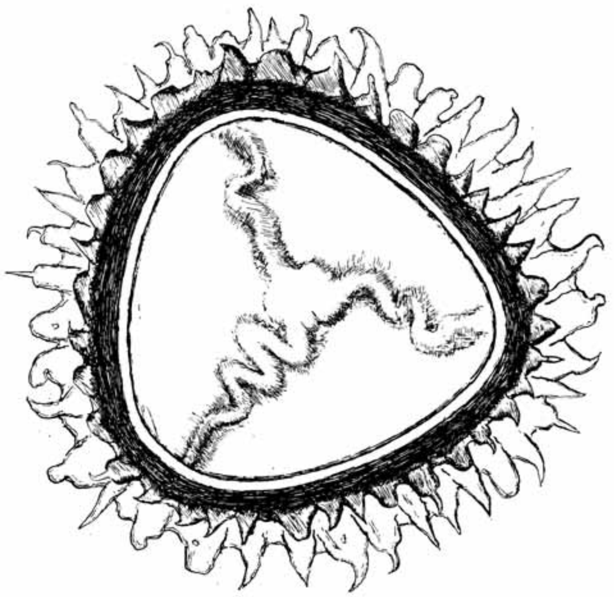
Savitrisporites nux (Butterworth and Williams) Sullivan 1964

Plate 61, fig. 11

1958 *Callisporites nux* Butterworth and Williams, p. 377, pl. 3, figs. 24, 25 and text-fig. 2.

1964 *Savitrisporites nux* (Butterworth and Williams) Sullivan, pp. 373–4, pl. 60, figs. 1–5.

Description. Radial, trilete, subtriangular in equatorial outline, interradial margins straight to slightly convex. Solid cingulum 5–8 μ wide. Laesurae straight, simple, commissure usually visible; length 16–25 μ, extending to body margin. Ornamentation oι broad, concentric distal ridges. Ridges are seldom continuous but are composed of short, closely spaced, irregulalry crested components. Continuous ridges do often border the



TEXT-FIG. 4. *Trochospora mastospinosa* gen. and sp. nov. Proximal surface; Slide O3V16–9 (A-1), location 12·4×124·3 (Ref. 31×116·5).

laesurae, but components of the other ridges, although appearing continuous at low magnification seldom exceed 10 μ in length.

Dimensions. (25 specimens.) Equatorial diameter 40–60 μ.

Discussion. The rounded apices occasionally bear shallow notches in the cingulum. Usually only one apex on a specimen is indented, rarely two, and no specimens were observed with all three apices indented. Such a feature was not noted by Butterworth and Williams (1958), and it does not appear with sufficient regularity to warrant specific division. Sullivan (1964*a*) has established *Callisporites* as a junior synonym of *Savitrisporites*. Bhardwaj's (1955) genotype is from the Stephanian A; we have encountered spores from U.S. deposits of corresponding age which conform to Bhardwaj's description but differ markedly from *Callisporites* (*sensu* Butterworth and Williams). Geological time differences are no absolute criteria for differentiation, but the large time difference between the Sullivan (1964*a*) and Bhardwaj (1955) assemblages, plus the apparent morphological differences, suggest that such an emendation is not acceptable. However, Sullivan (*personal communication*) has shown the writers evidence of morphological variations without demonstrable discontinuities in this taxon. In view of the fact that he has also personally examined type material, and Dr. M. A. Butterworth has collaborated on this examination and concurred with his findings, it is only reasonable to accept his emendation.

Other occurrences. Surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; subsurface Springer formation, Anadarko Basin.

Infraturma ZONATI Potonié and Kremp 1954
Genus CIRRATRIRADITES Wilson and Coe 1940

Type species. C. maculatus Wilson and Coe 1940.

Cirratriradites leptomarginatus sp. nov.

Plate 61, fig. 9

Diagnosis. Radial, trilete, convexly subtriangular. Laesurae distinct, straight with slight lip development, commissures visible at high magnification; rays usually extending two-thirds to four-fifths of central body radius, occasionally individual rays extend on the equatorial zona. Central body minutely punctate. Thin, membranous equatorial zona 7·5–10 μ in width, minutely granulose, bordered about its outer periphery by thickened rim about 1·5 μ thick.

Dimensions. (10 specimens.) Over-all equatorial diameter 56–66 μ. Body diameter 38–55 μ.

Holotype. Slide O3V17–1 (3). Location 11·6×107·6 (Ref. 31×119·5).

Description. Holotype 60×63·5 μ over-all. Thin, membranous zona 8 μ wide, including slightly thickened marginal rim 1·5 μ wide. Laesurae distinct, straight, 20 μ long, about four-fifths of body radius; no pronounced labial development. Spore body punctate; zona granulose.

Discussion. There is some reservation in assigning this spore to *Cirratriradites* since that genus is usually described as having strongly demarcated lips raised above the body and a broad equatorial zona. The zona here cannot be considered as broad.

Comparison. It resembles *Angulisporites* (Bhardwaj 1954), but *Angulisporites* described from Stephanian age deposits has a granulose body and some zonation of the zona.

Cirratriradites rusticus sp. nov.

Plate 61, figs. 6, 7

Diagnosis. Radial, trilete, convexly subtriangular. Laesurae distinct, sinuous, extending on to zona, frequently to the equator; bordered by conspicuous, strongly developed flexuous lips having a maximum height of 15 μ. Zona 12–25 μ in width, faintly granulose, intact specimens with peripheral border or rim about 3 μ wide; specimens frequently corroded about outer periphery and zona presents irregular, somewhat fringed appearance. Spore body wall 1·5–3 μ thick, granulose.

Dimensions. (25 specimens.) Over-all diameter 60–115 μ (average 85–90 μ). Body diameter 50–85 μ (average 60–65 μ).

Holotype. Slide O3V16–9 (6). Location 21·2 × 118 (Ref. 33·9 × 119·1).

Description. Holotype 86 × 96 μ over-all, body 60 × 66 μ. Zona 16 μ wide, minutely granulose, bordered by rim 3 μ wide. Laesurae distinct, sinuous, extending on to zona, attaining maximum length of 42 μ. Body wall 1·5 μ thick, granulose.

Discussion. The species shows some similarity to *Leiozonotriletes* Hacquebard 1957, but the latter is clearly not zonate and has a mesosporoid enclosed by the exoexine.

Cirratriradites saturni (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 62, fig. 1

Dimensions. (25 specimens.) Over-all equatorial diameter 70–105 μ. Body diameter 55–65 μ. Flange 13–20 μ in width. Distal fovea 20–30 μ in diameter.

Discussion. *C. saturni* has long been regarded as the type species of the genus, but Wilson (1966) has recently restored *C. maculatus* to the status of type species.

Other occurrences. Very common in subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus REINSCHOSPORA Schopf, Wilson, and Bentall 1944

Type species. *R. speciosa* (Loose) Schopf, Wilson and Bentall syn. *R. bellitas*.

Reinschospora speciosa (Loose) Schopf, Wilson, and Bentall 1944

Plate 62, fig. 3

1934 *Alatisporites speciosus* Loose, p. 151, pl. 7, fig. 1.
1944 *Reinschospora bellitas* Bentall *in* Schopf, Wilson, and Bentall, p. 53, fig. 2.
1955 *Reinschospora speciosa* (Loose) Schopf, Wilson, and Bentall; Horst, p. 187, pl. 21, figs. 38–39.
1956 *Reinschospora speciosa* (Loose) Schopf, Wilson, and Bentall; Potonié and Kremp, p. 132, pl. 19, fig. 419.

Description. Radial, trilete; body subtriangular with concave sides. Laesurae distinct, straight, about 30 μ long, extending nearly to equatorial margin; commissure distinct, lips narrow, not exceeding 1 μ in width. Prominent fimbriate corona with fine, narrow fimbrae so closely spaced as to appear fused; fimbrae number 40–50 between ray extremities, attain maximum length of 17–23 μ in central interradial area and minimum length of 5–7·5 μ at apices. Corona originates proximally about 5 μ beyond the spore wall. Spore body minutely punctate, wall 1·5 μ thick.

Dimensions. (15 specimens.) Over-all diameter 77–85 μ. Body diameter 52–65 μ.

Comparison. The Springer specimens differ only from Bentall's (Schopf, Wilson, and Bentall 1944) description of *R. bellitas* in being minutely punctate. However, the wall feature is often difficult to discern unless at high magnification. The punctations are not nearly so pronounced as in *R. punctata* Kosanke 1950, and the fimbriate elements are much finer and longer in *R. speciosa*. Bentall recognized the similarity of his *R. bellitas* to *R. speciosa* Loose but considered the size difference too great to permit assignment to the latter. However, Horst (1955) noted an error in Loose's figure and extended the size from 54 μ to 81 μ.

Other occurrences. Bentall's material was from the Gizzard formation, lower Pennsylvanian, Marion County, Tennessee. The authors have observed the species from the Lily Coal, Breathitt formation, lower Pennsylvanian, Laurel County, Kentucky.

Infraturma MEMBRANATI Neves 1961
Genus PROPRISPORITES Neves 1958

Type species. *P. rugosus* Neves 1958.

Proprisporites rugosus Neves 1958

Plate 62, fig. 4

Description. Spore minutely punctate. Laesurae straight, length two-thirds body radius, lips very thin. Perisporal folds projecting 6–8 μ.

Dimensions. (5 specimens.) Over-all diameter 80–85 μ. Body diameter 65–70 μ.

Discussion. *P. rugosus* is very rare in the Springer sediments, whereas *P. laevigatus* occurred in large numbers in several samples.

EXPLANATION OF PLATE 62

All figures ×500 unless otherwise indicated.

Fig. 1. *Cirratriradites saturni* (Ibrahim) Schopf, Wilson, and Bentall 1944. Proximal surface; Slide O3V16–3 (6), location 20×125·2 (Ref. 33×117·9).

Fig. 2. *Endosporites micromanifestus* Hacquebard 1957. Proximal surface; Slide O3V17–1 (5), location 11·5×115·3 (Ref. 32×119).

Fig. 3. *Reinschospora speciosa* (Loose) Schopf, Wilson, and Bentall 1944. Proximal surface; Slide O3V16–6 (1), location 39·8×117 (Ref. 31·4×118).

Fig. 4. *Proprisporites rugosus* Neves 1958. Proximal surface; Slide O3V16–10 (1), location 53·5×112 (Ref. 30×117·6).

Figs. 5–10. *Proprisporites laevigatus* Neves 1961. 5, Distal surface; Slide O3V16–3 (5), location 37×122·8 (Ref. 33·7×118). 6, Proximal surface; Slide O3V16–11 (1), location 50×119·5 (Ref. 32×118·7). 7, Proximal surface; Slide O3V16–9 (6), location 51×124·6 (Ref. 33·9×119·1). 8, Proximal surface; Slide O3V16–3 (6), location 22·5×107·4 (Ref. 33×117·9). 10, Proximal surface; Slide O3V16–10 (2), location 28×115·3 (Ref. 53×117·7).

Fig. 11. *Auroraspora solisortus* Hoffmeister, Staplin, and Malloy 1955. Slide O3V16–9 (B-2), location 36·6×118·5 (Ref. 31·7×118·2).

Fig. 12. *Hymenospora caperata* sp. nov. Holotype ×750. Slide O3V16–9 (A-1), location 43·6×111·9 (Ref. 31×116·5).

Fig. 13. *Schulzospora rara* Kosanke 1950. Proximal surface; Slide O3V16–4 (R-1), location 18·1×121 (Ref. 32·3×118·7).

Proprisporites laevigatus Neves 1961

Plate 62, figs. 5–10

Description. Spores laevigate. Laesurae straight, length about three-quarters body radius, lips thin, not exceeding 1 μ. The laevigate, perisporal membrane in the equatorial plane projects 6–7 μ, and the folded membrane in polar view gives the appearance of ridges 3–5 μ in width.

Dimensions. (50 specimens.) Over-all diameter 45–90 μ.

Discussion. The specimens in the Springer have a greater size variation than Neves (1961) cited. However, the average size range is 65–80 μ, and about 75 per cent. of the spores studied fell within a 68–72 μ size group. Only a few rare specimens were in the 45–50 μ (Pl. 62, fig. 5) range and probably represent anomalies. There is also a variation in the number of long folds, as well as in size. Plate 62, fig. 10 illustrates the minimum number observed with only four lobes appearing to encircle the body, while Plate 62, fig. 6 shows the maximum attained with seventeen lobes or folds present. The latter is an extreme instance, and Plate 62, figs. 7, 8 represent the usual character. However, the gradation both in size and fold characteristics precludes any clearcut specific distinction based on these features. A character not mentioned by Neves but appearing in his illustrations is the occurrence of isolated rounded bosses and small granular protuberances on the otherwise laevigate body. Plate 62, fig. 8 represents the maximum degree of occurrence of the granules, which are rounded, 1–5 μ in diameter, and usually in a small group on the distal mid-polar area. However they are not a consistent feature.

Jansonius (1962) proposed an emendation of *Proprisporites*, but the evidence he submits does not justify the change, and we reject it. In addition, it seems to tax credulity to extend this stratigraphically important Mississippian genus into the Triassic. Jansonius's comparison of *P. rugosus* with *Perotriletes perinatus* Hughes and Playford 1961 is similarly rejected on grounds of insufficient evidence.

Other occurrences. Both species are present in the subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma. An undescribed species of the genus has been recorded by the authors from the Stearns #1 coal, Gizzard formation, lower Pottsville, McCreary County, Kentucky. The spore cited as *Reticulatisporites* sp. 2 by Venkatachala and Beju (1962, pl. 1, figs. 22–24) is certainly *Proprisporites* and is probably *P. rugosus*.

Genus HYMENOSPORA Neves 1961

Type species. H. palliolata Neves 1961.

Hymenospora caperata sp. nov.

Plate 62, fig. 12

Diagnosis. Radial, trilete, circular outline. Laesurae indistinct, extending to, or nearly to, the body margin. Spore body covered by thin outer membrane, which forms a zonate-like margin about the body 4·5–7·5 μ in width; membrane wrinkled and distorted to give crinkled appearance. Spore body minutely punctate.

Dimensions. (20 specimens.) Diameter 35–52 μ.

Holotype. Slide O3V16–9 (A–1). Location 43·6 × 111·9 (Ref. 31 × 116·5).

Description. Holotype 43 × 44 μ. Membranous outer layer laevigate, extending 5–7·5 μ beyond body to produce zonate appearance; outer membrane densely plicated and appears wrinkled. Spore body minutely punctate. Laesurae extending nearly to spore margin, difficult to determine due to enveloping, wrinkled outer membrane.

Comparison. H. palliolata Neves, the only other described species, is considerably larger, possesses a laevigate body, and does not seem to have the degree of plication of the outer membrane. The rays of *H. caperata* are difficult to resolve, owing to the thickness of the outer membrane and its many plications. Although never conspicuous quantitatively, this spore is one of the most ubiquitous and has been noted in numerous other localities.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma; Kentucky 'C' seam coal, Kanawha formation, lower Pottsville, Harlan County, Kentucky.

Turma MONOLETES Ibrahim 1933
Subturma AZONOMONOLETES Luber 1935
Genus LAEVIGATOSPORITES Ibrahim 1933

Type species. L. vulgaris Ibrahim 1933.

Laevigatosporites ovalis Kosanke 1950

Plate 61, fig. 8

Description. Spores are bilateral, monolete, bean-shaped in longitudinal plan, oval in equatorial plan. Spore coat is laevigate, very thin (1 μ) with frequent minor folding. The monolete suture is distinct, simple, and one-half to three-fourths the length of the spore (22–36 μ).

