SPORES AND OTHER PLANT MICROFOSSILS FROM DEVONIAN STRATA

SPORES AND OTHER PLANT MICROFOSSILS FROM SELECTED DEVONIAN SEDIMENTARY FORMATIONS OF CANADA

By

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SCOPE AND CONTENTS:

Methods have been adapted for the extraction and classification of spores, hystrichosphaerids and other plant microfossils from five Devonian marine and non-marine sedimentary formations of Canada. Dominant genera and species have been recorded, and comparisons have been made on an intensive basis with other microfossils including those from the Russian Platform.

From the results, evaluations have been made that facilitate both botanical and stratigraphical conclusions. The first basis for a new conception of complexity within the flora of the Canadian Devonian has been established. The appropriateness of plant microfossils for zonation purposes has been demonstrated for Devonian rocks, some of which contain no other fossil evidence.

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FOREWORD

It seems fitting to offer some explanatory remarks about plant microfossils, in order that their significance may be completely appreciated within the context of this thesis.

Dispersed plant microfossils were casually recognized in various types of sedimentary strata at an early date (White 1862, Dawson 1871a). Since then they have been encountered in almost all types of sedimentary rock (Wilson 1946).

The most abundant and cosmopolitan of plant microfossils are spores and pollens, similar in appearance to those produced by terrestrial plants. These fossils abound in certain deposits, particularly in low and medium rank coals, many shales and some sandstones. The larger (female) units, megaspores, are relatively rarely encountered in the dispersed condition in non-coaly strata, perhaps because they are easily broken by pressure of mineral grains. The smaller units, the isospores, microspores and pollen grains, collectively known as miospores (Guennel 1952), on the other hand frequently occur intact even in coarse-grained sandstones.

Both megaspores and miospores may be folded and distorted to varying degrees depending on the rigidity of their wall. In addition they are, except for relatively rare exceptions, flattened to a disc-like form by the pressure of the enveloping matrix.

Evidently many of the spores and pollens which occur as fossils were wind-blown or waterborne, just as are some present-day ones. This is suggested by the tendency of some forms to persist across facies boundaries between marine, brackish-water and non-marine strata (Woods 1955).

A second important group of plant microfossils consists of the "shells" of Protista-like organisms, the hystrichosphaerids. Their systematic position is not clear, but according to recent opinions they are perhaps planktonic organisms allied at least in part to the Desmidaceae (Deflandre and Cookson 1955). In macerated preparations they are often strikingly similar to miospores in size and texture. However they lack the characteristic tetrad scars and germinal apertures of spores and pollens. Also unlike the latter, they occur most frequently in marine deposits, and usually only rarely in non-marine rocks.

Both spores and hystrichosphaerids are known from a wide vertical range of geological time. Miospores have been reported from Cambrian strata on several occasions, and are known to occur in all younger geological periods, with the possible exception of the Ordovician (Reissinger 1939, Kräusel 1939). Megaspores are known only rarely from pre-Carboniferous rocks (Høeg 1942) but are abundant in many younger strata, particularly in certain coals (Dijkstra 1952). The demonstrated geological range of the hystrichosphaerids is even more extensive, from late Precambrian (Deflandre 1948, Timofeev 1956) to Tertiary. Unlike miospores and megaspores, they are best known from the early Palaeozoic. Perhaps the most peculiar characteristic of their range is that they do not occur today, as far as is known (Deflandre 1947a).

The term plant microfossil as defined in the broad sense also includes fragments of plant cuticle and conductive tissue, sporangia, and various other microscopic plant fragments. Such remains accompany dispersed spores of all ages in different degrees of abundance. Usually they are too fragmentary, undifferentiated or obscure in structure to allow exact assessment of their botanical affinities, but occasionally some of them, such as tracheary fragments and cuticles, show distinctive features which allow their assignment to the larger taxa.

INTRODUCTION

1. The scope of earlier research:

Until recently, the accumulation of literature on plant microfossils has been slow, scattered and varied in emphasis. Latterly however, attention has been focussed on economic motives, and consequently contributions to some aspects have become exceedingly numerous. Much of the foregoing literature bears on the course of the present investigation, and therefore an account of the major developments will be appropriate.

The earliest literature on plant microfossils consists of occasional brief descriptions, usually associated with investigations of sporangia and other macroscopic remains (cf. Renault 1876, Nathorst 1902). Most of these early workers were little interested in the significance of spores and other microfossils per se, and consequently their descriptions were usually vague and incomplete.

Reinsch (1884) and Bennie and Kidston (1886) made the first attempts to apply spore studies to stratigraphic purposes. Only within approximately the last twenty-five years, however, is the potential geological and botanical significance of these fossils becoming generally realised. Raistrick (1934 ff.) and Ibrahim (1932, 1933), applying the technique of bulk maceration of their samples, first derived large-scale application of small spores to stratigraphic problems. They demonstrated that Carboniferous spores possess features sufficiently distinctive and constant to allow them to be classified in a practical manner, and that these spores may be useful for the correlation of some coal seams. In succeeding years, numerous papers were published applying both miospores and megaspores of various ages to the stratigraphy of coal deposits (Luber 1937, Kosanke 1950, Dijkstra 1952 et al.).

Within the last decade much data in micropalaeobotany has been forthcoming in the interests of oil exploration (Kuyl, Muller and Waterbolk 1955, Hoffmeister 1955). Russian, Dutch and American organizations have used spores and pollens for correlating and prospecting purposes, and as indicators of the position of ancient shorelines (vide Naumova 1953, Hoffmeister 1955). Through these studies it is evident that plant microfossils are often abundant in various sediments other than coal (i.e. in shale, sandstone and even limestone) (cf. also Wilson 1946, Hoffmeister, Staplin and Malloy 1955a).

Interest in the study of pre-Carboniferous spores, especially those of Devonian age, is also a recent development. Work has been done by Elovskaya (1936), Thomson (1952) Hsü (1953) and others in which quite significant numbers of spores were described, proving that the spore flora of the Devonian period can be at least as prolific as that of younger sediments. Naumova (1953) has given us the most comprehensive treatment of Devonian spores. She has described and evaluated approximately one thousand species of sporae dispersae from Middle and Upper Devonian terrigenous sediments of the Russian Platform.

On this continent dispersed spores of Devonian strata have been recorded by a few authors. Lang (1931), Arnold (1936), Lemon (1953) and Hoffmeister, Staplin and Malloy (1955a) refer briefly to spores and spore-like fossils from Canadian deposits. Winslow (1954) has revealed a megaspore assemblage from uppermost Devonian black shales of Ohio. Finally, Radforth and McGregor (1954), in a preliminary report, describe a prolific flora of miospores from the Gaspé sandstone.

Of the contributions which have described *sporae dispersae*, only a few have emphasised purely botanical relationships. Naumova (1953) and Potonié and Kremp (1956b) have made especially noteworthy contributions in this direction, mainly by comparing dispersed spores with those that have been found in fructifications. They inferred a certain degree of affinity when the spores so compared are morphologically similar. In these papers and others (Potonié 1952) they have also attempted to assess the palaeoecological and phylogenetic significance of the microfossils.

At about the same time as the initial work of Raistrick and Ibrahim appeared concerning spores, Eisenack (1931, 1934, 1938) initiated the first extensive study of the other major group of plant microfossils, the hystrichosphaerids. Since then, a mass of descriptive data has accumulated concerning hystrichosphaerids of all geological periods. (O. Wetzel 1933 *ff.*, Deunff 1951 *ff.*).

Hystrichosphaerids, like fossil spores, have received much less attention in this country than abroad. Baschnagel (1941), and Deunff 1954a, 1955) briefly describe a few specimens of hystrichosphaerid-like organisms of Devonian age from the Great Lakes region. Fisher (1953) did some similar work for the Silurian of the same region. Other than these, descriptions of North American hystrichosphaerids are not available, as far as the writer is aware.

Apparently, no work has been published, in this country or elsewhere, with emphasis on the use of these organisms for stratigraphy.

2. The direction of further research:

Clearly, one of the most improtant areas of research in need of exploration concerns plant microfossils of Devonian age. Several authors

(Radforth and McGregor 1954, Hoffmeister, Staplin and Malloy 1955a, Leclercq 1956) have pointed out the potential value of these fossils. There is no reason to doubt that once the miospores and other microfossils contained in Devonian deposits are defined, and their scope of occurrence and pattern of distribution clarified, they can be as useful for stratigraphy as have those of Carboniferous and younger sediments.

Some Devonian rocks apparently lack horizon markers or diagnostic fossils (DeWit and McLaren 1950, p. 10; Tozer 1956, p. 15). In such cases, demonstration of the presence of plant microfossils and of their appropriateness as stratigraphic indices would be welcome from the fundamental point of view of a better understanding of the geology of Canada.

Furthermore, although the presence of plant microfossils in large numbers in certain marine and non-marine Devonian sediments in Canada has been suggested (Radforth and McGregor 1956), their scope has not been adequately established. An investigation of this sort, using a selected variety of sediments, would provide a baseline for long-term study of the Devonian microflora of this country. Rich oil deposits have been discovered in Devonian strata in Canada and this provides an additional stimulus for investigation of their microflora.

The botanical significance of Devonian plant microfossils, particularly spores, promises to be at least as great as the geological. Because of their numbers and their capacity to disperse, spores can convey information about plants which because of their habitats or structure, were not suited for preservation as megafossils (Thomson 1952, Leclercq 1956). It may be possible to infer the existence of entire new groups of plants which were previously not known to exist.

From the megafossil record we know that vegetative differentiation on land was rapid throughout the Devonian period (Dorf 1955). It is possible that the spore evidence will help to clarify our knowledge of the patterns of floral evolution which accompanied these rapid changes. Also, the extraction of large numbers of spores from various matrices, and the relating of their patterns of distribution to major geological events (i.e. orogeny, marine transgressions and regressions, climatic changes, etc.) may provide a method of clarifying various problems of palaeoecology and phylogeny for the Devonian flora.

There are many other facets of the Devonian vegetation about which we know very little. The ancestors of the Devonian land floras, the derivation of heterospory among Devonian plants, the question of monophylogeny vs. polyphylogeny in the development of terrestrial plants, and the relative antiquities of the major taxa, represent areas of inquiry which may be at least partially clarified by a better knowledge of the plant microfossils of the Devonian period.

In addition to plant spores, the hystrichosphaerids also may be tools for both the palaeontologist and the botanist, once they have been adequately investigated. Interest in their use for oil exploration has recently been expressed (Wilson and Hoffmeister 1955, Woods 1955). The latter authors are optimistic concerning the stratigraphic value of these fossils, although too little information is available to allow a definite statement of their worth. The scarcity of published data on Canadian (or North American) hystrichosphaerids bears reemphasis, and the need for further study is indicated.

Furthermore, literature on plant microfossils almost invariably treats either hystrichosphaerids or spores and pollens, but not the two simultaneously. It would seem desirable to compare the patterns of occurrence of the two types of microfossil remains by including them in one coordinated work, when they are encountered in the same rock. It is reasonable to suggest that they should complement one another with respect to fundamental botanical and geological problems, since hystrichosphaerids were apparently typically marine in habitat as opposed to spores and pollens which were terrestrial or emergent in origin.

3. The objectives of the present study:

The aims of this investigation have been designed to serve two major functions as suggested by the foregoing remarks. Primarily they were outlined to provide a survey of the plant microfossils of Devonian strata, on a sufficiently broad scale to reveal a wide range of application. At the same time it is desirable that they allow the establishment of definitive data concerning the disclosed microfossils since this has not been done for Devonian deposits on this continent. In order to satisfy these terms, the following objectives were set out.

(a) The examination of several formations of Devonian age, selected from various parts of Canada, to determine their possible plant microfossil content. Both marine and non-marine sediments will be used representing a broad range of Devonian time. This objective will be fulfilled when suitable techniques for extraction have been developed, and when the microfossils have been made available for description.

(b) Detailed description of the disclosed microfossils. Each description will be accompanied, where possible, by comparison with forms described in the literature.

(c) Evaluation of the microfossils in the following ways:

(i) as assemblages.

(ii) as indicators of the structure of the flora which produced them.

(iii) as aids in the interpretation of certain problems of floral evolution and palaeoecology.

(iv) as tools for stratigraphic work.

SELECTION AND TREATMENT OF MATERIAL

1. Choice of samples:

For the purpose of choosing material to fulfill the prerequisite set out in objective (a), samples were taken from several formations of Devonian age and a preliminary assessment was made of their microfossil content. Samples from five of these formations, which yielded microfossils, were chosen for inclusion in the present investigation because they represented a range of age, sedimentary type and geographical locality.

2. Geographical and geological data:

A summary of the geographical and geological data for the selected samples is given in Table I. A more detailed account of certain aspects of the geological facts is presented in the paragraphs to follow. Table II is a correlation chart showing the approximate positions of the various formations in the standard North American and European sections. Cooper et al. (1942) and other more recent sources were consulted regarding the correlations.

(a) Sextant formation:

The best known and most accessible exposures of this formation occur on either side of the Abitibi River at Sextant Rapids in Northern Ontario, where our samples were obtained. Outcrops which are probably of the same age are known from only three other localities, the most distant being about seventy-five miles west of Sextant Rapids,

TABLE I

Formation	Age	Lithology	Locality	Collector
PERDRIX EQUIVALENT	UPPER DEVONIAN *Buchiola* zone of Bullock & Hughes	BLACK SHALY SANDSTONE (non-calcareous)	SOLO CREEK, YUKON Outcrop, Sample #213753 (Bullock & Hughes)	B. Bullock
MELVILLE ISLAND	UPPER DEVONIAN	COAL (HIGH VOLATILE B. BITUMINOUS)	STAVENS HEAD, MELVILLE ISLAND. Outcrop G.S.C. field No. 54-3-8.	E. T. Tozer
BATTERY POINT	MIDDLE DEVONIAN	SANDSTONE, greenish-grey, with small angular carbonaceous fragments	ANSE-À-BRILLIANT, GASPÉ PENINSULA. Outcrop.	N. W. Radforth
ONONDAGA	MIDDLE DEVONIAN	2" BLACK SHALE PARTINGS IN GREY LIMESTONE	NORFOLK COUNTY, ONTARIO, core #3, Oliver Iron Mining Div. of U.S. Steel Corp. [illegible] 278.5 ft. and 432 ft. in core.	
SEXTANT	UPPERMOST LOWER DEVONIAN (?) (Fritz and Cranswick 1953)	GREY MICACEOUS SHALE, SANDSTONE AND CONGLOMERATE. CROSS-BEDDING (Fig. 2 and 3.) See Appendix II for stratigraphic sections.	SEXTANT RAPIDS, ABITIBI RIVER, ONTARIO. Outcrop A-west bank, at base of rapids. Outcrop C-east bank at base of rapids.	C. McGregor

TABLE II

DEVONIAN CORRELATION CHART

Stages of Standard Section: Europe	Stages of Standard Section: North America		Formation		
	BRADFORDIAN			Melville Island (probable extent) ?; Interval of sample 54-3-8 ?	UPPER DEVONIAN
FAMENNIAN	CHAUTAUQUAN				
FRASNIAN	SENECAN		Perdrix		
GIVETIAN	ERIAN		Battery Point		MIDDLE DEVONIAN
EIFELIAN					
COBLENZIAN	ULSTERIAN	ONESQUETHAW	Onondaga ?		
		DEERPARK	Sextant ?		LOWER DEVONIAN
GEDINNIAN		HELDERBERG			

on the Wabiskagami River (Lemon 1953).

The Sextant rocks consist of alternating layers of shale, sandstone and conglomerate. Plant fossils abound in some of the layers, especially in the micaceous shales where they occur abundantly as compressions. The shale layers are rarely more than about six inches thick, and often do not persist for more than a few yards laterally. No marine fossils have been found.

Until now, neither the microflora nor the magaflora of the Sextant formation has been studied in detail. Bell (in Dyer 1928) identified Drepanophycus spinaeformis Göppert and Aphyllopteris (probably = Dawsonites arcuatus Halle). On this tentative basis, and also because of the stratigraphic position of the formation, Bell and others (Lemon 1953, Fritz and Cranswick 1953, Martison 1953) have assigned to it an uppermost Lower Devonian age. The Abitibi River formation, which overlies the Sextant with apparent conformity, has been correlated with the Bois Blanc-Detroit River-Dundee section of Ontario and the Onondaga of New York by the same authors. Cooper et al. (1942) however, placed the Abitibi River formation somewhat higher in the Middle Devonian section, so that the Sextant could conceivably be younger as well, perhaps lower Middle Devonian. On the correlation chart (Table II) the opinions of the previously named authorities are followed and the Sextant formation consequently is tentatively shown as uppermost Lower Devonian in age.

Lemon (1953, p. 50) makes the following comments on the deposition environment of the Sextant formation:

> "... most likely ... the sediments were deposited in a shallow lake, or series of lakes, by streams flowing from a region of higher ground developed on the Pre-cambrian rocks to the south. The climate was most probably monsoonal in type ... ."

In the rainy season, coarser deposits would be laid down, in which occasional plant fragments could be preserved, while in the dry season sluggish streams flowing across the fans at the base of the highland would deposit finer sediments that could allow preservation of abundant fragmentary plant remains. Lemon further states (1953, p. 16) that,

> "It is clear that deposition of the coarser siltstone and shale sediment and envelopment of plants were sufficiently rapid to have been completed before decay of the organic matter had progressed to any great extent."

Fritz and Cranswick (1953) and Martison (1953) emphasize the limited areal extent of sediments of the Sextant formation.

(b) Onondaga formation:

The Onondaga formation occurs over a considerable area of the region south and east of Lake Erie in the United States. At its northern limit, it occurs as a narrow strip along the north shore of the Lake in the Ontario peninsula. The sample used in this investigation was collected in this region (Table I). The specimens under consideration here were derived from black calcareous shale partings, about one centimeter thick, in limestone.

According to Cooper et al. (1942) and others, the Onondaga formation belongs to the lower part of the Middle Devonian (Onesquethawan stage) of the American classification. This assignment is widely accepted, and is followed here (Table II).

The abundance of corals and the wide areal extent of this formation indicate that it was probably laid down in a warm, clear sea, bordered by low land (Schuchert and Dunbar 1944). To the writer's knowledge no terrestrial plant remains have been found until now in Onondaga strata.

(c) Battery Point formation:

McGerrigle (1950) introduced the term Battery Point to designate the upper part of the thick succession of sandstone and shale known as the Gaspé Sandstone, which outcrops along the north and south shores of Gaspé Bay. McGerrigle (1950, pp. 84-90) discusses the stratigraphy of the Battery Point formation in some detail.

Numerous fragmentary plant remains have been found in these beds, as well as fossil fish remains, but they are not regarded as sufficiently diagnostic for precise dating of the beds. Dawson (1871 and 1882) reported fossil plants from the section, probably from the Battery Point formation (McGerrigle 1950, p. 86). These remains included Drepanophycus spinaeformis (Arthrostigma gracile) Göppert which Dorf and Cooper (1943) consider "indicative" of Lower Devonian age. According to Arnold (1946, p. 91) however, D. spinaeformis occurs in the Middle Devonian as well, so that the presence of this species in the Gaspé beds does not preclude a Middle Devonian age. McGerrigle (1950) reviews the opinions of Clarke (1908), White (1913), Kindle (1938), Cooper et al. (1942) and others, and concludes that the age of the Gaspé sandstones "... is the age of its mollusks and particularly of its pelecypods ...", and specifically that "... we must refer the ... Battery Point ... to the stratigraphic level of the Middle Devonian Hamilton formation." This age is adopted in the present investigation.

Most of the sediments which formed the Battery Point formation were evidently deposited in shallow seas, bordering the continental areas which were being uplifted to the east by the Acadian disturbance. There is much evidence of shallow water deposition (cross-bedding, ripple marks etc.) throughout the formation. McGerrigle (1950, p. 98) says that "... shallowing of the sea, and even local emergence ... probably recurred again and again during the deposition of the Gaspé Sandstones."

(d) Perdrix equivalent:

The Perdrix formation outcrops in west central Alberta, in the area between the Athabaska valley and the North Saskatchewan River. It includes black, gray and greenish shales, mostly calcareous, which are of variable thickness, often subject to rather abrupt lateral facies change.

On the basis of its lithological and stratigraphical relations supported by the meagre fauna, this formation is placed with considerable assurance in the lower part of the Upper Devonian (Senecan) (Fox 1954, Dewit and McLaren 1950).

Warren and Stelck (1950) assign the Perdrix shale to the Buchiola retrostriata zone, which "... is widespread in the Western Devonian sequence" (ibid., p. 70). Further north, this zone has been recognized in the upper part of the Fort Creek formation of the

Mackenzie valley and has been described from the Simpson shale in the vicinity of Fort Simpson (Kindle 1919).

The sample which is dealt with in the present study was obtained from an outcrop on Solo Creek (formerly Margery Creek), south of the Peel River in the northern Yukon, from a sandstone and shale succession containing Buchiola. According to C. R. Stelck[1], these beds are transitional in nature between the Fort Creek and Imperial formations.

Similar beds from the vicinity of Solo Creek are assigned to the top of the Fort Creek formation according to Hume (1954, p. 38, 43), but only for purposes of convenience, since they could as well be placed in the lower part of the Imperial formation (ibid., p. 40). Obviously, the exact nomenclature to be applied to this stratum is not clear.

Based on the information outlined above, and on the correlation of the Fort Creek, Simpson and Perdrix formations given by Kindle and Bosworth (1920), Cooper et al. (1942) and Warren and Stelck (1950), the Solo Creek beds are referred to in this investigation as the "Perdrix equivalent".

The Upper Devonian plant Pseudobornia has also been identified from these beds, in the sandstone layers of the section from which our sample was collected (C. R. Stelck[1]).

In the Mackenzie valley region, this zone apparently represents a transitional environment of deposition, because fine-grained

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[1]Personal communication. Dept. of Geology, University of Alberta, Edmonton, Alberta.

material associated with marine fossils alternates with coarser-grained sandy beds containing remains of terrestrial plants. The geology of the area is incompletely known (Hume 1954), so that the position of Devonian shorelines is not clear. However, conditions were apparently different here from further south, where the Perdrix formation was deposited in a shallow sea without evidence of any shoreline (McLaren 1953). The shale component of the series, which the writer's sample represents, was probably deposited under similar conditions to the shales of the Perdrix formation, as a fine clastic mud. Plant microfossils representing a considerable area of a bordering land mass could have been transported into the basin (Kuyl, Muller and Waterbolk 1955).

(e) Melville Island formation:

This formation was recently described by Tozer (1956) from Melville and Prince Patrick Islands in the western part of the Arctic Archipelago. It consists of a thick sequence (11,000 feet +) of sandstone, siltstone, shale and coal.

The formation is apparently divisible into two parts. The lower part consists of fine-grained clastic rocks carrying marine fossils of Middle Devonian (Givetian) and Upper Devonian (Frasnian-Senecan) age, the upper part is composed of sandstones with much carbonaceous material and several coal seams, and is regarded as Upper Devonian in age (Tozer 1956). No marine fossils were found in these upper beds, but they bear fragmentary plant remains, some of which, from Prince Patrick Island, were tentatively identified by W. L. Fry (in Tozer 1956) as Bothrodendron sp. L. and H. and " ... an axis similar to those associated with Archaeopteris."

The sample selected for this investigation was obtained from a coal seam in the upper part of the Melville Island formation, and thus is regarded as Upper Devonian in age (see Table II).

Regarding the origin of the sediments of the Melville Island formation, Tozer (1956, p. 18) concludes that,

> "Much of the upper part was deposited under non-marine conditions, and the predominant direction of the foreset dips may be interpreted as suggesting that the sediment was derived from the north."

Cross-bedding and ripple marks in the sandstones of the section suggest a shallow water, perhaps deltaic deposit. Deposition of some of the strata was probably sub-aerial, judging by the absence of marine fossils and the presence of several coal seams. The areal extent of the coal seams is not known, and it has not been established whether the deposition in them was autochthonous.

3. Laboratory techniques:

(a) Maceration:

Macerations of the samples were afforded using variations of the standard methods described by Radforth and McGregor (1954). Schultze's solution was prepared by adding about 1 cc. of crystalline $KClO_3$ to the HNO_3 (usually about 50 cc.) covering the sample in the beaker.

Before maceration, each sample was thoroughly washed, broken down to particles of about 1 mm. diameter, and about 20 cc. of it placed in a clean polyethylene beaker. Each of the reagents was then added in sufficient quantity to equal about twice the depth of the powdered rock in the beaker. The optimum times of immersion of each of the samples in the various reagents are listed in Table III. After each treatment the sediment was washed several times by addition of water and decantation after the sediment had been allowed to settle. Washing by decantation was found to be less conducive to breakage of the microfossils than centrifugation in the early stages of the maceration.

It was sometimes necessary, particularly with the coarser siliceous rocks, to add the hydrofluoric acid very slowly to minimize the violence of the reaction. In such instances the mixture usually became quite hot, but immersion of the beaker in cold water prevented melting of the polyethylene.

During each of the treatments, the sediment was stirred several times to hasten solution of the mineral portion.

Extended treatment of the samples in HCl or HF had no apparent harmful effect on the microfossils, but the times of immersion in Schultze's solution were more critical, so that periodic checks of the sediment were made under the microscope to establish the time when the microfossils began to clear. Once clearing had begun, the sediment was examined at intervals of 1/2 hour or less, and the maceration halted at the point where the microfossils were best defined. Overmaceration in Schultze's solution destroyed the microfossils.

Occasionally a very short (less than 6 hours) treatment of the sediment with HF after the removal of the Schultze's solution was employed to remove fine mineral crystals. Some of this very finely

TABLE III

TIMES OF MACERATION OF SAMPLES (HOURS)

Reagent	HCl conc.	HF 48%	Schultze's solution	NH_4OH 10%	KOH 10%
Sample					
A-3		60	36	1	
A-5		72	24		
A-6		72	60		
A-13		60	24		
A-17(1)		60	60	1	
A-17(2)		[illegible]	60	1	
C-1		72	100		
Onondaga	24	12			
Battery Pt.	24	144	144	12	
Perdrix	72	24	60		
Melville Is.		24	24		6

dispersed mineral material was not affected by HF, but it remained dispersed in the liquid during the NH_4OH treatment, and was decanted.

Further separation of the mineral components was possible during the final stages of treatment after the use of Schultze's reagent or the NH_4OH. After these steps the sediment was centrifuged and washed several times, and about 1/2 inch or less of material remained in the tapered bottoms of the centrifuge tubes. Usually, some levels of this remaining sediment contained no microfossils, and could be removed.

(b) Preparation of slides:

To each of the tubes, about 1 cc. of water was added to the sediment containing the microfossils, and the tube was carefully shaken. From this mixture, two drops were removed with a pipette, and mixed with corn syrup on a glass slide according to the method described by Radforth and Rouse (1954). The microfossils in some of the samples were stained with safranin. The dye was added as an aqueous solution to a portion of the sediment, allowed to stand for one or two hours, and then poured off and the sediment, washed to remove excess stain. The microfossils of the Sextant formation, were sufficiently dark in colour so that staining was not necessary to clarify their morphological features.

(c) Photography:

Photographs of the selected microfossils, were taken with an Exakta camera and Kodak microfile or panatomic-X 35 mm. film. Microfile developed in Kodak D-11 in a dilution of 1:1 with water, was preferred to panatomic-X for the thinner, less opaque microfossils, particularly the hystrichosphaerids and some spores, because of the high contrast obtainable. All photographs were taken by transmitted light through one ocular of a Bausch and Lomb binocular microscope, at magnifications of 200 or 475. Most of the photographs of microfossils on the final plates are at a magnification of 500 diameters; a few are easily-derived multiples of this (50, 100, 250 and 1000 diameters). Drawings were photographed using a Leitz Copying Apparatus and were reproduced on the plates at magnifications of 50X, 200X, 500X, 1000X and 2000X.

DESCRIPTION OF MICROFOSSILS

1. <u>Criteria and methods for description</u>:

Palaeozoic miospores and megaspores have been subject to several schemes of classification, and a confusion of nomenclatural terms, because of the separate development of several schools of spore research. Recently, however, the various schemes have been revised and incorporated into a single composite plan by Potonié and Kremp (1954), resulting in a classification which has been based on the principle of priority of authority for the various systematic categories. This classification is followed for the miospores and megaspores disclosed in the present investigation.

Several taxonomic categories have been introduced to the classification scheme at both the generic and suprageneric levels, to accommodate newly discovered forms of spores. In addition, the original organization of the scheme has been altered to the extent that megaspores are removed from the body of the classification and placed in a separate position following the miospores. This was done in order to facilitate subsequent reference to them as a group, and to emphasize the particular significance which they have in the Devonian flora.

Hyphenation was omitted from the spelling of several generic names by Potonié and Kremp (1954), although the original, and legal, spellings of the names were the hyphenated forms. In the present treatment the hyphenated spellings have been retained (i.e. <u>Granulati-sporites</u>).

After Zerndt (1934), Guennel (1952) and others, spores that are 200 μ or more in size are here regarded as megaspores. This size boundary is an arbitrary one, designed for convenience of reference. It is not meant to imply that all spores larger than this in size are megaspores (female spores), even though most of them are.

The classification of the hystrichosphaerids which has been adopted is that evolved by Wetzel (1933), Deflandre (1937), Eisenack (1938) and others, and employed most recently by Deflandre and Cookson (1955). This scheme, designed to embrace members of all geological ages, is the most widely accepted one for these fossils.

For both spores and hystrichosphaerids, each new species has been defined following inspection of at least ten specimens. In exceptional cases when less than ten specimens were available, this has been noted in connection with the description. When it was felt advisable to record single examples, these were not given a specific epithet. Rather, a generic name was applied, followed by a letter designation, (*e.g.* *Calamospora* sp. A.).

Within the description of each species comparisons have been made with other forms from the literature, under the heading of "similar forms". When the forms compared are closely alike but of widely differing ages, as Devonian and Mesozoic, or when only one or two characters distinguish the species, the designation *cf.* is applied. When the forms under consideration are regarded as synonymous, they are compared without the antecedent *cf.*

A holotype has been designated for each new species, and the position on a permanent slide is noted. The abbreviation M.P.C. indicates the McMaster Palaeobotanical Collection, in which location the slides are stored.

Microfossils other than spores and hystrichosphaerids are described and evaluated in a later section. They are not included in the systematic portion of the work, because they comprise a heterogeneous assemblage, for which precise taxonomic position is often uncertain.

2. Definition of terms:

For the purpose of describing features of ornamentation of the spores and hystrichosphaerids, several terms have been employed (e.g. laevigate, scabrate, etc.). Precise definitions of these terms are given by Harris (1955), and his definitions are followed in this investigation. An additional word, "reticulate", is used in the sense defined by Kosanke (1950).

Description of several other microfossil features required particular terms, which are here defined.

Outline: shape of specimen in transverse plane of compression.

Profile: shape of specimen in lateral plane of compression.

Apex: used for trilete spores, includes the areas adjacent to the tetrad scar and bounded by arcuate lines as in the genus Retusotriletes. Originated by Naumova (1953).

Area contagionis: darkened portions on the interradial areas of the proximal face of the spore; distinguished from the apex by its (usually) smaller area relative to the total proximal face, and by its opaque appearance. The area contagionis and the apex have both been interpreted as delimiting the areas of contact of the spores in the original tetrad (vide Kosanke 1950, Naumova 1953).

Perisporium: a cutinized layer outside the exine in certain spores (vide Hoskins and Cross 1943).

Mesosporium: a membranous cutinized body internal to the exine in some megaspores. Distinct from the endospore which is not cutinized (vide Høeg, Bose and Manum 1955).

3. Descriptions of miospores:

SPORITES H. Potonié 1893

Division: TRILETES Reinsch 1881

Subdivision: Azonotriletes Luber 1935

Series: Laevigati (Bennie and Kidston) Potonié and Kremp 1954

Genus: Leiotriletes (Naumova) Potonié and Kremp 1954

Leiotriletes simplex Naumova 1953, pp. 21 and 44;

Pl. I, Fig. 2; Pl. V, Fig. 9.

Pl. 1, Fig. 1.

Occurrence: Sextant and Onondaga formations. In U.S.S.R. : the Givetian and Frasnian series of the Moscow Basin (Naumova 1953).

Remarks: The diameter of this spore is 21 - 32 μ, which is almost identical with that given by Naumova (20 - 30 μ). However, the dimensions allowed for any of Naumova's species might better be regarded as only approximate, since she gives them as multiples of five in nearly every instance.

Leiotriletes exiguus sp. nov.

Pl. I, Fig. 2.

Occurrence: Battery Point formation.

Holotype: Pl. I. Fig. 2. Slide 28-33 (36.7 x 122.1), M.P.C.; 27 μ.

Diameter: 20 - 34 μ

Ornamentation: Laevigate.

Other features: Spores radial, trilete, subtriangular, with concave margins. Laesurae 2/3 - 3/4 the length of the radius of the spore. Lips low. Commissure closed or slightly open.

Remarks: The margins of Leiotriletes exiguus are always slightly concave, and one radius is usually longer than the other two. In these respects it differs from Granulatisporites politus Hoffmeister, Staplin and Malloy (1955b, p. 389; Pl. 36, Fig. 13). Also the diameter range is slightly smaller than that of G. politus.

Laevigate, subtriangular spores with concave margins are widespread in younger Palaeozoic strata. They also occur in many Mesozoic and Cenozoic rocks (Miner 1935, Rouse 1956). Several Cyatheaceous ferns have spores with this form (Thomas 1911).

Leiotriletes usitatus sp. nov.

Pl. I, Fig. 3.

Occurrence: Sextant formation.

Holotype: Pl. I, Fig. 3. Slide C-1-4 (61 x 122.5), M.P.C.; 39.5 μ.

Diameter: 36 - 42 μ.

Ornamentation: Laevigate.

Other features: Spores radial, subtriangular, margins straight or slightly concave. Laesurae 3/4 the length of the radius of the spore. Lips low, narrow. Commissure usually open. Wall up to 1.5 μ thick, rarely folded.

Similar forms: *cf.* *Deltoidospora Hallii* Miner 1935, p. 618; Pl. 24, Fig. 7,8. (Lower Cretaceous).
cf. *Levigatisporites marlisae* Thomson 1952, p. 158; Pl. 10, Fig. 1,3. (Lower Devonian).

Remarks: *L. marlisae* is smaller in size (- 30 μ), but otherwise closely resembles *Leiotriletes usitatus*. Thomson (1952, p. 159) remarks on its similarity to spores of *Zosterophyllum Llanoveranum* Croft and Lang (1942), also of Lower Devonian age.

Leiotriletes dissimilis sp. nov.

Pl. I, Fig. 4.

Occurrence: Melville Island formation.

Holotype: Pl. I, Fig. 4. Slide MI-12 (21.8 x 105.9), M.P.C.; 44.5 μ.

Diameter: 43 - 55 μ.

Ornamentation: Laevigate; punctate in contact areas.

Other features: Spores radial, trilete, subtriangular, margins convex. Laesurae extend almost to the equator of the spore. Commissure slightly open; lips low, distinct. Wall 1 - 1.5 μ thick.

Leiotriletes confertus sp. nov.

Pl. I, Fig. 5.

Occurrence: Melville Island formation.

Holotype: Pl. I, Fig. 5. Slide MI-22 (35.2 x 122), M.P.C.; 41 μ.

Diameter: 35 - 55μ

Ornamentation: Laevigate to infragranulate.

Other features: Spores radial, trilete, broadly subtriangular to circular in outline. Laesurae extend almost to the equator of the spore. Lips low, distinct, about 1.5μ wide. Wall 1 - 2μ thick.

<u>Leiotriletes marginalis</u> sp. nov.

Pl. I, Fig. 6.

Occurrence: Melville Island formation.

Holotype: Pl. I, Fig. 6. Slide MI-12 (48.4 x 104.1), M.P.C.; 33μ

Diameter: 33 - 54μ.

Ornamentation: Laevigate.

Other features: Spores radial, trilete, subtriangular, margins convex. Laesurae extend almost to the radius of the spore. 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. It thus resembles an enveloping layer rather than an equatorial structure. Perhaps it served as a cuticle-like protective covering over the exine.

<u>Leiotriletes incipiens</u> sp. nov.

Pl. I, Fig. 7.

Occurrence: Onondaga formation.

Holotype: Pl. I. Fig. 7. Slide 432-15 (24.8 x 120), M.P.C.; 43.5 μ.

Diameter: 38 - 57.5 μ.

Ornamentation: Laevigate.

Other features: Spores radial, trilete, broadly subtriangular with convex margins. Laesurae extend 3/4 to 4/5 the distance of the equator. Lips low. Wall dense, but less than 1 μ thick.

Leiotriletes microdeltoidus sp. nov.

Pl. I, Fig. 8.

Occurrence: Melville Island formation.

Holotype: Pl. I, Fig. 8. Slide MI-22 (33 x 117.6), M.P.C. 44 μ.

Diameter: 33 - 54 μ.

Ornamentation: Very minutely scabrate.

Other features: Spores radial, trilete, broadly subtriangular to circular. Laesurae simple, about 1/3 the length of the radius of the spore. The tips of the rays are joined to one another by distinct dark lines which delimit a well-defined triangle.

Remarks: The proximal triangular design is unique for this species.

Genus: Calamospora Schopf, Wilson and Bentall 1944.

Calamospora rotunda sp. nov.

Pl. I, Fig. 9.

Occurrence: Sextant formation.

Holotype: Pl. I, Fig. 9. Slide A-3-3 (35.6 x 110.5), M.P.C.; 39 μ.

Diameter: 36.5 - 47 μ.

Ornamentation: Laevigate.

Other features:	Spore radial, trilete, circular. Laesurae simple, about 2/3 of the length of the radius of the spore. Wall thin but rigid in appearance. Sometimes folded, but folds short.
Similar forms:	cf. Archaeopteris latifolia Arnold 1939, pp. 307-311; Pl. I, Fig. 10,11. (Upper Devonian).
Remarks:	This species differs from C. tenuis in having a more rigid wall, fewer folds, and a shorter commissure. The microspores of Archaeopteris latifolia are slightly smaller in size (average 35 μ, Arnold 1939; about 30 μ Arnold 1953) but otherwise similar to Calamospora rotunda.

Calamospora dura sp. nov.

Pl. I, Fig. 10.

Occurrence:	Battery Point formation.
Holotype:	Pl. I, Fig. 10. Slide 28-15 (54 x 114.8), M.P.C.; 43.5 μ.
Diameter:	36 - 55 μ.
Ornamentation:	Laevigate.
Other features:	Spores radial, trilete, oval to circular. Laesurae 2/3 - 4/5 the length of the radius of the spore. Lips low and narrow. Commissure usually closed. Wall 1.5 - 2.5 μ thick, usually folded near the equator.
Similar forms:	Designate E28, Radforth and McGregor 1954, p. 612, Fig. 42. (Battery Point formation).

cf. Leiotriletes devonicus Naumova 1953, p. 22; Pl. I, Fig. 5. (Givetian-Famennian).

Remarks: Small size and a thick wall distinguish this species. According to the description given by Naumova (1953), L. devonicus differs only by its smaller size (20 - 28 μ).

Calamospora tenuis sp. nov.

Pl. I, Fig. 11.

Occurrence: Battery Point and Onondaga formations, and Perdrix equivalent.

Holotype: Pl. I, Fig. 11. Onondaga formation, slide A92-20 (49.6 x 122), M.P.C.; 51 μ.

Diameter: 29 - 62 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, elliptical to circular. Laesurae simple, often obscured by folds. Commissure extends almost to the equator of the spore. Wall thin, with numerous folds.

Similar forms: cf. Leiotriletes microrugosus (Ibrahim) Naumova (1949). p. 21, 42, 103; Pl. I, Fig. 1; Pl. V, Fig. 1: Pl. XVI, Fig. 1. (Silurian-Cretaceous).

Remarks: Some specimens of this species are wholly or in part minutely infrapunctate. This may be due to the effect of corrosion, either natural or artificial.

L. microrugosus Naumova may be in part synonymous with Calamospora tenuis. Naumova (1949) gives the size of Leiotriletes microrugosus as 0.030 - 0.122 mm. The same author (1950) refers to this species as widespread from Silurian to Cretaceous. Its size range in the Middle and Upper Devonian of the Moscow basin is 30 - 50 μ (Naumova 1953), which agrees closely with the dimensions of Calamospora tenuis.

Calamospora retusa sp. nov.

Pl. I, Fig. 12.

Occurrence: Onondaga formation.

Holotype: Pl. I, Fig. 12. Slide 432-13 (65.8 x 118.3), M.P.C.; 72 μ.

Diameter: 64 - 77.5 μ.

Ornamentation: Laevigate. (Minutely scabrate under high magnification).

Other features: Spore radial, trilete, ovate. Laesurae simple, less than 1/4 the length of the radius of the spore, usually obscured by folds. Wall thin but opaque.

Similar forms: cf. Leiotriletes pullatus Naumova 1953, p. 22, 44, 121. Pl. I, Fig. 7. Pl. V, Fig. 12. (Givetian-Famennian).

Calamospora plicata (Waltz 1941) comb. nov.

Pl. I, Fig . 13, 14.

Occurrence: Battery Point formation.

Diameter: 63 - 115 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, subcircular. Laesurae simple, about 1/2 the length of the radius of the spore. Rays usually obscured by folding of the wall. Wall very thin.

Similar forms: Azonotriletes plicatus Waltz, in Luber and Waltz, 1941; Pl. XIV, Fig. 226.

Leiotriletes plicatus (Waltz) Naumova, 1953, p. 104; Pl. XVI, Fig. 4. (Devonian, Carboniferous, Permian).

