A TOURNAISIAN SPORE FLORA FROM THE CEMENTSTONE GROUP OF AYRSHIRE, SCOTLAND

by H. J. SULLIVAN

ABSTRACT. A well-preserved spore flora containing elements diagnostic of a Tournaisian age has been obtained from a horizon approximately 100 ft. above the base of the Cementstone Group in Ayrshire. A total of twenty-two species of spores have been recognized in the assemblage; of these, eight are new. Comparison with assemblages from other parts of the world has indicated regional variations in the composition of the Tournaisian spore floras.

THE oldest Carboniferous sediments in the Midland Valley of Scotland are assigned to the Cementstone Group of the Calciferous Sandstone Measures (MacGregor 1960). The sequence consists of thin argillaceous dolomites ('cementstones') interbedded with grey to green shales and mudstones. Films of gypsum, halite pseudomorphs, and mud cracks which are present on many of the bedding surfaces are evidence of the arid environment under which these sediments were laid down. The nodular development and unfossiliferous nature of the cementstones favour the view that much of the material was chemically precipitated from hypersaline waters. The Cementstone Group displays considerable lateral variation in thickness and lithology; for details, see MacGregor (1930, pp. 491–4), George (1958, pp. 304–9), Francis in Craig (1965, pp. 311–17). At many localities, the Cementstone Group succeeds the Upper Old Red Sandstone with apparent conformity. The change from the red sandstones and cornstones of the Upper Old Red Sandstone into the shales and cementstones of the Cementstone Group is continuous and transitional, and frequently the lithologies are interbedded in a passage zone between the two formations. The base of the Cementstone Group is drawn at the lowest occurrences of the cementstones.

PREVIOUS RECORDS OF FOSSILS FROM THE CEMENTSTONE GROUP

The lack of diagnostic fossils which are used for the conventional zonal subdivision of Dinantian sequences in Britain and Europe has precluded a reliable palaeontological age determination for the Cementstone Group. The fauna consists of ostracods, entomostracans, inarticulate brachiopods, fish teeth and scales, and lamellibranchs. Plant compressions and petrefactions are also common at many horizons and their distribution is adequately documented (Crookall 1932). Spores have been illustrated and described from fructifications (e.g. Smith 1962*a*, 1962*b*; Alvin 1965). Knox (1959, p. 92) has also recorded the presence of fourteen genera of dispersed spores in the Calciferous Sandstone Measures which was penetrated in an unspecified borehole in Dumfriesshire. The palynological data so far published have little stratigraphical application.

Marine limestones are intercalated with cementstones in the lower part of the Cementstone Group at Randerstone, Fife (Kirkby 1902). The faunas had been dated as Tour-

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naisian in age by comparison with the occurrences in northern England. George (1958) has challenged the validity of this age determination (and also the evidence of conformable contact between the Cementstone Group and the Upper Old Red Sandstone) and has suggested the faunas at Randerstone may be of Viséan age. He concludes (p. 304): 'The precise age of the oldest Carboniferous sediments remains unproved. On the evidence of the earliest goniatite beds, and on general palaeogeographical grounds of comparison with the developments in Ulster and Northumbria, it is not likely to be greater than latest Caninian or perhaps Seminulan.'

LOCATION AND PREPARATION OF THE SAMPLES

The sample of cementstone was collected by Dr. E. C. Freshney from a horizon approximately 100 ft. above the base of the Cementstone Group in Bracken Bay, Heads of Ayr, Ayrshire (Grid ref.: 2830 1860). The location of the sample is shown in text-fig. 1.

The cementstone was first treated with hydrochloric acid and then with hydrofluoric acid. The residue was oxidized with Schulze Solution for 10 minutes and washed with 5% caustic potash and distilled water.

The slides containing the holotypes and all illustrated specimens have been deposited in the collection of the Research Centre, Pan American Petroleum Corporation, Tulsa. The slides are identified with a preparation number and the coordinates are those of a Leitz Ortholux microscope (No. 618559).

SYSTEMATIC DESCRIPTIONS

Anteturma SPORITES H. Potonié 1893
Turma TRILETES (Reinsch) Potonié and Kremp 1954
Subturma AZONOTRILETES Luber 1935
Infraturma APICULATI (Bennie and Kidston) R. Potonié 1956
Genus BACULATISPORITES Thomson and Pflug 1953

Type species. *B. primarius* (Wolff) Thomson and Pflug 1953.

Baculatisporites fusticulus sp. nov.

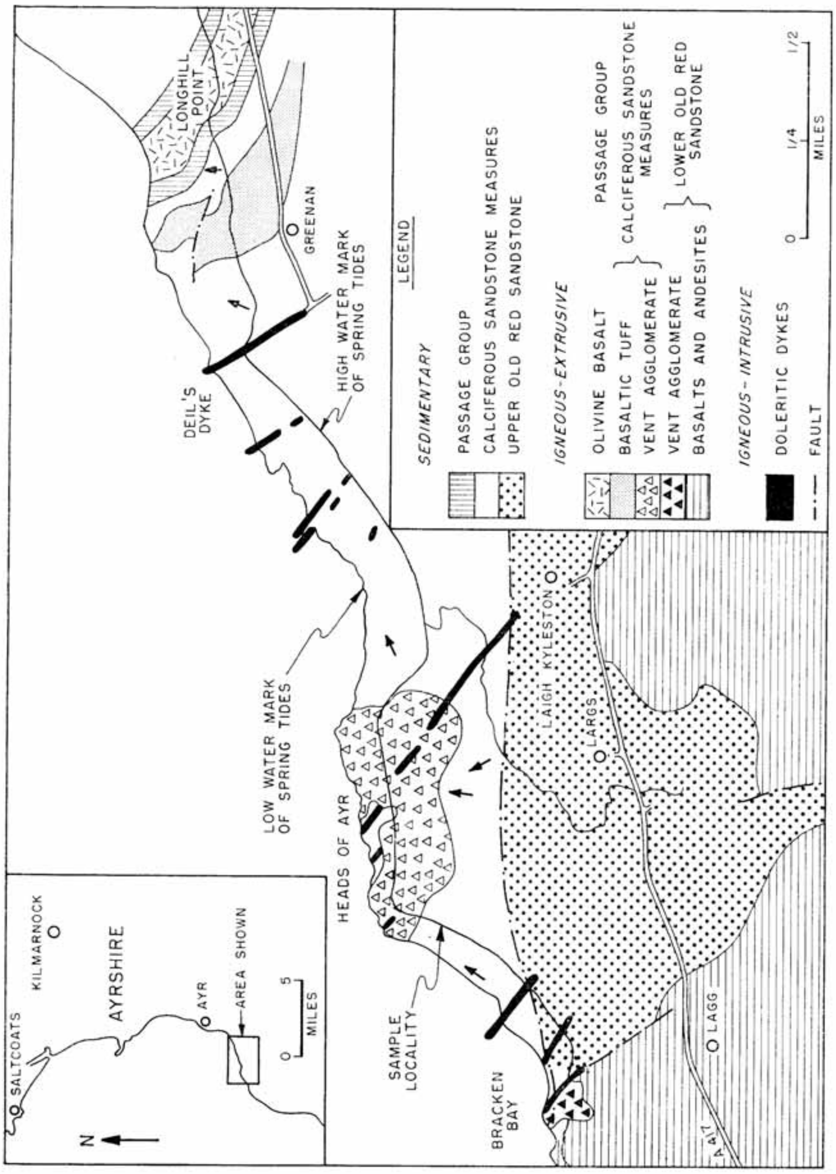
Plate 25, figs. 1, 2

Holotype. Slide P26381-A-04, 115·0 53·0. Size 86 μ.

