DEVONIAN SPORES FROM MELVILLE ISLAND CANADIAN ARCTIC ARCHIPELAGO

by D. C. McGREGOR

ABSTRACT. Twenty-four species of spores are described from a bituminous coal of Melville Island. Of these, twenty species of small spores and three species of megaspores are new, and two of the latter represent new genera, *Hystricosporites* and *Circumsporites*. Evidence suggests that lycopsids were dominant constituents in the flora which produced the spores. The assemblage differs distinctly from those described by Naumova (1953) and may contain elements of an uppermost Devonian-Lower Carboniferous flora, related to assemblages detected elsewhere in the Canadian Arctic. The geological significance of the assemblage is indicated.

INTRODUCTION

ONE of the most neglected areas of palaeobotany awaiting exploration concerns spores of Devonian age. Naumova (1953), Chaloner (1959), and others have demonstrated the potential botanical and geological significance of these fossils, and there have been reports of their abundance in certain strata. Even so, detailed investigations of Devonian spore assemblages are rare, and there are no published accounts of small spores of Devonian age from the Canadian Arctic.

During geological reconnaissance in the Canadian Arctic Islands, E. T. Tozer of the Geological Survey of Canada obtained samples from thick sequences of sandstone, siltstone, shale, and coal, containing fragmentary remains of plant megafossils. Preliminary examination of several of these samples, from Melville, Ellesmere, and Prince Patrick Islands, revealed abundant small and large spores, often excellently preserved.

The spores described are from one of these samples, a bituminous coal collected at Stevens Head, on the west coast of Melville Island (Geological Survey of Canada Locality No. 5116). The beds containing the coal conformably overly strata with marine Middle Devonian (Givetian) faunas identified by D. J. McLaren (*in* Tozer 1956, p. 15). The coal is therefore not older than Givetian. More recent geological investigations of Melville Island have shown that at at least one locality marine Upper Devonian fossils lie above coal measures similar to the beds exposed at Stevens Head (E. T. Tozer, personal communication). It thus seems reasonable to dismiss the possibility that the Stevens Head coal is of Mississippian age. According to D. J. McLaren (personal communication) the coal is most probably of Frasnian age or, less likely, Famennian. Available evidence suggests that it is of approximately the same age as coal on Ellesmere Island, 500 miles to the east, from which six species of megaspores were recently obtained and described by Chaloner (1959).

This investigation was begun by the writer at McMaster University as part of a doctorate thesis, under the guidance of Prof. N. W. Radforth, whose continued support and encouragement are gratefully acknowledged. Particular thanks are also extended to Dr. Glenn E. Rouse for much stimulating discussion in the early stages of the work. The Geological Survey of Canada is thanked for provision of the material studied. Dr. E. T. Tozer and Dr. D. J. McLaren offered valuable criticism on matters pertaining to the geology of the area in question. Financial support for the major part of the in-

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Preparation of spores. Ten cc. of the coal was washed thoroughly and crushed. It was then treated with Schulze's solution, consisting of 1 cc. of crystalline potassium chlorate added to a sufficient quantity of concentrated nitric acid to equal twice the depth of the coal in the beaker. After twenty hours the supernatant liquid was decanted and the remaining sediment washed several times by addition of water and decantation after the sediment had been allowed to settle. A final short treatment with cold 10 per cent. potassium hydroxide solution followed, and the mixture was again washed several times. It was necessary to examine the mixture periodically during both the Schulze's and the alkali treatments in order to be able to stop the process at the point where the microfossils were best defined. Sufficient water was then added to the sediment to allow the use of a pipette for transfer of material to a microscope slide, where it was mixed with a small amount of corn syrup, following the method described by Radforth and Rouse (1954). Some preparations were stained with safranin; others were not stained.

SYSTEMATIC TREATMENT

The classification of Potonié and Kremp (1954) and Potonié (1956) is followed. Unless otherwise noted, the description of each new species is based on examination of at least ten specimens. Types are stored in the palaeobotanical collection of the Geological Survey of Canada, Ottawa.

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

Leiotriletes dissimilis sp. nov.

Plate 11, fig. 1

Diameter: 43–55 μ. Ornamentation: laevigate; punctate in contact areas. Other features: spore radial, trilete, subtriangular, margins convex. Laesurae extend almost to the equator. Commissure slightly open, lips low and distinct. Wall 1–1·5 μ thick.

Holotype. Pl. 11, fig. 1; Geological Survey of Canada (GSC) Plant Type no. 13019, slide no. MI–12; 44·5μ.

Leiotriletes confertus sp. nov.

Plate 11, fig. 2

Diameter: 35–55 μ. Ornamentation: laevigate to very minutely granulate. Other features: spore radial, trilete, broadly subtriangular to circular in outline. Laesurae extend almost to the equator. Lips low, distinct, about 1·5 μ wide. Wall 1–2 μ thick.

Holotype. Pl. 11, fig. 2; GSC Plant Type no. 13020, slide no. MI–22; 41μ.

Leiotriletes marginalis sp. nov.

Plate 11, fig. 3

Diameter: 33–54 μ. Ornamentation: laevigate. Other features: spore radial, trilete, subtriangular with convex interradial margins. Laesurae extend almost to the equator. A concentric margin about 1·5 μ in width encircles the periphery of the spore. This marginal structure is peripheral in all planes of compression, and has no apparent outer wall or folds.

Holotype. Pl. 11, fig. 3: GSC Plant Type no. 13021, slide no. MI–12; 33 μ.

Leiotriletes microdeltoidus sp. nov.

Plate 11, fig. 4

Diameter: 33–54 μ. Ornamentation: very minutely scabrate. Other features: spore radial, trilete, broadly subtriangular to circular. Laesurae simple, about one-third the length of the radius of the spore. Tips of rays joined to one another by dark lines which delimit a well-defined triangle.

Holotype. Pl. 11, fig. 4; GSC Plant Type no. 13022, slide no. MI–22; 44 μ.

PUNCTATISPORITES (Ibrahim) Potonié and Kremp

Punctatisporites arcticus sp. nov.

Plate 11, fig. 5

Diameter: 60–68 μ. Ornamentation: scabrate. Ornamentation faintly visible at margin. Other features: spore radial, trilete, subtriangular to ovate. Laesurae extend almost to the equator. Commissure distinct, lips low. Wall 1 μ thick.

Holotype. Pl. 11, fig. 5; GSC Plant Type no. 13023, slide no. MI–12; 60 μ.

EXPLANATION OF PLATE 11

All figs. are $\times$500, except fig. 13 ($\times$250) and fig. 16 ($\times$1,000).

Fig. 1. *Leiotriletes dissimilis* sp. nov., holotype (GSC 13019).
Fig. 2. *Leiotriletes confertus* sp. nov., holotype (GSC 13020).
Fig. 3. *Leiotriletes marginalis* sp. nov., holotype (GSC 13021).
Fig. 4. *Leiotriletes microdeltoidus* sp. nov., holotype (GSC 13022).
Fig. 5. *Punctatisporites arcticus* sp. nov., holotype (GSC 13023).
Fig. 6. *Punctatisporites scabratus* sp. nov., holotype (GSC 13024).
Fig. 7. *Punctatisporites putaminis* sp. nov., holotype (GSC 13025).
Fig. 8. *Cyclogranisporites amplus* sp. nov., holotype (GSC 13026).
Fig. 9. *Planisporites minimus* sp. nov., holotype (GSC 13027).
Fig. 10. *Planisporites dilucidus* sp. nov., holotype (GSC 13028).
Fig. 11. *Verrucosisporites grandis* sp. nov., holotype (GSC 13031).
Fig. 12. *Apiculatisporis elegans* sp. nov., holotype (GSC 13029).
Figs. 13, 14. *Hystricosporites delectabilis* gen. et sp. nov. 13, Holotype (GSC 13032); 14, Bifurcate appendages of *H. delectabilis*.
Fig. 15. *Verrucosisporites variabilis* sp. nov., holotype (GSC 13030).
Fig. 16. Tubercles with apical spines, on holotype of *Biharisporites submamillarius* sp. nov. (GSC 13033).

