LOWER CARBONIFEROUS SPORES FROM NORTH-WEST ENGLAND

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ABSTRACT. Assemblages of spores are described from coals and shales of the Lower Carboniferous (Bewcastle Beds to the Lewis Burn Coal Group) of north-west Cumberland and Northumberland. Forty-three species are recorded. The following new taxa are proposed: (Megaspores) *Setispora* gen. nov., *Aneuletes reticulata*, *Setispora pseudoreticulata*, *Triangulatisporites? membranatus*, *Zonalesporites conacies*; (Miospores) *Convolutispora planimuricata*, *Dictyotriletes plumosus*, *Lophotriletes plicatus*, *Lycospora rugulosa*, *Orbisporis convolutus*, *Tholisporites cumbriensis*.

THE samples examined occur in the Cementstone and overlying groups of the upper part of the Calciferous Sandstone Series. Garwood (1931) classified part of this sequence (Tuedian and lowermost Bernician), in the part of Cumberland lying between the Liddel Water and the River Irthing, as follows:

Coral-brachiopod zonation		
S2	Bernician Beds* (Oakshawford coal beds at base)	
S1 C2	Fell Sandstone and Kingwater Beds*	Tuedian Beds
C2	Cambeck Beds*	Tuedian Beds
C1	Main Algal Series Bewcastle Beds*	Tuedian Beds
C1 Z2	Lynebank Beds	Tuedian Beds

Four samples were obtained from horizons in the formations indicated by asterisks; the remaining three are of thin coals in the succeeding Lewis Burn (Scremerston) Coal Group (S2 in the coral-brachiopod zonation).

The samples examined, in ascending stratigraphical order, are as follows:

(1) Three-inch coal towards the top of the Bewcastle Beds; left bank of Stack Cleugh, 200–220 yd. upstream from the track leading from the Limekiln Inn in Bewcastle to High Grains Farm (National Grid Reference NY585747).

(2) Black shales in the Cambeck Beds; south bank of Whitberry Burn, about 300 yd. downstream from the point where it passes under the road from Roadhead to Crook (NY523740).

(3) Coal at least 2 ft. thick in left bank of the River Black Lyne about 100 yds. downstream from Dodgesontown Ford (NY499754).The sample examined from this locality was representative of the 2 ft. of coal exposed. The coal lies 170 ft. below the horizon of the Oakshawford coal (Mr. J. B. W. Day, personal communication).

(4) Coal at least 6 in. thick, immediately below drift, north bank of Whitberry Burn, a few yards above the footbridge below Nether Hill Farm (NY508754). This coal lies 100 ft. above the horizon of the Oakshawford coal (Mr. J. B. W. Day, personal communication).

(5) Half-inch coal in shales rich in plant remains, Lewis Burn Coal Group; left bank of Lewis Burn, approximately half-way between the Forks and the Old Bridge, opposite hut (NY631885).

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(6) 12 in. of pyritic coal lying 12 in. below coal 9 in. thick, Lewis Burn Coal Group; right bank of Lewis Burn, bend below the Old Bridge, where the strike of the beds runs parallel to the stream (NY630877).

(7) One inch of pyritic coal overlying coal which has been worked, Lewis Burn Coal Group; right bank of Barret's Sike, Lewis Burn (NY630877).

TECHNIQUES OF STUDY OF MICROFOSSILS

The pre-oxidation treatment employed in the preparation of both miospores and megaspores was the same; shales were immersed in 40% hydrofluoric acid for up to nine days at 60° C, to remove most of the silicates. Miospores were obtained by placing the residues and the coals in fuming nitric acid for up to one hour in order to liberate the spores. Megaspores were obtained by placing samples in Schulze's solution for up to 3 days, followed by washing with 5% potassium hydroxide until the filtrate runs clear. The megaspores are mounted as 'single grain' slides and the miospores are on composite mounts, the illustrated specimens being ringed. All slides are prefixed with the letter V followed by locality and slide number and are lodged in the Reference Collection, Micropalaeontology Laboratory, Geology Department, University of Sheffield.

Classification. The miospores (M. A. B.) are grouped according to the supra-generic classification proposed by Dettmann 1963. The megaspores are arranged in alphabetical order following the miospores, as the second author (E. S.) is reluctant to place the genera concerned in a supra-generic grouping at the present time. Miospore species which have already been described are treated in the present paper only if sufficient specimens were recovered to warrant a comparison with the type material.

THE MIOSPORES

Anteturma SPORITES H. Potonié 1893
Turma TRILETES (Reinsch) Dettmann 1963
Suprasubturma ACAVATITRILETES Dettmann 1963
Subturma AZONOTRILETES (Luber) Dettmann 1963
Infraturma LAEVIGATI (Bennie and Kidston) Potonié 1956
Genus PUNCTATISPORITES (Ibahim) Potonié and Kremp 1954

Punctatisporites debilis Hacquebard 1957

Plate 1, fig. 1

1957 *Punctatisporites debilis* Hacquebard, p. 308, pl. 1, figs. 5, 6.

Size. 40(46)57 μ for 25 specimens; sample 7.

Occurrence. Described by Hacquebard from the Horton Group, Mississippian, of Nova Scotia, Canada.

Genus CALAMOSPORA Schopf, Wilson, and Bentall 1944

Calamospora microrugosa (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 1, fig. 7

1932 *Sporonites microrugosus* Ibrahim *in* Potonié, Ibrahim, and Loose, p. 447, pl. 14, fig. 9.

1933 *Laevigati-sporites microrugosus* (Ibrahim) Ibrahim, p. 18, pl. 1, fig. 9.
1938 *Azonotriletes microrugosus* (Ibrahim) Waltz, in Luber and Waltz, p. 10, pl. 1, fig. 1 and pl. A, fig. 1.
1944 *Calamospora microrugosa* (Ibrahim) Schopf, Wilson, and Bentall, p. 52.
1952 *Leiotriletes microrugosus* (Ibrahim) Ishchenko, p. 15, pl. 2, fig. 19.
1955 *Calamotriletes microrugosus* (Ibrahim) Luber, p. 36, pl. 1, figs. 1–3.

Size. 61(73)96 μ, rays 20–28 μ, for 20 specimens; sample 2.

Remarks. The ranges given by Luber and Waltz (1938; 55–80 μ) and Ishchenko (1958, p. 36; 60–65 μ) for this species are rather smaller than that of the present population, and the length of the laesurae quoted by Ishchenko (one-third the spore radius) is less. The present figures are more similar to those of Playford (1962, p. 580; 62–104 μ, mean 82 μ) and of Potonié and Kremp (1955, p. 49; 70–100 μ for the Upper Westphalian B type material).

Occurrence. C. microrugosa has been recorded from many Carboniferous horizons, particularly from the Lower Carboniferous and the Namurian.

Calamospora cf. *nigrata* (Ishchenko) comb. nov.

Plate 1, fig. 8

1958 *Leiotriletes nigratus* Ishchenko, p. 35, pl. 1, fig. 5.

Description. Diameter 60(67)77 μ for 25 specimens; sample 4. Amb circular, margin smooth. Laesurae simple, one-quarter to one-third spore radius in extent. Contact area darkened. Exine thin, laevigate; folding very frequent.

Remarks. This spore is similar in all respects excepting size to Ishchenko's species (Ishchenko 1958; 90–110 μ); it has some of the characters of *Calamospora*, including a thin, much folded exine, and some of *Phyllothecotriletes* Luber 1955—very short laesurae with a prominent contact area. Since most of the species assigned to *Phyllothecotriletes* have a relatively thick, unfolded exine this species is assigned to the earlier genus.

Occurrence. Calamospora nigrata was recorded by Ishchenko from the Upper Devonian and Tournaisian of the Dnieper–Donetz Basin.

Genus RETUSOTRILETES Naumova 1953

Retusotriletes incohatus Sullivan 1964

Plate 1, figs. 12, 13

1964*a* *Retusotriletes incohatus* Sullivan, pp. 1251, 1252, pl. 1, figs. 5–7.

Size. Diameter 27(46)64 μ for 26 specimens; sample 1.

Remarks. The smaller size and denser exine of the present specimens are probably due to the use of fuming nitric acid rather than the nitric acid and caustic potash used to macerate the type material.

Comparison. Retusotriletes incohatus has a thicker exine and less prominent ornament than *A. multiseta*. It is smaller than *A. brandtii* Streel (1964, pp. 8–10, fig. 2, pl. 1, figs. 6–10), which has a thinner exine.

Infraturma APICULATI (Bennie and Kidston) Potonié 1956
Subinfraturma GRANULATI Dybová and Jachowicz 1957
Genus GRANULATISPORITES (Ibrahim) Potonié and Kremp 1954

Granulatisporites parvigranulatus Staplin 1960

Plate 1, figs. 2, 3

1960 *Granulatisporites parvigranulatus* Staplin, p. 15, pl. 3, figs. 8, 9.

Size. 27(31)35 μ for 20 specimens; sample 4.

Remarks. Granulati-sporites pipergranus Hacquebard and Barss (1957, p. 15, pl. 2, fig. 11) is very similar but has a smaller size (25–30 μ) and convex sides. Occasional specimens in the present material (Pl. 1, fig. 3) have a type of ornament approaching that of *Lophotriletes*.

Occurrence. Described by Staplin from the Golata Formation (Upper Mississippian) of Canada.

Granulatisporites rudigranulatus Staplin 1960

Plate 1, fig. 9

1960 *Granulatisporites rudigranulatus* Staplin, p. 15, pl. 3, fig. 10.

Description. Diameter 39(44)56 μ for 27 specimens, sample 4. Amb triangular, sides slightly concave, angles broadly rounded, margin crenulate. Laesurae simple, frequently parted, about two-thirds spore radius in extent. Dense ornament of coarse granules, less than 1 μ in diameter and in height, tending to coalesce in the area of the laesurae and on the distal surface, 70 to 80 projecting round the equator. Exine about 2 μ thick, including ornament, folding rare.