Calamotriletes plicatus (Waltz) Luber 1955, p.36; Pl. I, Fig. 4. (Lower Carboniferous).

cf. Calamospora type A, Hoffmeister et al., 1955 b, p. 382; Pl. 38, Fig. 17. (Upper Mississippian).

cf. C. münstereifelensis Thomson 1952, p. 159; Pl. 10, Figs. 10-13. (Lower Devonian).

Remarks: Spores assignable to this species are known from various localities, from Lower Devonian to Permian (Naumova 1953). Because of the lack of differentiation of the features of this species, and its extended geological range, it is reasonable to conclude that it embodies spores of various affinities, some of which may be immature.

Calamospora perplexa sp. nov.

Pl. I, Fig. 15.

Occurrence: Battery Point formation.

Holotype: Pl. I, Fig. 15. Slide 28-15 (48.8 x 112.7), M.P.C.; 90 μ.

Diameter: 80 - 116 μ.

Ornamentation: Laevigate, or with sparse, irregularly scattered small granules.

Other features; Spore trilete (?), oval to circular. Wall strongly folded on all specimens and distinctly thicker than that of *C. plicata* (1.5 - 2 μ). Faint lines suggestive of trilete laesurae visible on some specimens, but the existence of these structures is not proven.

Similar forms: Designate C_3 ", Radforth and McGregor 1954, p. 605; Pl. II, Fig. 48. (Battery Point formation).

Remarks: This type resembles the body of *Archaeozonotriletes crenorugosus* (Pl. VII, Fig.6).

Calamospora compacta sp. nov.

Pl. I, Fig.20.

Occurrence: Battery Point formation.

Holotype: Slide 28-21 (39.5 x 108), M.P.C. 124 μ.

Diameter: 101 - 130 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, ovate to circular. Laesurae more than 1/2 the length of the radius of the spore. Lips low. Wall 2 - 2.5 μ thick, and usually strongly folded. Folds close to the periphery often increase the apparent wall thickness.

Calamospora umbrata sp. nov.

Pl. I, Fig. 18.

Occurrence: Sextant formation.

Holotype: Pl. I, Fig. 18. Slide A-3-3 (43 x 103.9), M.P.C.; 64 μ.

Diameter: 50 - 70 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, ovate to circular. Laesurae 1/2 to 2/3 the length of the radius of the spore. Lips low. Wall slightly darkened adjacent to the rays in the interradial angles (= area contagionis). Wall about 1 μ thick, usually with one long fold.

Similar forms: cf. "Spore-type D" of Lang 1925, p. 257; Fig. 8. (Middle Devonian).

Remarks: Lang's type D has a slightly thinner wall than C. umbrata but is otherwise similar to it. C. saariana Bhardwaj (1957) differs in having longer laesurae, and probably a thinner exine.

Calamospora contagionis sp. nov.

Pl. I, Fig. 16.

Occurrence: Sextant formation.

Holotype: Pl. I, Fig. 16. Slide C-1-5 (60.7 x 118), M.P.C.; 70 μ

Diameter: 57.5 - 72 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, circular. Laesurae about 3/5 the length of the radius of the spore. Margins of commissure often faintly serrate. Lips low. Area contagionis distinct. Wall 1 - 1.5 μ thick.

Similar forms: cf. Leiotriletes atavus Naumova 1953, p. 23, 103; Pl. I, Fig. 8; Pl. XVI, Fig. 3; Pl. XXII, Fig. 107. (Middle and Upper Devonian).

Remarks: *L. atavus* is similar to *Calamospora contagionis*, but lacks the serrate condition of the commissure which is sometimes present in the latter species.

Calamospora radiegranulata sp. nov.

Pl. I, Fig. 19.

Occurrence: Sextant formation.

Holotype: Pl. I, Fig. 19. Slide A-5-6 (64.8 x 115), M.P.C.; 71 μ.

Diameter: 62 - 75 μ.

Ornamentation: Laevigate, except the *area contagionis*, which possesses low granules. The granules are so closely spaced that their bases are sometimes in contact with one another, forming a rugulate pattern.

Other features: Spore radial, trilete, circular. Laesurae 3/4 to 4/5 the length of the radius of the spore. Wall thin, occasionally folded.

Remarks: The granulate pattern of the interradial areas characterizes this species.

Calamospora sp. A.

Pl. I, Fig. 17.

Occurrence: Sextant formation.

Diameter: 52 μ. (One specimen only).

Ornamentation: Spore radial, trilete, subcircular. Laesurae simple, extend 3/4 the distance to the equator. *Area contagionis* distinct, has arcuate outer margin. Wall thin (except for the *area contagionis* ?), and folded.

Similar forms: *cf. C. mutabilis* (Loose) Schopf, Wilson and Bentall 1944, in Potonié and Kremp 1955, p. 49; Pl. 11, Fig. 133. (Westphalian-Stephanian).

cf. Macrostachya infundibuliformis Brongn, in Hartung 1933. (Westphalian).

cf. Palaeostachya decacnema Delevoryas 1955, p. 483; Fig. 15. (Pennsylvanian).

cf. Mazostachys pendulata Kosanke 1955, p. 16; Pl. 6, Fig. 6. (Middle Pennsylvanian (Carbondale)).

Remarks: *Calamospora mutabilis* is larger than the Sextant specimen but otherwise similar to it. The *area contagionis* is not so sharply defined in spores of *Macrostachya infundibuliformis*. Spores of *Mazostachys pendulata* have shorter trilete rays, and those of *Palaeostachya decacnema* have a thin perisporium. Chaloner (1953a, 1953b), and Schopf (1941) have described spores, of similar size to our specimens, which possess interradial dark spots, from lycopsid cones.

Genus: *Punctati-sporites* (Ibrahim) Potonié and Kremp 1954.

Punctati-sporites nitidus sp. nov.

Pl. II, Fig. 1.

Occurrence: Melville Island formation.

Holotype: Pl. II, Fig. 1. Slide MI-12 (58.5 x 105.7), M.P.C.; 64 μ.

Diameter: 64 - 68 μ.

Ornamentation: Scabrate, ornamentation faintly visible at margin.

Other features: Spore radial, trilete, subtriangular to ovate. Laesurae extend almost to the equator of the spore. Commissure distinct, lips low. Wall 1 μ thick.

Punctati-sporites scabratus sp. nov.

Pl. II, Fig. 2.

Occurrence: Melville Island formation.

Holotype: Pl. II, Fig. 2. Slide MI-32 (62.1 x 103.8), M.P.C.; 66 μ.

Diameter: 59 - 66 μ.

Ornamentation: Scabrate. Ornamentation minute.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae about 2/3 the length of the radius of the spore. Lips narrow, distinct. Wall 2 - 3 μ thick.

Similar forms: cf. Punctati-sporites orbicularis Kosanke, 1950, p. 16. Pl. II, Fig. 9. (Upper Pennsylvanian (McLeansboro)).

Remarks: P. scabratus is larger than P. orbicularis but otherwise identical with it.

Punctati-sporites putaminis sp. nov.

Pl. II, Fig. 3.

Occurrence: Melville Island formation.

Holotype: Pl. II, Fig. 3. Slide MI-23 (25 x 122.1), M.P.C.; 65 μ.

Diameter: 59 - 73 μ.

Ornamentation: Scabrate, Visible at margin under high power.

Other features: Spore radial, trilete, ovate to circular. Laesurae about 2/3 the length of the radius of the spore. Lips low. Wall 2.5 - 5.5 μ thick.

Remarks: The wall of this species is unusually thick for spores of the genus.

Genus: Granulati-sporites (Ibrahim 1933), Potonié and Kremp 1954.

Granulati-sporites minutissimus (Naumova 1953), comb. nov.

Pl. II, Fig. 4.

Occurrence: Sertant and Onondaga formations. U.S.S.R.: Givetian-Famennian, Moscow basin.

Diameter: 15 - 28 μ.

Similar forms: Lophotriletes minutissimus Naumova 1953, p. 56; Pl. VII, Fig. 11. (Middle and Upper Devonian).

cf. Cyclogranisporites pressoides Potonié and Kremp 1955, p. 62; Pl. 13, Fig. 187-190. (Westphalian).

cf. Apiculatisporites levis Balme and Hennelly 1956b, p. 246; Pl. 2, Fig. 19-21. (Permian).

Remarks: In appearance, agrees closely with the Pennsylvanian genus Cyclogranisporites pressoides especially with Fig. 187 and 190 (Potonié and Kremp 1955), which are distinctly subtriangular in outline. But, since the latter authors describe this species as nearly circular in outline, while ours is typically broadly subtriangular, the two are not placed in synonymy.

Ornamentation on the proximal side of Apiculatisporites levis is reduced. It is not clear whether or not our specimens possess this feature.

Genus: *Cyclogranisporites* Potonié and Kremp 1954.

Cyclogranisporites mediocris sp. nov.

Pl. II, Fig. 8.

Occurrence: Battery Point formation.

Holotype: Pl. II, Fig. 8. Slide 28-15 (44.3 x 110.7), M.P.C.; 60 µ.

Diameter: 35 - 84 µ.

Ornamentation: Granulate. Granules minute and closely spaced, visible very faintly at the periphery of the spore.

Other features: Spores radial, trilete, broadly subtriangular to circular. Laesurae simple, more than 2/3 the length of the radius of the spore. Wall thin, usually folded.

Similar forms: *cf. Granulati-sporites micaceus* Imgrund 1952, p. 23. Pl. 2, Fig. 30, 31. (Permian).

cf. Cyclogranisporites aureus (Loose) Potonié and Kremp 1955, p. 61. Pl. 13, Fig. 184-186. (Westphalian).

cf. Lophotriletes rugosus Naumova 1950, p. 26. Pl. II, Fig. 5. (Lower Silurian).

cf. L. magnus Naumova 1953, p. 58. Pl. VII, Fig. 20. (Givetian-Famennian).

Remarks: *Granulati-sporites micaceus* Imgrund and *Cyclogranisporites aureus* (Loose) Potonie and Kremp both fall within the size range of *C. mediocris*. Because of their close similarity to the Devonian species in all other respects, they are regarded as synonymous with it, although they are not synonymous with each other.

Two of Naumova's species, *Lophotriletes rugosus* and *L. magnus* also fall within the broad diameter range of *Cyclogranisporites mediocris*. These two species are ornamented with " ... closely spaced small tubercles ...", but the size of the tubercles is not defined. Also, Naumova's illustrations are too diagrammatic for critical comparison, and type specimens are not available. For these reasons, and because of the broader size range of *C. mediocris*, the foregoing species are not here regarded as synonymous with the latter.

Cyclogranisporites concisus sp. nov.

Pl. II, Fig. 6.

Occurrence: Battery Point formation.

Holotype: Pl. II, Fig. 6. Slide 28-21 (44.1 x 108.8), M.P.C.; 74 μ.

Diameter: 54 - 85 μ.

Ornamentation: Granulate. Granules small and closely spaced.

Other features: Spore radial, trilete, ovate to circular. Laesurae simple and about 1/4 the length of the radius of the spore. The rays are often obscured by folding of the wall. Wall thin.

Remarks: Superficially, this species resembles intact specimens of *Archaeozonotriletes contagionis*. (Pl. VII, Fig. 5).

Cyclogranisporites amplus sp. nov.

Pl. II, Fig. 7.

Occurrence: Melville Island formation.

Holotype: Pl. II, Fig. 7. Slide MI-22 (52.1 x 110), M.P.C.; 96 μ.

Diameter: 77 - 121 μ.

Ornamentation: Small, rounded, distinct granules.

Other features: Spore radial, trilete, broadly subtriangular to ovate or circular. Laesurae simple, 1/2 to 2/3 the length of the radius of the spore. Wall 1.5 - 3.5 μ thick.

Similar forms: cf. Cyclogranisporites sp., Hoffmeister et al. 1955a, Pl. I, Fig. 12. ("Upper Devonian, Alberta.")

cf. spores of Acitheca (Pecopteris) longifolia R. and W. Remy 1955, p. 46; Pl. 17, Fig. 11-14; Pl. 18, Fig. 1. (Upper Carboniferous).

Series: Apiculati (Bennie and Kidston) Potonié and Kremp 1954.

Genus: Perimetrisporites gen. nov.

Genotype: Perimetrisporites mundus sp. nov.

Generic diagnosis: Trilete miospores of subtriangular outline, which bear small more or less elongate projections equatorially, in depressions in the interradial margins. Wall thin.

Perimetrisporites parvus sp. nov.

Pl. II, Fig. 5,9,10,15. Pl.XIII, Fig. 1.

Occurrence: Sextant and Battery Point formations.

Holotype: Pl. II, Fig. 9. Sextant formation, Slide A-3-3 (70.9 x 114), M.P.C.; 33 μ.

Paratype: Pl. II, Fig. 10. Sextant formation, Slide A-17-14, (32.1 x 112.3), M.P.C.; 35 μ.

Diameter: 22 - 38 μ.

Ornamentation: Distal portion with small papillae, about 1 μ in length.

Proximal portion finely granulate. In the interradial depressions the papillae are up to 2.5 µ long.

Other features: Spore radial, trilete, subtriangular. Margins between radii straight or slightly concave. Profile anisopolar; Proximal portion flattened, distal slightly conical. (Pl. II, Fig. 5). Laesurae extend almost to the equator of the spore. Commissure closed, or gaping (Pl. II, Fig. 9). Interradial walls depressed at the equator and proximally, the depressions appearing as shallow arcuate hollows when the spore is viewed transversely. (Pl. II, Fig. 9). The hollows are inconspicuous in laterally compressed specimens. This characteristic feature is well-developed on some examples (Pl. XIII, Fig. 1), but poorly expressed or not evident on others. (Pl. II, Fig. 10).

Similar forms: cf. Hemitelia Karsteniana Kl., in Knox, 1938, p. 455, Fig. 79. (Recent).

Remarks: The spores of the present-day fern Hemitelia Karsteniana are the only spores, living or fossil which are known to possess interradial features of the order of those found in Perimetrisporites. It would not be wise to speculate on possible relationships between these two forms, because of the great difference in their ages.

The interradial ornamentations of Reinschospora Schopf, Wilson and Bentall (1944) and Tholosporites Balme and Hennelly (1956b) are not comparable.

<u>Perimetrisporites</u> <u>mundus</u> sp. nov.

Pl. II, Fig. 13, 14. Pl. XIII, Fig. 2, 3.

Occurrence: Sextant formation.

Holotype: Pl. II, Fig. 13. Slide C-1-5 (57.8 x 112.1), M.P.C.; 46 μ.

Diameter: 36 – 60 μ.

Ornamentation: Distal portion granular; proximal portion laevigate, except for "caps" of granular ornamentation at the apices, where the ornamentation of the distal face continues on to the proximal hemisphere.

Other features: Spore radial, trilete, subtriangular. Margins between radii slightly concave. Spore anisopolar in profile; proximal and distal portions somewhat flattened. (Pl. II, Fig. 14).

Interradial structures are similar to those of <u>P. parvus</u>, but the depressions are bordered in some specimens by short tangential lobes (Pl. XIII, Fig. 2). The lobes are much reduced, or not evident, on other specimens (Pl. XIII, Fig. 3).

Laesurae 1/2 to 3/4 the length of the radius of the spore. Commissure distinct, usually slightly open. Lips low, prominent.

Genus: <u>Plani-sporites</u> (Knox) Potonié and Kremp 1954.

<u>Plani-sporites</u> <u>minimus</u> sp. nov.

Pl. II, Fig. 12.

Occurrence: Melville Island formation.

Holotype: Pl. II, Fig. 12. Slide MI-22 (63.4 x 116), M.P.C.; 43.5 μ.

Diameter: 32 - 44.5μ

Ornamentation: Minutely echinate. Elevations distinctly conelike, less than 1μ long, and of about equal size.

Other features: Spore radial, trilete, circular. Laesurae about 2/3 the length of the radius of the spore. Lips low. Wall 1μ thick, unfolded.

Similar forms: cf. Lophotriletes rotundus Naumova 1953, p. 58, 96, 108; Pl. VIII, Fig. 19; Pl. XV, Fig. 11; Pl. XVI, Fig. 29, 30. (Middle and Upper Devonian).

cf. Fig. 41, Knox 1939. (Upper Carboniferous).

cf. Cyclogranisporites parvipunctatus (Kosanke) Bhardwaj, 1957, p. 85. Pl. 23, Fig. 3-6. (Upper Carboniferous).

Remarks: According to the drawings of Naumova, the rays of Lophotriletes rotundus Naumova vary in length and lips are not present. The ornamentation of Cyclogranisporites parvipunctatus (Kosanke) Bhardwaj consists of hemispherical granules while those of Plani-sporites minimus are distinctly conelike.

Plani-sporites dilucidus sp. nov.

Pl. II, Fig. 11.

Occurrence: Melville Island formation.

Holotype: Pl. II, Fig. 11. Slide MI-22 (60.6 x 116), M.F.C.; 60μ

Diameter: 51 - 67μ

Ornamentation: Echinate. Elevations conelike, less than 1μ long, about 80 visible on the circumference.

Other features: Spore radial, trilete, circular. Laesurae 2/3 to 3/4 the length of the spore radius. Lips low. Wall 1μ thick.

Similar forms: cf. Lophotriletes subrotundatus Naumova 1953, p. 27; Pl. II, Fig. 2. (Upper Givetian and Frasnian).
cf. Spores of Crossotheca Hoeninghausi Brongniart in Kidston, 1923, p. 332; Pl. LXXXVII, Fig. 5-10. (Upper Carboniferous).

Remarks: Lophotriletes subrotundatus has simple laesurae, but otherwise is probably identical with Plani-sporites dilucidus. Spores obtained from sporangia of Crossotheca Hoeninghausi closely resemble Plani-sporites dilucidus.

Genus: Lophotriletes (Naumova) Potonié and Kremp 1954.

Lophotriletes dentis sp. nov.

Pl. II, Fig. 16.

Occurrence: Sextant formation.

Diameter: 28 - 35μ.

Ornamentation: Echinate. Projections blunt when over-macerated.

Other features: Spore radial, trilete, subtriangular. Margins straight or slightly convex. Laesurae simple, almost as long as the radius of the spore. Wall thin, occasionally folded.

Similar forms: Acanthotriletes rugatus Naumova 1953, p. 48; Pl. V, Fig. 26. (Givetian-Famennian).

Remarks: Although Lophotriletes dentis is synonymous with Acanthotriletes rugatus, a new specific epithet must be introduced, because the binomial Lophotriletes rugatus is occupied (Naumova 1953).

Lophotriletes varius sp. nov.

Pl. II, Fig. 27.

Occurrence: Battery Point formation.

Holotype: Pl. II, Fig. 27. Slide 20-14 (29.4 x 114.7), M.P.C.; 54 μ.

Diameter: 37.5 - 56 μ.

Ornamentation: Granulate-papillate, i.e. projections more or less as long as wide or elongate, occasionally tapered, up to 2 μ in length. Both extremes of ornamentation may occur on the same specimen.

Other features: Spore radial, trilete, broadly subtriangular to ovate. Laesurae simple, at least 1/2 the length of the radius of the spore. Wall thin, often with one to a few folds.

Similar forms: cf. *L. impalpabilis* Naumova 1949, p. 55, Pl. II, Fig. 15. (Lower Cambrian).

Remarks: *L. impalpabilis* is in close agreement with *L. varius* in most of its features. A critical comparison is not possible from Naumova's description and illustrations.

The form here designated as the holotype of *L. varius* was illustrated by Radforth and McGregor (1954), Fig. 41, and accompanied by a brief description.

Genus: *Apiculatisporis* Potonié and Kremp 1956.

Apiculatisporis teneris sp. nov.

Pl. XI, Fig. 23.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XI, Fig. 23. Onondaga formation, slide 432-13 (17.8 x 118.2), M.P.C.; 60 μ.

Diameter: 42.5 - 66 μ.

Ornamentation: Delicate, small projections, some equidimensional, others slightly longer than wide, either tapered or untapered. Projections visible on margin distinctly.

Other features: Spore radial, trilete, circular. Laesurae simple, 1/2 to 3/4 the length of the radius of the spore. Wall thin. Laesurae often obscured by folding of the exine.

Similar forms: cf. Osmunda-sporites primarius Wolff 1935, in Rouse 1956, p. 51, Pl. XI, Fig . 57,58. (Cretaceous).

Remarks: Rouse points out the identity of appearance of O. primarius and spores of the present-day fern Osmunda claytoniana.

Spores similar to these have been reported throughout most geological periods, from Devonian to Recent (Radforth and Rouse,1956). For this reason, it is difficult to assess the degree of natural affinity which is signified by identity of form for these spores.

Apiculatisporis elegans sp. nov.

Pl. II, Fig. 18.

Occurrence: Melville Island formation.

Holotype: Pl. II, Fig. 18. Slide MI-12 (29.5 x 119), M.P.C.; 84 μ.

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 2/3 the length of the radius of the spore. Commissure simple.

Wall thin, rarely folded.

Apiculatisporis obtusus sp. nov.

Pl. II, Fig. 22.

Occurrence: Sextant formation.

Holotype: Pl. II, Fig. 22. Slide C-1-5 (31 x 105.5), M.P.C.; 32 μ.

Diameter: 30 - 35 μ.

Ornamentation: Echinate. Spines up to 3 μ in length, irregularly disposed, largest in the equatorial region. Often, spines are blunt-tipped or broad where two adjacent ones are coalescent.

Other features: Spores radial, trilete, broadly triangular to circular. Laesurae extend to the equator of the spore. Lips low. Wall about 1.5 μ thick at the equator, slightly thinner toward the poles.

Similar forms: cf. Acanthotriletes uncatus Naumova 1953, pp. 28-30; Pl. I, Fig . 23,24; Pl. V, Fig. 36. (Upper Givetian and Lower Frasnian).

Remarks: According to Naumova's illustrations, A. uncatus may be almost identical with Apiculatisporis obtusus, as in her Pl. I, Fig. 23, or it may be quite different in appearance, as in her Pl. V, Fig. 36. This fact indicates a broader interpretation of the features comprising her species than is given for A. obtusus.

(?) Apiculatisporis sp. A.

Pl. II, Fig. 21.

Occurrence: Onondaga formation.

Diameter: 20 - 38.5 μ.

Ornamentation: Apiculate. Projections 1 - 2 μ long, up to 1.5 μ wide at their base, and 2 - 5 μ apart.

Other features: No laesurae were observed on spores of this form. Wall thin, occasionally folded. Outline ovate to circular.

Similar forms: cf. Acanthotriletes crassus Naumova 1950, p. 179; Pl. I, Fig. 13-15. (Lower Silurian).

Remarks: A. crassus is trilete, but otherwise similar to Apiculatisporis sp. A.

(?) Apiculatisporis sp. B.

Pl. II, Fig. 19.

Occurrence: Battery Point formation.

Diameter: 48 μ (one specimen only).

Ornamentation: Closely crowded, tapered apiculations, which are sharp - or blunt - tipped. Apiculations vary in length, up to 3.5 μ, and are occasionally as wide as 3 μ at their base.

Other features: No laesurae observed. Outline circular. Wall thin, unfolded.

Similar forms: cf. Acanthotriletes serratus Naumova 1953, p. 25, Pl. I, Fig . 19,20. (Upper Givetian).

Remarks: A. serratus is trilete, but in other respects is apparently identical with (?) Apiculatisporis sp. B.

(?) Apiculatisporis sp. C.

Pl. II, Fig. 20.

Occurrence: Onondaga formation.

Diameter: 45 - 56 μ.

Ornamentation: Echinate. Projections up to 2 μ long, 2 - 5 μ apart. The bases of some of the projections are connected by thin lines which form a faintly discernible reticulate pattern on some specimens.

Other features: No laesurae observed. Outline ovate to circular. Wall thin, rarely folded.

Genus: Anapiculatisporites Potonié and Kremp 1954.

Anapiculatisporites brevispinosus sp. nov.

Pl. II, Fig. 24,25.

Occurrence: Battery Point formation.

Holotype: Pl. II, Fig. 24. Slide 28-33 (59.5 x 109.9), M.P.C.; 27 μ.

Diameter: 20 - 33 μ.

Ornamentation: Distal portion echinate; proximal portion laevigate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae 1/2 to 4/5 the length of the radius of the spore. Lips low. Wall thin, occasionally folded.

Remarks: A. spinosus (Kosanke) Potonié and Kremp 1954, is similarly constructed except that the projections are distinctly longer (up to 4 μ long according to Kosanke 1950).

Genus: Acanthotriletes (Naumova) Potonié and Kremp 1954.

Acanthotriletes spinellosus Naumova 1953, p. 23, Pl. I, Fig. 11,12.

Pl. II, Fig. 26.

Occurrence: Battery Point formation. U.S.S.R.: Upper Givetian.

Diameter: 36 - 53 μ.

Acanthotriletes inconfertus sp. nov.

Pl. II, Fig. 28.

Occurrence: Onondaga formation.

Holotype: Pl. II, Fig. 28. Slide 432-20 (53.2 x 104.7) M.P.C.; 62 μ.

Diameter: 62 - 75 μ.

Ornamentation: Distinct papillae, slightly or not at all tapered, 1 - 2 μ long, up to three times as long as wide.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae simple, 1/2 - 2/3 as long as the radius of the spore. Wall thin.

Acanthotriletes robustus sp. nov.

Pl. II, Fig. 29.

Occurrence: Sextant formation.

Holotype: Pl. II, Fig. 29. Slide S-1-5 (29.5 x 112), M.P.C.; 70 μ.

Diameter: 60 - 83 μ.

Ornamentation: Papillate. Projections 1 - 2 μ wide, up to 4 μ long, 3 - 5 μ apart, rounded or pointed at tips, occasionally slightly tapered. The projections are distinctly variable in size.

Other features: Spores radial, trilete, elliptical to circular. Laesurae 4/5 to 5/6 the length of the radius of the spore. Lips low and narrow. Wall 1 - 1.5 μ thick.

(?) Acanthotriletes sp. A.

Pl. II, Fig. 27.

Occurrence: Battery Point formation.

Diameter: 49 μ (one specimen only).

Ornamentation: Closely crowded, attenuate spines, up to 2.5 μ long, more than twice as long as wide.

Other features: No laesurae observed. Specimen folded, probably originally circular. Wall thin.

Similar forms: cf. Acanthotriletes tenuispinosus Naumova 1953, pp. 25, 49. Pl. I, Fig. 17; Pl. V, Fig. 32. (Upper Givetian). cf. A. ciliatus (Knox) Potonié and Kremp 1954, p. 133. Also in Potonié and Kremp 1955, p. 84; Pl. 14, Fig. 257. (Middle Westphalian C).

Remarks: Although both of the foregoing species resemble A. sp. A. very closely, they are not placed in synonymy with it because the range of variation of the latter is not yet established.

Genus: Raistrickia (Schopf, Wilson and Bentall) Potonié and Kremp 1954.

Raistrickia difficilis sp. nov.

Pl. III, Fig. 1.

Occurrence: Battery Point formation.

Holotype: Pl. III, Fig. 1. Slide 26-14 (26.8 x 116.2), MpP.C.; 79 μ.

Diameter: 70 - 81 μ.

Ornamentation: Large, blunt-tipped nodules, up to 15 μ wide at their base and as much as 8 μ long, slightly tapered.

Other features: Spore trilete (?), ovate to circular. Wall about 2 μ thick, and rigid in appearance. Occasionally low folds connect the bases of some of the nodules. Faint markings suggestive of a simple trilete scar were visible on two specimens. The fact that the outline is subovate suggests that the spores are or were trilete.

Remarks: The specimen designated here as the holotype of R. difficilis was figured by Radforth and McGregor (1954) as designate J5.

Genus: Converrucosisporites Potonié and Kremp 1954.

Converrucosisporites semilevis sp. nov.

Pl. III, Fig. 3,4.

Occurrence: Battery Point formation.

Holotype: Pl. III, fig. 3,4. Slide 24-15 (57.6 x 114.9), M.P.C.; 58.5 μ.

Diameter: 49.5 - 62 μ.

Ornamentation: Distal portion verrucate; projections densely spaced, blunt, rounded or flattened at their tips, 2 - 4.5 μ wide, 1.5 - 3 μ long, only slightly or not at all tapered. Outline of projections irregular, often angular in transverse view. Diameter of projections tends to increase in the vicinity of the distal pole. Proximal portion laevigate.

Other features: Spore radial, trilete, subtriangular to ovate. Laesurae almost as long as the radius of the spore. Commissure open or closed. Lips distinct, but low. Wall thin.

Similar forms: Designate H_7 ', Radforth and McGregor 1954, p. 613, Fig. 52. (Battery Point formation).

Genus: Verrucosi-sporites (Ibrahim) Potonié and Kremp, 1954.

Verrucosi-sporites variabilis sp. nov. Pl. III, Fig. 2.

Occurrence: Melville Island formation.

Holotype: Pl. III, Fig. 2. Slide MI-12 (30.9 x 106.8), M.P.C.; 68 µ.

Diameter: 43 - 76 µ.

Ornamentation: Broad, tapering pointed spines, up to 6 µ long, basal diameter about equal to their height; occasional rounded projections, which may reach 12 µ in diameter at their base and 10 µ in height. The complete range of variation of projections may occur on one specimen.

Other features: Spore radial, trilete, circular. Laesurae simple, at least 1/2 the length of the radius of the spore. Wall thin.

Remarks: This species bears a superficial resemblance to Raistrickia rubida Kosanke 1950, but the spore wall is much thickened in the latter.

Genus: Archaeotriletes (Naumova 1953) emend.

Genotype: A. delectabilis sp. nov.

Generic diagnosis: Trilete miospores and megaspores bearing long appendages with widened, or bifurcate, grapnel-like tips. Bases of appendages expanded, often bulbous.

In her generic diagnosis, Naumova compares Archaeotriletes to (mega-) spores of the present day water-fern Azolla.

The similarity which Naumova notes is only superficial, however, the bifurcate glochidia of Azolla having no evident homologue in the Devonian genus. The megaspore of the living and fossil Azolla is papillate, but has no elaborate processes such as are present in Archaeotriletes (Arnold, 1955).

Since Naumova did not specify a genotype, A. delectabilis is here so designated.

Archaeotriletes delectabilis sp. nov.

Pl. III, Fig. 5-8; Pl. XIII, Fig. 6.

Occurrence: Melville Island formation.

Holotype: Pl. III, Fig. 8. Slide MI-16 (64.11 x 113), M.P.C.; 206 μ.

Diameter: 145 - 340 μ, exclusive of appendages.

Ornamentation: Scabrate. Body also covered with characteristic large appendages with grapnel-like bifurcations at their tips. (Pl. III, Fig. 5,6). (Pl. XIII, Fig. 6). Appendages about 1/3 to 2/3 the length of the spore radius. Bases of appendages expanded, often bulbous. Appendages are present on all portions of the wall, including the proximal face.

Other features: Spore radial, trilete, circular. Laesurae almost as long as the radius of the spore. Lips prominent, convoluted. Commissure usually obscured. Laesurae poorly defined on many specimens. Wall thin.

Similar forms: See Table IV.

TABLE IV

PREVIOUS RECORDS OF SPORES WITH GRAPNEL-LIKE APPENDAGES

Reference	Designation	Body diameter	Length of appendages	Age	Locality
Lang, 1925	Type G_1 Type G_2	ca. 200 μ ca. 115 μ	ca. 30 μ	Middle Devonian	Cromarty, Scotland
Krausel & Weyland, 1929	Aneurophyton germanicum?	60 - 200 μ	ca. 1/5 - 1/3 body diameter	Middle Devonian	Elberfeld, Germany
Arnold, 1933, 1935	Lepidostrobus Gallowayi	ca. 150 μ or more		Upper Devonian	Pennsylvania
Arnold, 1936		120 - 200 μ	ca. 1/4 - 1/2 body diameter	Upper Devonian (= Portage - Chemung ?)	Scaumenac Bay, Quebec
Arnold, 1936	"...referable to Type G..."			Upper Devonian	Pittston, Pennsylvania
Høeg, 1942	Spore type e Spore type f	250 μ 120- 150 μ	50 - 60 μ ca. 20 μ	Upper Middle Devonian (or lowermost Upper Devonian)	Spitzbergen
Naumova, 1953	Archaeotriletes spp.	up to 120 μ	various	Middle and Upper Devonian	Russian Platform
Luber, 1955	Azonotriletes ancistrophorus	80 - 110 μ		Lower Carboniferous	Kazakhstan
Hoffmeister et al., 1955	"new genus"	ca. 60 - 70 μ	ca. 1/3 - 2/3 body diameter	Upper Devonian	Alberta

Remarks: "Spore type e" of Høeg (1942) agrees most closely with *A. delectabilis* in size and dimensions of spines.

Trilete spores with similarly constructed appendages have not been reported from rocks other than Middle and Upper Devonian and Lower Carboniferous. The unique and constant construction of the appendages would suggest derivation of the spores from a group of closely related extinct plants.

Examples of spores with similar structure in association with fructifications are rare and poorly defined. Kräusel and Weyland (1929) found a spore with bifurcate appendages, but only 15 μ in diameter, associated with *Aneurophyton germanicum*. Isolated spores with this feature occurred in the same locality but they measured 60 - 200 μ. The spores that Arnold (1933, 1935) has reported from the lycopodiaceous strobilus *Lepidostrobus Gallowayi* were poorly preserved, but apparently similar to *Archaeotriletes*.

Series: Murornati Potonié and Kremp 1954

Genus: *Convolutispora* Hoffmeister, Staplin and Malloy, 1955.

Convolutispora dissimilis sp. nov.

Pl. III, Fig. 9.

Occurrence: Battery Point formation.

Holotype: Pl. III, Fig. 9. Slide 28-13 (22.9 x 122.5), H.F.C.; 89 μ.

Diameter: 89 - 99 μ.

Ornamentation: Distal portion and peripheral part of proximal portion rugulate. Ridges irregularly anastomosing. Proximal face laevigate to within about 10 µ of the equator.

Other features: Spore radial, trilete, subcircular. Laesurae to periphery of laevigate proximal face. The thin-walled proximal portion is often lacking presumably because of the adverse effect of preservation or maceration.

<u>Convolutispora</u> <u>tessellata</u> Hoffmeister, Staplin and Malloy 1955b, p. 385; Pl. 38, Fig. 9.

Pl. III, Fig. 10.

Occurrence: Perdrix equivalent.

Similar forms: <u>cf</u>. <u>Azonotriletes</u> <u>tuberculatus</u> Waltz, in Luber and Waltz 1938, Pl. I, Fig. 12, and Pl. A, Fig. 6. (Tournaisean-Visean).

<u>cf</u>. <u>Filicitriletes</u> <u>tuberculatus</u> forma <u>karagandensis</u> Luber 1955, p. 54; Pl. II, Fig. 48, 49. (Lower Carboniferous).

Remarks: This species occurs in the Upper Mississippian of Illinois and Kentucky (Hoffmeister <u>et</u> <u>al</u>.) as well as in the Lower Carboniferous of Russia. It is reported here for the first time in Devonian rocks.

<u>Convolutispora</u> <u>rugulata</u> sp. nov.

Pl. III, Fig. 11, 12.

Occurrence: Melville Island formation.

Holotype: Pl. III, Fig. 12. Slide MI-22 (53.1 x 121.7), M.P.C.; 51 µ.

Diameter: 47 - 81 μ.

Ornamentation: Coarsely rugulate. Rugulae wide (up to 13 μ), low, irregularly disposed, anastomosing.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae 3/4 the length of the radius of the spore, but often obscured by the ornamentation of the exine. Lips low. Maximum wall thickness observed, 11 μ.

Remarks: The extreme coarseness of the ornamentation of C. rugulata distinguishes it from C. florida Hoffmeister et al. (1955b, p. 384; Pl. 38, Fig. 5, 6).

Genus: Cristatisporites Potonié and Kremp 1954.

Cristatisporites impeditus sp. nov.

Pl. III, Fig. 13.

Occurrence: Battery Point formation.

Holotype: Pl. III, Fig. 13, Slide 28-14 (30.2 x 110.4), M.P.C.; 78 μ.

Diameter: 76.5 - 116 μ.

Ornamentation: Entire surface thickly ornamented by transparent leaf-like anastomosing ridges, up to 13 μ high. It is not clear whether or not the ridges are arranged in a reticulate or striate pattern.

Other features: Spore trilete (?), subtriangular to ovate. No tetrad scar has been observed on this species, but the subtriangular outline suggests that it is triradiate.

Remarks: Spores with elevated transparent ridges disposed in a reticulate pattern, occur in some present-day Bryophyta (e.g. Fossombronia angulosa, in Knox 1939, Fig. 12) and in some Carboniferous spores (op cit., Fig. 50) as well as in some present-day ferns (cf. Asplenium spp., Knox 1952b, Harris 1955). No relationship between the recent and Paleozoic forms of this type can be suggested at present.

Cristatisporites speciosus sp. nov.

Pl. III, Fig. 14,15.

Occurrence: Sextant formation.

Holotype: Pl. III, Fig. 15. Slide A-3-3 (23.6 x 104.7), M.P.C.; 44.5 μ.

Diameter: 37 - 46 μ.

Ornamentation: Low, echinate to coarsely granular ornamentation disposed at intervals on the crests of narrow, irregularly anastomosing ridges.

Other features: Spores radial, trilete (?), broadly elliptical to circular. Trilete laesurae have not been definitely observed, but a tetrad was found. (Pl. III, Fig. 14).

Remarks: Although the tetrad of this species resembles a square one, it may be that it is tetrahedral, with the present appearance being caused by displacement of the components. The latter interpretation is preferred, because of the extreme rarity of monolete spores in Devonian sediments.

Genus: Dictyotriletes (Naumova) Potonié and Kremp, 1954.

Dictyotriletes minutus sp. nov.

Pl. III, Fig. 16.

Occurrence: Sextant formation.

Holotype: Pl. III, Fig. 16. Slide A-3-3 (41.4 x 114), M.P.C.; 19 μ.

Diameter: 18 - 25 μ.

Ornamentation: Reticulate. Muri thin, and less than 1 μ high; lacunae 2 - 3 μ in diameter.

Other features: Spore subtriangular to oval. Faint lines suggestive of a triradiate mark were seen on some specimens, but no distinct tetrad scar was observed. Wall thin, usually unfolded.

Dictyotriletes insolitus sp. nov.

Pl. III, Fig. 21

Occurrence: Sextant and Battery Point formations.

Holotype: Pl. III, Fig. 21. Sextant formation, slide C-1-5 (67.6 x 111.5), M.P.C.; 48 μ.

Diameter: 41 - 54 μ.

Ornamentation: Distal portion reticulate (or punctate, according to Kosanke, 1950). Lacunae 2.5 - 5 μ wide; muri up to 5 μ wide at base, thicker in areas of juncture of three adjacent "cells", and up to 5.5 μ high as seen at the periphery of the spore. Muri taper from broad base to rounded crest. Margin of spore crenulate. There is no evidence of superimposed reticulations, so the proximal side is judged to be smooth and very thin.

Other features: Spore broadly subtriangular in outline. Triradiate mark not distinct on any specimens. Faint features suggesting laesurae were observed on some specimens. The subtriangular outline of this species suggests that it was derived from a tetrahedral tetrad.

Remarks: *Dictyotriletes susus* (Loose) Potonié and Kremp 1955 and *Punctati-sporites quaesitus* Kosanke 1950 possess ornamentation of similar order to that of *Dictyotriletes insolitus*, but are not synonymous with it.

(?) *Dictyotriletes* sp. A.

Pl. III, Fig. 17.

Occurrence: Onondaga formation and Perdrix equivalent.

Diameter: 32 - 62 μ.

Ornamentation: Reticulate. Lacunae 2 - 5.5 μ wide, muri very low (1μ) and thin.

Other features: No tetrad scar has been observed. Wall thin. Outline subtriangular to circular.

Genus: *Reticulati-sporites* (Ibrahim) Potonié and Kremp 1954.

Reticulati-sporites ovoides sp. nov.

Pl. III, Fig. 22; Pl. XIII, Fig. 4,5.

Occurrence: Sextant and Battery Point formations.

Holotype: Pl. III, Fig. 22. Sextant formation, slide A-3-4 (40.5 x 113.4), M.P.C.; 83 μ.

Diameter: 58 - 102 μ.

Ornamentation: Distal portion reticulate. Lacunae 9 - 25 μ wide, muri up to 12 μ high. Muri thick at points of juncture of three adjacent lacunae. Lacunae may appear to overlap one another in transverse view, because the delicate muri are often slanted from the vertical position (Pl. XIII, Fig. 5). Proximal portion smooth to faintly infragranulate. Margin crenulate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae simple, almost as long as the spore radius, but rarely visible, probably because the thin proximal wall has been lost. Occasionally, loosely adhering tetrads were encountered, tetrahedral in form (P. XIII, Fig. 4).

Remarks: Lundblad (1954, p. 401) notes that Reticulati-sporites forms have been reported from the Palaeozoic, Mesozoic and Tertiary. Knox (1950, p. 335) says that "... a large proportion of the fossil spores assigned to ... the genus ... Reticulati-sporites are of Lycopodian affinity ...", but that " ... close parallels can also be drawn with spores of the Hepaticae."

Reticulati-sporites subgranifer sp. nov.

Pl. III, Fig. 20

Occurrence: Sextant formation.

Holotype: Pl. III, Fig. 20. Slide A-17-4 (25 x 117.4), M.P.C.; 57 μ.

Diameter: 49 - 59 μ.

Ornamentation: Reticulate. Lacunae 6 - 13 μ in diameter; muri narrow, up to 5 μ high. Wall between muri granulate; granules irregularly spaced.

Other features: Spore radial, trilete, sub-elliptical. Laesurae extend to the equator of the spore. Commissure closed. Lips present.

Reticulati-sporites sp. A.

Pl. III, Fig. 18.

Occurrence: Battery Point formation.

Diameter: 46 μ. (One specimen only).