Dimensions. (15 specimens.) Over-all length 42–60 μ. Width 26–38 μ.

Discussion. The spores have been placed in this species although there are some slight differences from Kosanke's description (1950). The Springer material does not seem to be as thick walled, and the question of lips is debatable. At very high power some of the specimens have tiny thickenings along the suture. Though not labial structures in the classic sense, these may be the lips referred to in the original description.

Genus MONOLETES (Ibrahim) Schopf, Wilson, and Bentall 1944

Type species. M. ovatus Schopf 1936.

Remarks. Monoletes is another example of the conflicting taxonomy so prevalent in plant microfossil research. The name was first used by Ibrahim (1933) for a spore group in an artificial system, but it was not used in a generic sense and no nomenclatural type was designated. Schopf (1936, 1938) used it in a generic sense, and Schopf, Wilson, and

Bentall (1944) published an emendation and designated *Monoletes ovatus* Schopf as the type species. However, recent workers tend to regard *Monoletes* as a division somewhat coordinate to the Reinsch (1884) genus *Triletes*. Potonié and Kremp (1954, 1956*a*) are foremost in using this treatment, and in their 1954 treatment they included *Monoletes* in the new genus *Schopfipollenites*, with *S. ellipsoides* as the type species. This classification does not clarify the taxonomy. *Monoletes* was originally meant to include typical bilateral spores, and Schopf, Wilson, and Bentall (1944) emended it to include the spores of a pteridospermic plant alliance such as the Whittleseyinae. Since this could include more than one genus, the genus will undoubtedly require refinement. However, *Schopfipollenites* does not resolve this problem since Potonié and Kremp created it for the Whittleseyinae spores also, thus still leaving *Monoletes* to include the majority of the bilateral spores. In our opinion *Monoletes* most nearly meets the natural designation of our spore.

Monoletes ovatus Schopf 1936

Plate 63, figs. 1, 2

Description. Bilateral, subovate; monolete suture medially deflected, ray about two-thirds length of spore body, measuring 105–40 μ in length; lips 4–5 μ wide on each side of commissure. Distal surface usually bearing two longitudinal grooves on expanded specimens; compressed specimens frequently with longitudinal folds parallel to groove. Body wall 5–10 μ thick. Thin, granular outer coat sometimes present, adhering closely to spore body; body proper laevigate.

Dimensions. (25 specimens.) Over-all dimensions 140 × 165 μ to 150 × 195 μ. Body 135 × 160 μ to 145 × 180 μ.

Discussion. In some specimens the distal grooves are absent, even in the case of excellent preservation. The grooves probably do not warrant the attention they have formerly received. Although Schopf (1938) distinguished *M. ellipsoides* from *M. ovatus* on the lack of such grooves, Winslow (1959) has noted that presence or absence of these features may be of limited diagnostic value. The Springer specimens are smaller than the size values given by Schopf (1938) for the species, but they are within the size of Winslow's material, several of which are referable to *M. ovatus*. Other than size, there are no features on which to differentiate these spores from those of Schopf.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Monoletes sp.

Plate 63, figs. 3, 4

Description. Bilateral, subovate; monolete suture medially deflected, ray often difficult to discern but measures up to 85 μ in length and over one-half length of body, lips 2–3 μ in width. Distal surface not bearing longitudinal grooves. Central body covered by a granulose membrane; spore body proper laevigate.

Dimensions. (25 specimens.) Over-all dimensions 90 × 120 μ to 120 × 140 μ. Body 65 × 85 μ to 75 × 115 μ.

Discussion. This particular *Monoletes* was numerous in only two samples (O3V16–9 and O3V17–2), and the manner in which a smaller body is enclosed within a surrounding membrane is very similar to *M. aureolus* Schopf. It lies considerably outside Schopf's (1938) minimum size of 200 μ, and does not display the bifurcating medial suture described for *M. aureolus*. Winslow (1959) encountered similar examples and suggested they might be 'sports' referable to *M. ovatus*, if fully developed. This seems a reasonable explanation for the Springer specimens, which have little to distinguish them from *M. ovatus* other than their small dimensions and loosely encompassing membrane.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Anteturma POLLENITES R. Potonié 1931
Turma SACCITES Erdtman 1947
Subturma MONOSACCITES Chitaley 1951
Genus ENDOSPORITES Wilson and Coe 1940

Type species. E. ornatus Wilson and Coe 1940.

Endosporites micromanifestus Hacquebard 1957

Plate 62, fig. 2

1956 *Hymenozonotriletes* aff. *variabilis* Naumova; Ischenko, p. 62, pl. 11, figs. 129–30.
1957 *Endosporites micromanifestus* Hacquebard, p. 317, pl. 3, fig. 16.
1960 *Auroraspora micromanifestus* (Hacquebard) Richardson, p. 51.
1963 *Endosporites micromanifestus* Hacquebard; Playford, p. 652, pl. 93, figs. 17–18.
1964 *Endosporites micromanifestus* Hacquebard; Playford, p. 37, pl. 11, fig. 2.

Dimensions. (50 specimens.) Over-all diameter 42–60 μ. Diameter of central body 30–48 μ.

Discussion. The specimens closely conform with previous descriptions of Hacquebard (1957) and Playford (1963, 1964). The spore is quite common in the Springer, particularly in sample O3V16–9.

Genus SCHULZOSPORA Kosanke 1950

Type species. S. rara Kosanke 1950.

Schulzospora rara Kosanke 1950

Plate 62, fig. 13

Description. Radial, trilete, spherical body. Bladder fold of 5–8 μ in width at body periphery. Bladder and body ornamentation finely punctate. Laesurae 23–28 μ in length, extending nearly to body margin, frequently split open, with minor lip development.

EXPLANATION OF PLATE 63

All figures ×500 unless otherwise indicated.

Figs. 1, 2. *Monoletes ovatus* Schopf 1936. 1, Distal surface; Slide O3V16–14 (6), location 55×122 (Ref. 33×117). 2, Proximal surface; Slide O3V17–1 (4), location 48·6×114·8 (Ref. 32×119·6).

Figs. 3, 4. *Monoletes* sp. 3, Proximal surface; Slide O3V16–5 (3), location 22×126·8 (Ref. 33·7×118·2). 4, Partially torn perispore; Slide O3V16–10 (2), location 33×119 (Ref. 53×117·7).

Fig. 5. *Cystoptychus velatus* sp. nov. Holotype. Proximal surface; Slide O3V16–9 (5), location 30·2×115 (Ref. 32·4×118·6).

Dimensions. (25 specimens.) Over-all diameter 66–92 μ. Body diameter 52–65 μ.

Discussion. The assignment to *S. rara* is based on the finely punctate ornamentation, the conspicuous folding of the bladder on the body, and the laesurae with spore coat frequently ruptured along the sutures. Although the dimensions of the Springer specimens are smaller than those cited by Kosanke (1950), they compare with those given for *S.* cf. *rara* Hoffmeister, Staplin, and Malloy (1955*b*). As Love (1960) has suggested, the specimen figured by Butterworth and Williams (1958) as *S. ocellata* is probably *S. rara*. On the basis of Horst's (1955) description of *S. ocellata*, any differentiation from *S. rara* is very difficult. An obliquity of the central body in the former seems to be the only means of distinguishing between the two species, and it is quite likely that examination of the types will result in their being analogous.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus FLORINITES Schopf, Wilson, and Bentall 1944

Type species. F. antiquus Schopf, Wilson, and Bentall 1944.

Florinites guttatus sp. nov.

Plate 64, figs. 1–3

Diagnosis. Bilateral, grains broadly elliptical, body spherical. Monolete suture 25–30 μ long, generally straight, frequently a distinct medial deflection of the suture is evident; occasionally the suture further develops a short, third ray, somewhat indistinct; rarely the vestigial ray develops to full length and forms a distinct trilete. Two prominent folds on the distal side of the body are oriented at right angles to the long axis of the spore, forming a narrow sulcus; although the folds have a considerable degree of uniformity (Pl. 64, fig. 1), they are often displaced inwardly or outwardly (Pl. 64, figs. 2, 3). The body is not enclosed by the bladder proper either distally or proximally, which is contrary to the classic generic description of the body being entirely enclosed by the bladder except for part of the distal side. The bladder proper is internally reticulate and does slightly overlap the body at the point of attachment. However, the dark tapering folds are features of the body and not of the bladder overlap. The spore body is enclosed within a delicate membrane, which is minutely granulose on the proximal side. However, on the distal side this membrane possesses a delicate, yet conspicuous, rugulate type of ornamentation consisting of an irregular, reticuloid pattern with segments 5–10 μ in diameter. Spore body proper is laevigate.

Dimensions. (50 specimens.) Over-all diameter 95–140 × 120–70 μ. Body diameter 45–85 × 65–95 μ.

Holotype. Slide O3V16–13 (A–2). Location 17·1 × 117·6 (Ref. 32·2 × 117·9).

Description. Holotype 103 × 145 μ over-all diameter, body 65 × 80 μ. Monolete suture 30 μ long. Two distinctive vertical folds on distal side of body; spore body covered by thin granulose membrane proximally and a coarser reticuloid membrane distally.

Discussion. The taxonomy of *Florinites* is not at all clear, and at present it includes a variety of monosaccate spores such as those with a well-developed trilete (*F. triletes*) and others with a sulcus (*F. diversiformis*). The writers feel that there is little doubt but that this spore belongs in *Florinites*, yet the present description creates several problems. The bladder never encloses the body, whereas considerable importance has been attributed to this character in saccate generic designations. The germinal aperture with its variation is noteworthy, since Bhardwaj (1955) has regarded the presence or absence of a germinal opening as very important in distinguishing between genera (i.e. *Kosankeisporites* and *Illinites*). *Potonieisporites* is a monosaccate, monolete spore, but *F. guttatus* shows a gradation from monolete to trilete.

Comparison. *F. guttatus* perhaps compares most closely with *F. diversiformis* Kosanke in the general appearance presented by the body folds. However, Kosanke (1950) did not note the readily discernible and variable germinal suture. He did not note, or figure, the rugulate perispore-like covering of the distal body and the contrasting granulose proximal covering. An examination of several specimens of *F. diversiformis* from Kosanke's maceration No. 618 did not disclose these characteristics in his species. There are several saccate spores described with ornamentation similar to the distal pattern of *F. guttatus*. Peppers (1964, p. 43) figured a similar monosaccate grain which he described as polygonally areolate distally, but he did not formally describe the specimen, and properly speaking the ornamentation of *F. guttatus* probably cannot be regarded as areolae.

Other occurrences. Subsurface Springer formation, Anadarko Basin.

Florinites visendus (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 64, fig. 4

1933 *Reticulata-sporites visendus* Ibrahim, p. 39, pl. 8, fig. 66.
1944 *Florinites* (?) *visendus* (Ibrahim) Schopf, Wilson, and Bentall, p. 60.
1956 *Florinites visendus* (Ibrahim) Schopf, Wilson, and Bentall; Potonié and Kremp, p. 170, pl. 21, figs. 476–7.
1957 *Florinites visendus* (Ibrahim) Schopf, Wilson, and Bentall; Bhardwaj, p. 129, pl. 26, fig. 106.

Description. Spore elliptical to circular in equatorial outline. Central body usually absent, indistinct in intact specimens. Bladder coarsely reticulate. No definite laesurae observed.

Dimensions. (50 specimens.) Equatorial diameter 130–240 μ.

EXPLANATION OF PLATE 64

All figures ×500 unless otherwise indicated.

Figs. 1–3. *Florinites guttatus* sp. nov. 1, Holotype. Proximal surface; Slide O3V16–13 (A-2), location 17·1×117·6 (Ref. 32·2×117·9). 2, Distal surface; Slide O3V16–11 (6), location 53×113 (Ref. 31·7×116·9). 3, Distal surface; Slide O3V16–11 (1), location 50·2×95·2 (Ref. 32×118·7).

Fig. 4. *Florinites visendus* (Ibrahim) Schopf, Wilson, and Bentall 1944. Slide O3V16–3 (6), location 21·5×120·6 (Ref. 33×117·9).

Figs. 5, 6. *Costatascyclus crenatus* sp. nov. 5, Distal surface; Slide O3V16–3 (5), location 39×129 (Ref. 33·7×118). 6, Holotype. Distal surface; Slide O3V16–11 (5), location 42·5×108·6 (Ref. 32·6×117·8).

Discussion. The central body usually appeared to be missing, with the central spore region very thin and frequently displaying a slit-like opening. In a few instances damaged specimens were observed with a definite central body enclosed within the large bladder. The differential in size of reticulations between the central area and the saccus as described by Potonié and Kremp (1956*a*) was not observed in the Springer. Actually there appears to be little means of distinguishing *F. visendus* from *F. pumicosus* other than on size. This is generally an unreliable criterion when it is the sole difference, but in this instance there does appear to be a definite wide gap in the size ranges of the two species.

Other occurrences. Subsurface Springer formation, Anadarko Basin; subsurface Morrow formation, upper Pennsylvanian, Anadarko Basin; surface Wildhorse Mountain formation, Jackfork group, upper Mississippian, Le Flore County, Oklahoma.

Genus AURORASPORA Hoffmeister, Staplin, and Malloy 1955

Type species. A. solisortus Hoffmeister, Staplin, and Malloy 1955.

Auroraspora solisortus Hoffmeister, Staplin, and Malloy 1955

Plate 62, fig. 11

Description. Radial, trilete. Central body laevigate, circular to subcircular. Laesurae distinct, slight lip development of 1–1·5 μ, extending two-thirds to three-fourths central body radius. Thin, translucent bladder, frequently plicated, surface finely granulose; bladder width beyond central body, 15–20 μ.

Dimensions. (25 specimens.) Over-all diameter 60–82 μ (70–75 μ average). Diameter of central body 32–50 μ (40–45 μ average).

Discussion. The body is rarely found covered with the thin membrane described by Hoffmeister, Staplin, and Malloy (1955*b*), but the specimens otherwise conform with the original diagnosis.

Other occurrences. Subsurface Springer formation, Anadarko Basin; surface Goddard formation, upper Mississippian, Johnston County, Oklahoma.

Genus COSTATASCYCLUS gen. nov.

Type species. C. crenatus sp. nov.

Diagnosis. Spores bilateral, outline elliptical in transverse plane. Monosaccate, occasionally appearing bisaccate due to orientation. Central body outline circular to elliptical. Bladder intrareticulate; proximal side of body free, distal side characterized by radiating ribs about body periphery. Monolete, with occasional vestigial trilete.

Discussion. Specimens occasionally appear bisaccate due to compression distortion. There is some resemblance to *Rhizomaspora* (Wilson 1962), but the latter is definitely bisaccate. *Costatascyclus* is Wilson's (1965) Sporomorph D (pl. 3, fig. 8) reported from the Springer of the Ti Valley, Pittsburgh County, Oklahoma.

Costatascyclus crenatus sp. nov.

Plate 64, figs. 5, 6

Diagnosis. Monosaccate, bilateral and elliptical in transverse plane, body spherical. Bladder partially inserted on distal surface of body, proximal side free. The distal attachment of the bladder is characterized by a distinct series of folds about the body periphery, forming radiating ribs diverging toward the equator; the resulting structure is a row of deep crenulations around the periphery of the central body distally. The folds are twenty to thirty in number on a specimen, 20–25 μ in length and 5–7·5 μ in width. Suture indistinct, monolete, about one-fourth to one-third length of body, rarely with slight medial deflection, rarely forming a short vestigial ray at the point of deflection to give a trilete appearance. Bladder ornamentation intrareticulate. Spore body laevigate.