Diagnosis. Size 73–100 μ, mean 89 μ (34 specimens); amb oval to circular; exine 1·5–2 μ thick, ornamented with bacula and pila up to 1 μ high and 0·7 μ wide.

Description. Amb circular to oval, may be irregular due to presence of secondary folds. Trilete mark visible to indistinct, rays exceed half radius of spore, simple and slightly sinuous. Exine yellow in colour, 1·5–2 μ thick. Ornamentation consists of bacula and pila which are of uniform size and comprehensively distributed. Elements are up to 1 μ high, 0·5–0·7 μ wide and 1–2 μ apart. Occasionally the ornament may be absent from a narrow zone bordering the rays. Secondary folds common.

Remarks. The spores described above cannot conveniently be accommodated in any known Palaeozoic genus. The elements are of a different shape to those in *Cyclogranisporites*



TEXT-FIG. 1. Geological map of the Heads of Ayr region (after Bassett 1958) showing location of sample.

Potonié and Kremp 1954, and are considerably smaller than the bacula in *Raistrickia* Schopf, Wilson and Bentall 1944. The ornament in *Bullatisporites* Allen 1965 is exclusively pilose.

Genus PUSTULATISPORITES Potonié and Kremp 1954

Type species. P. pustulatus Potonié and Kremp 1954.

Pustulatisporites gibberosus (Hacquebard) Playford 1964

Plate 25, fig. 3

Remarks. This species occurred rarely in the Cementstone Group assemblage. The specimens agreed closely with the emended description of *P. gibberosus* given by Playford (1964, pp. 18–19).

Previous records. Horton Group (Tournaisian) of eastern Canada (Hacquebard 1957, Playford 1964).

Genus RAISTRICKIA Schopf, Wilson, and Bentall 1944

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

Raistrickia clavata Hacquebard emend. Playford 1964

Plate 25, figs. 4, 5

Remarks. A total of 30 specimens of *R. clavata* were identified in the Cementstone Group assemblage. They showed a similar morphological variation to the examples illustrated by Playford (1964, pl. 6, figs. 5–10) from the Horton Group.

Previous records. Horton Group (Tournaisian) of eastern Canada (Hacquebard 1957, Playford 1964).

Raistrickia corynoges sp. nov.

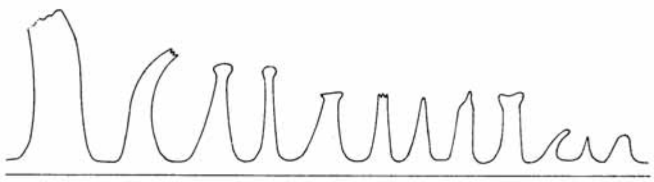
Plate 25, figs. 6–8; text-fig. 2

1963 *Acanthotriletes macrurus* (*non* Luber and Waltz 1938, p. 30; pl. 7, fig. 94) Kedo, p. 44; pl. III, fig. 58.

Holotype. Slide P26381-A-04, 109·4 45·3. Size, 58 μ.

Diagnosis. Size (excluding ornament) 50–75 μ, mean 64 μ (44 specimens); amb circular to oval; exine ornamented with bacula, coni and verrucae; equatorial elements baculose, up to 15 μ high and 5 μ wide; trilete rays may be obscured by ornamentation.

Description. Amb circular to oval. Trilete mark may be distinct or obscured by ornamentation. Rays extend half to two-thirds radius of spore, straight, vertex high. Exine up to 4 μ thick, yellow to brown in colour. Ornamentation extremely variable in size and shape on any individual specimen. In the spore (Pl. 25, fig. 8), the proximal polar region is ornamented with dispersed broad-based cones and verrucae up to 2 μ high and wide and up to 4 μ apart. Towards the equator, the elements become larger, more densely distributed, and baculose in shape. Equatorial bacula 8–10 μ high and 4–5 μ (rarely 7 μ) wide. The bacula usually have rounded tops; less frequently, the tops are pointed or blunted (text-fig. 2). The distal polar region of the specimen is ornamented with cones and verrucae which may be discrete or coalescent and up to 4 μ high and wide. The equatorial elements in the specimen (Pl. 25, fig. 6) are up to 15 μ high and 3–5 μ wide. The distal surface is also covered with bacula but with a few broad based cones among them. The proximal polar region is ornamented with verrucose and spatulate processes up to 4 μ in height and 8 μ in width. In the spore (Pl. 25, fig. 7), the elements are dominantly baculose and are connected at the base by low ridges. Secondary folds rare. Spores frequently preserved in off-polar compression.



TEXT-FIG. 2. Profile view of sculptural elements of *Raistrickia corynoges* sp. nov.

Comparison. The species *Acanthotriletes sphaerites* Kedo 1963 (p. 44; pl. 3, fig. 58) is similar to *R. corynoges*, but differs in possessing longer trilete rays, and larger (up to 24 μ high) and more uniform processes. *Archaeotriletes hamulus* (Naumova 1953, p. 52; pl. 6, fig. 54) from the Middle Frasnian of the Moscow Platform is inadequately decribed and illustrated, but the ornamentation appears to be of a larger size, more uniform in shape, and less densely distributed than in *R. corynoges*.

Remarks. Kedo's illustration of *Acanthotriletes macrurus* differs considerably from the drawing of Luber in Luber and Waltz (1938, 1941) and those of other Russian authors (e.g. Ishchenko 1956, pl. 4, fig. 43; 1958, pl. 2, figs. 28, 29). The photograph given by Playford (1962, pl. 81, fig. 3) is of a specimen similar to the original drawing of Luber.

Raistrickia sp. described and illustrated by Sullivan (1964, p. 1252, pl. 1, fig. 8) from the Lower Limestone Shales of the Forest of Dean is undoubtedly *R. corynoges*.

Previous records. The Tournaisian (Cherepet horizon) of the Pripyat Basin of eastern Russia (Kedo 1963). Lower Limestone Shales (Tournaisian) of the Forest of Dean, Gloucestershire (Sullivan 1964).