Punctatisporites scabratus sp. nov.

Plate 11, fig. 6

Diameter: 55–66 μ. Ornamentation: scabrate, minute. Other features: spore radial, trilete, broadly subtriangular. Laesurae about two-thirds the length of the radius of the spore. Lips narrow, distinct. Wall 2–3 μ thick.

Holotype. Pl. 11, fig. 6; GSC Plant Type no. 13024, slide no. MI–12; 66 μ.

Similar forms. *Punctati-sporites orbicularis* Kosanke (1950) is smaller than *P. scabratus* but otherwise closely resembles it.

Punctatisporites putaminis sp. nov.

Plate 11, fig. 7

Diameter: 55–73 μ. Ornamentation: scabrate; visible at margin under high magnification. Other features: spore radial, trilete, ovate to circular. Laesurae about two-thirds the length of the radius of the spore. Lips low. Wall 2·5–5·5 μ thick, unfolded.

Holotype. Pl. 11, fig. 7, GSC Plant Type no. 13025, slide no. MI–23; 64 μ.

Similar forms. *Punctatisporites ambiguus* Leschik (1955) resembles *P. putaminis*, but its two-layered wall is a distinguishing feature.

Infraturma APICULATI (Bennie and Kidston) R. Potonié

CYCLOGRANISPORITES Potonié and Kremp

Cyclogranisporites amplus sp. nov.

Plate 11, fig. 8

Diameter: 77–121 μ. Ornamentation: small, rounded, distinct granules. Other features: spore radial, trilete, broadly subtriangular to circular. Laesurae simple, half to two-thirds the length of the radius of the spore. Wall 1·5–3·5 μ thick.

Holotype. Pl. 11, fig. 8; GSC Plant Type no. 13026, slide no. MI–22; 92 μ.

Similar forms. Spores of *Acitheca* (*Pecopteris*) *longifolia* R. and W. Remy (1955) from the Upper Carboniferous are similar but are perhaps slightly smaller and have a thinner wall than *Cyclogranisporites amplus*. *Cyclogranisporites sp*., figured but not described by Hoffmeister, Staplin, and Malloy (1955*a*) from the Upper Devonian of Alberta, falls within the size range of *C. amplus* (according to their illustration), and appears in other respects to be similar.

Planisporites (Knox) Potonié and Kremp

Planisporites minimus sp. nov.

Plate 11, fig. 9

Diameter: 32–44·5 μ. Ornamentation: minutely echinate. Elevations distinctly conelike, less than 1 μ long, and alike in size. Other features: spore radial, trilete, circular. Laesurae about two-thirds the length of the radius of the spore. Lips low. Wall 1 μ thick, and unfolded.

Holotype. Pl. 11, fig. 9; GSC Plant Type no. 13027, slide no. MI–22; 43 μ.

Similar forms. Naumova's (1953) Middle and Upper Devonian species *Lophotriletes rotundus* may agree in part with *Planisporites minimus*, but the rays vary in length, according to her illustrations, and lips are not present. *Cyclogranisporites parvipunctatus* (Kosanke) Bhardwaj (1957) possess hemispherical granules, while those of *Planisporites minimus* are distinctly conelike. The Upper Carboniferous spore figured by Knox (1939, fig. 41), as nearly as can be determined from her illustration, resembles *P. minimus* rather closely.

Planisporites dilucidus sp. nov.

Plate 11, fig. 10

Diameter: 51–67 μ. Ornamentation: echinate. Elevations conelike, less than 1 μ long, about eighty visible on the equator. Other features: spore radial, trilete, circular. Laesurae two-thirds to three-quarters the length of the radius. Lips low. Wall 1 μ thick, rarely folded.

Holotype. Pl. 11, fig. 10; GSC Plant Type no. 13028, slide no. MI–22; 55 μ.

Similar forms. Lophotriletes subrotundatus Naumova (1953) closely resembles this species, but a critical comparison of the ornamentation of her specimens would be necessary before any conclusions could be reached as to synonymy. Spores of *Crossotheca Hoeninghausi* Brongniart and *C. Hughesiana* Kidston in Kidston (1923) also show similarity to *Planisporites dilucidus*.

APICULATISPORIS Pontonié and Kremp

Apiculatisporis elegans sp. nov.

Plate 11, fig. 12

Diameter: 67–85 μ. Ornamentation: closely spaced, elongate apiculations, up to 1·5 μ long, slightly variable in size. Other features: spore radial, trilete, circular. Laesurae about two-thirds the length of the radius. Commissure simple. Wall thin, rarely folded.

Holotype. Pl. 11, fig. 12; GSC Plant Type no. 13029, slide no. MI–12; 80 μ.

Similar forms. The spore called *Lophotriletes magnus* Naumova by Ishchenko (1956, p. 42) compares well with *A. elegans*, but some confusion exists because Naumova's original description of the species (1953) does not conform with Ishchenko's interpretation. Naumova restricted the species to roundly triangular spores with rays as long as the radius of the spore, which are features not possessed by *A. elegans*.

VERRUCOSISPORITES (Ibrahim) Potonié and Kremp

Verrucosisporites variabilis sp. nov.

Plate 11, fig. 15

Diameter: 43–76 μ. Ornamentation: broad, tapering, pointed spines up to 6 μ long, their basal diameter about equal to their height; occasional sharply pointed papilla-like projections; also occasional rounded projections which may reach 12 μ in diameter at their base and 10 μ in height. The complete range of variation may occur on a single specimen. Other features: spore radial, trilete, circular. Laesurae simple, at least half the length of the radius. Wall up to 3 μ thick.

Holotype. Pl. 11, fig. 15; GSC Plant Type no. 13030, slide no. MI–12; 68 μ.

Similar forms. Raistrickia rubida Kosanke (1950) superficially resembles this spore, but its wall is much thicker than that of *V. variabilis*.

Verrucosisporites grandis sp. nov.

Plate 11, fig. 11

Diameter: 98–150 μ. Ornamentation: stout verrucate projections cover the entire spore. On the distal portion, the projections are polygonal or irregular in transverse view, up to 6 μ wide, rounded or somewhat flattened at their apex, or occasionally ending in a small papilla. On the proximal face they are of smaller size but otherwise similar. There is usually a very slight elongation and fusion of verrucae at the outer boundary of the contact faces. Other features: spore radial, trilete, broadly subtriangular to circular in polar view, distinctly anisopolar in lateral view, proximal face flattened, distal portion hemispherical. Laesurae simple, about three-quarters the length of the radius, usually obscured by ornamentation.

Holotype. Pl. 11, fig. 11; GSC Plant Type no. 13031, slide no. MI–22; 128 μ.

Similar forms. Verrucosisporites ovimammus Imgrund (1952) possesses similar ornamentation, but is distinguishable from *V. grandis* by its lack of any suggestion of equatorial arcuate structure or anisopolar profile. In general form *V. grandis* shows some similarity to both *Lycospora magnifica* sp. nov. and *Biharisporites ellesmerensis* Chaloner (1959). It was excluded from *Lycospora* because of its large size, its distinctive verrucate ornamentation, and its very weak arcuate zone, and from *Biharisporites* because of the ornamentation of the contact faces and much smaller size.

HYSTRICOSPORITES gen. nov.

Type species *H. delectabilis* gen. et sp. nov.