Dimensions. (50 specimens.) Over-all size 77×125 μ to 110×165 μ. Body dimensions 54×72 μ to 60×84 μ.

Holotype. Slide O3V16–11 (5). Location 42·5×108·6 (Ref. 32·6×117·8).

Description. Holotype elliptical in outline, central body spherical. Over-all size 99×165 μ; body 54×67 μ. Radiating folds of bladder on distal side extend to 20 μ in length and are 5–7 μ in width.

Genus POTONIEISPORITES Bhardwaj 1954

Type species. *P. novicus* Bhardwaj 1954.

Potonieisporites elegans (Wilson and Kosanke) Wilson and Venkatachala 1964

Plate 66, fig. 1

1944 *Florinites elegans* Wilson and Kosanke, p. 330, fig. 3.
1964 *Potonieisporites elegans* (Wilson and Kosanke) Wilson and Venkatachala, pp. 67–68, figs. 1, 21.

Description. Monosaccate, elliptical in transverse plane, body elliptical to oval in outline. Monolete suture parallel to long axis, one-half of body length, usually splitting at maturity to form gaping fissure extending entire length of body. Bladder intrareticulate,

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EXPLANATION OF PLATE 65

All figures ×500 unless otherwise indicated.

Figs. 1–3. *Hadrohercos stereon* sp. nov. 1, Holotype. Proximal surface; Slide O3V16–10 (2), location 23·5×114 (Ref. 53×117·7). 2, Wall detail; ×750. Slide O3V16–3 (6), location 41×125 (Ref. 33×117·9). 3, Wall detail; ×750. Slide O3V16–10 (2), location 23·5×114 (Ref. 53×117·7).

Figs. 4, 5. *Tantillus triquetrus* sp. nov. Holotype. Distal surface; ×750. Slide O3V16–11 (6), location 40·8×110·1 (Ref. 31·7×116·9).

Figs. 6–8. *Nexuosisporites comtus* sp. nov. 6, Holotype. Proximal surface; Slide O3V16–11 (6), location 48·5×125·5 (Ref. 31·7×116·9). 7, Distal surface; Slide O3V16–11 (6), location 48·5×125·5 (Ref. 31·7×116·9). 8, Distal surface; Slide O3V16–11 (6), location 49·5×106·5 (Ref. 31·7×116·9).

Fig. 9. *Diatomozonotriletes sp.* Proximal surface; Slide O3V16–7 (2), location 24·5×116 (Ref. 31·5×116·8).

covering distal side of body, proximal body surface free of bladder attachment. Body marked by conspicuous distal folds, probably compressional, elliptical or biconvex in outline and oriented perpendicular to the monolete fissure. Another series of folds not so conspicuous and appearing to develop first, are formed along the margin of the central body. Central spore body itself is laevigate.

Dimensions. (50 specimens.) Over-all size $100 \times 137\ \mu$ to $145 \times 200\ \mu$. Body 70–72 μ to $102 \times 108\ \mu$.

Discussion. As with most fossil species, there are a number of variations evident in a study of large numbers. The conspicuous, characteristic lateral split is evidently a feature of development and subsequent compression. Excellently preserved specimens were observed with the suture intact and the lateral slit not yet developed. Similarly, in a few specimens, the distal folds across the suture are not formed or are only slightly developed in those specimens in which the full opening has not developed. In these instances however, the first series of folds about the margin of the central body are already evident.

Genus CYSTOPTYCHUS gen. nov.

Type species. *C. velatus* sp. nov.

Diagnosis. Spores monosaccate, radial, trilete; body circular to irregularly subcircular. Distinct central body surrounded by thin, flexuous bladder, which is characteristically folded obliquely to one side. Laesurae distinct, simple, straight, extending nearly to body margin; germinal apertures usually breached.

Cystoptychus velatus sp. nov.

Plate 63, fig. 5

Diagnosis. Monosaccate, trilete; spore body circular to irregularly subcircular. Laesurae straight, simple, 20–34 μ long, extending nearly to body margin. Trilete area characteristically gaped open, forming triangular opening with dimensions $30 \times 40\ \mu$ to $35 \times 55\ \mu$. Thin, flexuous bladder entirely surrounding spore body and characteristically folded obliquely to one side. Bladder insertion at body equator and width up to 45 μ. Spore body laevigate, wall 2 μ thick, bladder minutely granulose.

Dimensions. (25 specimens.) Diameter of body 55–76 μ.

Holotype. Slide O3V16–9 (5). Location $30{\cdot}2 \times 115$ (Ref. $32{\cdot}4 \times 118{\cdot}6$).

Description. Holotype body $70 \times 75\ \mu$; body laevigate, wall 2 μ thick; bladder minutely granulose, laterally compressed, extending 15 μ beyond periphery of body. Trilete rent to form triangular opening $35 \times 55\ \mu$.

Discussion. The asymmetrical appearance produced by the inclination of the bladder to fold in one direction, and the triangular breach or rent in the wall as a result of the open trilete, are the main distinguishing characters. Very rarely was a specimen observed with the bladder visible about the entire body periphery. The actual insertion of the thin bladder upon the body was difficult to ascertain. However, the orientation of the bladder to one side is not fortuitous but probably due to an oblique angle of insertion upon the body. This was never definitely observed, but fully 95 per cent. of the specimens had the asymmetrical form shown in Plate 63, fig. 5. Similarly, at least 95 per cent. had the breached germinal opening. There is a superficial resemblance to *Auroraspora*, but in addition to the bladder insertion and the breached trilete, the body size is significantly greater than in *Auroraspora*, the ratio of body diameter to bladder width is appreciably less in *Cystoptychus*, and the bladder insertion on the body is much more pronounced in *Cystoptychus*.

ADDITIONAL SPRINGER TAXA

As is the case in most studies of the scope of this one, a number of unresolved problems remain. In many instances the authors have used their own judgement in evaluating the importance of a spore, and accordingly some representatives have been omitted. This is especially true of the *Granulatisporites* group where taxonomy is confused and morphological characteristics almost nonexistent. The majority of the spores probably assignable to this taxon from the Springer are omitted, but these and other taxa will receive further study should future developments in palynology render it advisable. Several identifiable entities were also observed but not treated formally because of poor preservation and/or insufficient specimens. Several of these are illustrated on Plates 65 and 66. Prominent among these is *Florinites volans* (Pl. 66, fig. 2), which was definitely identified but represented by only three specimens.

The zonate microspores referable to *Simozonotriletes* and *Murospora* are rare in the Springer, but a few were observed. Considerable disagreement still exists on the nomenclatural status of these genera, even though Playford (1962) has established a synonymy. In view of the still unsatisfactory taxonomy, both names are provisionally retained. Too few specimens were encountered in the Springer to allow any adequate interpretation. The specimen figured on Plate 66, fig. 8 is definitely assignable to *Murospora aurita* (Waltz) Playford 1962. The specimens on Plate 66, figs. 9, 10 are assignable to *Simozonotriletes* (*sensu* Sullivan 1958) and also exhibit the morphological variations he demonstrated in his nomenclatural treatment.

EXPLANATION OF PLATE 66

All figures ×500 unless otherwise indicated.

Fig. 1. *Potonieisporites elegans* (Wilson and Kosanke) Wilson and Venkatachala 1964. Proximal surface; Slide O3V16–3 (5), location 24×110·8 (Ref. 33·7×118).

Fig. 2. *Florinites volans* (Loose) Potonié and Kremp 1955. Proximal surface; Slide O3V16–4 (R-1), location 34×120 (Ref. 32·3×118·7).

Fig. 3. Cellular sporangium. Slide O3V16–11 (7), location 29×110·9 (Ref. 31·9×117·9).

Fig. 4. Unknown spore. Proximal surface; Slide O3V16–9 (R-1), location 47×129 (Ref. 32·4×118·6).

Fig. 5. *Raistrickia* sp. Proximal surface; Slide O3V16–13 (A-2), location 36×116 (Ref. 32·2×115·5).

Fig. 6. *Alatisporites* sp. Showing six wings; Slide O3V17–7 (1), location 25×108·5 (Ref. 32×118).

Fig. 7. *Granulatisporites* sp. Proximal surface; Slide O3V16–4 (R-1), location 21·2×124·5 (Ref. 32·3×118·7).

Fig. 8. *Murospora aurita* (Waltz) Playford 1962. Proximal surface; Slide O3V16–6 (2), location 45×109 (Ref. 33×117·8).

Figs. 9, 10. *Simozonotriletes* sp. 9, Distal surface; Slide O3V16–10 (A-2), location 18·6×107 (Ref. 30×117·6). 10, Proximal surface; Slide O3V16–10 (A-2), location 48×121 (Ref. 30×117·6).

Fig. 11. *Procoronaspora fasciculata* Love 1960. Proximal surface; Slide O3V16–3 (1), location 25×127 (Ref. 33×117·1).

REFERENCES / SPORE SPECIES	MISSISSIPPIAN														PENNSYLVANIAN								SURFACE SPRINGER
	KINDER-HOOK		OSAGE		MERA-MEC		CHESTER								MORROW						ATOKA		
	TOURNAISIAN				MIDDLE VISEAN		UPPER VISEAN						NAMURIAN A		B&C	WESTPHAL. A					WEST-PHAL. B		
	PLAYFORD 1962 & 1963	HACQUEBARD 1957	PLAYFORD 1964	SULLIVAN 1964 b	PLAYFORD 1962 & 1963	LOVE 1960	WIGGINS 1962	STAPLIN 1960	H.S. & M. 1955 b	SULLIVAN 1964 a	SULL. & MARSH 1966	HACQ. & BARSS 1957	BUTT. & WILL. 1958	NEVES 1961	NEVES 1961	NEVES 1958	ARTÜZ 1957	SULLIVAN 1964 a	KOSANKE 1950	GUENNEL 1958	KOSANKE 1950	GUENNEL 1958	
LOPHOTRILETES CONIFERUS	●																						●
KNOXISPORITES HEDERATUS	●			●																			●
LEIOTRILETES ORNATUS	●				●																		●
L. SUBINTORTUS VAR. ROTUNDATUS	●				●																		●
CONVOLUTISPORA CRASSA	●				●																		●
STENOZONOTRILETES SPETCANDUS	●				●																		●
DENSOSPORITES VARIABILIS	●				●								●										●
PEROTRILETES PERINATUS	●		●																				●
CONVOLUTISPORA VERMIFORMIS	●		●																				●
ENDOSPORITES MICROMANIFESTUS	●	●	●			●					●												●
CYCLOGRANISPORITES LASIUS	●				●						●												●
PUNCTATISPORITES SOLIDUS		●																					●
PUNCTATISPORITES IRRASUS		●																					●
GRANDISPORA ECHINATA		●																					●
LYCOSPORA UBER		●			●		●			●	●	●											●
DENSOSPORITES ACULEATUS			●				●																●
KNOXISPORITES TRIRADIATUS				●	●	●			●		●					●							●
RETICULATISPORITES PELTATUS					●		●																●
ANAPICULATISPORITES CONCINNUS					●																		●
DENSOSPORITES RARISPINOSUS					●																		●
DENSOSPORITES IRREGULARIS					●							●											●
WALTZISPORA SAGITTATA					●	●																	●
SCHULZOSPORA RARA						●										●			●				●
LEIOTRILETES TUMIDUS						●					●		●										●
LYCOSPORA NOCTUINA						●	●				●		●										●
CONVOLUTISPORA MELLITA						●	●			●	●		●										●
KNOXISPORITES STEPHANEPHORUS						●	●			●	●												●
CONVOLUTISPORA FLORIDA						●	●		●	●	●		●										●
KNOXISPORITES CORPOREUS							●																●
PROPRISPORITES RUGOSUS							●									●							●
CIRRATRIRADITES SATURNI							●											●				●	●
SAVITRISPORITES NUX							●						●					●					●
TRIPARTITES VETUSTUS							●				●		●										●
KNOXISPORITES DISSIDIUS							●							●	●								●
SECARISPORITES REMOTUS							●								●								●
DICTYOTRILETES PACTILIS							●				●												●
DICTYOTRILETES CLATRIFORMIS							●										●	●					●
CRASSISPORA KOSANKEI'							●			●					●								●
SPENCERISPORITES RADIATUS							●				●		●										●
ROTASPORA FRACTA							●				●		●										●
GRANDISPORA SPINOSA							●		●		●												●
LYCOSPORA NITIDA							●				●		●				●						●
AURORASPORA SOLISORTUS							●	●		●			●										●
GRANULATISPORITES TUBERCULATUS									●														●
CONVOLUTISPORA VENUSTA									●														●
GRANULATISPORITES POLITUS									●				●										●
LYCOSPORA PSEUDOANNULATA									●										●		●	●	●
GRANULATISPORITES PALLIDUS									●										●	●		●	●
TRICIDARISPORITES CF BALTEOLUS											●												●
SIMOZONOTRILETES INTORTUS											●	●	●										●
DICTYOTRILETES INSCULPTUS															●								●
MOOREISPORITES TRIGALLERUS														●	●								●
FLORINITES VISENDUS														●									●
PROPRISPORITES LAEVIGATUS														●	●								●
REINSCHOSPORA SPECIOSA														●									●
LOPHOTRILETES LABIATUS																		●					●
LAEVIGATOSPORITES OVALIS																			●			●	●
CALAMOSPORA PARVA																				●		●	●
GRANULATISPORITES SPINOSUS																					●	●	●
LYCOSPORA BREVIJUGA																					●	●	●

TABLE 1

Comparison of the Springer spore assemblage with other recorded spore assemblages.

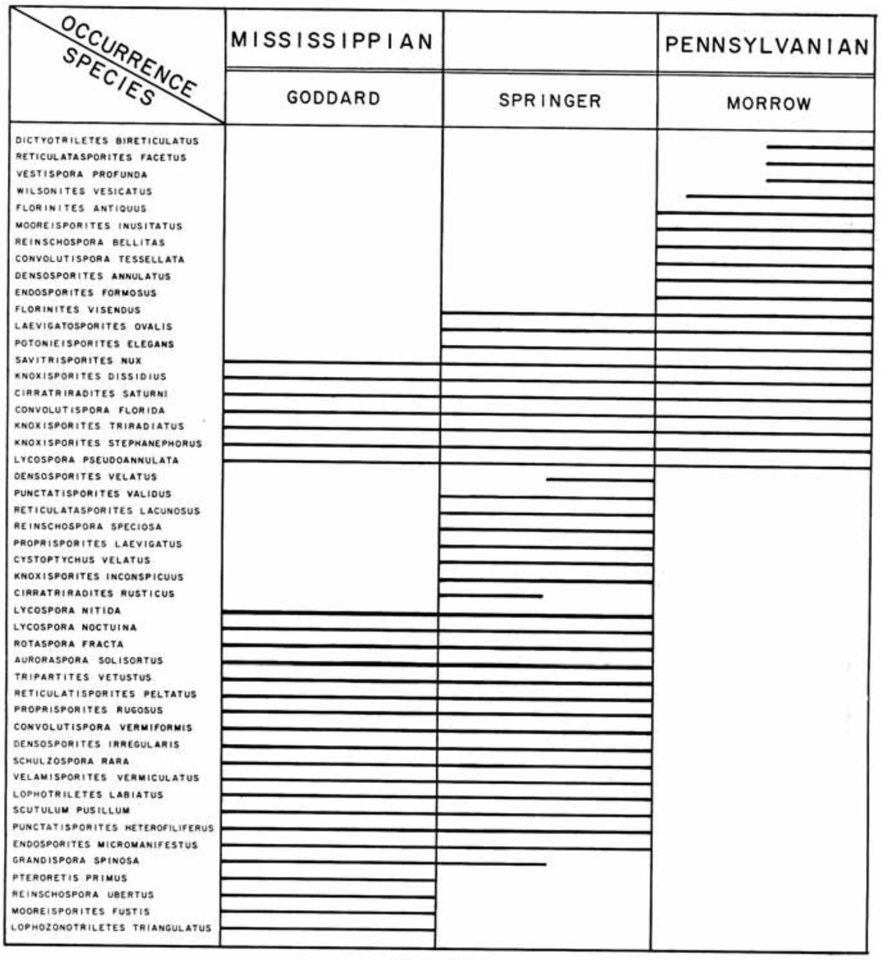

TABLE 2

The ranges of key spores illustrated are based upon the occurrence of spores in the surface Goddard and Springer formations of Johnston County, Oklahoma at the Goddard Ranch locality. The Morrow occurrences are the results of subsurface studies in the Anadarko Basin and from the examination of surface samples from the Morrow type area of Arkansas.