EXPLANATION OF PLATE 25

All figures ×650.

Figs. 1–2. *Baculatisporites fusticulus* sp. nov. 1, Holotype, distal surface, slide P26381-A-04, 115·0 53·0. 2, Proximal surface, slide P26381-A-04, 127·7 30·6.

Fig. 3. *Pustulatisporites gibberosus* (Hacquebard) Playford 1964; distal surface, slide P26381-A-01, 119·6 37·9.

Figs. 4–8. *Raistrickia spp.* 4–5, *Raistrickia clavata* Hacquebard emend. Playford 1964. 4, Proximal surface, slide P26381-A-08, 120·0 40·8. 5, Oblique view, slide P26381-A-08, 109·7 41·5. 6–8, *Raistrickia corynoges* sp. nov. 6, Holotype, distal surface, slide P26381-A-04, 109·4 45·3. 7, Proximal surface, slide P26381-A-O3. 123·6 43·2. 8, Proximal surface, slide P26381-A-01, 118·8 40·4.

Figs. 9–10. *Schopfites claviger* sp. nov. 9, Holotype, ? distal surface, slide P26381-A-03, 125·0 26·5. 10, Oblique view, slide P26381-A-02, 125·2 57·3.

Figs. 11–12. *Verrucosisporites scoticus* sp. nov. 11, Holotype, distal surface, slide P26381-A-08, 116·9 43·9. 12, Distal surface, slide P26381-A-03, 123·9 44·5.

Genus SCHOPFITES Kosanke 1950

Type species. S. dimorphus Kosanke 1950.

Schopfites claviger sp. nov.

Plate 25, figs. 9, 10

Holotype. Slide P26381-A-03, 125·0 26·5. Size, 50 μ.

Diagnosis. Size 40–52 μ (excluding ornament), mean 47 μ (28 specimens); trilete rays not observed; exine ornamented with clava and bacula up to 4 μ high and 3 μ wide; portion of exine without ornamentation.

Description. Amb circular to oval. Trilete rays not observed. Exine thin, thickness not determinable, finely and densely infrapunctate. Ornamentation consists of clava and bacula, up to 4 μ high and 3 μ wide, which cover between 60–80% of the total exine surface. Parallel-sided compression folds are sometimes located near the equator.

Comparison. S. augustus Playford (1964, p. 26, pl. 7, figs. 2–7) is larger (up to 122 μ), has a more pronounced ornamentation and a distinct trilete mark.

Genus VERRUCOSISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. V. verrucosus (Ibrahim) Ibrahim 1933.

Verrucosisporites scoticus sp. nov.

Plate 25, figs. 11, 12

Holotype. Slide P26381-A-08, 116·9 43·9. Size, 42 μ.

Diagnosis. Size 38–45 μ, mean 42 μ (18 specimens); exine 2–3 μ thick, ornamented with discrete dome-shaped verrucae or mammilate elements, 2–4 μ high, 2–6 μ wide; ornament mainly confined to distal surface.

Description. Amb circular, rounded triangular or oval. Trilete mark distinct to visible, rays straight or gently curved, exceed two-thirds radius of spore. Exine 2–3 μ thick, laevigate, reddish-brown in colour. Exine ornamented with discrete verrucae which usually have rounded tops, only occasionally truncated. In some specimens, the equatorial elements are mammilate. Verrucae 2–4 μ high (excluding exine thickness), 2–6 μ in basal diameter, and 1–4 μ apart. Ornamentation confined mainly to distal and equatorial surfaces. Some elements may be present on the proximal hemisphere where they are usually located at the termini of the rays. The number of elements visible at the outline varies between 14 and 25. Secondary folds are absent.

Comparison. Pustulatisporites gibberosus (Hacquebard) Playford 1964 bears a superficial resemblance to *V. scoticus*. It may be differentiated by its more discrete and larger verrucae and by the infragranulate exine.

Verrucosisporites variotuberculatus sp. nov.

Plate 26, figs. 1–4

Holotype. Slide P26381-A-01, 114·7 38·3. Size, 64 μ.

Diagnosis. Size 57–90 μ, mean 72 μ (45 specimens); amb circular to oval; trilete rays half to two-thirds radius; exine 4–10 μ thick, verrucae 1–3 μ high and 2–10 μ wide, reduced in size towards proximal pole.

Description. Amb circular to oval. Trilete mark distinct, sometimes gaping, rays extend one-half to two-thirds radius of spore. Exine 4–10 μ thick; thickness constant in any single specimen. Exine ornamented with low, dome-shaped verrucae 1–3 μ high (excluding exine thickness), surface smooth to irregularly pitted (corrosion?). Verrucae are polygonal in basal view (usually irregularly pentagonal), rarely circular, and are 4–10 μ wide. Elements are separated by narrow, stripe-like channels which form a discontinuous negative reticulum. Characteristically, there is a reduction in size of the ornament in the region of the proximal pole (Pl. 26, figs. 1, 2, 4). Secondary folds are absent.

Comparison. *V. congestus* Playford 1964 and *Convolutispora stigmoidea* Bharadwaj and Venkatachala 1962 can easily be differentiated from *V. variotuberculatus* by the fact that there is no reduction in the size of the verrucae at the proximal pole. *V. grumosus* (Naumova) Sullivan 1964 resembles *V. variotuberculatus*, but is smaller in size (up to 70 μ), has a thinner exine and a less distinct trilete mark.

Infraturma MURORNATI Potonié and Kremp 1954

Genus CONVOLUTISPORA Hoffmeister, Staplin, and Malloy 1955

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

Convolutispora cf. *mellita* Hoffmeister, Staplin, and Malloy 1955

Plate 26, figs. 5–7

Description. Size 60–95 μ, mean 81 μ (40 specimens). Amb circular to oval. Trilete mark distinct, but may be obscured by ornamentation, rays exceed half radius of spore, straight to slightly curved. Exine 6–8 μ thick, ornamented with broad, low anastomosing ridges which rarely exceed 2 μ in height (excluding exine thickness) and 8 μ in width. Lumina are of two kinds: one set is circular to oval in shape and up to 4 μ in the longest diameter, and a second set consists of narrow, irregularly sinuous depressions less than 3 μ wide and up to 25 μ long. Margin smooth to slightly undulating.

Comparison. A detailed examination of the holotype is necessary before it can be established whether the specimens described above are truly conspecific with *C. mellita*.

EXPLANATION OF PLATE 26

All figures × 650.

Figs. 1–4. *Verrucosisporites variotuberculatus* sp. nov. 1, Semi-oblique view, slide P26381-A-01, 125·0 54·4. 2, Holotype, semi-oblique view, slide P26381-A-01, 114·7 38·3. 3, Proximal surface, slide P26381-A-08, 117·3 43·7. 4, Proximal surface, slide P26381-A-03, 123·8 22·1.