Diagnosis. Trilete miospore or megaspore bearing discrete appendages which taper throughout their length and bear bifurcate grapnel-like tips. Appendages dispersed on both proximal and distal portions of the spore. Outline of spore subcircular in transverse plane of compression.

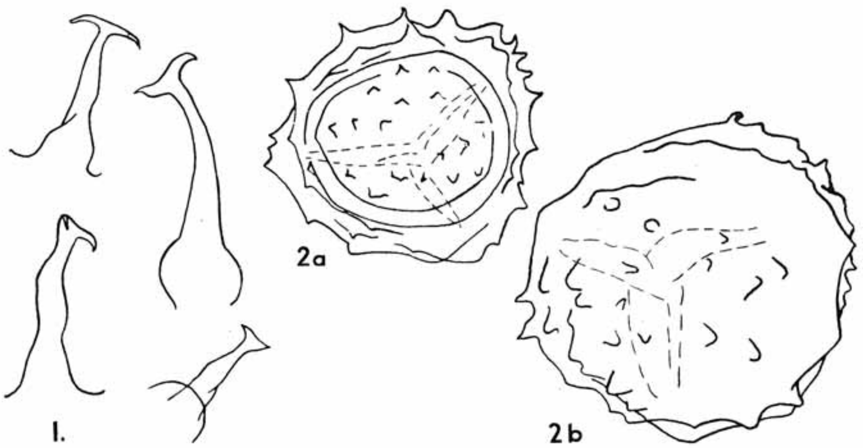
Remarks. Hystricosporites differs from *Archaeotriletes* (Naumova) Potonié (1958) in the absence of any equatorial flange or any apparent concentration of the appendages in the equatorial region, and from *Nikitinsporites* Chaloner (1959) in the absence of '. . . greatly elevated triradiate lips forming an apical prominence'. As in *Nikitinsporites*, the appendages of *Hystricosporites* cover the proximal and distal portions of the spore. *Ancyrospora* Richardson (1960) bears bifurcate processes, but is monosaccate.

It may be argued that there is sufficient similarity among these spores in their possession of anchor-like appendages to justify their inclusion in a single genus, and that Naumova's original description of *Archaeotriletes* (1953, p. 51) was valid even though she did not designate a type (see also Funkhouser 1958). Evidently much difference of opinion has existed regarding necessity of type designation for validity of fossil plant names. In this particular case I believe that less confusion would be caused by creation of a new genus (*Hystricosporites*) in conformity with the views of Potonié (1958) and Chaloner (1959) than by retention of Naumova's circumscription of *Archaeotriletes*.

Hystricosporites delectabilis gen. et sp. nov.

Plate 11, figs. 13, 14; text-fig. 1

Diameter: 145–340 μ, exclusive of appendages. Ornamentation: scabrate. Body also bears elongate, slightly tapering appendages with grapnel-like bifurcations at their tips (Pl. 11, fig. 14; text-fig. 1). Appendages one-third to two-thirds the length of the radius



TEXT-FIGS. 1, 2. 1, Appendages of *Hystricosporites delectabilis* sp. nov., ×500, showing variation in form in the holotype (GSC 13032). *2a*, *2b*, Specimens of *Hymenozonotriletes inaequus* sp. nov., ×500, showing variation in prominence of ornamentation, distal view; *2a*, holotype (GSC 13042); *2b* (GSC slide MI–13).

of the spore body. Base of appendages expanded, often bulbous. Other features: spore radial, trilete, circular. Laesurae almost as long as the radius of the body, with more or less well-defined lips, sometimes raised and convoluted. On some specimens the triradiate structure is poorly defined. Wall thin.

Holotype. Pl. 11, fig. 13; GSC Plant Type no. 13032, slide no. MI–16; 196 μ, exclusive of appendages.

Similar forms. Chaloner (1959) refers to several records of spores with anchor-like spine apices from deposits of Middle or Upper Devonian age. Of these, type 'e' of Høeg (1942) and Type G_1 of Lang (1925) most closely resemble *A. delectabilis* and may be at least in part synonymous with it. *Azonotriletes ancistrophorus* Luber (Luber 1955, p. 70) from the Upper Devonian and Lower Carboniferous of the U.S.S.R. is similar to *Hystricosporites* except for its apparent lack of any triradiate mark. Table 1 gives previously recorded occurrences of spores with anchor-like appendages.

In her description of *Archaeotriletes*, Naumova (1953, pp. 8, 51) noted a similarity between the Devonian spores and 'megaspores' of the present-day *Azolla*. This resemblance, which would presumably apply to spores here named *Hystricosporites* is, however, only superficial. The bifurcate glochidia of *Azolla* have no evident homologue in the Devonian spores. The megaspore of both living and fossil *Azolla* is papillate, and possesses no elaborate bifurcate processes (Arnold, 1955).

BIHARISPORITES R. Potonié

Biharisporites submamillarius sp. nov.

Plate 11, fig. 16; Plate 12, figs. 1–3

Diameter: 280–610 μ. Ornamentation: stout hemispherical tubercles spaced irregularly over all portions of the spore except the contact areas. Tubercles 6–12 μ wide at their base and up to 10 μ high. Each bears at its summit a small, tapering, pointed spine (Pl. 11, fig. 16). Tubercles discrete and typically wider than long, but in some specimens approximately equidimensional. A gradation exists between specimens with the wall thickly set with tubercles and those with very few tubercles (cf. Pl. 12, figs. 1, 2). Considerable variation also exists in the size of the tubercles from one specimen to another; on those with few tubercles they are usually smaller in size. Rarely there is some fusion of the tubercles at the outer boundary of the contact faces. Between the tubercles and on the contact faces the wall is ornamented by small pits and elevations of irregular pattern (similar to 'scabrate' of Harris (1955) but on a larger scale). Other features: spore radial, trilete, broadly subtriangular in polar view. Triradiate ridges prominent, often slightly convoluted, about two-thirds to three-quarters the length of the radius of the spore, up to 55 μ high at the pole, tapering to their extremities. Distinct contact faces extend about two-thirds the distance to the equator. On some spores a membranous, laevigate, centrally located body is apparent in the interior of the spore. Its relation to the surrounding spore wall is obscure; if it were unfolded it would be difficult to discern in an intact specimen, and this may be the case in those specimens in which it was not seen. In a few specimens, the mesosporium-like structure was found projecting from the edges of a broken spore; occasionally similar structures were found completely free (Pl. 12, fig. 3).

Holotype. Pl. 12, fig. 1; GSC Plant Type no. 13033, slide no. MI–12; 372 μ. *Paratype*. Pl. 12, fig. 2, GSC Plant Type no. 13034, slide no. MI–12; 600 μ.

Similar forms. Chaloner (1959) has described *Biharisporites ellesmerensis* which resembles *B. submamillarius* rather closely, although several differences are apparent when specimens of each are compared. *B. submamillarius* is larger (280–610 μ as compared with 204–304 μ); the triradiate ridges of *B. submamillarius* are slightly higher relative to the total size of the spore than those of *B. ellesmerensis*, and slope away from the pole to their extremities while those of the latter species maintain a much more uniform height throughout. A more marked difference lies in their ornamentation. That of *B. submamillarius* consists of tubercles which are rarely fused, even at the outer boundaries of the contact faces, and which are less closely spaced than in *B. ellesmerensis*. In addition, the papilla at the tip of each tubercle is a prevalent feature in *B. submamillarius* rather than only an occasional one as in *B. ellesmerensis*. The tubercles of the former are quite symmetrically rounded both transversely and laterally, which is not true for specimens of *B. ellesmerensis* that I have examined.