Remarks. In some specimens, which are otherwise similar to this species, the ornament is coarser at the angles.

EXPLANATION OF PLATE 1

All specimens × 500, transmitted light.
Fig. 1. *Punctatisporites debilis* Hacquebard; sample 7, slide V7/4.
Figs. 2, 3. *Granulatisporites parvigranulatus* Staplin; sample 4, slide V4/10.
Fig. 4. *Cyclogranisporites commodus* Playford; sample 4, slide V4/1.
Figs. 5, 6. *Convolutispora planimuricata* sp. nov. 6, Holotype, sample 4, slide V4/1.
Fig. 7. *Calamospora microrugosa* Schopf, Wilson, and Bentall; sample 1, slide V1/1.
Fig. 8. *Calamospora* cf. *nigrata* (Ishchenko) comb. nov.; sample 4, slide V4/4.
Fig. 9. *Granulatisporites rudigranulatus* Staplin; sample 4, slide V4/2.
Figs. 10, 11. *Lophotriletes plicatus* sp. nov. 10, Holotype, sample 5, slides V5/3, V5/2.
Figs. 12, 13. *Retusotriletes incohatus* Sullivan; sample 1, slides V1/6, V1/2.
Figs. 14, 17. *Perotrilites perinatus* Hughes and Playford; sample 5, slides V5/6, V5/7.
Fig. 15. *Convolutispora* cf. *finis* Love; sample 1, slide V1/1.
Fig. 16. *Corbulispora ?subalveolaris* (Luber) Sullivan; sample 4, slide V4/3.
Fig. 18. *Raistrickia ponderosa* Playford; sample 1, slide V1/4.
Figs. 19, 20. *Orbisporis convolutus* sp. nov. 19, Holotype, sample 7, slide V7/8.

Occurrence. Described by Staplin from the Golata Formation (Upper Mississippian) of Canada.

Genus CYCLOGRANISPORITES Potonié and Kremp 1954

Cyclogranisporites commodus Playford 1963

Plate 1, fig. 4

1963*b* *Cyclogranisporites commodus* Playford, p. 12, pl. 2, figs. 3–5.

Size. 26(35)42 μ for 30 specimens; sample 4.

Remarks. The peripheral arcuate folding noted by Playford is not so common in these specimens which may have a slightly thicker exine (about 2 μ thick); the reduction in the size of sculpture at the proximal pole occurs in both populations but is not so marked in the British specimens.

Occurrence. Playford recorded this species from the Horton Group (Mississippian) of Nova Scotia, Canada.

Subinfraturma NODATI Dybová and Jachowicz 1957
Genus LOPHOTRILETES (Naumova) Potonié and Kremp 1954

Lophotriletes plicatus sp. nov.

Plate 1, figs. 10, 11

Holotype. Plate 1, fig. 10.

Type locality. Half-inch coal in Lewis Burn Group (sample 5), Lewis Burn, Northumberland.

Diagnosis. Diameter 43(52)62 μ for 20 specimens. Amb triangular, sides straight or slightly concave or convex, angles broadly rounded. Laesurae slightly folded, about one-half spore radius in extent. Proximal and distal ornament of tightly packed cones and bacula, approximately 1·5 μ in diameter and height, sometimes increasing in size towards the angles, between 60 and 72 projecting around the equator. Exine 4 μ thick, including ornament, sometimes folded.

Comparison. *Microreticulatisporites densus* (Love) Sullivan 1964*b* has more concave sides, longer laesurae, and ornament consisting of punctae separated by domed elevations.

Genus APICULIRETUSISPORA Streel 1964

Apiculiretusispora multiseta (Luber) comb. nov.

Plate 2, figs. 13, 18

1938 *Azonotriletes multisetus* Luber, in Luber and Waltz, p. 32, pl. 5, fig. 61, p. 23.
1955 *Filicitriletes multisetus* (Luber) Luber, pp. 55–56, pl. 3, fig. 52.
1955 *Acanthotriletes multisetosus* (Luber) Potonié and Kremp, p. 84.
1957 *Acanthotriletes multisetus* (Luber); Kedo, p. 1167.

Description. Diameter 43(54)70 μ by 35(46)62 μ for 44 specimens; sample 1. Amb

circular to oval. Laesurae straight, simple, two-thirds to three-quarters spore radius in extent, connected by curvaturae, sometimes not discernible. Ornament of spines or bacula, up to 2 μ long in the equatorial area, less than 1 μ wide, less prominent in the proximal area, about 100 projecting at the equator. Exine thin, folding frequent.

Remarks. This species is transferred to the genus *Apiculiretusispora* because of the presence of curvaturae joining the extremities of the laesurae, and the less prominent ornament on the interradial areas of the proximal surface. The former feature is prominent in one of the specimens of this species figured by Playford (1962, pl. 80, fig. 14) from the Lower Carboniferous of Spitsbergen.

Comparison. Apiculiretusispora brandtii Streel (1964, p. 138, pl. 1, figs. 6–10, text-fig. 2) differs from *A. multiseta* in its greater size, more prominent laesurae, and finer ornament.

Occurrence. Described by Luber from the Lower Carboniferous of the Karaganda Basin, recorded by Love (1960) from the Oil Shale Group of Scotland, and by Playford (1962) from the Lower Carboniferous of Spitsbergen.

Subinfraturma BACULATI Dybová and Jachowicz 1957
Genus RAISTRICKIA (Schopf, Wilson, and Bentall) Potonié and Kremp 1954

Raistrickia ponderosa Playford 1963

Plate 1, fig. 18.

1963*b* *Raistrickia ponderosa* Playford, p. 25, pl. 6, figs. 11, 12, pl. 7, fig. 1.

Size. 64(82)98 μ for 25 specimens; sample 1.

Remarks. The present spores are smaller than those described by Playford (69(90)115 μ) and have a thinner exine and slightly smaller bacula, with rather more of these projecting at the equator (35, compared with 28 recorded by Playford); otherwise they are similar.

Occurrence. Playford recorded this species from the Horton Group (Mississippian) of Nova Scotia, Canada.

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

Convolutispora cf. *finis* Love

Plate 1, fig. 15

1963*b* *Convolutispora* cf. *finis* Love 1960; Playford, p. 27, pl. 8, figs. 1, 2.

Size. 69(87)113 μ for 20 specimens; sample 1.

Remarks. In *Convolutispora finis* Love (1960, p. 115, pl. 1, fig. 7) the muri are flatter than in the present specimens which have a more irregular outline and appear to be identical with the spores figured by Playford; the latter are slightly larger.

Occurrence. Playford recorded this species from the Horton Group (Mississippian) of Nova Scotia, Canada. Love described *C. finis* from the Oil Shale Group of Scotland.

Convolutispora planimuricata sp. nov.

Plate 1, figs. 5, 6

Holotype. Plate 1, fig. 6.

Type locality. Nether Hill coal (sample 4), near Roadhead, Cumberland.

Diagnosis. Diameter 45(51)58 μ for 31 specimens. Amb oval to roundly triangular, margin undulating. Laesurae simple, prominent, one-half to two-thirds radius of spore in extent. Proximal and distal ornament of broad, meandering muri up to 10 μ in width, 2 μ in height, enclosing narrow, elongate lumina which form an irregular reticulum. Exine 3–4 μ thick, including ornament, seldom folded.

Comparison. *Microreticulatisporites hortonensis* Playford (1963*b*, p. 28, pl. 8, figs. 3, 4) has less prominent laesurae, narrower and more numerous muri, and less elongate lumina.

Genus DICTYOTRILETES (Naumova) Potonié and Kremp 1954

Dictyotriletes pseudopalliatus (Staplin) comb. nov.

Plate 2, figs. 8, 9

1960 *Reticulatisporites pseudopalliatus* Staplin, p. 13, pl. 2, fig. 24.

Description. Diameter 42(51)58 μ for 30 specimens; sample 3. Amb circular, oval, or roundly triangular. Laesurae simple, two-thirds spore radius, seldom seen. Exine with high, narrow muri forming weak reticulum, height of muri up to 6 μ, mesh up to 20 μ in diameter, frequently much less. At the equator the muri may give the appearance of a membraneous flange when they are aligned parallel to the equator, or of radial ridges when they cross the equator at right angles.

Remarks. This species is transferred to the genus *Dictyotriletes* because of Neves's (1964) emendation of *Reticulatisporites* to include only spores with a divided cingulum.

Occurrence. Staplin recorded this species from the Golata Formation (Upper Mississipian) of Canada.

Dictyotriletes plumosus sp. nov.

Plate 2, figs. 10, 11

Holotype. Plate 2, fig. 11.

Type Locality. Dodgesontown Ford coal (sample 3), River Black Lyne, Cumberland.

Diagnosis. Diameter 35(45)60 μ for 35 specimens. Amb rounded triangular, margin very irregular. Laesurae tectate, tecta up to 4 μ high, extent about two-thirds that of the body radius. Body thick, about 6 μ, punctate. Muri up to 5 μ broad at base but tapering rapidly, with fimbriate crests; at the equator they may simulate a membraneous flange; lumina irregular, up to 20 μ in diameter. Ornament frequently obscured by thickness of body exine. Folding infrequent.

Comparison. *Reticulatisporites cheveriensis* Playford (1963*b*, p. 30, pl. 9, figs. 1–3) is

similar to this species but differs in having a circular amb, a greater density of ornament, and in being much larger.

Genus CORBULISPORA Bharadwaj and Venkatachala 1962

Corbulispora ?subalveolaris (Luber) Sullivan 1964

Plate 1, fig. 16

1938 *Azonotriletes subalveolaris* Luber, in Luber and Waltz, pl. 5, fig. 72, p. 24.
1955 *Dictyotriletes subalveolaris* (Luber) Potonié and Kremp, p. 108.
1964*a* *Corbulispora subalveolaris* (Luber) Sullivan, p. 1,253, pl. 1, figs. 16–20.