Figs. 5–8. *Convolutispora spp*. 5–7, *Convolutispora* cf. *mellita* Hoffmeister, Staplin, and Malloy 1955. 5, Distal surface, slide P26381-A-08, 120·0 44·2. 6, Proximal surface, slide P26381-A-04, 119·7 28·5. 7, Proximal surface, slide P26381-A-04, 117·9 30·8. 8, *Convolutispora* cf. *tuberosa* Winslow 1962. Proximal surface, slide P26381-A-02, 124·3 43·3.

Fig. 9. *Vallatisporites vallatus* Hacquebard 1957. Proximal surface, slide P26381-A-03, 116·0 39·2.

Fig. 10. *Lycospora torulosa* Hacquebard 1957. Proximal surface, slide P26381-A-02, 122·6 22·4.

Fig. 11–12. *Hymenozonotriletes*? *hastulus* sp. nov. 11, Proximal surface, slide P26381-A-04, 122·1 50·2. 12, Holotype, proximal surface, slide P26381-A-04, 125·9 52·7.

The width of the ridges exceed the dimensions quoted by Hoffmeister, Staplin, and Malloy (1955, p. 385), but otherwise they are similar to the published description.

Convolutispora cf. *tuberosa* Winslow 1962

Plate 26, fig. 8

Description. Size 65–72 μ (5 specimens). Amb subcircular. Trilete mark not observed. Exine 2 μ thick, ornamented with verrucae, frequently with expanded tops, up to 6 μ high and 10 μ wide. The verrucae may be fused laterally into broad irregular ridges up to 12 μ long. Bacula up to 2·5 μ high and 4 μ wide are interspersed among the ridges.

Comparison. Winslow (1962, p. 71) stated that the 'tuberculate ridges' in *C. tuberosa* tended to lie parallel to the rays. This feature could not be demonstrated in the five specimens examined.

Turma ZONALES (Bennie and Kidston) R. Potonié 1956
Subturma ZONOTRILETES Waltz 1935
Infraturma CINGULATI Potonié and Klaus 1954
Genus LYCOSPORA Schopf, Wilson, and Bentall 1944

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

Lycospora torulosa Hacquebard 1957

Plate 26, fig. 10

Remarks. A total of seven specimens were identified from the Cementstone Group assemblage. They agreed closely with the forms described by Hacquebard (1957, p. 312) and Playford (1964, p. 35), from the Horton Group (Tournaisian) of eastern Canada.

Genus VALLATISPORITES Hacquebard 1957

Type species. *V. vallatus* Hacquebard 1957.

Vallatisporites vallatus Hacquebard 1957

Plate 26, fig. 9

Remarks. Only five specimens were observed. For description see Hacquebard (1957, pp. 312–13) and Staplin and Jansonius (1964, p. 112).

Previous records. Horton Group (Tournaisian) of eastern Canada (Hacquebard 1957, Playford 1964). Banff Formation (Tournaisian) of Alberta (Staplin and Jansonius 1964).

Genus KNOXISPORITES (Potonié and Kremp) Neves 1964

Type species. *K. hageni* Potonié and Kremp 1954.

Knoxisporites pristinus sp. nov.

Plate 27, figs. 1–5

Holotype. Slide P26381-A-08, 123·1 48·9. Size, 66 μ.

Diagnosis. Size 62–103 μ, mean 85 μ (63 specimens); distal thickenings ill-defined and of variable form; cingulum one-fifth to one-seventh of the total radius; rarely preserved in good proximo-distal orientation.

Description. Amb sub-circular, may be irregular due to folding. Trilete rays extend three-quarters radius of spore cavity, usually bifurcating at their termini. Cingulum varies between one-fifth and one-seventh total radius of spore, uniform in thickness, but may be variable in width. Exine thickened on distal surface: thickenings are variable in shape and usually ill-defined. In some cases (e.g. Pl. 27, fig. 5), they are visible only as a slight colour differentiation of the distal exoexine. The thickened bands may extend from the interradial regions of the spore cavity or cingulum and fuse at the distal pole, (Pl. 27, figs. 1, 3). The muri may also enclose a small unthickened circular area near the distal pole (Pl. 27, fig. 2). In other specimens (Pl. 27, fig. 4), there may be a circular thickened band with short interradial extensions. The spores are rarely preserved in good proximo-distal orientation. Compression frequently results in the splitting of the exine and the presence of at least one parallel-sided secondary fold.

Remarks. This species is distinguished from other previously described species of *Knoxisporites* by the ill-defined thickenings and the lack of good proximo-distal orientation.

Subturma PSEUDOSACCITITRILETES Richardson 1965
Infraturma INTRORNATI Butterworth and Williams 1958
Genus AURORASPORA Hoffmeister, Staplin and Malloy 1955

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

Auroraspora macra sp. nov.

Plate 27, figs. 6–10

Holotype. Slide P26381-A-04, 120·2 34·6. Size, 49 μ.

Diagnosis. Size 48–68 μ, mean 58 μ (65 specimens); amb subcircular to irregular; exoexine laevigate, intexine laevigate to scabrate; trilete mark exceeds two-thirds radius of spore body.

Description. Amb subcircular, frequently irregular due to folding. Intexine 1·5 μ thick, laevigate to scabrate. Trilete rays straight, simple, extend two-thirds to three-quarters of the radius of the spore body. Exoexine thin, thickness not determinable, often finely folded in an irregular pattern. Exoexine usually pitted and torn (Pl. 27, figs. 9, 10).

EXPLANATION OF PLATE 27

All figures × 650.

Figs. 1–5. *Knoxisporites pristinus* sp. nov. 1, Distal surface, slide P26381-A-01, 108·8 37·4. 2, Distal surface, slide P26381-A-03, 115·4 56·8. 3, Distal surface, proximal surface missing, slide P26381-A-08, 111·7 38·4. 4, Holotype, distal surface, slide P26381-A-08, 123·1 48·9, 5, Proximal surface, slide P26381-A-03, 114·0 55·3.

Figs. 6–10. *Auroraspora macra* sp. nov. 6, Distal surface, slide P26381-A-03, 114·0 50·0. 7, Holotype, proximal surface, slide P26381-A-04, 120·2 34·6. 8, Proximal surface, slide P26381-A-09, 117·2 42·9. 9, Proximal surface, slide P26381-A-04, 111·2 27·7. 10, Proximal surface, slide P26381-A-01, 112·9 30·9.