A mesosporium-like body is present both in the interior of *B. submamillarius* and in the type specimen of Potonié's (1956) designated genotype, *B. spinosus*, although it has not been stated as a distinguishing criterion of either species, or of the genus. Such internal structures do, of course, occur in other genera than *Biharisporites*. Høeg, Bose, and Manum (1955) list several references from the literature on fossil megaspores in which 'mesosporoid' bodies are mentioned or illustrated.

Infraturma MURORNATI Potonié and Kremp

CONVOLUTISPORA Hoffmeister, Staplin and Malloy

Convolutispora flexuosa forma *minor* Hacquebard 1957

Plate 12, fig. 4

Remarks. The diameter range of this spore is 47–81 μ, which would include the 72 μ measurement given by Hacquebard (1957, p. 312). The only apparent points of difference between the present type and *C. flexuosa* forma *minor* as originally described are the occasional subtriangular shape and greater width of rugulae (up to 13 μ) in the former. However, it is impossible to judge the variation in dimensions that may have existed in the Horton spore on the basis of the two specimens recorded by Hacquebard. The circumscription of the species is consequently regarded here as extended to include the Melville Island spore. Laesurae, observed on a few specimens, extend about three-quarters the distance to the equator. Diameter of figured specimen, 78 μ.

Convolutispora florida Hoffmeister *et al.* (1955*b*) is smaller than *C. flexuosa* forma *minor*, but otherwise resembles it. *Periplectotriletes amplectus* (Luber) Ishchenko forma *kasachstanensis* Luber (*in* Ishchenko 1956, p. 46) has narrower rugulae than *Convolutispora flexuosa* forma *minor*.

Infraturma PERINOTRILITI Erdtman

CIRCUMSPORITES gen. nov.

Type species *C. melvillensis* gen. et sp. nov.

Diagnosis. Trilete megaspore with enveloping perisporium-like wall appressed over its complete area to a more or less thin-walled central body. Perisporium and central body ornamented. Spore subtriangular to circular in polar view.

Circumsporites melvillensis gen. et sp. nov.

Plate 12, figs. 6, 7

Diameter: 203–292 μ, including ornamentation; body 187–270 μ. Ornamentation: perisporium thickly covered by sac-like projections which taper from broad bases to blunt or pointed apices. Projections frequently joined to one another for most of their length, their tips remaining free (Pl. 12, fig. 6). The perisporium, if partly dissociated from the

EXPLANATION OF PLATE 12

All figs. are ×500, except fig. 1 (×250), fig. 2 (×110), fig. 3 (×200), and fig. 7 (×250).

Figs. 1, 2. *Biharisporites submamillarius* sp. nov. 1, holotype (GSC 13033); 2, paratype (GSC 13034).

Fig. 3. Thin-walled structure similar to those seen in interior of *Biharisporites submamillarius* (GSC Slide MI–12).

Fig. 4. *Convolutispora flexuosa* forma *minor* Hacquebard (GSC Slide MI–16).

Fig. 5. *Lycospora magnifica* sp. nov., holotype (GSC 13036).

Figs. 6, 7. *Circumsporites melvillensis* gen. et sp. nov. 6, ornamentation of perisporium; 7, holotype (GSC 13035).

Fig. 8. *Perotrilites sp.* (GSC Slide MI–14).

Figs. 9, 10. *Lycospora magnifica* forma *endoformis* sp. et f. nov. 9, holotype (GSC 13037); 10, paratype (GSC 13038), internal body apparently close to the proximal wall of the spore.

Fig. 11. *Lycospora pallida* sp. nov., paratype, distal view (GSC 13040).

central body (as in the holotype), has a beaded appearance. Central body with small pits and elevations similar in appearance to those on the contact faces of *Biharisporites submamillarius*. Other features: spore radial, trilete, broadly subtriangular to circular. Laesurae usually weakly defined or inevident, but, where visible, almost as long as the radius of the body. Walls of perisporium and body thin.

Holotype. Pl. 12, fig. 7; GSC Plant Type no. 13035, slide no. MI–20; 228 μ, including ornamentation.

PEROTRILITES Couper

Perotrilites sp.

Plate 12, fig. 8

Diameter: 90 μ (one specimen only). Ornamentation: perisporium granulate; granules 3–7 μ apart. Body laevigate. Other features: spore radial, trilete, very broadly subtriangular. Laesurae about two-thirds the length of the radius, consist of three convoluted, fold-like rays, no commissure being visible. Thin-walled perisporium closely envelops body.

Remarks. Only one specimen of this type was found. In the double nature of its wall it resembles a complex of spores which occurs at several localities in the Lower and Middle Devonian of eastern Canada (McGregor 1957), and also resembles Middle and Upper Devonian species which Naumova (1953) has described as *Hymenozonotriletes*. However, *Perotrilites sp.* cannot be placed in *Hymenozonotriletes* as emended by Potonié (1958, p. 29). It also differs from *Endosporites* in several features, the most prominent being the close appression of the perisporium and the body.

Turma ZONALES (Bennie and Kidston) R. Potonié
Subturma ZONOTRILETES Waltz
Infraturma CINGULATI Potonié and Klaus
LYCOSPORA (S. W. and B.) Potonié and Klaus

Lycospora magnifica sp. nov.

Plate 12, fig. 5; Plate 13, figs. 2–4

Diameter: 69–119 μ. Ornamentation: distal portion scabrate, this ornamentation superimposed upon verrucate units of low relief (about 1–2 μ high) and up to about 5 μ in diameter. Proximal portion scabrate. Some specimens possess low verrucate projections up to 4 μ in diameter in the angles of the rays near the proximal pole (Pl. 12, fig. 5). On some specimens the verrucate pattern is less apparent. Verrucate elements tend to be joined laterally on the arcuate thickening, often possess minute papilla-like extensions in this area. Other features: spore radial, trilete, broadly subtriangular to circular. Arcuate thickenings form narrow cingulum at outer boundary of proximal face. Laesurae extend to, or almost to, the cingulum. Lips low and narrow. Proximal face flattened, distal portion hemispherical.

Holotype. Pl. 12, fig. 5; GSC Plant Type no. 13036, slide no. MI–12; 87 μ.

Similar forms. This species and the other species from the Melville Island formation which have been assigned to *Lycospora* are unusually large for the genus. The large size of *L. magnifica* distinguishes it from *L. torulosa* Hacquebard (1957) to which it is superficially similar.

Lycospora magnifica forma *endoformis* sp. et f. nov.

Plate 12, figs. 9, 10

A thin-walled, transparent body is present in the interior of this spore. Its relationship to the outer wall of the spore is not clear; it may be in contact with the inner side of the outer wall at the proximal pole (Pl. 12, fig. 10). In other respects, including size (69–124 μ), this spore is identical with *L. magnifica*.

Holotype. Pl. 12, fig. 9; GSC Plant Type no. 13037, slide no. MI–12; 83μ. *Paratype*. Pl. 12, fig. 10; GSC Plant Type no. 13038, slide no. MI–12; 82μ.

Lycospora pallida sp. nov.

Plate 12, fig. 11; Plate 13, fig. 1

Diameter: 64–82 μ. Ornamentation: granulate; granules on distal side of spore more or less joined at their base to form a rugulate pattern. Ornaments often more elongate at equator, appearing mammillate in transverse view. Ornaments reduced in size on proximal face, granules discrete. Other features: spore radial, trilete, broadly subtriangular to circular. Laesurae extend almost to the equator, are often indistinct. Lips low and narrow. Proximal face flattened, distal portion hemispherical. The degree of elongation and lateral fusion of ornaments at the equator is somewhat variable from specimen to specimen, so that the cingulum so formed varies in prominence.