Sullivan and Marshall (1966) have considered *Procoronaspora* as a junior synonym of *Rotaspora*, making retention of *Procoronaspora* unnecessary. Their basis for this is the possession of a cingulum which is wider interradially than at the apices. However, a few specimens have been observed in the Springer (Pl. 66, fig. 11), which possess an incipient corona and no definable cingulum. These compare most closely with *Procoronaspora fasciculata* Love (1960). Sullivan and Marshall (1966) may be justified in their interpretation of *P. ambigua* as *Rotaspora*, but it appears quite likely that the specimens of Love and those from the Springer cannot be assigned to *Rotaspora*. Sullivan and Marshall (1966) did place Love's species in their new genus *Tricidarisporites*, but we have chosen to reject this assignment and question whether their illustrated specimens are the same as that of Love. Since Sullivan and Marshall's synonymy involved the holotype of *Procoronaspora*, there is no depository for our specimens. We lack sufficient material to make an adequate study, but restudy of *P. fasciculata* should provide clarification as to whether assignment to *Rotaspora* is warranted or if a new taxon is required.

Also observed in the Springer from samples O3V16–6 and O3V16–14, but not illustrated, were specimens assignable to the genus *Tricidarisporites* described by Sullivan and Marshall (1966) and probably referable to their species *T. balteolus*.

The specimen figured on Plate 54, fig. 4 offers the possibility of a definable taxon because of its unusual morphology, but insufficient specimens were observed for formal treatment.

The cellular mass illustrated on Plate 66, fig. 3 was very conspicuous throughout the Springer section and was especially common in sample O3V16–11. It is definitely a sporangial structure, and occasionally small trilete spores were observed associated with the cells, but these spores were not treated separately in this study. Poorly preserved specimens of *Spencerisporites* were also noted; the extreme rarity of this genus was somewhat unexpected since we have often observed it in considerable numbers from older sediments, and frequently it is abundant in lower Pennsylvanian strata.

EVALUATION OF THE PALYNOLOGY OF THE SPRINGER

Our initial interpretation of the Springer formation was one of a transitional microflora, ranging from predominantly Mississippian in the lower Springer to Pennsylvanian in the upper part of the formation. However, our study has not borne out all early expectations. The Springer formation does have a transitional spore flora in the qualitative sense as illustrated in Table 1, for it does contain spores representative of lower Mississippian (Tournaisian) through the lower Pennsylvanian (Westphalian B). Table 2 demonstrates that the Springer formation in the study area contains several spore species commonly associated only with Pennsylvanian age sediments, as well as some characteristic only of the Mississippian. It also has a number of longer ranged species, which extend without interruption from the upper Mississippian into the lower Pennsylvanian. However, quantitatively the Springer is not as transitional as it is simply a mixed microflora, and the anticipated gradation from predominantly Mississippian in the lower Springer to a predominantly Pennsylvanian in the upper Springer did not materialize. Expectations were that the lower Springer would be entirely Mississippian in character, with the Mississippian spores progressively decreasing both quantitatively and qualitatively upsection and a subsequent quantitative and qualitative increase in Pennsylvanian representatives to a completely Pennsylvanian population in the upper Springer. There is, in actuality, an erratic occurrence of predominantly Pennsylvanian or predominantly Mississippian population throughout the entire Springer section (Table 4). At times there is a considerable percentage of both Mississippian and Pennsylvanian

SAMPLE / SPORE SPECIES	03V16–1	03V16–3	03V16–4	03V16–5	03V16–6	03V16–7	03V16–8	03V16–9	03V16–10	03V16–11	03V16–12	03V16–13	03V16–14	03V17–1	03V17–2	03V17–4	03V17–5	03V17–7	03V18–1	03V19–1
*CHAETOSPHAERITES POLLENISIMILIS	.5	.5	.5		.5	.5	.5		●	●		●	●				●			
*LEIOTRILETES ORNATUS		.5		●						●	.5	.5		.5					●	
*LEIOTRILETES SUBINTORTUS VAR ROTUNDATUS		●	●				●		1.5	●		●	●	.5	1.5					
*LEIOTRILETES TUMIDUS	.5	●		●		.5	.5			.5	.5	●	●							
PUNCTATISPORITES DIVARICATUS	●	1.5		.5					●	●			●	●						
PUNCTATISPORITES FLEXUOSUS								●	●	.5				●	.5					
PUNCTATISPORITES HETEROFILIFERUS	1.0	10.0	5.5	3.5	5.5	2.5	9.0	9.5	7.0		.5	●			7.0		13.0			
PUNCTATISPORITES INCOMPTUS	.5							.5	1.0	●		.5								
PUNCTATISPORITES IRRASUS	1.0		.5				.5	●					●							
*PUNCTATISPORITES SOLIDUS	2.0	.5		1.5	.5	3.0	1.0	2.0	4.0	.5				.5	1.0			1.0		1.0
PUNCTATISPORITES TRIFIDUS		.5		.5			.5		1.5	●		.5		●						
PUNCTATISPORITES VALIDUS	4.0	1.0	1.0	3.5	3.5	2.5	3.5	.5	8.5	2.0	1.0	.5	1.5	.5	3.0		1.5	1.0	.5	10.0
CALAMOSPORA CF. HARTUNGIANA	2.0	4.5	4.5	1.5	3.5	.5	4.5	4.5	2.0	2.5	1.0	1.5	2.5	3.0	3.0	●	8.0	9.0	2.5	
CALAMOSPORA CF. PARVA	2.0	4.5	4.5	2.5	2.0	1.0	1.5	3.0	.5	2.0	1.0	.5		1.5	3.0		3.5	3.0	1.0	
*WALTZISPORA SAGITTATA		●	●	1.0	●			1.5		.5	.5	●		●	●	●				
GULISPORITES INCOMPTUS	.5	●	.5	2.0	1.5	1.0	.5	●	2.5	.5		●	●	.5		●				4.0
HADROHERCOS STEREON		●		.5	●		●		●											
*CYCLOGRANISPORITES LASIUS	1.5	2.0	1.0	2.0			.5		2.5	1.5	1.0	.5	1.0	2.0	1.0	●	.5	1.5	1.5	
GRANULATISPORITES CF. PALLIDUS	10.5	9.0	4.5	5.5	5.0	2.5	2.5	2.5	7.0	8.5	4.5	4.5	1.0	5.0	9.0		.5		3.5	
GRANULATISPORITES POLITUS	.5	1.5	.5	.5	●			●		●		●	.5							
GRANULATISPORITES SPINOSUS	2.5	1.5	●	1.0	1.0				1.0	●	.5			.5			.5		.5	
GRANULATISPORITES TUBERCULATUS	2.5	2.5	1.0	1.0	.5		1.5	.5		2.5	.5	.5	.5	1.5	2.5				1.0	
*LOPHOTRILETES CONIFERUS	●	.5			●			●				.5	●	●	.5	●				
LOPHOTRILETES LABIATUS	●	●	●							●		●		●	●			●		
LOPHOTRILETES OBTUSUS	1.5	1.0	●	1.0	.5		●	●	2.5	1.5	.5	●	.5	.5	1.5					
*ANAPICULATISPORITES CONCINNUS	.5	.5			●							●	●							
RAISTRICKIA VULGATA	●	●						.5	●	●		●	.5	.5						
IBRAHIMISPORES SENTUS		●																		
SPINOZONOTRILETES PROCINCTUS		.5		1.0	.5				●	2.5		●		●	●					
MOOREISPORITES LUCIDUS										●		.5	●							
MOOREISPORITES TRIGALLERUS					●					●		●	●							
CYCLOBACULISPORITES GRANDIVERRUCOSUS	1.0	.5		.5	1.5	.5	1.0			.5		●		1.5	●					
GRANDISPORA ECHINATA		●	●	●			●	●		●		●	●							
*GRANDISPORA SPINOSA	●	●			1.0	●	.5		●											
CONVOLUTISPORA CRASSA									●	●										
CONVOLUTISPORA FLORIDA	1.0	1.5		1.5	.5	.5			1.5	●				1.0	2.5			1.0		1.0
CONVOLUTISPORA LEPIDA								●		●			●		●					
*CONVOLUTISPORA MELLITA		●	.5	●	.5	.5	.5					●	.5	1.0	2.5	●		●		
CONVOLUTISPORA SCULPTILIS		●					●	●	●											
CONVOLUTISPORA SUPERFICIALIS		●	●	.5	●		●	.5		●		●	●		●					
CONVOLUTISPORA VENUSTA		●	●		●	.5			1.0	●				.5						
CONVOLUTISPORA VERMIFORMIS		●	●				●	●												
*DICTYOTRILETES CLATRIFORMIS	2.0	1.5	.5				.5	.5	.5	2.0	1.5	1.0	1.5		12.5					
*DICTYOTRILETES PACTILIS	3.0		.5				.5	.5	●	●	.5			●						
DICTYOTRILETES INSCULPTUS		●	●	●			●	●	●	●			●		●					
RETICULATISPORITES DECORATUS			●	.5				●				●		●						
*RETICULATISPORITES PELTATUS		●			.5	●		●	●	.5		●		●	●	●		●	.5	
FOVEOSPORITES FUTILIS	1.0	.5						●		●		.5								
SECARISPORITES REMOTUS	.5	●	.5		.5		.5	1.5	.5	●		●	●	1.0	●	●	●			
RETICULATASPORITES LACUNOSUS		.5						.5	.5	●				●				.5		1.0
PEROTRILETES PERINATUS		.5	.5	.5	●			●		●				.5	●	●				
*VELAMISPORITES DESCRETUS			.5	.5	●		●	●	●				●							
VELAMISPORITES VERMICULATUS		●		.5		●		●	.5				●							
TRIPARTITES DUBITALIS				●	●	●	●					●		●	●					
*TRIPARTITES VETUSTUS		●	●		●	.5		●	.5			●		.5	2.0			●		
AHRENSISPORITES IRRORATUS		●	●							●		●	●	●	●					
SCUTULUM PUSILLUM								●		●	.5	●	●							
TANTILLUS TRIQUETRUS	1.0	1.0	●		●		●	.5	●	.5		.5	.5	.5	.5	●			.5	
LYCOSPORA BREVIJUGA		4.5	1.0	.5	1.0	●	.5	5.5		1.5		2.0	3.0	1.0						
*LYCOSPORA NITIDA	1.0	.5								●	●	●	●	●	●	●	●		.5	
*LYCOSPORA NOCTUINA	.5	3.5	12.5	7.5	5.0	4.5	9.0	7.5		30.5	11.0	16.5	8.5	6.0			.5		2.5	
LYCOSPORA PSEUDOANNULATA	3.0	11.0	20.5	16.5	17.5	20.5	21.5	13.5	3.0	9.5	54.5	44.0	51.5	11.0	8.5		2.0	3.0	42.5	58.0
*LYCOSPORA UBER		●	●	●	●	2.0		2.5	1.0	1.5	1.5	6.0								
*ROTASPORA FRACTA			●	●	●	●	●	.5		●		●	●	●						
SIMOZONOTRILETES INTORTUS										●										
DENSOSPORITES VELATUS												●	●	.5	.5		6.5	8.5		

SAMPLE / SPORE SPECIES	O3V16–1	O3V16–3	O3V16–4	O3V16–5	O3V16–6	O3V16–7	O3V16–8	O3V16–9	O3V16–10	O3V16–11	O3V16–12	O3V16–13	O3V16–14	O3V17–1	O3V17–2	O3V17–4	O3V17–5	O3V17–7	O3V18–1	O3V19–1
*DENSOSPORITES ACULEATUS		●	.5		●	●		.5	.5			●		.5						1.0
DENSOSPORITES HISPIDUS		1.0	10.5	2.5	5.5	12.0	6.5	1.5	●	1.0	2.0	5.0	9.5	.5	.5			.5	6.5	2.0
*DENSOSPORITES IRREGULARIS		●	1.5	1.5	1.0	3.0		.5				●	.5	●					.5	●
DENSOSPORITES RARISPINOSUS	.5	.5		.5	1.0	.5	.5	●	3.0	●		1.5	.5	3.0						
*DENSOSPORITES VARIABILIS			1.0	1.5	4.0	4.5	2.5	●		.5	.5	.5	2.5	1.0					1.5	1.0
DENSOSPORITES DISSIMILIS		●	●	●	.5	1.0	1.0	.5		.5	1.0		●						5.0	1.0
KNOXISPORITES CORPOREUS	●	●					●		●	.5										1.0
*KNOXISPORITES DISSIDIUS		●	●	.5				●		●		●		●	●					
*KNOXISPORITES HEDERATUS		.5			.5		.5	1.5	1.0	.5				.5	.5					
KNOXISPORITES INCONSPICUUS	●	.5			●		.5	1.5		●	.5	●		●						
*KNOXISPORITES TRIRADIATUS	1.0	.5		●	●	.5	.5	●	.5	.5		●	●	●						●
*KNOXISPORITES STEPHANEPHORUS	.5	●	●	●			1.5	.5		●	.5	●	●	●	1.5					
NEXUOSISPORITES COMTUS	●					.5		●		●			●		●					
*STENOZONOTRILETES CF. SPETCANDUS		●	●	.5	.5		●	.5	.5				●	.5				●		
CRASSISPORA KOSANKEI′		.5	.5	1.5	1.0	1.0	1.5	1.5	●	.5	●	.5	.5	2.0	2.5		10.5	6.5		
CRISTATISPORITES INDIGNABUNDUS		●	.5	.5	1.0		.5	.5		.5	.5	●		●						
CINCTURASPORITES MINIMUS				●			●	.5	●		●									
CINCTURASPORITES MAGNUS				.5	●		●	●						●	.5					
TROCHOSPORA MASTOSPINOSA			.5	.5			.5	●		●			.5							
SAVITRISPORITES NUX	1.0	.5	●	●	.5	.5	.5	.5	.5	●		●	.5	1.0	7.0	●		●	1.5	
CIRRATRIRADITES LEPTOMARGINATUS	●	●	.5	.5				●		.5				●						
CIRRATRIRADITES RUSTICUS			●	3.0	1.5	●	.5	.5												
CIRRATRIRADITES SATURNI	●	.5	.5	.5	1.5	2.5	1.5	.5	2.0	●		●	.5	1.0	.5					1.0
REINSCHOSPORA SPECIOSA			●	●	●		●	●				●								
PROPRISPORITES RUGOSUS							●			●										
*PROPRISPORITES LAEVIGATUS	●	.5	●					.5	2.5	●		●								2.0
HYMENOSPORA CAPERATA	.5	.5	●	.5	.5		●	●	●	●			.5	1.0	1.5	●				
LAEVIGATOSPORITES OVALIS		●			●	●		●		●		●		1.0						
MONOLETES OVATUS		.5	●	2.5	3.5	.5	●	1.5	2.5	.5		.5	.5	6.0	1.5	●	1.5	23.0	●	
MONOLETES SP.				.5			●	.5	.5			●		●	●					
*ENDOSPORITES MICROMANIFESTUS		.5	●		●			.5	.5					1.0						
*SCHULZOSPORA RARA		.5	●		●			.5		●			●	●	.5		1.5	.5		
FLORINITES GUTTATUS	2.5	●		●					5.0	●		●		●	●	●		1.0	1.0	
FLORINITES VISENDUS	11.5	●	.5				.5	●	3.0		.5	●	●	22.0	6.0	●	3.5	11.5	3.0	2.0
*AURORASPORA SOLISORTUS	1.0	.5	.5	.5	●		.5	.5	1.0	.5		●		●	1.0		●			
COSTATASCYCLUS CRENATUS		●	.5					.5	1.0	1.0		●	●		.5					
POTONIEISPORITES ELEGANS	1.0	1.5	1.5	.5			1.0	●	3.0	4.5	1.0	.5	.5	.5		●	●	2.0	1.5	5.0
CYSTOPTYCHUS VELATUS	5.0	8.5	●	2.0	1.0		●	1.0	.5				●	●	●		.5			