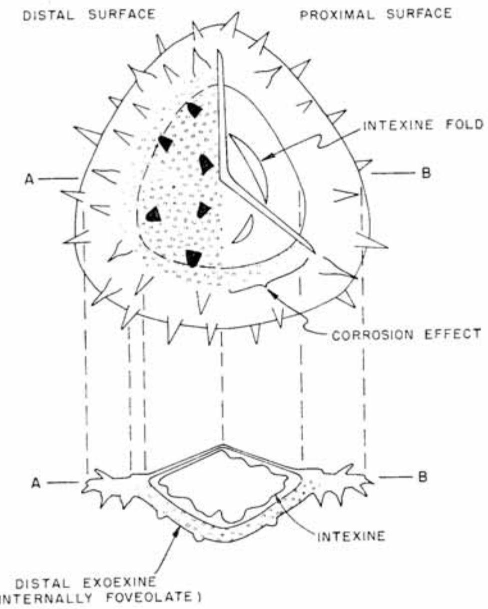
Figs. 11–13. *Grandispora echinata* Hacquebard 1957. 11, Distal surface, slide P26381-A-08, 123·3 32·1. 12, Distal surface, slide P26381-A-08, 120·3 36·4. 13, Distal surface, slide P26381-A-01, 118·9 42·0.

Comparison. *Auroraspora solisortus* is larger (up to 78 μ), has longer trilete rays, and the folds of the exoexine are usually arranged in a radial pattern.

Infraturma EXTRORNATI Butterworth and Williams 1958
Genus HYMENOZONOTRILETES (Naumova 1937?, 1939) Potonié 1958

Type species. *H. polyacanthus* Naumova 1953.

Remarks. The genus *Hymenozonotriletes* as interpreted by Russian palynologists includes species which can be more conveniently assigned to other zonate genera, e.g. *Grandispora* Hoffmeister, Staplin, and Malloy 1955, *Spinozonotriletes* Hacquebard 1957, *Vallatisporites* Hacquebard 1957, *Densosporites* (Berry) Potonié and Kremp 1954, and *Lycospora* Schopf, Wilson, and Bentall 1944. This broad circumscription of *Hymenozonotriletes* is inconsistent with the principles of classification of Potonié and Kremp and, if



TEXT-FIG. 3. Diagrammatic representation of *Hymenozonotriletes*? *hastulus* sp. nov. and its hypothetical cross-section.

it is to be incorporated into this system, a redefinition will be necessary. Such an emendation is not possible at this time because of the doubts concerning the details of structure and exine stratification of the type species, *H. polyacanthus*. The species *H. hastulus* sp. nov. described below is provisionally assigned to *Hymenozonotriletes* since it conforms with the most recent interpretation of the genus (Staplin and Jansonius 1964).

Hymenozonotriletes? hastulus sp. nov.

Plate 26, figs. 11, 12; text-fig. 3

Holotype. Slide P26381-A-04, 125·9 52·7. Size, 58 μ.

Diagnosis. Size 42–63 μ, mean 54 μ (31 specimens); distal exoexine thickened, infrapunctate (? internally foveolate) sparsely ornamented with cones; cingulum covered with spines up to 9 μ high and 5 μ wide.

Description. Amb circular to rounded triangular. Trilete rays, when preserved, extend to margin of spore cavity. Rays usually accompanied by folds which may reach on to the cingulum. Intexine thin, laevigate, frequently torn and folded. Distal exoexine thickened beneath spore cavity, finely and densely infrapunctate (? internally foveolate). Proximal exine over spore cavity laevigate. Cingulum one-third to one-half of the total radius; bizonate, dark zone wider than light zone. Cingulum ornamented with prominent solid spines up to 9 μ high and 5 μ wide in basal diameter. Spines may be evenly tapered or may arise from a swollen base. Cones are occasionally present on the distal exoexine beneath the spore cavity. Proximal surface low and pyramidal, distal surface markedly inflated.

Comparison. In *Hymenozonotriletes? gregarius* Staplin and Jansonius 1964, the proximal as well as the distal exoexine has a prominent structure. The cingulum also has internal vacuoles and the ornament is more variable in shape.

Remarks. All the specimens examined of *H.? hastulus* showed evidence of exine damage caused by tearing and corrosion. The infrapunctation of the distal exoexine imparts a spongy appearance to the spores. This may be a surface feature of the exine or may be due to the accentuation, by corrosion, of an internal foveolation.

Genus GRANDISPORA Hoffmeister, Staplin, and Malloy 1955

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

Grandispora echinata Hacquebard 1957

Plate 27, figs. 11–13

Description. Size 52–70 μ (1 specimen 80 μ), mean 62 μ (42 specimens). Amb rounded triangular. Trilete rays accompanied by folds which are up to 5 μ high at the apex. Folds extend almost to equator of spore. Intexine thin (less than 1 μ thick), laevigate, frequently folded. Exoexine 1·5 μ thick, often displays an irregular punctation due to corrosion. Ornamentation variable among specimens but generally uniform on individuals. It may consist of spines (Pl. 27, fig. 11), galeae (Pl. 27, fig. 13), or cones (Pl. 27, fig. 12). Ornamentation usually confined to distal exoexine, but may occasionally be present on the equatorial portion of the proximal exoexine. Spines and galeae are up to 5 μ high and 2 μ wide; cones up to 2 μ high and wide with broadly rounded tops.

Remarks. The shape of the ornament is more variable than in previously described specimens of *G. echinata*.

Previous records. Horton Group (Tournaisian) of eastern Canada (Hacquebard 1957, Playford 1964). Laurel Formation of Western Australia (Balme 1960). Upper Sedimentary Group and Lower Limestone Group (Viséan) of the Midland Valley of Scotland (Sullivan and Marshall 1966).

COMPOSITION AND AGE OF THE ASSEMBLAGE

The following twenty-two species were identified in the Cementstone Group spore flora: *Punctatisporites irrasus* Hacquebard 1957, *P. planus* Hacquebard 1957, *P. viriosus* Hacquebard 1957; *Retusotriletes incohatus* Sullivan 1964; *Baculatisporites fusticulus* sp. nov.; *Pustulatisporites gibberosus* (Hacquebard) Playford 1964; *Raistrickia clavata* Hacquebard emend. Playford 1964, *R. corynoges* sp. nov.; *Schopfites claviger* sp. nov.; *Verrucosisporites scoticus* sp. nov., *V. variotuberculatus* sp. nov.; *Convolutispora* cf. *mellita* Hoffmeister, Staplin and Malloy 1955, *C.* cf. *tuberosa* Winslow 1962; *Reticulatisporites textilis* Balme and Hassell 1962; *Perotrilites magnus* Hughes and Playford 1961; *Lycospora torulosa* Hacquebard 1957; *Vallatisporites vallatus* Hacquebard 1957; *Knoxisporites pristinus* sp. nov.; *Auroraspora macra* sp. nov.; *Endosporites micromanifestus* Hacquebard 1957; *Hymenozonotriletes*? *hastulus* sp. nov.; *Grandispora echinata* Hacquebard 1957.

