



# GEOLOGICAL SURVEY OF CANADA COMMISSION GÉOLOGIQUE DU CANADA

This document was produced  
by scanning the original publication.

Ce document est le produit d'une  
numérisation par balayage  
de la publication originale.

**BULLETIN 279**

## **LOWER TO MIDDLE DEVONIAN ACRITARCHS OF THE MOOSE RIVER BASIN, ONTARIO**

Geoffrey Playford



Energy, Mines and  
Resources Canada

Energie, Mines et  
Ressources Canada

**1977**

**LOWER TO MIDDLE DEVONIAN ACRITARCHS OF THE  
MOOSE RIVER BASIN, ONTARIO**



©Minister of Supply and Services Canada 1977

Available by mail from

Printing and Publishing Supply and Services Canada,  
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada  
601 Booth Street, Ottawa, Canada K1A 0E8

or through your bookseller

A deposit copy of this publication is also available  
for reference in public libraries across Canada

Catalogue No. M42-279      Price: Canada: \$4.50  
ISBN No. 0-660-00816-5      Other countries: \$5.40

Price subject to change without notice

Critical Readers  
D. C. MCGREGOR  
W. A. M. JENKINS

Editor  
MARK KENNEDY

Text printed on Georgian offset, smooth (brilliant white)  
Set in Times Roman with News Gothic captions  
by SOUTHAM MURRAY, TORONTO

Artwork by CARTOGRAPHIC UNIT, GSC

1,200-1977-6645-7



**GEOLOGICAL SURVEY  
BULLETIN 279**

# **LOWER TO MIDDLE DEVONIAN ACRITARCHS OF THE MOOSE RIVER BASIN, ONTARIO**

Geoffrey Playford





## Preface

The Hudson Bay Lowlands is one of 10 regions in Canada that may contain deposits of oil and natural gas. There has been some exploration in the area but to date this has not resulted in any discoveries.

Limited fossil evidence has prevented precise correlation of parts of the Devonian succession and increasing use has been made of spores and acritarchs. In this report the author describes 53 species of acritarchs distributed among 24 genera. In addition to providing data useful for stratigraphic correlation of marine and nonmarine sequences, the current study provides the first account of acritarch suites from a Lower to Middle Devonian sequence in North America.

*D. J. McLaren*  
Director-General  
Geological Survey of Canada

Ottawa, 4 October 1976





## Figures

1. Index map showing Moose River Basin and adjacent geological provinces.	3
2. Columnar stratigraphic section, Jaab Lake No. 1 well.....	5
3. Processes of <i>Baltisphaeridium crebrum</i> sp. nov.....	11
4. Processes of <i>Baltisphaeridium distentum</i> sp. nov.....	12
5. Processes of <i>Baltisphaeridium juliae</i> Cramer, 1964.....	13
6. Processes of <i>Baltisphaeridium microfurcatum</i> (Deunff) Stockmans and Willière, 1962.....	14
7. Processes of <i>Baltisphaeridium stamineum</i> sp. nov.....	15
8. Processes of <i>Diexallophasis remota</i> (Deunff) comb. nov., emend.....	20
9. Processes of <i>Gorgonisphaeridium disparatum</i> sp. nov.....	23
10. Processes of <i>Gorgonisphaeridium</i> sp. A.....	24
11. Processes of <i>Gorgonisphaeridium</i> sp. B.....	24
12. Processes of <i>Hapsidopalla exornata</i> (Deunff) comb. nov., emend.....	25
13. Processes of <i>Hapsidopalla sannemannii</i> (Deunff) comb. nov., emend.....	26
14. Processes of <i>Lophosphaeridium dumalis</i> sp. nov.....	27
15. Processes of <i>Multiplicisphaeridium ampliatus</i> sp. nov.....	28
16. Processes of <i>Multiplicisphaeridium ramusculosum</i> (Deflandre) Lister, 1970	29



## LOWER TO MIDDLE DEVONIAN ACRITARCHS OF THE MOOSE RIVER BASIN, ONTARIO

### Abstract

Profuse and well-preserved assemblages of acritarchs (microphytoplankton *incertae sedis*) occur in the majority of samples from the Lower to Middle Devonian (late Siegenian to Givetian), marine, subsurface sequence of Ontario Department of Mines Jaab Lake No. 1 well, in the Moose River Basin, northern Ontario. The samples are cored representatives of five, mostly conformable lithostratigraphic units. In ascending order, these are: Stopping River, Kwataboahagan, Moose River, Murray Island and Williams Island formations.

Fifty-three species of acritarchs are recognized, described systematically, and distributed among 24 genera of which four, *Costatilibus*, *Goniolopadion*, *Hapsidopalla* and *Tyligmasoma*, are newly instituted herein. The genus *Onondagealla* Cramer is given an emended diagnosis. New species described are: *Baltisphaeridium anfractum*, *B. crebrum*, *B. distentum*, *B. stamineum*, *Costatilibus undulatus* (type species), *Dictyotidium cavernosulum*, *D. variatum*, *Divetipellis ventricosa*, *Goniolopadion prolixum* (type species), *Gorgonisphaeridium cumulatum*, *G. disparatum*, *G. granatum*, *Lophosphaeridium dumalis*, *Multiplicisphaeridium ampliatum*, *Polyedryxium carnatum*, *P. fragosulum* and *Veryhachium radiosum*. Of previously published species identified in the assemblages, many were described originally by J. Deunff from an imprecisely dated Devonian sample from southern Ontario.

The paper concludes with documentation and discussion of the stratigraphic occurrence of the acritarch species. The age of the sediments implied by the acritarch palynoflora is in accord with that indicated by other fossil groups present; and the restricted ranges of some of the acritarch species are potentially useful for stratigraphic correlation.

### Résumé

Des assemblages abondants et bien conservés d'acritarques (microphytoplancton *incertae sedis*) apparaissent dans la plupart des échantillons du Dévonien inférieur au Dévonien moyen (fin du Siégénien au Givétien) qui ont été prélevés dans la séquence sous-jacente d'origine marine du puits no. 1 du lac Jaab, du ministère des Mines de l'Ontario; ce puits se trouve dans le bassin de la rivière Moose, dans le nord de l'Ontario. Les échantillons sont des carottes représentatives de cinq unités lithostratigraphiques qui sont le plus souvent concordantes. De bas en haut, on trouve: les formations de Stopping River, de Kwataboahagan, de Moose River, de Murray Island et de William Island.

Cinquante trois espèces d'acritarques ont été identifiées, systématiquement décrites et réparties parmi 24 genres, dont quatre, *Costatilibus*, *Goniolopadion*, *Hapsidopalla* et *Tyligmasoma*, viennent d'être créés. Le genre *Onondagealla* Cramer a fait l'objet d'une diagnose améliorée. Voici les nouvelles espèces qui sont décrites: *Baltisphaeridium anfractum*, *B. crebrum*, *B. distentum*, *B. stamineum*, *Costatilibus undulatus* (espèce du type), *Dictyotidium cavernosulum*, *D. variatum*, *Divetipellis ventricosa*, *Goniolopadion prolixum* (espèce du type), *Gorgonisphaeridium cumulatum*, *G. disparatum*, *G. granatum*, *Lophosphaeridium dumalis*, *Multiplicisphaeridium ampliatum*, *Polyedryxium carnatum*, *P. fragosulum* et *Veryhachium radiosum*. Parmi les espèces qui avaient déjà fait l'objet de publications et que l'on a identifiées dans les assemblages, beaucoup ont été décrites à l'origine par J. Deunff à partir d'un échantillon daté du Dévonien de façon imprécise et recueilli dans le sud de l'Ontario.

L'ouvrage se termine par une documentation et une discussion sur la répartition stratigraphique des espèces acritarques. L'âge des sédiments évalué d'après les organismes polliniques acritarques correspond à celui indiqué par d'autres groupes fossiles présents; par ailleurs, les périodes d'existence restreintes de quelques espèces acritarques pourraient s'avérer utiles pour l'établissement des corrélations stratigraphiques.

### Introduction

Organic-walled microplanktonic remains of great physicochemical durability and uncertain natural alliance are assuming increasing prominence in precise dating and correlation of pre-Carboniferous Paleozoic strata of marine derivation. This applies particularly to subsurface sections and to outcropping strata in which age-diagnostic megafossils are rare or absent. These microfossils, known generally as acritarchs (Evitt, 1963), range from Late Precambrian to Holocene, but they achieve their greatest abundance and morphological diversity in the Cambrian to Devonian

interval, with an apparent acme of development in the Ordovician (Loeblich, 1970; Tappan and Loeblich, 1973, p. 214-216). Taxonomically, the acritarchs are treated as an *incertae sedis* (and probably polyphyletic) 'Group', the Acritarcha Evitt, 1963. However, a significant proportion of the group's contents are probably cyst-remains of marine planktonic algae (Downie, 1973) and consequently it is reasonable that the formal nomenclature of the Acritarcha follow the tenets of the International Code of Botanical Nomenclature. This is fortunate and expedient inasmuch as the Botanical Code, in contradistinction to the Zoological Code, permits recognition of form genera and form species, which acritarch taxa inevitably are.

The present account is concerned with the nature, taxonomy and vertical distribution of acritarchs recovered from a continuously cored succession of marine rocks of

MS submitted: September 1976

Approved for publication: October 1976

Author's address: Department of Geology and Mineralogy, University of Queensland, St. Lucia, Brisbane, Australia 4067.

Early to Middle Devonian age, in the Moose River Basin of northern Ontario. Other palynomorphs, specifically miospores, from the same section (plus two others) have been described and discussed by McGregor *et al.* (1970) and, more fully, by McGregor and Camfield (1976). The latter authors alluded to the abundant presence of acritarchs in association with the miospores, thus foreshadowing the present investigation.

McGregor and Camfield's (1976) work has provided a detailed biostratigraphic framework for the studied sequence, and has established precise ages of the constituent formations, including the approximate positioning of the Silurian-Devonian boundary as well as that between the Lower and Middle Devonian (Fig. 2). The present study is thus to be regarded as complementary to that of McGregor and Camfield, being concerned with the principal nonspore palynomorph component of the main section (Jaab Lake well) from which their miospore floras derive.

The Moose River Basin, and contiguous onshore and offshore Hudson Bay Basin, are of economic interest as a potential source for petroleum and natural gas (Sanford and Norris, 1973, 1975). Clearly, detailed knowledge of the palynostratigraphic sequence can be expected to play a significant role in subsurface correlation within these basins. In a wider geographic context, the current study provides the first account of acritarch suites from a Lower to Middle Devonian sequence in North America. Moreover, it is hoped that integration of miospore and acritarch distributions in the same section will constitute a useful basis for correlation of marine and nonmarine sequences deposited during this time interval.

This work was undertaken at the Geological Survey of Canada (GSC), Ottawa, while the author was on sabbatical leave from the University of Queensland. Grateful acknowledgment is extended to D. C. McGregor (GSC) for suggesting the project and, with W. A. M. Jenkins (GSC), for critically reviewing the manuscript; to B. V. Sandford (GSC) for stratigraphic information; to G. H. Haggis and Elizabeth Ford (Research Branch, Agriculture Canada, Ottawa) for considerable assistance during scanning electron microscopy of the microfossils; and to W. A. S. Sarjeant (University of Saskatchewan) for loan of literature. Martha Camfield and Paula Webb (both of GSC) were responsible for laboratory extraction of the microfossils; and the former assisted in translating certain French and German passages from the literature.

## Outline of Stratigraphy

The Hudson Platform, covering an area of about 375 000 square miles, includes two intracratonic Phanerozoic basins in which Devonian rocks constitute part of the bedrock surface. These are the Moose River Basin, centred mainly in northern Ontario; and, to the immediate north, the Hudson Bay Basin, which is largely covered by waters of Hudson Bay but is developed onshore also as a narrow coastal strip (Hudson Bay Lowlands) extending from James Bay into northern Manitoba (Fig. 1). The two basins are separated by a northeast-trending positive feature, the Cape Henrietta Maria Arch, which comprises Precambrian rocks.

The Moose River Basin and the lesser known Hudson Bay Basin are regarded as erosional remnants of a once very extensive cratonic cover that formerly connected them with the Appalachian, Michigan and Williston basins to the south, and with the Arctic Platform to the north (*see* Sanford and Norris, 1973, p. 390–391). Of special economic interest is close lithostratigraphic similarity between Devonian sequences of the Hudson Platform and the Michigan Basin. This relates to the hydrocarbon-bearing character of Devonian carbonate rocks of the latter basin, which produce about 80 per cent of the oil and natural gas in southern Ontario and Michigan and which have close lithological and time equivalents on the Hudson Platform. Although no definite hydrocarbon shows have been reported from either the Moose River or Hudson Bay basins, relatively little exploratory drilling has been done and the areas clearly merit continued exploration (Sanford and Norris, 1973, 1975).