Holotype. Pl. 13, fig. 1; GSC Plant Type no. 13039, slide no. MI–12; 64μ. *Paratype*. Pl. 12, fig. 11; GSC Plant Type no. 13040, slide no. MI–12; 74μ.

DENSOSPORITES (Berry) Potonié and Kremp

Densosporites crassus sp. nov.

Plate 13, fig. 8

Diameter: 83–96 μ (three specimens). Ornamentation: punctate. Other features: spore radial, trilete, broadly subtriangular to ovate. Laesurae simple, extend to margin of body. Dense equatorial thickening (cingulum), 10–20 μ wide. Wall of body only slightly less opaque than that of cingulum.

Holotype. Pl. 13, fig. 8; GSC Plant Type no. 13041, slide no. MI–12; 83 μ.

EXPLANATION OF PLATE 13

All figs. are ×500, except fig. 4 (×100).

Fig. 1. *Lycospora pallida* sp. nov., holotype (GSC 13039).

Figs. 2–4. *Lycospora magnifica* sp. nov. 2, 3, spores from periphery of mass shown in fig. 4; 4, mass of spores (GSC Slide MI–13).

Fig. 5. *Hymenozonotriletes inaequus* sp. nov., holotype (GSC 13042).

Figs. 6, 7. *Tholisporites densus* sp. nov. 6, holotype (GSC 13043), transverse view; 7, paratype (GSC 13044), lateral view.

Fig. 8. *Densosporites crassus* sp. nov., holotype (GSC 13041).

Fig. 9. *Tholisporites tenuis* sp. nov., holotype (GSC 13045).

Fig. 10. *Tholisporites punctatus* sp. nov., holotype (GSC 13046).

Figs. 11, 12. (?) *Latosporites sp.* (GSC Slide MI–22).

Infraturma ZONATI Potonié and Kremp

HYMENOZONOTRILETES (Naumova) Potonié

Hymenozonotriletes inaequus sp. nov.

Plate 13, fig. 5; Text-fig. 2

Diameter: 93–121 μ. Ornamentation: proximal portion laevigate toward the pole. Distal portion with low, pointed, tapering projections up to 4 μ wide and about 3 μ high. Toward equator, projections increase in size and are joined basally to form sub-concentric flange-like structures, either prominently displayed (text-fig. 2*a*) or of lesser size (text-fig. 2*b*). Equatorial projections with papillate tips. Other features: spore radial, trilete, circular. Laesurae almost as long as body of spore. Commissure obscured by thick folds along rays. A dense ring, similar to that present in species of *Densosporites*, is evident near the equator on some specimens; on other specimens it is discontinuous or inevident.

Holotype. Pl. 13, fig. 5; GSC Plant Type no. 13042, slide no. MI–22; 93 μ.

Similar forms. One of the specimens of *Hymenozonotriletes argutus* illustrated by Naumova (1953, pl. 9, fig. 9) resembles *H. inaequus*, and may be synonymous with it, although Naumova interprets the equatorial portion as a perisporium. *Densosporites aseki* Potonié and Kremp (1956) differs from *Hymenozonotriletes inaequus* in its smaller size and relatively less opaque central portion. *Lepidozonotriletes aculeatus* Hacquebard (1957) has larger ornaments and flange-like rays. *Densosporites devonicus* Richardson (1960) has smaller, bifurcate appendages.

The marginal structure of spores similar to *Hymenozonotriletes inaequus* has been variously interpreted as a perisporium (Naumova 1953; Hacquebard 1957) and a zona (Potonié 1958). *H. inaequus* is here regarded as having a zona in the sense of Potonié and Kremp (1955, p. 15). Its structure is apparently fundamentally similar to that of *Densosporites devonicus* Richardson, but it is placed in *Hymenozonotriletes* rather than in *Densosporites* because of its conformity to the emended diagnosis of *Hymenozonotriletes* by Potonié (1958, p. 29).

Infraturma PATINATI Butterworth and Williams

THOLISPORITES Butterworth and Williams

Tholisporites densus sp. nov.

Plate 13, figs. 6, 7

Diameter: 45–89 μ. Ornamentation: laevigate. Other features: spore radial, trilete, broadly oval to circular in polar view, distal portion hemispherical, proximal portion less convex than the distal. Laesurae simple, about four-fifths the length of the radius. Patina extending over entire distal portion, of equal thickness over all of its area (up to 11 μ thick), except where it becomes thin abruptly at the outer margin of the proximal face. Proximal wall thin. On most specimens a thin, transparent, veil-like structure extends over the proximal face, apparently enveloping the laesurae (Pl. 13, fig. 7). This membranous layer appears to be an extension of the outer part of the thick distal patina. Thickness of patina equals 4–14 per cent. of total spore diameter, and bears no constant relation to the total spore size.

Holotype. Pl. 13, fig. 6; GSC Plant Type no. 13043, slide no. MI–12; 69 μ. *Paratype*. Pl. 13, fig. 7; GSC Plant Type no. 13044, slide no. MI–12; 86 μ.

Similar forms. Tholisporites scoticus Butterworth and Williams (1958) is the only species previously placed in this genus. *T. densus* differs from it in larger size, laevigate wall, and constant thickness of patina (i.e. not thickened at the equator), and the membranous layer over the proximal face. From the Lower Carboniferous and Upper Devonian of the U.S.S.R., Luber (1955, p. 64) reports the occurrence of a spore (*Zonotriletes pelorius* Luber) of variable size and form, which possesses a distal thickening of the wall with 'growth layers'. This laminated nature of the patina of *Z. pelorius* seems to distinguish it from spores of the *Tholisporites* type.

Tholisporites tenuis sp. nov.

Plate 13, fig. 9

Diameter: 54–77 μ. Ornamentation: Laevigate. Other features: spore radial, trilete, ovate to circular in polar view. Laesurae almost as long as radius, simple. Distal wall thickened to a slight patina (up to 3 μ). Proximal wall thin, with a thin membranous layer, often weakly defined, covering the proximal face, as in *T. densus*.

Holotype. Pl. 13, fig. 9; GSC Plant Type no. 13045, slide no. MI–12; 72 μ.

Tholisporites punctatus sp. nov.

Plate 13, fig. 10

Diameter: 57–92 μ. Ornamentation: scabrate. Other features: spore radial, trilete, subcircular. Laesurae simple, almost as long as radius. Distal patina 3–10 μ thick, becoming thin abruptly near the equator, of constant thickness over distal portion. There is a suggestion of a thin proximal membrane similar to that of *T. densus* and *T. tenuis*, but its presence has not been confirmed.

Holotype. Pl. 13, fig. 10; GSC Plant Type no. 13046, slide no. MI–12; 82 μ.

Turma MONOLETES Ibrahim
Subturma AZONOMONOLETES Luber
Infraturma PSILAMONOLETI v. d. Hammen
LATOSPORITES Potonié and Kremp

(?) *Latosporites sp.*

Plate 13, figs. 11, 12

Diameter: 50·5 μ and 66 μ (two specimens only). Ornamentation: minutely punctate. Other features: spores bilateral (?). The tetrad mark resembles a monolete commissure, but possesses a very short, poorly defined Y-like bifurcation. On the larger specimen (Pl. 13, fig. 11) the small arm is at one end of the large aperture, and the arms of the Y are short, without raised margins. On the smaller specimen (Pl. 13, fig. 12) the locus of the division is about two-thirds the distance from the end of the major aperture; one arm continues in line with the major aperture and bears low lips, while the other division is very short and without lips. Wall of large specimen 4·5 μ thick; wall of small specimen 2 μ thick. Outline elliptical to subcircular.