Size. 58(71)90 μ for 40 specimens; sample 4.

Remarks and Occurrence. Luber, in Luber and Waltz 1938, gives a size range of 50–90 μ for this species in the original description from the Lower Carboniferous of the Karaganda Basin; Love (1960, p. 116) records a range of 45–95 μ for a population from the Lower Oil Shale Group of Scotland; Sullivan (1964*a*, p. 1253) gives 53(66)88 μ from the Lower Limestone Shales of the Forest of Dean, and (1964*b*, p. 368), 61(65)68 μ from the Drybrook Sandstone of the Forest of Dean. If alkali had been used by the present authors to obtain these spores their size limits might have been greater than those quoted by Luber and by Love. It is therefore possible that the present assemblage represents a form transitional between *C. subalveolaris* and *C. cancellata* (Waltz) Bharadwaj and Venkatachala 1962 which was given an original range of 120–30 μ by Waltz, in Luber and Waltz 1938, 75–130 μ by Ishchenko 1956, and 70(99)132 μ by Playford 1962.

Subturma ZONOTRILETES Waltz 1935
Infraturma CINGULATI (Potonié and Klaus) Dettmann 1963
Genus ORBISPORIS Bharadwaj and Venkatachala 1962

Remarks. *Orbisporis* was assigned by Bharadwaj and Venkatachala to their new Infraturma Crassiti which Smith and Butterworth (in press) have emended to include trilete, cavate miospores with a crassitudinous margin not distinctly demarcated from the rest of the spore. The present authors consider that *Orbisporis*, which is not cavate, is best accommodated in the Infraturma Cingulati.

EXPLANATION OF PLATE 2

All figures $\times$ 500, under transmitted light unless stated otherwise.
Figs. 1, 2. *Lycospora rugulosa* sp. nov. 1, Holotype. 2, Distal surface; sample 5, slide V5/2.
Figs. 3–5. *Lycospora tenebricosa* Staplin; sample 2, slides V2/7, V2/2, V2/1.
Figs. 6, 7. *Lycospora noctuina* Butterworth and Williams; sample 3, slides V3/2, V3/7.
Figs. 8, 9. *Dictyotriletes pseudopalliatus* (Staplin) comb. nov.; sample 3, slide V3/3.
Figs. 10, 11. *Dictyotriletes plumosus* sp. nov. 11, Holotype; sample 3, slide V3/3.
Figs. 12, 14. *Vallatisporites ciliaris* (Luber) Sullivan; sample 1, slides V5/2, V1/5.
Figs. 13, 18. *Apiculiretusispora multiseta* (Luber) comb. nov.; sample 1, slides V1/1, V1/5.
Figs. 15, 20. *Didymosporites scotti* Chaloner, $\times$ 100, illustrating the two abortive members of the tetrad; sample 4, slide V4/39. 20, sample 4, slide V4/39.
Fig. 16. *Dictyotriletes admirabilis* Playford 1963; sample 7, slide V7/2.
Fig. 17. *Velosporites echinatus* Hughes and Playford; sample 3, slide V3/4.
Fig. 19. *Knoxisporites literatus* (Waltz) Playford; sample 1, slide V1/2.

Orbisporis convolutus sp. nov.

Plate 1, figs. 19, 20

Holotype. Plate 1, fig. 19.

Type locality. One inch coal in right bank of Barret's Sike, Lewis Burn, Northumberland; Lewis Burn Coal Group (sample 7).

Diagnosis. Diameter 69(91)116 μ for 40 specimens. Amb circular or oval, margin irregularly lobed. Laesurae prominent, about two-thirds spore radius in extent with individual tecta up to 8 μ wide, terminating against an irregular arc of thickening, 8–12 μ wide, situated on the proximal side of the equator; proximal surface otherwise devoid of ornament. Distal surface with irregular, discontinuous, rounded muri up to 16 μ wide, variable in number and complexity; muri rarely extending beyond the thickened band on the proximal surface. Exine thick, approximately 6 μ, excluding ornament.

Comparison. *O. orbiculus* Bharadwaj and Venkatachala (1961, p. 30, pl. 3, figs. 45–48) has no distal ornament; in *O. muricatus* Bharadwaj and Venkatachala (1961, p. 30, pl. 3, figs. 41–44) and *O. suborbiculus* Bharadwaj and Venkatachala (1961, p. 30, pl. 3, figs. 49, 50) the distal muri form a more or less regular reticulum.

Azonotriletes amplectus Naumova, in Luber and Waltz 1938 (pl. 1, fig. 7) appears to have a similar distribution of ornament and tectate laesurae but it is smaller and lacks the thickened band on the proximal side of the equator. *Euryzonotriletes stamineus* Ishchenko (1956, p. 59, p. 10, fig. 123) may be conspecific with *Orbisporis convolutus* sp. nov. but no details are given of the nature of the laesurae nor of the proximal surface (the distal surface only is figured). *Convolutispora harlandii* Playford (1962, p. 593, pl. 81, figs. 6–9) has similar distal ornament, which is stated to be bounded by a continuous equatorial band simulating a cingulum in some specimens, but differs from the present specimens in having simple laesurae and discrete patches of ornament in the interradial areas of the proximal surface.

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

Lycospora noctuina Butterworth and Williams 1958

Plate 2, figs. 6, 7

1958 *Lycospora noctuina* Butterworth and Williams, p. 376, pl. 3, figs. 14, 15.

Size. 26(30)35 μ for 35 specimens; sample 3.

Remarks. The present spores are rather smaller than those from the type locality which ranged from 30 to 45 μ in diameter. Staplin (1960, p. 20) lists *L. noctuina* as a synonym of *Lycospora uber* (Hoffmeister, Staplin, and Malloy) Staplin and this synonomy is supported by Playford (1963*b*, p. 636). The descriptions of *L. uber* given by these authors could include *L. noctuina*, which differs from *L. punctata* in the coarseness of its distal ornament, but in fact none of the photographs published (Staplin 1960, pl. 4, figs. 13, 17, 18, 20 and Playford 1963*a*, pl. 89, figs. 16, 17) shows ornament typical of *L. noctuina*, and the spores figured by the first author have not the characteristic subtriangular outline.

Occurrence. This species was described from the Namurian A and has been recorded by Smith and Butterworth (1967) from throughout the Namurian and Westphalian A.

Lycospora rugulosa sp. nov.

Plate 2, figs. 1, 2

Holotype. Plate 2, fig. 1.

Type Locality. Half-inch coal, Lewis Burn Group; Lewis Burn, Northumberland (sample 5).

Diagnosis. 20(29)38 μ for 60 specimens. Amb circular to rounded triangular, margin minutely crenulate. Laesurae distinct, simple, extending almost to the equator; apical papillae prominent. Proximal surface minutely granulose or punctate, distal surface rugulose. Cingulum tapering, plicated, 2–3 μ wide, barely discernible. Exine thin but rarely folded.

Remarks. This species is very similar to *Cyclogranisporites tripapillatus* Staplin 1960 (p. 9, pl. 1, fig. 29) which that author (personal communication) considers to be a related species, distinguished from *L. rugulosa* by its lack of rugulose ornament.

Occurrence. Staplin recorded large numbers of *Cyclogranisporites tripapillatus* from the Golata Formation (Upper Mississippian) of Canada.

Lycospora tenebricosa Staplin 1960

Plate 2, figs. 3–5

1960 *Lycospora tenebricosa* Staplin, p. 20, pl. 4, figs. 15, 16.

Description. 29(36)44 μ for 52 specimens; sample 2. Amb circular or rounded-triangular, margin minutely notched. Laesurae prominent, tectate, reaching almost to the margin of the spore body; tecta up to 3 μ high. Inner thickened part of cingulum up to 3 μ wide, may have the appearance of curvaturae, outer zone very minutely granulose, plicated, 2 μ wide. Exine in polar areas thick, granular, relatively unfolded.

Comparison. In some specimens the outer part of the cingulum is extremely narrow, when the spore may be confused with *Retusotriletes golatensis* Staplin 1960 (p. 22, pl. 4, figs. 21–23). In *Lycospora micrograna* Hacquebard and Barss (1957, p. 20, pl. 2, fig. 23) the outer part of the zona is slightly broader and the laesurae are indistinct.

Occurrence. Staplin described this species from the Golata Formation (Upper Mississippian) of Canada.

Genus VALLATISPORITES (Haquebard) Sullivan 1964

Vallatisporites ciliaris (Luber) Sullivan 1964

Plate 2, figs. 12, 14

1938 *Zonotriletes ciliaris* Luber, in Luber and Waltz, p. 25, pl. 6, fig. 82.
1964*b* *Vallatisporites ciliaris* (Luber) Sullivan, p. 370, pl. 59, figs. 14, 15.

Size. 49(58)73 μ for 13 specimens, sample 1. 49(58)78 μ for 12 specimens; sample 2.

Remarks. The mean diameters of the spore body in the Bewcastle (1) and Cambeck (2) samples were 34 μ and 36 μ respectively. Luber gives a range of 40–50 μ and Sullivan a constant proportion of three-fifths (37 μ mean); the present specimens have therefore relatively smaller central areas than those hitherto described.

Occurrence. Described by Luber from the Lower Carboniferous of the Karaganda Basin, and recorded by Sullivan from the Drybrook Sandstone (Viséan) of the Forest of Dean, Gloucestershire.

Infraturma PATINATI Butterworth and Williams 1958
Genus THOLISPORITES Butterworth and Williams 1958

Tholisporites cumbriensis sp. nov.

Plate 4, figs. 7–9

Holotype. Plate 4, fig. 9.

Type locality. Nether Hill coal, near Roadhead, Cumberland (sample 4).