The following summary of the Moose River Basin's Devonian stratigraphy derives mainly from Sanford and Norris (1975), to which publication the reader is referred for a comprehensive coverage of the stratigraphy and economic geology of the Devonian rocks of the Hudson Platform.

Devonian lithostratigraphic units of the Moose River Basin range in age from Early to Late Devonian and, for the most part, reflect deposition under shallow-water marine to supratidal conditions. They attain a maximum aggregate thickness of about 1500 feet. In ascending order, the units are as follows: upper member of the Kenogami River Formation, and Stopping River Formation (Lower Devonian); Kwataboahagan Formation (Lower to Middle Devonian); Moose River, Murray Island, and Williams Island formations (Middle Devonian, with possible extension into the lower Upper Devonian [upper part of Williams Island Formation]); and Long Rapids Formation (Upper Devonian). Confined to the southeastern margin of the Moose River Basin is a wedge of continental (fluvial) deposits termed the Sextant Formation, which on dispersed-spore evidence (McGregor and Camfield, 1976) are of late Early Devonian age, being correlative with a portion of the upper Stopping River Formation.

### *Kenogami River Formation, upper member*

This partly evaporitic unit consists of a variety of dolomites (oolitic, argillaceous, calcareous, cherty and brecciated); and was seemingly deposited under shallow-water tidal flat to intertidal conditions with short emergent interludes. In the Jaab Lake well (this study), the member is 104 feet thick; elsewhere in the Moose River Basin, its thickness ranges from 33 to 137 feet. The contact with the underlying middle member of the Kenogami River Formation (composed largely of evaporitic red to grey-green shales and siltstones) is transitional and, therefore, is drawn somewhat arbitrarily. Prior to spore studies by McGregor and collaborators (1970, 1976), the Kenogami River Formation was placed in the Upper Silurian. In the case of the middle and upper members, this was not founded on any definitive paleontological criteria, as determinable megafossils are virtually absent from both. However, McGregor and Camfield (1976) were able to demonstrate, by reference to spore ranges established elsewhere in the northern hemisphere (Britain, Libya), that



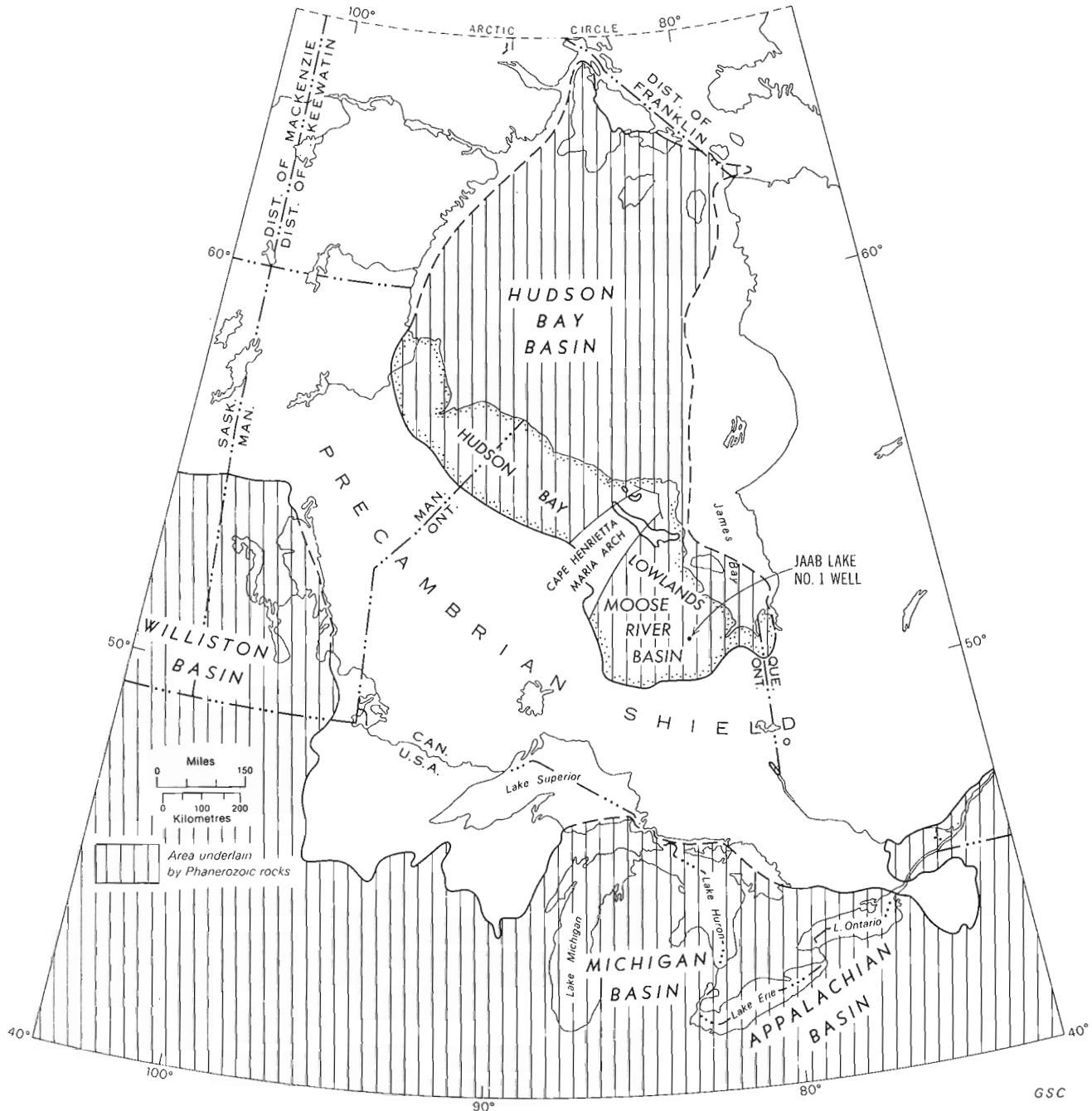


Figure 1. Index map showing Moose River Basin and adjacent geological provinces. Modified from Sanford and Norris (1975).

the upper member contains an immediately post-Silurian miospore suite datable as Gedinnian to, probably, early Siegenian. They expressed the view that the Silurian-Devonian systemic boundary, is located "within the upper beds of the (middle) member" (McGregor and Camfield, 1976, p. 29).

#### *Stooping River Formation*

Limestone, dolomitic limestone, cherty limestone and dolomite are the principal lithological constituents of the Stooping River Formation, which has an essentially conformable

relationship with the underlying upper member of the Kenogami River Formation through most parts of the Moose River Basin. In the southeastern part of the basin, the Stooping River Formation interfingers with and overlaps the terrestrial Sextant Formation (not studied here), which itself is developed directly on Precambrian crystalline rocks. The Stooping River Formation has a maximum thickness of 469 feet in the vicinity of the basin's centre (i.e., in the Jaab Lake well) and is clearly the product of shallow-water marine sedimentation. Invertebrate megafossils (i.e., brachiopods, corals, bryozoans, tentaculitids, crinoids), conodonts

and spores collectively indicate a late Siegenian to Emsian (or possibly early Eifelian) age for the Stooping River Formation.

#### *Kwataboahagan Formation*

This formation consists predominantly of massive to thick bedded, coralline, crinoidal and stromatoporoidal limestones. In peripheral areas of the Moose River Basin, its contact with the underlying Stooping River Formation is sharp and possibly disconformable; whereas in the central part, the Kwataboahagan Formation is relatively thick (e.g., 251 feet in the Jaab Lake well) and succeeds the underlying unit without discernible break. The marine conditions under which the formation was deposited permitted massive biostromal buildups over basement topographic highs: viz., in the southeastern part of the basin. The Kwataboahagan Formation is reportedly the most richly fossiliferous unit in the Hudson Bay Lowlands, preserving an abundance and diversity of invertebrate megafossils (especially corals, brachiopods, crinoids, stromatoporoids). Conodont faunas have also been recovered and assessed biostratigraphically. The available megafaunal, conodont and spore data suggest that the Kwataboahagan Formation is largely or entirely of early Middle Devonian (Eifelian) age and probably coeval with the lower part (Edgecliff Member) of the well-known Onondaga Formation of New York State. McGregor and Camfield (1976) considered that the lower 50 feet of the Kwataboahagan Formation in the Jaab Lake borehole might well (on spore evidence) be late Emsian.

#### *Moose River Formation*

Conformably overlying the Kwataboahagan Formation are largely unfossiliferous and evaporitic sediments—limestones, dolomites and gypsum—that constitute the distinctive Moose River Formation. This formation, which evidently accumulated under supersaline and faunistically unfavourable conditions, has a maximum known thickness of 291 feet. Extreme paucity of paleontological evidence militates against independent dating of the Moose River Formation, but on the ground of stratigraphic position it is attributed to the early Middle Devonian (mid-Eifelian).

#### *Murray Island Formation*

The Murray Island Formation, which disconformably succeeds the Moose River Formation, is characterized by fossiliferous limestone that is partly dolomitic, partly argillaceous and includes minor shale interbeds. The lithologies and faunas indicate a resumption of normal marine conditions and basinal subsidence. Thickness is relatively insubstantial (maximum 65 feet). Invertebrate faunas of the Murray Island Formation, though not plentiful, include a wide variety of brachiopods, which together with conodonts, attest to a late Eifelian age.

#### *Williams Island Formation*

The Williams Island Formation is divisible into two conformable marine units of member status (not formally named). The lower, comprising calcareous shale, siltstone and sandstone, with some limestone beds, reaches a maximum thickness of 147 feet; it rests with probable discon-

formity upon the Murray Island Formation. The upper member (maximum thickness, 154 feet) is a carbonate unit of evaporitic limestone, together with some argillaceous limestone and shale; it is not represented in the Jaab Lake well section studied herein. The two members can, in general, be discerned readily throughout the Moose River Basin; they are mostly subtidal in origin, but evince brief episodes of supratidal conditions. Brachiopods are particularly plentiful in the lower clastic member of the Williams Island Formation, and are associated with other invertebrates (corals, stromatoporoids, bryozoans). This fauna, together with another (principally coralline) from the lower part of the upper carbonate member, displays many similarities with those known from the Givetian Hamilton Group of Ontario and correlative Traverse Group of Michigan. McGregor and Camfield (1976) reported early to middle Givetian spores from the lower unit of the Williams Island Formation. Therefore, the formation as a whole is regarded as dominantly Givetian in age, with the possibility that its uppermost transitional beds are early Frasnian (i.e., earliest Late Devonian).