Ornamentation: Distal portion reticulate. Muri thin, 1.5 μ or less in height. Lacunae irregular in outline, 7 - 14 μ in diameter. Proximal portion laevigate.

Other features: Spore radial, trilete, circular. Laesurae distinct, equal in length to the radius of the spore. Lips present. Wall thin.

Reticulati-sporites sp. B.

Pl. III, Fig. 19

Occurrence: Sextant formation.

Diameter: 47 μ. (One specimen only).

Ornamentation: Distal portion reticulate. Lacunae 7 - 12 μ in diameter; muri thin, up to 3.5 μ high.

Other features: Spore radial, trilete, subelliptical. Laesurae simple, equal in length to the radius of the spore. Commissure open. Wall thin.

Similar forms: cf. Dictyotriletes nigratus Naumova 1953, p. 28; Pl. II, Fig. 8. (Givetian).

Genus: Radiaspora gen. nov.

Genotype: R. rotata sp. nov.

Generic diagnosis: Trilete miospores with radially disposed rib-like thickenings on the proximal portion. Outline of transversely compressed specimens subtriangular to circular.

Hoffmeister et al. (1955a, p. 12) refer to "... "Radiaspora", a circular trilete spore with numerous radial ribs on the distal surface..." as "An unpublished genus of Stanley age ...". Opinion is reserved as to whether the latter type truly has distal ribs or has been wrongly interpreted. Of several hundred specimens of the genus which have been examined by us from Devonian rocks, all have the ribs on the proximal face.

Radiaspora rotata sp. nov.

Pl. IV, Fig. 1-4.

Occurrence. Sextant, Battery Point and Onondaga formations.

Holotype: Pl. IV, Fig. 1. Battery Point formation, Slide 28-19 (44.4 x 116), M.P.C.; 42 μ.

Diameter: 33 - 55 μ.

Ornamentation: Radial rib-like thickenings on the proximal face, extending from the equator to the proximal pole. About 4-8 ribs on each interradial area. Distal hemisphere laevigate.

Other features: Spore radial, trilete, subtriangular, with convex margins. Laesurae extend almost to the equator of the spore.

Commissure usually slightly open. Lips low and narrow. Wall may be thickened up to 4 - 5 μ at the equator, or be less than 1 μ thick overall, with the exception of the proximal thickenings. Spore rarely folded, but occasionally laterally compressed. (Pl. IV, Fig. 3).

Similar forms: Designate E_{17}, Radforth and McGregor 1954, p. 611; Fig. 37. (Battery Point formation).

cf. Stenozonotriletes ornatissimus Naumova, in Naumova 1953, Pl. XXII, Fig. 111. (Givetian).

cf. "Radiaspora" in Hoffmeister et al. 1955a, Pl. III, Fig. 7. (Lower Pennsylvanian).

cf. Saccoloma elegans Klf., in Knox 1948, p. 452, Fig. 72. (Recent).

Remarks: Stenozonotriletes ornatissimus, illustrated by Naumova (1953) but not accompanied by a description of any kind, is probably closely allied to Radiaspora rotata, but possesses a small area contagionis.

The parental affinities of Radiaspora are not known. To the writer's knowledge, the only plant which produces spores with proximal radial striations is the living species Saccoloma elegans Klf., of the family Dicksoniaceae. According to Knox (1948, p. 452), this species possesses fine striations radiating from the apex of the spore, "... resulting in an ornamentation which appears to be exceedingly rare among living ferns."

Radiaspora annulata sp. nov.

Pl. Iv, Fig. 5,6.

Occurrence: Sextant formation.

Holotype: Pl. IV, Fig. 5. Slide C-1-5 (21.2 x 113), M.P.C.; 43.5 μ.

Diameter: 34 - 54 μ.

Ornamentation: Radial spoke-like thickenings on the proximal face extend from the equator to the proximal pole. On the distal portion is a thickened ring concentric to the equator, up to 6 μ wide, situated about 1/3 the distance from the margin toward the distal pole. Remainder of spore laevigate.

Other features: Spore radial, trilete, subtriangular to circular. Laesurae simple, almost as long as the radius of the spore, and often poorly defined. Spore rarely folded, and rarely laterally compressed (Pl. Iv, Fig. 6).

Radiaspora simple forma laevigata sp. et f. nov.

Pl. Iv, Fig. 7,8; Pl. XIII, Fig. 7,8.

Occurrence: Sextant formation.

Holotype: Pl. Iv, Fig. 7. Slide A-3-3 (25.4 x 123), M.P.C.; 60 μ.

Diameter: 40 - 60 μ.

Ornamentation: On the proximal portion, radial spoke-like thickenings extend from an equatorially situated, thickened girdle toward the proximal pole. These thickenings tend to converge at loci located in each interradial area, about 3/4 the distance to the proximal pole. (Pl. IV, Fig. 7; Pl. XIII, Fig. 7). From these loci, shorter thickenings radiate toward the laesurae. On the distal portion is a second thickened ring, concentric to the equatorial one, situated about halfway toward the equator (Pl. III, Fig. 8, and Pl. XIII, Fig. 8). Wall laevigate between the proximal thickenings and on the distal surface.

Other features: Spore radial, trilete, subtriangular to subcircular. Laesurae simple, almost as long as the radius of the spore. Commissure usually slightly open. Wall rarely folded.

Radiaspora ampla forma granulata sp. et.f. nov.

Pl. IV, Fig. 9.

Occurrence: Sextant formation.

Holotype: Pl. IV, Fig. 9. Slide A-3-3 (25.5 x 107.4), M.P.C.; 68 μ.

Diameter: 51 - 80 μ.

Ornamentation: Similar to that of R. ampla forma laevigata except that the wall between the proximal thickenings and on the distal portion is granulate.

Other features: The same as for R. ampla forma laevigata.

Remarks: The two forms of R. ampla are the only representatives of spores with similar elaborate form, either living or as fossils, to be recorded in the literature. There is at present no evidence as to their affinities. They may well belong to a closely interrelated group of plants along with the other species of the genus Radiaspora.

Radiaspora obscura sp. nov.

Pl. IV, Fig. 11.

Occurrence: Onondaga formation.

Holotype: Pl. IV, Fig. 11. Slide 432-15 (26.5 x 123.4) M.P.C.; 76 μ.

Diameter: 61 - 76 μ.

Ornamentation: Indistinct radial thickenings on the proximal portion extend from the equator to the proximal pole. Distal portion laevigate.

Other features: Spore radial, trilete, subtriangular with convex margins. Laesurae extend to the equator of the spore. Lips low, narrow. Wall 1 - 2 μ thick, occasionally folded.

Remarks: Distinguished from R. rotata by its larger size and less distinct radial thickenings.

Radiospora robusta sp. nov.

Pl. IV, Fig. 12.

Occurrence: Battery Point and Onondaga formations, and Perdrix equivalent.

Holotype: Pl. IV, Fig. 12. Battery Point formation, slide 28-12 (59.3 x 122.5), M.P.C.; 70.5 μ.

Diameter: 51 - 70 μ.

Ornamentation: Prominent radial thickenings, up to 9 μ wide at the equator, extend on the proximal portion from the equator to the vicinity of the proximal pole. The thickenings are raised up to 3 μ above the spore surface.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae extend to the equator of the spore, are often obscured by the strongly developed radial bands. Wall up to 5 μ thick at the equator, thinner on distal portion.

Remarks: The large size and prominent thickenings of this form ar distinctive.

Radiaspora cuneata sp. nov.

Pl. IV, Fig. 10.

Occurrence: Battery Point formation.

Holotype: Pl. IV, Fig. 10. Slide 28-14 (63.3 x 119.6), M.P.C.; 54 μ.

Diameter: 51 - 55 μ.

Ornamentation: Thickenings on proximal portion, extending approximately parallel to one another from the equator to the margin of the commissure, thus forming a "herring-bone" pattern. Distal portion laevigate.

Other features: Spore radial, trilete, subtriangular. Laesurae simple, extend to the equator of the spore. Wall thin, except where thickened proximally.

Series: Arcuati ser. nov.

Azonate miospores and megaspore genera of varied ornamentation which possess an *area*, i.e. the interradial areas of the proximal face of the spore delimited by more or less thickened arcuate lines.

Establishment of this series entails relocation of the megaspore genera *Laevigati-sporites* and *Triletisporites*, which Potonié and Kremp (1954) have placed in the series Laevigati and Apiculati respectively.

Genus: *Retusotriletes* (Naumova)1953) emend.

Genotype: *R. elegans* sp. nov.

Generic diagnosis: Miospores with obvious arcuate lines, more or less thickened, delimiting the interradial areas of the proximal portion of the spore. They thus possess an *area* in the sense of Naumova 1953, p. 8. Spores laevigate or variously ornamented. The area possesses similar ornamentation to the rest of the spore, or at most differs from the rest of the spore only to a minor degree.

Retusotriletes simplex Naumova 1953, p. 29, 97; Pl. II, Fig. 9: Pl. XV, Fig. 4; Pl. XXII, Fig. 21.

Pl. IV, Fig. 13, 14.

Occurrence: Sextant formation. U.S.S.R.: Givetian-Famennian.

Remarks: The diameter range of the Sextant specimens is 22 - 44.5 μ, which is slightly greater than that given by Naumova (30 - 40 μ).

Retusotriletes mediocris sp. nov.

Pl. IV, Fig. 15.

Occurrence: Sextant and Battery Point formations.

Holotype: Pl. IV, Fig. 15. Battery Point formation, slide 28-15 (33.9 x 121.7), M.P.C.; 43 μ.

Diameter: 36 - 54 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, ovate to circular. Laesurae 1/2 to 3/4 the length of the radius of the spore. Area delineated by narrow dark lines which meet the tips of the rays with broad v's. The area is distinctly smaller in area than the proximal face of the spore. Wall thin, but rigid in appearance; may appear to be thicker on some specimens because of marginal folding.

Similar forms: cf. Calamospora diversiformis Balme and Hennelly 1956, p. 246; Pl. 2, Fig. 14-18. (Permian).

Remarks: Although it is much younger in age, C. diversiformis is very close in appearance to some forms of Retuso-triletes mediocris. According to Balme and Hennelly (1956b, p. 246), "A clearly defined contact area delimited by incipient curvaturae is present in some specimens ... [which] ... bears a marked resemblance to Mesozoic and Tertiary spores assigned by Cookson (1953) to Sphagnites."

Retusotriletes levis sp. nov.

Pl. IV, Fig. 16.

Occurrence: Battery Point formation.

Holotype: Pl. IV, Fig. 16. Slide 28-12 (42.1 x 119.8), M.P.C.; 64 µ.

Diameter: 47 - 82 µ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae almost as long as the radius of the spore. Lips low. The area covers almost the entire proximal portion; the outer margin of the area joins the end of each ray with a distinct v. Wall thin but opaque.

Similar forms: cf. Asterocalamotriletes glabratus Luber 1955, p. 39; Pl. I, Fig. 17-19. (Carboniferous).

Remarks: A. glabratus is smaller than Retusotriletes levis, but otherwise similar to it.

Retusotriletes cf. R. verruculatus Naumova 1953, p. 29; Pl. II, Fig. 10.

Pl. IV, Fig. 17.

Occurrence: Sextant formation.

Diameter: 39 - 51 μ.

Ornamentation: Small closely spaced granules which are faintly visible on the margins of the spore.

Other features: Spore radial, trilete, subtriangular. Laesurae extend almost to the equator. The apex covers almost the entire proximal face, except for the apices, where the rays meet the outer margin of the apex slightly proximally.

Remarks: This form bears a close resemblance to R. verruculatus except perhaps in one respect. Naumova describes the latter as possessing "... small, slightly connected granules." This feature is not apparent on our specimens, but according to Naumova's description and figures it is evidently an inconspicuous feature on R. verruculatus. R. verruculatus occurs in the Givetian, Frasnian and Famennian of the Moscow basin.

Retusotriletes tenuis sp. nov.

Pl. IV. Fig. 18.

Occurrence: Sextant and Onondaga Formations.

Holotype: Pl. IV, Fig. 18. Sextant Formation, slide A-3-3 (18.8 x 105), M.P.C., 54 μ.

Diameter: 38 - 65 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae simple, extend almost to the equator of the spore. The outer extremity of the apex marked by faint arcuate lines at the equator. Wall 1 μ thick, rigid in appearance, usually unfolded.

Remarks: This species may be distinguished from R. *simplex* by its thinner wall and poorly defined trilete rays.

Retusotriletes laevigatus sp. nov.

Pl. IV, Fig. 20,21.

Occurrence: Sextant and Battery Point formations.

Holotype: Pl. IV, Fig. 20. Sextant formation, slide A-17-4 (57 x 102.6), M.P.C.; 75 μ.

Diameter: 51 - 78.5 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, elliptical to circular. Laesurae 2/3 to 4/5 the length of the radius of the spore. *Apex* distinct, outlined by a thin, dark line which turns inward to make broad v's with the ray extremities. Wall thin, usually with one or two long folds.

Retusotriletes elegans sp. nov.

Pl. IV, Fig. 25.

Occurrence: Sextant formation.

Holotype: Pl. IV, Fig. 25. Slide C-1-5 (55 x 113.8), M.P.C.; 77 μ.

Diameter: 58 - 91 μ.

Ornamentation: Granulate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae 2/3 to 4/5 the length of the radius of the spore. Apex delimited by a thin line which may be indistinct on some specimens. *Apex* rim only slightly or not at all turned inward at juncture with the tips of the rays. Wall thin, usually with minor folds.

Retusotriletes magnus sp. nov.

Pl. IV. Fig. 19.

Occurrence: Sextant formation.

Holotype: Pl. IV, Fig. 19. Slide A-9-3 (39.3 x 109.7), N.P.C.; 112.5 μ.

Diameter: 92 - 112.5 μ.

Ornamentation: Distinct coarse granules.

Other features: Spore radial, trilete, elliptical to oval. Laesurae 1/2 to 2/3 the length of the radius of the spore. Lips low. Apex weakly delimited, forming slight v's at the tips of the rays. Wall thin, usually with one long fold.

Retusotriletes ornatus sp. nov.

Pl. IV, Fig. 24.

Occurrence: Sextant formation.

Holotype: Pl. IV, Fig. 24. Slide A-17-4 (40.8 x 117), N.P.C.; 65 μ.

Diameter: 54 - 80.5 μ.

Ornamentation: Granulate-papillate. Projections up to 2 μ long, closely spaced.

Other features: Spore radial, trilete, broadly elliptical to circular. Laesurae simple, about 2/3 the length of the radius of the spore. Apex distinct; covers about 3/4 of the proximal portion of the spore. Wall thin but opaque.

Similar forms: Cf. R. devonicus Naumova, in Naumova 1953, Pl. XXII, Fig. 108. (Givetian).

Remarks: R. devonicus may be synonymous with R. ornatus, but

Naumova gives neither a description of this species, nor a reference to the original description. Her illustration of it is insufficient for accurate comparison.

Retusotriletes solidus sp. nov.

Pl. IV. Fig. 26.

Occurrence: Battery Point formation.

Holotype: Pl. IV, Fig. 26. Slide 28-12 (42.2 x 118.6), M.P.C.; 106 μ.

Diameter: 78 - 113 μ.

Ornamentation: Granulate. Occasional small papillae.

Other features: Spore radial, trilete, broadly elliptical-ovate. Laesurae simple 2/3 to 4/5 the length of the radius of the spore. The apex occupies almost all of the proximal face, and is often obscured by folding of the spore wall. Wall 1.5 - 2 μ thick.

Retusotriletes arcuatus sp. nov.

Pl. IV, Fig. 23.

Occurrence: Sextant formation.

Holotype: Pl. IV, Fig. 23. Slide A-5-6 (70.5 x 104.8), M.P.C.; 54 μ.

Diameter: 42.5 - 80 μ.

Ornamentation: Laevigate to infragranulate. Faint irregular radial striations are visible on the proximal face of some specimens.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae extend to the equator. Lips low. The apex occupies the entire proximal portion, except in the apical regions where the trilete rays meet the outer margin of the apex slightly proximally. Margin of apex thickened and distinct. Proximal face flattened. Wall 2 - 4 μ thick.

Remarks: The very faint radial striations and overall form of R. arcuatus suggest that it may be related to the Radiaspora group.

Retusotriletes magnificus sp. nov.

Pl. V, Fig. 1,2,3; Pl. XVI, Fig. 1,7,8.

Occurrence: Melville Island formation.

Holotype: Pl. V, Fig. 1. Slide MI-12 (39.4 x 114.2), N.P.C.; 92 μ.

Paratype: Slide MI-11 (43.9 x 114.2), N.P.C.; 115 μ. The paratype, a laterally compressed specimen (Pl. V, Fig. 2) was chosen to illustrate the profile of the species, and the verrucate ornamentation of the proximal face.

Diameter: 69 - 119 μ.

Ornamentation: Distal portion scabrate; elements of sculpture arranged in groups of irregular outline, about 5 μ in diameter. These groups are of low relief (less than 1 μ high) or raised up to 2 μ above the surface to form a verrucate pattern. Proximal portion minutely scabrate. Some specimens possess low verrucate projections up to 4 μ in diameter in the angles of the rays near the proximal pole (Pl. V, Fig. 2).

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae extend almost to the equator. Lips low and narrow. At the outer margin of the apex the wall is slightly thickened to form arcuate ridges. Proximal face flattened, distal portion hemispherical.

Remarks: This species and the four to follow, all restricted to the Melville Island formation, possibly represent a group of interrelated plants, distinct from those which produced the other species of the genus Retusotriletes.

Retusotriletes endoformis sp. nov.

Pl. V, Fig. 4,5; Pl. XIII, Fig. 11.

Occurrence: Melville Island formation.

Holotype: Pl. V, Fig. 4. Slide MI-12, (58.8 x 104.6) M.P.C.; 83 μ.

Diameter: 69 - 124 μ.

Ornamentation: Similar to the ornamentation of R. magnificus.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae extend almost to the equator. Lips low and narrow. Slightly thickened, low, arcuate ridges mark the outer extent of the apex. A thin-walled, transparent body is present in the interior of the spore. This sac-like structure is apparently not attached to the inner wall of the spore, at least on some specimens (Pl. XIII, Fig. 11). Nevertheless, it maintains its central position relative to the spore body.

Remarks: Except for the presence of the central body, this species is identical with R. magnificus.

Retusotriletes vulgaris sp. nov.

Pl. V, Fig. 6.

Occurrence: Melville Island formation.

Holotype: Pl. V, Fig. 6. Slide MI-12 (47.8 x 102.8) M.P.C.; 83 μ.

Diameter: 83 - 113 μ.

Ornamentation: Distal portion scabrate. Ornamentation of proximal portion similar but not so prominent.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae extend almost to the equator of the spore. Lips low and narrow. Apex delimited by moderately thickened arcuate ridges slightly proximal to the equator. Distal portion of spore hemispherical, proximal flattened.

Retusotriletes pallidus sp. nov.

Pl. V. Fig. 7,9,10.

Occurrence: Melville Island formation.

Holotype: Pl. V, Fig. 9. Slide MI-21 (18.8 x 107.2), M.P.C.; 67 μ.

Diameter: 64 - 82 μ.

Ornamentation: Granulate. Granules on distal portion more or less joined at their bases to form a rugulate pattern (Pl. V, Fig. 7). At the equator of some specimens the ornamentation is more elongate, appearing irregularly mamillate in transverse view. Ornamentation reduced and more regular on proximal portion.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae extend almost to the equator of the spore. Lips low and narrow. Area indistinct, bounded by slightly thickened arcuate ridges at the equator. Distal portion of spore hemispherical, proximal portion flattened (Pl. V, Fig. 10).

Retusotriletes grandis sp. nov.

Pl. V, Fig. 8.

Occurrence: Melville Island formation.

Holotype: Pl. V, Fig. 8. Slide MI-22 (43.6 x 118) M.F.C.; 129μ

Diameter: 98 x 150μ.

Ornamentation: Stout verrucate projections cover the entire distal portion. Projections polygonal or irregular in transverse view, up to 6μ wide, rounded or ending in small papillae. Projections on proximal face similar but reduced in size.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae simple, about 3/4 the length of the radius of the spore. Laesurae usually obscured by the coarse ornamentation. Weakly developed arcuate ridges delimit the area near the equator on the proximal side of the spore. Proximal face flattened, distal hemispherical.

Remarks: Verrucosisporites ovimammus Imgrund (1952, p. 34, Fig. 75-77) possesses similar ornamentation and is of similar size, but is distinguished from Retusotriletes grandis by its lack of arcuate thickenings. It also lacks the distinctly anisopolar profile of R. grandis.

Retusotriletes sp. A.

Pl. IV, Fig. 22.

Occurrence: Sextant formation.

Diameter: 41 μ (One specimen only).

Ornamentation: Small but distinct apiculations on the lateral walls of the interradial areas. Wall laevigate near the poles and at the angles.

Other features: Spore radial, trilete, broadly subtriangular with strongly convex margin . Laesurae 2/3 the length of the radius of the spore. Lips low and narrow. A dark triangular *area contagionis* is present in the angles of the rays. Also present is an indistinct *apex* which extends to the margin in the interradial areas, but is outlined on the proximal face at the apices.

Remarks: This form is unusual in that it has both an *area contagionis* (*sensu* Kosanke 1950) and an *apex* (*sensu* Naumova 1953).

Division: ZONALES (Bennie and Kidston) Potonié and Kremp 1954.

Subdivision: Zonotriletes (Waltz), Potonié and Kremp, 1954.

Series: Cingulati Potonié and Klaus 1954.

Genus: *Lycospora* (Schopf, Wilson and Bentall), Potonié and Kremp 1954.

Lycospora scabrata sp. nov.

Pl. V, Fig. 11.

Occurrence: Sextant formation.

Holotype: Pl. V, Fig.11. Slide A-5-6 (68.4 x 123.2), M.P.C.; 51 μ.

Diameter: 39 - 72 μ.

Ornamentation: Body and cingulum scabrate to minutely rugulate.

Other features: Spore radial, trilete, oval to circular. Laesurae extend almost to the equator of the spore body, are simple or with weak lips. A dark ring about 1 μ wide marks the attachment of the equatorial cingulum. Cingulum 3 - 5 μ wide.

Remarks: As seen in polar view, the dark concentric ring may be interpreted either as the margin of an endosporial body (cf. Archaeozonotriletes Naumova) or the locus of attachment of a flange or cingulum (as in Lycospora). Although the continuity of the ornamentation from the pole to the periphery of the spore would support the former interpretation, the fact that all of the specimens encountered were compressed transversely (proximo-distally) suggests either the presence of the stabilizing influence of an equatorial structure or an anisopolar form, or both (as in Lycospora). The latter view is further favoured by the inevidence of a double wall in broken specimens.

Archaeozonotriletes gloriosus Naumova (1953, Pl. XIV, Fig. 4) superficially resembles Lycospora scabrata, but the structure visible at the equator is a perisporium not a cingulum.

Genus: Anulati-sporites (Loose) Potonié and Kremp, 1954.

Anulati-sporites anulatus (Loose) Potonié and Kremp 1956, p. 112, Pl. 17, Fig. 365-372.

Pl. V, Fig. 12.

Occurrence: Sextant formation. Europe: Westphalian B and C (Potonié and Kremp 1956a).

Remarks: The maximum diameter (63µ) is slightly greater than that given by Potonié and Kremp (60µ).

Anulati-sporites imperfectus sp. nov.

Pl. V, Fig. 13.

Occurrence: Battery Point and Onondaga formations.

Holotype: Pl. V, Fig. 13. Battery Point formation, slide 28-16 (48.6 x 104), M.F.C.; 71µ.

Diameter: 49 - 83.5µ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae 1/2 to 2/3 the length of the radius of the spore. Equatorial annulus present, may vary in width, even on one specimen, from 3 to 7µ. The annulus is discontinuous on some specimens. Wall thin in polar regions. Wall readily folded, especially along the laesurae and in the equatorial region. Spore compresses readily in various planes (Pl. XIV, Fig. 1, 2, 3).

Anulati-sporites granulatus sp. nov.

Pl. V, Fig. 14; Pl. XIV, Fig. 1, 2, 3.

Occurrence: Battery Point formation.

Holotype: Pl. V, Fig. 14. Slide 28-19 (24.2 x 105.9), M.F.C. 54µ

Diameter: 50 - 62 μ.

Ornamentation: Body granulate. Annulus laevigate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae simple, almost as long as the radius of the spore. An annulus, 3 - 6.5 μ thick, encircles the spore at the equator. Annulus sometimes discontinuous. Occasional folding at margin of spore.

Remarks: Pl. XIII, Fig. 1,2, and 3 illustrate this species in three planes of compression.

Genus: Denso-sporites (Berry) Potonié and Kremp 1954.

Denso-sporites verrucatus sp. nov.

Pl. V, Fig. 15, 16.

Occurrence: Battery Point formation.

Holotype: Pl. V, Fig. 15. Slide 28-15 (36.8 x 114.5), M.P.C.; 62 μ.

Diameter: 46 - 79 μ.

Ornamentation: Distal portion verrucate. The verrucate warts 3 - 10 μ wide, up to 2.5 μ high, largest in the vicinity of the distal pole. Warts may or may not be present on the annulus; if they are, the annulus has a segmented appearance (Pl. V, Fig. 16). Proximal portion laevigate.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae extend to the inner margin of the annulus. Lips may be as wide as 3 μ. Proximal wall thin, often with weakly defined short folds or wrinkles.

Denso-sporites crassus sp. nov.

Pl. VI, Fig. 1.

Occurrence: Melville Island formation.

Holotype: Pl. Vi, Fig. 1. Slide MI-12 (25.6 x 112.6), M.P.C.; 85 μ.

Diameter: 85 - 96 μ. (Three specimens).

Ornamentation: Punctate.

Other features: Spore radial, trilete, broadly subtriangular to subovate. Laesurae simple, extend to margin of spore body. A dense equatorial thickening extends beyond the periphery of the body. Wall of body only slightly less opaque than that of the equatorial structure.

Denso-sporites inaequus sp. nov.

Pl. VI, Fig. 2; Pl. XIII, Fig. 9,10.

Occurrence: Melville Island formation.

Holotype: Pl. Vi, Fig. 2. Slide MI-22 (59.3 x 119) M.P.C.; 93 μ.

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 the equator these projections are magnified and joined basally to form a series of concentric flange-like structures, either prominently displayed (Pl. XIII, Fig. 9) or of lesser degree (Pl. XIII, Fig. 10). The equatorial projections possess papillate tips.

Other features: Spore radial, trilete, circular. Laesurae almost as long as the body of the spore. Commissure usually obscured by thick folds along the rays. Wall not appreciably thinner in the polar regions than at equator.

Remarks: Hymenozonotriletes argutus Naumova (1953, Pl. IX, Fig. 9) superficially resembles Denso-sporites inaequus, but Naumova regards the ornamented encircling structure as a perisporium.

Denso-sporites ascki Potonié and Kremp (1956a), p. 116; Pl. 18, Fig. 379) differs in its smaller size and relatively less opaque central portion.

Genus: Velasporites gen. nov.

Genotype: Velasporites densus sp. nov.

Generic diagnosis: Trilete miospores, circular, subcircular or broadly subtriangular in outline. Distal hemisphere thick-walled, proximal portion thin. A transparent, membranous layer, apparently an extension of the outer portion of the distal wall, encloses the proximal face and the laesurae like a veil.

Velasporites densus sp. nov.

Pl. VI, Fig. 3,4.

Occurrence: Melville Island formation.

Holotype: Pl. VI, Fig. 4. Slide MI-12 (29.8 x 107.9), M.P.C.; 74 µ.

Paratype: Pl. VI, Fig. 3. Slide MI-12 (58.8 x 106.1), M.P.C.; 89 µ.

Diameter: 45 - 89 µ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae about 4/5 as long as the radius of the spore. Distal wall 11 μ thick, thinning abruptly near the equator. Proximal wall thin, transparent. A thin, transparent veil-like structure with numerous short wrinkles extends over the proximal face of the spore, completely enveloping the laesurae. This membranous layer appears to be an extension of the outer part of the thick distal wall. The thickness of the distal wall represents 4 - 14% of the total diameter of the spore. The amount of this thickening bears no apparent constant relation to the total spore diameter.

Remarks: The veil-like structure that covers the proximal face must have completed its development after the spores were released from the tetrad, since it covers the triradiate aperture of the underlying wall. At present the genus *Velasporites* is known only from the Melville Island formation.

Velasporites tenuis sp. nov.

Pl. VI, Fig. 5.6.

Occurrence: Melville Island formation.

Holotype: Pl. VI, Fig. 6. Slide MI-12 (26.6 x 111.7) M.P.C.; 77 μ.

Diameter: 54 - 77 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, ovate to elliptical. Laesurae almost as long as the radius of the spore. Lips low and narrow. Distal wall slightly thickened (up to 3μ). Proximal wall thin. A membranous layer covers the laesurae and the proximal face.

Velasporites punctatus sp. nov.

Pl. VI, Fig. 7, 8.

Occurrence: Melville Island formation.

Holotype: Pl. VI, Fig. 7. Slide MI-12 (34.2 x 111.1), M.P.C.; 56μ.

Paratype: Pl. VI, Fig. 8. Slide MI-12 (40.7 x 120.7), M.P.C.; 92μ. The paratype illustrates the profile of the spore and the appearance of the proximal membrane.

Diameter: 57 - 92μ.

Ornamentation: Punctate (scabrate according to Harris 1955).

Other features: Spore radial, trilete, subcircular. Laesurae simple, almost as long as the radius of the spore. Distal wall 3 - 10μ thick, becomes thin abruptly near the equator. Proximal wall thin. A membranous layer, apparently homologous with the veil-like structure of V. densus, partly or completely covers the proximal wall of the spore. This layer may completely cover the laesurae but bears no evidence of a triradiate scar.

Series: Zonati Potonié and Kremp 1954.

Genus: Cirratriradites Wilson and Coe 1940.

Cirratriradites splendens Balme and Hennelly, 1956b.

p. 252; Pl. 5, Fig. 57-59; Pl. 6, Fig. 60-61.

Pl. VI, Fig. 9.

Occurrence: Sextant formation. Australia: Permian.

Remarks: The similarity between the Sextant form and C. splendens is remarkable, and especially so when one considers the difference in their ages. Balme and Hennelly note that "C. splendens is a very variable form ...". The range of variation of the Sextant example is not known, since only one specimen was found.

Cirratriradites decorus sp. nov.

Pl. VI, Fig. 10, 12.

Occurrence: Battery Point formation.

Holotype: Pl. VI, Fig. 10. Slide 23-15 (49.6 x 103.1), M.P.C.; 92 μ.

Diameter: 72 - 109.5 μ. Body 58 - 80% of total diameter.

Ornamentation: Body granulate-rugulate, irregular in texture. Flange laevigate, or with very small scattered granules.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae extend to the equator of the body. Folds along the rays may continue onto the flange. Flange membranous, commonly with weak radial folds or wrinkles. The flange also possesses a dark peripheral rim up to 4 μ wide.

Similar forms: cf. Zonotriletes mirabilis Luber 1938, in Luber 1955, p. 66; Pl. VII, Fig. 141. (Carboniferous).

Cirratriradites microdecorus sp. nov.

Pl. VI, Fig. 11.

Occurrence: Battery Point formation.

Holotype: Pl. VI, Fig. 11. Slide 28-15 (50.6 x 106.8), M.P.C.; 65µ.

Diameter: 38 - 66µ. Body 69 - 86% of total diameter.

Ornamentation: Body granulate-rugulate. Flange laevigate.

Other features: Spore radial, trilete, subtriangular, usually distorted by folding. Laesurae to body margin, often obscured by folds which may continue into the flange beyond the tips of the rays. Flange membranous, with weak radial folds and a slightly darkened peripheral rim about 4µ wide.

Remarks: This species bears a marked resemblance to _C. decorus_ but is smaller.

Cirratriradites inusitatus sp. nov.

Pl. VI, Fig. 13, 14.

Occurrence: Battery Point formation.

Holotype: Pl. VI, Fig. 13. Slide 28-15 (57.6 x 118), M.P.C.; 89.5µ.

Paratype: Pl. VI, Fig. 14. Slide 28-13 (34.5 x 116.7), M.P.C.; 101µ.

Diameter: 83 - 116µ.

Ornamentation: Body scabrate and irregularly verrucate. Flange scabrate, with minutely serrate margin.

Other features: Spore radial, trilete, subtriangular to circular. Laesurae 1/2 to 2/3 as long as the radius of the body, but indistinct on most specimens. Distal portion of body hemispherical; proximal portion flattened (Pl. VI, Fig. 14).

Cirratriradites megazonalis sp. nov.

Pl. VI, Fig. 15.

Occurrence: Sortant formation. Estonia: Middle Devonian.

Holotype: Pl. VI, Fig. 15. Slide A-3-3 (56.4 x 105.5), M.P.C.; 147 µ.

Diameter: 110 - 174 µ.

Ornamentation: Body and flange scabrate.

Other features: Spore radial, trilete, subtriangular. Body broadly subtriangular to circular. Laesurae extend to the equator of the body. Folds along the laesurae may extend onto the flange. The flange girdles the body at the equator, varies in width from 1/3 to 1/2 of the total spore diameter at the apices to 1/5 to 1/4 of the total diameter interradially. Body opaque, flange semitransparent.

Similar forms: Spore "Gruppe Laevigato-Zonales I", Thomson, 1940, Pl. I, Fig. 1a, 1b, 2a, 2b. (Lower Givetian).

Remarks: The latter spore, found by Thomson in a clay-like matrix near Pärnu, Estonia, and illustrated by good photographs, is here regarded as synonymous with *C. megazonalis*.

Genus: *Camarozonotriletes* (Naumova 1937) emend.

Genotype: *Camarozonotriletes fulgens* sp. nov.

Emended diagnosis: Trilete miospores with an equatorial flange (*zona*) which is discontinuous at the corners of the body of the spore. Flange not thickened at its periphery (thus differs from *Rotaspora* Schemel 1950). Body subtriangular.

The genus *Camarozonotriletes* was cited in Naumova, 1937. The Russian edition of this paper was not available.

An English translation, which may be an abstract, contains the following brief description of the genus: "*Camarozono-triletes* Naum.- margin discontinuous at the corners of the body of the spore;". No genotype was designated.

In accord with the policy of Potonié and Kremp (1955), the genus is here described as an emendation of Naumova's description, the original epithet being retained.

Camarozonotriletes *fulgens* sp. nov.

Pl. VII, Fig. 1.

Occurrence: Battery Point formation.

Holotype: Pl. VII, Fig. 1. Slide 28-12 (27.6 x 106.7), M.P.C.; 29 μ.

Diameter: 26 - 37 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, subtriangular with strongly convex margins. Body margins straight to slightly convex. Laesurae about 2/3 as long as the radius of the spore. Commissure usually open. Lips low and narrow. A marginal structure, flange-like in transverse view, encircles the periphery of the spore. This structure is up to 3 μ wide in the interradial areas, but becomes very narrow or disappears opposite the apices. All of the specimens were compressed transversely.

Similar forms: *cf.* *Camarozonotriletes* *pusillus* Naumova, in Naumova 1953, Pl. XXII, Fig. 97. (Upper Givetian).

Remarks: Naumova (1953) does not describe C. pusillus, nor does she give a reference to the original description. According to the diagrammatic illustration of C. pusillus given by her, however, the resemblance to C. fulgens is very close.

Division: DUOMURALES div. nov.

Miospores and megaspores with triradiate tetrad mark, and no other germinal apparatus, and without auriculae, cingulum, zona or sacci. Distinguished by possession of a perisporium-like wall, laevigate or variously ornamented, which completely surrounds, and is more or less closely appressed to, an internal body.

It is believed that the degree of complexity represented by the double wall structure justifies separation of these forms from the azonate division TRILETES, and the creation of a new division. According to Potonié and Kremp (1954, p. 119), members of the division TRILETES must show no "strong differentiation."

Subdivision: Membranites subdiv. nov.

Trilete miospores and megaspores, with a perisporium-like outer wall which is thin-walled and semitransparent. Outer wall variously ornamented or occasionally laevigate. Inner body also thin-walled, usually unornamented.

Genus: Archaeozonotriletes (Naumova) emend.

Genotype: Archaeozonotriletes arenorugosus sp. nov.

Emended diagnosis: Trilete miospores with an outer envelope (here designated as a perisporium), which is more or less appressed to the body of the spore. Perisporium laevigate or with low ornamentation. Body laevigate.

Archaeozonotriletes is here emended to include only miospores and is restricted to those with a thin-walled perisporium. Although the generic name suggests the presence of a zonate flange, such as occurs in Cirratriradites (= Hymenozonotriletes Naumova), such a structure is not present in Archaeozonotriletes.

Archaeozonotriletes minor sp. nov.

Pl. VII, Fig. 2,3.

Occurrence: Battery Point formation.

Holotype: Pl. VII, Fig. 2. Slide 28-19 (38.5 x 111), M.P.C.; 34μ.

Diameter: 26 - 40μ.

Ornamentation: Small papillae, densely spaced.

Other features: Spore radial, trilete. Body subtriangular, total outline broadly subtriangular to circular. Laesurae more than 2/3 the length of the radius of the spore. Commissure frequently open. In transversely compressed specimens, a peripheral structure is visible surrounding the body of the spore. This peripheral structure is up to 3.5μ wide in the interradial areas and narrow or absent at the apices. When the spores are compressed laterally, the structure in question is seen to resemble a perisporium, completely surrounding the central body.

Remarks: Although it superficially resembles Naumova's genus *Camarozonotriletes*, *Archaeozonotriletes minor* is of fundamentally different construction. It is suggested that *Camarozonotriletes obtusus* Naumova (1953, p. 89; Pl. XIV, Fig. 9a) may have been interpreted differently by Naumova than by us, and is actually synonymous with *Archaeozonotriletes minor*.

Archaeozonotriletes deltoides sp. nov.

Pl. VII, Fig. 4.

Occurrence: Sextant formation.

Holotype: Pl. VII, Fig. 4. Slide C-1-4 (37 x 105.3), M.P.C.; 54 μ. (Body 49 μ).

Diameter: 44 - 54 μ.

Ornamentation: Laevigate.

Other features: Spore radial, trilete, subtriangular. Laesurae simple, 2/3 to 3/4 the length of the radius of the body of the spore. A membranous perisporium completely encircles the body, but is separated from it by about 5 - 6 μ. Perisporium often folded.

Archaeozonotriletes contagionis sp. nov.

Pl. VII, Fig. 5

Occurrence: Sextant and Battery Point formations.

Holotype: Pl. VII, Fig. 5. Sextant formation, slide A-3-3 (13.7 x 106.3), M.P.C.; 70 μ.

Diameter: 42.5 - 74 μ.

Ornamentation: Perisporium scabrate. Body laevigate.

Other features: Spore radial, trilete, elliptical to circular. Laesurae about 1/2 as long as the radius of the spore. A darkened zone (area contagionis) is present on the body of the interradial areas adjacent to the commissure. The perisporium is thin, and when intact is very closely appressed to the body. It is frequently torn however, and partially separated from the body.

Archaeozonotriletes arenorugosus sp. nov.

Pl. VII, Fig. 6,7,8.

Occurrence: Sextant, Battery Point and Onondaga formations.

Holotype: Pl. VII, Fig. 7,8. Sextant formation, slide A-3-3 (65.7 x 106.5), M.P.C.; 102 μ.

Diameter: 70 - 113 μ.

Ornamentation: Perisporium finely but distinctly granular. Body laevigate (Pl. VII, Fig. 6).

Other features: Spore radial, trilete, broadly subtriangular, to circular, or irregular. Laesurae at least 1/2 the length of the radius of the body. Commissure open or closed, but frequently obscured by folds of the body and perisporium. The thin-walled perisporium (Pl. VII, Fig. 8) closely envelopes the body but is often worn away partially or completely. The folds of the body usually do not coincide with those of the perisporium.

Similar forms: cf. *A. decumanus* Naumova 1953, p. 82; Pl. XII, Fig. 2. (Upper Frassian, Russian Platform).

Remarks: *A. decumanus* may be synonymous with *A. arenorugosus*. According to the description of the former the similarity is marked, but Naumova's diagrammatic illustration leaves some doubt as to their identity. The ornaments of the perisporium are perhaps too widely spaced in *A. decumanus*, and the perisporium not closely enough appressed to the body.

Calamospora perplexa (Pl. I, Fig. 15) may represent, at least in part, the free body of *Archaeozonotriletes arenorugosus*.

Archaeozonotriletes crassus sp. nov.

Occurrence: Battery Point formation.

Holotype: Pl. VII, Fig. 9. Slide 28-21 (52.7 x 111.7), M.P.C.; 90 μ.

Paratype: Pl. VII, Fig. 10. Slide 28-19 (23.3 x 113.6), M.P.C.; 87 μ. The paratype illustrates the condition in which the perisporium is partially worn away.

Diameter: 83 - 110 μ.

Ornamentation: Perisporium granulate-papillate, coarse. Body laevigate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae simple, 2/3 to 3/4 the length of the radius of the spore. Margins of commissure may be folded. The perisporium closely envelopes the body, but is frequently worn away in patches. (Pl. VII, Fig. 10).

<u>Archaeozonotriletes papillatus</u> sp. nov.

Pl. VII, Fig. 11.

Occurrence: Sextant formation.

Holotype: Pl. VII, Fig. 11. Slide A-3-3 (49.9 x 124.1), M.P.C.; 89.5 μ.

Diameter: 83 - 121 μ, including perisporium.

Ornamentation: Perisporium densely papillate; papillae up to 4μ long. Body laevigate.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae 1/2 to 2/3 the length of the radius of the body. Low shadowy lips (or <u>area contagionis</u>?) present. Perisporium loosely appressed to the body, frequently torn, often only fragmentary.