The assemblage was dominated by species of *Punctatisporites*. Present in proportions between 5 and 1% were *Retusotriletes incohatus*, *Verrucosisporites variotuberculatus*, *Convolutispora* cf. *mellita*, *Knoxisporites pristinus* and *Auroraspora macra*. The remaining species individually comprised 1% or less of the total.

The assemblage from the Cementstone Group contains eight species whose known occurrences are restricted to rocks of Tournaisian age. *Pustulatisporites gibberosus*, *Raistrickia clavata*, *Vallatisporites vallatus* and *Lycospora torulosa* are present in the Horton Group of eastern Canada (Hacquebard 1957, Playford 1964). *Retusotriletes incohatus* was a dominant element of the assemblages from the Lower Limestone Shales of the Forest of Dean, Gloucestershire (Sullivan 1964), and is also very common in the Tournaisian of the Ardenno-Rhine region of Belgium and Germany. *Raistrickia corynoges* (*Raistrickia* sp. A. of Sullivan 1964) has been recorded from the Tournaisian of the Forest of Dean, the Ardenno-Rhine region and (as *Acanthotriletes macrurus*) from the Pripyat Depression of White Russia (Kedo 1963). Two newly described species, *Baculatisporites fusticulus* and *Knoxisporites pristinus*, have also been observed in the Lower Limestone Shales in the Cement Works quarry, near Mitcheldean, Forest of Dean (Sullivan, M. S.).

Punctatisporites irrasus, *P. viriosus*, *Endosporites micromanifestus* and *Grandispora echinata* have more extended ranges than the taxa referred to above, but are common constituents of Tournaisian assemblages. Indeed, they were first described by Hacquebard (1957) from the Horton Group of Nova Scotia.

Thus, there is convincing evidence that the assemblage from 100 ft. above the base of the Cementstone Group is of Tournaisian age. It differs markedly in composition from the spore floras described by Sullivan and Marshall (1966) from the Upper Sedimentary Group of the Calciferous Sandstone Measures, which were all of Viséan age. The Tournaisian/Viséan boundary in the western part of the Midland Valley of Scotland would, therefore, lie within the interval between the upper part of the Cementstone Group and the lowermost horizons of the Upper Sedimentary Group. The Clyde

Plateau Lavas, which over much of the region separate the Cementstone Group and the Upper Sedimentary Group, may represent a volcanic episode spanning the Tournaisian/Viséan boundary.

COMPARISON WITH OTHER TOURNAISIAN ASSEMBLAGES

The Cementstone Group spore flora closely resembles the assemblages described by Playford (1964) from the Horton Bluff Formation (the lower of the two divisions of the Horton Group) of eastern Canada. The principal difference would appear to be the greater relative abundance of *Vallatisporites* species and *Lycospora torulosa* in the Canadian assemblages. The Cheverie Formation of the Horton Group has a markedly dissimilar composition from the Horton Bluff Formation. *Vallatisporites* species and *Lycospora torulosa* are absent from the Cheverie Formation, and the most abundant and characteristic species is *Pustulatisporites pretiosus* Playford 1964. No species shown to be restricted to the Cheverie Formation (Playford 1964, Table 1, pp. 38–39) was present in the Cementstone Group.

The Tournaisian spore floras of the Forest of Dean (Sullivan 1964) and the Ardenno-Rhine region (Streel 1966) are very similar. The assemblages are dominated by species of *Punctatisporites* and *Retusotriletes incohatus* and several important accessory spores are common to both areas (Streel 1966, fig. 6).

The Tournaisian spore floras recorded by Winslow (1962) from Ohio display some similarities to those from eastern Canada, Britain, and the Ardenno-Rhine region. The early Kinderhookian assemblages from Ohio contain species of *Vallatisporites* (as *Cirratriradites hystricosus* Winslow, *C.* sp. A, *Lycospora* sp. A), whereas the later ones are characterized by *Punctatisporites? logani* Winslow (a species which resembles *Pustulatisporites pretiosus* in all characters except size). This distribution reflects the differences noted by Playford (1964) between the spore floras from the Horton Bluff and Cheverie Formations. Other taxa reported by Winslow and which may occur in other Tournaisian assemblages are: *Convolutispora tuberosa* Winslow (related to *Verrucosisporites congestus*), *Convolutispora* sp. (similar to *Convolutispora flexuosa* forma *major* Hacquebard), and *Anapiculatisporites tersus* (resembles *Schopfites augustus* Playford).

Two assemblages from the Laurel Formation of north-western Australia have been reported by Balme (1960). Comparison at specific level with spore floras from other areas can only be of a tentative nature since the spores were not formally named and only briefly described. The following characteristic Tournaisian taxa are probably represented in the Laurel Formation: *Vallatisporites* (as Cingulati gen. et sp. nov), *Retusotriletes incohatus* (as *Retusotriletes sp.*) *Punctatisporites irrasus* (as *Punctatisporites* B), *Raistrickia abtrusa* Playford (as *Apiculatisporis* sp.), and *Grandispora echinata* (as *Grandispora* cf. *G. spinosa*).

The *Raritubercülatus* Assemblage of Tournaisian age from Spitsbergen (Playford 1962, 1963) contrasts markedly with contemporaneous floras from eastern Canada, Britain, and western Europe. The Spitsbergen spore floras contain the following species in abundance: *Punctatisporites glaber* (Naumova) Playford 1962, *Acanthotriletes multisetus* (Luber) Potonié and Kremp 1955, *Tripartites incisotrilobus* (Naumova) Potonié and Kremp 1956, *Anulatisporites anulatus* (Loose) Potonié and Kremp 1954, *A. labiatus* Hughes and Playford 1961, *Densosporites dentatus* Potonié and Kremp 1956, *D. spits-*

bergensis Playford 1963, *D. variomarginatus* Playford 1963, *Lophozonotriletes rarituberculatus* (Luber) Kedo 1957 and *Vallatisporites foveolatus* (Hughes and Playford) Staplin and Jansonius 1964. With the exception of two possible specimens of *Lophozonotriletes rarituberculatus* recorded by Streel (1966) from the Ardenno-Rhine region, none of these species have so far been observed from the Tournaisian of eastern Canada, western Europe, and Britain.

The Tournaisian assemblages described from Russia by Ishchenko (1952, 1956, 1958) and Luber and Waltz (1938, 1941) have a similar composition to the Spitsbergen spore floras.

Species of *Anulatisporites* and *Densosporites* are absent from the Tournaisian spore floras reported by Kedo (1963) from White Russia, but in other respects they are closely comparable to the Russian and Spitsbergen assemblages.

It is proposed to refer to the Tournaisian spore floras of Russia and Spitsbergen as the *Lophozonotriletes* suite because this genus is a particularly characteristic component of the assemblages from these areas.