Diagnosis. 40(49)58 μ for 30 specimens. Amb circular, margin slightly undulating. Laesurae simple, extending almost to the equator. Patina about 4 μ thick at the distal pole, expanding to form a cingulum from 10 μ to 20 μ wide at the equator which may be lobed. Patina punctate or minutely spinose, frequently with a crescentic fold. Cingulum smooth or lobate. Proximal polar area microrugulate, about 2 μ in thickness; in lateral compression, the most frequent preservation, it is commonly collapsed below the level of the cingulum.

Comparison. *Tholisporites scoticus* Butterworth and Williams 1958 (p. 382, pl. 3, figs. 48–50) is a smaller species (the range 35–52 μ is for specimens macerated with Schulze solution followed by treatment with alkali) with a patina thicker in the distal area and forming a narrower cingulum. The forms described by McGregor (1961, pp. 37, 38, pl. 13, figs. 6, 7, 9, 10) from the Devonian of the Canadian Arctic are larger and the patina is not thickened equatorially.

Suprasubturma PERINOTRILITES Erdtman 1947
Genus PEROTRILITES Erdtman ex Couper 1953

Perotrilites perinatus Hughes and Playford 1961

Plate 1, figs. 14, 17

1961 *Perotrilites perinatus* Hughes and Playford, p. 33, pl. 2, figs. 7–10.

Size. Diameter of spore body 40(52)68 μ for 7 specimens, perine projecting 3–12 μ at the equator; sample 5, 44–90 μ, mean 70 μ for 80 specimens; Playford 1962.

Remarks. Apart from their smaller size the present specimens appear to be identical with those described by Hughes and Playford (1961), and by Playford (1962), from the Lower Carboniferous of Spitsbergen.

THE MEGASPORES

Genus ANEULETES Harris 1961

Type species. A. patera Harris 1961.

Remarks. Harris (1961, p. 69) proposed this genus for bodies resembling megaspores, generally more than 200 μ in maximum diameter, and lacking visible haptotypic structures.

Aneuletes reticulata sp. nov.

Plate 3, figs. 5, 6

Holotype. Plate 3, fig. 5.

Diagnosis. ?Megaspores, circular to elliptical in outline varying between 355 and 475 μ in maximum diameter. Tetrad mark indistinct. Body wall reticulate, lumina circular to angular, 20 to 50 μ in maximum diameter, muri 2 to 4 μ in height and width.

Description. Mean diameter 422 μ (15 specimens mounted in hydrous medium). Body wall often folded, the folds running approximately parallel to the margins of the compressed body; original body more or less spherical. Wall appears to consist of single layer, often folded, with a reticulate ornament. Mean diameter of lumina 35 μ (50 measurements). Muri sharply crested, and the wall frequently ruptured along them. At the corners of the lumina the crests of the muri may under high focus simulate a short, weak trilete mark.

The folds of the wall curved parallel to the body margin simulate an inner central body. However, focusing reveals that the muri are involved in the folding. On some specimens the wall appears irregularly punctate.

EXPLANATION OF PLATE 3

All figures $\times 50$ by transmitted light unless otherwise stated.

Figs. 1, 7. *Lagenicula crassiaculeata* Zerndt; sample 4, slide V4/53. 1, Lateral compression. 7, Part of fig. 1, illustrating large and small sculptural elements, $\times 100$.

Figs. 2, 3, 4. *Lagenicula subpilosa* forma *major* Dijkstra ex Chaloner; sample 4, slide V4/31*a*. 2, Lateral compression. 3, Part of fig. 2, $\times 100$, illustrating ornamentation, irregularly thickened curvature and laevigate contact faces. 4, Polar compression; sample 3, slide V3/31*a*.

Figs. 5, 6. *Aneuletes reticulata* sp. nov. 5, Holotype, $\times 100$; sample 3, slide V3/2. 6, $\times 100$; sample 3, slide V3/2.

Figs. 8, 9, 10. *Triangulatisporites membranatus* sp. nov. 8, Oblique compression; sample 3, slide V3/20. 9, 10, Specimens with outer layer of exine partly removed; sample 3, slide V3/16.

EXPLANATION OF PLATE 4

All figures by transmitted light unless stated otherwise.

Figs. 1, 3, 4, 6. *Setispora pseudoreticulata* sp. nov. 1, Holotype $\times 50$, lateral compression; sample 3, slide V3/40. 3, Capillate type laesurae $\times 100$; sample 3, slide V3/46. 4, Part of fig. 1 $\times 100$ illustrating ornamentation of exine. 6, Lateral compression $\times 50$, reflected light; sample 3, slide V3/30.

Figs. 2, 5, 10. *Triangulatisporites membranatus* sp. nov. 2, Holotype $\times 100$; sample 3, slide V3/15. 5, Part of outer layer of exine, $\times 500$; sample 3, slide V3/12. 10, Polar compression $\times 100$ illustrating loosely attached outer layer of exine; sample 3, slide V3/19.

Figs. 7, 8, 9. *Tholisporites cumbriensis* sp. nov. $\times 500$. 9, Holotype; sample 4, slides V4/10, V4/1.

Comparisons. A. reticulata sp. nov. is similar to *Triletes*? *obscuris* (Dijkstra 1957) but this species is smaller in overall size (220–340 μ, mean 256 μ) and in the size of the reticulation (lumina 8–14 μ in diameter). Dijkstra described the haptotypic features of *T? obscuris* as being obscure. Probably this species should also be placed in *Aneuletes* rather than *Triletes*.

Remarks. The sharply crested muri along which the wall readily sutures may have been a method of germination. The characteristic folding of the body wall probably has some structural significance, but this is not clear.

Affinities. Unknown.

Occurrence. Sample 3.

Genus DIDYMOSPORITES Chaloner 1958

Didymosporites scotti Chaloner 1958

Plate 2, figs. 15, 20

1958 *Didymosporites scotti* Chaloner, p. 198, pl. 1, fig. 1.

Holotype. Chaloner 1958, pl. 1, fig. 1 (description, p. 198).

Remarks. The size range of the tetrads recorded here varies between 434 μ and 650 μ (longest axis of flattened tetrad; 20 specimens in hydrous medium); Chaloner gave a range of 360 μ to 582 μ for his specimens. The smaller abortive spores vary between 20 μ and 50 μ in diameter and are often difficult to distinguish due to the darker colour of the overlapping portions of the larger spores. This genus is unusual in that it is based on spore tetrads; as with Chaloner (1958, p. 203), no instances of isolated spores were observed. If found isolated the spores might possibly be referred to the miospore genera *Calamospora* Schopf, Wilson, and Bentall 1944 or *Punctatisporites* (Ibrahim) Potonié and Kremp 1954.

Affinities. Stauropteris burntislandica P. Bertrand (Chaloner 1958).

Stratigraphic distribution. Chaloner (1958) recorded this species from Ballycastle coalfield, Northern Ireland (Dinantian–Namurian); Fife, Berwickshire, Scotland (Dinantian); Scremerston Coal Group, Cumberland, England (Dinantian).

Occurrence. Samples 3, 4. These samples are possibly from the same, or at least, very close to Locality 4 of Chaloner (1958, p. 200) from which he reported this species.

Genus LAGENICULA (Bennie and Kidston) Potonié and Kremp 1954

Lagenicula subpilosa (Ibrahim) forma *major* Dijkstra ex Chaloner 1954

Plate 3, figs. 2–4

1933 *Setosi-sporites subpilosus* Ibrahim, p. 27, pl. 5, fig. 40.
1950 *Triletes subpilosus* forma *major* Dijkstra, p. 871 (nom. nud.).
1954 *Triletes subpilosus* forma *major* Chaloner p. 27, pl. I, figs. 4–8.
1957 *Triletes subpilosus* (Wicher) S. W. & B. forma *major* Dijkstra; Dijkstra and Piérart, pp. 12–13, pl. 11, figs. 126–7.

1957? *Triletes* cf. *Triletes subpilosus* (Ibrahim) S. W. & B. forma *major*, type 27 bl. Dijkstra 1957, p. 14, pl. 9, figs. 94–96, pl. 10, figs. 97–103.

1959 *Triletes subpilosus* forma *major* (Dijkstra) ex Chaloner; Winslow, pp. 18–20, pl. 1, figs. 1–9.

Description. Trilete megaspores with a circular to oval body and an apical prominence which gives a 'bottle-shaped' appearance to lateral compressions. Both polar and lateral compressions are found. Maximum diameter 780 μ to 1300 μ, mean 1196 μ (15 specimens in hydrous medium). Laesurae and apical parts of contact faces raised to form an apical prominence up to 300 μ high. Contact faces distinct, occupying approximately one-third proximal surface of compressed spore, ornamented with small cones, spines, and verrucae. Cones and spines 6–20 μ high, basal diameter 3–10 μ, and concentrated mainly around base of apical prominence. On the distal parts of the contact faces the elements are more verrucose, smaller, approximately 5 μ diameter, and less densely spaced. The positions of the curvaturae are marked by a slight thickening of the exine and the closely spaced spines which cover the remainder of the spore wall.

Distal surface covered more or less with parallel sided spines straight or slightly curved in outline, 80–200 μ long. Basal diameter of spines 20–40 μ, tapering quickly to 10–20 μ along greater part of length. At the tips, spines bluntly rounded or pilose due to small constrictions a short distance below the tips. In the region of the curvaturae spines smaller, rarely more than 90 μ long, and more densely placed. Wall 12–15 μ thick, punctate to vermiculate.

Comparisons. This forma is distinguished by its larger size of body and spines than *L. subpilosa* (Ibrahim) Potonié and Kremp 1956. *Lagenicula crassiaculeata* Zerndt 1937 can be distinguished from *L. subpilosa* forma *major* by the larger apical prominence, the presence of small (50 μ long) spines, distributed between the larger (360 μ long) distal spines, which are longer than in *L. subpilosa* forma *major*. The spore wall in *L. crassiaculeata* is approximately as thick as in *L. subpilosa* forma *major*. In *Lagenicula horrida* Zerndt 1934 the spines generally taper from base to tip, the sides not appearing parallel as in *L. subpilosa* forma *major*. Also both long and short spines occur on the distal surface of *L. horrida* as in *L. crassiaculeata*.