Similar forms. Spores of *Asterotheca meriani* (Brongn.) Stur described by Bhardwaj and Singh (1957) occasionally possess a 'pseudotrilete mark', which is interpreted by these authors as a secondary feature caused by flattening during fossilization. *Leschikisporis* *aduncus* (Leschik) R. Potonié (1958) has an asymmetrical triradiate mark but the one shorter ray stands perpendicular to the locus of the other two rays, which it does not do in either of the specimens from Melville Island.

COMPOSITION OF THE ASSEMBLAGE

Twenty new species and one new forma of miospores and three new species of megaspores are recognized, as well as specifically unnamed specimens of *Perotrilites* and (?) *Latosporites*. One species, *Convolutispora flexuosa* forma *minor* Hacquebard, has been previously reported, from the Horton group (Mississippian) of Nova Scotia.

Lycospora magnifica is the most abundant miospore in the assemblage, comprising 35 per cent. of the total of the small spores. Next in abundance are *Tholisporites densus* (28%), *Lycospora vulgaris* (20%), *Tholisporites punctatus* (5%), *Lycospora pallida* (3%), and *L. magnifica* forma *endoformis* (2%). None of the other small spore species constitutes as much as 2 per cent. of the total.

Biharisporites submamillarius comprises 72 per cent. of the megaspores, with *Hystricosporites delectabilis* 18 per cent., and *Circumsporites melvillensis* 10 per cent. The percentages are based on separate counts of 200 specimens each for the miospores and the megaspores.

In diameter range there is a distinct break between those of 45 μ to 110 μ and those of 200 μ to 600 μ, with only a few specimens lying outside these limits.

COMPARISON WITH OTHER ASSEMBLAGES

Naumova's (1953) Frasnian and Famennian assemblages of the Russian Platform comprise several dozen species, and none, with the exception of some of the weakly ornamented circular forms, offer similarity with those from Melville Island. Evidently the latter represent a flora not reported by Naumova, especially since her dominant sub-groups *Retusotriletes*, *Lophozonotriletes*, and *Hymenozonotriletes* (except for *H. inaequus* and possibly *Perotrilites sp.*) are not present in the arctic assemblage. Spores comparable with those of Naumova do occur in the Gaspé Sandstone (McGregor 1957) but again there are no spores in this assemblage which resemble those from Stevens Head.

'Upper Devonian' spores briefly reported by Hoffmeister, Staplin, and Malloy (1955*a*) from western Canada bear little resemblance to those from Melville Island, except for the form with bifurcate appendages which is comparable with *Hystricosporites delectabilis*. These authors do not give exact geological data, and there is apparently some evidence of contamination in their preparations (1955*a*, p. 10).

Closest agreement with the larger spores from Melville Island is evident in those described by Chaloner (1959) from Okse Bay, Ellesmere Island. There is a general similarity between *Biharisporites submamillarius* and *B. ellesmerensis* Chaloner, and between *Hystricosporites delectabilis* and *Nikitinsporites canadensis* Chaloner. In addition, small spores that I have examined from the Okse Bay locality (unpublished) are of relatively large size, as are those from Stevens Head, and the megaspores, as first pointed out by Chaloner, tend to be relatively small, just as do the megaspores from Stevens Head. In both there is a tendency toward convergence in size between the megaspores and the miospores.

Regarding spores with grapnel-like appendages, resembling in this respect *Hystricosporites*, Table I shows that their known geological range is from the Middle Devonian (Lower Givetian in Richardson 1960) to perhaps as high as the Tournaisian.

Tholisporites, one of the dominant miospore genera in this coal, has been reported from one other source, the lower part of the Limestone Coal (Namurian) of Scotland (Butterworth and Williams 1958). The significance of this comparison is not yet known, since the two assemblages are otherwise quite different, and other Upper Devonian or Lower Carboniferous strata in which *Tholisporites* may occur have not been studied.

One of the species encountered here, *Convolutispora flexuosa* forma *minor*, also occurs in the early Mississippian of Nova Scotia (Hacquebard 1957), but the two floras are otherwise not alike, except that both lack distinctive younger Mississippian genera such as *Tripartites*, *Rotaspora*, and *Reinschospora*, or distinctive Devonian genera such as *Retusotriletes* and *Lophozonotriletes*.

Evidently the spores from the Melville Island coal possess only a suggestion of relationship to known Devonian and early Carboniferous records. Their closest affiliations seem to be with other assemblages from the Arctic, still incompletely known. Evidence concerning Upper Devonian and lowermost Carboniferous spores and relationships to their sporophyte counterparts is still too fragmentary to confirm the presence of a distinct flora of this age, of which this may be a part, or to speculate on the extent of such a flora in the arctic. If the suggested age assignment for the coal (Frasnian or perhaps Famennian) is correct, this new assemblage existed contemporaneously with Naumova's (1953) Givetian–Frasnian–Famennian flora.

BOTANICAL RELATIONSHIPS OF THE SPORES

The spores here assigned to *Lycospora* possess several features in common, which suggests that they were produced by a closely related group of parent plants. They are distinctly anisopolar, have a narrow equatorial zona, a broadly subtriangular outline, and an ornamentation of low projections. *Verrucosisporites grandis* may also belong to this complex, since it too possesses most of these characteristics. These features have also been associated with lycopsid affinity (Potonié and Kremp 1955). Chaloner (1959) suggests that the megaspore *Biharisporites ellesmerensis* is lycopsid, and its similarity to *B. submamillarius* would consequently be tentatively in favour of a lycopsid affinity for the latter as well.

There is some justification for suspecting that species of two of the dominant genera in the assemblage, *Lycospora* and *Biharisporites*, represent the microspores and megaspores of the same complex of plants, and that at least one of the species of *Lycospora*, perhaps *L. magnifica*, was borne by the same parent as *Biharisporites submamillarius*. These two species possess similar ornamentation (granulate-scabrate to verrucate, even with occasional papilla-like extensions on the ornaments of some specimens of *Lycospora magnifica*), both have reduced ornamentation on the proximal face, and both are broadly subtriangular in transverse outline. Furthermore, both possess gradations of similar order in the size and shape of ornaments. If these species do represent the same parent, the presence of the thin 'mesosporoid' body in some specimens of each might be expected.

A spore-mass composed of *Lycospora magnifica* was encountered (Pl. 13, figs. 2–4).

The elongate-oval shape and the dimensions of the mass (0·9mm. × 0·4 mm.), and its compactness, suggest that it may represent the original form of a sporangium. No remnant of sporangial wall was seen, or any evidence of synangial or columellate structure. No tetrads were evident, although the spores were definitely trilete. Various palaeozoic plants, both lycopsids and non-lycopsids, bore sporangia of this general size and shape.

Butterworth and Williams (1958) postulated a relationship between *Tholisporites* and *Densosporites*, and more recently Chaloner (1958) established that at least one species of *Densosporites* was produced by a herbaceous lycopod. If Butterworth and Williams are correct, the three species of *Tholisporites* in the Melville Island coal might have had lycopsid origin as well, and would perhaps have been precursors of *Densosporites* species of the Carboniferous.