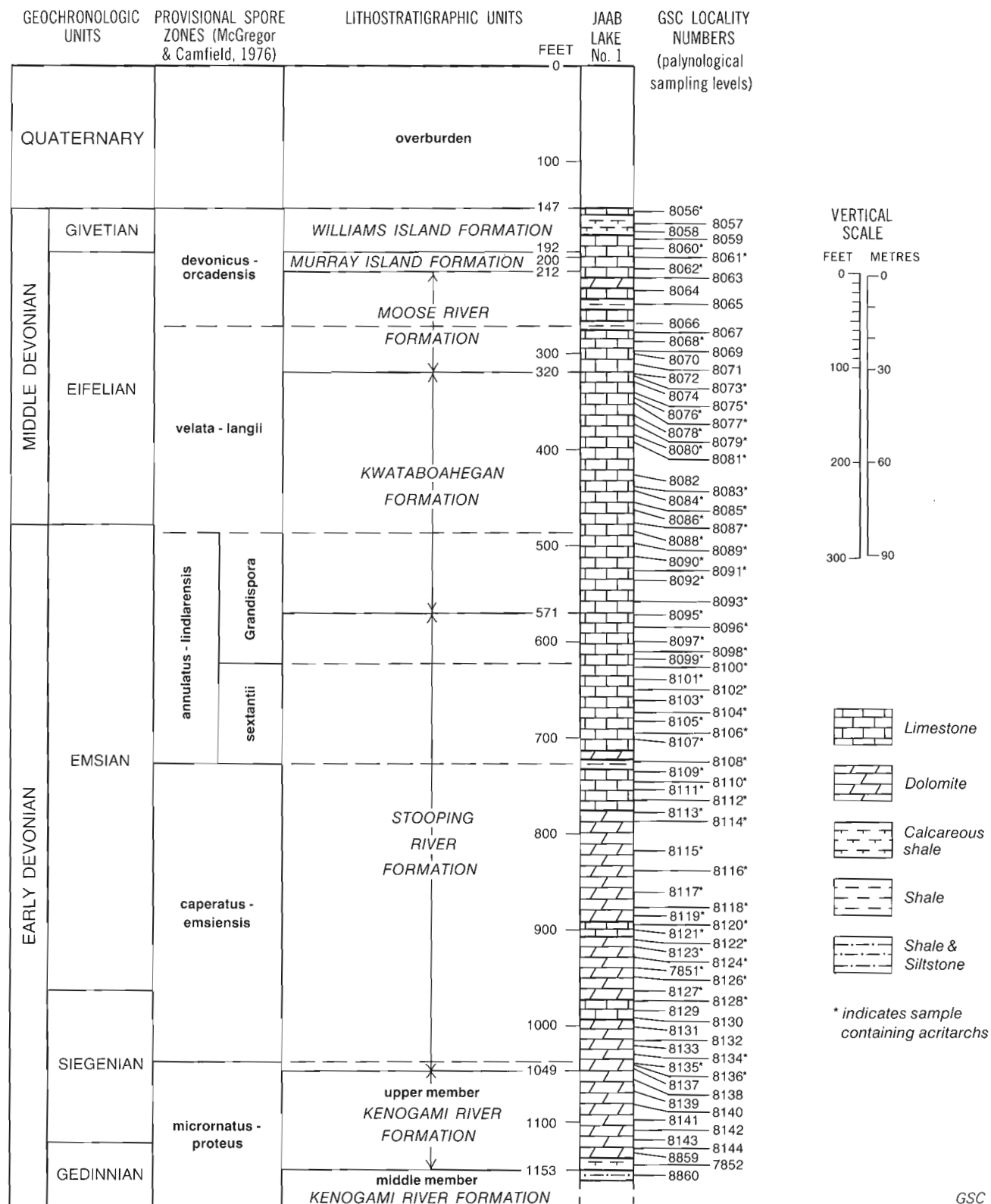
#### *Long Rapids Formation*

The youngest Devonian unit in the Moose River Basin is the Long Rapids Formation, consisting dominantly of dark, fissile, bituminous shale up to 285 feet thick. Contact with the underlying Williams Island Formation is nowhere exposed; it may be disconformable. The Long Rapids Formation, typically developed in the south-central part of the Moose River Basin, is not present in the sequence studied herein (Jaab Lake well). Its strata are indicative of distinctly anaerobic conditions, as in the then possibly interconnected Allegheny and Michigan basins. Conodont faunas from the Long Rapids Formation attest to a Late Devonian (Frasnian to early Famennian) age. Further, D. C. McGregor (*pers. comm.*, 1976) has observed Frasnian spores in several samples of the formation.

## Material and Methods of Study

#### *Section and Samples Studied*

All of the material examined during this study was obtained from Ontario Department of Mines Jaab Lake No. 1 well, a continuously cored borehole sited at 51°11'54"N, 82°56'00"W. The well was drilled in 1949–1950 and its location is near the centre of the Moose River Basin. Devonian lithostratigraphic units penetrated and cored include all those mentioned in the foregoing section, with the exception of the Sextant Formation and the Long Rapids Formation. Thus the subject sequence is wholly marine, dominantly calcareous and well-representative of the Lower to Middle Devonian strata developed in the Moose River Basin. Figure 2 depicts the stratigraphic column and sampling levels (designated by GSC locality numbers) in the Jaab Lake well, together with the spore assemblage zones established provisionally by McGregor and Camfield (1976). The lithological sequence is fairly generalized in Figure 2, but the complete borehole log is detailed in Sanford and Norris (1975, Pt. II, p. 118–138).



GSC

Figure 2. Columnar stratigraphic section, Jaab Lake No. 1 well, showing generalized lithology and palynological sampling levels.

### Preparation Techniques

Palynological residues and many of the strew slides examined by McGregor and Camfield (1976) in their dispersed-spore study were also used in the present investigation. However, some of the samples were reprocessed for improved acritarch yields and several hundred single-specimen slides, together with some additional strew slides from previous residues, were made.

Laboratory extraction and concentration of the palynomorphs was achieved as follows.

Between 5 and 15 grams of each sample were processed, depending upon amount of core available. Following careful cleaning and crushing (to approximately pea-sized lumps), calcium carbonate was dissolved by treatment with diluted hydrochloric acid for up to 24 hours. After decantation and washing, the sample was then demineralized by immersion in cold, 49 per cent hydrofluoric acid for at least 8 hours and frequently for as long as 7 to 14 days. Any resultant gellike fluorides were then removed by standing the residue in cold, 50 per cent hydrochloric acid. After decantation/washing, it sometimes proved advantageous to pass the residue through a 150  $\mu\text{m}$  sieve or to subject it to heavy-liquid separation (zinc bromide: S.G. 2.0). If the quantity of residue obtained at this point (or, indeed, after the hydrofluoric acid treatment) was meagre, or required no oxidation whatsoever, no further chemical treatment was undertaken. For most residues, however, controlled oxidation was necessary. The oxidant used was Schulze reagent (concentrated nitric acid plus potassium chlorate) and optimum treatment time for individual samples varied from about 1 to 40 minutes. Oxidized and washed residues were then usually, and beneficially, washed briefly in very dilute ammonium hydroxide, and ultimately washed with water to neutrality. If the residue contained an obtrusive quantity of very fine material, this could usually be removed either by short centrifuging or by fine-screening (with 20  $\mu\text{m}$  screen). The final productive residue was then stored in small air-tight glass bottles in concentrated phenol solution.

Productiveness of the samples (i.e., in terms of acritarch yield) was found to vary considerably through the sequence. In general, samples from the Stopping River Formation, Murray Island Formation and Williams Island Formation yielded profuse and well preserved assemblages; while from the Kenogami River Formation (upper member) and Moose River Formation, acritarch yields were very meagre or nonexistent.

For light microscopy, the residues were mounted as strew slides in unstained glycerine jelly under no. 1 cover glasses (22 mm  $\times$  40 mm). The edges of the cover glasses were thoroughly sealed with colourless nail varnish. Individual acritarch specimens were selected from water-glycerine smears of some of the more productive residues and mounted in glycerine jelly under small circular cover glasses (diameter, 18 mm), in turn ringed by paraffin wax.

Micromanipulative picking, mounting and recovery of specimens selected for scanning electron microscopy were accomplished by means of the procedures described by Dettmann (1973, p. 8).

### Microscopic Examination, Photography

Slides from the productive residues were examined by means of a Leitz Dialux binocular microscope equipped with apochromatic bright-field objectives and mechanical stage. Use was also made of a Leitz Ortholux binocular microscope having interference-contrast optical facility. Ilford Pan F 35 mm film was used for photography under the light microscopes.

Selected acritarch specimens were viewed under an AMR-1000 scanning electron microscope and recorded on Ilford FP4 120 mm film.

## Previous Studies of Devonian Acritarchs

In an editorial preface to a special issue of the *Review of Palaeobotany and Palynology* (v. 18, no. 1/2, p. vii), incorporating contributions to a 1973 symposium on acritarchs, C. Downie, S. Jardiné and H. Visscher commented upon the paucity of published data on Devonian acritarchs. Since then several papers dealing with Devonian acritarchs have appeared; but it remains true that, in comparison with those of the Lower Paleozoic, acritarchs of the Devonian (and later Paleozoic systems) await detailed study from both northern and southern hemispheres. A geographically arranged summary of published works concerned with acritarchs of Devonian age, more particularly of those studies based upon North American material (see also Table 1), is given below.

### North America

The initial publication concerned with North American Devonian acritarchs dates back to 1942, when Baschnagel described and figured a number of the microfossils in cherts belonging to the Onondaga Formation of central New York State. The acritarchs were referred to living genera and families of freshwater algae. Baschnagel's paper is mainly of historical interest, because his observations were exclusively from thin sections and the acritarchs were largely opaque.

The sediment infilling of a compound corallum (of the tabulate coral species *Favosites turbinata* Billings) was the somewhat surprising source of the first whole acritarchs to be described and illustrated from the Devonian, indeed from the Paleozoic, in North America. The acritarchs so obtained were the subject of an initial and brief report by the French micropaleontologist J. Deunff (1954b). This was followed by a series of papers by Deunff (1955; 1957; 1961; 1966b; 1971, in part) dealing with the taxonomy of the microfossils at generic and specific levels. Unfortunately, some uncertainty exists about the geographic location and host strata, hence age, of Deunff's material. Deunff stated that it came from the Onondaga Limestone (Middle Devonian) and gave the locality (1954b, explanation of Figs. 1-16) as "Decew, Ontario (Canada)". However, Winder (1968, p. 714) has pointed out that the bedrock at Decew, Ontario, is Silurian, not Devonian, in age. Winder concluded that Deunff's sample probably came from Decewville, near Cayuga, Ontario, where he reported the bedrock as being Bois Blanc Formation (Lower Devonian: Emsian). However, in that area the host strata could conceivably be Amherstburg



SERIES	STAGE	ONTARIO	ALBERTA	N.W.T.	NEW YORK	OHIO	OKLAHOMA
Upper Devonian	Famennian					<div style="text-align: center;">           9                         8         </div>	(10)
	Frasnian	②	⑤				
Middle Devonian	Givetian	<div style="text-align: center;">           3  </div>		⑥			
	Eifelian	(1)			(7)		
Lower Devonian	Emsian						
	Siegenian						
	Gedinnian						⑪

GSC

Table 1. Stratigraphic/geographic distribution of published data on Devonian acritarchs from North America. Key to authors: 1, Deunff (1954*b*, 1955, 1966*b*, 1957, 1961); 2, Deunff (1967); 3, Legault (1973); 4, Playford (this paper); 5, Staplin (1961); 6, Audretsch (1968); 7, Baschnagel (1942); 8, Winslow (1962); 9, Wicander (1974, 1975); 10, Wilson and Urban (1963, 1971), Wilson and Skvarla (1967); 11, Loeblich and Drugg (1968), Loeblich and Tappan (1970), Loeblich (1970, in part), Loeblich and Wicander (1974). Note: broken circles signify some uncertainty regarding stratigraphic level; N.W.T. denotes Northwest Territories.

Formation, which is equivalent to the lower portion of the Eifelian Onondaga Formation (Sanford and Norris, 1975; Sanford, *pers. comm.*, 1976).

Generic and specific taxa of Early Devonian (Gedinnian) acritarchs from Oklahoma have been described and notably well illustrated in a number of papers by A. R. Loeblich Jr. and collaborators: viz., Loeblich and Drugg (1968), Loeblich and Tappan (1970), Loeblich (1970), Loeblich and Wicander (1974). These papers are innovative, not only in a taxonomic sense, but in their inclusion of scanning electron micrographs to illustrate the extraordinarily intricate morphological detail of many acritarchs.

From the Hamilton Formation (Group) of southwestern Ontario, Legault (1973) investigated Middle Devonian (Givetian) chitinozoans and acritarchs. This paper constitutes a useful reference for the present work, as Legault's sediments are age-equivalents of the upper part of the Jaab Lake well section.

In a paper concerned mainly with miospores, Audretsch (1968) illustrated and described briefly several acritarchs from the Middle Devonian of the Great Slave Lake area, Northwest Territories.

Staplin (1961) presented results of a study of Upper Devonian microplankton, chiefly acritarchs, from subsurface off-reef Frasnian sediments (Duvernay shale facies) in central Alberta. He described 40 species of acritarchs (many new) and demonstrated the distribution pattern of three artificial groupings of these in relation to lateral distance from the Leduc reef facies.

From Upper Devonian (presumably Frasnian) chert at Kettle Point, Ontario, several species of acritarchs were briefly described and figured by Deunff (1967).

A reportedly tasmanitid palynomorph, *Quisquilites* Wilson and Urban, has been described in three papers (Wilson and Urban, 1963, 1971; Wilson and Skvarla, 1967) from the Upper Devonian of Oklahoma.

Upper Devonian-Lower Mississippian sediments of Ohio have been analyzed palynologically by Winslow (1962) and Wicander (1974, 1975). Winslow's study embraced miospores, megaspores and organic-walled microplankton. Wicander investigated the microplankton (acritarchs and prasinophycean algae) in considerable morphological and taxonomic detail (1974) as well as in a quantitative context (1975).

#### Europe

From northwestern France (Armorican Massif principally), samples from various levels of the Devonian, mainly within the Lower and Middle Series, have been investigated for their acritarch content (Deunff, 1954a, 1965, 1966a, 1968; Deunff and Paris, 1972; Moreau-Benoit, 1967, 1969, 1972, 1974; Rauscher *et al.*, 1965; Rauscher and Doubinger, 1968; Rauscher, 1969a). Bain and Doubinger (1965) have illustrated a few acritarchs from a Famennian sample collected in the Ardennes. Despite the relatively large number of published contributions, no definitive acritarch-based biostratigraphy has emerged for the French Devonian.

The Silurian-Devonian sequences of northwestern Spain have been intensively investigated palynologically by F. H. Cramer and reported upon by him in a series of papers

beginning in 1963. Cramer has covered all three components of the palynological assemblages: chitinozoans, acritarchs and miospores. The Devonian acritarchs studied by him were recovered mostly from the upper (Gedinnian) portion of the San Pedro Formation and the succeeding La Vid Formation (Gedinnian-Emsian) in the Cantabrian Mountains (Cramer, 1963; 1964a, b; 1966a, b, c; 1967).