Remarks. The mean size of the specimens described here is in general agreement with those of other workers (Chaloner 1954, Dijkstra 1952, 1957, Winslow 1959) although the range in size is considerably less than that given by Dijkstra 1952 (500–1300 μ) and Winslow (465–1790 μ). Nor were any spines observed as long as 360 μ (Winslow, p. 19) on the distal surface. Although Chaloner gave no measurements for the spines in his description, his illustrations (pl. 1, figs. 7–8) clearly show them to be approximately the same as those described above. Dijkstra (1957) described a form, which he compared with this forma and which should probably be included (see synonymy). However, he reported radially running folds on the contact faces, arcuate ridges 15–25 μ broad, and distal spines not generally swollen at the base. Such features were not seen on the specimens described here. Similar features were described by Dijkstra and Piérart (1957) on specimens from the Lower Carboniferous of the Moscow Basin.

Affinities. Lepidodendraceae (Potonié and Kremp 1954).

Stratigraphic distribution. Europe: Turkey, Namurian A, B, C (Dijkstra 1952); Ireland, Lower Carboniferous (Dijkstra 1957); Scotland, Dinantian–Namurian Chaloner 1954,

Dijkstra 1957, Sen 1964), Moscow Basin, Lower Carboniferous (Dijkstra and Piérart 1957). U.S.A.: Illinois, Indiana, Kentucky, Michigan, Mississippian (Chaloner 1954, Winslow 1959).

Occurrence. Sample 4.

Lagenicula crassiaculeata Zerndt 1937

Plate 3, figs. 1, 7

1937 *Lagenicula crassiaculeata* Zerndt, pp. 12–13, fig. 9.
1944 *Triletes crassiaculeatus*; Schopf, Wilson, and Bentall, pp. 21–22.
1946 *Triletes crassiaculeatus*; Dijkstra, pp. 44–45.
1959 *Triletes crassiaculeatus*; Winslow, pp. 21–22, pl. 3, figs. 2, 3.

Description. See Zerndt 1937, p. 12, and Winslow 1959, p. 21.

Remarks. An insufficient number of well-preserved specimens was found in order to warrant a detailed description. The characteristic features of this species have been described under 'Comparisons' in *Lagenicula subpilosa* forma *major*.

Occurrence. Sample 4.

Stratigraphic distribution. Europe: Upper Silesia? Dinantian–?Namurian A (Zerndt 1937); Turkey, Namurian A–B (Dijkstra 1952); Scotland, Dinantian (Chaloner 1953). U.S.A.: Indiana, Kentucky, Chester Series (Winslow 1959).

Affinities. *L. crassiaculeata* type spores have been obtained from *Lepidostrobus alantonensis* (Chaloner 1953).

Genus SETISPORA gen. nov.

Type species. *Setispora pseudoreticulata* sp. nov.

Generic Diagnosis. Trilete megaspores, more or less spherical in shape; no preferred direction of compression is apparent. Laesurae distinct, straight or slightly wavy in outline and may extend to spore margin, characterized by dense ornamentation of a general capillate type of appendage. Laesurae raised, but there is generally little difference between the height at the proximal pole and at the junction with the curvaturae. On lateral compressions, the raised laesurae may project from the spore outline and simulate a low, broad apical prominence. Spore wall may be folded giving an irregular outline to the margin.

Comparisons and Remarks. *Lagenicula* (Bennie and Kidston) Potonié and Kremp 1954, can be distinguished from *Setispora* by its long polar axis which results in preferred lateral compression. However, due to the raised laesurae, lateral compressions of *Setispora* may resemble *Lagenicula*. The apical prominence in *Lagenicula* is formed by the expansion of part or all of the laesurae and contact faces. The raised laesurae in *Setispora* are due to the dense capillate type of ornamentation. There are thus good morphographic grounds for proposing a new genus. Spores of the type referred here to *Setispora* were first described by Chaloner 1954 as two species *Triletes echinoides* and *T. cristatus* (= *T. palaeocristatus* Chaloner 1956) which resemble the type species of this genus.

These species are formally recombined here to *Setispora echinoides* (Chaloner) comb. nov., *Setispora palaeocristatus* (Chaloner) comb. nov.; *Triletes subpalaeocristatus* Alvin 1965 (based on sectioned spores only) may also be assignable to *Setispora*.

Setispora pseudoreticulata sp. nov.

Plate 4, figs. 1, 3, 4, 6

Holotype. Plate 4, fig. 1.

Diagnosis. Trilete megaspores, approximately circular to elliptical in outline, maximum diameter 875–1500 μ. Laesurae appear as distinct ridges, straight to slightly wavy in outline 400–600 μ long, 80–100 μ width, 150–250 μ height. No marked height difference along length of laesurae. Height and width of these ridges result from dense ornamentation of capillate type elements, partly fused, along the line of the commissures. Contact faces, forming approximately half proximal surface of compressed spore, are folded and thickened. Distal surface folded, irregularly thickened, crassitudes 30–40 μ wide. Capillate to spinose elements, 50–150 μ long and 20–60 μ wide, cover distal surface.

Description. Medium to large trilete megaspores, circular to elliptical in outline (oblique, polar compressions) mean maximum diameter 1200 μ (25 'dry' specimens); 1050–1990 μ, mean 1485 μ (14 'wet' specimens). The margin of the compressed spore is slightly irregular in outline. Originally the spore body was approximately spherical; lateral compressions may show a slightly 'bottle-shaped' outline due to the protrusion of the laesurae. Conate to baculate elements 25–70 μ high, 10–25 μ in basal diameter are densely placed on the contact faces especially in the apical parts. Radial plications (?crassitudes) extend to the curvaturae, which are formed by arcuate ridges 60 μ wide (projection from spore margin) and wavy in outline. Capillate to spinose elements are developed in the distal surface, mainly from the thickened areas; they may be branched at the base as well as at their apices. Some of these elements appear finely granulose. The local thickenings and sculptural elements adpressed to the spore wall give a somewhat reticulate appearance under transmitted light. The spore wall is often folded, 30–40 μ thick, ?finely punctate.

Comparisons. *S. pseudoreticulata* sp. nov. is similar in haptotypic features to *S. echinoides* (Chaloner) comb. nov.; *S. echinoides* is, however, larger overall (up to 2660 μ, Chaloner 1954, p. 28) and has very large spines (up to 960 μ in length) covering the spore wall. *S. palaeocristata* (Chaloner) comb. nov. can also be distinguished from *S. pseudoreticulata* by its larger size (1700–2200 μ), and by its laevigate spore wall. *Triletes pannosus* Alvin (1966) has similar haptotypic structures to *S. pseudoreticulata* and may be assignable to the same genus; however, in *T. pannosus* the ornamentation of the exine does not appear reticulate (based on personal examination and photographs supplied by Dr. K. Alvin, 12 November 1965).

Affinities. *S. pseudoreticulata* has not been recorded from any known fructification. Alvin (1965) recorded *T. subpalaeocristatus* in association with *Oxroadia gracilis* Alvin. *S. echinoides* has been recorded from *Lepidostrobophyllum fimbriatum* (Allen 1961, Lacey 1962).

Occurrence. Localities 3, 5, 6, 7.

Genus TRIANGULATISPORITES Potonié and Kremp 1954

Triangulatisporites membranatus sp. nov.

Plate 3, figs. 8, 9, 10; plate 4, figs. 2, 5, 10

Holotype. Plate 4, fig. 2.

Diagnosis. Trilete megaspores, central body maximum diameter 450–650 μ, contact faces laevigate, approximately three-quarters proximal surface of compressed central body, bounded distally by narrow (40–70 μ) zona. Outermost layer of exine loosely attached to inner central body and has vermiculate–conate ornament.

Description. Trilete megaspores which are circular to rounded triangular in outline. Spore body mean maximum diameter 539 μ (15 specimens; hydrous medium). Originally, the spore body was more or less spherical, with a small projecting subequatorial zona. No preferred direction of compression is apparent. Tetrad mark laesurae approximately three-quarters of spore body radius; laesurae straight to slightly sinuous in outline, raised 40–70 μ, being highest near the proximal pole. However, there is no indication of an apical prominence. The laesurae are firmly attached to the central body. The contact faces occupy approximately three-quarters or more of the proximal surface of the compressed body. These appear laevigate, and are delimited distally by narrow thickened arcuate ridges, which form the curvaturae. A narrow zona-like structure projects from the arcuate ridges.

Exine structure and sculpture. At least three layers of exine can be distinguished (transmitted light). Innermost layer thin, folded, rounded triangular in outline and appears to be attached to the extremities of the laesurae. External to this layer is a thicker (15–30 μ) dark coloured, smooth layer, which might be regarded as forming the wall of the central body. Outermost layer thin, fragile, easily removed from the remainder of the spore. Entire specimens rare. In the region of the curvaturae outermost layer is extended radially to form relatively narrow, zonate-type structure, which projects 40–70 μ from the margin of the central body. Distally the outer layer of exine appears to be only loosely attached to the remainder of the spore, and on some oblique to laterally compressed specimens it extends irregularly beyond the margin of the central body. Distal to the contact faces, this outer layer of exine has a vermiculate type of sculptural pattern: small lumina 5–15 μ in diameter, with between the lumina small positive sculptural elements (cones) approximately 5 μ high. The cones are seen as small light areas on the distal surface on high focus, and as small projections at the margin of the compressed spores.