<u>Archaeozonotriletes subrugulatus</u> sp. nov.

Pl. VII, Fig. 12.

Occurrence: Sextant formation.

Holotype: Pl. VII, Fig. 12. Slide A-3-4 (37.4 x 120.6), M.P.C.; 76 μ.

Diameter: 69.5 - 82 μ.

Ornamentation: Perisporium very weakly and irregularly rugulate. Ornamentation of body obscured by that of the perisporium.

Other features: Spore radial, trilete, broadly elliptical to circular. Laesurae about 2/3 the length of the radius of the spore, but usually indistinct. Perisporium thin-walled, loosely enveloping the body, usually not folded.

Archaeozonotriletes sp. A.

Pl. VII, Fig. 13,14.

Occurrence: Melville Island formation.

Diameter: 90 μ (one specimen only).

Ornamentation: Perisporium granular; granules 3 - 7 μ apart. Body laevigate.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae about 2/3 the length of the radius of the spore. The laesurae consist of three convoluted, fold-like rays, no commissure being visible. The thin-walled perisporium closely envelopes the body.

Remarks: This form was the only example of its genus to be encountered in the Melville Island formation.

Division: MONOLETES Ibrahim 1933

Subdivision: Azonomonoletes Luber 1935.

Genus: *Laevigato-sporites* Ibrahim 1933.

(?) *Laevigato-sporites* sp. A.

Pl. VIII, Fig. 6,7.

Occurrence: Melville Island formation.

Diameter: 50.5 μ and 68 μ. (Two specimens only).

Ornamentation: Minutely infrapunctate.

Other features: Spores bilateral (?). The tetrad mark resembles a monolete commissure, but with a very short, poorly defined Y-like bifurcation. On the larger specimen (Pl. VIII, Fig. 6), the small arm is at one end of the

Large aperture; the arms of the Y are short, without raised margins. On the smaller form, the locus of division is about 2/3 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 weak and without lips. Wall of large specimen, 4.5 _ thick; of small specimen, 2 _ thick. Outline elliptical to subcircular.

Remarks: There have been few reports of monolete spores from pre-Carboniferous rocks, and none of these forms are fully described.

According to Nikitin (1934), the microspores of Kryshtofovichia Africani are monolete.

Hoffmeister et al. (1955a, p. 10; Pl. I, Fig. 1) record a monolete small spore from the Upper Devonian of Alberta. They refer to it as "cf. Latosporites (?) sp." The same authors also report " ... a monolete megaspore" from the same area and remark that "A typical bean-shaped Laevigatosporites from the same beds may have been a contaminant from other preparations."

The spores of Baragwanathia are bilateral, according to Harris (1956, p. 46).

Naumova (1950) reports thirty-nine species of monolete spores from the Lower Silurian of the Baltic, under the genus Azonomonoletes. An accurate evaluation of the latter types is impossible here, since Naumova's illustrations are diagrammatic drawings, and the type material is not available.

None of the foregoing forms possess the weak bifurcation which characterises the Melville Island species. Whether these spores are truly bilateral, or represent rudimentary trilete forms, is not known.

POLLENITES R. Potonié 1931.

Potonié and Kremp 1954, p. 169, are careful to point out that the Super-Division (Oberabteilung) POLLENITES is intended, as defined, to be a strictly morphographic unit designed to include all saccate miospores, and that it does not necessarily contain only pollen " ... im entwicklungsgeschichtlichen Sinne ...".

Division: SACCITES Erdtman 1947.

Subdivision: Monosaccites Chitaley 1951.

Genus: <u>Endosporites</u> Wilson and Coe 1940.

<u>Endosporites</u> <u>insolitus</u> sp. nov.

Pl. VIII, Fig. 1.

Occurrence: Battery Point formation.

Holotype: Pl. VIII, Fig. 1. Slide 26-14 (69.4 x 106.7), M.P.C.; 138 µ.

Diameter: 138 - 150 µ.

Ornamentation: Perisporium laevigate. Body possesses minute closely-spaced granules.

Other features: Spore radial, trilete, broadly elliptical to circular. Laesurae simple, extend to the equator of the body. Wall of perisporium thin, and usually folded. Body apparently in close contact with the perisporium for part of its surface, probably proximally. The exact zone of their union has not been determined.

Remarks: This species rarely occurs intact in the Battery Point formation.

Genus: Grandispora Hoffmeister, Staplin and Malloy 1955.

Grandispora spinosa Hoffmeister et al. 1955b, p. 388; Pl. 39, Fig. 10, 14.

Pl. VIII, Fig. 2, 3: Pl. XIV, Fig. 6.

Occurrence: Sextant formation. U.S.A.: Upper Mississippian.

Remarks: G. spinosa is abundant in sample C-1 of the Sextant formation, but was not found elsewhere in the Sextant sections. Hoffmeister et al. (1955b) report it as rare in the Hardinsburg formation of Kentucky. The Devonian representatives described here tend to be slightly larger in diameter than the Mississippian forms (115 - 166 µ: 100 - 143 µ).

The spines on the perisporium are variable in form (Pl. XIV, Fig. 6).

Grandispora crenulata sp. nov.

Pl. VIII, Fig. 4, 5; Pl. XIV, Fig. 4.

Occurrence: Perdrix equivalent.

Holotype: Pl. VIII, Fig. 5. Slide P-15 (30.7 x 110.1), M.P.C.; 163 μ (Body 95 μ).

Paratype: Pl. VIII, Fig. 4. Slide P-20 (57.9 x 113), M.P.C.; 115 μ (Body 70 μ).

Diameter: 115 - 202 μ. Body 64 - 103 μ.

Ornamentation: Perisporium possesses tapering, pointed spines, up to 9 μ long and as much as 10 μ wide at their base. Ornamentation continuous over the distal portion, and approximately to the body margin on the proximal side. (Pl. XIV, Fig. 4).

Other features: Spore radial, trilete, subelliptical to circular. Body subtriangular to ovate. Laesurae simple, 2/3 to 3/4 the length of the diameter of the body. Body and perisporium thin-walled, adherent to one another proximally, and possibly distally also.

4. Description of megaspores:

SPORITES H. Potonié 1893.

Division: TRILETES Reinsch 1881.

Subdivision: Azonotriletes Luber 1935.

Series: Laevigati (Bennie and Kidston) Potonié and Kremp 1954.

Genus: Arenosisporites gen. nov.

Genotype: A. subtilis sp. nov.

Trilete megaspores with ornamentation of small pits and elevations of irregular outline (similar to "scabrate" of Harris (1955) but on a larger scale). Wall thin, porous in appearance.

<u>Arenosisporites</u> <u>subilis</u> sp. nov.

Pl. IX, Fig. 2.

Occurrence: Melville Island formation.

Holotype: Pl. IX, Fig. 2. Slide MI-12 (54.9 x 119.8), M.P.C.; 540 μ.

Diameter: 433 - 575 μ.

Ornamentation: Irregular small pits and elevations, giving a porous texture.

Other features: Spore radial, trilete, broadly subtriangular in outline, subelliptical in profile. Laesurae 2/3 to 3/4 the length of the radius of the spore. Lips prominent, up to about 60 μ high, their width approximately equal to their height; occasionally convoluted, but usually in the form of straight ridges. Wall thin, may be folded.

Remarks: The ornamentation of this species is identical with that of the surface of <u>Tuberculatisporites</u> <u>submamillarius</u>, exclusive of the tubercles of the latter (Pl. IX, Fig. 4). These two species occur together in the Melville Island formation, but have not been found elsewhere.

<u>Arenosisporites</u> sp.

Pl. IX, Fig. 1.

Occurrence: Melville Island formation.

Diameter: 220 μ (One specimen only).

Ornamentation: Irregular small pits and elevations.

Other features: Spore radial, trilete, circular. Laesurae almost as long as the radius of the spore. Lips up to 5 μ high. There is a weakly defined, centrally located body, 160 μ in diameter, which is unfolded and little differentiated from the outer envelope. Walls of central body and outer structure thin.

Remarks: Because of its small size, this form could be regarded as either a small megaspore or a large miospore. As Pant (1954, p. 35) points out, it is often impossible to distinguish with certainty between megaspores, isospores and microspores, when the size is intermediate (*i.e.* between about 200 μ and about 300 μ).

Megaspores of similar form are rarely reported. *Sporites michiganensis* Arnold (1950, p. 91; Pl. XVIII, Fig 2), of early Pennsylvanian age, has similar ornamentation and shape, but is much larger (about 1500 μ) and without a central body or lips.

Series: Apiculati (Bennie and Kidston) Potonié and Kremp 1954.

Genus: *Tuberculati-sporites* (Ibrahim 1933) Potonié and Kremp 1954.

Tuberculati-sporites submamillarius sp. nov.

Pl. IX, Fig. 3-9; Pl. XIV, Fig. 5.

Occurrence: Melville Island formation.

Holotype: Pl. IX, Fig. 5-9; Pl. XIV, Fig. 5. Slide MI-12 (46.8 x 103.4), M.P.C.; 372 μ.

Daimeter: 280 - 610 μ.

Ornamentation: Stout, rounded tubercles are scattered irregularly over all portions of the spore except the contact areas.

Tubercles about 8 - 12 μ wide at their base, and up to about 10 μ long. Each tubercle bears at its summit a small, tapering, pointed spine. Tubercles characteristically wider than long, (Pl. IX, Fig. 5,6), but more or less equidimensional on some specimens (Pl. IX, Fig. 4). Between the tubercles and in the contact areas the wall is ornamented by small, irregular pits and elevations as in _Arenosisporites_.

Other features: Spore radial, trilete, broadly subtriangular. Laesurae at least 2/3 as long as the radius of the spore. Lips prominent, usually convoluted, up to 35 μ high. Distinct contact faces extend about 2/3 of the distance to the equator of the spore. On some specimens, a membranous, centrally located body is visible (Pl. XIV, Fig. 5). Occasionally this body occurs free from the outer envelope (Pl. IX, Fig. 9).

Remarks: This species superficially resembles _Tuberculatisporites_ (_Triletes_) _mamillarius_ (Bartlett) Potonié and Kremp 1954, as the specific name implies. _T. submamillarius_ is much smaller however, and has more symmetrical apiculations (see illustrations of apiculations of _Triletes mamillarius_ in Chaloner 1953). Chaloner (1953a) has demonstrated that some spores belonging to _T. mamillarius_ were borne by _Sigillaria_. The distinct contact areas possessed by these spores are present also in _Laevigati-sporites_, a genus associated, at least in part, with the Sigillariaceae (Potonie and Kremp 1955, p. 52).

The internal body, or mesosporium is a feature reported by several authors (Høeg et al. 1955). Its significance is unknown. Høeg et al. suggest that extended knowledge of mesosporia may have some influence on the classification of fossil megaspores.

Series: Incertis.

Triletes sp. A.

Pl. X, Fig. 6.

Occurrence: Battery Point formation.

Diameter: 211 μ and 250 μ. (Two specimens only).

Ornamentation: Reticulate pattern on distal portion. Proximal portion granular, except for a narrow region at the equator which is reticulate. Lacunae 5 - 20 μ wide, those near the equator being smaller, and elongate. Muri thin, 1 μ high.

Other features: Spore radial, trilete, ovate. Laesurae poorly defined, probably more than 1/2 the length of the radius of the spore. Wall 4 μ thick at margin. Reticulate portion of spore membranous.

Remarks: The reticulate membranous structure may be an enveloping structure distinct from the main body of the spore. This interpretation is favoured by the appearance of the spore walls in the figured specimen (see top of photo, Pl. X, Fig. 6). Several fragments bearing reticulate structure identical in appearance with that borne by this spore was seen free in the preparations.

Since the systematic position of this form is in doubt, it is assigned to the form genus Triletes.

Triletes sp. 8.

Pl. X, Fig. 7.

Occurrence: Battery Point formation.

Diameter: 229 μ (One specimen only).

Ornamentation: Granulate. Granules small, irregularly scattered over the surface of the spore.

Other features: Spore radial, trilete, probably originally broadly subtriangular. Laesurae simple, about 2/3 the length of the radius of the spore. Wall 4 μ thick.

Division: DUOMURALES div. nov.

Subdivision: Membranites subdiv. nov.

Genus: Circumsporites gen. nov.

Genotype: Circumsporites melvillensis sp. nov.

Generic diagnosis: Trilete megaspores with an enveloping perisporium-like wall appressed over its complete area to a thin-walled central body. Both perisporium and central body ornamented. Spores subtriangular to circular.

Circumsporites melvillensis sp. nov.

Pl. X, Fig. 1-5.

Occurrence: Melville Island formation.

Holotype: Pl. X, Fig. 1. Slide MI-20 (27.1 x 109.1), M.P.C.; 220 μ, including ornamentation; body 187 μ. (Pl. X, Fig. 1).

Diameter: 203 - 292 μ, including ornamentation; body 187 - 234 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. X, Fig. 3). The perisporium may be partially dissociated from the body, and in such condition may have a beaded appearance (Pl. X, Fig. 4). Body with irregular small pits and elevations, similar to *Arenosisporites*.

Other features: Spore radial, trilete, broadly subtriangular to circular. Laesurae almost as long as the radius of the body of the spore, but usually weakly defined. Walls of perisporium and body thin.

Remarks: In fundamental structure, this species resembles *Archaeozonotriletes*. Because of its larger size, it is regarded as a megaspore. It is, however, small for a megaspore, as are most of the large spores reported from the Devonian (Lang 1925, Høeg 1942).

5. Description of hystrichosphaerids:

Order: HYSTRICHOSPHAERIDEA.

Family : Hystrichosphaeridae.

Genus: *Micrhystridium* Deflandre 1937.

Micrhystridium penicillatum sp. nov.

Pl. XI, Fig. 1.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XI, Fig. 1. Onondaga formation, slide 432 - 15 (39.7 x 120.4), H.P.C.; 17 μ.

Body diameter: 12.5 - 19 μ.

Other features: Body circular, laevigate and semitransparent. Appendages numerous, slender, about as long as the diameter of the body. Appendages divided several times near their tips to form brush-like ends.

Remarks: Xanthidium Ehrenberg, figured by White (1862, Fig. 14-15) from the "Corniferous limestone" (Onondaga formation) of central and western New York, and the "fossil Zygospore" from the Onondaga formation, assigned to the Desmidaceae by Baschnagel (1941, p. 6, Pl. I, Fig. 11) are generally similar to Micrhystridium penicillatum, but the descriptions of these authors are insufficient to allow critical comparison of these forms with the present specimens.

Micrhystridium cf. M. stellatum Deflandre 1944.

Pl. XI, Fig. 2.

Occurrence: Onondaga formation.

Body diameter: 12.5 - 19.5 μ.

Other features: Body subcircular to polyhedral, laevigate, thin but rigid in appearance. Appendages six in number, tapering sharply from broad base to pointed undivided tips, and shorter than the diameter of the body.

Similar forms: *cf.* *Micrhystridium stellatum* Deflandre 1944, p. 27; Pl. III, Fig. 16-19. (Silurian).

cf. Figs. 17, 18, Timofeev 1956. (Cambrian).

Remarks: The Onondaga form shows a particularly close resemblance to one of the specimens of *M. stellatum* figured in Pl. III, Fig. 19 of Deflandre.

The form illustrated by Timofeev (1956) is apparently similar but is not accompanied by a description or name.

Micrhystridium microattenuatum sp. nov.

Pl. XI, Fig. 3.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XI, Fig. 3. Onondaga formation, slide 432-19 (53.8 x 121), M.P.C.; 19 μ.

Body diameter: Ca. 16 - 19 μ.

Other features: Body thin, laevigate, polyhedral. Appendages six, slender, undivided, about 1 1/2 times the diameter of the body. Appendages broad at their base, tapering gradually to pointed tips.

Similar forms: *cf.* *Hystrichosphaeridium* n. sp., Fisher 1953, p. 17, Pl. 7, Fig. 16-18. (Lower Middle Silurian).

Remarks: The six-appendaged variety of the form described by Fisher is regarded as synonymous with our species.

This species closely resembles *Veryhachium attenuatum* (Pl. XI, Fig. 15) in all respects except size.

Genus: <u>Veryhachium</u> (Deunff 1954b) emend.

Genotype: <u>Veryhachium trisulcum</u> (Deunff) Deunff 1954b.

Emended diagnosis: Body laevigate or granular, pyramidal, globular, or attenuated at loci of juncture of appendages. Appendages one to many in number, at least as long as the diameter of the body, straight or curved, sometimes recurved, with pointed tips. Body more than 20 μ in diameter, usually less than 50 μ.

As originally defined, this genus was not clearly distinguished from <u>Hystrichosphaeridium</u> and <u>Micrhystridium</u>. It is now distinguished from the former by the length and non-bifurcation of its appendages, and from the latter by its greater size.

<u>Veryhachium triquetrum</u> sp. nov.

Pl. XI, Fig. 4-5.

Occurrence: Battery Point and Onondaga formations, and Perdrix equivalent.

Holotype: Pl. XI, Fig. 4. Onondaga formation, slide 432-20 (51.1 x 122.1), M.P.C.; 20 μ.

Body diameter: 15 - 25.5 μ, (longest diameter).

Other features: Body laevigate, triangular in compressed condition, and unfolded. Three appendages, one at each apex of the body, very slender, 1 to 2 times the diameter of the body.

Similar forms: <u>Hystrichosphaeridium</u> <u>cf</u>. <u>H</u>. <u>trispinosum</u> Eisenack in Woods, 1955, Pl. I, Fig. 36. (Age not given).
<u>Cf</u>. <u>Xanthidium</u> Ehrenberg in White 1862, p. 306, Fig. 2.

(Onondaga formation).

cf. Tetraedron sp. cf. triappendiculatum (Bernard) Wille in Baschnagel 1941, p. 5; Pl. I, Fig. 6. (Onondaga formation).

cf. Hystrichosphaeridium geometricum Deflandre 1944 in Fisher, 1953, p. 16; Pl. 7, Fig. 6,8. (Lower Middle Silurian).

Remarks: Except for its slightly smaller size, the form recorded by Woods (1955) appears identical in all respects to Veryhachium tricuspitrum. Hystrichosphaeridium trispinosum Eisenack, however, with which Woods compares his form, is much larger (80 - 100μ), according to Eisenack (1938).

The figures of White (1862) and Baschnagel (1941) are unsuitable for critical comparison with our species. The form attributed to H. geometricum by Fisher may be, in part synonymous, in particular the forms he illustrated in Fig. 6,8.

Veryhachium asymmetricum sp. nov.

Pl. XI, Fig. 8,9.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 8,9. Slide 432-15 (23.8 x 107.4), M.P.C.; 145μ.

Body diameter: 130 - 155μ from the truncated apex to the mid-point of the opposite side.

Other features: Body mottled-granular, subtriangular in compressed condition, and thin-walled. Two of the apices bear sickle-shaped appendages, about equal in length to the diameter of the body, which taper to pointed tips from widened bases formed by extensions of the body apices. The third apex is truncated and bears minute attenuated structures at its extremity (Pl. XI, Fig. 9).

Similar forms: "Veryhachium asymmetricum", Deunff 1954a, Fig. 15, and Deunff 1955, Fig. 15 and Pl. IV, Fig. 6. (Onondaga formation).

Remarks: Deunff 1954a and 1955) has illustrated this species, but without a full description or reference to such a description.

Veryhachium quadrangulatum sp. nov.

Pl. XI, Fig. 10.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 10. Slide 432-15 (25.1 x 108.6), M.F.C.; 69 μ.

Diameter: 60 - 80 μ, longest diameter, including appendages.

Other features: Body laevigate, thin, tetrahedral, of indefinite diameter because of the lack of differentiation between the body and the bases of the appendages. Appendages four, about as long as the body diameter, strongly tapered, sharp-pointed.

Similar forms: cf. Tetraedron sp. cf. regularis, in Baschnagel 1941, p. 5; Pl. I, Fig. 8. (Onondaga formation).

cf. Palaeotetradinium hyalodermum Cookson, 1956, p. 188; Pl. I, Figs. 12-16. (Cretaceous).

cf. "Veryhachium tetraedron" Deunff 1954a, Fig. 9, and Deunff 1955, Fig. 9. (Onondaga formation).

Remarks: The foregoing forms reported by Baschnagel (1941) and Deunff (1954) are possibly synonymous with Veryhachium quadrangulatum. The fact that the former was described from thin-sections prevents accurate comparison with V. quadrangulatum. The form reported by Deunff was illustrated, but not described.

The wall of Palaeotetradinium hyalodermum Cookson may be thicker than that of our species.

Veryhachium flaccidum sp. nov.

Pl. XI, Fig. 11.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 11. Slide 432-15 (37.2 x 108.8), M.P.C.; 24 μ.

Body diameter: 23 - 26 μ.

Other features: Body ovate to circular, laevigate and very thin. Numerous appendages, which taper slightly from narrow bases to pointed tips. Appendages as long as diameter of body, or slightly longer, delicate in appearance.

Similar forms: Cf. Xanthidium Ehrenberg, in White 1862, p. 386, Fig. 18 (Onondaga formation).

Remarks: The extremely thin body and delicate appearance of this species are characteristic features.

Veryhachium teneris sp. nov.

Pl. XI, Fig. 14.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XI, Fig. 14. Onondaga formation, slide 432-15 (70.4 x 119), M.P.C.; 32 μ.

Body diameter: 27 - 36 μ.

Other features: Body subcircular, thin, laevigate. Appendages 8-12 in number, slender, tapering slightly to pointed tips, up to twice the length of the diameter of the body.

Remarks: The body of this species is thinner and more angular than that of *Hystrichosphaeridium longispinosum* Eisenack 1938.

Timofeev (1956, Fig. 9) illustrates a form which resembles *Veryhachium teneris* but he does not name or describe it.

Veryhachium attenuatum sp. nov.

Pl. XI, Fig. 15.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 15. Slide 432-15 (33 x 109.6), H.P.C.; 42.5 μ.

Body diameter: 33 - 46.5 μ.

Other features: Body subcircular, very thin, and laevigate. Appendages six in number, gradually tapering from broad bases to pointed tips, and usually slightly longer than the diameter of the body.

Veryhachium *cf.* *V.* *crucistellatum* Deunff 1955.

Pl. XII, Fig. 1; Pl. XIV, Fig. 13.

Occurrence: Onondaga formation.

Body diameter: 37 - 51 μ.

Other features: Body tetrahedral in form, thin-walled, laevigate to weakly scabrate, bears an appendage at each apex. Appendages membranous, transparent, 1 to 1 1/2 times as long as the diameter of the body. Two vein-like strands extend from each body apex into the corresponding appendage, and continue almost to the distal end of the appendage. The appendages are continuations of a membranous sac which completely envelopes the body.

Similar forms: *Veryhachium crucistellatum* Deunff (1955, p. 146; Pl. III, Fig. 3), also encountered in the Onondaga formation of Ontario, is probably synonymous with our form. The illustrations given by Deunff are unsatisfactory for a critical comparison.

Genus: *Hystrichosphaeridium* Deflandre 1937.

Hystrichosphaeridium truncatum sp. nov.

Pl. XI, Fig. 6.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 6. Slide 432-15 (37.4 x 117.4), M.P.C.; 38 μ.

Body diameter: 34 - 45.5 μ.

Other features: Body triangular, in flattened condition, laevigate, thin. Appendages short (about 4 - 8 μ long), attenuated, three in number, located at the apices of the body. Apparent on some specimens is a triangular opaque area, such as would be caused by the presence of material in the lumen of the cell.

Hystrichosphaeridium articulum sp. nov.

Pl. XI, Fig. 7.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 7. Slide A32-20 (60.2 x 103), M.P.C.; 27 μ.

Body diameter: 21 - 23 μ.

Other features: Body triangular in flattened condition, and 1 μ thick. Three appendages, one at each apex of the body, their length equal to about 1 1/2 to 2 times the diameter of the body. Appendages flattened, membranous, up to 5 μ wide, may be undivided, or once or twice bifurcate. The locus of union of each appendage with the body bears a constriction or cross-wall.

Hystrichosphaeridium acanthospinosum sp. nov.

Pl. XI, Fig. 12.

Occurrence: Battery Point formation.

Holotype: Pl. XI, Fig. 12. Slide 28-35 (63.5 x 107.5), M.P.C.; 27 μ.

Body diameter: 22 - 23 μ.

Other features: Body subcircular, laevigate, usually with narrow folds. Appendages numerous, shorter than the diameter of the body, each tapering from 2 - 4 μ at its base to a pointed tip.

Remarks: Several species of *Hystrichosphaeridium* possess undivided appendages which are shorter than the diameter of the body, but none appear to be synonymous with this species. These characteristics occur frequently on forms of lower Palaeozoic age.

Hystrichosphaeridium dispertum sp. nov.

Pl. XI, Fig. 13.

Occurrence: Battery Point formation.

Holotype: Pl. XI, Fig. 13. Slide 28-21 (51 x 109.7), M.P.C.; 33 μ.

Body diameter: 30 - 33 μ.

Other features: Body ovate to circular, thin, but rigid in appearance. Six appendages, up to 50 μ long, and about 5 μ wide at their point of junction with the body. Appendages dichotomise once or twice near their tips.

<u>Hystrichosphaeridium</u> <u>robustum</u> sp. nov.

Pl. XI, Fig. 16; Pl. XIV, Fig. 7.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 16. Slide 432-15 (21.8 x 107), M.P.C.; 49 μ.

Body diameter: 43 - 57.5 μ.

Other features: Body circular, thin, laevigate. Appendages numerous, about as long as the diameter of the body, with tips once, twice or three times bifurcate, or occasionally trifurcate.

<u>Hystrichosphaeridium</u> <u>varium</u> sp. nov.

Pl. XI, Fig. 17.

Occurrence: Perdrix equivalent.

Holotype: Pl. XI, Fig. 17. Slide P-15 (27.2 x 102.4), M.P.C.; 55.5 μ.

Body diameter: 41 - 57.5 μ.

Other features: Body subcircular, outline distorted by extensions of the body to form the appendages. Body thin, laevigate to infragranulate. Appendages five to eight in number, about equal in length to the diameter of the body, once or twice bifurcate near their tips, stout and broad-based.

Hystrichosphaeridium cf. H. intermedium Eisenack.

Pl. XI, Fig. 18.

Occurrence: Battery Point formation.

Body diameter: 42 μ (One specimen only).

Other features: Body circular, laevigate, thin. Appendages numerous, undivided, shorter than the diameter of the body, variable in length, 1 - 3.5 μ wide at their base. Appendages all borne in a distinct, narrow equatorial zone which is folded concentrically.

Similar forms: Hystrichosphaeridium intermedium Eisenack 1954, p. 208, Pl. I, Fig. 3,9 and Text-fig. 3,4. (Lower Silurian).

Hystrichosphaeridium appendiculatum sp. nov.

Pl. XI, Fig. 21; Pl. XIV, Fig. 8.

Occurrence: Onondaga formation.

Holotype: Pl. XI, Fig. 21. Slide 432-15 (64.3 x 114.1), M.F.C.; 64 μ.

Body diameter: 45 - 66 μ.

Other features: Body circular, thin, bearing papillae up to 7 μ long, which taper slightly and are distinctly capitate. These projections occur about 6 - 8 μ apart over the whole of the body. They may be flattened to the surface of the body and thus simulate an imperfect reticulum.

Similar forms: cf. Micrhystridium Bigoti Deflandre 1947b, p. 6, Fig. 5, 6. (Jurassic).

Remarks: Except for its smaller size, M. Bigoti is like Hystrichosphaeridium appendiculatum. H. centrocarpum Deflandre and Cookson (1955) is superficially similar, but the processes are seen at high magnification to be divided at the tips.

Hystrichosphaeridium pannosum sp. nov.

Pl. XI, Fig. 19.

Occurrence:	Onondaga formation.
Holotype:	Pl. XI, Fig. 19. Slide 432-13 (29.3 x 118.4), M.P.C.; 43 μ.
Body diameter:	19 - 35 μ.
Other features:	Body circular, thin, laevigate, with many undivided appendages, about 1/4 to 1/2 the length of the body diameter, ragged in appearance.

Hystrichosphaeridium problematicum sp. nov.

Pl. XI, Fig 20.

Occurrence:	Perdrix formation.
Holotype:	Pl. XI, Fig. 20. Slide P-15 (21.1 x 104.6), M.P.C.; 34 μ.
Body diameter:	13 - 35 μ.
Other features:	Body ovate to circular, thin, unfolded, bearing closely spaced narrow spines up to 5 μ long. Some of the projections taper from a base 2 - 3 μ wide, while others on the same specimen may be only 1 μ wide at the base.
Remarks:	This species may be a spore, since its subovate outline and short densely-spaced spines are relatively rare among known hystrichosphaerids. However, it occurs in abundance in an assemblage which consists of several hystrichosphaerids but few undoubted plant spores. Thus, and because it apparently lacks a tetrad mark, it is regarded as a *Hystrichosphaeridium*.

Family: Pterospermopsidae.

Genus: Pterospermopsis W. Wetzel 1952.

Pterospermopsis concentricus sp. nov.

Pl. XII, Fig. 7, 8.

Occurrence: Onondaga formation.

Holotype: Pl. XII, Fig. 7. Slide 432-15 (21.8 x 125), M.P.C.; body 50.5 μ ; total diameter 90 μ, (Pl. XII, Fig. 7).

Paratype: Pl. XII, Fig. 8. Slide 432-13 (37.6 x 121.9), M.P.C.; body 44 μ ; total diameter 94 μ.

Body diameter: 37 - 51 μ.

Other features: Body circular in outline, subelliptical in profile (Pl. XII, Fig. 8); ornamented by distinct low, narrow concentric ridges on both hemispheres. Wall thin. Encircling the body equatorially is a membranous laevigate flange, equal in width to the radius of the body.

Pterospermopsis parvus sp. nov.

Pl. XII, Fig. 6.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XII, Fig. 6. Perdrix equivalent, slide P-20 (38 x 109.9), M.P.C.; body 32 μ.

Diameter: Body 28 - 38 μ. Flange width 1/5 to 2/5 the diameter of the body.

Other features: Body circular, laevigate, or mottled with small vaguely outlined black spots. A membranous, laevigate flange encircles the equator of the body. Rib-like extensions of the body, of varying prominence, project at intervals to the margin of the flange.

Remarks: *P. ginginensis* Deflandre and Cookson 1955, from the Upper Cretaceous of Australia resembles *P. parvus*. The range of variation for the former is not established, since the authors encountered only one specimen.

Pterospermopsis equatorius sp. nov.

Pl. XII, Fig. 11.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XII, Fig. 11. Perdrix equivalent, slide P-20 (60.2 x 108.7), M.P.C.; body 55 μ; total diameter 71 μ.

Diameter: Body 43 - 74 μ; flange width 1/5 to 1/3 the diameter of the body.

Other features: Body circular, weakly mottled with small vaguely outlined granules. A membranous, laevigate flange encircles the body at its equator. At irregular intervals, narrow rib-like extensions of the body project into the flange.

Remarks: *Leiosphaera maculosa* (Pl. XII, Fig. 17) may be the body of *Pterospermopsis equatorius*.

(?) *Pterospermopsis* sp.

Pl. XII, Fig. 10

Occurrence: Onondaga formation.

Total diameter: 76 - 112 μ.

Other features: Microfossil opaque; wall dense, 1 μ thick, and characteristically cracked. A thickening, concentric with the margin of the microfossil and about 3/5 of the distance toward the centre, is continuous with the rest of the wall in some specimens. On other specimens there is a break at the outer extremity of this thickening (Pl. XII, Fig. 10). Frequently, there are thick folds along the periphery of the microfossil.

Remarks: The structure of this microfossil is difficult to interpret, since it bears little relief, and no variations in appearance that can be attributed to differing compression planes of a bipolar microfossil. Only two walls are discernible in the central area, instead of the three or four that would be distinguishable if this area represented a subspherical body.

Genus: *Cymatiosphaera* (O. Wetzel) Deflandre 1954.

Cymatiosphaera vela sp. nov.

Pl. XII, Fig. 2; Pl. XIV, Fig. 9.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XII, Fig. 2 and Pl. XIV, Fig. 9. Onondaga formation, slide 432-15 (50.7 x 124.1), M.P.C.; body 43 μ.

Body diameter: 32 - 46 μ.

Other features: Body circular, 1 - 2 μ thick, and with distinct sparse granules. Six appendages, each about equal in length to the body diameter, connected to one another by delicate, laevigate membranes which divide the surface of the body into polygonal areas.

Similar forms: Cf. "*Cymatiosphaera prismatica*" in Deunff 1955, Fig. 6. (Onondaga formation).

Remarks: Critical comparison with C. prismatica is not possible from the illustration given by Deunff. He gives no description of this form.

Cymatiosphaera stellata sp. nov.

Pl. XII, Fig. 3.

Occurrence: Perdrix equivalent.

Holotype: Pl. XII, Fig. 3. Slide P-15 (45.9 x 11.6), H.P.C.; 38.5 μ.

Body diameter: 32 - 44.5 μ.

Other features: Body circular, laevigate, thin-walled. Eight membranous appendages, each about equal in length to the diameter of the body, are extensions of low membranous walls which divide the surface of the body into polygonal areas. One or two thread-like strands traverse each appendage for its full length.

Cymatiosphaera obscura sp. nov.

Pl. XII, Fig. 4.

Occurrence: Perdrix equivalent.

Holotype: Pl. XII, Fig. 4. Slide P-15 (21 x 117.1), H.P.C.; body 36 μ.

Body diameter: 34 - 38.5 μ.

Other features: Body circular, thin-walled, laevigate. Six tenuous appendages, connected to one another for about the lower half of their length by delicate, laevigate, membranous walls which divide the surface of the body into polygonal areas. Outline of body may be obscured by folding of the appendages and their connecting membranes.

Cymatiosphaera sp. A.

Pl. XII, Fig. 5.

Occurrence: Onondaga formation.

Total diameter: 51 μ (One specimen only).

Other features: Body subcircular and laevigate. Surface of body divided into polygonal areas, 16 - 24 μ wide, by membranous walls that are as much as 6 μ high.

Similar forms: Cf. "Cymatiosphaera Canadensis" in Deunff 1955, Fig. 10. Onondaga formation). Deunff gives no description, or reference to a description, for this form.

Genus: Saccosphaera gen. nov.

Genotype: Saccosphaera membranacea sp. nov.

Generic diagnosis: Body circular in flattened specimens (probably originally spherical), partially enclosed by a sac-like structure that encircles the body equatorially and is attached to the body on opposite hemispheres.

Saccosphaera membranacea sp. nov.

Pl. XII, Fig. 9.

Occurrence: Onondaga formation.

Holotype: Pl. XII, Fig. 9. Slide 432-15 (60 x 119.6), M.P.C.; total diameter 62 μ.

Diameter: 62 - 72 μ (including sac).

Other features: Body circular, thin, laevigate and transparent. A laevigate sac-like structure encircles the body equatorially, is attached above and below the equatorial region, and envelopes the body around its circumference for about

1/3 the radius, as seen in transversely oriented specimens. Body and sac usually strongly wrinkled or folded.

Remarks: Some of the forms included by Naumova (1950) in the genus *Archaealetes* possess a "frill" or sac-like structure which resembles that of *Saccosphaera*. The bifurcate appendages of *Archaealetes* are not present on *Saccosphaera*, however.

Family: Leiosphaeridae.

Genus: *Leiosphaera* Eisenack 1938.

Leiosphaera minuta sp. nov.

Pl. XII, Fig. 14.

Occurrence: Onondaga formation.

Holotype: Pl. XII, Fig. 14. Slide 432-15 (38.6 x 119.2), M.P.C.; 14 μ.

Diameter: 11.5 - 17 μ.

Other features: Microfossil circular, laevigate, thin-walled but opaque, occasionally ruptured but rarely folded.

Similar forms: *cf.* "Fungal or bryophyte spore", Rouse 1956, pp. 57 and 160, Pl. XIV, Fig. 49.

Remarks: Alete, sculptureless microfossils occur in strata of all geological ages, from Devonian to Recent (Balme and Hennelly, 1956a). Very little can be inferred as to their affinities, since alete spores are known to belong to various groups of the Tracheophyta, as well as to the Bryophyta.

Some of the forms that are included in the genus *Leiosphaera* may be miospores, in which case they would be more appropriately assignable to the genus *Pilasporites* Balme and Hennelly (1956a).

Leiosphaera dubia sp. nov.

Pl. XII, Fig. 13.

Occurrence: Perdrix equivalent.

Holotype: Pl. XII, Fig. 13. Slide P-15 (24.4 x 122.1), M.P.C.; 30.5 μ.

Diameter: 12.5 - 42 μ.

Other features: Microfossil ovate to circular, thin-walled, mottled-granulate, often with a single fold.

Similar forms: cf. "Fungal or bryophytic spores", Rouse 1956, Pl. VI, Fig. 41,42. (Cretaceous).

Leiosphaera maculosa sp. nov.

Pl. XII, Fig. 17.

Occurrence: Perdrix equivalent.

Holotype: Pl. XII, Fig. 17. Slide P-15 (36.1 x 111.7), M.P.C.; 65 μ.

Diameter: 55 - 72 μ.

Other features: Microfossil ovate to circular, thin-walled, mottled-granular. The wall is inaperturate and usually not folded.

Remarks: This species is similar in structure and size to the body of Pterospermopsis equatorius. It has not been encountered in the Onondaga formation although it occurs in association with P. equatorius in the Perdrix.

Leiosphaera macromaculosa sp. nov.

Pl. XII, Fig. 20.

Occurrence: Perdrix equivalent.

Holotype: Pl. XII, Fig. 20. Slide P-15 (28.7 x 118.5), M.P.C.; 89.5 μ.

Diameter: 77 - 90 μ.

Other features: Microfossil circular, dense, mottled-granular. There is no distinct wall visible on this form. Not folded.

Leiosphaera plicata sp. nov.

Pl. XII, Fig. 15.

Occurrence: Perdrix equivalent.

Holotype: Pl. XII, Fig. 15. Slide P-20 (17.5 x 107.4), M.P.C.; 64 μ.

Diameter: 59 - 70 μ.

Other features: Microfossil subcircular, thin-walled, laevigate, usually with several long folds.

Leiosphaera perspicua sp. nov.

Pl. XII, Fig. 12.

Occurrence: Onondaga formation.

Holotype: Pl. XII, Fig. 12. Slide 432-20 (20.7 x 103.1), M.P.C.; 84 μ.

Diameter: 71 - 89.5 μ.

Other features: Microfossil ovate to circular, laevigate, and thin-walled, characteristically strongly folded.

Remarks: Except for the inevidence of a tetrad scar, this form would be classifiable as *Calamospora*.

Leiosphaera compressa sp. nov.

Pl. XII, Fig. 18.

Occurrence: Onondaga formation.

Holotype: Pl. XII, Fig. 18. Slide 432-13 (65.1 x 112.7), M.P.C.; 90 μ.

Diameter: 69 - 94 _ .

Other features: Microfossil subovate, laevigate or minutely scabrate, thin-walled but opaque, with broad untapered folds. Each fold possesses a median dark line.

Remarks: The unusual construction of the folds characterise this species.

Leiosphaera densa sp. nov.

Pl. XII, Fig. 16.

Occurrence: Onondaga formation and Perdrix equivalent.

Holotype: Pl. XII, Fig. 16. Onondaga formation, slide 432-13 (55.6 x 115.2), M.P.C.; 69 _ .

Diameter: 64 - 90 _ .

Other features: Microfossil circular, laevigate. Wall 1 - 1.5 _ thick, but may seem thicker because of folding concentric to the margin. Wall usually broken.

Leiosphaera cf. *L. media* Eisenack 1938.

Pl. XII, Fig. 19.

Occurrence: Onondaga formation.

Diameter: 71 - 92 _ .

Other features: Microfossil circular, laevigate. Wall 3.5 - 7 _ thick. Surface featureless except for occasional cracks probably caused by pressure.

Similar forms: *Leiosphaera media* Eisenack 1938, p. 26, Pl. 3, Fig. 11. (Lower and Upper Silurian).

Genus: *Leiofusa* Eisenack 1938

Leiofusa tomaculata sp. nov.

Pl. XIII, Fig. 21.

Occurrence: Onondaga formation.

Holotype: Pl. XIII, Fig. 21. Slide A32-15 (41.4 x 111.5), N.P.C.; 134 μ x 54 μ.

Diameter: Length, 108 - 171 μ; width, 40 - 63 μ; width/length, 0.34 - 0.47.

Other features: Microfossil sausage-shaped, with broadly rounded extremities. Wall thin, laevigate or faintly mottled, often broken at one end as if by pressure.

Remarks: Two other species of *Leiofusa*, *L. bacillum* and *L. minutum*, have been reported from the Onondaga formation by Deunff (1955), but these were not encountered in our samples.

Leiofusa navicula Eisenack 1951.

Pl. XIII, Fig. 22.

Occurrence: Perdrix formation. Europe: Silurian.

Remarks: Eisenack (1951, p. 192; Pl. I, Fig. 8), gives 50 μ x 210 μ as the dimensions of his holotype. The dimensions of our form are: width, 38 - 51 μ; length, 179 - 267 μ; width/length, 0.18 - 0.26.

CHARACTERISTICS OF THE MICROFOSSIL ASSEMBLAGES

The conditions of the first two objectives of this investigation have been dealt with in the foregoing sections. Consideration now remains to be given to evaluation of the microfossils already disclosed and described. As an approach, it seems expedient to review the microfossils not as individuals but as assemblages, and this is the aim in the present section.