F. Stockmans and Y. Willière, who pioneered acritarch studies of Belgian strata, have produced several papers on Late Devonian assemblages and their taxonomy (Stockmans and Willière, 1960, 1962a, 1962b, 1969, 1974). Streel (*in* Becker *et al.*, 1974) figured several acritarchs from the late Famennian-Strunian of Belgium but gave no descriptions. Dricot (1968) discussed the paleogeographic significance of Belgian Frasnian acritarchs.

Knowledge of German Devonian acritarchs is currently limited to four papers on material from the Federal Republic; viz. Bergisches Land (Famennian: Jux, 1975), Eifel region (Lower-Middle Devonian: Pilcher, 1971; Riegel, 1974), and Frankenwald (Sannemann, 1955). Riegel commented upon paucity of phytoplankton assemblages in the Rhineland's Emsian-Eifelian, in comparison with abundant preservation of invertebrate fossils and miospores.

In Poland, Górka (1974a, b) reported on late Famennian forms from the Holy Cross Mountains. From the Barrandian Basin of Czechoslovakia, Corná (1969, pl. 13) figured several leiofusid acritarchs and Lele (1972) provided brief unillustrated lists of some acritarch genera observed in Middle Devonian strata. Beju (1967) gave a brief account of Lower Devonian palynomorphs (spores, acritarchs, chitinozoans) from the Moesian Platform of Rumania.

Several Russian papers concerned mainly with miospores include illustrations and descriptions of Devonian acritarchs, particularly from the southern Urals and Cisuralia, Bashkirian S.S.R. (Chibrikova, 1970, 1972).

#### Asia

Very little is known of the acritarch content of Devonian sediments of the Asiatic continent. Sheshegova (1971a, b) and Nadler (1973) provided brief accounts of microphytoplankton from the Devonian of the Kuznetsk Basin, Siberia, but the microfossils were very summarily discussed and inadequately illustrated.

#### Africa

A relatively large number of published contributions have accrued on the Middle and Late Paleozoic subsurface sediments of the Saharan region of Algeria. These papers stem from detailed palynostratigraphic work of French palynologists associated with petroleum exploration in the region; they include some systematic-descriptive contributions and are concerned mainly with Silurian-Devonian palynomorphs (spores, acritarchs, chitinozoans) and their stratigraphic distributions (Magloire, 1968; Lanzoni and Magloire, 1969; Jardiné and Yapaudjian, 1968; Jardiné *et al.*, 1972, 1974; Jardiné, 1972). The latest of these (Jardiné *et al.*, 1974) provides a particularly useful summary of vertical ranges of acritarchs in the Paleozoic of the Algerian Sahara: 23 acritarch zones are defined within the Tremadoc-Strunian interval.

Deunff (1964, 1966a) has described several acritarch species from the Devonian of Tunisia.

#### South America

The bulk of what is known of Devonian acritarchs in South America comes from studies of Brazilian strata of the Maranhão Basin, northern Brazil (Brito and Santos, 1965; Brito, 1967a–d, 1968, 1969, 1971). In the Amazonas Basin of northern Brazil, Sommer and van Boekel (1963, 1966) and van Boekel (1968) have described tasmanitids believed to be of Middle Devonian age. Farther south, Lange (1967) and Daemon *et al.* (1967) recorded some acritarchs in probable Emsian-Frasnian strata of the Paraná Basin. In northern Uruguay, near the southern limit of the Paraná Basin, Martinez-Macchiavello (1968) described an assemblage of putatively Early Devonian age.

E. D. Pöthe de Baldi has been responsible for several descriptive papers on Argentinian Silurian acritarchs dating from 1971. In 1974 she described a suite of Devonian acritarchs from northwestern Paraguay (Pöthe de Baldi, 1974a); these were adduced on spore evidence to be probably of Middle Devonian age.

#### Australia

Uppermost Devonian (Fa2d-Strunian) and Tournaisian sediments of the Canning Basin, northwestern Australia, contain some acritarchs in association with profuse spore assemblages. The palynoflora has been described by Playford (1976). No other records of Australian Devonian acritarchs have been documented.

## Systematic Paleontology

### Preservation and Designation of Types

Holotypes and other figured specimens of this study are permanently deposited in the National Palynological Type Collection at the Geological Survey of Canada, Ottawa. Each specimen has been allocated a unique GSC type number, as cited in the systematic-descriptive text or plate explanations. The specimens, in both strew and single-specimen slide mounts, are cited herein as follows: GSC locality-slide number (e.g., 8124-2 is palynological slide no. 2 of sample from GSC locality 8124), followed by 'east-west' and 'north-south' mechanical-stage readings of GSC's Leitz Dialux microscope (no. 59-123) and then the GSC type specimen number.

### Descriptive Procedure and Terminology

In the ensuing systematic descriptions, all new species are based upon a minimum of 14 adequately preserved specimens that are considered to comprise a cohesive group, distinct at specific level from any so far published. Where sufficient specimens of what is judged to be a new species are unavailable, an informal letter-designation is used, viz., 'sp.A', 'sp.B'. If some doubt exists as to precise compliance of a specific group of specimens with a previously named species, the abbreviation 'cf.' is introduced immediately prior to the species name.

The diagnostic morphological features of genera and

species newly instituted herein are detailed under respective 'Diagnosis' headings. 'Amplification of diagnosis' denotes a somewhat expanded or more explicit, but not materially altered, version of a taxon's circumscription; whereas 'Emended diagnosis' indicates that a significant alteration to the taxon's circumscription is enunciated. For previously instituted genera that are not emended herein, a summary of the salient morphological attributes is provided under 'Generic characters', with citation of the source(s) of information. The purpose of this is to indicate, unequivocally and with standard terminology, the present author's understanding and application of the genera, some of which have, in the past, been applied with varying degrees of imprecision or inconsistency. The term 'Description' signifies a description of Moose River Basin specimens attributed either to a previously instituted species or to an informally designated species ('sp.A', etc.).

Morphological terminology used in the systematic descriptions and relating mainly to form and sculpture of vesicles and processes conforms with current practice: see glossaries provided by Kjellström (1971, p. 9–13), Lister (1970, p. 24–26), Eisenack and Cramer (1973, p. 9–18), and Williams *et al.* (1973). Some ambiguity, however, exists in the application of certain terms, and for the present paper an explanation is necessary for the following:

*Echinate*: Wall with spiny or conelike sculptural projections; see Kjellström (1971, Fig. 4).

*Scabrate*: Wall with scarcely perceptible unevenness or roughness that is difficult to characterize in detail; after Evitt (1967, p. 360).

*Homomorphic processes* constitute a single morphological process order occurring exclusively on a given vesicle (e.g. furcate or simple processes); after Kjellström (1971, p. 12).

*Heteromorphic processes* constitute, on the same vesicle, two discrete morphological process orders (e.g. furcate and simple processes); after Kjellström (1971, p. 12).

A new term, *epibystra*, is proposed for a spheroidal or hemispherical pluglike structure that occurs on or within a circular excystment opening (cyclopyle), effecting partial or complete closure of the latter; see description of *Onondagaella asymmetrica* (Deunff) Cramer, 1966, below.

Following Tappan and Loeblich (1971, p. 386), the prefix 'micro-' is used for ultra-fine sculptural characteristics that are evident under the scanning electron microscope, but not at all clearly under the light microscope; e.g., microgranulate, microrugulate. Tappan and Loeblich's (1971, p. 387) suggested upper limit of 1  $\mu\text{m}$  for use of 'micro-' is regarded as being too high, because features of 1  $\mu\text{m}$  dimension and somewhat less are usually determinable without difficulty with the  $\times 100$  objective of a light microscope. As mentioned previously, the light microscope was used as the primary means of observation; but the scanning electron microscope was also used extensively for the examination of numerous species. Unquestionably, the latter instrument is of great value for the elucidation of surficial morphological detail of microfossils, and is particularly advantageous to acritarch studies, as Loeblich (1970, and joint papers with Tappan) has already pointed out and amply demonstrated. However, the high quality light microscope still constitutes the primary facility for palynological descriptions and identifications. It

is considered inappropriate or impractical, therefore, to base species, let alone genera, on criteria that can confidently be recognized or evaluated solely by means of scanning electron microscopy.

Size ranges of specimens are quoted, under 'Dimensions' for a particular species, with the arithmetic mean parenthesized between low and high values.

No meaningful or widely accepted suprageneric classification has yet emerged for the Acritarcha (see discussion in Wicander, 1974, p. 10–11) so that, for convenience of reference, genera with their specific contents are arranged below in alphabetical sequence. The taxa are treated as form genera and species in accordance with the provisions of the International Code of Botanical Nomenclature (ICBN). It should be noted, however, that some of the cited genera, viz. *Cymatiosphaera*, *Dictyotidium*, *Duvernaysphaera*, *Pterospermella*, are probably allied sufficiently closely to present-day green algae of the class Prasinophyceae to be removed from the Acritarcha and placed formally in that class (Boalch and Parke, 1971; Downie, 1973).

#### List of Species

The following is an inventory of specific taxa recognized in the Moose River Basin samples of this study and described below.

- Baltisphaeridium anfractum* sp. nov.
- Baltisphaeridium crebrum* sp. nov.
- Baltisphaeridium distentum* sp. nov.
- Baltisphaeridium juliae* Cramer, 1964
- Baltisphaeridium microfurcatum* (Deunff) Stockmans and Willière, 1962
- Baltisphaeridium stamineum* sp. nov.
- Costatilibus undulatus* gen. et sp. nov.
- Cymatiosphaera canadensis* Deunff, 1961
- Cymatiosphaera cornifera* Deunff, 1955
- Cymatiosphaera multisepta* Deunff, 1955
- Cymatiosphaera winderi* Deunff, emend.
- Cymatiosphaera* sp. cf. *C. pavimenta* (Deflandre) Deflandre, 1954
- Dateriocradus* sp. A
- Dateriocradus* sp. B
- Dictyotidium cavernosulum* sp. nov.
- Dictyotidium variatum* sp. nov.
- Dictyotidium* sp. A
- Diexallophasis remota* (Deunff) comb. nov., emend.
- Divetipellis ventricosa* sp. nov.
- Duvernaysphaera tenuicingulata* Staplin, 1961
- Goniolopadion prolixum* gen. et sp. nov.
- Gorgonisphaeridium cumulatum* sp. nov.
- Gorgonisphaeridium disparatum* sp. nov.
- Gorgonisphaeridium granatum* sp. nov.
- Gorgonisphaeridium* sp. cf. *Micrhystridium sericum* Deunff, 1961
- Gorgonisphaeridium* sp. A
- Gorgonisphaeridium* sp. B
- Hapsidopalla exornata* (Deunff) comb. nov., emend.
- Hapsidopalla sannemannii* (Deunff) comb. nov., emend.
- Lophosphaeridium dumalis* sp. nov.
- Micrhystridium stellatum* Deflandre, 1945
- Multiplicisphaeridium ampliatus* sp. nov.

- Multiplicisphaeridium ramusculosum* (Deflandre) Lister, 1970.
- Navifusa bacillum* (Deunff) comb. nov.
- Onondagaella asymmetrica* (Deunff) Cramer, 1966, emend.
- Ozotobrachion furcillatus* (Deunff) comb. nov.
- Ozotobrachion palidodigitatus* (Cramer) comb. nov.
- Palacanthus ledanoisii* (Deunff) comb. nov., emend.
- Polyedryxium bathyaster* Deunff, 1961
- Polyedryxium carnatum* sp. nov.
- Polyedryxium decorum* Deunff, 1955
- Polyedryxium deflandrei* Deunff, 1961
- Polyedryxium embudum* Cramer, 1964
- Polyedryxium fragosulum* sp. nov.
- Polyedryxium pharaonis* Deunff, 1961
- Pterospermella circumstriata* (Jardiné, Combaz, Magloire, Peniguel, and Vachey) Eisenack and Cramer, 1973
- Stellinium micropolygonale* (Stockmans and Willière) comb. nov.
- Tunisphaeridium tentaculiferum* (Martin) Cramer, 1971
- Tyligmasoma alargadum* (Cramer) comb. nov.
- Veryhachium downiei* Stockmans and Willière, 1962
- Veryhachium lairdii* Deflandre ex Deunff, 1959
- Veryhachium polyaster* Staplin, 1961
- Veryhachium radiosum* sp. nov.

#### Systematic Descriptions

##### Group ACRITARCHA Evitt, 1963

Genus *Baltisphaeridium* Eisenack emend. Eisenack, 1969

*Type species.* *Baltisphaeridium longispinosum* (Eisenack) Eisenack, 1958; by original designation.