It is more difficult to select a suitable name for the spore floras of eastern Canada, Britain and the Ardenno-Rhine region. No genus which has both a common and widespread occurrence is at present known to be restricted to the Tournaisian assemblages of these areas. The term *Vallatisporites* suite is provisionally applied because the genus *Vallatisporites* has certainly a greater numerical abundance and a more extended stratigraphical range in the Tournaisian of eastern Canada and western Europe than in Russia or Spitsbergen.

Tournaisian spores have been illustrated from North Africa (Wray 1964, Hemer 1965). However, there are insufficient data currently available to decide whether they belong to either the *Lophozonotriletes* suite or the *Vallatisporites* suite.

Playford (1964, pp. 41–42) has drawn attention to the marked contrast displayed by the Horton Group assemblages from those of Spitsbergen and Russia. He observed: 'The extensive northern floral province, implied by the remarkably similar microfloras of Russia and Spitsbergen . . . , evidently did not encompass eastern Canada. . . .'

Differences in composition of Upper Mississippian (Viséan and Namurian A) spore assemblages have been interpreted by Sullivan (1965) to be the result of a regional differentiation of the parent floras. Three distinctive spore associations were recognized:

1. The *Monilospora* suite—typically present in western Russia, Spitsbergen and western Canada.
2. The *Grandispora* suite—found in Mid-continent United States, eastern Canada and western Europe.
3. The *Kazakhstan* suite—known only from Kazakhstan.

It is apparent that the areas characterized by the *Monilospora* suite in Viséan and Namurian A time are essentially those in which the *Lophozonotriletes* suite is present during the Tournaisian; the *Grandispora* suite, on the other hand, has the same general geographical limits as the *Vallatisporites* suite. One possible exception to this distribution pattern may be the Lower Carboniferous assemblages of Australia. The single Viséan spore flora known from Australia (Venkatachala 1964) appears to belong to the *Monilospora* suite, whereas the Tournaisian assemblages (Balme 1960) have more in common with the *Vallatisporites* suite.

The oldest spore floras described by Luber (1955) from Kazakhstan were from the Ashliarik Series whose age has not been defined more precisely than Tournaisian–Viséan. Until a more accurate age determination is available, there is no means of knowing whether the Kazakhstan suite was recognizable as a separate entity during Tournaisian times.

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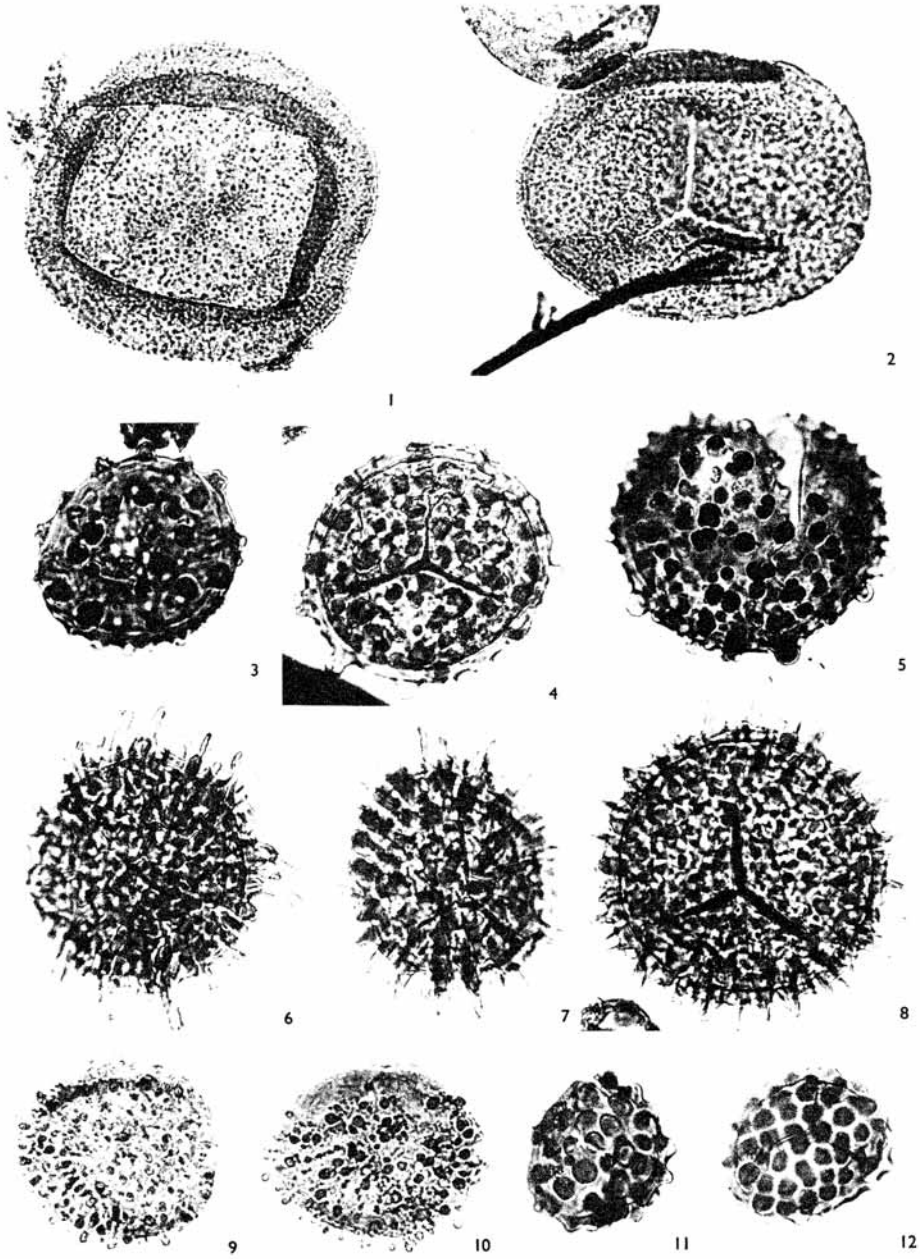
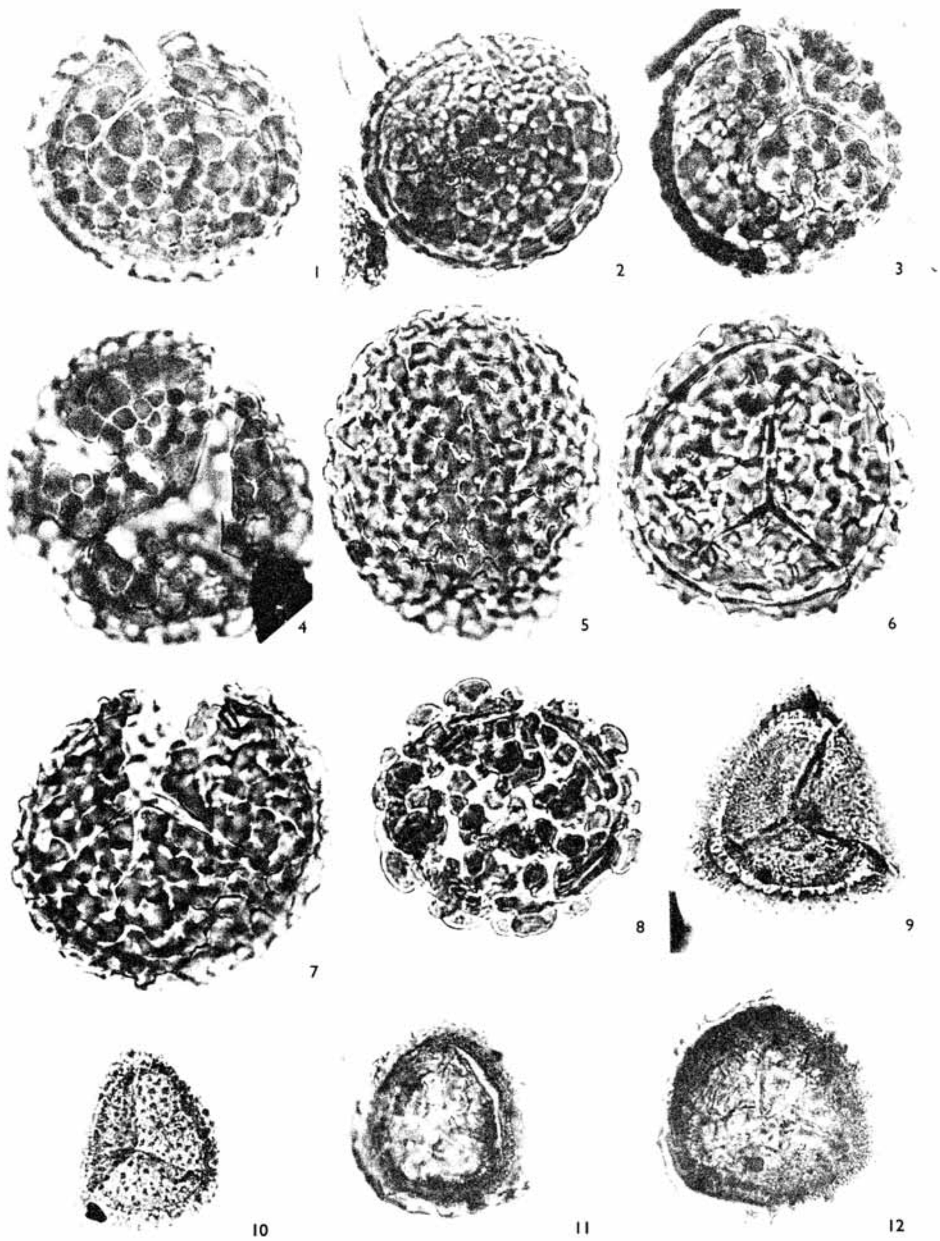