TABLE 1. *Previous records of spores with grapnel-like appendages*

Reference	*Designation*	*Locality*	*Age*
Lang 1925	Types G_1, G_2	Cromarty, Scotland	Middle Devonian
Kräusel and Weyland 1929	*Aneurophyton germanicum*?	Elberfeld, Germany	Middle Devonian
Arnold 1933; 1935	*Lepidostrobus gallowayi*	Pennsylvania, U.S.A.	Upper Devonian
Nikitin 1934	*Kryshtofovichia africani*	Voronezh district, U.S.S.R.	Middle Devonian
Arnold 1936		Scaumenac Bay, Canada	Upper Devonian
Arnold 1936	'. . . referable to Type G . . .'	Pittston, Penn., U.S.A.	Upper Devonian
Høeg 1942	Spore types e, f	Spitzbergen	Middle/Upper Devonian
Eisenack 1944	*Triletes ancyreus*	Baltic	Middle and (?) Upper Devonian
Naumova 1953	*Archaeotriletes spp.*	Russian Platform	Middle and Upper Devonian
Luber 1955	*Azonotriletes ancistrophorus*	European and Asiatic U.S.S.R.	Upper Devonian
		Kazachstan	Tournaisian
Hoffmeister *et al.* 1955*a*	'new genus'	Alberta, Canada	Upper Devonian
Kedo 1957	*Archaeotriletes spp.*	Pripiat depression, U.S.S.R.	Upper Devonian
Chaloner 1959	*Nikitinsporites canadensis*	Ellesmere Island, Canada	Upper Devonian
Chaloner 1959		Perry, Maine, U.S.A.	Upper Devonian
Richardson 1960	*Ancyrospora, Cosmosporites, Densosporites spp.*	Cromarty, Scotland	Middle Devonian

Hystricosporites is probably closely allied to the various spore-types with anchor-like appendages that have been reported previously (Table 1), and which are prominent constituents of certain Middle and Upper Devonian floras. Undoubtedly a corresponding prominent megafloral component existed, but to date none has been demonstrated. Whatever the origin of the spores bearing these appendages may have been, their presence here is evidence of a denominator in the Canadian Arctic which is common to

Devonian floras of Quebec, Spitzbergen, Scotland, Germany, eastern United States, and Russia.

It is difficult to assess the affinities of those spores with relatively simple features, here assigned to *Punctatisporites*, *Cyclogranisporites*, *Apiculatisporis*, and *Planisporites*. Spores with granulate or apiculate ornamentation occur in almost all sediments in which dispersed spores have been found. Some of them may be allied to the ferns (Potonié and Kremp 1955; R. and W. Remy 1955) and the pteridosperms (Kidston 1923), but caution is necessary because the role played by homoplasy is not known. Based on present evidence, therefore, it would be unwise to more than suggest a fern or pteridosperm element in the Stevens Head coal.

As previously mentioned, three species of miospores and one of megaspores are exceedingly abundant in the coal. One would perhaps expect a greater degree of similarity among the percentages of the various species if the locale of deposition were accessible to wind-blown spores. Certainly the thick-walled spores so prevalent in the assemblage and the numerous megaspores argue against dispersal by wind. Probably then deposition was autochthonous, from a vegetation possibly dominated by the plants (lycopsids?) which bore the four most abundant spore species. Even if these plants were not dominant in the vegetation, they must have been most prolific in spore production.

Naumova's contention (1953), based on her study of Devonian miospores, that thin wall and reduced sculpture indicate a hydrophytic flora, while thick wall and prominent sculpture point to a mesophytic or xerophytic one is not easy to apply here. There is a definite over-all reduction in wall sculpture, but almost all of the miospores are thick walled.

There is little evidence to indicate the degree of relationship with the megaflora of Nathorst (1904) from the Upper Devonian of Ellesmere Island. Types that could be compared with known spores of *Archaeopteris*, a major constituent of Nathorst's flora, are not present in the spore assemblage. Fry (*in* Tozer 1956) identified *Bothrodendron sp.* L. and H. along with '. . . an axis similar to those associated with *Archaeopteris*' from similar beds on Prince Patrick Island, but again the relationship to the spores is not known.

GEOLOGICAL IMPLICATIONS

Previously, spore assemblages of comparable abundance and variety to this one have been applied profitably in correlation and dating of strata of various ages. So far, this has been particularly effective when groups of species are used (Balme 1957; Naumova 1953). Now, the application of spores from Devonian deposits in the Arctic in a similar way depends only on establishment and analysis of reference collections to which unknown samples can be compared. It may be possible to go even farther, and select single species as zonal guide fossils, since several of the species described here are of unusual construction.

Preliminary work on other Devonian strata in the Arctic has shown that other assemblages exist, not only in coal but also in shale and sandstones. There is thus broad scope for further exploration of these fossils in order to establish their full value to the geology of this area.