Comparisons. *T. membranatus* sp. nov. is similar to *T. zonatus* (Ibrahim) Potonié and Kremp 1956, in over-all size, and in lacking a distinct reticulate ornamentation on the distal surface. However, the zona is very narrow in *T. membranatus*, and the outer layer of exine is loosely attached, projecting beyond the central body margin in oblique or lateral compressions. *T. triangulatus* (Zerndt) Potonié and Kremp 1954 and *T. regalis* (Ibrahim) Potonié and Kremp 1956 can both be distinguished from *T. membranatus* by the large reticulate ornamentation on the distal surface of the spores. *T. rootsii* Chaloner 1959 can be distinguished from *T. membranatus* by its smaller spore body (300–370 μ), larger (70–107 μ) dissected zona with prominent radiating 'bars'. The 'irregular verrucose to reticulate ornamentation' on the distal surface of *T. rootsii* is probably similar to

that of *T. membranatus*, but Chaloner (1959, p. 324) described this type of ornamentation as being present on both proximal and distal surfaces of *T. rootsii*. In *T. membranatus* the ornamentation is not present on the contact faces (proximal surface), which are laevigate.

T. membranatus is also similar in general structure to *Triletes catenulatus* var. *marginatus* Winslow 1962. However, *T. catenulatus* var. *marginatus* has a relatively large apical prominence (120–235 μ high, Winslow 1962, p. 32) and a distal catenulate ornamentation. *T. membranatus* is similar to *T. catenulatus* var. *marginatus* in that in broken specimens the laesurae tend to adhere to the spore body. As Winslow points out (p. 33) in typical *Triangulatisporites* the tecta tend to be removed from broken specimens where the outer layer of exine has been removed.

Remarks. This species is atypical of the genus in that the laesurae, or folds of exine extending from the laesurae, do not project on to the narrow zonate structure. The outer layer of the exine is also unusual in the absence of relatively large distal reticulations and in its loose attachment to the remainder of the spore. One specimen (Plate 5, fig. 10) reveals a completely laevigate central body, except for small fragments of the zona remaining in the region of the curvaturae. This may suggest that the outer layer of exine is only or most firmly attached to the central body in the region of the curvaturae.

Affinities. Selaginellaceae (Potonié 1956).

Occurrence. Locality 3.

Genus ZONALESPORITES (Ibrahim) Potonié and Kremp emend. Spinner 1965

Zonalesporites conacies sp. nov.

Plate 5, figs. 1–4

1957 ?*Triletes brasserti*; Dijkstra and Piérart *pars*, p. 10, pl. 4, figs. 66–73.

Holotype. Plate 5, fig. 1. The name refers to the ornamentation of the corona.

Diagnosis. Large trilete megaspores with distinct central body and corona. Central body maximum diameter 820–1450 μ, laesurae approximately three-quarters radius of central body, straight to sinuous, raised 30–120 μ, highest near margin of spore body. Corona 360–650 μ wide, formed by partial coalescence of capilli, ornamented by cones with elongate apices, 10–30 μ length, 8–15 μ basal diameter. Distal surface generally smooth.

Description. Central body more or less circular in outline, mean maximum diameter 1020 μ (28 specimens; hydrous medium). Polar compressions are most common, probably due to the longer equatorial axis; spore body originally more or less spherical. Laesurae approximately twice as high at distal terminations as at proximal pole. On some specimens secondary folds can be seen on the equatorial structure opposite the laesurae. Small baculate type elements 10–45 μ long, 5–15 μ wide, occur on upper parts of some laesurae. No specimens were observed with a ruptured commissure. Contact faces smooth, forming approximately three-quarters of the proximal surface of the compressed spore body. No thickened arcuate ridges represent the curvaturae, the contact faces being bound distally by the elements forming the proximal part of the equatorial structure.

Exine structure and sculpture. Equatorial structure surrounding central body has the form of a corona and is attached in a narrow zone slightly proximal to the equator of the compressed central body. The corona width 360–650 μ (12 specimens, as measured from point of proximal attachment to margin), projects 300 to 460 μ from the margin of the spore body; maximum width generally opposite the laesurae, giving entire spores a slightly rounded triangular outline. Corona formed by layers of elongated elements which coalesce near outer margin to form a continuous fimbriate rim; proximal layer of capilli 20–40 μ wide at the base and closely spaced, can be traced for approximately one-third of corona radius before they coalesce. In the distal region of attachment the elements are more completely fused. Outer part of corona characterized by small circular to oval dissections, maximum diameter 10–80 μ. From the rim of the corona small cone-like elements (10–30 μ long and 8–15 μ in basal diameter) with elongated terminals project; similar elements are arranged more or less in rows over the fused part of the corona. Many of these elements are atypical of conate ornament in that approximately halfway along the length there is an abrupt decrease in width, thus giving an elongated effect to the apex. Distal surface of central body generally laevigate, although occasional specimens (2 during the present study), ornamented on distal surface with scattered baculate to pilate elements, 20–50 μ long, 10–20 μ wide. Small cones (2–4 μ long) project from the apices of these elements. Generally, these elements are found only in the region just distal to the attachment of the corona. Wall of central body 35–50 μ thick (?infrastructure); in many specimens a thin shrunken layer can be seen (transmitted light) within the central body.

Comparisons. Z. conacies sp. nov. is very similar to *Zonalesporites ramosus* (Arnold) (*Rotatisporites* of Potonié and Kremp 1956) in the general structure and in the size of the central body (580–1744 μ, average 1036 μ; Arnold 1950, p. 72). However, the marginal rim in *Z. ramosus* is narrower than in *Z. conacies*, and the elements projecting have 'rounded or slightly swollen tips' (Arnold 1950, p. 73). The distal surface in *Z. conacies* is generally smooth, whereas in *Z. ramosus* it is more generally ornamented with elements similar to those forming the corona.

In *Zonalesporites rotatus* (Bartlett) (*Rotatisporites* of Potonié and Kremp 1954) the size of central body is smaller (700–998 μ; Bartlett 1929, Zerndt 1937) than in *Z. conacies*. Also the equatorial structure in *Z. rotatus* is characterized by larger dissections and less fimbria (?1 layer) than *Z. conacies*.

It is difficult to compare *Z. conacies* with *Zonalesporites brasserti* (Stach and Zerndt) Potonié and Kremp 1954 for the limits of this species are poorly defined. Many workers, e.g. Zerndt 1937, Dijkstra 1946, have included various forms within this species which differ in detail. Dijkstra (1955–7) proposed several subspecific taxa within the species. Potonié and Kremp (1956, p. 122) gave a more restricted circumscription of the species, but did not give any detailed description of the equatorial structure which they referred to as a cingulum. Since this structure is formed by the fusion or partial fusion of fimbria it is here regarded as a corona, reserving cingulum for forms with an equatorial thickening such as the miospore genus *Densosporites* (Berry) Potonié and Kremp 1954. This interpretation of *Z. brasserti* is in close agreement with that of Winslow (1959, p. 35) and on this basis some comparisons can be made with *Z. conacies*. The corona in *Z. brasserti* consists of several layers of fimbria, which are more completely fused than

in Z. *conacies*, and the dissections in *Z. brasserti* are less common and restricted to the marginal part of the corona. The elongate conate elements which characterize the corona of *Z. conacies* are not present in *Z. brasserti*, although 'bar-like' processes (?bacula) may project from the rim of the corona (compare Pl. 5, fig. 15).

The differences in structure of the corona referred to above are difficult to see on dry specimens under reflected light, especially if the specimens are insufficiently bleached. Under such conditions, the specimens described here as *Z. conacies* might be included in '*Triletes brasserti*' *sensu* Dijkstra. From the description and illustrations of Dijkstra and Piérart (1957, pp. 9–10, pls. 3, 4), it is possible that some specimens of *Z. conacies* were recorded as *Z. brasserti*. This has been indicated in the synonymy.

One small specimen found (Pl. 5, fig. 4), shows thickened contact areas forming a triangular platform around the proximal pole. This may be an abortive or immature form by comparison with similar thickened specimens assigned to the genera *Laevigatisporites* Ibrahim 1933, *Tuberculatisporites* (Ibrahim) Potonié and Kremp 1954. However, *Z. conacies*-type megaspores have not been described from any fructification, and further studies may warrant the creation of a new taxon for such a form.

Affinities. ?Lycopsida (Potonié and Kremp 1954).

Occurrence. Sample 4. ?Lower Carboniferous, Moscow Basin (Dijkstra and Piérart 1957).

Species A

Plate 5, fig. 6

Description. Megaspores? more or less circular in outline, maximum diameter approximately 450 μ (2 specimens). No haptotypic structure visible. Exine ornamented with densely placed verrucae 5–15 μ in diameter, grading into cones 4–8 μ in basal diameter, up to 4 μ high. Exine secondarily folded.

Remarks. The specimens exhibit some similarity in exine ornamentation with *Biharisporites ellesmerensis* Chaloner 1959 but are larger and lack visible haptotypic structures.

Occurrence. Sample 4.

THE MIOSPORE ASSEMBLAGES

Because of the fragmentary nature of the sequence examined it is not proposed to give a detailed comparison of the present assemblages with the now considerable number of assemblages examined from the Viséan of this country and elsewhere. The distributions of the spores recognized in the seven samples examined are shown in Table 1. The

EXPLANATION OF PLATE 5

All figures by transmitted light.

Figs. 1, 2, 3, 4. *Zonalesporites conacies* sp. nov. 1, Holotype, polar compression × 50, sample 4, slide V4/16. 2, Part of corona × 100, sample 4, slide V4/21. 3, oblique compression × 50, sample 4, slide V4/9. 4, Abortive? specimen with thickened contact faces, sample 4, slide V4/13.

Fig. 5. Part of corona of *Zonalesporites brasserti* (Stach and Zerndt) Potonié and Kremp, × 100; Wernddu Clay pit, South Wales coalfield, Westphalian B; slide WD/6 (for comparison with fig. 2).

Fig. 6. Species A, × 100, sample 4, slide V4/40.

occurrences elsewhere of the spores described are listed in the systematics section. The following points appear to be worthy of note:

1. Species of *Rotaspora*, *Tripartites* and *Diatomozonotriletes*, not found by Smith

TABLE 1. Distribution of spores in the seven samples studied.