TABLE 3

Spore distribution in the Springer formation from samples suitable for quantitative specific estimation. Constituent species are listed as percentages based upon individual counts of 300 specimens. Species observed in a particular sample but not occurring in actual count are indicated by '●'. Species utilized in compiling composite percentages in Table 4 are indicated by '*'.

representatives together in samples as in O3V16–1, O3V16–3, O3V16–10, and O3V17–1. On occasion the assemblage is dominated by either Pennsylvanian alone or only Mississippian as in O3V16–4 through O3V16–9 which is largely Mississippian or O3V17–7 and O3V19–1 which is largely Pennsylvanian. It might be best said that the Springer represents a final transgressional facies of the Mississippian Goddard formation rather than being transitional. There are a number of spores observed to be restricted to the Springer formation, both in the surface area of interest and in the subsurface of the Anadarko Basin. Chief among these are *Densosporites velatus*, *Reticulatasporites lacunosus*, *Cystoptychus velatus*, *Cirratriradites rusticus*, and *Proprisporites laevigatus*. However, valuable though they may be, they constitute such a numerical minority that the over-all features of the assemblage must be considered in each sample and the mixed nature of the 'population' enters into any analysis.

The formation is characterized by the occurrence of a number of genera usually regarded as restricted to the Mississippian and considered to be reliable Mississippian age indicators. Among these are *Auroraspora*, *Rotaspora*, *Proprisporites*, and *Tripartites*. Similarly, such species as *Lycospora noctuina*, *L. nitida*, *Reticulatisporites peltatus*, and *Densosporites irregularis* also regarded as Mississippian are present. A number of other genera considered to be at least predominantly Mississippian are also recorded; *Schulzospora* is perhaps the principal one, while *Cincturasporites*, *Velamisporites*, and *Waltzispora* may be included within this category. On the other hand, a number of spores usually regarded as Pennsylvanian in range occur throughout the Springer, often in large numbers and frequently in association with the Mississippian representatives. The monosaccate genera *Florinites* and *Potonieisporites* and the monolete *Laevigatosporites* are perhaps the most striking examples. The saccate genera also best illustrate the absence of a transitional microflora, for two of the highest percentage occurrences of saccate forms are in the lowermost and uppermost samples (Table 4). In both samples the principal saccate representative is *Florinites visendus* (Table 3). The presence of the saccata genera is not unique, and Neves (1961, p. 276) recorded *Florinites elegans*, *F. similis*, and *F. visendus* from the Namurian A, the first records of these monosaccate grains from this age deposit. The saccate genera constitute one of the most noticeable differences between the Goddard and the Springer. In his Goddard investigation, Wiggins (1962) recorded only ten or fifteen saccate specimens in a survey of 600 slides.

Although the Springer is difficult to characterize in its entirety on the basis of a distinct entity or even assemblage, it does have a number of noteworthy trends (Tables 3, 4). Over-all the lower Springer is marked by the large numbers of *Punctatisporites*, and the lowermost Springer (O3V16–1, 3) has 5·0–8·5 per cent. of *Cystoptychus*, which is rare in the remainder of the formation. The middle Springer is distinguishable by the large numbers of *Lycospora noctuina*. In the upper Springer *Densosporites velatus* does not appear until O3V16–13 and ranges from 6·5–8·5 per cent. in the upper Springer. Although *Monoletes ovatus* is present throughout the section in small numbers, it is a conspicuous representative in the upper Springer where it composes 23 per cent. of sample O3V17–7. Several genera are completely absent from the upper Springer, and most notable among these and not recorded above O3V17–2 are *Ibrahimispores*, *Mooreisporites*, *Grandispora*, *Velamisporites*, *Rotaspora*, *Nexuosisporites*, and *Cincturasporites*. However, they usually constitute such a small part quantitatively that their presence or absence is often difficult to detect.

Relatively few significant trends are evident in the distribution of genera, and *Lycospora* and the saccate genera are the most noteworthy (Table 4). The species included in the composite saccate grouping of Table 4 are *Florinites guttatus*, *F. visendus*, *Costatascyclus crenatus*, *Cystoptychus velatus*, and *Potonieisporites elegans*. Both spore groups demonstrate changes in crossing the sandstone intervals. At the Overbrook sand the assemblage is marked by the near disappearance of *Lycospora* statistically, but with a considerable increase in the saccate spores, particularly *Florinites* and *Potonieisporites*. A somewhat similar trend is also present at the Lake Ardmore sand. It might also be significant that, whereas the percentage of *Lycospora* as a whole decreases in crossing the sandstone intervals, in both instances *Lycospora noctuina* disappears completely qualitatively and quantitatively. These patterns of distribution tend to indicate the possibility of an additional sandstone section in the covered interval between samples O3V16–14 and O3V17–1. The over-all *Lycospora* population and the saccate genera demonstrate trends comparable to those present in crossing the Overbrook and Lake Ardmore sandstones. However, *Lycospora noctuina* does not substantiate this since it is present in fair numbers. There is the possibility that shales immediately adjacent to a covered section were not sampled. However, field examination of the exposure did not indicate the existence of such a sand, and the sole evidence is based upon the pattern of general spore populations.

SAMPLE / SPORES	O3VI6-1	O3VI6-3	O3VI6-4	O3VI6-5	O3VI6-6	O3VI6-7	O3VI6-8	O3VI6-9	O3VI6-10	O3VI6-11	O3VI6-12	O3VI6-13	O3VI6-14	O3VI7-1	O3VI7-2	O3VI7-5	O3VI7-7	O3VI8-1	O3VI9-1
LYCOSPORA	4.5	19.5	34.0	24.5	23.5	27.0	31.0	29.0	4.0	43.0	67.0	68.5	63.0	18.0	8.5	2.5	3.0	45.5	8.0
SACCATE	20.0	10.0	2.5	2.5	1.0	1.5	1.5	1.5	13.0	5.5	1.5	0.5	0.5	22.5	6.5	3.5	14.0	5.5	25.0
COMPOSITE 6 MISSISSIPPIAN	1.0	1.0	0.5	1.0	1.0	0.5	1.0	1.5	4.0	0.5	–	–	–	0.5	3.0	–	–	–	2.0
COMPOSITE 32 MISSISSIPPIAN	9.5	12.0	19.0	17.0	14.0	19.0	19.0	20.0	16.0	40.0	17.5	25.5	14.5	14.5	25.5	2.5	3.0	7.0	5.0

TABLE 4

Spore distribution of composite groupings of selected species from the Springer formation.

The lack of a well-defined gradation from Mississippian to Pennsylvanian is further demonstrated by the percentage occurrences of several Mississippian species. A composite group of six reliable Mississippian species in Table 4 shows the highest percentage occurrence to be only 4 per cent., near the middle of the section. In some samples these species are not even represented. The six species utilized are *Grandispora spinosa*, *Tripartites vetustus*, *Lycospora nitida*, *Rotaspora fracta*, *Proprisporites laevigatus*, and *Auroraspora solisortus*. A second evaluation was made grouping thirty-two species considered as predominantly Mississippian. These are each indicated by an asterisk in Table 3 and include the six species used in the previous discussion. Here, again, no gradational pattern was evident, and in truth the upper Springer has perhaps a slightly more Mississippian appearance than does the lower Springer. The percentage of Mississippian species is often affected by *Lycospora noctuina*, which sometimes occurs in sufficiently high numbers to obscure the other components.

It is admittedly difficult, when working with such assemblages as these, to identify them accurately since given samples may be Pennsylvanian or Mississippian in character. The Springer assemblages are probably ecologically influenced in deposition, and on occasion it could be impossible to place a sample in its proper place in the section. Floras such as the Springer are not unusual in megafossil studies, and Tschudy (1964) has cited what he terms as transitional floras in the Devonian–Mississippian, the Mississippian–Pennsylvanian, the Pennsylvanian–Permian, the Jurassic–Cretaceous, and the Cretaceous–Tertiary. He also noted that pollen and spore assemblages also demonstrate similar transitions.

Wilson (1964) has discussed the problem of recycling in the Springer of the Anadarko Basin, and his (1965) Ti Valley study is also described as containing recycled fossils. The authors are well aware of redeposition possibilities and of the presence of such processes in the Anadarko Basin and adjacent areas. The Springer has been regarded at times as being a mixture of Pennsylvanian spores and recycled Mississippian spores. However, there is no evidence for such an interpretation of the Springer in the area considered. The microfossils do not show the colour, stain, or preservational features utilized by Wilson (1964, 1965) in determining recycling. During a period of ten years this laboratory has made an extensive study of Morrow–Springer–Chester palynology throughout the Anadarko Basin subsurface, as well as many surface exposures in the south-western United States. Recycling such as Wilson described for the Springer (1964, p. 428) in the western Anadarko Basin has been observed on occasions, and we have established a detailed zonation of the Morrow formation based upon the presence of recycled Springer. However, it would not be realistic to expect the entire vast Anadarko Basin to be uniformly recycled, and most of the subsurface Springer compares with the surface populations treated in this study and reveals no evidence for recycling or stratigraphic leakage.

Location of types. The exact field position of specimens is noted in text and plate explanations as coordinates, in parentheses, followed by a reference point coordinate for each slide. Calibration was on a Leitz Ortholux microscope mechanical stage to tenths of millimetres, with horizontal (smaller) reading listed first. Traverse (1958, 1960) and Pierce (1959) have dealt in detail with methods of coordinate conversion used here. Type slides are filed in the Sun Oil Company Paleontological Collections, Richardson, Texas, U.S.A.

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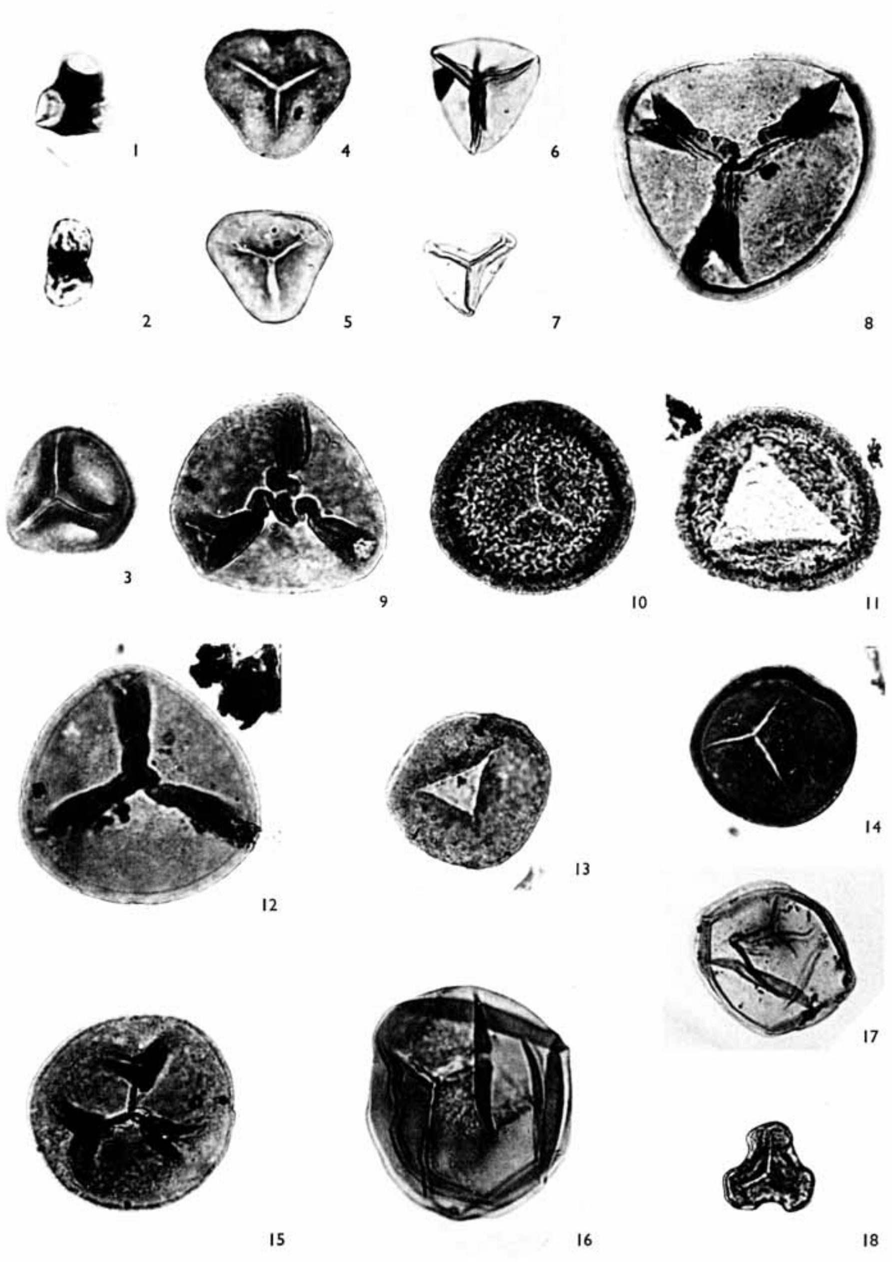