An account of the distribution of form features and of the representation of genera in all the samples is therefore given in the succeeding paragraphs. It will serve as a framework for assessment of total floral structure and palaeoecology, and will be referred to during the discussion of stratigraphic applications. Spores and hystrichospheerids have been treated separately for convenience, but with no intention of minimizing the importance of coordinated study of these two most important groups of microfossils. Other remains, particularly of conductive tissue, are considered at lesser length since they occur more rarely and are usually fragmentary.

The graphs, Plates XVII, XVIII and XIX, illustrate the percentages of those genera and species of spores and hystrichospheerids which were encountered in each of the strata in an abundance of two per cent or more. These forms are here referred to as the dominant forms. For each sample the same number of counts was made (four), each from a different slide, and these were averaged to obtain the graph. Complete lists of the species found in each sample are given in Appendix 1.

I. Spores:

The spore assemblages described from Devonian formations collectively contain thirty four genera and one hundred and sixteen species. Five of the genera are new (Perimetrisporites, Radiaspora, Velasporites, Arenosisporites and Circumsporites), and four are emendations (Archaeotriletes, Retusotriletes, Camarozonotriletes and Archaeozonotriletes). Ninety three species are new, and two are new combinations.

Of the genera of spores which occur in our Canadian samples, several of those which were previously recorded are not listed for the Devonian period by Hoffmeister, Staplin and Malloy (1955a), on their charts of geologic range presented for North American spores. Some of these unlisted genera (Leiotriletes, Acanthotriletes, Raistrickia, Radiaspora, Grandispora and Converrucosisporites) have been reported in younger rocks on this continent, and some (Leiotriletes, Raistrickia, Radiaspora, Converrucosisporites) were reported from the Devonian of Canada, but not described, by Radforth and McGregor (1954). Species assignable to all of these genera with the exception of Converrucosisporites occur in the Devonian of the Moscow basin (Naumova 1953). The present report is the first to record forms belonging to Perimetrisporites, Velasporites and Circumsporites.

In general, the spores are highly varied in size, ornamentation and shape, and in structure of specialized features such as the perisporium. Several features are present which suggest structual complexity. Examples are flanges (as in Cirratriradites), cingula (as in Anulati-sporites) complicated thickenings (as in Radiaspora) and reticulate or "cellular" pattern (as in Dictyotriletes and Reticulatisporites). On the other hand, certain features, in particular monolete apertures, germinal furrows and paired air-sacs, which are prominent in younger assemblages, are not known with certainty from our Devonian samples. Laevigato-sporites sp. A. may perhaps be a monolete spore, but its interpretation is uncertain as yet.

A survey of the total spore population of the samples investigated reveals several features which are prominent. The most outstanding of these is the triradiate aperture (trilete). This feature is obvious on most specimens, even though it is sometimes obscured by heavy ornamentation. With few exceptions (Raistrickia difficilis, Cristatisporites impeditus, Dictyotriletes insolitus, and questioned forms such as Apiculatisporis sp.A), all of these described species were either obviously trilete or proved to be so after detailed examination of a large number of individuals. A few apparently alete forms of doubtful affinity were encountered, but these were placed with the hystrichosphaerids, in the genus Leiosphaera.

Another well expressed character is the closely-enveloping perisporium of the type present in Archaeozonotriletes and Circumsporites. There have been no reports of a similar enveloping layer from dispersed spores of younger Palaeozoic rocks, so that its presence in the Devonian may prove to be an important criterion separating rocks of this age from those of the Carboniferous.

An equally prominent structural feature among Devonian miospores is the proximal apex (sensu Naumova), characteristic of the genus Retusotriletes. The present evidence is the first to support the data of Naumova (1953), and the observation that these two features, perisporium and apex, have their maximum development in the Devonian period.

Radial striations of the Radiaspora-type and the grapnel-like appendages possessed by the genus Archaeotriletes are additional features which appear to be best developed in Devonian assemblages. The present evidence substantiates the literature on this point. (cf. Naumova, 1953, Arnold 1936).

Spores with reticulate, apiculate and spinose ornamentation, and with flanges and zona, are conspicuous but not abundant. A broadly sub-triangular outline in transverse compression is the most common shape, but circular and ovate outlines are also well represented in all of the samples.

In diameter the spores of our samples range from 15 μ to 610 μ, but most of them lie between 25 μ and 70 μ (Plates XX to XXI). The diameters of most of the Sextant and Battery Point spores fall within this range. The Perdrix and Onondaga spores tend to be smaller (i.e. most lie between 10 μ and 50 μ), while those of the Melville Island are larger (mostly from 50 μ to 110 μ). Small megaspores occur in the Melville Island formation, and less commonly in the Battery Point.

A few words seem appropriate concerning diameter range within the genus Retusotriletes. Naumova (1953, p. 10) observes that spores of this genus in Lower Devonian deposits of the Russian Platform are never larger than 10 μ to 15 μ, that in the Middle Devonian they reach a maximum size of 60 μ to 70 μ and are the dominant genus, and then in the Upper Devonian they are again smaller (30 μ to 40 μ). None of our species are as small as 15 μ. Most are from 50 μ to 90 μ in size, thus agreeing with Naumova's Middle Devonian size range.

Tetrads of spores were present in all of the samples. There was no appreciable association of tetrad presence with forms which had reduced ornamentation or showed other evidence of immaturity. Neither did tetrads appear to be much more abundant in one formation than in another. They were slightly more numerous in the Sextant, and somewhat less common in per cent in the Onondaga formation and the Perdrix equivalent than in the Battery Point or Melville Island formations.

Occasionally masses of spores were encountered, some of which contained closely adhering components, and were of broadly fusiform or linear-oval shape, suggesting the original shape of elongate sporangia. Two such masses were seen in the Sextant samples. One (Plate XVI, Fig. 2, 4 and 6) contained spores of Perimetrisporites mundus, while the other (Plate XVI, Fig. 3 and 5) was composed of small granulate spores resembling Granulatisporites minutissimus. In the Melville Island assemblage, a mass composed of Retusotriletes magnificus was discovered (Plate XVI, Fig. 1, 7 and 8). In none of these masses did the spores occur in tetrads. The comparative sizes of these spore aggregates is shown in Plate XIV, fig. 10, 11 and 12. Frequently smaller groups of spores were seen, but these were loosely adhering and of indefinite shape.

Each of the five formations bears a set of distinctive spore features in addition to diameter by which it isdistinguishable from the others. The Sextant is characterized in all of its productive samples by two genera which predominate, Perimetrisporites and Retusotriletes. Subtriangular outline is also particularly favoured in this formation, the feature being characteristic for Perimetrisporites, Leiotriletes, Dictyotriletes, Radiaspora and Lycospora. In these respects the Sextant differs from the Battery

Point with which it has most similarity. In the latter, the genera Perimetrisporites and Retusotriletes are very minor constituents (less than 2% of the total generic representation), while spores with smooth or granulate to apiculate walls (Calamospora, Cyclogranisporites and Lophotriletes) are numerous. The presence of these genera in the Battery Point also gives predominance to circular and ovate form, which is another difference from most spores of the Sextant assemblage.

The Onondaga formation and the Perdrix equivalent contain assemblages which are alike in diameter of spores and in representation of hystrichosphaerids, but are quite distinct as to certain predominant spore features. The Onondaga bears several smooth-walled forms of the genera Leiotriletes and Calamospora, and one species Leiotriletes incipiens, which is dominant. The Perdrix, on the other hand, is characterized by spores with thickened or spinose walls (Convolutispora, Grandispora) and contains relatively few smooth-walled types. One species, Grandispora crenulata, is known only from the Perdrix and composes about 50% of the total representation of the spores in it.

The corroded appearance of the microfossils of the Perdrix equivalent is of course a feature of secondary origin, but it nevertheless aids in distinguishing the assemblage from that of the Onondaga.

The Onondaga and Perdrix assemblages are both outstanding because of their low percentage of spores (11% and 4% respectively), the remainder of the total being composed almost entirely of hystrichosphaerids. Spores are not as abundant here, but display almost as much variety and complexity of form as those of the assemblages of the other formations.

Many of the species of spores from these two marine strata occur in the continental sediments as well. Eight of the sixteen species of the Onondaga formation and two of the six species of the Perdrix equivalent were present in the Sextant or Battery Point assemblages. (Appendix I). There is no evidence, however, that these similarities link either the Onondaga or the Perdrix more closely with one of the latter assemblages than with the other.

The remaining formation, the Melville Island, possesses a unique spore conspectus. Several of the form characteristics, present in the other assemblages, such as radial thickenings, ridges, cingula, flanges and reticula, do not occur here. Others, for example perisporium, thin wall and spinose ornamentation, are rare. Calamospora and Hadiaspora, which are present in all of the other assemblages, are not represented. Two genera, Retusotriletes and Velasporites, comprise 90% of the assemblage, and two genera of larger spores, Archaeotriletes and Tuberculatisporites, are conspicuous components not encountered in any of the other strata. Velasporites, with its characteristic proximal "veil", is not known among spores of any other locality or age.

Two additional features of the Melville Island assemblage which separate it from the others are the larger size of most of its miospores and the presence in it of several species of small megaspores. There is a clearly defined break in the size range of the spores of this assemblage, between those measuring 50 μ to 110 μ and those measuring 200 μ to 600 μ, with only a few species or individuals lying outside these limits.

The six forms of Retusotriletes which occur in the Melville Island coal deserve additional attention here, since they are in some respects distinct from species of Retusotriletes found in the other samples. They are all densely scabrate, granulate or apiculate, large anisopolar with distinctly flattened proximal portion, and possess a poorly defined cingulum. All are new species.

For one of the formations, the Sextant, the availability of six productive samples, each representing a different stratum, allows us to examine trends in spore form and species at one locality and within a single section.

Several trends can be traced in Section A. Levigate, thin-walled types (Calamospora and Leiotriletes) are numerous toward the top of the section (i.e. in samples A-3, A-5 and A-6) but are rare on the three lower levels. Spores with an apex (Retusotriletes) are abundant throughout the section. In the six samples of section A, the latter spores vary in general inversely as the abundance of the genus Perimetrisporites. Reticulate spores (Dictyotriletes and Reticulatisporites) are present throughout the section, but never comprise more than 5% of the totals.

Of the seventeen genera recorded from section A, only Perimetrisporites, Radiaspora, Retusotriletes and Archaeozonotriletes are consistently present, usually in an abundance of 2% or more. Within these four genera, three species, Perimetrisporites nudus, Radiaspora rotata and Retusotriletes simplex, qualify as dominant species. Several species occur in almost every sample although they are never dominant. These are Cristatisporites speciosus, Radiaspora ampla, Granulati-sporites minutissumus, Retusotriletes magnus and Archaeozonotriletes papillatus.

In contrast to the aforementioned spores which are of wide occurrence, some others are restricted to particular levels of the section. *Lycospora scabrata* and *Calamospora radiagranulata* were found only in sample A-5. *Retusotriletes arcuatus* comprised 7% of the A-5 assemblage, but was rare in the other samples, and *Calamospora umbrata*, 2.5% of the total in A-5, was also rare elsewhere. An additional feature of A-5, perhaps the most striking, is that it is the only level of the section in which *Perimetrisporites* was not encountered.

In sample A-3 *Retusotriletes* predominates, and the species *R. elegans* is particularly abundant. This level also bears the highest percentage of *R. laevigatus* (8%) and of reticulate spores (5%).

In samples of A-17 (1) and A-17 (2) *Perimetrisporites* is extraordinarily well represented, with the result that there is an apparent impoverishment of the number of genera and species in these samples. Actually, however these levels contain no fewer types than most of the other samples, but the abundance of *Perimetrisporites* allows a smaller number of other genera to qualify as dominant.

Levels A-3 and A-6 are not as sharply delimited by typical species as are the ones discussed in the preceding paragraphs. A-3, the highest productive zone of the section, contains an unusually high percentage of *Archaeozonotriletes* (12.5%), while the percentage of *Perimetrisporites* is low. Most characteristic for A-3 is the relatively large number of dominant genera and species, by which this stratum marks the high point of a tendency toward increase in number of dominant forms from the bottom of the section (A-17 (2)) toward the top (Plate XVII). A-6 resembles A-3 in possessing a higher percentage of Retusotriletes simplex than do the other samples of the Sextant.

In sample C-1, the only productive layer of section C, the aspect of the spore assemblage is in general like those from section A (Plate XVII). Perinotrisporites and Retusotriletes are still the most abundant genera, and Radiaspora, Dictyotriletes and Archaeozonotriletes are present in low percentages, as they are in most of the samples of section A.

In total numbers of dominant genera and species, the assemblage of C-1 agrees most closely with that of sample A-3. Each possesses eight genera and eleven species. Only five of the species are common to both strata, but seven of the eight genera are shared by both. The large number of spores of the genera Leiotriletes and Calamospora in C-1 presents a similarity between this sample and the upper part of section A.

In other respects, particularly with regard to species, differences between C-1 and A-3 are evident. Radiaspora annulata, Apiculatisporis obtusus and Grandispora spinosa occur only in C-1. The occurrence of the latter species in Upper Mississippian rocks of Kentucky (Hoffmeister et al. 1955b) might further suggest, however, that C-1 belongs high in the Sextant formation. Granulati-sporites minutissimus, a dominant genus in A-3, is absent from C-1, and the relative abundance of Perinotrisporites mundus and Retusotriletes simplex are reversed in the two samples.

2. Hystrichosphaerids:

Hystrichosphaerids were not found in either the Sextant formation or the Melville Island formation. In the Battery Point they occurred only occasionally, comprising 2.5% of the spore-hystrichosphaerid assemblage. Four species were present in the Battery Point, all of them forms with long appendages, of the genera Hystrichosphaeridium (three species) and Veryhachium (one species).

In contrast to the condition in the Sextant, Melville Island and Battery Point assemblages, the microfossil contents of the Onondaga formation and the Perdrix equivalent contain a preponderance of hystrichosphaerids with relatively few spores. In the Onondaga there are eight genera and twenty-seven species of hystrichosphaerids, one of the genera (Saccosphaera) and twenty-three of the species being new. The Perdrix equivalent has seven genera and seventeen species, of which sixteen species are new.

In general aspect, the hystrichosphaerid assemblages of these two strata are not alike. Only eight of the thirty-seven species of these two strata occur in both, and four of these are not dominant species. On the other hand, even within the Onondaga formation considerable diversity of species apparently exists, since only seven of our species bear close similarity to species of Deschnagel (1941) and Deunff (1954a, 1955).

Forms with thin walls and long, divided or undivided appendages (Micrhystridium, Veryhachium and Hystrichosphaeridium) comprise more than 60% of the hystrichosphaerid population of the Onondaga sediment. The Perdrix equivalent, in contrast, contains over 60% of circular or subcircular types without appendages (Leiosphaera). In the Onondaga, forms with a body diameter of less than 30 μ predominate, while in the Perdrix equivalent most forms exceed 30 μ.

While the difference between these two assemblages are most evident, there are some elements of similarity as well. For example, *Pterospermopsis parvus* and *P. equatorius* are present in both. Indeed, the total percentages of the genus *Pterospermopsis* are similar in the two samples (6.3% in the Perdrix and 8.4% in the Onondaga). Each assemblage also possesses one species of *Leiofusa*, neither of which is a dominant form in its assemblage.

On the graphs of dominant genera (Plate XIX), more than 20% of the totals are listed as "other hystrichosphaerids". This miscellaneous category is included because each assemblage possesses several forms which are less than dominant in percentage, but which must be counted in order to give a comparative picture of the sum of the hystrichosphaerids compared to the total spore population.

3. Other microfossils:

Most of the microfossils other than spores and hystrichosphaerids are either fragments of conductive tissues, or irregular remains that possess very few or no distinctive features. The latter remains, because of their ambiguous nature, have not been considered in this investigation.

Fragments of woody remains occurred frequently in the Battery Point and Melville Island preparations. In the Battery Point sediment annular, scalariform and pitted elements were recognized. The annularly thickened, apparently flattened tube-like fragments, shown in Plate XV, Figs. 6 and 8, occurred frequently in this sediment, although not on all of the slides. The thickenings of the tubes are 4 μ to 8 μ apart, and the tubes themselves are about 20 μ to 25 μ wide. None of them showed any evidence of transverse walls or branching. One slide contained several fragments of scalariform elements, one of which is illustrated in Plate XV, Fig. 9. Fragments bearing bordered pits occurred occasionally (Plate XV, Fig. 10).

Scalariform elements with a distinctive septate appearance were the most abundant of the tracheary fragments in the Melville Island coal. Often, fragments of these septate structures were found which were composed of several tubes united laterally. The latter elements were apparently not associated in the sediment with any particular type of spore. In the same sample, another more obscure structure (Plate XV, Fig. 1) was always associated with small, smooth, subcircular spores. This structure was net-like, with meshes of irregular size and shape, and was usually of indefinite form, as if distorted or torn. The associated spores, from 20 μ to 50 μ in size, adhered to the mesh, sometimes in closely packed groups or more usually singly, but never in tetrads or with any evidence of a tetrad scar.

One rather large fragment 1 mm. long, bearing node-like structures, was also discovered in the Melville Island sediment. It was densely fibrous in appearance, with closely aligned, irregularly anastomosing strands. At intervals of about 30 μ the strands were joined laterally at node-like joints (Plate XV, Fig. 2).

Another, larger woody fragment from the Melville Island coal is figured in Plate XV, Fig. 3. Very little structure was visible in it, but it bears a distinct branch-like division as if it were a portion of a main stem with a smaller lateral branch. Part of the central portion of the branch is missing. Almost opposite this branch is a stub-like knob which may represent the base of another branch. There is some evidence of a fibre-like structure, visible at the thin terminal portion of the branch and the main "stem".

A microfossil fragment with uniseriate pits along one margin was also present in the coal. It was 110 μ long and 32 μ wide at its widest part. The oblong-elliptical apertures were 5 μ to 6 μ long and about 2/3 as wide, and in a distinctly linear arrangement close to one margin of the fragment and parallel to it. The long axes of the pits were slightly angled to the margin (Plate XV, Fig. 7). Each of the apertures bore a narrow border.

In the Sextant samples no fragments other than spores were found which were of diagnostic value. Numerous small angular fragments were present on all of the slides, some of which were spore fragments and others of which were of unknown relationship.

The Onondaga formation and the Perdrix equivalent contained very few fragments that were not assignable to spore or hystrichosphaerids. In the Perdrix, several structures occurred which closely resembled spore exines in colour and texture, but which did not resemble the form of any known plant structure (Plate XVI, Figs. 9 -13). Dr. A. K. Miller[1] has examined photographs of these remains and has identified them as scolecodonts. They are of particular interest because the appearance of their walls so closely resembles that of the exines of spores. They may possibly occur in other sediments in association with plant fragments.

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BOTANICAL SIGNIFICANCE OF THE MICROFOSSILS

1. <u>Assumption basic to interpretation of fossil floras:</u>

To estimate evolutionary, distributional and ecological patterns among fossil plants the use of certain basic assumptions fundamental to palaeontology will be required.

First, it is assumed that plants in the past underwent adaptive change in response to climatic fluctuations, competitive pressure, and ecological barriers, in a fashion similar to that of present-day plants. (Wilson and Hoffmeister 1955, Cross 1947.)

It is also assumed that although the climate and physiography of the earth displayed immense variations throughout the past cycles of the earth's history, the erosional, depositional and orogenic forces that were operative then were similar in kind to those of today.

Assuming these circumstances to be valid, one can assess a plant or a plant fragment contained in a particular sedimentary rock, in terms of both the botanical appurtenances of the fossil and the features of the enclosing rock. Thereby additional or substantiating data can be derived of both botanical and sedimentological value.

2. <u>Validity of plant microfossils as indicators of floral structure and relationships:</u>

The principal difficulty involved in assessing the botanical significance of microfossils of any age is that they may represent only fragments of plants, which are largely unidentifiable with the plants which produced them.

Even so, some microfossils, spores in particular, are probably representative of variations equivalent to familial, generic, or even specific differences in their sporophyte parents. This conclusion is enforced by the evidence of definite and often extraordinary structural features on the microfossils, and by evidence of association of certain spore features with particular plant taxa. The observations of several authors supports this point. (Wilson 1934, Thomson 1952, Naumova 1953, Potonié and Kremp 1956b).

Opinions are by no means unanimous however, concerning the degree to which certain microfossil features parallel the criteria used to separate the natural plant groups. Species of some Palaeozoic fern genera (i.e. Botryopteris and Scolecopteris) apparently possess spores that are widely different (Remy 1950). On the other hand, Chaloner (1957) quotes several instances which convincingly support the consistency of spores as indicators of natural species, and Harris (1955) states that "... features of the spore coat provide, in many cases, constant characters by which the parent genus or even species may be recognised."

This need arising through lack of data relating microfossils to their parent plants is gradually being met on the particular level by the work of Halle (1933), Radforth (1939), Remy (1953) and others who have extracted and described spores from sporangia. Certain spore forms are in this way related to species of megafossils. Undoubtedly, this approach provides the basic data upon which future conclusions on spore-parent relationships will be built.

At still another level of approach, plant microfossils show promise of being useful for reconstruction of successions of living forms on a broad scale, and for evaluating patterns of population change through time. This approach is to some extent dependent on results achieved at the particular level, but works with combinations of morphological features and is concerned with higher taxa than genus and species. Subtriangular miospores with equatorial flange-like structures and zona of the form of the genera Cirratriradites and Lycospora, for example, have repeatedly been found or associated with lycopsid cones (Chaloner 1953c, 1954, Hoskins and Abbott 1956). They are not known from any plant outside the lycopsid group. This is strong indication that dispersed miospores which possess these structures are allied with the Lycopsida, as Potonié and Kremp (1956) believe. It is of course assumed that conclusions derived in this manner will be reinforced or revised as further evidence is brought forward.

Proof or assumption of identity with established taxa is not the only means of assessing sporae dispersae for reconstruction of past floras. These microfossils show persistent and fluctuating structural trends throughout their geological record, trends that can be evaluated separately from consideration of the form classification of the parent plants. These microfossil structures, "morphographic" in the sense of Potonié and Kremp (1954), undoubtedly bear some coordinated relationship to trends in the parents, and it is the assumed existence of such relationship, rather than its quality, that is valuable at this stage. Radforth and McGregor (1956) proposed this approach, using miospores and assessing presence and abundance of twenty-four structural features throughout the Palaeozoic. They state that although form features of isolated spores may ultimately be traced to specific natural groups of plants,

> "In the meantime, it may be distribution of spore form, even more than that of artificial genera, which can provide the better circumstantial evidence for interpretation of the ecology and phylogeny of the Palaeozoic flora."

There is evidence that these approaches to floral interpretation can be extended to microfossils other than spores. For example, it is well known that certain large groups of plants possess scalariform or pitted tracheids, while these features are not known to occur in other groups. Fragments of these structures and others which often occur as isolated microfossils, can thus lend themselves to interpretations of the structure of the palaeo-flora.

Evaluations of ecology and phylogeny are also important aspects in a comprehensive interpretation of fossil floras. Because of several factors, such evaluations depend on methods and approaches that are in many ways different from those used for living plants. Perhaps the most significant factor is that of difference between fossil and recent floral components, differences which become more marked with increasing age of the fossil flora. In addition, fossils represent only a very incomplete record of the floras of the past. Those plants which are preserved are selected by both geological and biological factors, and represent only a few of the possible environments (e.g. the coal swamp).

When plant microfossils are applied to interpretation of these problems, several other aspects exist which are not present when megafossils are used. Especially for spores, emphasis is not placed on the complete organism or on large fragments of vegetative tissue, but rather on a relatively transient portion of the life-cycle. At least some of the spores may become distributed in patterns which are different from the original distribution patterns of the parent plants. Furthermore, spores may indicate slower changes within palaeo-floras than do megafossils, since it is the contention of many botanists (Harris 1955, Wilson and Hoffmeister 1956, and others) that modifications in reproductive structures were less rapid and tended to lag behind vegetative modifications.

The necessity of recognition of the foregoing factors is emphasized so that appropriate care may be taken in drawing conclusions from the evidence of this investigation.

Three methods will therefore be applied to the botanical interpretation of the microfossils of the five formations in question. These are the relation of certain structural features of groups of dispersed spores and secondarily of other microfossils to features borne by megafossils for which natural affiliations are known, the identification of species of isolated spores with spores for which the botanical affiliations are known, and finally the evaluation of form features of the microfossils without reference to biological affinities.

3. Interpretation of floras using microfossil evidence:

In this work evaluations of botanical relationships within the Devonian flora will therefore first deal with affinities of the various form features of the microfossils, and ecological and phyletic evaluations will be made where appropriate. Particular species and larger groups of microfossils can conveniently be considered simultaneously.

Initial interpretations of affinity within the various microfossil assemblages are possible, based on form features possessed by groups of microfossils. The triradiate mark is perhaps the most widespread feature in all of the assemblages, and certain remarks are appropriate concerning its value as an indicator of botanical relationship.

A broad range of living and fossil plants within the Bryophyta, Psilopsida, Sphenopsida, Lycopsida and Filicineae have trilete spores, as do several fossil forms of unknown affinities such as Cooksonia and Zosterophyllum (Croft and Lang 1942), Hostimella globosa (Lang 1925) and Protosalvinia (Arnold 1954). Notable among those which do not bear this feature are the Psilotales, certain lycopsids (i.e. Isoetes and Paraguanathia (Harris 1955), and some members of the families Schizaeaceae, Gleicheniaceae, Cyatheaceae and Polypodiaceae within the leptosporangiate ferns, all of which have monolete rather than trilete spores.

Triradiate apertures are not known among living or fossil conifers or angiosperms, even though it has been speculated that ancestors of these groups possessed spores of this form (Kosanke 1950, Pflug 1953). Trilete genera of sporae dispersae such as Illinites and Endosporites have been placed for convenience with the Coniferales (Potonié and Kremp 1956), but their true affinities are probably not with the conifers.

Evidently, conclusions concerning affiliations of the dispersed spores in this account, if based on the tetrad scar must be broad and not restricted to groups whose relationships are known. It can be concluded that the groups mentioned in the foregoing remarks which do not possess trilete spores were either extremely rare in the Devonian flora of the five assemblages, or were absent.

Thin-walled and laevigate circular spores are associated by many workers with Calamariaceae, largely because of the frequent association of Calamospora with this group in the Carboniferous. This suggests that at least some of the Calamospora spores of our assemblages belong to this group, and further that this group, or related forms with similar spores, was more widespread in the Middle and Upper Devonian than previously supposed. It must be remembered however, that other fossil plants possessed thin and laevigate spores, of which the Upper Devonian fern-like species *Archaeopteris latifolia* (Arnold 1939) is an example.

The thin-walled subtriangular, laevigate miospores (*Leiotriletes*) that are numerous in most of the Devonian assemblages are possibly related to several plant groups. Similar spores have been borne by ferns of various genera, *i.e.* *Anemia poolensis* (Chandler 1955, Tertiary), *Leceopteris Colleyi* (Miner 1935, Cretaceous), *Coniopteris* (Thomas 1911, Vladimirovich 1950, Jurassic) and *Boweria minor* (Knox 1938, Carboniferous). Some may be pteridospermous (*cf.* *Renaultia gracilis*, Kidston 1923), and some may belong to the Silurian-Devonian genera *Cooksonia* (Lang 1937), *Zosterophyllum* (Croft and Lang 1942) and *Psilophyton* (Rosenberg 1954). In view of the variety of plants known to possess this type of spore, it would be difficult to definitely correlate *Leiotriletes* with any single supra-generic plant group.

Naumova (1953) interprets the thin-walled, laevigate spore in broader terms, having noted the association of these features with certain types of sedimentary rocks and having drawn analogies with present-day plants. She says that spores and pollens of hydrophytes tend to be thin-walled with reduced sculpture, and also of relatively small size, while those of mesophytes and xerophytes have more or less prominent sculpture and thickened walls. Applying this interpretation to the present assemblages, mixed populations containing moisture-loving or lowland, and mesophytic and xerophytic or upland elements would be indicated for the Sextant and Battery Point formations, with perhaps a greater degree of hydrophytic forms in the latter sample. The spores of the Onondaga would represent a hydrophytic flora for the most part, but those of the Perdrix equivalent a more varied source because of the greater percentage of ornamented species. It is more difficult to interpret the Melville Island assemblange in this way, since although its spores certainly possess reduced sculpture they at the same time are in general opaque and thickened, as well as being large in size.

The widespread occurrence in our samples, as in those of Naumova (1953), of spores with a perisporium characteristic of the genus Archaeo-zonotriletes favours affiliation of this feature with a group of inter-related plants. There are some indications as to the possible character-istics of this group. The report of Naumova (1953) that spores with a perisporium occur in Sphenopteridium Keilhaui Nath. suggests a fern or perhaps pteridosperm relationship. Walton (1949) reports spores of Alcicornopteris Hallei which apparently possess a thin perisporium that readily separates from the rest of the spore, which further indicates that the perisporium was present on the spores of at least some pteridosperms. On the other hand, Hoskins and Cross (1943) show that spores of some species of Bowmanites (Sphenophyllales) also have a perisporium and they postulate that the class Sphenophyllales " ... possess a similar structure either in some or in all of its members." (ibid., P. 131).

Bower (1935, P.429) noted the presence of a perisporium in certain leptosporangiate ferns and stated that it was "... clearly a feature adopted late in descent, and restricted to certain circles of affinity." This opinion appears to be no longer tenable, since Devonian forms may represent elements affiliated with Sphenophyllales and the pteridosperms as well as the leptosporangiate forms. In fact, relationship with the latter is more doubtful than with the other groups, since the perisporium is most frequently associated with monolete forms among the living leptosporangiates, while it is apparently restricted to trilete spores in the Devonian.

The perisporium of Devonian spores in the assemblage emphasized in this account would thus be homoplastic with the counterpart of living fern spores, rather than homologous. The perisporium apparently became an extremely rare feature among sporae dispersae by the end of the Devonian period, or in the Lower Carboniferous, since it is not evident in the prolific Upper Paleozoic spore flora.[1]

The abundance of forms bearing an apex also suggests that spores with this feature were, like the perispore, derived from plants of common relationship. Indications of the possible botanical affinity of these spores are scarce. Proximal faces delimited by arcuate lines and thickenings occur on Carboniferous megaspores of several form genera (i.e. Laevigatisporites, Sotosisporites and Zonalesporites) that have been related to the ligulate Lepidophytales (Sigillariaceae and Bothrodendraceae) (Potonié and Kremp 1956b), but miospores of comparable age do not possess this feature. Assignment of lycopsid affinity to species of Retusotriletes would be only tentative on this basis.

Naumova (1953) assigns spores of Retusotriletes to the Marattiales, because some examples of this group of ferns (she mentions Danaeopsis)

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[1] Unless Laevigato-sporites includes the exines of species that have failed to retain their perisporium on preservation. This is unlikely, since no vestige of a perispore-like structure has been reported in association with this genus.

have a similar apea. It is not clear whether or not she has more evidence for this conclusion, or whether she would suppose Marattiaceous affinity for all spores with an apea, on the basis of this one similarity. The writer has a more reserved opinion but agrees that an affinity may be justified at least in part with this fern order, especially since megafossil remains from the Carboniferous (*Pecopteris*, *Scolecopteris*) suggest that the family Marattiaceae is one of the oldest of ferns.

It must be concluded therefore that although the correct affiliations of *Retusotriletes* are not known, possible relationships to the ferns, particularly the Marattiales and more questionably to the lycopods, are indicated. It may be mentioned that many of the spores of present-day lycopods have smooth proximal portions or contact faces, with arcuate outer margins.

To the writer's knowledge, no record exists of association of spores with radial striations (*Radiaspora*) with any sporangial remains. It is impossible at present to judge whether the resemblance between these dispersed spores and the spores of the present-day fern *Saccoloma elegans* is indicative of botanical affinity. Whatever their relationships maybe it is probable that they were borne by a group of plants that were adapted to a fairly broad range of habitat, or, if they were restricted in habitat preference, the particular environment in which they grew was widespread in the Devonian period. This conclusion seems valid in view of the fact that *Radiaspora* occurs in as many as four of the five formations investigated. Possibly the parent plants were herbaceous, and hence not amenable to the preservation as megafossils.

Affinities of the spores of the unique genus Archaeotriletes, present in the Melville Island coal, have in the past been speculated upon by several investigators. Kräusel and Weyland's (1929) association of a small spore of this form with Aneurophyton may indicate an affinity for the much larger sporae dispersae of similar form, but the evidence of these authors would be more convincing if it had been accompanied by clear photographs. Even so, these authors figure dispersed spores from the same locality which undoubtedly belong to Archaeotriletes. Arnold (1933, 1935) reports spores, which are perhaps similar to Archaeotriletes, from a sporangium called Lepidostrobus Gallowayi, but again the evidence is not convincing. If these spores are borne by both Aneurophyton, and Lepidostrobus, the presence of spores with similar unusual features on plants that are probably not related would be very interesting from an evolutionary standpoint. Other references to spores of this genus do not suggest an affinity with any particular parent.

As pointed out earlier (p. 56) the writer does not agree with Naumova's (1953) alignment of Archaeotriletes with Azolla. The massula which surrounds Azolla megaspores and bears the glochidia is delicate and easily destroyed, so it is very doubtful if it could be preserved as a fossil except under extremely unusual conditions. Moreover, the massula in Azolla is not a part of the megaspore proper, as the appendage-bearing wall of Archaeotriletes appears to be. Even if the two structures were homologous, the difference in their ages is too great to allow any but a most tentative suggestion of their affinities. We must therefore conclude that at present the botanical relationships of Archaeotriletes are unknown.

Lang (1925) states that a considerable number of the dispersed spores from Middle Devonian rocks of Cromarty, including forms assignable to Archaeotriletes, are between 100 μ and 200 μ in diameter. This, he says is " ... remarkably large for spores of homosporus Pteridophyta or Pteridosperms." Possibly then, Archaeotriletes is the small megaspore of a heterosporous plant. This conclusion is favoured by the association with Archaeotriletes in the Melville Island coal of larger spores that are probably megaspores, but which are also smaller in size than most Carboniferous megaspores. In addition, most megaspores that have been found in Devonian rocks by other investigators (i.e. Archaeopteris latifolia (Arnold 1953), Enigmophyton superbum (Høeg 1942), Kryshtofovichia Africani (Nikitin 1934) are of correspondingly small size.

At this point it is appropriate to consider the floristic implications of the presence of heterospory within the Devonian, as they are influenced by the assemblages presented in this investigation. The existence of megaspores in the Upper Devonian has been demonstrated by the authors cited in the preceding paragraph, and the megaspores of the Melville Island coal are further examples. If the large spores (Triletes sp. A. and T. sp. B.) which were found in the Battery Point sediment are megaspores, they add a Middle Devonian record to the geological range of this feature.

It may be significant as an indicator of the course of development of heterospory that the miospores of at least some Devonian assemblages, including the Melville Island, tend to be unusually large (Elovskaya 1936, Høeg 1942, Thomson 1952), while Devonian megaspores, as illustrated by the present assemblages and others, are distinctly smaller than those of the overlying Carboniferous. This fact suggests that heterosporous plants, while well established in the flora of the upper part of the Devonian, had not yet developed to the stage where the male and female spores were as greatly different in size as they were in the Carboniferous.

The megaspores of the Melville Island assemblage may perhaps be lycopsid, since all could be assigned to the form genus Triletes, which Schopf (1938), Harris (1935) and others have placed with the heterosporous free-sporing lycopods. Lycopsid, particularly sigillarioid, affinity is also favoured for them because of the resemblance of Tuberculati-sporites submamillarius to spores associate with Sigillaria (Chaloner 1953a).

The significance of the cutinized mesosporium of T. submamillarius is not clear. A similar structure has been observed in several Carboniferous megaspores and in megaspores of Gondwana rocks (Hoeg et al. 1955), so that it is not a feature that is restricted to the Devonian. Even some present-day megaspores possess mesosporium-like structures that are cutinized (i.e. Selaginella and Isoetes), but it is not known whether or not they could be preserved as fossils. The mesosporium of fossil megaspores may thus be a lycopsid feature since it is present in several examples of the group. On the other hand, some of the megaspores that Surange et al. (1953) discovered in the Lower Gondwana of India appear to possess a mesosporium, and lycopods are not known to occur in Indian rocks of this age.

Most available evidence, therefore, although not conclusive, points to lycopsid affinity for the small megaspores of the Melville Island coal, and perhaps for those of the Battery Point formation.

The Devonian species of miospores which bear equatorial flanges (Cirratriradites) may also be lycopsid, at least in part. Schopf et al. (1944) suggest such affinity for this genus, and later work has proved the relationship of C. annulatus with the herbaceous heterosporous lycopod Selaginellites crassicinctus (Hoskins and Abbott 1956) and of spores similar to C. annulatus with Selaginellites suissei Zeiller (Chaloner 1954). It may be significant that some living species of Selaginella (i.e. S. rupestris) bear microspores with an equatorial wing (Knox 1938) and in fact resemble Cirratriradites decorus of the Battery Point formation (Plate XI, figs. 10 and 12). It is not known, of course, whether all Paleozoic miospores with equatorial flanges belong with the heterosporous lycopods, or even with the Lycopsida, but as yet there is no evidence that they were produced by any other group of plants.

The tendency for production of equatorial structures is also present in another lycopsid, Lepidodendron. Reports of spores with an equatorial cingulum of the type borne by Lycospora are numerous in connection with Lepidostrobus (Potonié and Kremp 1956). The presence of both Cirratriradites and Lycospora in the Devonian sediments selected here therefore suggests the existence in their floras of both herbaceous and arborescent lycopods, and perhaps both homosporous and heterosporous members of this group.

Other cingulate miospores (Densosporites and Anulatisporites) are of more doubtful affinity, although there are some indications of lycopsid relationship for them as well. Potonié and Kremp (1956) place Densosporites with "Lycopsida unbekannter Stellung" because transitional forms exist between it and *Lycospora*. To the writer's knowledge, the only published reference to small spores resembling *Denso-sporites* from any sporangium is that of Nathorst (1914) to the spores of *Porostrobus Zeilleri*, a lycopod. Assignment of Devonian species of *Denso-sporites* to the Lycopsida is only tentative therefore, and the same is true of *Anulati-sporites*.

Some indication of the habitat preference of the plants which produced *Denso-sporites* is given by Kramp (1951). He notes that in coals studied by him *Denso-sporites* is most common in the durain components, which were deposited in limnic swamps and lacked a protective forest canopy. *Denso-sporites* would thus probably have been derived from plants which grew on the higher land surrounding the swamp. If this is true it is not surprising that there should be little record of the parent plants of *Denso-sporites*, since their upland environment would not likely lend them to preservation.

Indications are incomplete as to the affiliations of miospores with a single inflated wing, of the genera *Endosporites* and *Grandispora*. The evidence of Chaloner (1951, 1953c) that spores agreeing with *Endosporites* have been borne by *Spencerites* and *Lepidostrobus* is convincing, and both he and Florin (in Crookall and Morris 1952) agree that assignment of *Endo-sporites* with the cordaitaleans as indicated by Schopf *et al*. (1944) and Crookall and Morris (1952) is unwise at present. Thus, *Endosporites insolitus* of the Battery Point assemblage may be lycopsid. On the other hand, Remy (1953, 1955) relates spores with an enveloping wing to the pteridosperms and the Sphenophyllales, so that evidently this feature was borne by spores of at least three major plant groups in the Carboniferous.

There is no evidence available to indicate whether the Devonian representatives were related to those of the Carboniferous, or whether they may represent, at least in part, an entirely different type of parent.

Reticulate spores similar to those present in the Devonian assemblages (Dictyotriletes and Reticulati-sporites) have been discussed elsewhere in the literature. Among present-day plants, reticulate spores are most prevalent in the Bryophyta (Knox 1939) and the Lycopodiaceae (Knox 1950), and Lundblad's (1954) discussion of the affinities of reticulate spores as fossils (see p. 64) indicates that a large portion of these may belong to the same two groups. In view of the suggestions of Knox (1939) and Lundblad (1954) regarding this abundance of Carboniferous members of the Bryophyta, and Neuburg's (1956) opinion that the mosses originated at least as early as the Devonian, it is probable that Devonian reticulate spores are partly bryophytic in origin. Nevertheless, some undoubtedly have lycopodiaceous parents (Naumova 1953). These bryophytic-lycopsid elements were thus well established in the Sextant and Battery Point assemblages.

Spores with granulate or apiculate ornamentation, which comprise a large segment of the Devonian assemblages, occur in every geological period from Devonian to recent and may represent quite a few plant groups. Nevertheless, several particular examples noted in the present assemblages point rather convincingly to certain taxa. Schopf et al. (1944) express the opinion that some species of their genus Punctati-sporites (our Punctati-sporites, Cyclogranisporites, Plani-sporites and Apiculati-sporites) seem "beyond much question" to have affinity with the pteridosperms. They particularly mention alliance with Crossotheca, just as has been indicated here for Plani-sporites dilucidus of the Melville Island coal. Several other species here placed in Cyclogranisporites and Plani-sporites also bear similarities in size, form and ornamentation to spores obtained from Crossotheca fructifications by Kidston (1906). This is further evidence for the existence of pteridosperms in the Melville Island assemblage and in the Middle Devonian Battery Point (cf. p. 154).

Comparisons also suggest alliance of some of the granulate and apiculate spores to the ferns. Many of the spores of living and fossil Marattiaceae are granulate, papillate or minutely spinose (Knox 1938), this agreeing with several species in the Battery Point and Melville Island assemblages. The resemblance of Cyclogranisporites amplus to Acitheca longifolia (R. and W. Emry 1955) is particularly close and implies a Marattiaceous element in the Melville Island coal flora.