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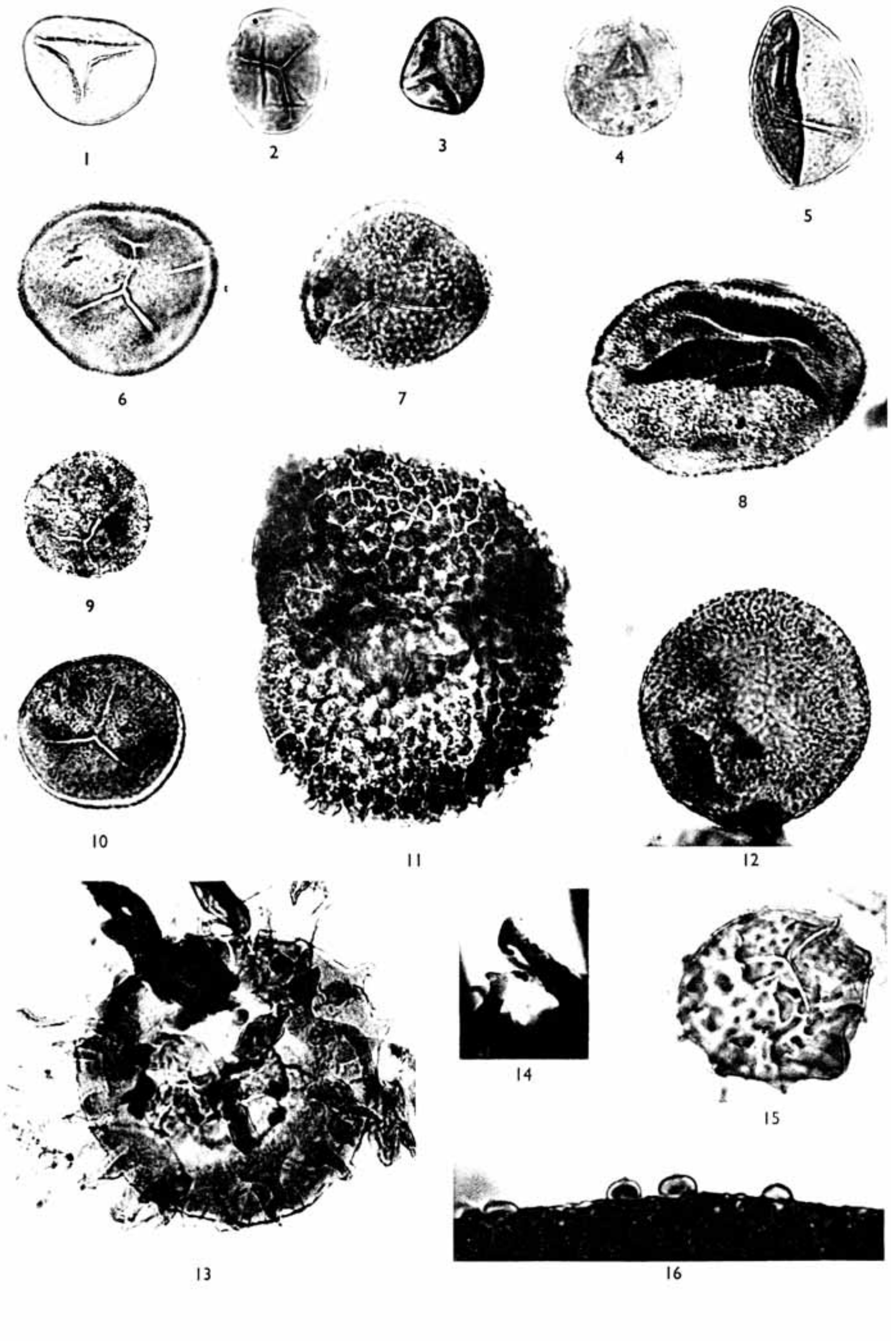
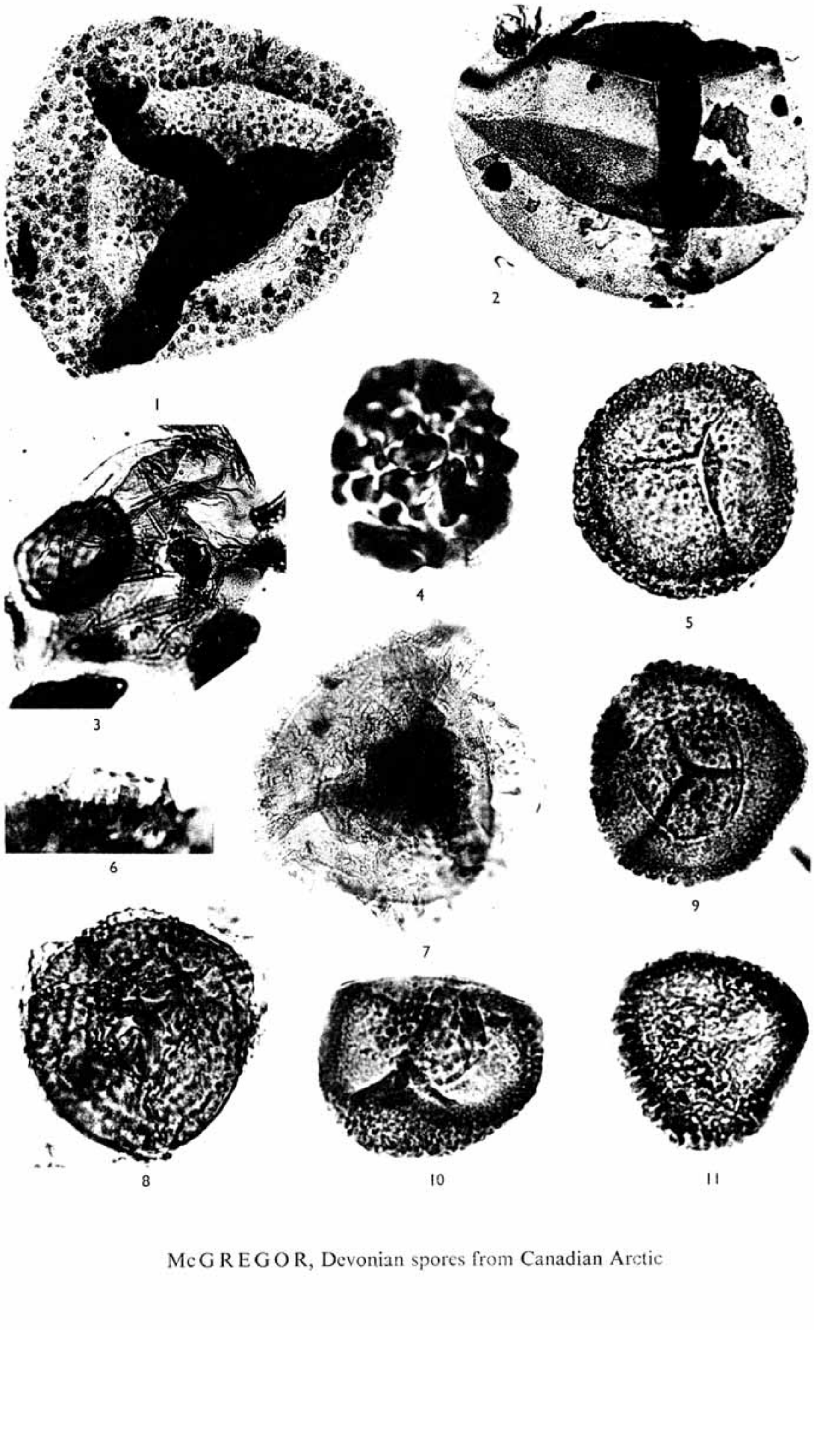
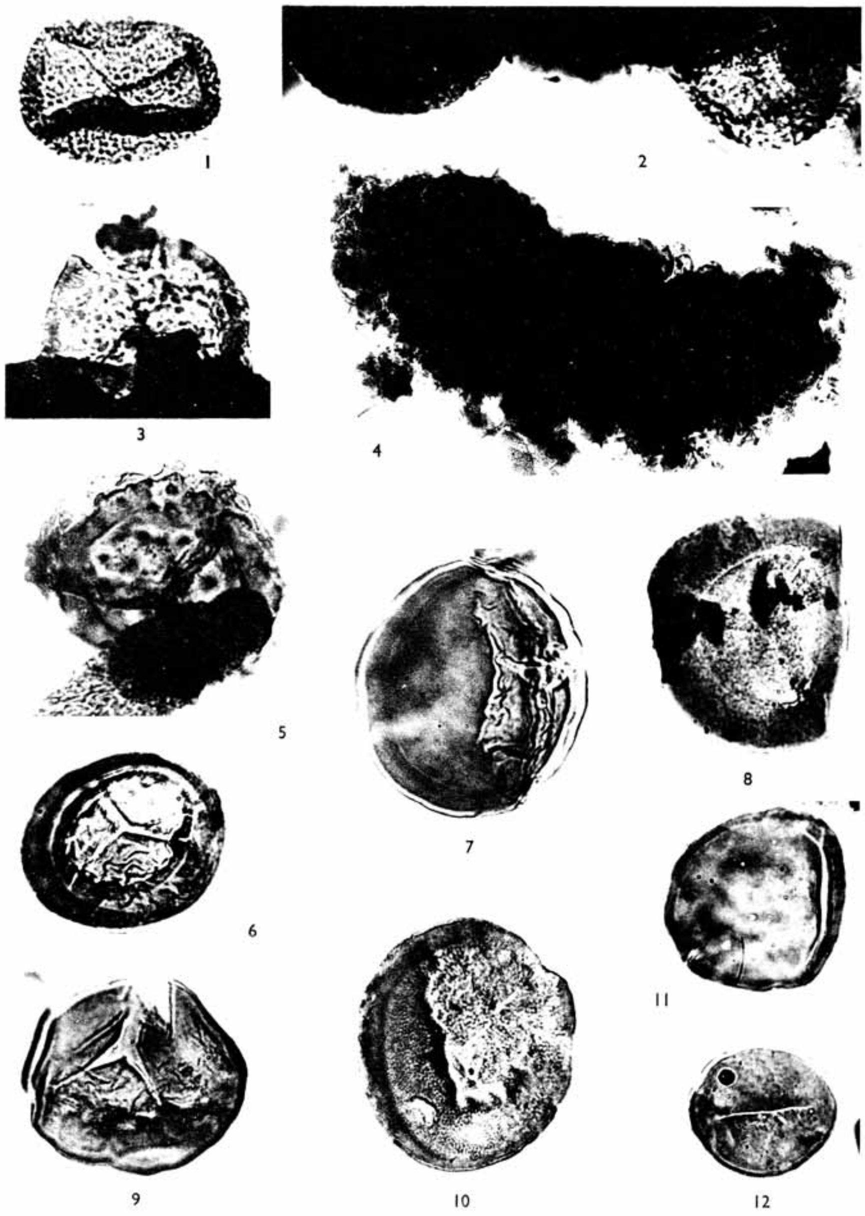


McGREGOR, Devonian spores from Canadian Arctic



McGREGOR, Devonian spores from Canadian Arctic



McGREGOR, Devonian spores from Canadian Arctic