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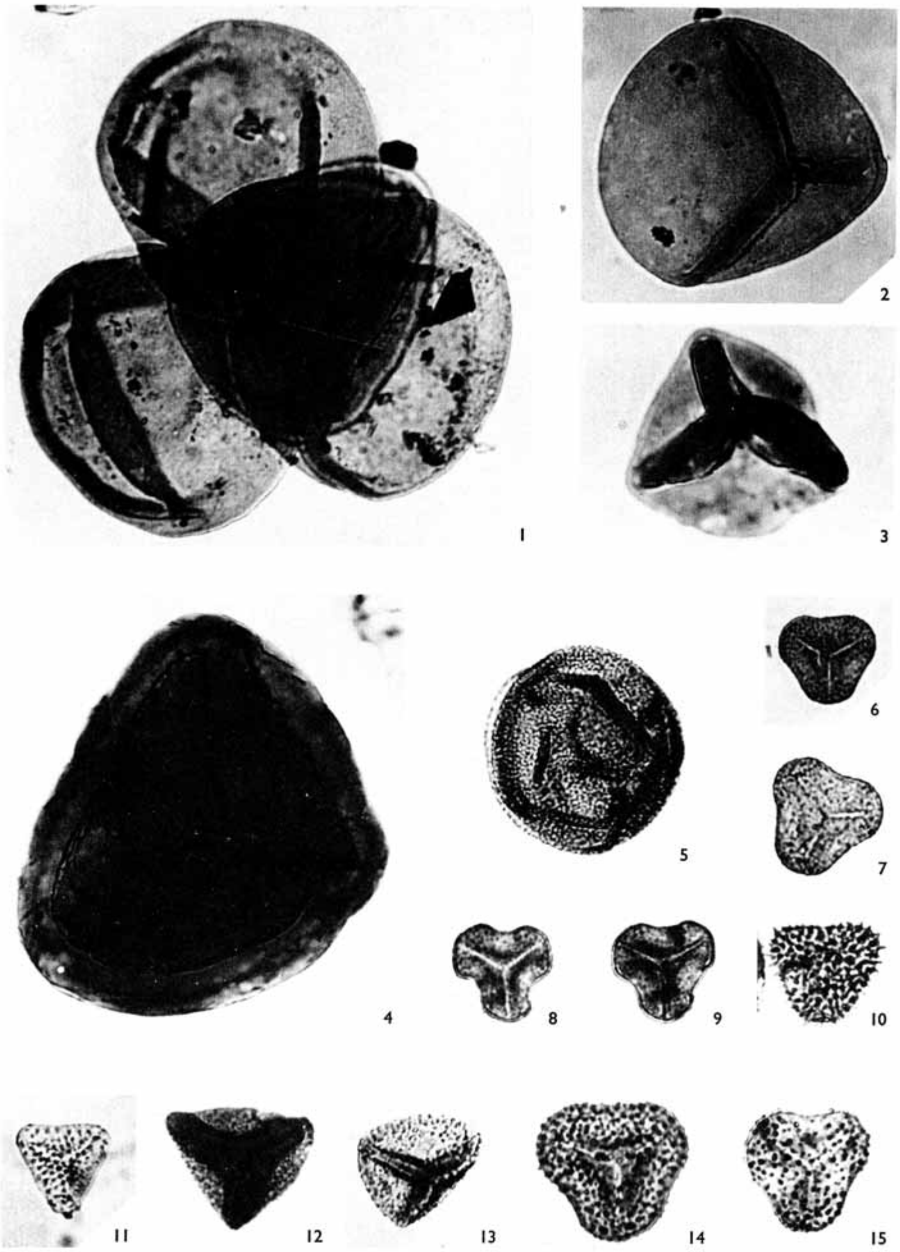

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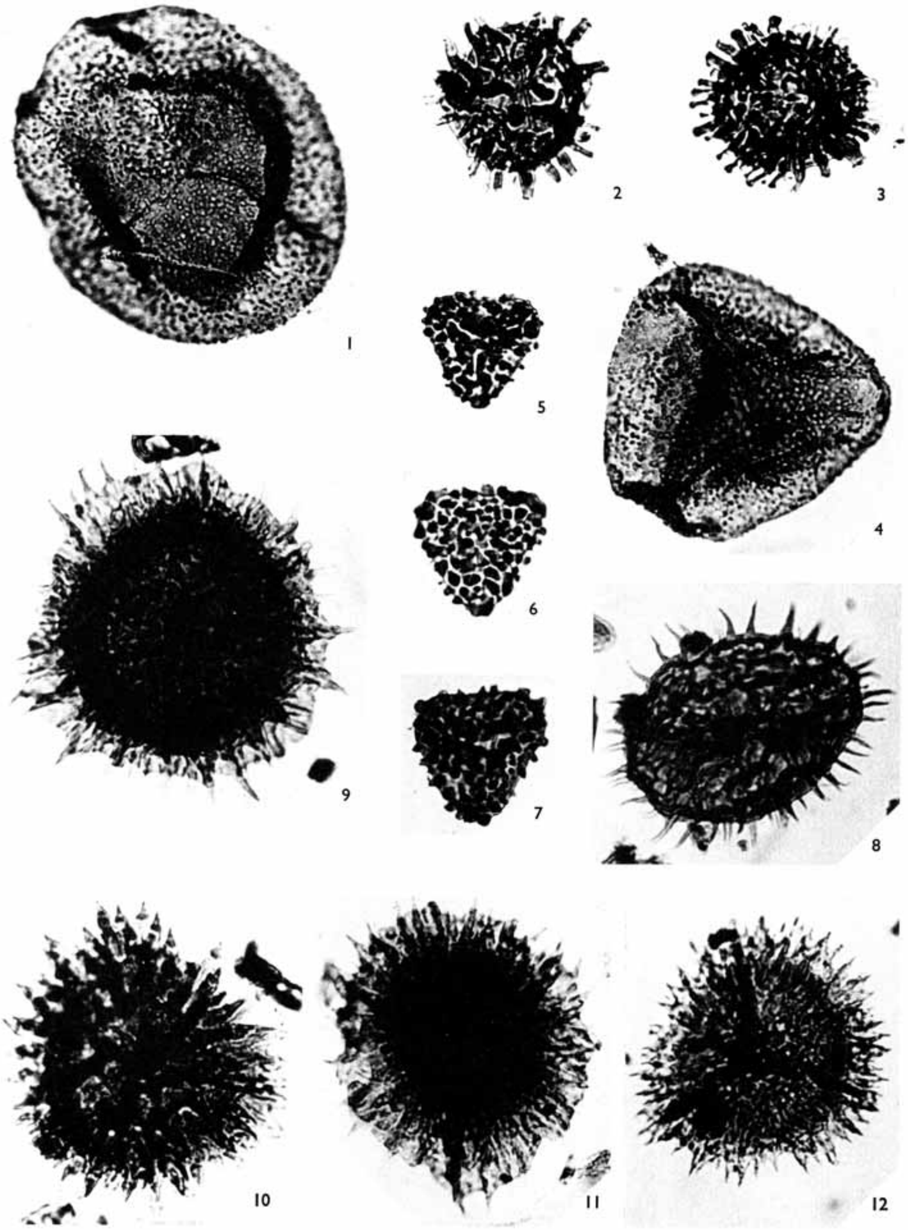

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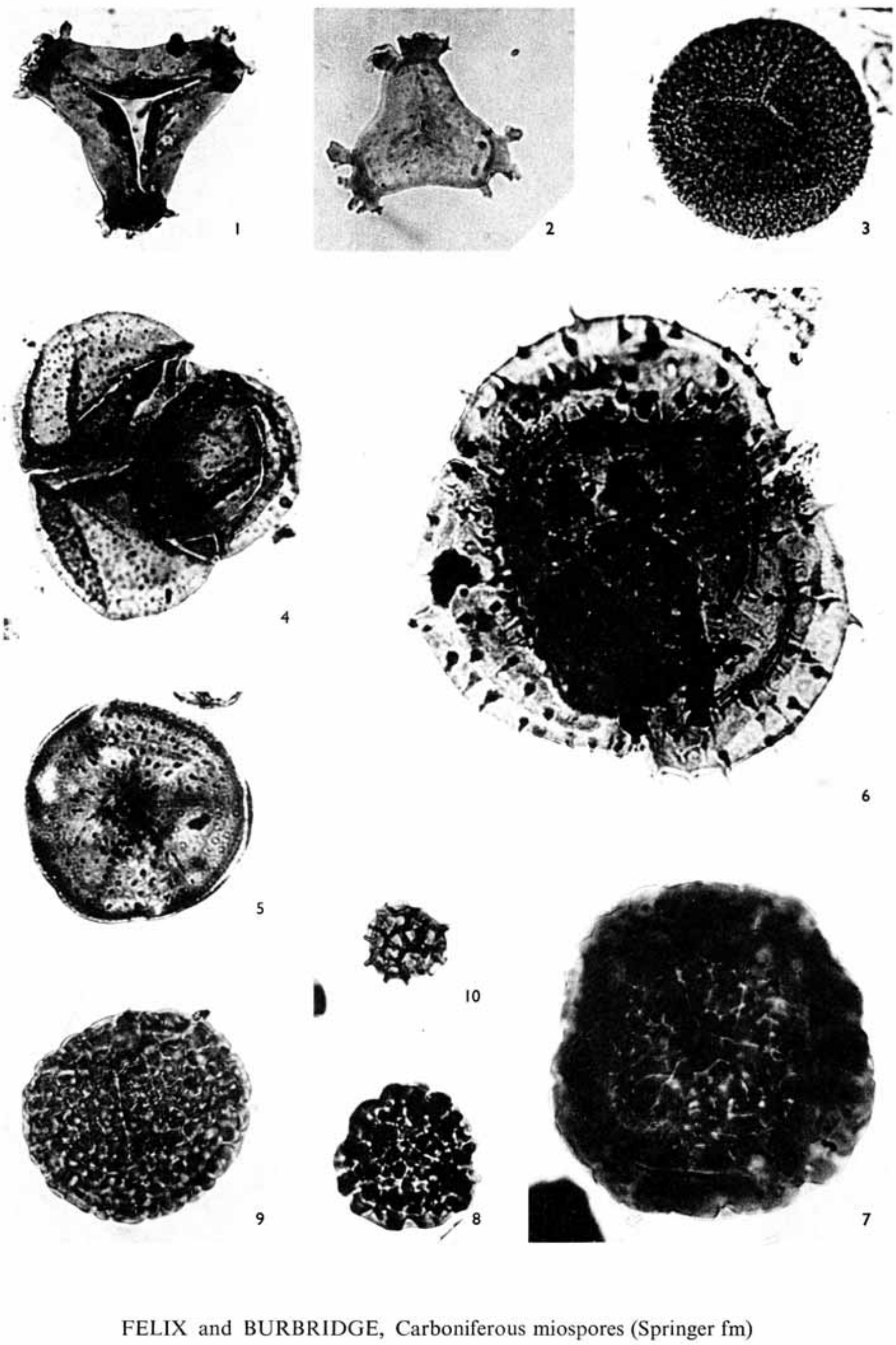

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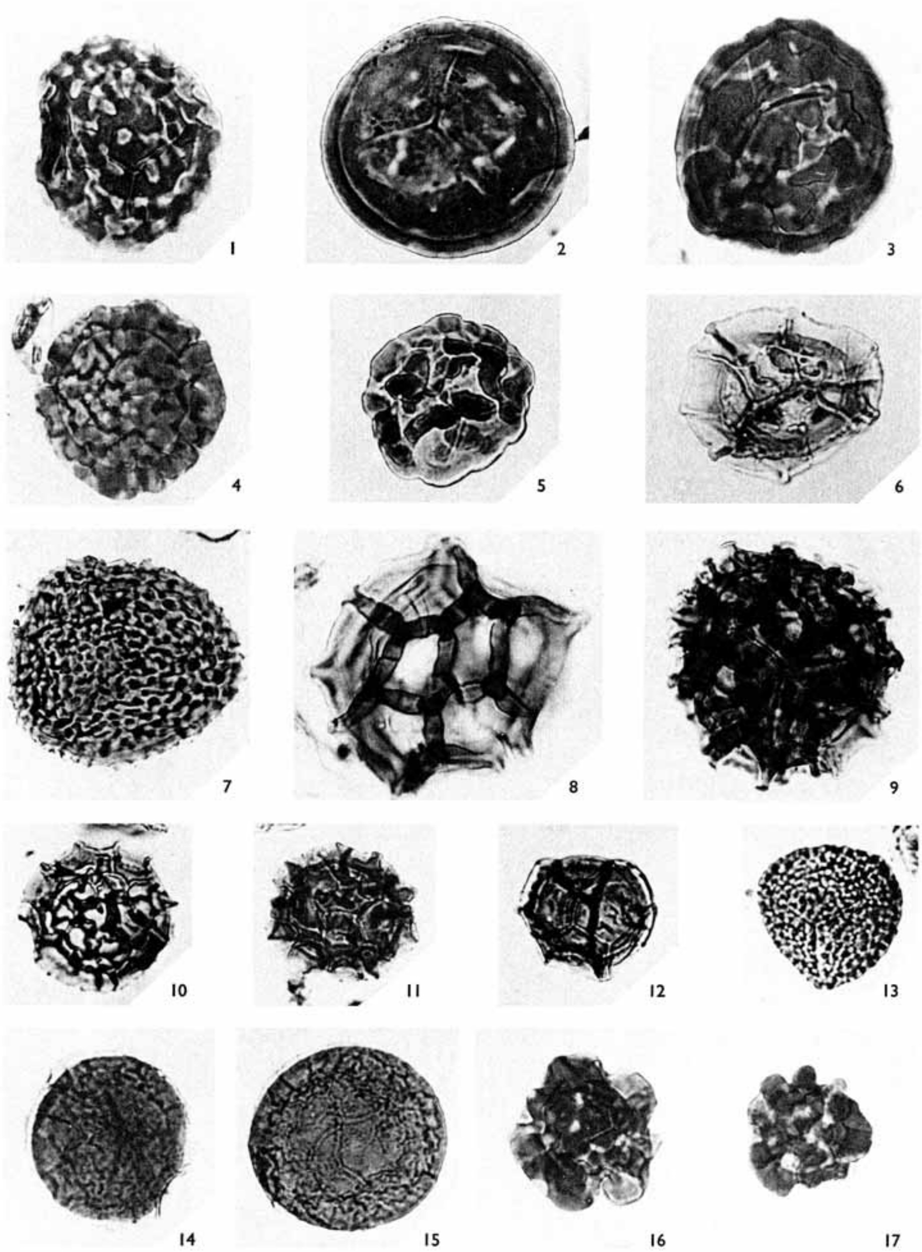

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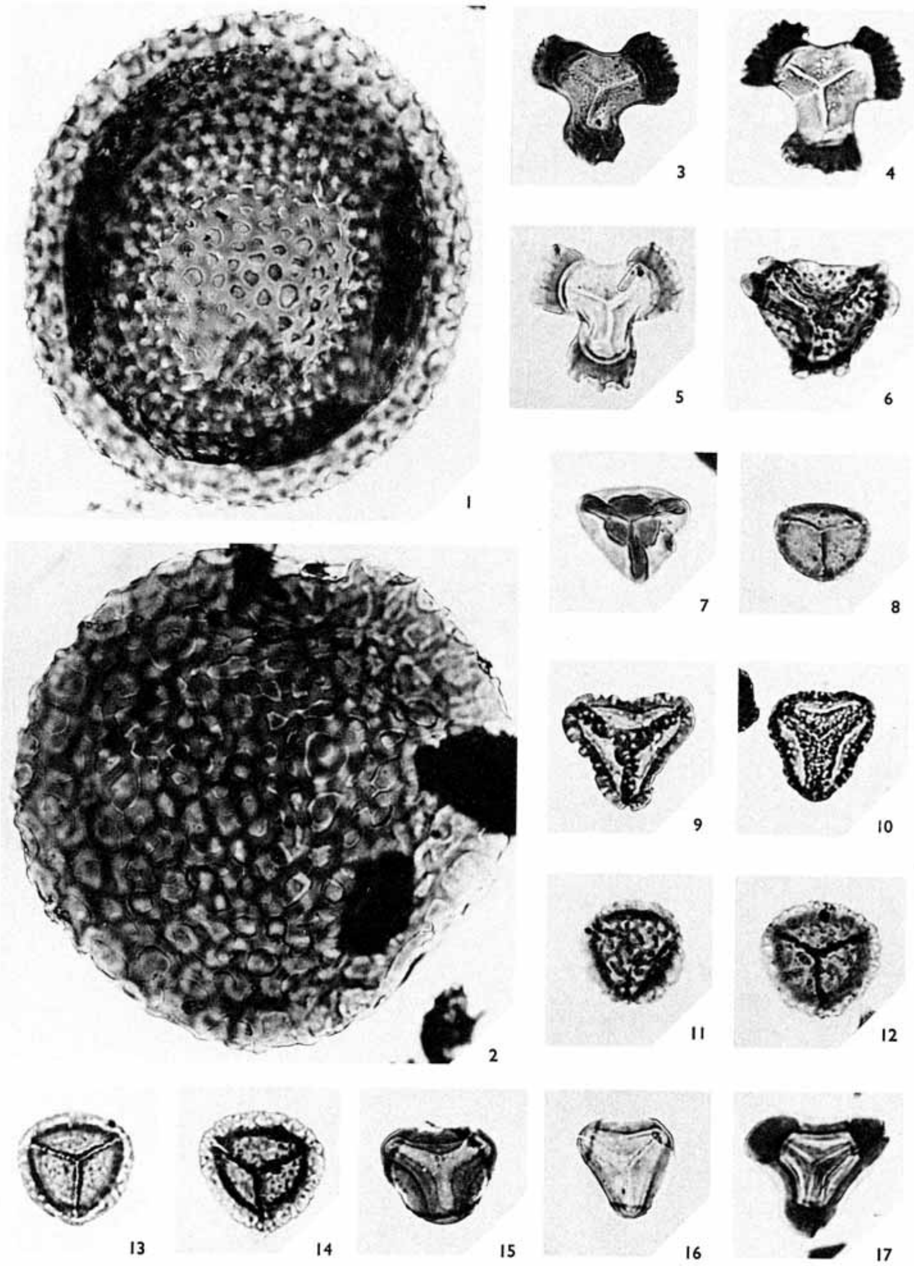