Although undoubted similarities in some forms of granulate and apiculate dispersed spores indicate ferns and pteridosperms, much remains to be discovered as to the exact affinities of these spores in the Palaeozoic. Homoplasy may play a part in causing the occurrence of similar forms of spores throughout various geological ages (cf. Schopf et al. 1944), and this may be particularly true for spores with reduced ornamentation. The resemblance between Apiculatisporis teneris (Plate 11, fig. 23), and Osmunda-sporites and Osmunda (p. 48) may be attributable to homoplasy. Since spores with this appearance occur in most geological periods, it is reasonable that they were produced by more than one taxon of plants.

Possibly some of these forms may be immature specimens which have not yet developed full ornamentation, and would be placed in a different form genus when mature. Knox (1938) believes that this phenomenon is probably rare among sporae dispersae since, as she points out,

> "Only spores in which the wall has been cutinised are capable of preservation as fossils, and such spores already exhibit the type of sculpturing characteristic of the adult. The assumption is thus justifiable that microspores found in coals, [... and other sedimentary rocks ...] if they have not actually reached maturity will at least have the characteristics of the adult and can be classified as belonging to the same type."

On the other hand, Radforth (1938) has shown that even immature spores of Senftenbergia plumosa are capable of preservation and that they possess ornamentation of the Punctati-sporites or Cyclogranisporites form as opposed to the ridged spinose condition (cf. Cristatisporites) of the mature specimen. Certainly then, it appears as if some immature specimens could contribute to the assemblages presented in this investigation. Probably they would, however, occur most frequently in groups as Radforth (1938) and Balme and Hennelly (1956) suggest, and thus be recognized as immature. Such groups of spores occur in the present assemblages, but they are mostly small and laevigate forms, not associated in tetrads.

Dispersed spores which possess ridged, spinose ornamentation (Cristatisporites) as mentioned in the preceding paragraph, resemble certain spores obtained by Radforth (1938, 1939) from sporangia of Schizaeaceous ferns of Carboniferous age. The presence of species of this genus in the Battery Point formation suggest that ferns of Schizaeaceous affinity may occur in this portion of the Devonian flora, especially since spores of the present-day genus Aneimia, also of the family Schizaeaceae, possess ridged, spinose spores as well. Cristatisporites speciosus resembles spores of Senftenbergia pennaeformis (Radforth 1939) particularly closely.

Spines that are not connected at their base by ridges, as in Raistrickia difficilis, are also borne by some fern spores (cf. Botryopteris spinosa Hamay 1950). Schopf et al. (1944) mention spores obtained from schizaeaceous sporangia of Pennsylvanian age which contain spores of the Raistrickia type, which further favours the opinion that spinose spore wall is a fern character. The statement of Schopf et al. (1944, p. 55) that "Typical forms of Raistrickia are without doubt filicinean." may be too inclusive since some living species of Selaginella possess spinose spores, but even so, relationship of Devonian spinose forms to the ferns is not easily doubted on the basis of comparisons with forms from Palaeozoic fructifications.

There remain to be considered some spores of unusual morphology, for which there are no comparable forms in the literature. One of these, Perinetrisporites, possesses the subtriangular shape and the granular ornamentation which is a feature of many fern spores. On the basis of morphological comparisons, this genus may be related to Granulati-sporites and perhaps to Reinschospora, although the interradial ornamentation of the latter genus is much more accentuated than that of Perimetrisporites.

According to the distribution pattern of this genus among the Sextant samples (Plate XVII), the plants which produced it were probably locally very abundant in the land surrounding the Sextant basin of deposition, which suggests that they were selective as to habitat, and that plants in this habitat did not always contribute to the sedimentary basin.

In this connection the ecology of the parent plants of Perimetrisporites can be partially inferred. The genus apparently was not being produced in the source locality of the A-5 sediment, while sphenopsid- and pteropsid-like plants (probable producers of Calamospora and Leiotriletes) and the unknown, probably cosmopolitan producers of Radiaspora spp. were dominant elements. Thus we may logically conclude that the habitat preference of the parents of Perimetrisporites was not similar to that which was preferred by the former plants. According to the opinion of Naumova (vide p.153) and the fact that the structure of many fossil and recent sphenopsids indicates their adaption to a moist habitat it could then be inferred that Perimetrisporites was produced in a more upland locality. The existence of such a highland source close to the locus of deposition of the Sextant samples would be expected in view of the probable depositional environment of the Sextant formation (p. 12).

Whatever may have been the exact affinities of Perimetrisporites it apparently was produced by a unique group of plants, since the character of the genus is an unusual one, which has nothing comparable in any of the Devonian assemblages.

The genus Perimetrisporites may serve as an example of the possibility that abundances of certain genera or forms of spores in various sediments may give a false picture of the flora which they represent, if they are not interpreted with caution. For example, in samples A-17 (1) and A-17 (2) of the Sextant formation, Perimetrisporites constitutes more than 40% of the total numbers of spores. This may mean that the plants which produced these spores produced them in exceptionally large numbers, or that they grow very near to the locus of deposition of the sediment, or that they were somehow better adapted for dispersal than other contemporary spores. It may, but not necessarily, indicate that the parent plants were themselves more numerous. It follows that the greater percentage of certain other genera and species of spores in the absence of *Perimetrisporites* may not necessarily indicate an increase in numbers of the type of plant which bore these spores, although the writer is inclined toward the latter view.

Velasporites is another genus for which the botanical relationships are unknown. As may have been true for *Perimetrisporites* and *Radiaspora*, the plants which produced members of this genus possibly exhibited unusual vegetative characteristics. The fact that no spores are known from any age which resemble these, or which might be regarded as related forms, further indicates that the parent plants were unique and perhaps represent a group for which there is no evidence in the megafossil record.

Velasporites is one of the two dominant genera of the Melville Island coal, and as such it may be related to the megaspore forms which are also prominent constituents. If this is true, its affinities would probably be lycopsid. However, species of the other major miospore component of this formation, *Retusotriletes*, could also be aligned with the megaspores, as their corresponding microspores.

More indications are available concerning the ecological preference of the plants which bore *Velasporites* than concerning its phyletic position. Since the spores were dominant constituents in a coaly matrix, probably they represent one of the dominant plant groups of a Devonian coal swamp. Moreover, the swamp was probably in a forest locality, where the spore deposition was autochthonous, as suggested by the fact that there are only two dominant genera in the assemblage, whereas there would probably be many more if the locality allowed access to wind-blown spores from the hinterland. The action of forest cover in preventing free transport of spores has been discussed by Kremp (1951) for Carboniferous and Harris (1955) for Recent material.

The occasional compact masses of spores which were encountered in some samples allow derivation of certain conclusions which would not be possible from spores in the isolated condition. These masses, (Plate XVI, Fig. 1, 2, 3) compact and linear-oval in outline, suggest the shape of sporangia. Radforth (1939) has demonstrated that fossil spores which are separated from the sporangial wall still hold the form of the outline of the sporangium and such may be the condition here. All of the aggregates have in common their apparent radial symmetry, and their lack of association with sporangial wall. Also, there is no evidence of septa, inner walls or central sterile core that would suggest that they were synangial (as in some Carboniferous ferns, e.g. Marattiales), or columellate (as in Sporogonites or Horneophyton). The largest mass, composed of Retusotriletes magnificus, is comparable in length (1 mm.) and shape (elongate oval) to the terminal sporangia borne by several Middle and Upper Devonian plants of varied affinities (e.g. Rhynia, Psilophyton, Calamophyton, Archaeopteris), but because of the distinctive ornamentation and large size of the spores (Plate XVI, Fig. 7, 8) it is apparently not related to any of these genera. The mass composed of Perimetrisporites muncus is about half the length of the former one, and the one containing Granulati-

sporites cf. *G. minutissimus* is still smaller, *i.e.* less than 200 μ long, which is smaller than most known Palaeozoic sporangia. It is difficult to be more precise as to the phyletic relationships of any of the aggregates since there is no indication as to the wall structure or manner of origin of the sporangium itself.

In Table V the suggested affinities of the spore features discussed in the preceding paragraphs are summarized. Assignment of any feature to a particular group is not meant to infer that spores of all members of the group possess the characteristic, but rather that a degree of relationship is suggested on the basis of available evidence.

As an additional assessment, there remains the evaluation of form trends in the spores apart from their phylogenetic relationships. Form trends can be best assessed when broad ranges of geological time are compared, and this was the approach of Radforth and McGregor (1956). The microfossils revealed here substantiate the occurrence of the features described for the Devonian by these authors. They also stress the apparent distinctiveness of the Devonian spore flora.

Trends of form which are established among the spores of most of the Devonian samples include perisporium, *apea*, and proximal radial striations. These features, while not restricted to the Devonian, are apparently best developed here. Other features, which appear to reach the apex of their prominence in the Lower Carboniferous (*i.e.* thick wall, spinose encircling wing (as in *Grandispora*), equatorial cingulum and reticulate ornamentation (*vide* Luber and Waltz 1938, Knox 1948 and Hoffmeister, Staplin and Malloy 1955b)) are foreshadowed in the Middle and Upper Devonian but are not the most prominent features as they are in the

TABLE V

Devonian spore feature	Suggested affinity
Trilete	Many groups
Thin wall, laevigate, circular	Calamariaceae Primofilices and others
Thin wall, laevigate, subtriangular	Filicineae Pteridospermae
Perisporium	Pteridospermae Sphenophyllales Filicineae
Apex	Lycopsida Marattiales
Radial striations	Unknown
Bifurcate appendages	Unknown
Equatorial flange	Heterosporous Lycopsida
Cingulum	Lycopsida
Encircling wing	Lycopsida Pteridospermae Sphenophyllales
Reticulate	Bryophyta Lycopsida
Granulate-apiculate	Pteridospermae Filicineae Marattiales Schizaeaceae
Ridged-spinose	Schizaeaceae
Spinose	Filicineae
Marginal papillae and depressions	Unknown
Proximal "veil"	Unknown

subsequent period. Other features prevalent in the later Carboniferous have not appeared in the Devonian (e.g. bean-like form (as in Laevigato-sporites), triangular form with thickened corners (as in Triquitrites) or furrows and pores.

The features represented by the spores in the Melville Island assemblage are difficult to evaluate in terms of any trends, since they comprise a complex for which there is as yet no comparison. They may, with disclosure of other assemblages in the future, perhaps from other material of northern latitudes, represent a portion of an unknown Upper Devonian microfossil complex.

In addition to spores, other microfossils in certain of the samples show similarity to features borne by megafossils, and relationships can be inferred at both the broad and the particular levels. The fragments shown in Plate XV, Fig. 6, 8, 9 and 10, from the Battery Point formation, are similar to conducting elements that occur in various groups of both living and fossil plants. The annularly thickened fragments (Plate XV, Fig. 6 and 8), for example, show striking similarity in size and structure of their walls to the wider tubes which Lang (1937) observed in Nematothallus pseudo-vasculosa. Lang prefers to regard Nematothallus as a land plant "of peculiar type". It bore resistant spores, and the annular tube-like elements were possibly additional adaptation to a terrestrial or semi-terrestrial habitat, such as may have existed on the emergent portions of a delta. The presence of this fragment suggests the existence of members of the Nematophytales if not more precisely Nematothallus in the portion of the Middle Devonian flora represented by the Battery Point assemblage. Conceivably, other plants in the Middle Devonian may have borne annularly thickened conductive elements that are indistinguishable in the isolated condition from those of Nematothallus (Asteroxylon Mackiei (Kidston and Lang 1920) may be an example, although here spiral construction of the thickenings is the more usual condition), but this view is reserved until substantiated by other evidence.

Fragments with scalariform pattern which are present in the Battery Point assemblage (Plate XV, Fig. 9) resemble the scalariform tracheids in the metaxylem of various pteridophyte plants and are particularly common in the Lycopsida. No particular plant has been found to compare especially closely in its tracheary structure with these fragments.

It should be pointed out that the scalariform structure is believed to be a more advanced type phylogenetically than the annular or spiral one.

Other scalariform elements, discovered in the Melville Island sample, resemble the small elements in the "septate metaxylem" described by Fry (1954) for the lycopod Paurodendron, and found in a restricted number of other fossil species, all lycopsid, in the Carboniferous. To the writer's knowledge, this is the first Devonian record of this feature. These comparisons are convincing evidence of the derivation of these Melville Island fragments from the Lycopsida, and perhaps, as Fry (1954) indicates for Paurodendron, from herbaceous numbers of the group.

The presence of bordered pits (Plate XV, Fig. 10) in the Middle Devonian Battery Point assemblage is of greater significance, because it is a feature long associated with the most advanced stage of tracheid construction, which reaches its best development in the conifers of the late Palaeozoic. Even though it is regarded as advanced, this feature has been recognized in several apparently unrelated plant groups in the Middle and Upper Devonian (Palaeopitys Milleri (Kidston and Lang 1923), Aneurophyton (Kräusel and Weyland 1923), Xenocladia (Arnold 1952) and Callixylon (Arnold 1930)), so that its phyletic implications in this period are difficult to assess. The report by Hsü (1946) of bordered pits in Taeniocrada cf. T. dubia gives even more scope to the possible relationships of the pits encountered in the Battery Point assemblage. From the few fragments in the latter assemblage it is not evident whether the pits were uniseriate or multiseriate.

Pits of another type discovered in the Melville Island coal (Plate XV, Fig. 7) are similar to pits that Kräusel and Weyland (1923) record from Hostimella hostimensis of Middle Devonian age. The likeness is not exact, since the latter fragments are smaller, according to the illustration of Krausel and Weyland, but in other respects (oval shape, the tilted angle of the axes of the pits and the relatively large area of unpitted surface on both fragments) the similarity is marked. Kräusel and Weyland assign to their specimen a psilopsid affinity, but allocation of the Melville Island specimens to this group must be more cautious since there are no other well-established records of psilophytes in the Upper Devonian.

The axis found in the Melville Island assemblage, which possesses node-like intervals (Plate XV, Fig. 2), suggests sphenopsoid construction. More specific relationships cannot be suggested at present. The other fragment from the same assemblage (Plate XV, Fig. 3) shows no node-like construction, and possesses few features that are here regarded as diagnostic for assignment of affinity.

The association of smooth, apparently alete spores with the net-like strands shown in Plate XV, Fig. 1 is not comparable with any record in the literature. Lang (1937, p. 273) records laevigate spores of similar size (30 - 35 μ) which occur with fragments of fine tubes, but the tubes are suggested as being related to some form of _Nematothallus_ (_ibid._ p. 274), so that they are evidently of different structure from those of the Melville Island coal.

Since the botanical relationships of the remaining group of plant microfossils, the hystrichosphaerids, are not clear, these fossils are not discussed at this time.

STRATIGRAPHICAL SIGNIFICANCE OF THE MICROFOSSILS

Demonstration and assessment of the occurrence of spores, hystrichosphaerids and certain other microfossils in the five formations examined, and evaluation of their botanical relations, has provided a basis for interpretation of their value for stratigraphic purposes. The establishment of clearly circumscribed taxonomic units is of primary importance as a baseline for any stratigraphic interpretations and this has been done for the plant microfossils of five sedimentary formations, not previously examined intensively. The appropriateness of their application to geological problems must be evident, and this is the case for the strata investigated here (p. 8). The Melville Island and Sextant formations apparently contain no fossils which could act as horizon markers or age indicators, with the exception of the microfossils here described. Also, the meagre fossil contents of the Battery Point formation and the Perdix equivalent are supplemented here by numerous new forms. The Onondaga formation is now shown to have, in addition to its fauna, an extensive population of plant microfossils, and certain of these (appendix I) are similar to examples found in non-marine sediments.

Zonation of strata other than coal using plant microfossils has been less precise than with microfaunas (Woods 1955). Now, with the demonstration that Canadian sediments of different matrices yield spores and other plant microfossils, research has a basis for active extension of planned work toward the establishment of index assemblages for strata other than coal. Further investigation will reveal whether assemblages of species rather than single species will best provide zonal units for those strata. Evidence based on populations of similar size and scope of forms from Carboniferous coals suggests that the former may be true. On the other hand, there are some species in the assemblages here investigated, that were encountered in one formation only, and have not been reported in other Devonian assemblages in the literature (Perimetrisporites spp., Hadiaspora ampla, Velasporites spp.) These in time may prove to be zonal guide fossils.

As an additional aspect of zonation using plant microfossils, the establishment of ranges of form features (rather than genera or species) is suggested. Certain form features of spores (i.e. radial striations, grapnel-like appendages, apex, and perisporium) are prominent components in the assemblages revealed here, and this occurrence contrasts with their rarity among the Lower Carboniferous sporae dispersae and their complete absence among those of Upper Carboniferous.

Naumova (1953) has demonstrated that these same form features are characteristic for the Middle and Upper Devonian of the Moscow Basin and that they are applicable to distinguishing zones within the Devonian of that area. Now, close agreement as to the occurrence of these features in Canadian deposits establishes a basis for similar work on this continent.

Certain conclusions may be derived on the basis of comparisons of spore form, regarding the age of the Sextant formation. The Sextant has provided assemblages of spores which vary from horizon to horizon in the vertical sense, but which nonetheless possess certain elements of form (apex and perisporium) that resemble those of Middle Devonian strata investigated here and elsewhere. Since it compares in occurrence and magnitude of certain form features of its spores with both the Battery Point assemblage and Middle Devonian assemblages from the Moscow Basin (Naumova (1953), a suggestion is not unreasonable that its age is somewhat younger than previously thought (lower Middle Devonian rather than Upper Lower Devonian). This conclusion is strengthened by correlation of the diameter range within the genus Retusotriletes (p.136) with that given by Naumova (1953) for Middle Devonian forms, and by contrast between the complexity of features in the Sextant with the simplicity of features of Lower Devonian spores reported by Naumova (1953) and Thomson (1952).

Additional research may substantiate this conclusion, and at the same time more fully demonstrate a means of making inter-continental correlations within certain non-marine sediments.

Assessment of age of microfloras on the basis of trends in spore form (rather than genera or species) has been suggested by Radforth and McGregor (1956) and applied to the age determination of certain unknown assemblages (e.g. the Intrepid Bay formation) by the writer, (unpublished work), and the present investigation has provided further application for this proposal.

The usefulness of hystrichospherids as tools for zonation depends on the derivation of basic information concerning their presence and distribution, and this investigation has provided such information for three sedimentary strata. This makes available data that will be collateral to other data from investigations of these fossils that are currently in progress (Loeblich, A. R. Jr. 1957, pp. 200-201).

In addition, this investigation demonstrates that where both spores and hystrichosphaerids occur, as in the Battery Point and Onondaga formations and the Perdrix equivalent, future investigations can apply them simultaneously since the same methods serve for extraction of both. Their simultaneous utilisation for zonation purposes may have particular significance as an aid in the extension of biostratigraphic zones across facies boundaries between marine and non-marine strata. Spores have been useful in this respect (Woods 1955), and the spores in the assemblages presently under consideration show promise of being useful in this way (Appendix I), but to the author's knowledge spores and hystrichosphaerids have not been used in conjunction toward this end.

The microfossils derived here also supply certain information concerning the environments of sedimentation of the strata from which they were derived. For four of the assemblages, the microfossil data confirms conclusions (pp.11-16) derived from other sources. The Battery Point and Sextant formations, believed to be continental in origin, possess few or no examples of marine microfossils (hystrichosphaerids) but possess an abundance of spores. The Onondaga and Perdrix on the other hand possess abundant hystrichosphaerids and a lower content of spores, which agrees with interpretation of their origin as marine.

For the Melville Island formation spores, in the absence of hystrichosphaerids, provide the major basis for interpretation of the environment in which the coal was deposited, i.e. in an autochthonous deposit (p. 168) with no evidence of marine conditions.

SUMMARY AND CONCLUSIONS

Methods that have been adapted for the extraction of plant microfossils from five Devonian formations in this country have revealed one hundred and sixteen species of spores, ninety-three of them new. The same methods have disclosed forty species of hystrichosphaerids, of which thirty-five are new, as well as certain other plant microfossils. These discoveries have provided the first extensive record of plant microfossils from these deposits.

The disclosed spores and hystrichosphaerids have been systematically described, thereby establishing a basis for their evaluation in both botanical and geological terms. Classification of the spores according to the scheme of Potonié and Kremp (1954) has provided the first application of spores of Devonian age to this system.

Preparatory to further evaluations, the spores, hystrichosphaerids and other microfossils of the five formations were examined as assemblages and salient characteristics organized. The prominence of triradiate aperture, perisporium and apex among the spores confirms for Canadian material the dominance of these features reported in Devonian rocks of the Russian Platform. The abundance and variety of hystrichosphaerids in certain of the strata which also contain spores has prompted the suggestion that they may be applied in conjunction with the spores toward the solution of botanical and geological problems. The features described for other plant microfossils, particularly fragments of conductive tissue, have proved to be additional points of reference, particularly for evaluation of botanical relationships.

Several features of spores have been described for the first time, i.e. the marginal structures of Perimetrisporites, the proximal "veil" of Velasporites, the radial ornamentation of Radiaspora, and the distinctive association of features possessed by the Retusotriletes complex of the Melville Island coal. The diversity of these features in the accompaniment of others such as the bifurcate appendages of Archaeotriletes, the small megaspores, and the closely appressed perisporium, emphasize the need for further studies of spore - sporangial relationships within the Devonian period, and provides new evidence bearing on several questions of fundamental botanical interest.

Such a complexity of species and features in the spores indicates at least as great a scope of variation in the parent floras of the Devonian period. Evaluations that have been made of the affinities of the spores in this investigation have suggested relationship to Psilopsida, Sphenopsida, Lycopsida, Filicineae and Pteridospermae, and what is even more significant, to strong representation and wide scope of complexity within all of these groups.

It is indicated, therefore, that the Devonian examples of these plant groups must have been the products of a long evolutionary development prior to the Devonian, as has been suggested by Leclerq (1954), Radforth and McGregor (1956) and others. Several separate lines of plants, as represented by the spores encountered here, were quite distinct at least as far back as the time represented by the lower part of the Middle Devonian.

The indication of extreme antiquity of the Lycopsida, evidenced by Kryshtofovichia Africani (Nikitin 1934) and Baragwanathia (Lang and Cookson 1935), is strengthened by the present evidence of numerous spore species for which lycopsid affinity is proposed.

The representation of spore forms in samples from each of the formations is far greater than that of the plant megafossils from the same formations, which demonstrates that these microfossils may provide abundant records of plants in localities where they are not preserved as megafossils.

Illustration of fluctuating patterns of occurrence of dominant genera and species of spores within section A of the Sextant formation has demonstrated satisfactorily the range of variation that may occur in the Devonian microfossil population at one locality, within even a relatively short interval of time, such as is represented by this section.

Evaluations of certain ecological and phylogenetic relationships of the microfossils, that were made in conjunction with assessment of the components of the flora, illustrate the applicability of these fossils to several areas that would not be easily interpreted from megafossil records.

The appropriateness of the application of the plant microfossils of the five formations to stratigraphic problems has been indicated and proposals have suggested that the plant microfossils may be applicable to zonation, using both species and trends of form features.

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APPENDIX I

Distribution of Species of Spores

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
Leiotriletes simplex Naum.	x	x			
L. exiguus sp. nov.			x		
L. usitatus sp. nov.	x				
L. dissimilis sp. nov.					x
L. confertus sp. nov.					x
L. marginalis sp. nov.					x
L. incipiens sp. nov.		x			
L. microdeltoidus sp. nov.					x
Calamospora rotunda sp. nov.	x				
C. dura sp. nov.					x
C. tenuis sp. nov.		x	x	x	
C. retusa sp. nov.		x			
C. plicata (Waltz) comb. nov.			x		
C. perplexa sp. nov.			x		
C. compacta sp. nov.			x		
C. umbrata sp. nov.	x				

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
C. contagionis sp. nov.	x				
C. radiagranulata sp. nov.	x				
C. sp. A	x				
Punctati-sporites nitidus sp. nov.					x
P. scabratus sp. nov.					x
P. putaminis sp. nov.					x
Granulati-sporites minutissimus (Naum) comb. nov.	x	x			
Cyclogranisporites mediocris sp. nov.			x		
C. concisus sp. nov.			x		
C. amplus sp. nov.					x
Perimetrisporites parvus sp. nov.	x				
P. mundus sp. nov. sp. nov.	x				
Plani-sporites minimus sp. nov.					x
P. dilucidus sp. nov.					x
Lophotriletes dentis sp. nov.	x				
L. varius sp. nov.			x		

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
Apiculatisporis teneris sp. nov.		x			
A. elegans sp. nov.					x
Apiculatisporis obtusus sp. nov.	x				
(?) *A.* sp. A.		x			
(?) *A.* sp. B.			x		
(?) *A.* sp. C.		x			
Anapiculatisporites brevispinosus sp. nov.			x		
Acanthotriletes spinellosus Naum.			x		
A. inconfertus sp. nov.		x			
A. robustus sp. nov.	x				
(?) *A.* sp. A.			x		
Raistrickia difficilis sp. nov.			x		
Converrucosisporites semilevis sp. nov.			x		
Verrucosi-sporites variabilis sp. nov.					x
Archaeotriletes delectabilis sp. nov.					x

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
Convolutispora dissimilis sp. nov.			x		
C. tessellata Hoff. *et al.*				x	
C. rugulata sp. nov.					x
Cristatisporites impeditus sp. nov.			x		
C. speciosus sp. nov.	x				
Dictyotriletes minutus sp. nov.	x				
D. insolitus sp. nov.	x			x	
D. sp. A.		x		x	
Reticulati-sporites ovoides sp. nov.	x		x		
R. subgranifer sp. nov.	x				
R. sp. A.			x		
R. sp. B.	x				
Radiaspora rotata sp. nov.	x	x	x		
R. annulata sp. nov.	x				
R. ampla forma laevigata sp. nov.	x				
R. ampla forma granulata sp. nov.	x				
R. obscura sp. nov.		x			

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
R. robusta sp. nov.		x	x	x	
R. quaesita sp. nov.			x		
Retusotriletes simplex Naum.	x				
R. mediocris sp. nov.	x		x		
R. levis sp. nov.			x		
Retusotriletes cf. R. verruculatus Naum.	x				
R. tenuis sp. nov.	x	x			
R. laevigatus sp. nov.	x		x		
R. elegans sp. nov.	x				
R. magnus sp. nov.	x				
R. ornatus sp. nov.	x				
R. solidus sp. nov.			x		
R. arcuatus sp. nov.	x				
R. magnificus sp. nov.					x
R. endoformis sp. nov.					x
R. vulgaris sp. nov.					x
R. pallidus sp. nov.					x
R. grandis sp. nov.					x
R. sp. A	x				

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
Lycospora scabrata sp. nov.	x				
Anulati-sporites anulatus (Loose) Pot. & Kr.	x				
A. imperfectus sp. nov.		x	x		
A. granulatus sp. nov.			x		
Denso-sporites verrucatus sp. nov.			x		
D. crassus sp. nov.					x
D. inaequus sp. nov.					x
Velasporites densus sp. nov.					x
V. tenuis sp. nov.					x
V. punctatus sp. nov.					x
Cirratriradites splendens Balme & Henn.	x				
C. decorus sp. nov.			x		
C. microdecorus sp. nov.			x		
C. inusitatus sp. nov.			x		
C. megazonalis sp. nov.	x				
Camarozonotriletes fulgens sp. nov.			x		

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
Archaeozonotriletes minor sp. nov.			x		
A. deltoides sp. nov.	x				
A. contagionis sp. nov.	x		x		
A. arenorugosus sp. nov.	x	x	x		
A. crassus sp. nov.			x		
A. papillatus sp. nov.	x				
A. subrugulatus sp. nov.	x				
A. sp. A					x
(?) *Laevigato-sporites* sp. A.					x
Endosporites insolitus sp. nov.			x		
Grandispora spinosa Hoff. *et al.*	x				
G. crenulata sp. nov.				x	
Arenosisporites subtilis sp. nov.					x
A. sp.					x
Tuberculati-sporites submamillarius sp. nov.					x
Triletes sp. A.			x		
T. sp. B.			x		
Circumsporites melvillensis sp. nov.					x

Distribution of Species of Hystrichosphaerids

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
Micrhystridium penicillatum sp. nov.	x		x		
M. cf. M. stellatum Defl.	x				
M. microattenuatum sp. nov.	x		x		
Veryhachium triquetrum sp. nov.	x	x	x		
V. asymmetricum sp. nov.	x				
V. quadrangulatum sp. nov.	x				
V. flaccidum sp. nov.	x				
V. teneris sp. nov.	x		x		
V. attenuatum sp. nov.	x				
V. cf. V. crucistellatum Deunff	x				
Hystrichosphaeridium truncatum sp. nov.	x				
H. articulum sp. nov.	x				
H. acanthospinosum sp. nov.		x			
H. dispertum sp. nov.		x			
H. robustum sp. nov.	x				
H. varium sp. nov.			x		
H. cf. H. intermedium Eis.		x			
H. appendiculatum sp. nov.	x				

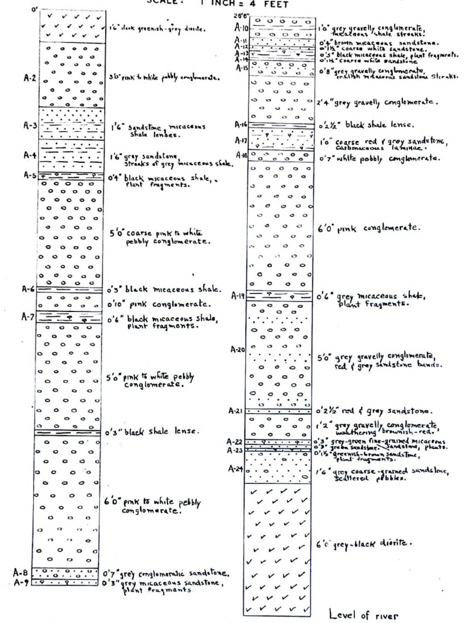
	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
H. pannosum sp. nov.		x			
H. problematicum sp. nov.				x	
Pterospermopsis concentricus sp. nov.		x			
P. parvus sp. nov.		x		x	
P. equatorius sp. nov.		x		x	
(?) *P.* sp.		x			
Cymatiosphaera vela sp. nov.		x		x	
C. stellata sp. nov.				x	
C. obscura sp. nov.				x	
C. sp. A.		x			
Saccosphaera membranacea gen. et sp. nov.		x			
Leiosphaera minuta		x			
L. dubia				x	
L. maculosa				x	
Leiosphaera macromaculosa sp. nov.				x	
L. plicata				x	
L. perspicua		x			
L. compressa		x			
L. densa		x		x	

	Sextant fm.	Onondaga fm.	Battery Pt. fm.	Perdrix equiv.	Melville Is. fm.
L. *cf.* *L.* *media* Eis.		x			
Leiofusa *tomaculata* sp. nov.		x			
L. *navicula* Eis.				x	

APPENDIX II

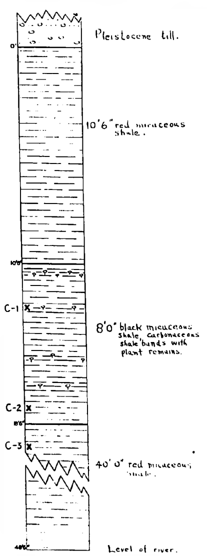
SEXTANT FORMATION — SECTION A (WEST BANK)

SCALE: 1 INCH = 4 FEET



SEXTANT FORMATION
SECTION C (EAST BANK)

SCALE : 1 INCH = 4 FEET



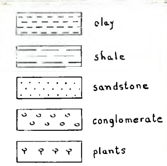


PLATE I

Magnifications of all plates X500 unless otherwise stated.

Figure 1. Leiotriletes simplex Naumova.
Onondaga formation.

2. Leiotriletes exiguus sp. nov.
Battery Point formation. Holotype.

3. Leiotriletes usitatus sp. nov.
Sextant formation. Holotype.

4. Leiotriletes dissimilis sp. nov.
Melville Island formation. Holotype.

5. Leiotriletes confertus sp. nov.
Melville Island formation. Holotype.

6. Leiotriletes marginalis sp. nov.
Melville Island formation. Holotype

7. Leiotriletes incipiens sp. nov.
Onondaga formation. Holotype

8. Leiotriletes microdeltoidus sp. nov.
Melville Island formation. Holotype.

9. Calamospora rotunda sp. nov.
Sextant formation. Holotype.

10. Calamospora dura sp. nov.
Battery Point formation. Holotype.

11. Calamospora tenuis sp. nov.
Onondaga formation. Holotype.

12. Calamospora retusa sp. nov.
Onondaga formation. Holotype.

PLATE I, continued

Figure 13. Calamospora plicata (Waltz) comb. nov.

Battery Point formation.

14. Calamospora plicata (Waltz) comb. nov.

Battery Point formation. Tetrad.

15. Calamospora perplexa sp. nov.

Battery Point formation. Holotype.

16. Calamospora contagionis sp. nov.

Sextant formation. Holotype.

17. Calamospora sp. A.

Sextant formation

18. Calamospora umbrata sp. nov.

Sextant formation. Holotype.

19. Calamospora radiagranulata sp. nov.

Sextant formation. Holotype.

20. Calamospora compacta sp. nov.

Battery Point formation. Holotype.

PLATE I

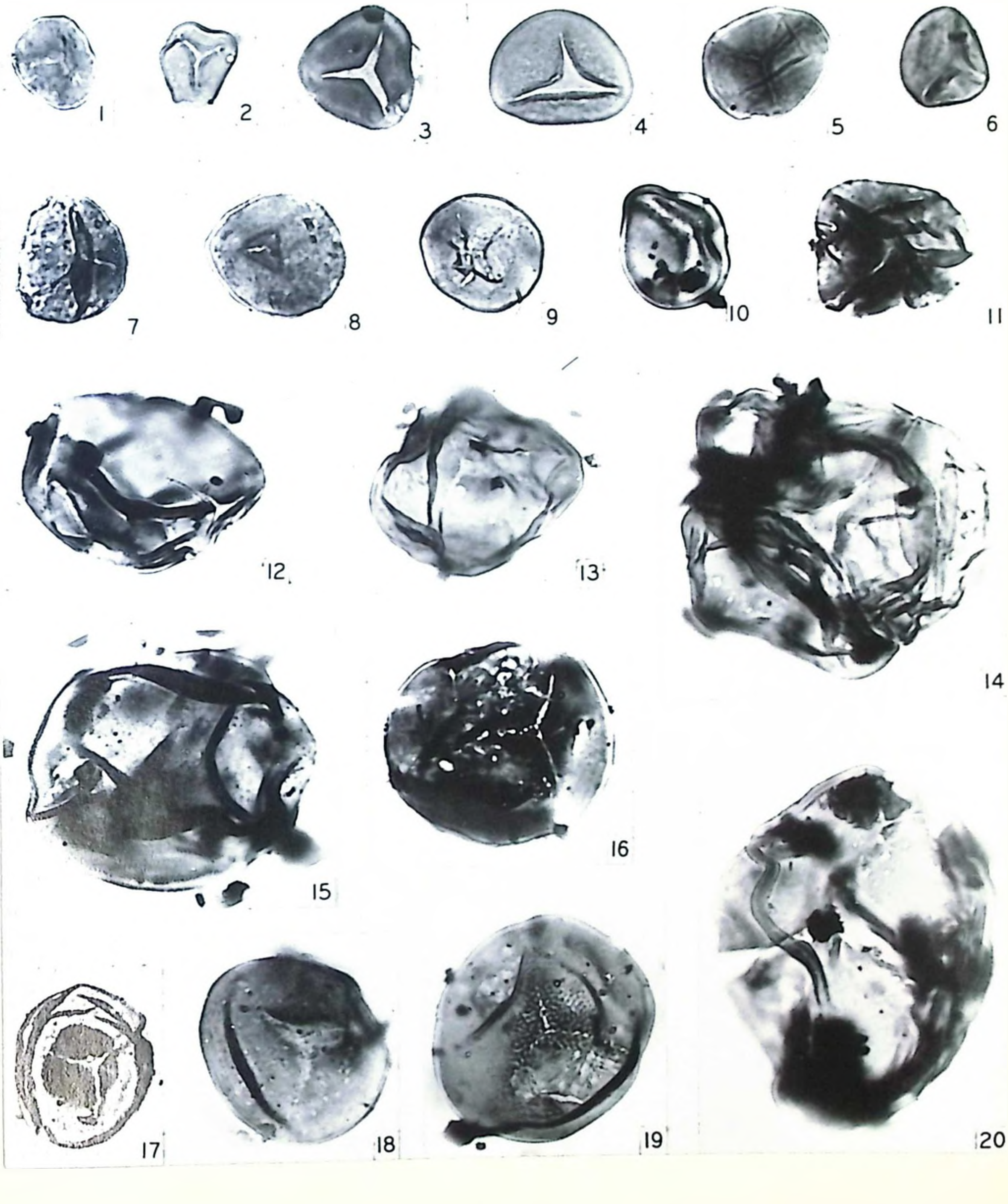


PLATE II

Figure 1. *Punctati-sporites nitidus* sp. nov.
Melville Island formation. Holotype.

2. *Punctati-sporites scabratus* sp. nov.
Melville Island formation. Holotype.

3. *Punctati-sporites putaminis* sp. nov.
Melville Island formation. Holotype.

4. *Granulati-sporites minutissimus* (Naumova) comb. nov.
Sextant formation.

5. *Perimetrisporites parvus* gen. et. sp. nov.
Sextant formation.

6. *Cyclogranisporites concisus* sp. nov.
Battery Point formation. Holotype.

7. *Cyclogranisporites amplus* sp. nov.
Melville Island formation. Holotype.

8. *Cyclogranisporites mediocris* sp. nov.
Battery Point formation. Holotype.

9. *Perimetrisporites parvus* gen. et sp. nov.
Sextant formation. Holotype.

10. *Perimetrisporites parvus* gen. et sp. nov.
Sextant formation. Paratype.

11. *Plani-sporites dilucidus* sp. nov.
Melville Island formation. Holotype.

12. *Plani-sporites minimus* sp. nov.
Melville Island formation. Holotype.

13. *Perimetrisporites mundus* gen. et sp. nov.
Sextant formation. Holotype.

PLATE II, continued

Figure 14. *Perimetrisporites mundus* gen. et sp. nov.
Sextant formation.

15. *Perimetrisporites parvus* gen. et sp. nov.
Sextant formation. Tetrads.

16. *Lophotriletes dentis* sp. nov.
Sextant formation.

17. *Lophotriletes varius* sp. nov.
Battery Point formation. Holotype.

18. *Apiculatisporis elegans* sp. nov.
Melville Island formation. Holotype.

19. (?) *Apiculatisporis* sp. B.
Battery Point formation.

20. (?) *Apiculatisporis* sp. C.
Onondaga formation.

21. (?) *Apiculatisporis* sp. A.
Onondaga formation.

22. *Apiculatisporis obtusus* sp. nov.
Sextant formation. Holotype.

23. *Apiculatisporis teneris* sp. nov.
Onondaga formation. Holotype.

24. *Ampiculatisporites brevispinosus* sp. nov.
Battery Point formation. Holotype.

25. *Ampiculatisporites brevispinosus* sp. nov.
Battery Point formation.

Figure 26. *Acanthotriletes spinellosus* Naumova.
Battery Point formation.

27. (?) *Acanthotriletes* sp. A.
Battery Point formation.

28. *Acanthotriletes inconfertus* sp. nov.
Onondaga formation. Holotype.

29. *Acanthotriletes robustus* sp. nov.
Sextant formation. Holotype.

PLATE II

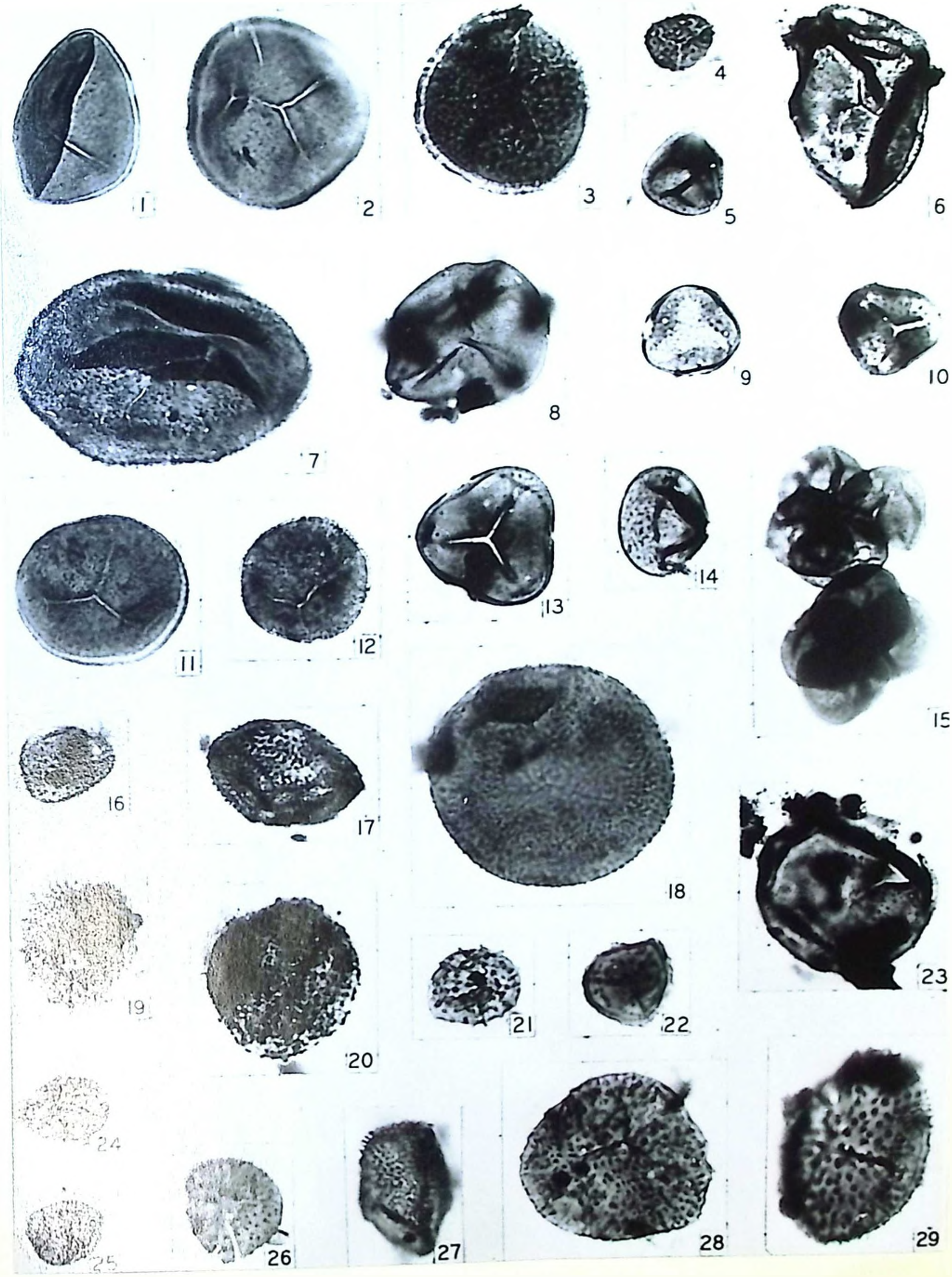


PLATE III

Figure 1. Reistrickia difficilis sp. nov.
Battery Point formation. Holotype.