	Bewcastle Beds	*Cambeck Beds*	*Dodgesontown Ford*	*Nether Hill*	*Lewis Burn*		
Samples	1	2	3	4	5	6	7
Chaetosphaerites pollenisimilis	—	—	—	P	—	—	P
Punctatisporites debilis	C	C	A	C	C	C	A
Calamospora microrugosa	C	A	C	A	P	C	C
C. cf. *nigrata*	—	—	—	P	—	—	—
Retusosporites incohatus	P	P	—	—	—	—	—
Granulatisporites parvigranulatus	—	—	—	C	—	P	P
G. rudigranulatus	—	—	P	P	P	P	—
Cyclogranisporites commodus	—	P	P	C	P	P	—
Verrucosisporites baccatus Staplin	—	—	—	P	—	—	—
Lophotriletes plicatus	—	—	—	—	P	—	—
Anapiculatisporites concinnus	—	—	—	P	—	—	P
Anaplanisporites baccatus	—	P	C	C	P	A	C
Apiculiretusispora multiseta	C	P	—	—	—	—	—
Raistrickia ponderosa	P	—	—	—	—	—	—
Convolutispora cf. *finis*	P	—	—	—	—	—	—
C. planimuricata	—	P	—	P	P	—	P
Dictyotriletes admirabilis	—	—	—	—	—	—	P
D. pseudopalliatus	—	P	P	—	P	—	P
D. plumosus	—	—	C	—	P	—	—
Corbulispora subalveolaris	—	—	—	P	P	C	P
Orbisporis convolutus	—	—	—	—	—	—	P
Procoronaspora dumosa	—	—	—	P	—	—	—
Knoxisporites hederatus Ishch.	—	—	—	P	—	—	—
K. literatus	P	—	—	—	—	—	—
Endosporites micromanifestus Hacq.	P	P	—	—	—	—	P
Schulzospora campyloptera	—	—	P	P	P	—	P
Velosporites echinatus	—	P	P	—	—	—	—
Densosporites regalis	—	—	P	A	P	P	—
Lycospora noctuina	A	A	A	A	C	A	A
L. rugulosa	—	A	A	—	A	P	—
L. tenebricosa	—	P	—	—	—	—	—
Cingulizonates bialatus (Waltz	—	—	—	—	—	P	—
Vallatisporites ciliaris	P	P	—	—	P	—	—
Tholisporites cumbriensis	—	—	—	P	—	—	—
Perotrilites perinatus	P	—	—	—	P	—	P
Aneuletes reticulata	—	—	C	—	—	—	—
Didymosporites scotti	—	—	C	P	—	—	—
Lagenicula subpilosa f. *major*	—	—	—	C	—	—	—
L. crassiaculeata	—	—	—	P	—	—	—
Setispora pseudoreticulata	—	—	A	—	P	—	—
Triangulatisporites membranatus	—	—	C	—	—	—	—
Zonalesporites conacies	—	—	—	A	—	—	—
Species A	—	—	—	P	—	—	—

A = abundant (more than 10%); C = common (1–10%); P = present (less than 1·0%)

and Butterworth (1967) below the higher part of the D1 Zone, were not recorded in the present samples.

2. Species of *Chaetosphaerites*, *Anapiculatisporites*, and *Procoronaspora*, recorded by Smith and Butterworth (loc. cit.) in the Oakshawford Seam, were not found at lower horizons in the present investigations but all occurred at one or more of the higher horizons examined (samples 4–7).

3. Species of *Granulatisporites* and *Schulzospora*, and *Denosporites regalis*, occurred in the S1 Zone Dodgesontown Ford coal, but not at lower horizons.

4. *Cyclogranisporites commodus*, *Anaplanisporites baccatus*, *Convolutispora planimuricata* sp. nov., *Dictyotriletes pseudopalliatus*, *Lycospora rugulosa* sp. nov., *L. tenebricosa*, and *Velosporites echinatus* occurred in the C2 Zone Cambeck shales and at certain higher horizons but were not found in the C1 Zone Bewcastle coal.

5. The C1 Zone Bewcastle coal is characterized by significant numbers of *Retusotriletes incohatus* and *Apiculiretusispora multiseta* and is the only horizon at which *Raistrickia ponderosa*, *Convolutispora* cf. *finis* and *Knoxisporites literatus* (Waltz) Playford were recorded.

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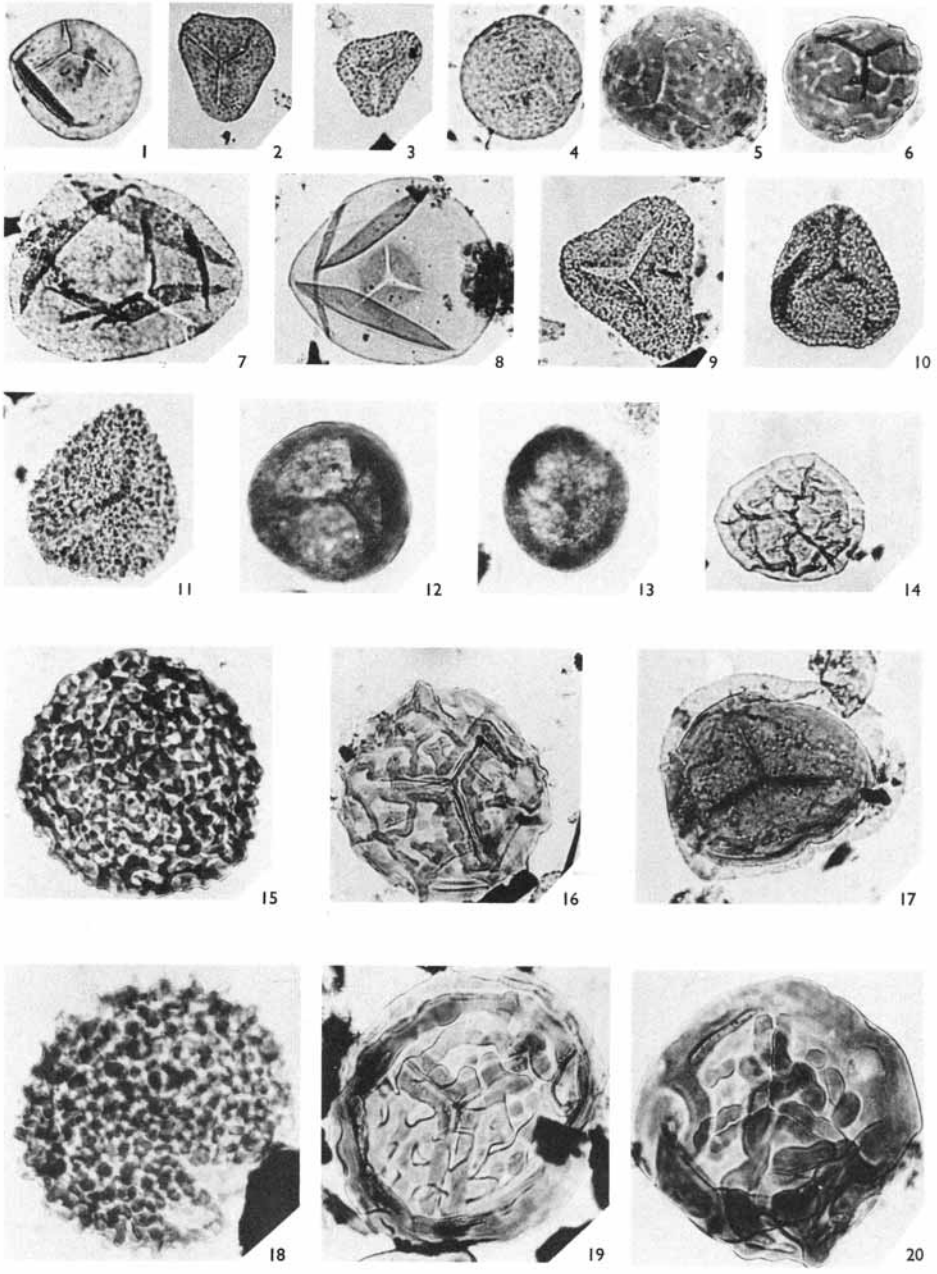
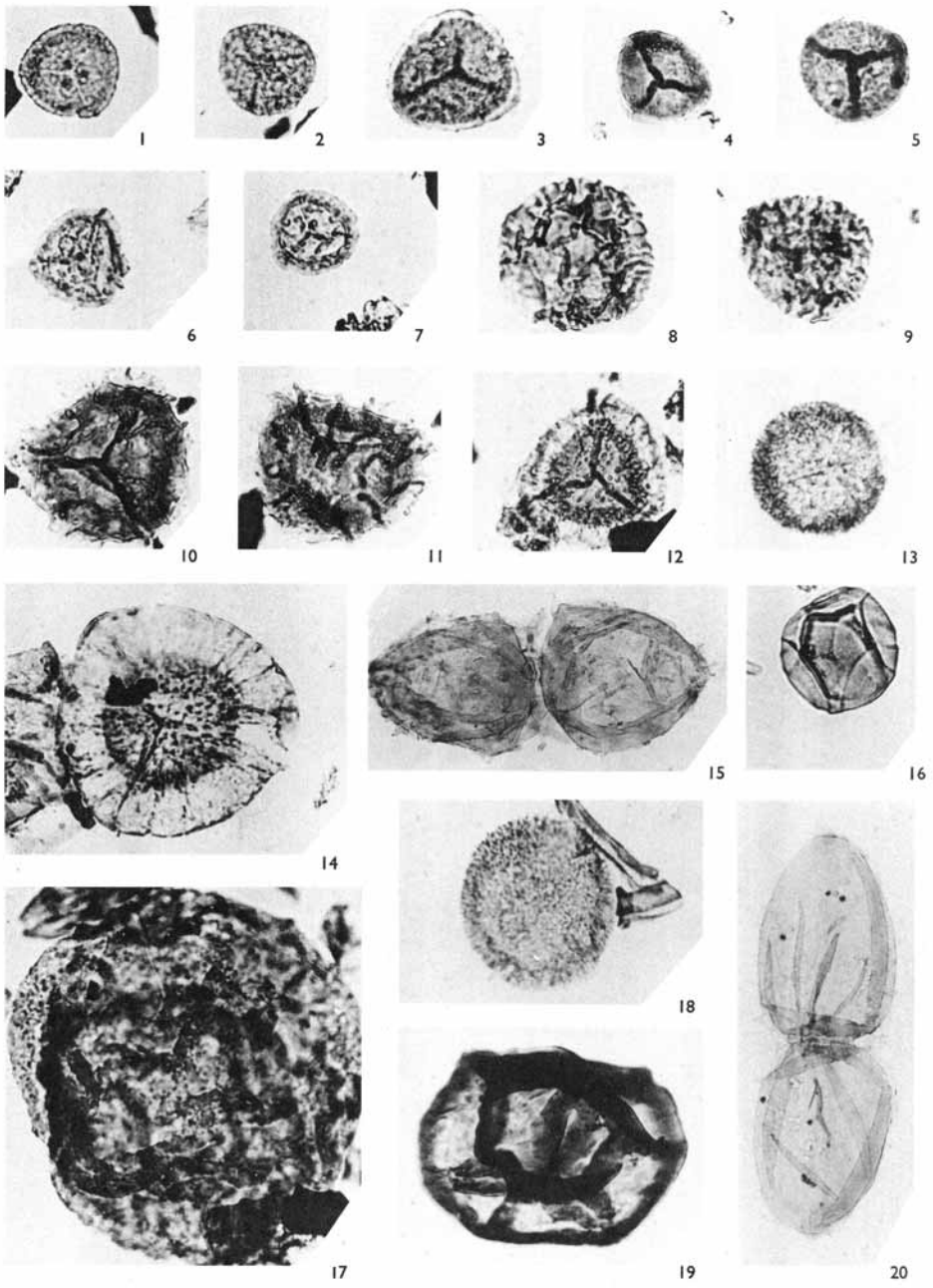