*Generic characters.* Vesicle single-walled, hollow, originally spherical to ellipsoidal; outline circular to subcircular; with well-defined processes of fairly regular form and distribution and  $\pm$ homomorphic character. Processes often at least partly hollow, invariably closed distally, may be branched but usually simple. Proximal process contact typically angular; vesicle cavity usually closed off from process interiors. Process walls usually sculpturally distinct (viz., psilate) from vesicle wall (viz., granulate, porate, scabrate). After Staplin *et al.* (1965, p. 188), Eisenack (1969, p. 249), and Kjellström (1971, p. 17).

*Discussion.* As indicated by Lister (1970, p. 50–54), Kjellström (1971, p. 17) and others—and indeed by the number of species vacillating between, for instance, *Baltisphaeridium* and *Multiplicisphaeridium* Staplin, 1961—no clear consensus has emerged as to the most appropriate circumscription for *Baltisphaeridium* and the unequivocal separation of it from morphologically allied genera.

Most authors accept *Multiplicisphaeridium* as distinct from *Baltisphaeridium*, the former displaying unobstructed internal communication between vesicle and (hollow) process interiors and essential homogeneity of surface features on vesicle and processes alike (but cf. Eisenack and Cramer, 1973, p. 519).

*Baltisphaeridium anfractum* sp. nov.

Plate 1, figures 1–8

**Diagnosis.** Vesicle originally spherical; outline circular to subcircular, clearly differentiated from processes. Vesicle wall 1.5–2  $\mu\text{m}$  thick; psilate to scabrate under light microscope, faintly roughened to irregularly microgranulate under scanning electron microscope. Processes discrete, homomorphic, long, slender, flexible, 6–16 in number (average 9); semisolid, being relatively thick walled (0.5–1.5  $\mu\text{m}$ ) but with narrow, continuous, central cavity present through most of length—from near narrow, blunted-acuminate, distal tip to near level of curved proximal process contact. Process interiors do or do not connect with vesicle cavity; in former instance, communication is via either a  $\pm$ conspicuous conical cavity occupying proximal interior of process or a narrow central canal. Process walls similar surficially to vesicle wall; i.e., psilate-scabrate/microgranulate, but usually with slightly stronger sculpture. Processes about 30–60  $\mu\text{m}$  long, with circular bases that are 2–5.5  $\mu\text{m}$  broad and about 7–18  $\mu\text{m}$  apart. Excystment structure: a simple split in vesicle wall.

**Dimensions** (46 specimens). Diameter of vesicle 17 (25) 37  $\mu\text{m}$ .

**Holotype.** Slide 8111-6, 59.5  $\times$  111.6, GSC 42866; Plate 1, figure 1. Vesicle 22  $\mu\text{m}$  in diameter, subcircular in outline; wall 1.7  $\mu\text{m}$  thick, psilate; 9 homomorphic processes developed, each with scabrate wall about 0.5  $\mu\text{m}$  and 1.5  $\mu\text{m}$  thick distally and proximally respectively, enclosing narrow, continuous, subcylindrical cavity that penetrates to vesicle cavity; processes twisted and bent, length about 45–60  $\mu\text{m}$ , basal diameter 3–4  $\mu\text{m}$ , spacing regular (about 12  $\mu\text{m}$  apart); no indication of excystment structure.

**Type locality.** Ontario, Moose River Basin; Stooping River Formation; Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 755–757 feet; GSC loc. 8111.

**Name derivation.** Lat., *anfractus*, bending, winding.

**Remarks and comparison.** *Baltisphaeridium anfractum* sp. nov. is an abundantly represented, well-characterized and

hence conspicuous form in the Moose River Basin material. Despite the relative simplicity of its morphology, it could not decisively be attributed to any previously established specific taxon.

It might perhaps find inclusion in a *sensu lato* interpretation of *Baltisphaeridium longispinosum* (Eisenack) Eisenack, 1958, as has been adopted by several authors concerned with Ordovician, Silurian and Devonian acritarchs. However *B. longispinosum* and its component varieties have considerably larger vesicles and larger processes than *B. anfractum*, and the process interiors are wholly non-communicative with the vesicle cavity (see, for example, Eisenack, 1959, 1974; Eisenack and Cramer, 1973, p. 139–141; Staplin *et al.*, 1965, p. 189–190; Górka, 1969, p. 34–35; Kjellström, 1971, p. 29–31).

The Belgian Famennian species, *B. medium* Stockmans and Willièvre, 1974 (p. 15; Pl. 4, figs. 2–4), differs from *B. anfractum* in having finer and generally more numerous processes.

Two species instituted by Wicander (1974, p. 31–32) from the Upper Devonian of Ohio, *Pustulisphaeridium levibrachium* and *Solisphaeridium folliculum*, are sufficiently close to *B. anfractum* to merit comparison with it. *P. levibrachium* differs from the Ontario form by incorporating mostly larger vesicles (diameter 35–40  $\mu\text{m}$ ) which are said to be 'lightly granulate' and on which are borne numerous psilate processes that open freely into the vesicle cavity. *S. folliculum* is thinner walled than *B. anfractum* with more numerous, shorter, psilate processes that have free internal communication with the vesicle cavity.

*Baltisphaeridium crebrum* sp. nov.

Plate 1, figures 9–12; Figure 3

**Diagnosis.** Vesicle originally spherical; outline circular to subcircular, well demarcated from processes. Vesicle wall 1–2.5  $\mu\text{m}$  thick; distinctly granulate to echinate (elements <1  $\mu\text{m}$  in basal diameter and height; spaced 0.5–1.5  $\mu\text{m}$  apart) to scabrate or almost psilate. Processes discrete,

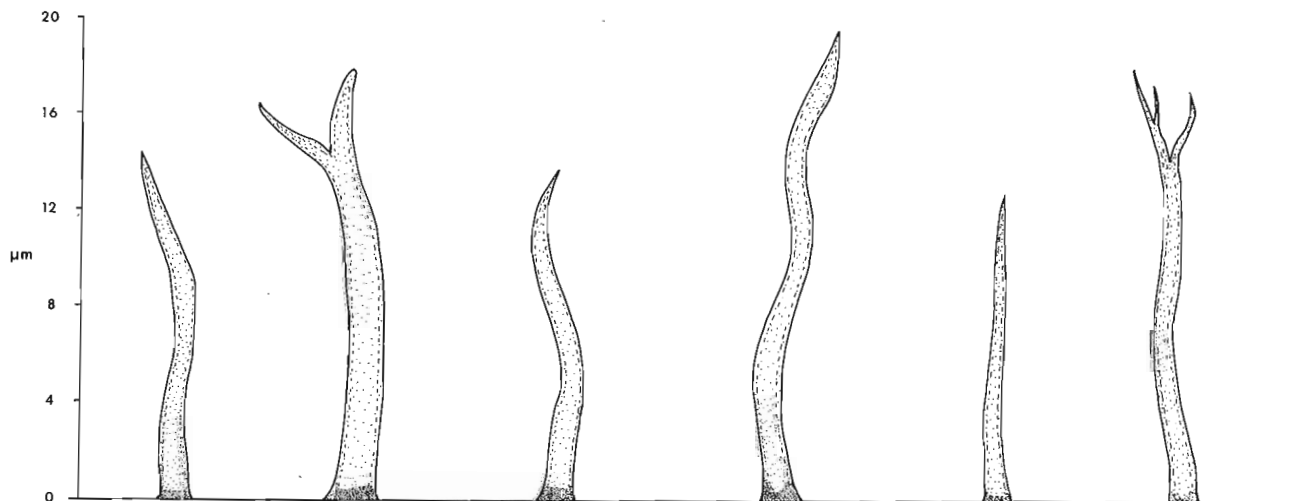


Figure 3. Processes of *Baltisphaeridium crebrum* sp. nov.; lateral view.

homomorphic or heteromorphic (depending on absence or presence of branched processes), hollow, straight to tenuous;  $\pm$ evenly, densely distributed; walls psilate to scabrate,  $<0.5 \mu\text{m}$  thick; length of processes 8–26  $\mu\text{m}$ ; bases circular in outline, 1–3  $\mu\text{m}$  in diameter and 1–8  $\mu\text{m}$  apart; about 18–38 processes cross vesicle margin. In the majority of specimens, process interiors are closed off from vesicle cavity by development of a  $\pm$ distinct basal 'plug'; however, in a few (especially smaller) specimens, communication does exist in absence of plug. Proximal process contacts are curved to almost angular. Processes predominantly unbranched, acuminate, tapering gently from base to apex, though in some specimens as many as about 20 per cent of the processes are bifurcant (up to second order), the bifurcation usually being terminal, but may commence as little as one sixth of distance from proximal to distal extremity. Ultimate process tips  $\pm$ sharply acute. Excystment—rarely evident—by simple splitting of vesicle wall.

**Dimensions** (23 specimens). Diameter of vesicle 16 (24) 32  $\mu\text{m}$ ; overall diameter 37 (52) 70  $\mu\text{m}$ .

**Holotype**. Slide 8124-11,  $36.5 \times 103.1$ , GSC 48273; Plate 1, figure 9. Vesicle circular in outline, 24  $\mu\text{m}$  in diameter, wall firm (2  $\mu\text{m}$  thick), sculptured with distinct echinae and grana and bearing numerous, long, thin-walled processes of which the large majority have acuminate ends; processes virtually psilate and thinwalled apart from proximal (basal) extremities, which are distinctly plugged so that communication between process interiors and vesicle cavity is nonexistent; length of intact processes 10–25  $\mu\text{m}$ , diameter at base 1–3.5  $\mu\text{m}$ , separation of bases 2–7  $\mu\text{m}$ .

**Type locality**. Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 925–927 feet; GSC loc. 8111.

**Name derivation**. Lat., *creber*, multitudinous.

**Remarks**. Chief morphological variables among specimens attributed to *Baltisphaeridium crebrum* sp. nov. are form of processes and sculptural detail of vesicle (i.e., as viewed with  $\times 100$  oil immersion objective of light microscope). These variables are by no means extensive, and the species is considered to be an easily recognizable, cohesive entity that conforms well with the circumscription of *Baltisphaeridium* adopted herein. As mentioned in the specific diagnosis,

specimens of *B. crebrum* having plugs separating process interiors from vesicle cavity are much more abundant than are those lacking this feature. The latter specimens are, moreover, almost invariably smaller than their 'plugged' counterparts. This circumstance suggests that plug development could well be a mark of maturity of the individual (cf. Staplin *et al.*, 1965, p. 188).

**Comparison**. Cramer and Diez (1968, Pl. 6, fig. 14) figured, from the Spanish Emsian, a specimen labelled '*Micrhystridium* sp.' which could possibly be identical with *Baltisphaeridium crebrum*. However, no description was provided by Cramer and Diez (1968) aside from their indication of the presence of 'filose processes'.

An Algerian Silurian species, *Baltisphaeridium areolatum* Jardiné *et al.* (1974, p. 120–121; Pl. 3, figs. 2, 7, 10), shows general similarity to the Ontario species, but differs chiefly in having processes that are basally constricted and are each implanted in a circular depression developed on vesicle wall around proximal contact.

#### *Baltisphaeridium distentum* sp. nov.

Plate 1, figures 13, 14; Plate 2, figures 1–5; Figure 4

**Diagnosis**. Vesicle originally spherical; outline circular to subcircular, clearly set off from processes. Vesicle wall 0.5–1.5  $\mu\text{m}$  thick; psilate to scabrate under light microscope, microgranulate to microrugulate under scanning electron microscope. Approximately 6 to 23 hollow, very thin-walled, transparent, and frequently folded, discrete processes emanate from vesicle wall, with which they typically have constricted contacts (rarely angular or slightly curved). Processes psilate to faintly scabrate under light microscope; faint longitudinal striae sometimes discernible under scanning electron microscope; normally homomorphic, subcylindrical to fusiform, tapering gradually, or occasionally strongly, to simple acute apex; sometimes processes are heterogeneous to the extent that a minority on a given specimen display forked distal termini. Almost invariably, process interiors and vesicle cavity do not communicate due to development of distinct basal plugs; very rarely, a narrow central canal may exist in plug, affording slight communication. Processes normally 20–40  $\mu\text{m}$  long (rarely as much as 60  $\mu\text{m}$ ); bases circular, diameter 1.5–4.5  $\mu\text{m}$ , spacing 4–16  $\mu\text{m}$

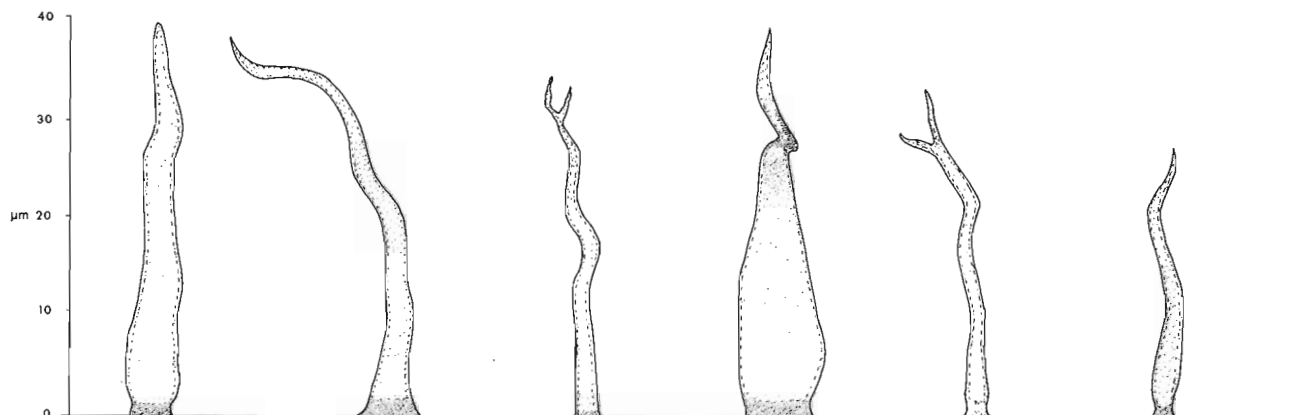


Figure 4. Processes of *Baltisphaeridium distentum* sp. nov.; lateral view.