2. Verrucosi-sporites variabilis sp. nov.
Melville Island formation. Holotype.

3. Converrucosisporites semilevis sp. nov.
Battery Point formation. Holotype, distal surface.

4. Converrucosisporites semilevis sp. nov.
Holotype, proximal surface.

5. Archaeotriletes delectabilis sp. nov.
Melville Island formation. Appendage.

6. Archaeotriletes delectabilis sp. nov.
Melville Island formation. Appendage.

7. Archaeotriletes delectabilis sp. nov.
Melville Island formation. X250. Focus on appendages.

8. Archaeotriletes delectabilis sp. nov
Melville Island formation. Holotype. X250.

9. Convolutispora dissimilis sp. nov.
Battery Point formation. Holotype.

10. Convolutispora tessellata Hoffmeister, Staplin and Malloy.
Perdrix equivalent. Tetrad.

11. Convolutispora rugulata sp. nov.
Melville Island formation.

12. Convolutispora rugulata sp. nov.
Melville Island formation. Holotype.

Figure 13. Cristatisporites inceditus sp. nov.
Battery Point formation. Holotype.

14. Cristatisporites speciosus sp. nov.
Sextant formation. Tetrad.

15. Cristatisporites speciosus sp. nov.
Sextant formation. Holotype.

16. Dictyotriletes minutus sp. nov.
Sextant formation. Holotype.

17. (?) Dictyotriletes sp. A.
Onondaga formation.

18. Reticulati-sporites sp. A.
Battery Point formation.

19. Reticulati-sporites sp. B.
Sextant formation.

20. Reticulati-sporites subgranifer sp. nov.
Sextant formation. Holotype.

21. Dictyotriletes insolitus sp. nov.
Sextant formation. Holotype.

22. Reticulati-sporites ovoides sp. nov.
Sextant formation. Holotype.

PLATE III

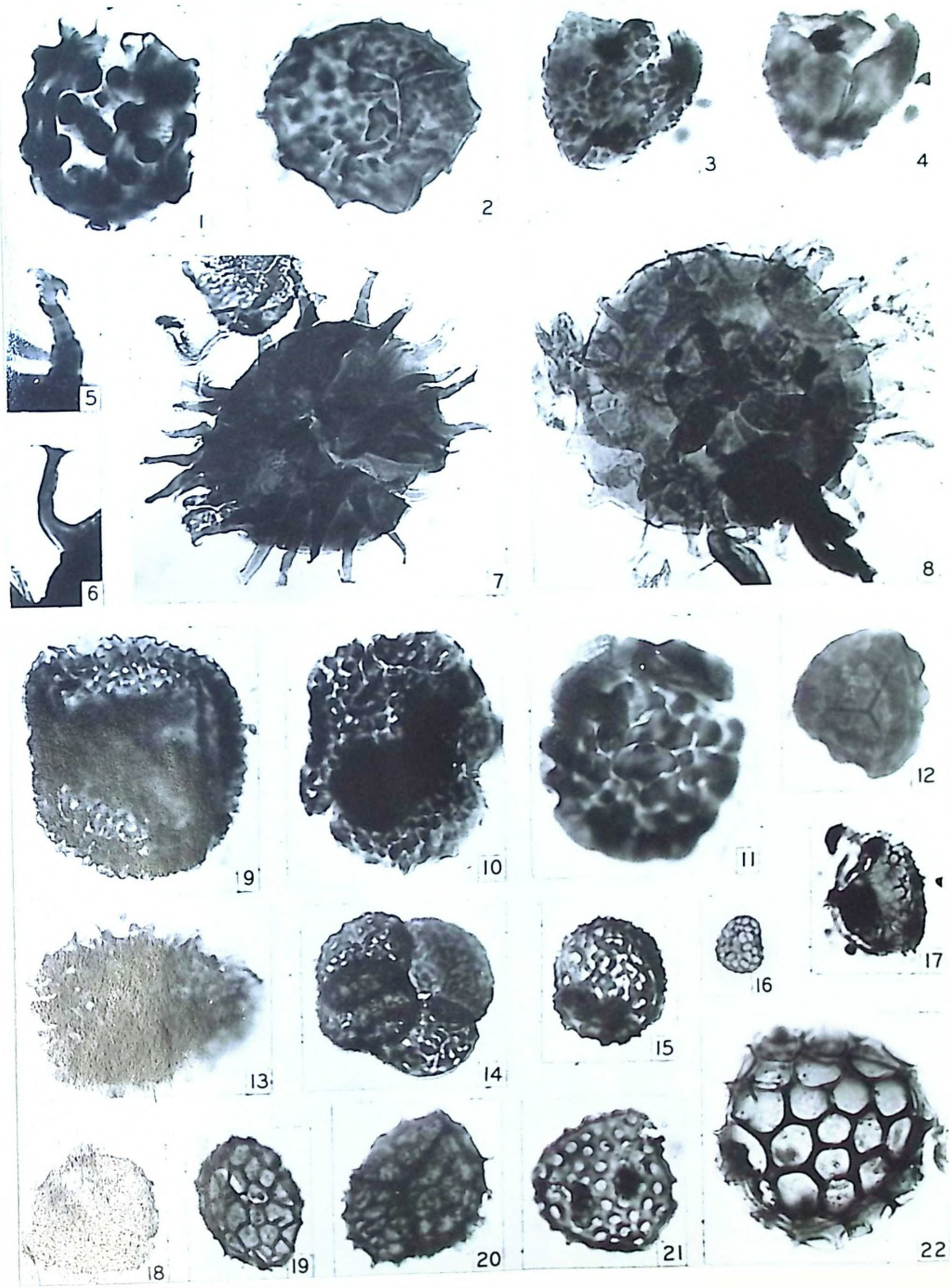


PLATE IV

Figure 1. _Radiaspora rotata_ gen. et sp. nov.
Battery Point formation. Holotype

2. _Radiaspora rotata_ gen. et sp. nov.
Sextant formation

3. _Radiaspora rotata_ gen. et sp. nov.
Sextant formation. Folded specimen, showing portion of laevigate distal side.

4. _Radiaspora rotata_ gen. et sp. nov.
Sextant formation. Tetrad.

5. _Radiaspora granulata_ gen. et sp. nov.
Sextant formation. Holotype.

6. _Radiaspora granulata_ gen. et sp. nov.
Sextant formation. Laterally compressed specimen.

7. _Radiaspora ampla_ forma _laevigata_ gen., sp. et f. nov.
Sextant formation. Holotype.

8. _Radiaspora ampla_ forma _laevigata_ gen., sp. et f. nov.
Sextant formation. Tetrad.

9. _Radiaspora ampla_ forma _granulata_ gen., sp. et f. nov.
Sextant formation. Holotype.

10. _Radiaspora quaesita_ gen. et sp. nov.
Battery Point formation. Holotype.

11. _Radiaspora obscura_ gen. et sp. nov.
Onondaga formation. Holotype.

12. _Radiaspora robusta_ gen. et sp. nov.
Battery Point formation. Holotype.

Figure 13. *Retusotriletes simplex* Naumova.
Sextant formation.

14. *Retusotriletes simplex* Naumova.
Sextant formation. Specimen in semi-lateral compression.

15. *Retusotriletes mediocris* sp. nov.
Battery Point formation. Holotype.

16. *Retusotriletes levis* sp. nov.
Battery Point formation. Holotype.

17. *Retusotriletes* cf. *R. verruculatus* Naumova.
Sextant formation.

18. *Retusotriletes tenuis* sp. nov.
Sextant formation. Holotype.

19. *Retusotriletes magnus* sp. nov.
Sextant formation. Holotype

20. *Retusotriletes laevigatus* sp. nov.
Sextant formation. Holotype.

21. *Retusotriletes laevigatus* sp. nov.
Sextant formation.

22. *Retusotriletes* sp. A.
Sextant formation.

23. *Retusotriletes arcuatus* sp. nov.
Sextant formation. Holotype.

24. *Retusotriletes ornatus* sp. nov.
Sextant formation. Holotype.

25. *Retusotriletes elegans* sp. nov.
Sextant formation. Holotype.

26. *Retusotriletes solidus* sp. nov.
Battery Point formation. Holotype.

PLATE IV

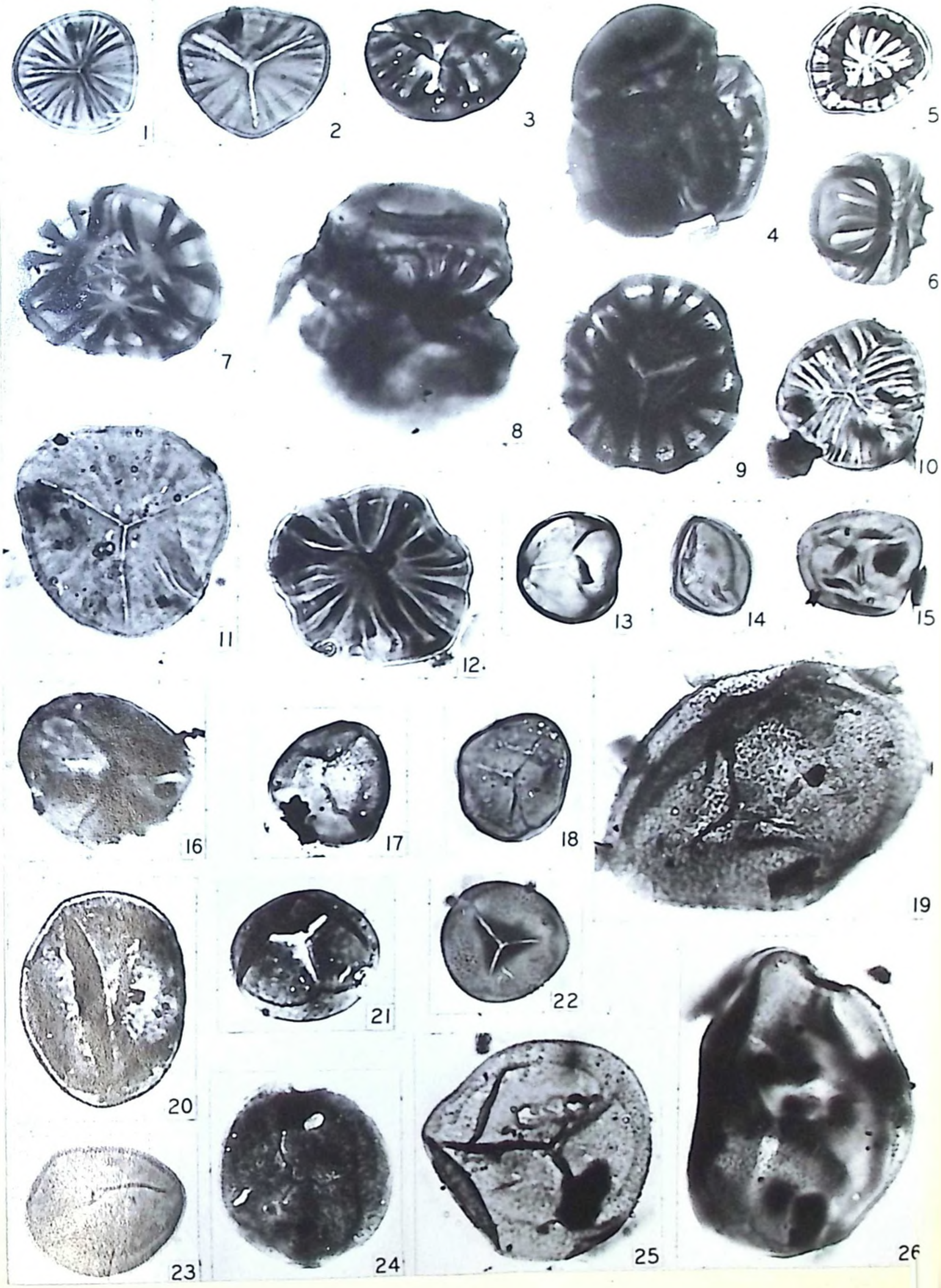


PLATE V

Figure 1. Retusotriletes magnificus sp. nov.

Melville Island formation. Holotype.

2. Retusotriletes magnificus sp. nov.

Melville Island formation. Paratype, laterally compressed.

3. Retusotriletes magnificus sp. nov.

Melville Island formation. Tetrad.

4. Retusotriletes endoformis sp. nov.

Melville Island formation. Holotype.

5. Retusotriletes endoformis sp. nov.

Melville Island formation. Semi-laterally compressed.

6. Retusotriletes vulgaris sp. nov.

Melville Island formation. Holotype.

7. Retusotriletes pallidus sp. nov.

Melville Island formation. Distal surface.

8. Retusotriletes grandis sp. nov.

Melville Island formation. Holotype.

9. Retusotriletes pallidus sp. nov.

Melville Island formation. Holotype.

10. Retusotriletes pallidus sp. nov.

Melville Island formation. Laterally compressed.

11. Lycospora scabrata sp. nov.

Sextant formation. Holotype.

12. Anulati-sporites anulatus (Loose) Potonie and Kremp.

Sextant formation.

Figure 13. <u>Anulati-sporites imperfectus</u> sp. nov.

Battery Point formation. Holotype.

14. <u>Anulati-sporites granulatus</u> sp. nov.

Battery Point formation. Holotype.

15. <u>Denso-sporites verrucatus</u> sp. nov.

Battery Point formation. Holotype.

16. <u>Denso-sporites verrucatus</u> sp. nov.

Battery Point formation. Specimen with "segmented" annulus.

PLATE V

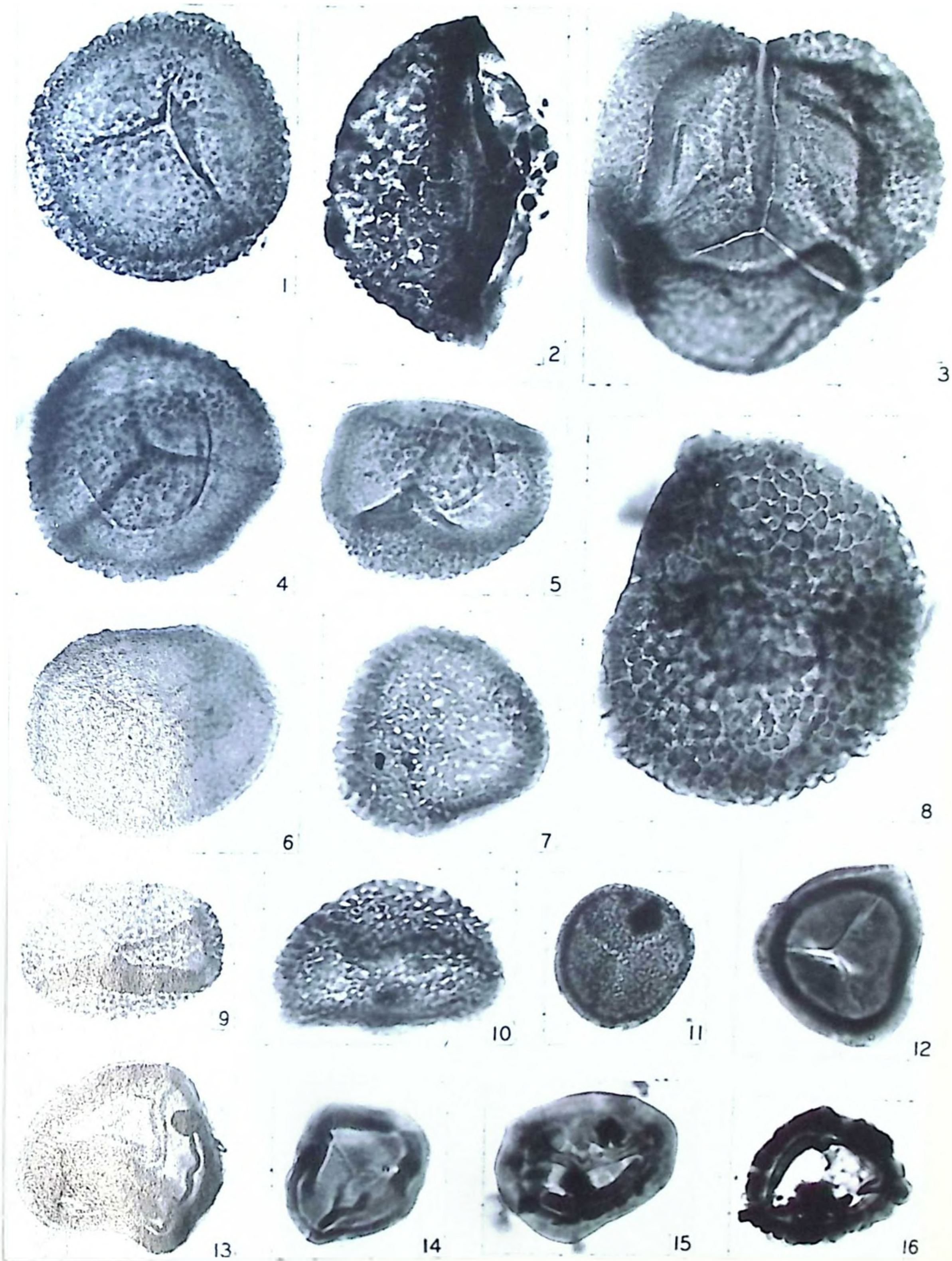


PLATE VI

Figure 1. *Denso-sporites crassus* sp. nov.

Melville Island formation. Holotype.

2. *Denso-sporites inaequus* sp. nov.

Melville Island formation. Holotype.

3. *Velasporites densus* sp. nov.

Melville Island formation. Paratype. Laterally compressed.

4. *Velasporites densus* sp. nov.

Melville Island formation. Holotype

5. *Velasporites tenuis* sp. nov.

Melville Island formation. Semi-laterally compressed.

6. *Velasporites tenuis* sp. nov.

Melville Island formation. Holotype.

7. *Velasporites punctatus* sp. nov.

Melville Island formation. Holotype.

8. *Velasporites punctatus* sp. nov.

Melville Island formation. Paratype. Laterally compressed

9. *Cirratriradites splendens* Balme and Hennelly

Sextant formation.

10. *Cirratriradites decorus* sp. nov.

Battery Point formation. Holotype.

11. *Cirratriradites microdecorus* sp. nov.

Battery Point formation. Holotype.

Figure 12. *Cirratriradites decorus* sp. nov.

Battery Point formation. Laterally compressed.

13. *Cirratriradites inusitatus* sp. nov.

Battery Point formation. Holotype.

14. *Cirratriradites inusitatus* sp. nov.

Battery Point formation. Paratype. Laterally compressed.

15. *Cirratriradites megazonalis* sp. nov.

Sextant formation. Holotype.

PLATE VI

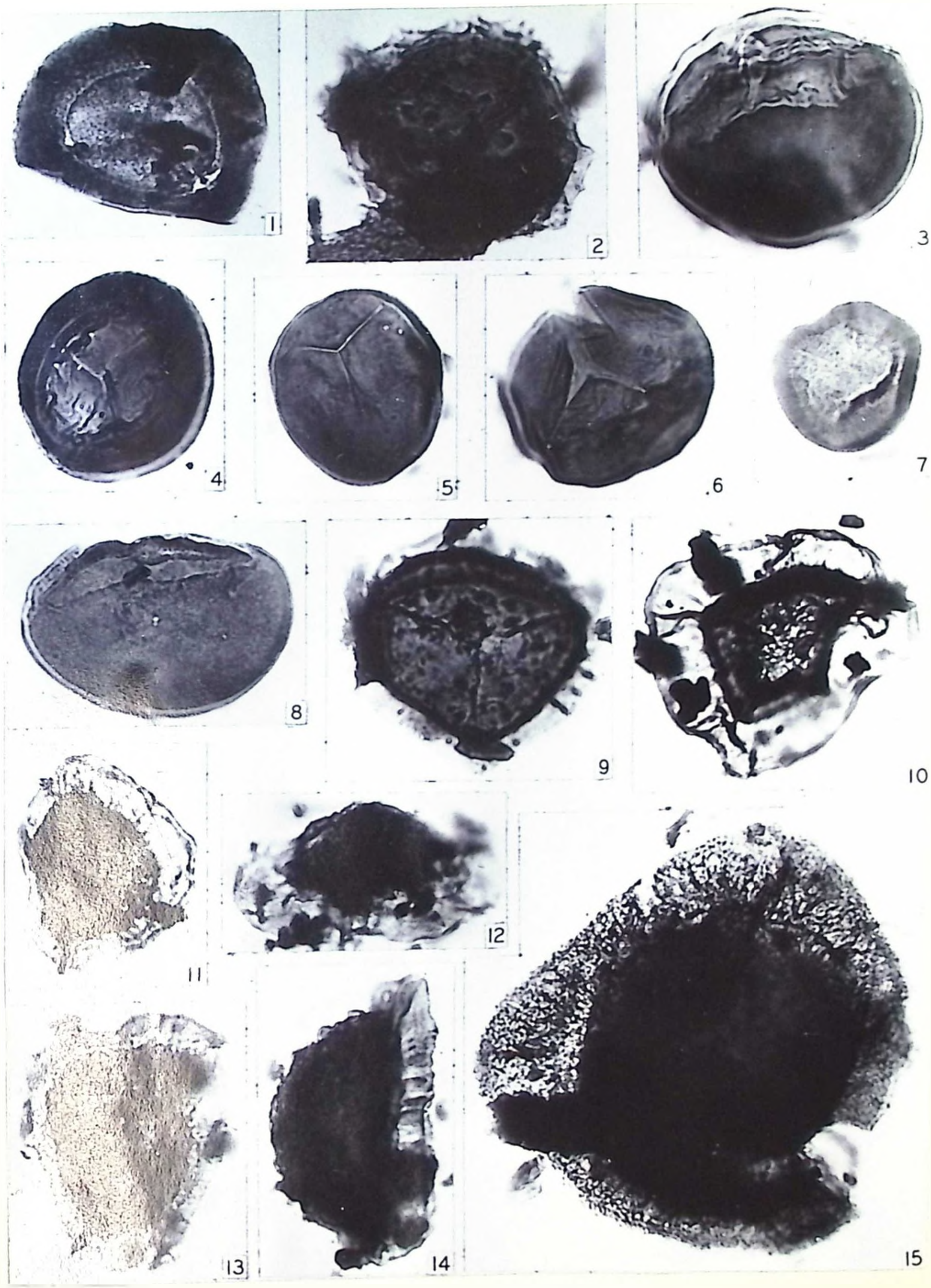


PLATE VII

Figure 1. Camarozonotriletes fulgens sp. nov.

Battery Point formation. Holotype.

2. Archaeozonotriletes minor sp. nov.

Battery Point formation. Holotype.

3. Archaeozonotriletes minor sp. nov.

Battery Point formation. Tetrad.

4. Archaeozonotriletes deltoides sp. nov.

Sextant formation. Holotype.

5. Archaeozonotriletes contagionis sp. nov.

Sextant formation. Holotype

6. Archaeozonotriletes arenorugosus sp. nov.

Sextant formation. Laevigate body partially exposed.

7. Archaeozonotriletes arenorugosus sp. nov.

Sextant formation. Holotype. Proximal surface.

8. Archaeozonotriletes arenorugosus sp. nov.

Sextant formation. Holotype. Margin in focus.

9. Archaeozonotriletes crassus sp. nov.

Battery Point formation. Holotype.

10. Archaeozonotriletes crassus sp. nov.

Battery Point formation. Paratype, perisporium almost completely worn away.

11. Archaeozonotriletes papillatus sp. nov.

Sextnat formation. Holotype.

Figure 12. *Archaeozonotriletes subrugulatus* sp. nov.

Sextant formation. Holotype.

13. *Archaeozonotriletes* sp. A.

Melville Island formation. Margin in focus.

14. *Archaeozonotriletes* sp. A.

Same specimen, laesurae in focus.

PLATE VII

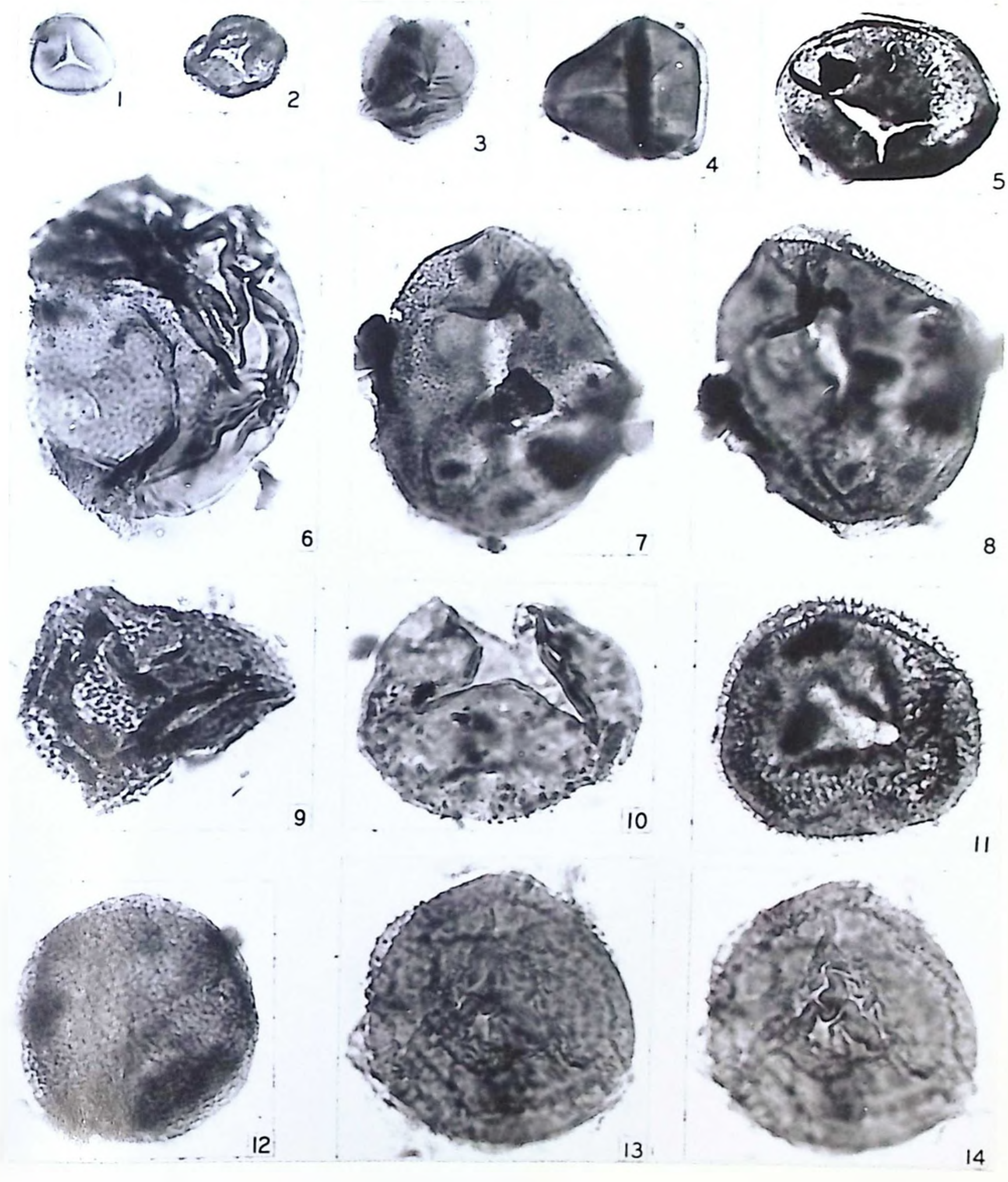


PLATE VIII

Figure 1. *Endosporites insolitus* sp. nov.

Battery Point formation. Holotype.

2. *Grandispora spinosa* Hoffmeister, Staplin and Malloy

Sextant formation.

3. *Grandispora spinosa* Hoffmeister, Staplin and Malloy

Sextant formation.

4. *Grandispora crenulata* sp. nov.

Perdrix equivalent. Paratype, laesurae visible.

5. *Grandispora crenulata* sp. nov.

Perdrix equivalent. Holotype.

6. (?) *Laevigato-sporites* sp. A.

Melville Island formation.

7. (?) *Laevigato-sporites* sp. A.

Melville Island formation.

PLATE VIII

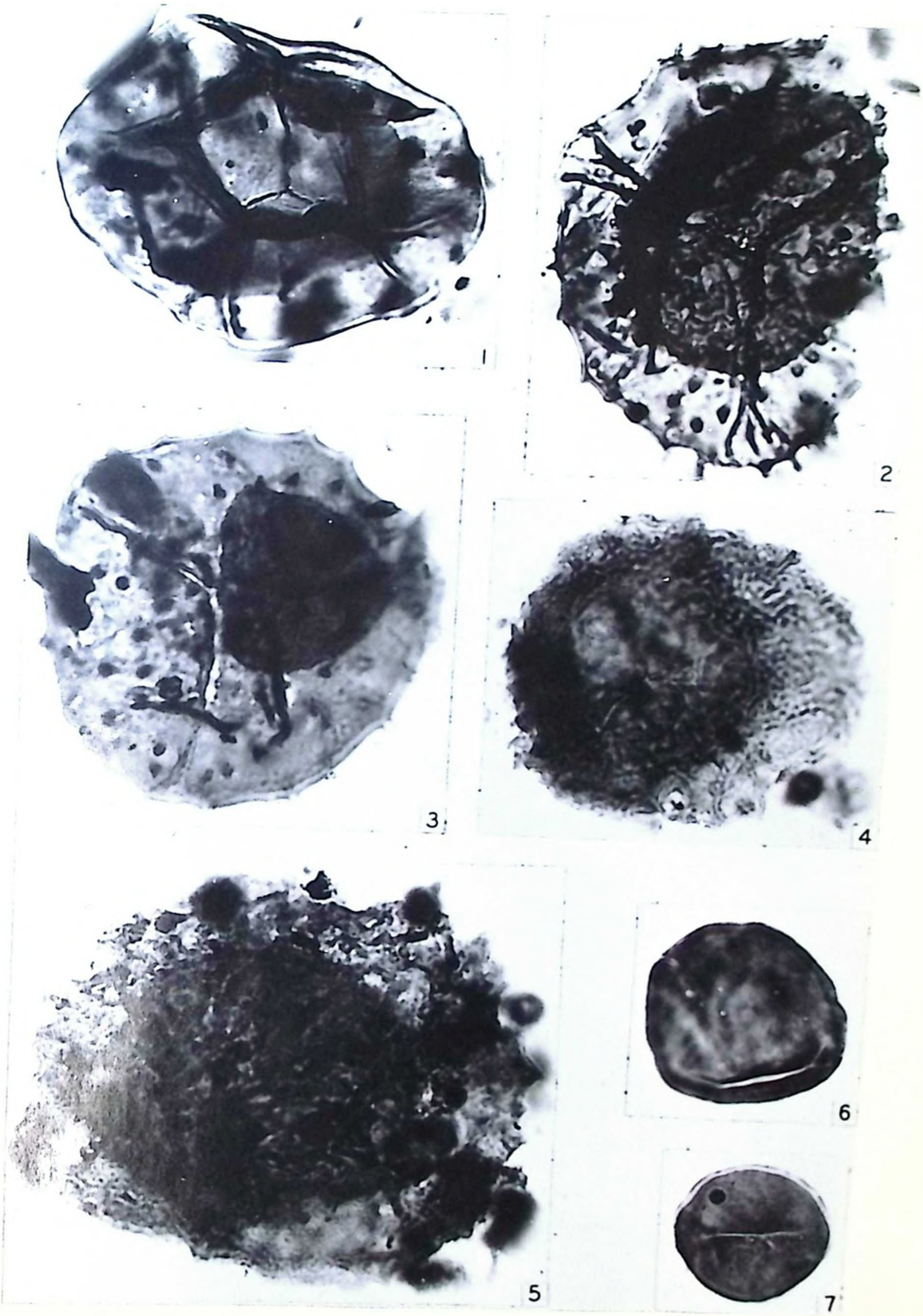


PLATE IX

Figure 1. _Arenosisporites_ sp., gen. nov.

Melville Island formation. X250.

2. _Arenosisporites subtilis_ gen. et sp. nov.

Melville Island formation. Holotype. X100.

3. _Tuberculati-sporites submamillarius_ sp. nov.

Melville Island formation. Laterally compressed. X100.

4. _Tuberculati-sporites submamillarius_ sp. nov.

Melville Island formation. Tubercles as long as wide.

5. _Tuberculati-sporites submamillarius_ sp. nov.

Melville Island formation. Typical appearance of tubercles. Holotype.

6. Portion of preceding, X1000.

7. _Tuberculati-sporites submamillarius_ sp. nov.

Melville Island formation. Holotype. X100.

8. Same specimen as preceding. X250. Membranous central body faintly visible.

9. Central body of _Tuberculati-sporites submamillarius_ sp. nov.

PLATE IX

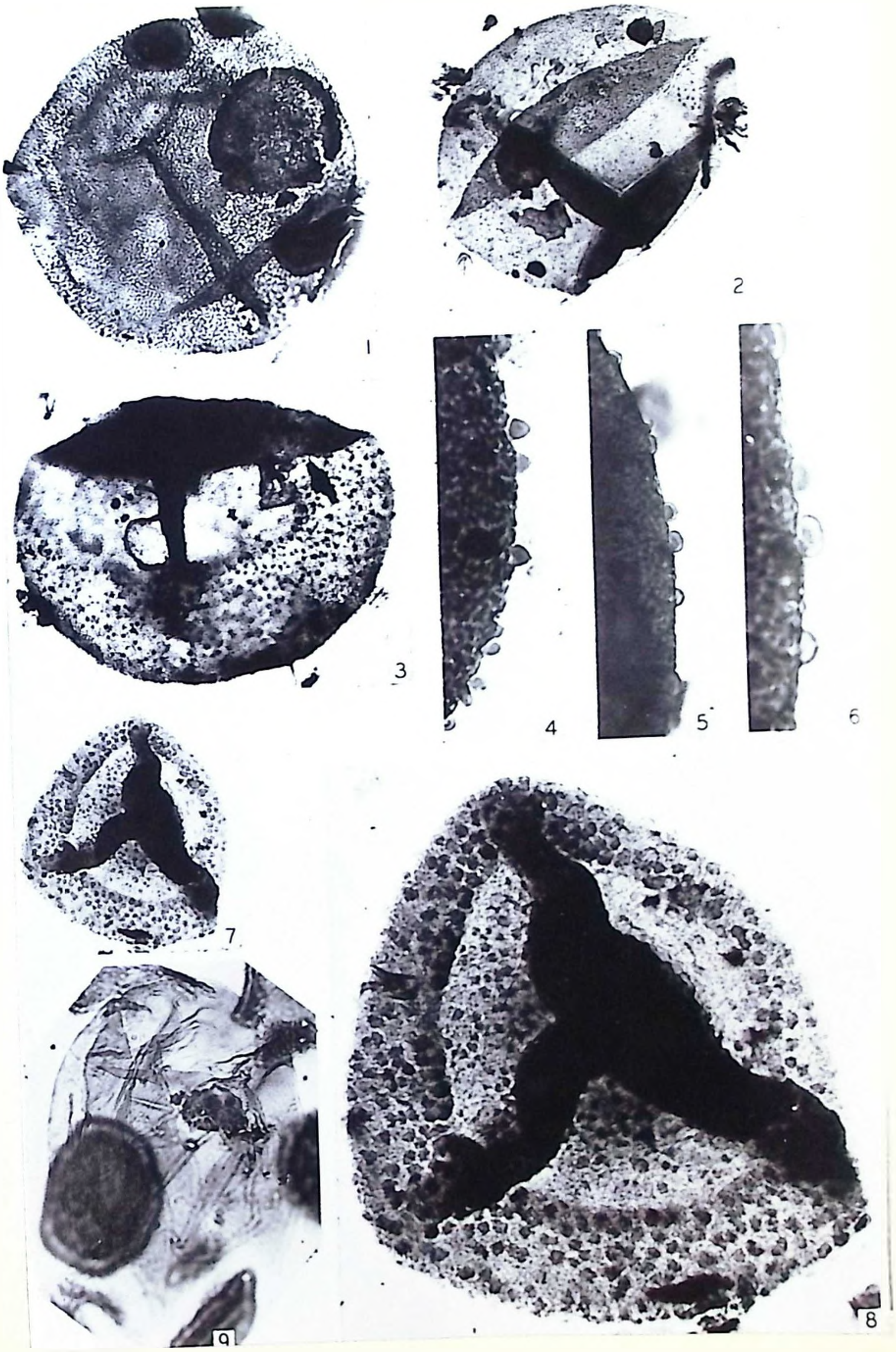


PLATE X

Figure 1. *Circumsporites melvillensis* gen. et sp. nov.
Melville Island Formation. Holotype. X250.

2. *Circumsporites melvillensis* gen. et sp. nov.
Melville Island Formation. Specimen with perispore closely appressed to central body. X250.

3. Portion of margin of preceding specimen, showing details of ornamentation of perisporium.

4. *Circumsporites melvillensis* gen. et sp. nov.
Holotype, showing details of ornamentation of perisporium.

5. Central body of *Circumsporites melvillensis* gen. et sp. nov.
Melville Island formation.

6. *Triletes* sp. A.
Battery Point Formation.

7. *Triletes* sp. B.
Battery Point Formation.

PLATE X

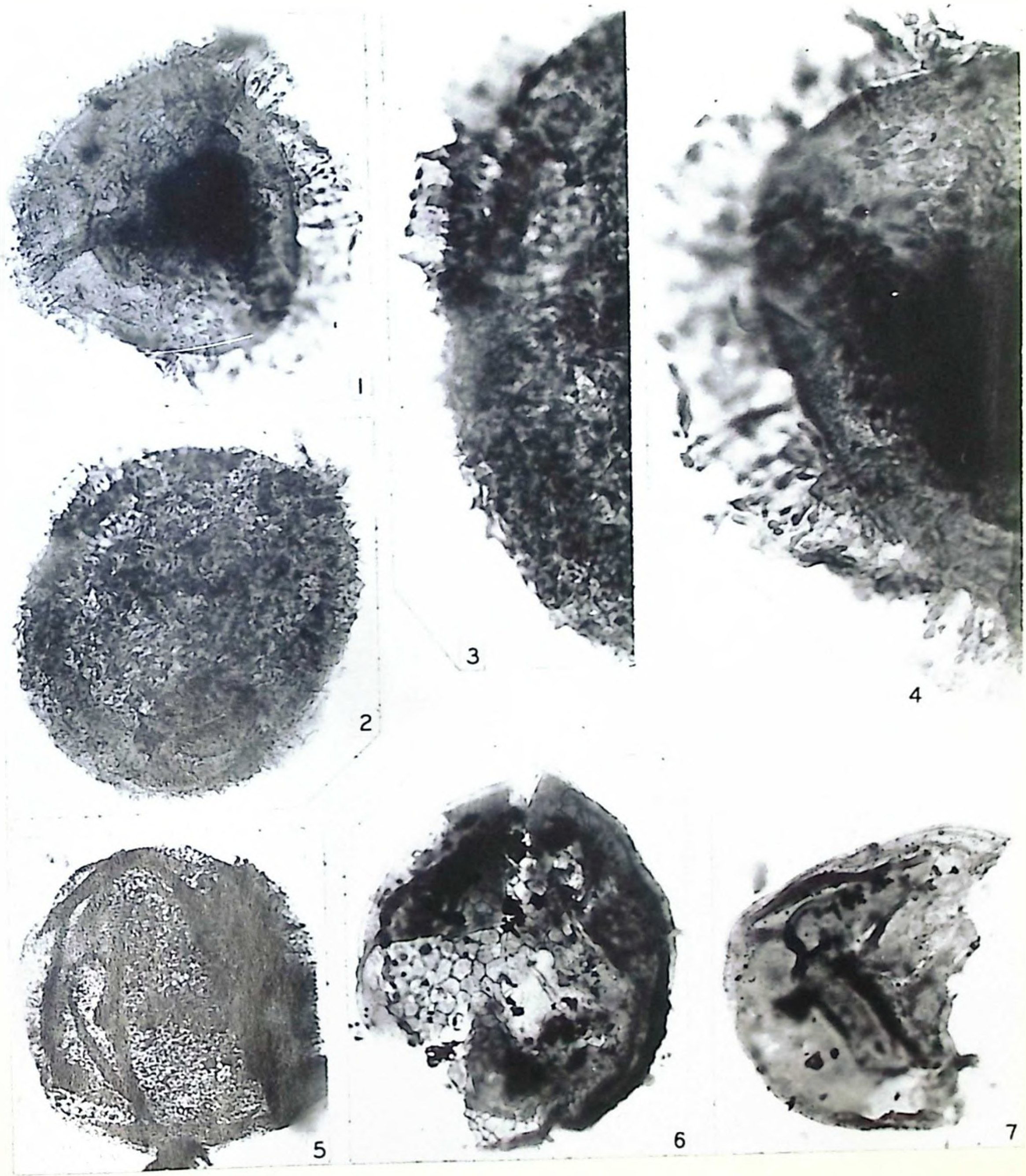


PLATE XI

Figure 1. *Micrhystridium penicillatum* sp. nov.