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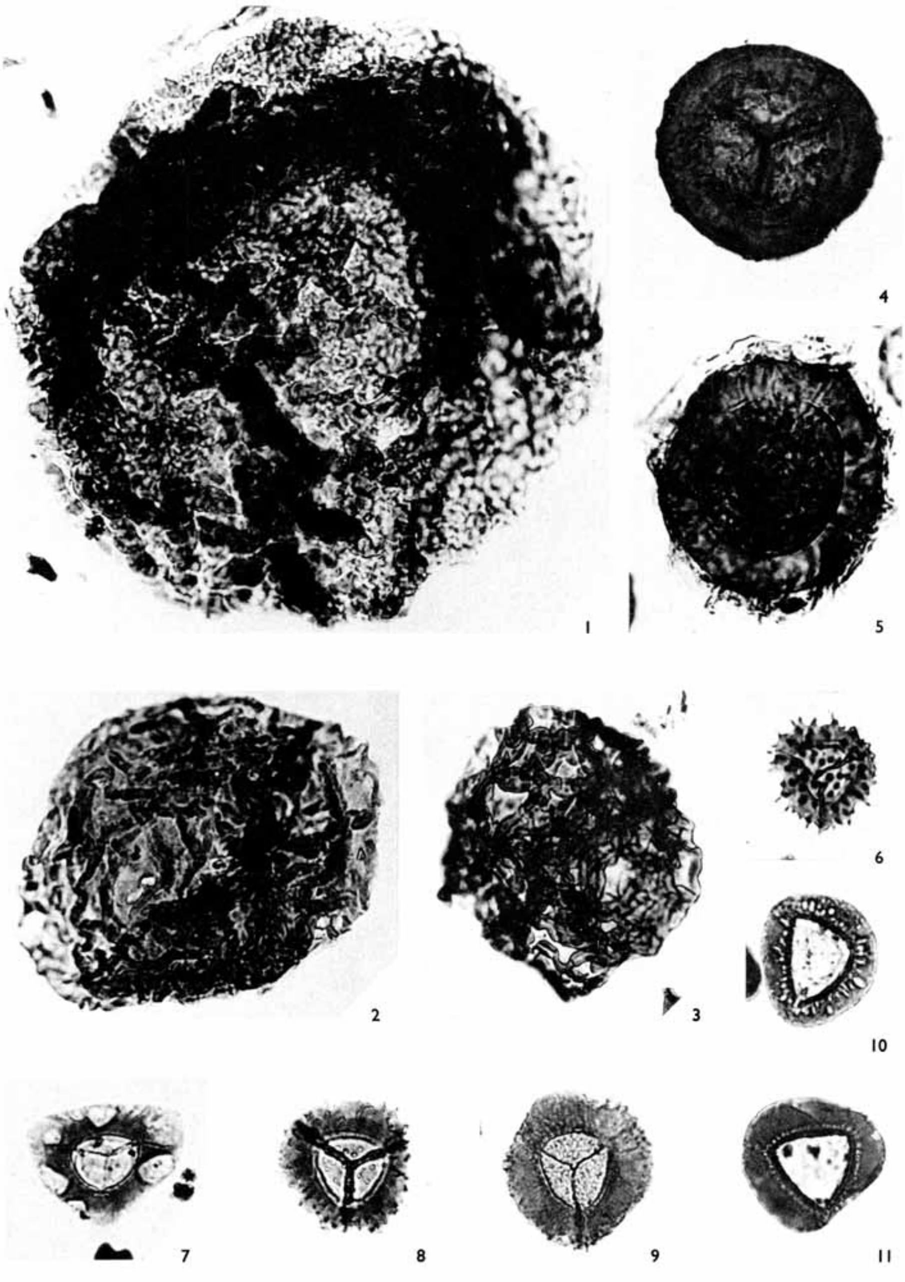

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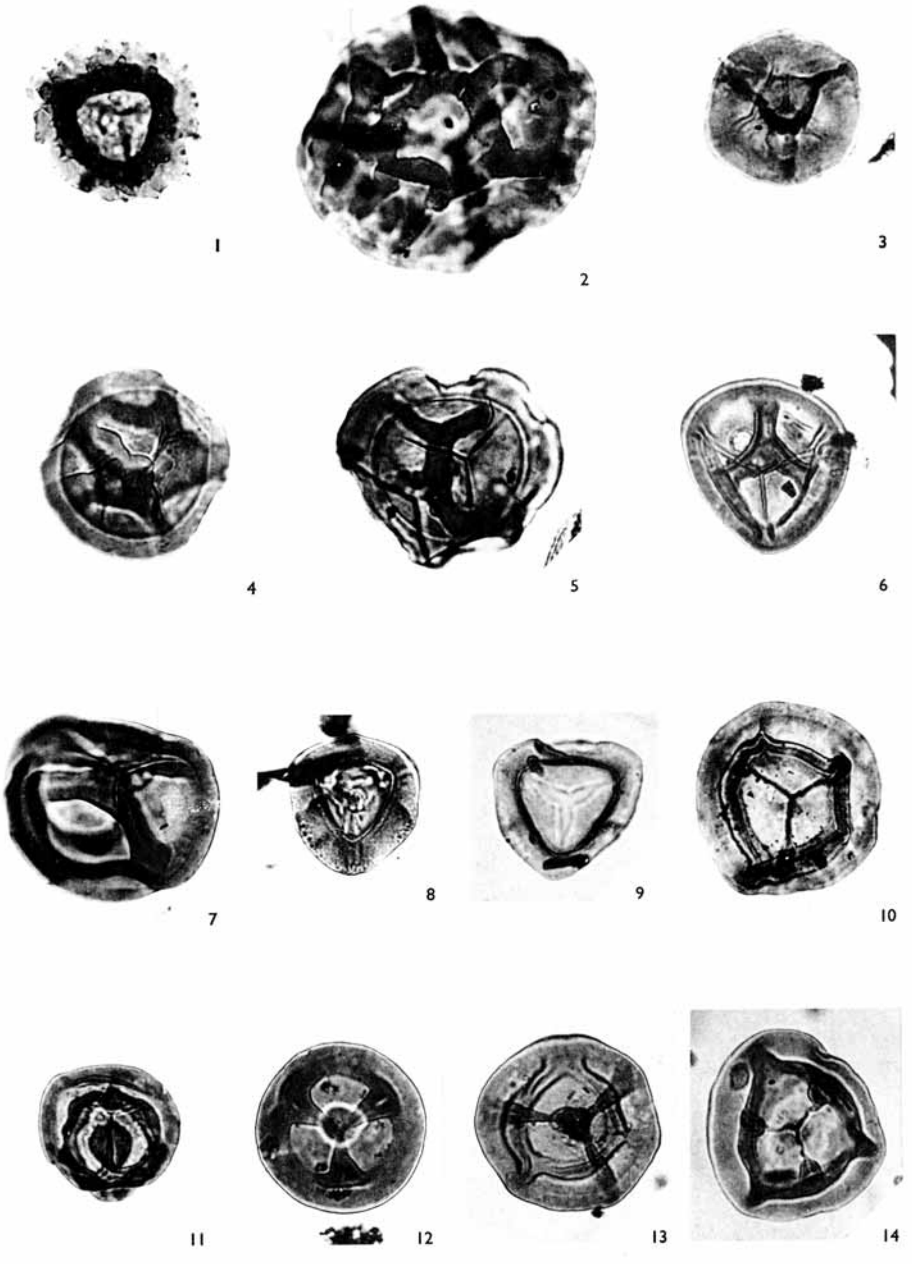

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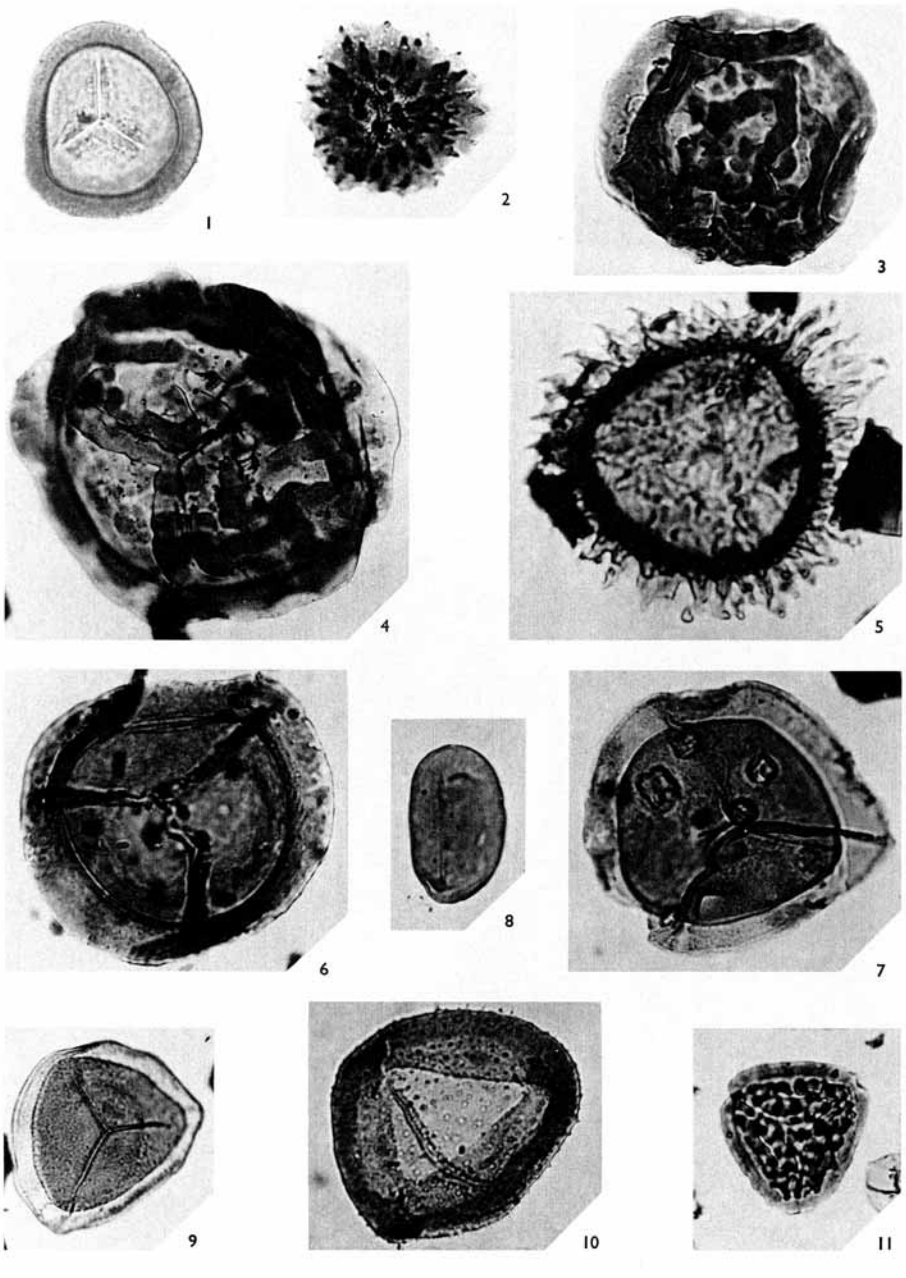

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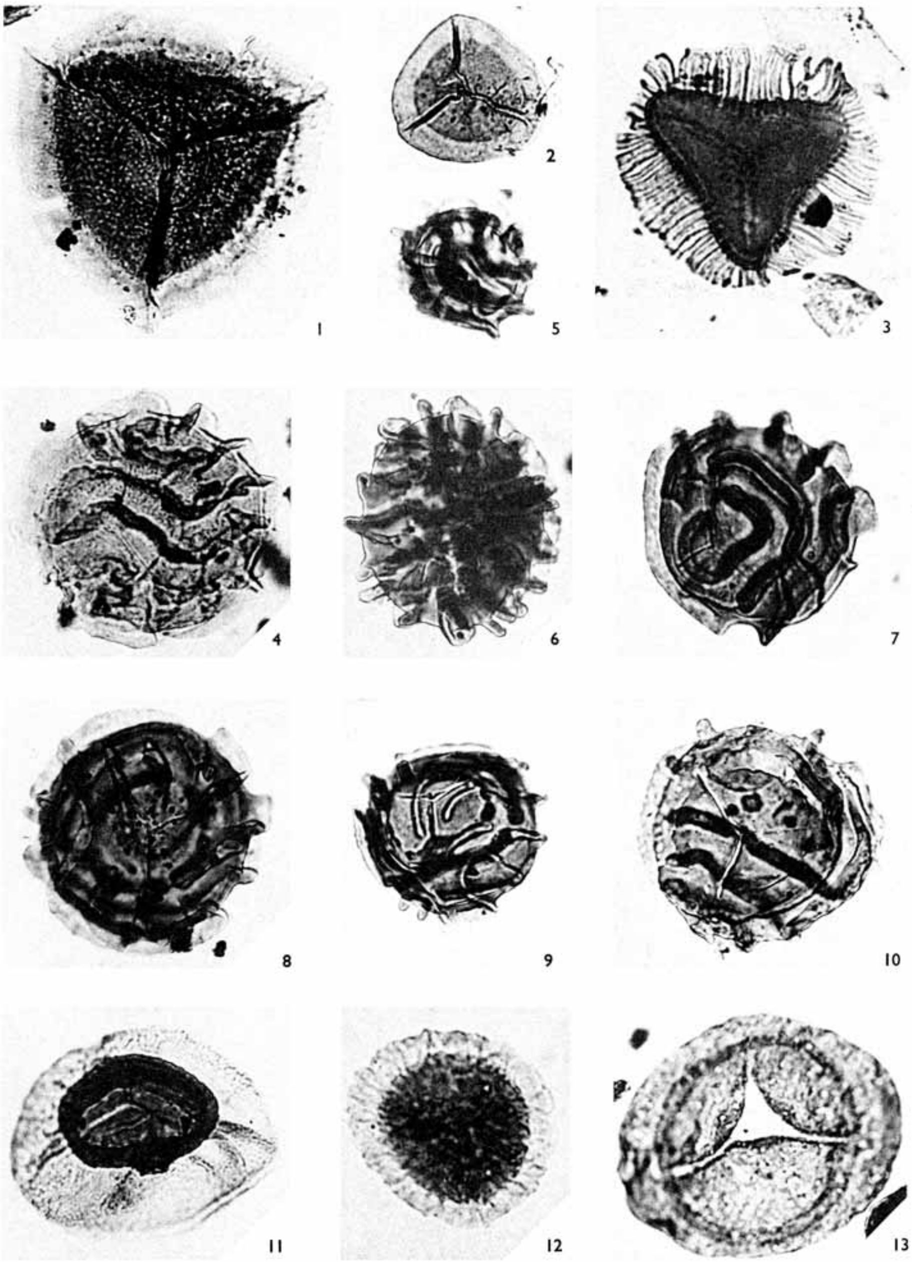