SULLIVAN, Scottish Tournaisian miospores



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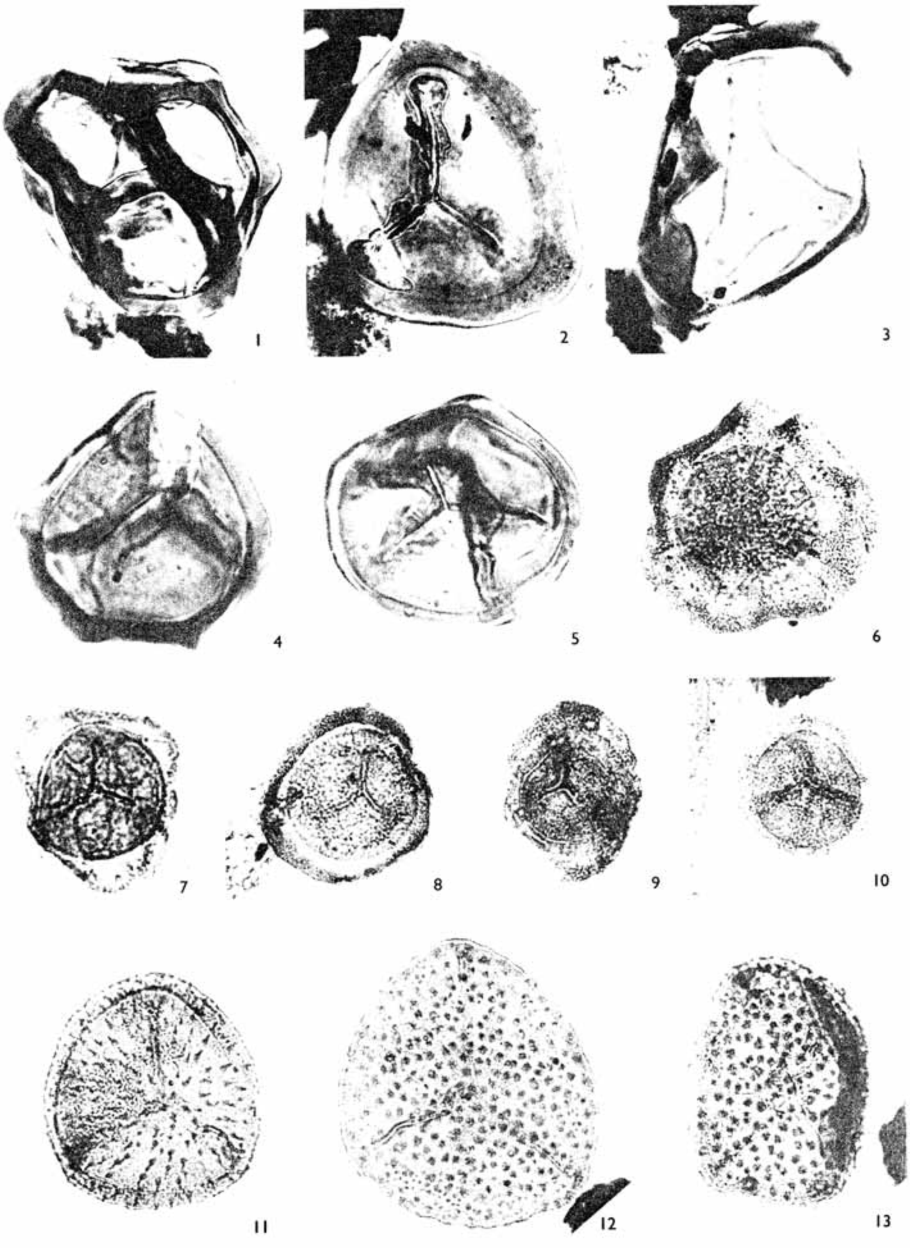

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