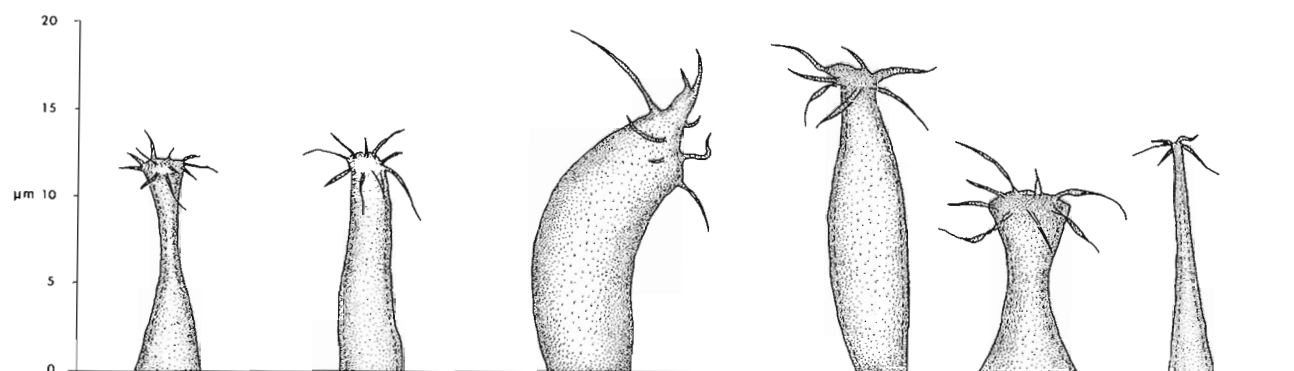


Figure 5. Processes of *Baltisphaeridium juliae* Cramer, 1964; lateral view.

apart. A simple slit in vesicle wall constitutes excystment aperture.

**Dimensions** (47 specimens). Diameter of vesicle 17 (24) 32  $\mu\text{m}$ .

**Holotype.** Slide 8127-18,  $34.1 \times 102.5$ , GSC 48278; Plate 2, figure 1. Vesicle with circular outline, diameter 30  $\mu\text{m}$ ; wall about 1.2  $\mu\text{m}$  thick, psilate; processes subcylindrical to fusiform, with very thin filmy walls twisted and folded through compression, length about 35–40  $\mu\text{m}$ , (constricted) bases 3–4  $\mu\text{m}$  broad, 7–12  $\mu\text{m}$  apart; processes number about 12 and have simple acuminate distal ends; interiors of all processes closed off proximally from vesicle cavity by distinct plug development; excystment structure a simple slit in vesicle wall.

**Type locality.** Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 960–962 feet; GSC loc. 8127.

**Name derivation.** Lat., *distentus*, extended, drawn-out.

**Comparison.** *Baltisphaeridium distentum* sp. nov. shows some resemblance to an Algerian Late Silurian species, *B. areolatum* Jardiné et al., 1974 (p. 120; Pl. 3, figs. 2, 7, 10), notably in general form of processes. However, the Algerian species has a depressed circlet of vesicle wall surrounding the constricted base of each process and the remainder of the wall has a granulate to rugulate sculpture that is clearly visible under the light microscope.

Certain acritarchs figured by Combaz and Streel (1970, Pl. 6, figs. 14, 15) from the Strunian of France seem to be closely akin to *B. distentum*. Combaz and Streel identified their specimens as '*Baltisphaeridium flandrium* Stockmans and Willièrè 1962'; but so far as the author is aware that binomen does not formally exist. Perhaps Combaz and Streel were referring to *Michrystidium flandrium* Stockmans and Willièrè, 1963 (p. 464; Pl. 2, fig. 12; Fig. 22). The latter is, however, dissimilar to their own specimens and certainly does not merit comparison with *B. distentum*.

The species under consideration is distinguishable from typical *B. crebrum* sp. nov. (described above) in possessing an unsculptured or only faintly sculptured vesicle wall. Moreover, *B. distentum* has generally larger, less numerous, basally constricted processes.

### *Baltisphaeridium juliae* Cramer, 1964

Plate 2, figures 6–11; Figure 5

1964 *Baltisphaeridium juliae* Cramer, p. 296 (1964b); Pl. 1, fig. 4; Figs. 19(5), 20.

1973 *Multiplicisphaeridium juliae* (Cramer) Eisenack and Cramer, p. 699.

**Description.** Vesicle originally spherical; outline circular to subcircular, clearly defined from processes. Vesicle wall psilate (under both light and scanning electron microscopes), commonly folded (due to compression), thickness 0.5–1  $\mu\text{m}$ . Processes discrete,  $\pm$ homomorphic, hollow, very thin walled, psilate, fairly evenly distributed (2–12  $\mu\text{m}$  apart), length 7–16  $\mu\text{m}$ ; interiors do not communicate with vesicle cavity. Proximal process contact angular to slightly curved or constricted. Processes taper gradually from circular or subcircular bases, 1–4  $\mu\text{m}$  in diameter, to point near apex or at least one third of distance to apex, then usually expand to distal extremity which is rounded, truncate or acuminate and from which project 2–10 small spinose elements (each 1.5–8  $\mu\text{m}$  long). A few simply acuminate processes may occur among the predominantly compound processes. Excystment by simple splitting of vesicle wall.

**Dimensions** (24 specimens). Diameter of vesicle 28 (35) 44  $\mu\text{m}$ ; overall diameter 41 (48) 65  $\mu\text{m}$ .

**Remarks.** Eisenack and Cramer's (1973) attribution of *Baltisphaeridium juliae* Cramer, 1964 to the genus *Multiplicisphaeridium* Staplin, 1961, is not upheld here, because the process interiors are distinctly separated from the vesicle cavity. Lister (1970, p. 84) had earlier suggested transfer to *Multiplicisphaeridium*, partly on the mistaken belief that internal process-vesicle communication does exist. Retention of the species in *Baltisphaeridium* is provisional, pending resolution of taxonomic problems, discussed below under *B. microfurcatum*, regarding the baltisphaerid-multiplicisphaerid group of acritarchs. *B. juliae* is possibly compatible with the genus *Visbysphaera* Lister, 1970 (p. 98), but the latter is said to possess a bilayered vesicle wall which is not demonstrable in the present species.

**Comparison.** The northern hemisphere Silurian species, *Baltisphaeridium piriferum* (Eisenack) Eisenack, 1965 (1965a, p. 263; Pl. 21, fig. 1), and its probable synonym *B. dilatispinosum* Downie, 1963 (p. 642; Pl. 92, fig. 4), differ from *B. juliae* in being considerably larger and in having differently shaped processes.



*Previous records.* Cramer (1964b) reported *Baltisphaeridium juliae* from middle Siegenian–Emsian strata of northwest Spain. Records by Martin (1966, p. 311; 1968, p. 55–56) from the Silurian of Belgium need more confirmation than the line-drawing and microphotograph she has provided so far. Eisenack and Cramer (1973, p. 669) discounted Martin's second (1968) reported occurrence.

*Baltisphaeridium microfurcatum* (Deunff) Stockmans and Willière, 1962

Plate 2, figures 12–15; Plate 3, figures 10–12; Figure 6

1957 *Hystichosphaeridium microfurcatum* Deunff, p. 6; Pl. 13, fig. 2.  
1962 *Baltisphaeridium microfurcatum* (Deunff) Stockmans and Willière, p. 92–93 (1962b); Pl. 2, figs. 18–20; Fig. 12.

*Description.* Vesicle originally spherical; outline circular to subcircular, clearly demarcated from processes; wall variable in thickness (1–3  $\mu\text{m}$ ), with dense granulate sculpture in which grana are uniformly close-spaced but fairly irregular in form. Processes  $\pm$ homomorphic, loosely to rather densely distributed (spaced 2–18  $\mu\text{m}$  apart); length 6–22  $\mu\text{m}$ ; basal diameter 1.5–3  $\mu\text{m}$ ; apparently partly hollow (oil immersion); invariably with branched distal extremities (branching variable: multi-, tri- or bifurcant), branches 0.5–4  $\mu\text{m}$  long. Under light microscope, processes appear  $\pm$ psilate; under scanning electron microscope, they are longitudinally striate, with alternating ridges/grooves that diverge proximally and are truncated by granulate sculpture of vesicle. Processes have angular or slightly curved proximal contact with vesicle and do not communicate with interior of vesicle; processes undulant, curved or  $\pm$ straight. Excystment structure, occasionally seen, is a simple split in vesicle wall.

*Dimensions* (42 specimens). Diameter of vesicle 17 (27) 38  $\mu\text{m}$ ; overall diameter 35 (49) 66  $\mu\text{m}$ .

*Remarks.* Stockmans and Willière's (1962b) referral of the species to the genus *Baltisphaeridium* is followed here, as in Cramer and Diez (1972, p. 142), although it is appreciated that consistent branching of process tips is not normally compatible with *Baltisphaeridium*. Generic assignment elsewhere would be less tenable and, in view of current taxonomic instability relating to the baltisphaerid-multiplicisphaerid group, it is not proposed at this time to create a new generic category for *B. microfurcatum*.

Lister's (1970, p. 49) suggestion that *B. microfurcatum* be included within his genus *Ammonidium* is untenable because the species does not display only one order of process branching, and the branches are not of equal length. Moreover, *Ammonidium* has free communication between process interiors and vesicle cavity; this is not the case with *B. microfurcatum*.

*Previous records.* Originally recorded from the Devonian of Ontario (Deunff, 1957), *B. microfurcatum* has subsequently been cited as occurring in the Frasnian of Belgium (Stockmans and Willière, 1962b) and in the Silurian of eastern North America (Cramer and Diez, 1972).

*Baltisphaeridium stamineum* sp. nov.

Plate 3, figures 1–3; Figure 7

1973 *Ammonidium* sp. of Downie, Pl. 27, fig. 3. (no description).

*Diagnosis.* Vesicle originally spherical or nearly so; outline circular to subcircular and sharply defined from processes. Vesicle wall 1–2.5  $\mu\text{m}$  thick, psilate to scabrate (corrosion effect). Processes discrete, weakly heteromorphic, tenuous, angular to slightly curved contact with vesicle; of regular or irregular, sparse distribution over vesicle wall; interiors hollow, but noncommunicative with vesicle interior. Processes branched (bifurcant to first, second or rarely third



Figure 6. Processes of *Baltisphaeridium microfurcatum* (Deunff) Stockmans and Willière, 1962; lateral view.