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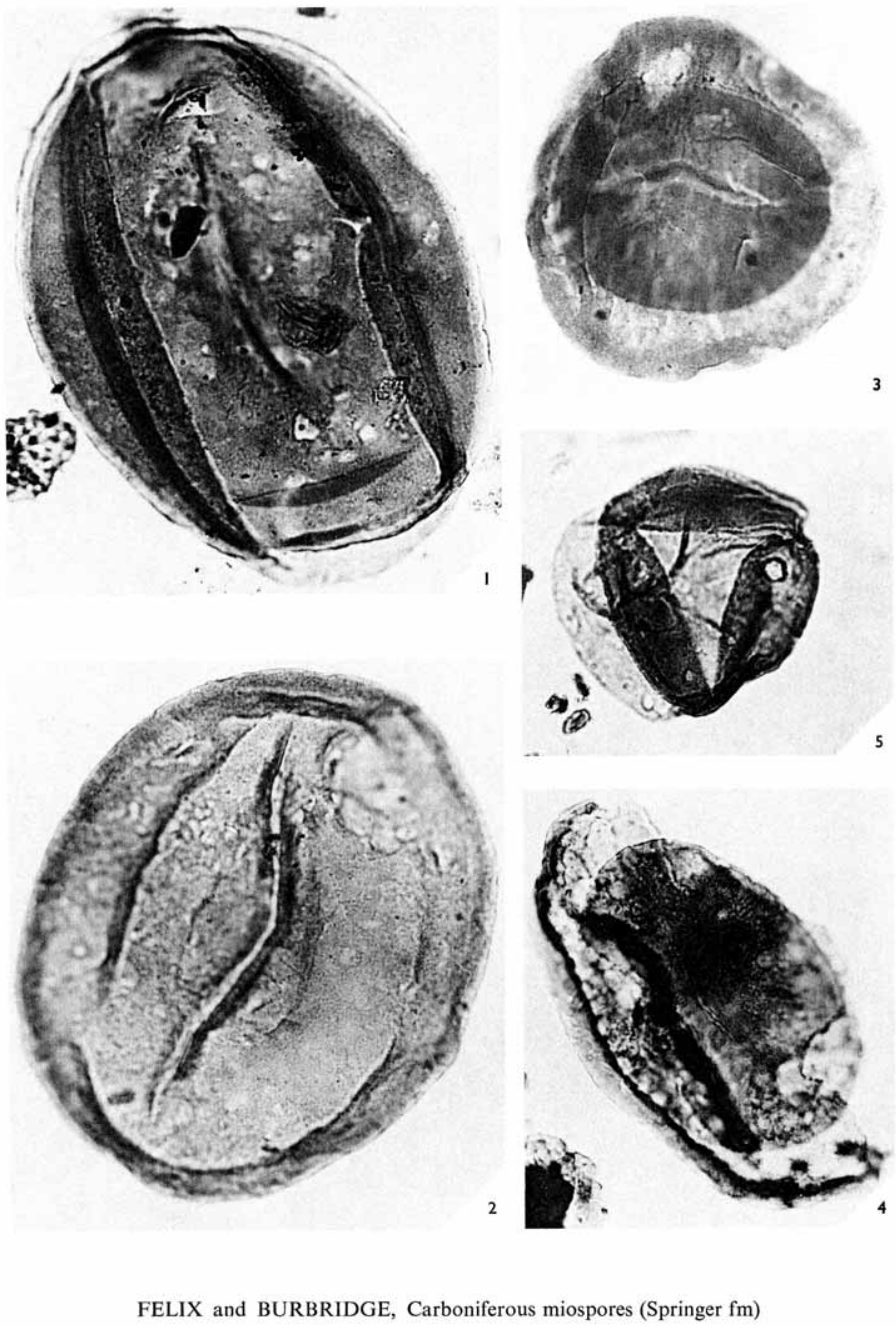

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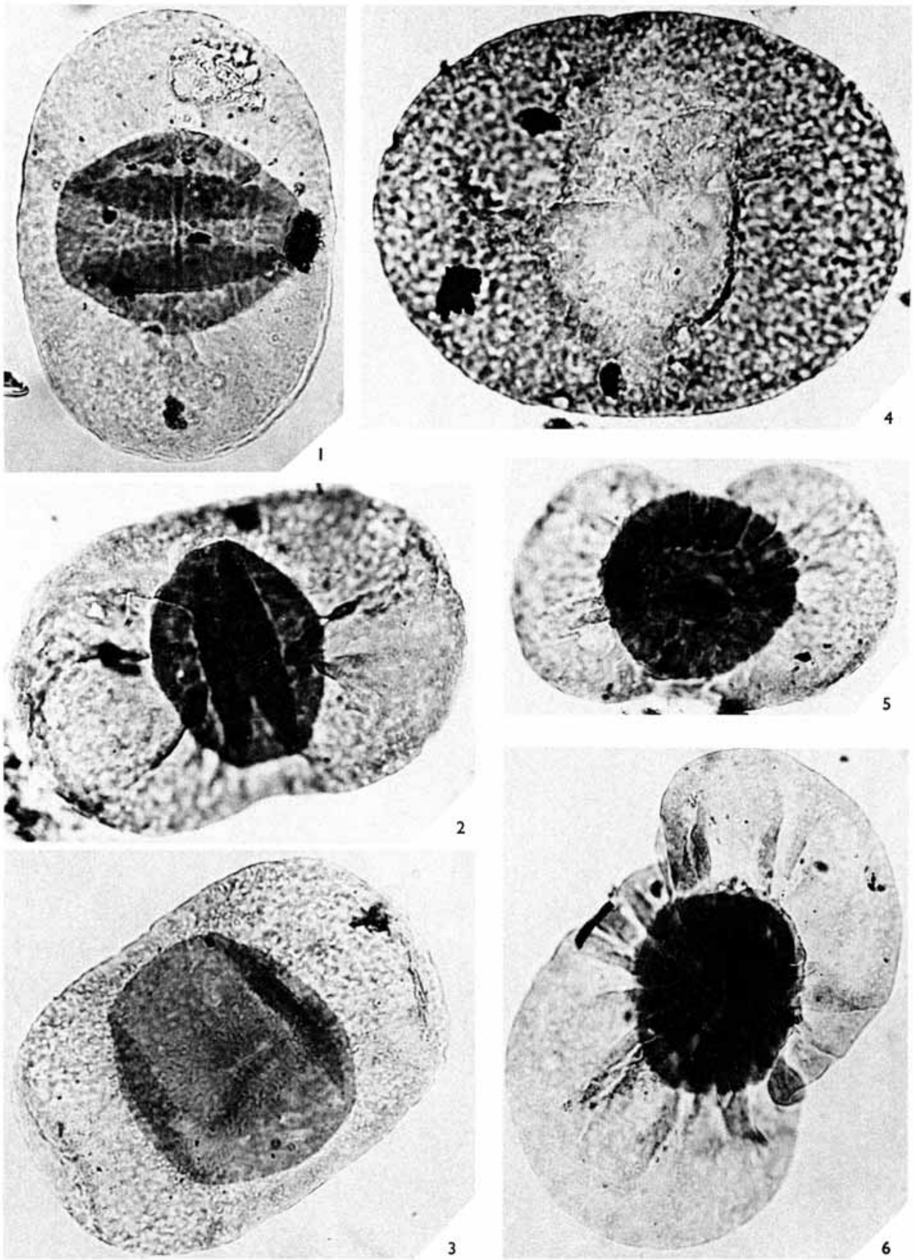

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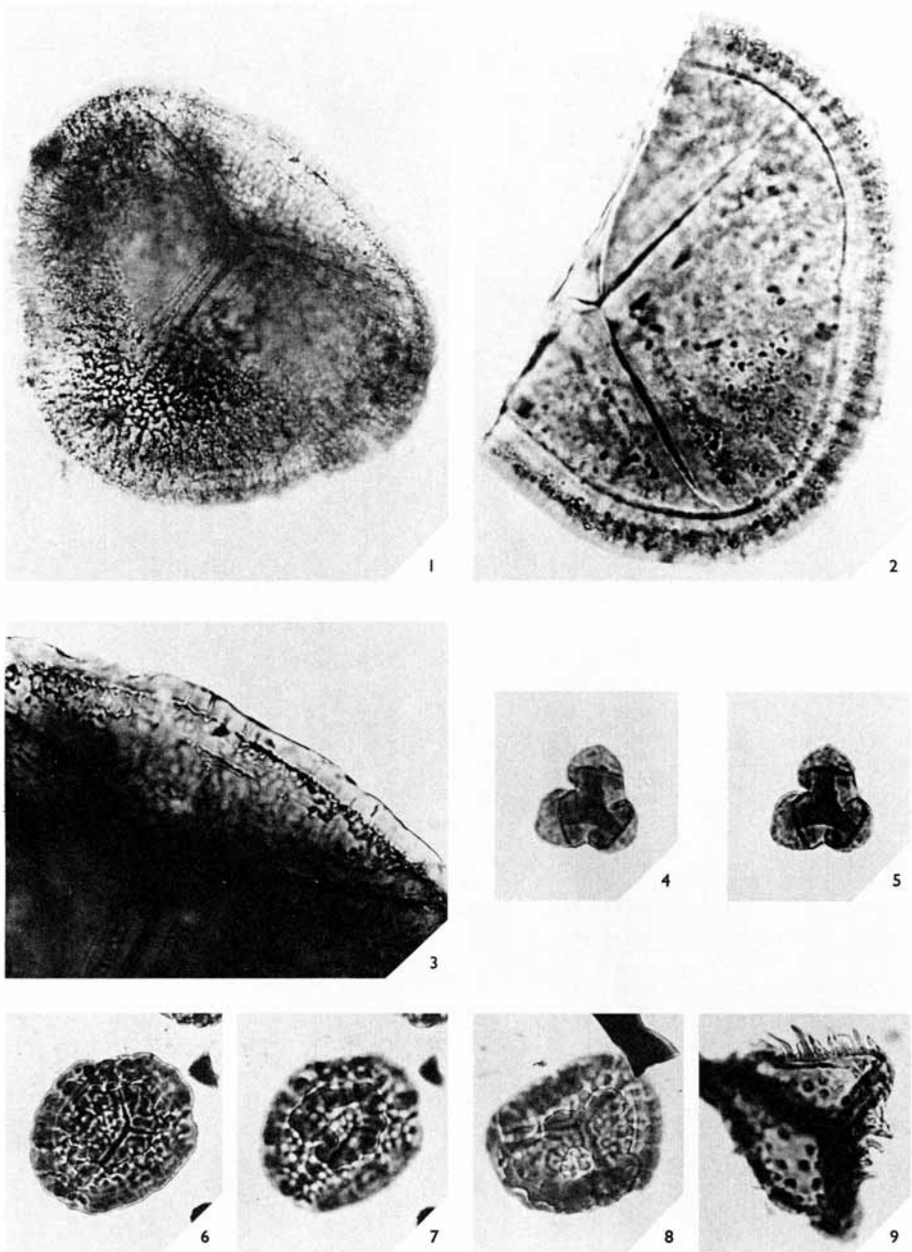

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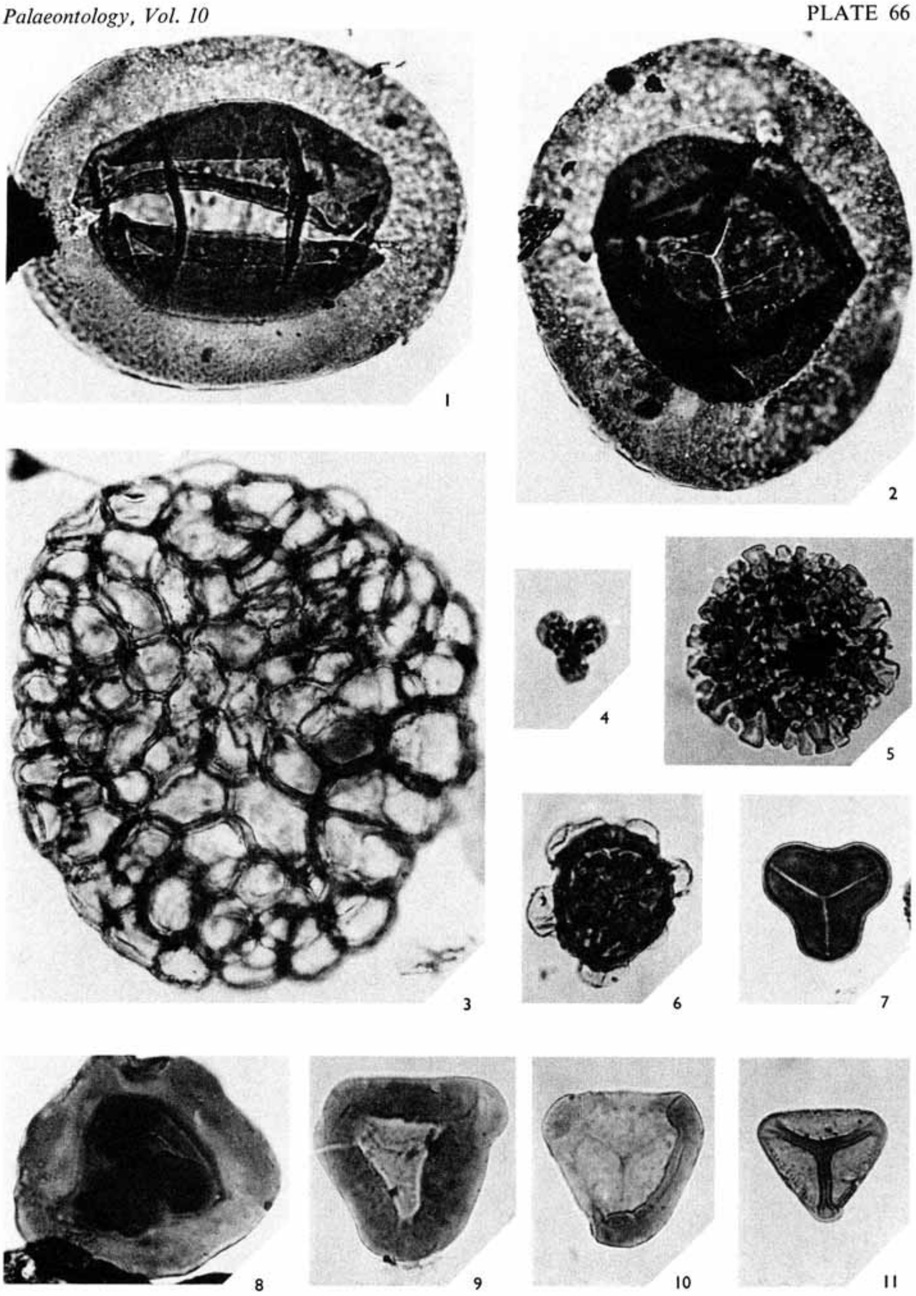

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