BUTTERWORTH and SPINNER, Lower Carboniferous miospores



BUTTERWORTH and SPINNER, Lower Carboniferous miospores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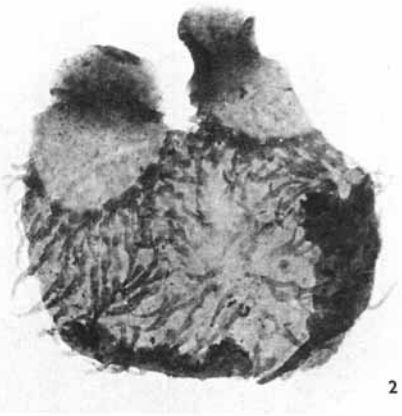
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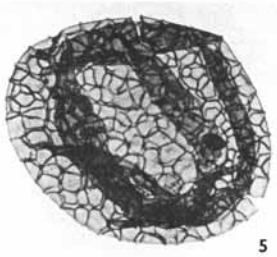
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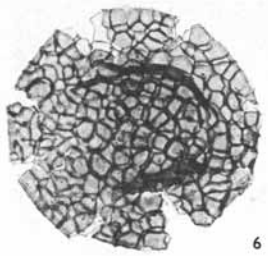
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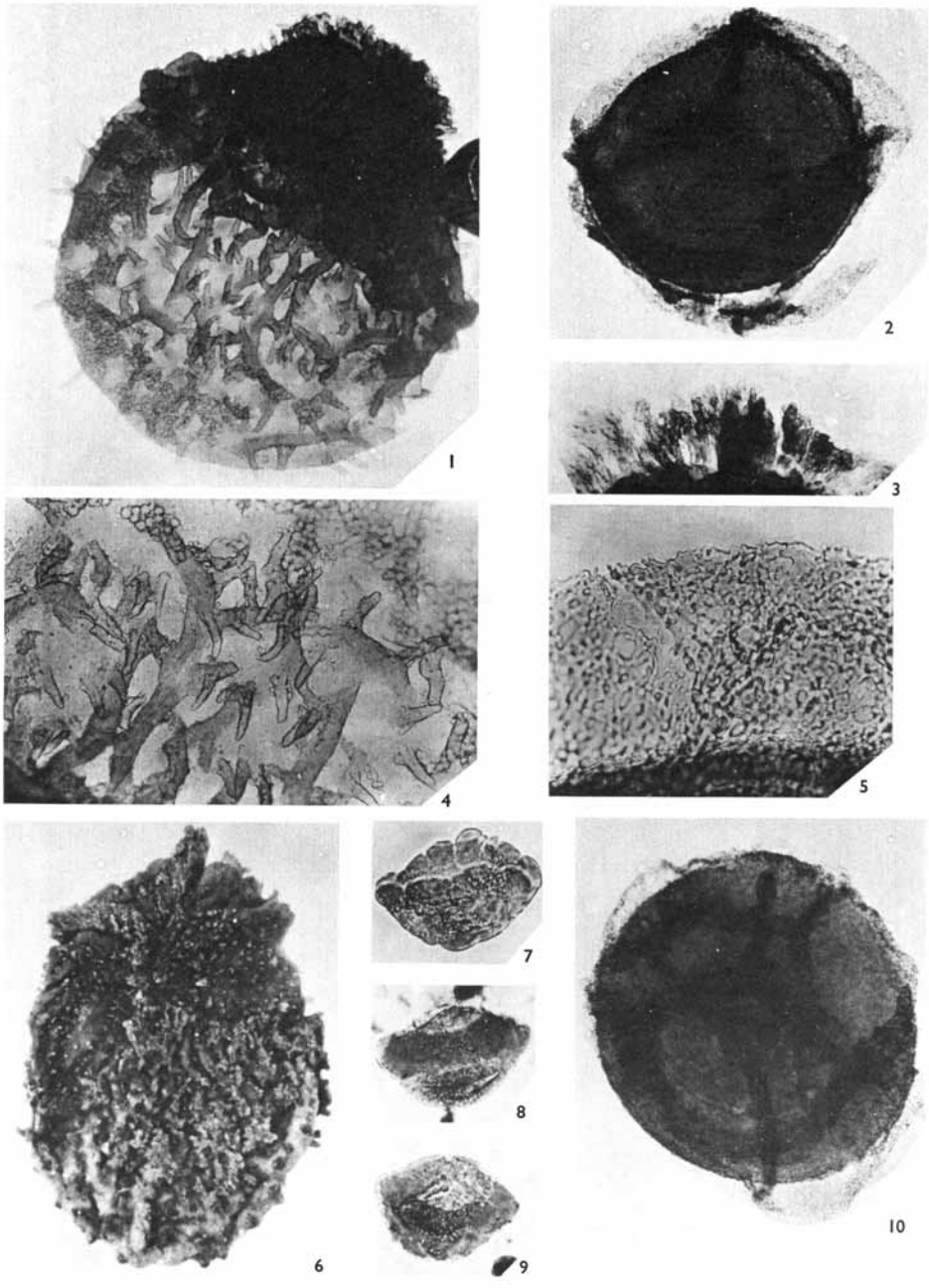

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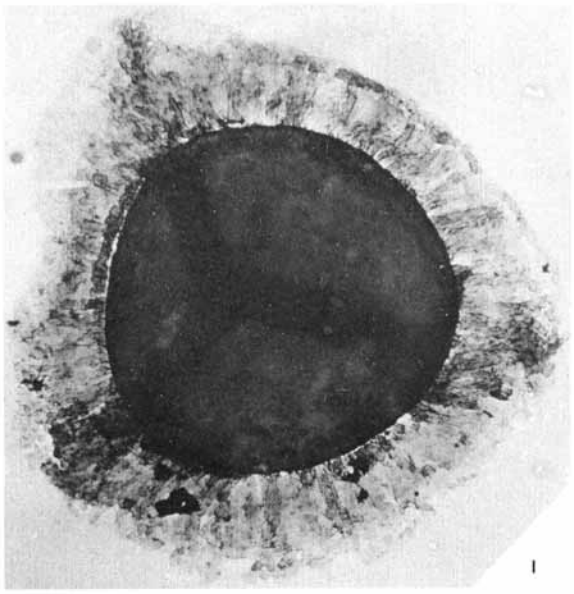
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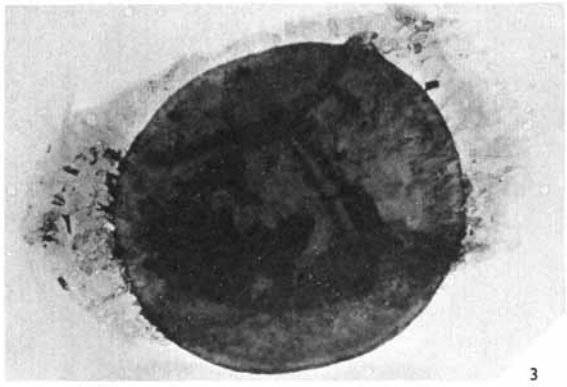
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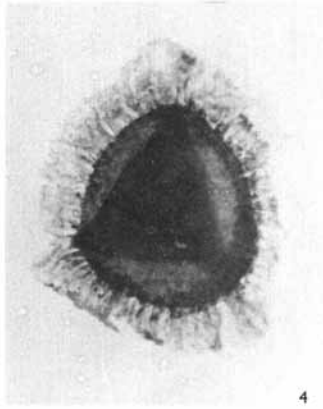
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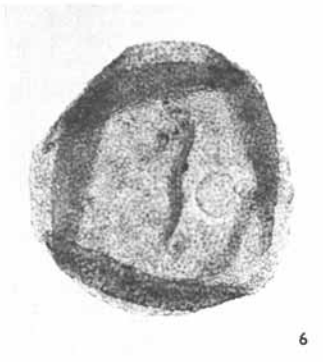
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