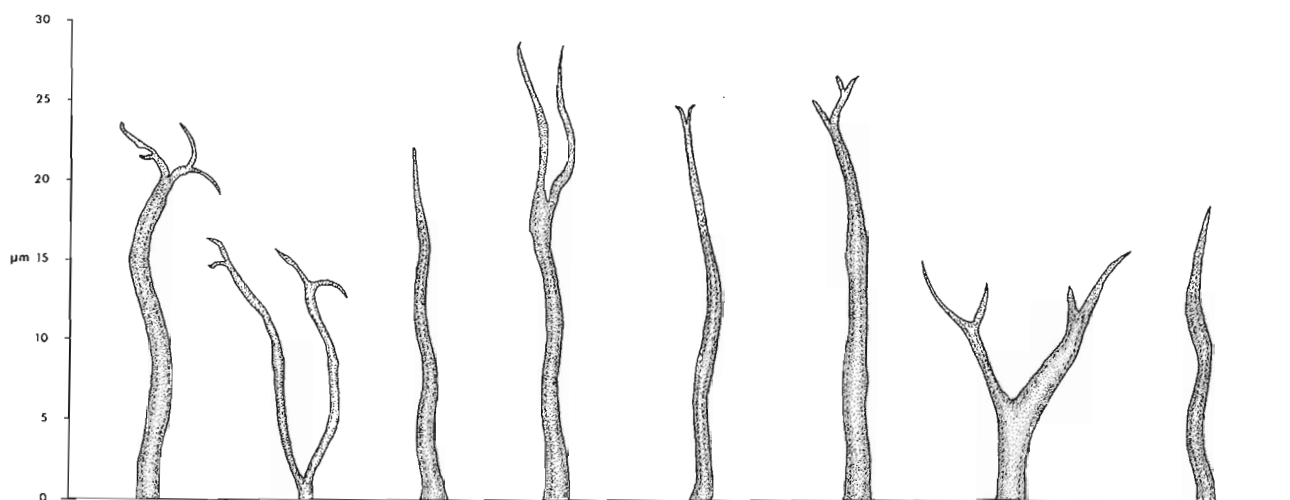


Figure 7. Processes of *Baltisphaeridium stamineum* sp. nov.; lateral view.

order) and unbranched (with simple acuminate tips) on same specimen; furcations usually confined to process extremity, but occasionally begin as little as 5  $\mu\text{m}$  from proximal contact; branching usually somewhat asymmetrical. Wall of processes  $<0.5$   $\mu\text{m}$  thick, psilate. Basal diameter of processes 0.5–3.5  $\mu\text{m}$  (average 1–2  $\mu\text{m}$ ); length 8–38  $\mu\text{m}$  (average 15–25  $\mu\text{m}$ ); spacing 2–20  $\mu\text{m}$ . Excystment by simple splitting of vesicle wall.

*Dimensions* (15 specimens). Diameter of vesicle 41 (71) 94  $\mu\text{m}$ ; overall diameter 56 (91) 115  $\mu\text{m}$ .

*Holotype*. Slide 8111-3, 48.8  $\times$  113.3, GSC 48289; Plate 3, figure 1. Vesicle with subcircular outline (diameter 76  $\mu\text{m}$ ), almost psilate wall (thickness 2.5  $\mu\text{m}$ ); processes distally bifurcate and simply acuminate (about half in each category), breadth at base 1–2  $\mu\text{m}$ , length 10–20  $\mu\text{m}$ , spaced 1–20  $\mu\text{m}$  apart.

*Type locality*. Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 755–757 feet; GSC loc. 8111.

*Name derivation*. Lat., *stamineus*, consisting of threads, fibrous.

*Remarks*. Many specimens show a preponderance of distally branched processes, but in others (e.g., holotype) acuminate and branched processes are in approximately equal proportions. Note that relatively poorly preserved specimens tend to bear mainly unbranched processes: this can be accounted for by the delicacy of the terminal bifurcation and its tendency to be broken from the remainder of the process.

*Comparison*. The most closely comparable taxon appears to be *Baltisphaeridium carinosum* Cramer, 1964 (1964b, p. 284; Pl. 1, fig. 13; Figs. 14-7, 14-8), from the Spanish Upper Silurian. Cramer's species differs, however, in being considerably smaller and in its much more variable modes of process branching and vesicle sculpturing.

*Previous records*. The location of Downie's (1973) undescribed specimen attributed to this species was cited as 'Bailey Formation (Devonian), U.S.A.'. Presumably this is

the Bailey Limestone of western Kentucky which is shown on the correlation chart of Oliver *et al.* (1969) as Lower Devonian.

#### Genus *Costatilobus* gen. nov.

*Diagnosis*. Vesicle hollow, with a relatively thin and apparently single wall layer, shape originally  $\pm$ spherical; outline circular to subcircular, well delineated from processes. Processes homomorphic to slightly heteromorphic, hollow, discrete, elongate-spinose in form, unbranched or with minor irregular branches, tips closed. Free communication exists between process interiors and vesicle cavity. Distribution of processes tends to be sparse (about 4–10 per vesicle) and irregular. Walls of processes thinner than, or about the same thickness as, vesicle wall, and distinctively modified by fine costate sculpture consisting of  $\pm$ continuous longitudinal ridges extending from base to apex. Vesicle wall finely sculptured (rugulate to granulate). Excystment mechanism not known.

*Name derivation*. Lat., *costatus*, ribbed, ridged; Lat., *lobus*, elongate projection. Gender masculine.

*Type species* (here designated). *Costatilobus undulatus* sp. nov.; described below.

*Other species*. *Costatilobus traumaticus* (Cramer) comb. nov. Basionym: *Baltisphaeridium traumaticum* Cramer, 1964b, p. 286; Pl. 1, figs. 3, 5; Fig. 14 (2, 3, 5). Occurrence: Northwest Spain, Upper Silurian (Ludlow); Florida, Middle Silurian (Wenlock) to Lower Devonian (basal Gedinian) (Cramer, 1964b; Cramer and Diez, 1972).

*Comparison*. The well-developed longitudinally disposed costae ornamenting the process walls serve to distinguish *Costatilobus* gen. nov. from other acritarch genera of generally similar morphology. The genus *Tylotopalla* Loeblich, 1970 (p. 737–738), to which Eisenack and Cramer (1973, p. 1073–1074) assigned *Baltisphaeridium traumaticum* Cramer, 1964 (see above), differs from *Costatilobus* in having more numerous, shorter and somewhat stubby processes that typically display terminal bifurcations or other, feather- or rosettelike modifications.

*Costatilobus undulatus* sp. nov.

Plate 3, figures 4–9

**Diagnosis.** Vesicle originally spherical; outline subcircular or circular, set off  $\pm$  clearly from processes; wall about 0.8–1.5  $\mu\text{m}$  thick, with fine, dense and somewhat irregular sculptural pattern (rugulate or rugulate to granulate). Five to 10 elongate, spinelike, homomorphic, hollow processes developed sparsely and irregularly over vesicle wall, with which they have curved proximal contact. Processes are unbranched, tapering uniformly from subcircular bases (diameter 5–9  $\mu\text{m}$ ) and are mostly about 22–50  $\mu\text{m}$  long; one or two much shorter processes (about 5–10  $\mu\text{m}$  long) rarely occur also on vesicle; distal termini bluntly pointed; interiors communicate freely with vesicle cavity. Process walls of similar thickness, but markedly dissimilar sculpture, to vesicle wall: under both light microscope and, particularly, scanning electron microscope, process surfaces are sculptured with  $\pm$  continuous, longitudinally disposed, narrow, bladelike ridges, 0.5  $\mu\text{m}$  or less in both width and lateral separation. Scanning electron microscopy shows that the ridge elements persist for a short distance beyond proximal vesicle contact to lose their identity within the finer,  $\pm$  contorted vesicle sculpture. No excystment aperture observed.

**Dimensions** (18 specimens). Diameter of vesicle 28 (35) 45  $\mu\text{m}$ .

**Holotype.** Slide 8124-13, 32.2  $\times$  101.9, GSC 48292; Plate 3, figures 4, 5. Vesicle semicircular in outline, diameter 37  $\mu\text{m}$ ; wall thin, very finely granulate to rugulate; nine long, straight to somewhat bent, longitudinally costate processes emanate from vesicle surface; processes variable in length (22–50  $\mu\text{m}$ ), basal diameter (5–9  $\mu\text{m}$ ) and basal separation (5–15  $\mu\text{m}$ ), apices blunt.

**Type locality.** Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, 925–927 feet; GSC loc. 8124.

**Name derivation.** Lat., *undulatus*, wavy.

**Comparison.** *Costatilobus traumaticus* (Cramer) comb. nov. differs from *C. undulatus* sp. nov. in being somewhat smaller overall, with generally smaller vesicles (maximum diameter 30  $\mu\text{m}$ ) and processes that attain a maximum length of 25  $\mu\text{m}$ . Moreover the processes of Cramer's species are heteromorphic to the extent that some are slightly modified by minor branching; and the process walls are distinctly thinner than the vesicle wall. Another distinction probably lies in the vesicle sculptural detail of the two species.

Genus *Cymatiosphaera* O. Wetzel ex Deflandre, 1954

1933 *Cymatiosphaera* O. Wetzel, p. 24; Pl. 4, fig. 8 (invalid I.C.Z.N., Art. 13b).

1954 *Cymatiosphaera* O. Wetzel ex Deflandre, p. 257.

1963 *Cymatiosphaeropsis* Mädlar, p. 355.

**Type species.** *Cymatiosphaera radiata* O. Wetzel, 1933; by subsequent designation of Deflandre (1954, p. 257).

**Generic characters.** Vesicle globular (spherical to ellipsoidal), hollow; surface uniformly and conspicuously reticulate with distinct membranous muri separating polygonal lacunae

that may have psilate or finely sculptured floors. No projections developed on muri. After Deflandre (1954, p. 257).

**Comparison.** According to its author, *Cymatiosphaeropsis* Mädlar, 1963 (p. 355) differs from *Cymatiosphaera* O. Wetzel ex Deflandre, 1954 by its development of sculptural elements on the lacunate surfaces (viz., punctae, grana, tubercles). However, it seems more reasonable, as suggested by Eisenack and Cramer (1973, p. 369) and also by scanning-electron and light microscopy in the present study, to regard such modifications as specific rather than generic taxonomic criteria. Hence, *Cymatiosphaeropsis* is here regarded as a junior synonym of *Cymatiosphaera*. Another of Mädlar's genera, *Pterosphaeridia* Mädlar, 1963 (p. 341), displays morphology closely akin to that of *Cymatiosphaera* (Eisenack and Cramer, 1973, p. 1023), but the presence of 'pore canals' in the former's vesicle could provide an apt basis for distinction.

Discrimination between *Dictyotidium* Eisenack emend. Staplin, 1961 (p. 417) and *Cymatiosphaera* rests, not altogether unequivocally, on degree of reticulation: the former having low but distinct muri which, moreover, may be the sites of subsidiary echinate projections.

The genus *Muraticavea* was said by Wicander (1974, p. 14) to differ from *Cymatiosphaera* and *Dictyotidium* 'in not having as many fields over the vesicle and in lacking ridges that extend out from the vesicle'.

*Cymatiosphaera canadensis* Deunff, 1961

Plate 4, figures 1, 2

1954 *Cymatiosphaera canadensis* Deunff, p. 1065 (1954b), Fig. 10 (nom. nud.).

1955 *Cymatiosphaera canadensis* Deunff, p. 142, Fig. 10 (nom. nud.).

1961 *Cymatiosphaera canadensis* Deunff, p. 218.

**Description.** Vesicle subspherical to rounded polyhedral. Vesicle surface divided regularly into 10–12 polygonal, typically pentagonal, areas (lacunae) by psilate, membranous, transparent, very thin muri 5–12  $\mu\text{m}$  high. Vesicle wall within lacunae scabrate or faintly granulate, 1–2  $\mu\text{m}$  thick. Excystment mechanism: simple splitting of vesicle wall.

**Dimensions** (45 specimens). Overall diameter 41 (56) 71  $\mu\text{m}$ .

**Remarks.** The specimens described above comprise a rather varied group in which Deunff's *Cymatiosphaera canadensis* seems to constitute an approximate morphological centre-point. Unfortunately, the brief original description of *C. canadensis* (see Deunff, 1961, p. 218) seems to rest upon only one specimen: a specimen figured by Deunff in 1954 and 1955 as a line drawing. Clearly, a realistic appreciation of the species needs to be sought from Deunff's material if *canadensis* is to be applicable in a precise and meaningful way.

**Previous records.** Deunff (1954b, 1955, 1961, 1966b) recorded this species from an imprecisely dated Devonian sample (Middle or Lower Devonian) of Ontario. Legault's (1973) specimens identified with *C. canadensis* are also from Ontario, viz. Middle Devonian Hamilton Group. Górka (1969, 1974a) reported *C. canadensis* from the upper Tremadoc and upper Famennian, respectively, of Poland.

*Cymatiosphaera cornifera* Deunff, 1955

Plate 4, figures 4–14

1955 *Cymatiosphaera cornifera* Deunff, p. 147; Fig. 23.

**Amplification of diagnosis.** Vesicle spherical. Surface of vesicle divided into about 6–12 relatively large, polygonal to subcircular lacunae (averaging 15  $\mu\text{m}$  in longest dimension) by distinctly projecting, diaphanous, psilate, membranous muri varying from 5 to 11  $\mu\text{m}$  in height. Within lacunae (i.e., on lacunate surfaces of vesicle wall), a fine sculpture, characteristically irregular in form and distribution, is developed, varying among granulate, echinate, finely verrucate, finely rugulate. Vesicle wall 1–2.5  $\mu\text{m}$  thick, sculpture excluded. Excystment structure, rarely observed, a simple split in vesicle wall.