Onondaga formation. Holotype

2. *Micrhystridium cf. Micrhystridium stellatum* Deflandre.

Onondaga formation.

3. *Micrhystridium microattenuatum* sp. nov.

Onondaga formation. Holotype.

4. *Veryhachium triquetrum* sp. nov.

Onondaga formation. Holotype

5. *Veryhachium triquetrum* sp. nov.

Battery Point formation.

6. *Hystrichosphaeridium truncatum* sp. nov.

Onondaga formation. Holotype.

7. *Hystrichosphaeridium articulum* sp. nov.

Onondaga formation. Holotype.

8. *Veryhachium asymmetricum* sp. nov.

Onondaga formation. Holotype.

9. *Veryhachium asymmetricum* sp. nov.

Truncated apex of holotype.

10. *Veryhachium quadrangulatum* sp. nov.

Onondaga formation. Holotype.

11. *Veryhachium flaccidum* sp. nov.

Onondaga formation. Holotype.

12. *Hystrichosphaeridium acanthospinosum* sp. nov.

Battery Point formation. Holotype.

Figure 13. *Hystrichosphaeridium dispertum* sp. nov.

Battery Point formation. Holotype.

14. *Veryhachium tenoris* sp. nov.

Onondaga formation. Holotype.

15. *Veryhachium attenuatum* sp. nov.

Onondaga formation. Holotype.

16. *Hystrichosphaeridium robustum* sp. nov.

Onondaga formation. Holotype.

17. *Hystrichosphaeridium varium* sp. nov.

Perdrix equivalent. Holotype.

18. *Hystrichosphaeridium* cf. *H. intermedium* Eisenack.

Battery Point formation.

19. *Hystrichosphaeridium pinnosum* sp. nov.

Onondaga formation. Holotype.

20. *Hystrichosphaeridium problematicum* sp. nov.

Perdrix equivalent. Holotype.

21. *Hystrichosphaeridium appendiculatum* sp. nov.

Onondaga formation. Holotype.

PLATE XI

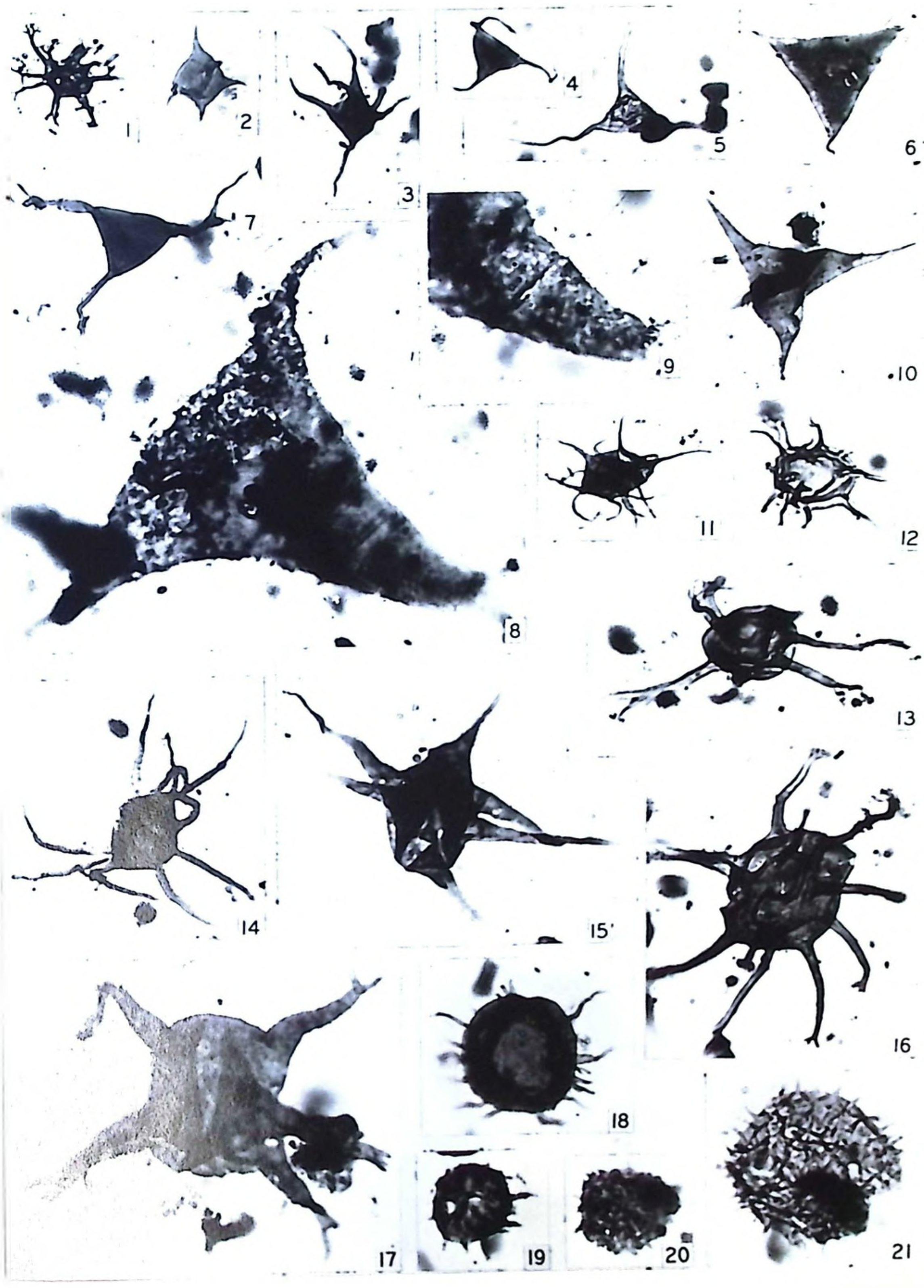


PLATE XII

Figure 1. *Veryhachium* cf. *V. crucistellatum* Deunff.

Onondaga formation.

2. *Cymatiosphaera vela* sp. nov.

Onondaga formation. Holotype.

3. *Cymatiosphaera stellata* sp. nov.

Perdrix equivalent. Holotype.

4. *Cymatiosphaera obscura* sp. nov.

Perdrix equivalent. Holotype.

5. *Cymatiosphaera* sp. A.

Onondaga formation.

6. *Pterospermopsis parvus* sp. nov.

Perdrix equivalent. Holotype.

7. *Pterospermopsis concentricus* sp. nov.

Onondaga formation. Holotype.

8. *Pterospermopsis concentricus* sp. nov.

Onondaga formation. Paratype, laterally compressed.

9. *Saccosphaera membranacea* gen. et sp. nov.

Onondaga formation. Holotype.

10. (?) *Pterospermopsis* sp.

Onondaga formation.

11. *Pterospermopsis equatorius* sp. nov.

Perdrix equivalent. Holotype.

12. *Leiosphaera* [illegible] sp. nov.

Onondaga formation. Holotype.

Figure 13. Leiosphaera dubia sp. nov.
Perdrix equivalent. Holotype.

14. Leiosphaera minuta sp. nov.
Onondaga formation. Holotype.

15. Leiosphaera plicata sp. nov.
Perdrix equivalent. Holotype.

16. Leiosphaera densa sp. nov.
Onondaga formation. Holotype.

17. Leiosphaera maculosa sp. nov.
Perdrix equivalent. Holotype.

18. Leiosphaera compressa sp. nov.
Onondaga formation. Holotype.

19. Leiosphaera cf. L. media Eisenack.
Onondaga formation.

20. Leiosphaera macromaculosa sp. nov.
Perdrix equivalent. Holotype.

21. Leiofusa tomaculata sp. nov.
Onondaga formation. Holotype.

22. Leiofusa navicula Eisenack.
Perdrix equivalent.

PLATE XII

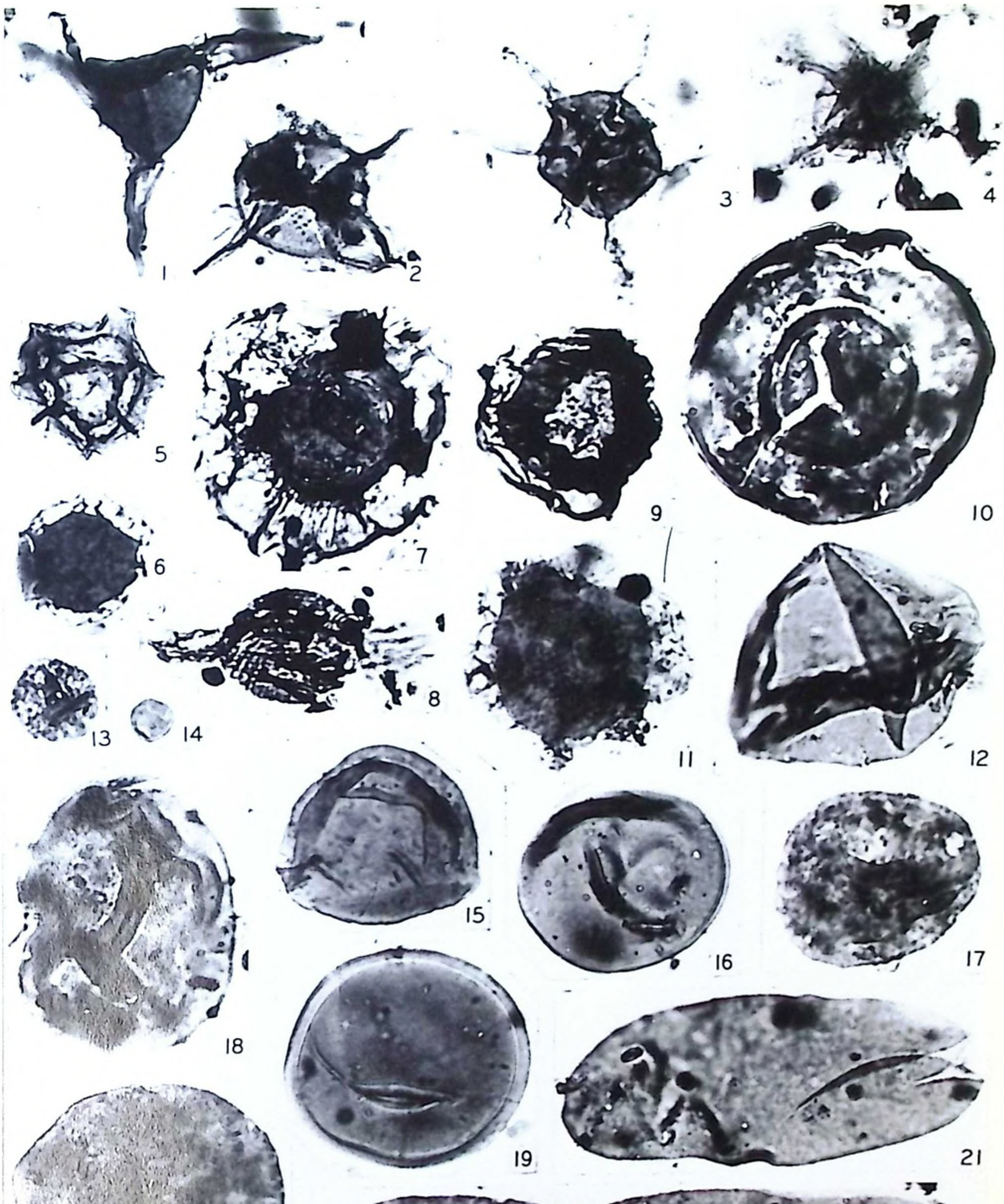


PLATE XIII

Figure 1. Perimetrisporites parvus sp. nov.

2. Perimetrisporites mundus sp. nov.

   Specimen with prominent interradial structure.

3. Perimetrisporites mundus sp. nov.

   Specimen with reduced interradial structure.

4. Reticulati-sporites ovoides sp. nov.

   Three spores of tetrad. Laevigate proximal face evident.

5. Reticulati-sporites ovoides sp. nov.

   Portion of spore, showing appearance of muri in transverse and lateral views.

6. Appendages of Archaeotriletes delectabilis.

7. Radiaspora amula forma laevigata sp. et f. nov.

   Transverse view, proximal face.

8. Radiaspora amula forma laevigata sp. et f. nov.

   Lateral view.

9. Denso-sporites inaequus sp. nov.

   Holotype, distal surface.

10. Denso-sporites inaequus sp. nov.

   Specimen with irregular, reduced spines. Distal surface.

11. Retusotriletes endoformis sp. nov.

   Outline of spores in tetrad, showing positions of central body (broken lines).

PLATE XIII

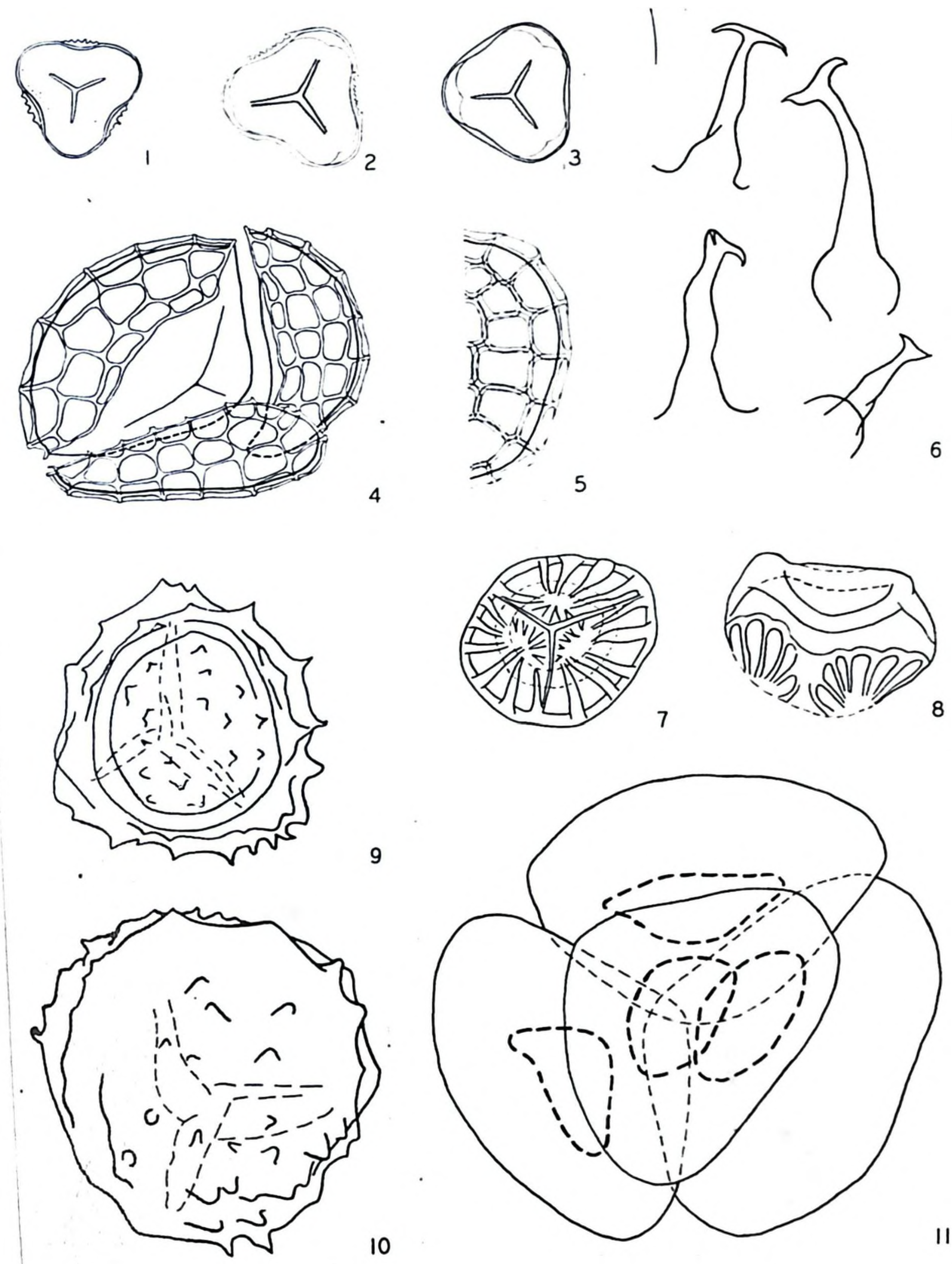


PLATE XIV

Figure 1. [illegible] sp. nov.

Transverse view of proximal face, showing appearance of discontinuous annulus.

2. [illegible] sp. nov.

Lateral view.

3. [illegible] sp. nov.

Distal face, specimen slightly tilted.

4. [illegible] sp. nov.

Transverse view, proximal portion.

5. [illegible] sp. nov.

Holotype, showing position of central body (broken line). [illegible]

6. Spines of [illegible] sp. nov.

Range of variation on one specimen. [illegible]

7. Appendages of [illegible] sp. nov.

Range of variation on one specimen. [illegible]

8. Appendages of [illegible]

sp. nov. [illegible]

9. [illegible] sp. nov.

Holotype.

10. Outline of spore mass of [illegible] (see [illegible], Fig. 1), indicating probable shape of sporangium outline. [illegible]

Melville Island formation.

Figure 11. Outline of spore mass of *Perimstrisporites mundus* (see Pl. XVI, Fig. 2), indicating probable shape of sporangium. X50. Sextant formation.

12. Outline of spore mass of *Granulati-sporites* *cf.* *G.* *minutissimus*, indicating probably shape of sporangium. X50. Sextant formation.

13. *Veryhachium* *cf.* *V.* *crucistellatum* Deunff.

PLATE XIV

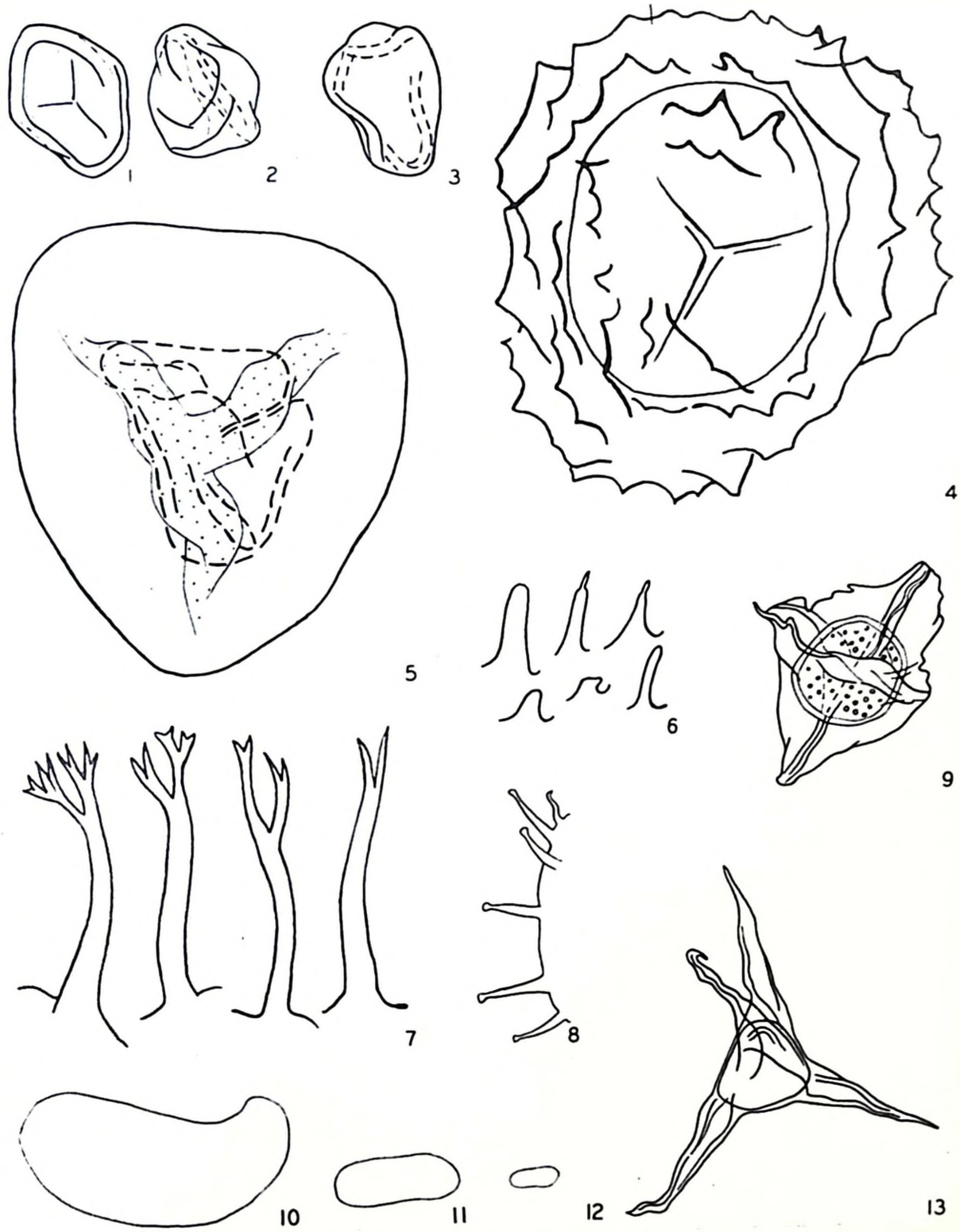


PLATE XV

Figure 1. Net-like structure, associated with small, laevigate, subcircular spores. X250.
Melville Island formation.

2. Fragment with closely-aligned strands, and node-like intervals. [illegible]
Melville Island formation.

3. Branching stem-like fragment. X50.
Melville Island formation.

4. Scalariform elements with septate structure. X250.
Melville Island formation.

5. Fragment similar to previous. X500.
Melville Island formation.

6. Annularly thickened tube-like fragment. X250.
Battery Point formation.

7. Fragment with oblong-elliptical pits. X500.
Melville Island formation.

8. Fragment similar to that in Fig. 6. X500.
Battery Point formation.

9. Scalariform tracheid-like fragment. X250.
Battery Point formation.

10. Fragment with bordered pits. X250.
Battery Point formation.

PLATE XV

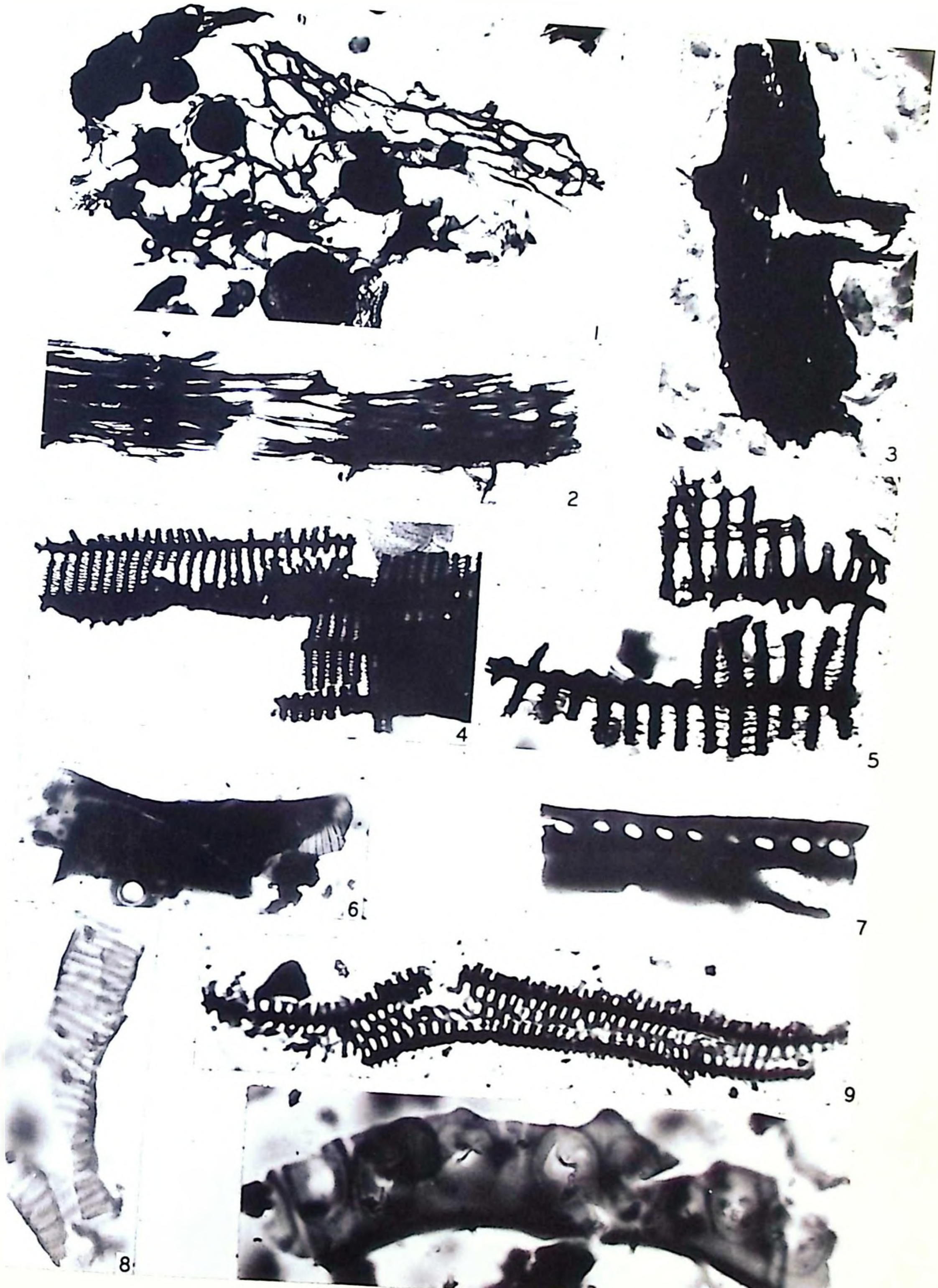


PLATE XVI

Figure 1. Spore-mass of *Retusotriletes magnificus*. X100.
Melville Island Formation.

2. Spore-mass of *Perinotrisporites* [illegible]. X250.
Sextant formation.

3. Spore-mass of *Granulati-sporites* cf. *G. minutissimus*. X250.
Sextant formation.

4. Portion of spore-mass shown in Fig. 2. X500.

5. Portion of spore-mass shown in Fig. 2. X500.

6. Portion of spore-mass shown in Fig. 3. X500.

7. Portion of spore-mass shown in Fig. 1. X500.

8. Single spore from mass shown in Fig. 1. X500.

9. Scolecodont. X250.

10. Scolecodont. X250.

11. Scolecodont. X250.

12. Portion of scolecodont shown in Fig. 11. X500.

13. Portion of scolecodont shown in Fig. 10. X500.

PLATE XVI

PLATE XVII

Percentages of dominant genera and species (i.e. those comprising 2% or more of their assemblage).
Sextant formation.

PLATE XVIII

Percentages of dominant genera and species.
Battery Point and Melville Island formations.

PLATE XIX

Percentages of dominant genera and species.
Onondaga formation and Perdrix equivalent.

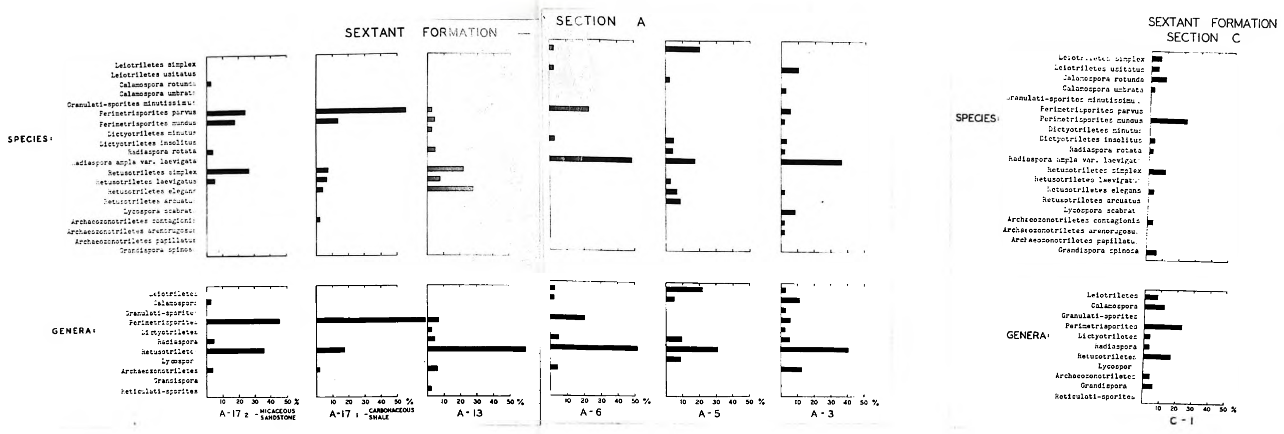
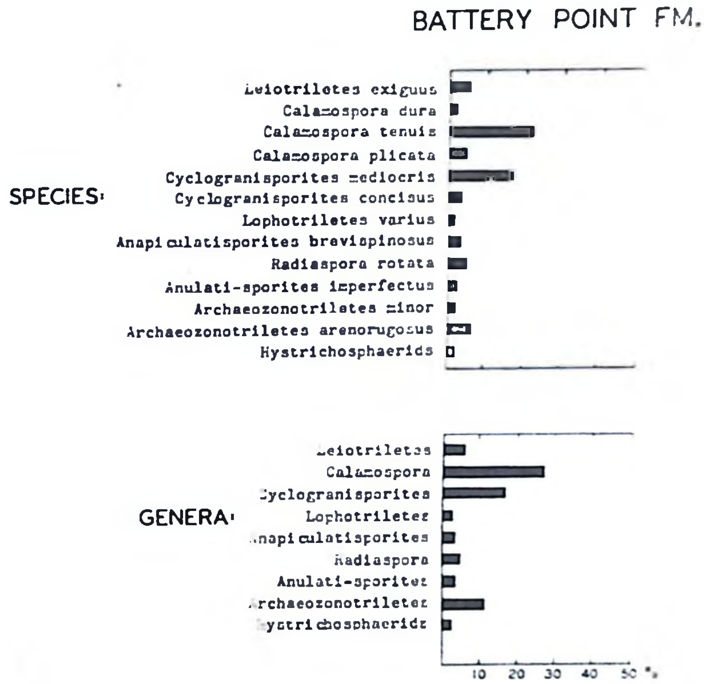
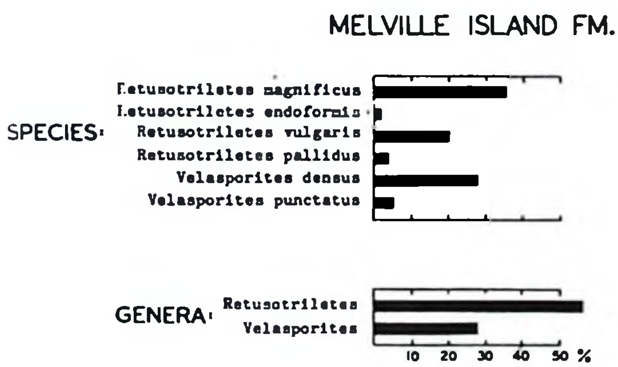

SEXTANT FORMATION — SECTION A
SPECIES:
GENERA:
A-17 2 - MICACEOUS SANDSTONE
A-17 1 - CARBONACEOUS SHALE
A-13
A-6
A-5
A-3
SEXTANT FORMATION
SECTION C
C-1

PLATE XVII

PLATE XVIII

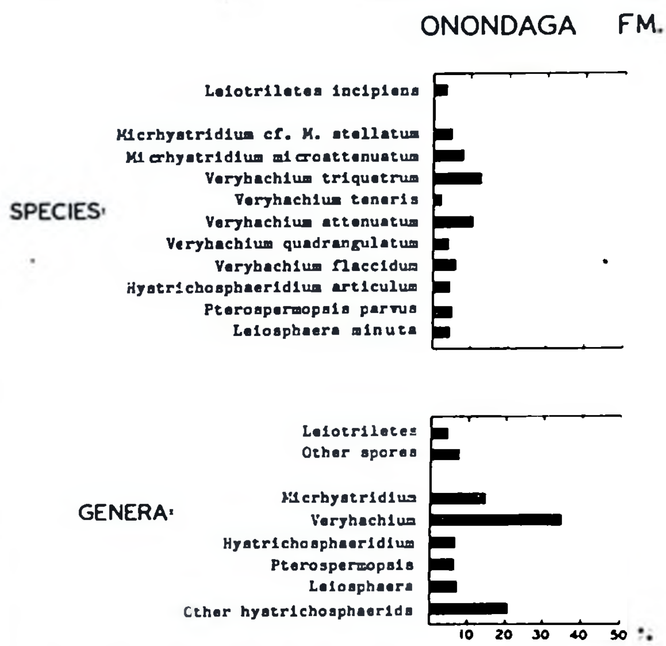


BATTERY POINT FM.
SPECIES:
Leiotriletes exiguus
Calamospora dura
Calamospora tenuis
Calamospora plicata
Cyclogranisporites mediocris
Cyclogranisporites concisus
Lophotriletes varius
Anapiculatisporites brevispinosus
Radiaspora rotata
Anulati-sporites imperfectus
Archaeozonotriletes minor
Archaeozonotriletes arenorugosus
Hystrichosphaerids
GENERA:
Leiotriletes
Calamospora
Cyclogranisporites
Lophotriletes
Anapiculatisporites
Radiaspora
Anulati-sporites
Archaeozonotriletes
Hystrichosphaerids
10 20 30 40 50 %



MELVILLE ISLAND FM.
SPECIES:
Retusotriletes magnificus
Retusotriletes endoformis
Retusotriletes vulgaris
Retusotriletes pallidus
Velasporites densus
Velasporites punctatus
GENERA:
Retusotriletes
Velasporites
10 20 30 40 50 %

PLATE XIX


ONONDAGA FM.
SPECIES:
Leiotriletes incipiens
Micrhystridium cf. M. stellatum
Micrhystridium microattenuatum
Veryhachium triquetrum
Veryhachium teneris
Veryhachium attenuatum
Veryhachium quadrangulatum
Veryhachium flaccidum
Hystrichosphaeridium articulum
Pterospermopsis parvus
Leiosphaera minuta
GENERA:
Leiotriletes
Other spores
Micrhystridium
Veryhachium
Hystrichosphaeridium
Pterospermopsis
Leiosphaera
Other hystrichosphaerids
10 20 30 40 50 %

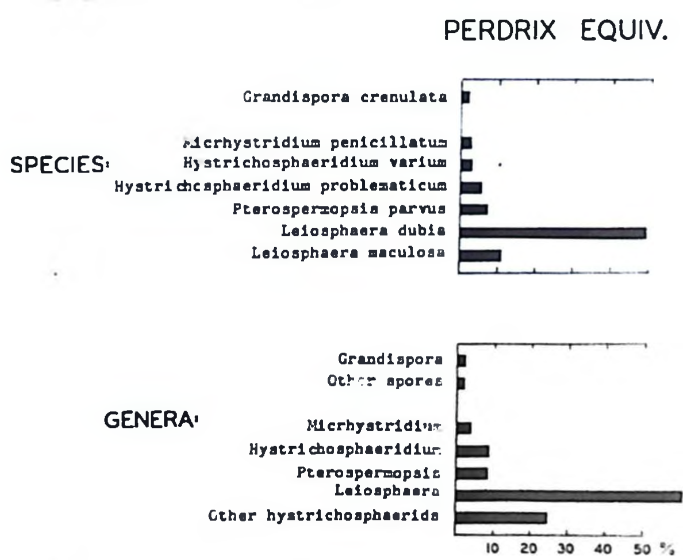

PERDRIX EQUIV.
SPECIES:
Grandispora crenulata
Micrhystridium penicillatum
Hystrichosphaeridium varium
Hystrichosphaeridium problematicum
Pterospermopsis parvus
Leiosphaera dubia
Leiosphaera maculosa
GENERA:
Grandispora
Other spores
Micrhystridium
Hystrichosphaeridium
Pterospermopsis
Leiosphaera
Other hystrichosphaerids
10 20 30 40 50 %

PLATE XX

Range of diameter of spores (μ).

Sextant formation.

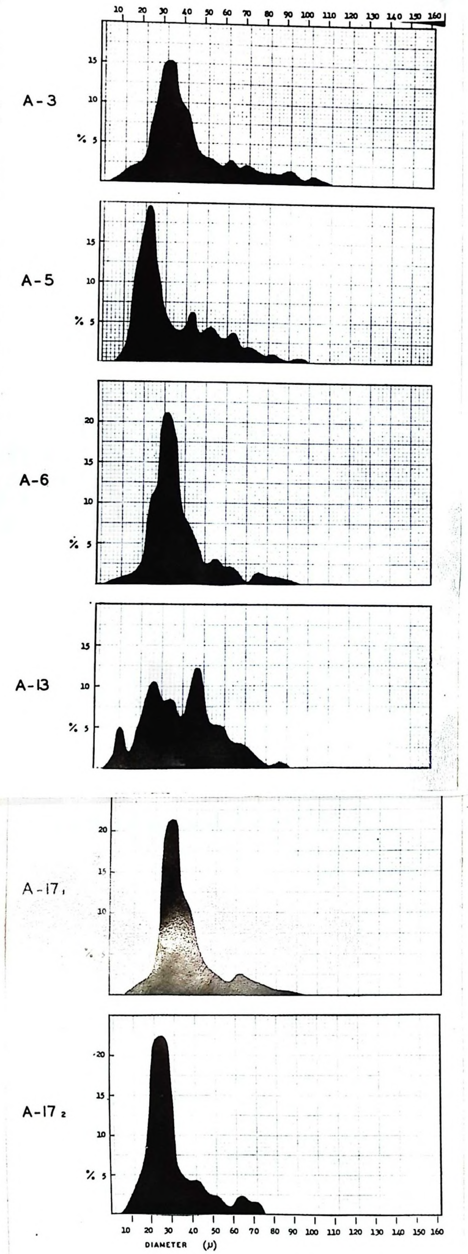
PLATE XXI

Range of diameter of spores (μ).

Onondaga, Battery Point and Melville Island formations

and Perdrix equivalent.

SEXTANT FORMATION — SECTION A



SEXTANT FORMATION — SECTION C

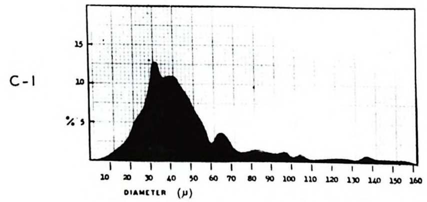
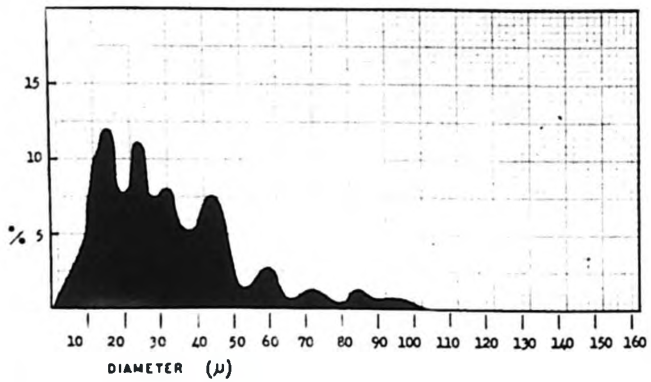
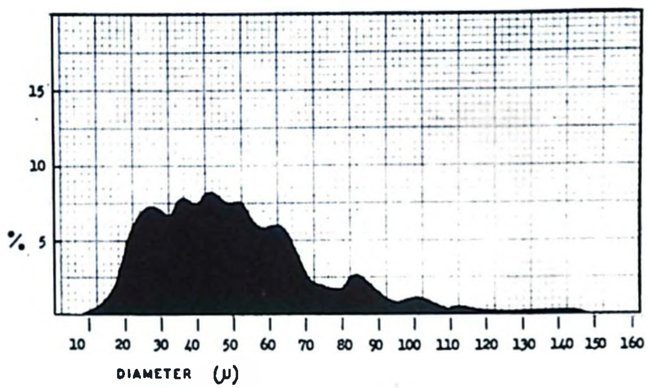


PLATE XXI

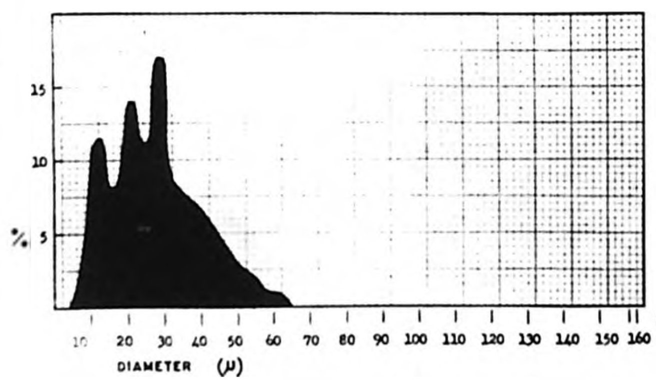
ONONDAGA FM.



BATTERY POINT FM.



PERDRIX EQUIV.



MELVILLE ISLAND FM.