**Dimensions** (60 specimens). Overall diameter 21 (34) 45  $\mu\text{m}$ , diameter of vesicle 14 (21) 29  $\mu\text{m}$ .

**Remarks.** The original description, accompanied by a single line drawing (Deunff, 1955), was seemingly based on one specimen. As such, it scarcely conveys an adequate appreciation of the morphology of *Cymatiosphaera cornifera*. Opportunity has been taken of the abundance of the species in the present material to document its morphological variation: particularly in the fine sculpture of the lacunae floors, which Deunff stated to be spinose, but in fact may be variously ornamented. Despite this variation, the species is easily recognizable from its delicate high muri, that if corroded have a ragged appearance; relatively large meshes of the reticulum; and much darker, comparatively thick walled vesicle.

**Previous records.** Deunff (1955, 1966b, 1967) recorded *C. cornifera* from the Devonian of Ontario. Stockmans and Willièrè (1969) figured an example from the Belgian Famennian.

*Cymatiosphaera multisepta* Deunff, 1955

Plate 4, figure 3

1955 *Cymatiosphaera multisepta* Deunff, p. 147; Fig. 25.

**Description.** Vesicle spherical. Surface divided regularly into numerous polygonal lacunae, about 1–4  $\mu\text{m}$  in maximum dimension, by narrow, psilate, transparent muri, 1.5–2.5  $\mu\text{m}$  high. Vesicle wall between muri 1–2  $\mu\text{m}$  thick, psilate or nearly so.

**Dimensions** (30 specimens). Overall diameter 13 (20) 29  $\mu\text{m}$ .

**Remarks and comparison.** The brief original description and sole illustration of *Cymatiosphaera multisepta* Deunff, 1955 is not an adequate basis for subsequent recognition of the species. Nevertheless the above specimens, while extending the size range and displaying, in many instances, more than 20 lacunae per hemisphere, can be attributed reasonably confidently to Deunff's species.

**Previous records.** Deunff's (1955) record is from the Middle or perhaps Lower Devonian of Ontario. *C. multisepta* was subsequently reported by Stockmans and Willièrè (1969, 1974) from the Belgian Devonian and by Deunff (1966b) from the Tunisian Devonian.

*Cymatiosphaera winderi* Deunff, emend.

Plate 4, figures 15–21

1967 *Cymatiosphaera winderi* Deunff, p. 259–260; Figs. 13, 17.  
1967 *Cymatiosphaera* cf. *winderi* Deunff, Fig. 15.

**Emended diagnosis.** Vesicle spherical to ellipsoidal, outline circular to oval. Surface of vesicle divided into about 8–12 large, polygonal to subcircular lacunae (averaging 30  $\mu\text{m}$  in longest dimension) by conspicuously projecting, diaphanous,  $\pm$ psilate, membranous muri (8–20  $\mu\text{m}$  high). Within the large lacunae, an additional, very fine reticulate sculpture is developed  $\pm$ uniformly, consisting of muri, 0.7  $\mu\text{m}$  or less in width, defining typically polygonal (less commonly triangular or quadrangular) lacunae up to 3  $\mu\text{m}$  in longest dimension. Each of these small lacunae contains one subcentral granum, or rarely two or three grana, about 0.5  $\mu\text{m}$  in basal diameter and height. Vesicle wall, less sculpture, about 2–3  $\mu\text{m}$  thick. Excystment by simple splitting of vesicle wall.

**Dimensions** (38 specimens). Diameter of vesicle (excluding muri) 30 (39) 52  $\mu\text{m}$ .

**Remarks.** Deunff's (1967) diagnosis is emended to take account of the intricate reticulate and associated modification of the vesicle wall. The salient features of this distinctive species are clearly displayed by scanning electron micrographs (e.g., Pl. 4, figs. 19, 20) and are evident also with conventional light microscopy, especially using  $\times 100$  oil-immersion objective (Pl. 4, fig. 21).

**Previous records.** The only previously reported occurrence is that by Deunff (1967) from Frasnian sediment of Kettle Point, Ontario.

*Cymatiosphaera* sp. cf. *C. pavimenta* (Deflandre)  
Deflandre, 1954

Plate 5, figures 9–11

Cf. 1945 *Michrhystridium pavementum* Deflandre, p. 68; Fig. 41; Pl. 3, figs. 20, 21.

Cf. 1954 *Cymatiosphaera pavimenta* (Deflandre) Deflandre, p. 258.

**Description.** Vesicle spherical. Surface divided regularly into polygonal lacunae, about 5–10  $\mu\text{m}$  across, by narrow, psilate, transparent muri, 2–3.5  $\mu\text{m}$  high. Vesicle wall between muri 1–2  $\mu\text{m}$  thick, psilate to scabrate.

**Dimensions** (32 specimens). Overall diameter 18 (24) 30  $\mu\text{m}$ .

**Remarks and previous records.** The specimens described above can be referred only tentatively to *Cymatiosphaera pavimenta* (Deflandre) Deflandre, 1954. The latter is a somewhat loosely defined category, clearly in need of more precise circumscription; it has been recorded by various authors from Silurian (e.g., Deflandre, 1945; Downie, 1959; Deunff, 1959) and Devonian deposits (e.g., Deunff, 1966b; Stockmans and Willièrè 1969, 1974). Some of the Moose River Basin specimens seem to intergrade with those identified above as *C. multisepta*. Both species are persistently represented in the section studied, but the latter is the less prevalent.

# Genus *Dateriocradus* Tappan and Loeblich, 1971

*Type species.* *Dateriocradus polydactylus* Tappan and Loeblich, 1971; by original designation.

*Generic characters.* Vesicle hollow, single-walled; usually subtriangular in outline and with a long, hollow, homomorphic process arising from each vesicle apex; sometimes a fourth process is developed on broad face of vesicle. Processes ramose to aborescent: bifurcating distally up to fifth or sixth order. Process interiors open freely into vesicle cavity; wall of processes and vesicle psilate. Excystment structure consists of a flaplike opening (epityche) between two processes. After Tappan and Loeblich (1971, p. 394, 396).

*Comparison.* *Dateriocradus* was instituted by Tappan and Loeblich (1971) for the reception of *Veryhachium*-like species that possess distally branched processes rather than the simple, acuminate processes characteristic of *Veryhachium* Deunff ex Downie, 1959.

The diagnoses of *Dateriocradus* and the earlier established genus *Evittia* Brito, 1967a (p. 477) are virtually identical and, *prima facie*, the two could be considered congeneric. However, as Loeblich (1970, p. 721) and Tappan and Loeblich (1971, p. 394, 396) have pointed out, the type species *E. sommeri* Brito, 1967a (p. 477-478; Pl. 1, figs. 9-12) is not particularly *Veryhachium*-like, being characterized by an inflated polygonal vesicle bearing stout, broadbased processes having simple or digitate distal ends. Therefore, it seems appropriate to retain *Dateriocradus* as a discrete generic entity.

## *Dateriocradus* sp. A

### Plate 5, figure 1

*Description.* Vesicle triangular in outline with  $\pm$ straight sides and bearing three short, stout, hollow processes, one at each of the triangular apices. Vesicle wall thin (about 0.4  $\mu$ m), psilate to faintly scabrate. Processes homomorphic, 4-10  $\mu$ m long, 3-7  $\mu$ m broad basally, freely communicating internally with vesicle cavity. Multifurcate distal termini of processes have smoothly 'frilled' appearance: a congregation of 6-10 short, close-spaced, rounded-lobate closed projections. Excystment aperture consists of a marginal slit along one side of vesicle.

*Dimensions* (3 specimens). Diameter 62-66  $\mu$ m overall.

*Remarks.* Despite shortness of its processes, this distinctive form seems to be more appropriately accommodated in *Dateriocradus* than in *Evittia*.

## *Dateriocradus* sp. B

### Plate 5, figures 12-14

*Description.* Vesicle rectangular; bearing six hollow, homomorphic processes, four of which arise from vesicle corners and the remaining two from central part of the vesicle (upper and lower surfaces respectively). Processes average 18  $\mu$ m long, 3-4  $\mu$ m broad at base from which they show a gentle taper towards the multifurcate distal ends; distal branching

up to fourth, fifth, or sixth order, tips closed. Vesicle and process interiors in free communication; walls psilate, about 0.5  $\mu$ m thick. No excystment structure observed.

*Dimensions* (2 specimens). Diameter of vesicle 18, 20  $\mu$ m.

*Remarks.* The process number exceeds the norm of three per vesicle stated by Tappan and Loeblich (1971), but otherwise the two specimens are compatible with the genus *Dateriocradus*.

# Genus *Dictyotidium* Eisenack emend. Staplin, 1961

*Type species.* *Dictyotidium dictyotum* (Eisenack) Eisenack, 1955; by original designation.

*Generic characters.* Vesicle spherical, hollow, with uniformly reticulate surface. Muri low, distinct; enclosing polygonal lacunae, the floors of which may be sculptured. Small echinate projections may arise from muri. After Staplin (1961, p. 417).

*Comparison.* See genus *Cymatiosphaera*.

## *Dictyotidium cavernosulum* sp. nov.

### Plate 5, figures 5-8

*Diagnosis.* Vesicle originally spherical, outline circular to subcircular; wall thick (3.5-4  $\mu$ m) with fine, uniform reticulate to almost vermiculate sculpture. Muri flat-topped, 1  $\mu$ m or less (average 0.5  $\mu$ m) in both height and width. Lacunae subcircular, roundly elliptical or roundly polygonal in outline; about 0.5-1  $\mu$ m in maximum dimension. Excystment aperture consisting of a simple split in vesicle wall.

*Dimensions* (14 specimens). Vesicle diameter 40 (56) 78  $\mu$ m.

*Holotype.* Slide 8124-9, 56.4  $\times$  103.9, GSC 48318; Plate 5, figure 5. Vesicle subcircular, diameter 64  $\mu$ m; wall 3.5  $\mu$ m in thickness, finely and regularly reticulate; simple split in vesicle wall constitutes excystment structure.

*Type locality.* Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 925-927 feet. GSC loc. 8124.

*Name derivation.* Lat., *cavernosus*, with numerous hollows or cavities.

*Comparison.* The fineness of the vesicle's reticulate sculpture serves to distinguish *Dictyotidium cavernosulum* sp. nov. from otherwise similar members of the genus.

## *Dictyotidium variatum* sp. nov.

### Plate 5, figures 2-4; Plate 6, figures 1-6

*Diagnosis.* Vesicle spherical to subspherical; wall 2.5-4  $\mu$ m thick, including fine reticulate sculpture. Muri psilate, 0.5-2  $\mu$ m wide, average width about 0.7  $\mu$ m, with rounded tops, 0.5-1  $\mu$ m high. Lacunae angular-polygonal to rounded-polygonal in outline, with slightly concave to convex floors that are psilate or almost so under both light and scanning electron microscopes; maximum breadth of lacunae ranges from 1-4.5  $\mu$ m. Excystment aperture consists of a simple split in vesicle wall.

*Dimensions* (63 specimens). Overall diameter 25 (40) 62  $\mu\text{m}$ .

*Holotype*. Slide 8124-3, 42.8  $\times$  99.8, GSC 48328; Plate 6, figure 3. Vesicle subcircular, 54  $\mu\text{m}$  in diameter; wall 2.7  $\mu\text{m}$  thick, uniformly reticulate overall; muri 0.7–1.5  $\mu\text{m}$  broad, 0.7–1  $\mu\text{m}$  high, psilate; lacunae normally polygonal to subcircular in surface view, 1–3  $\mu\text{m}$  across, floors slightly convex, psilate.

*Type locality*. Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 925–927 feet; GSC loc. 8124.

*Name derivation*. Lat., *variatus*, varied.

*Remarks*. The above diagnosis is based upon detailed observations, from both light and scanning electron microscopes, of a large number of specimens recovered from samples throughout the section studied. The author is aware that, by comparison with other, similarly reticulate, specific taxa of the genus *Dictyotidium*, the circumscription of *D. variatum* might appear to be of inordinate breadth. Chief amongst the variables are thickness of wall, overall vesicle size and size/shape of lacunae. What proved to be continuous intergradation of these attributes, amongst specimens in a given sample, disallowed attempts at consistent subdivision at either specific or infraspecific levels.

*Comparison*. Several previously described species resemble *D. variatum*, viz. *D. dictyotum* (Eisenack) Eisenack, 1955 (p. 179–180; Pl. 4, figs. 12, 13; Silurian, Europe), *D. stenodictyum* Eisenack, 1965 (1965a, p. 264–265; Pl. 22, figs. 2, 3; Silurian, Europe), and *D. polygonium* Staplin, 1961 (p. 417; Pl. 49, fig. 14; Upper Devonian, Alberta). Both of Eisenack's species are generally larger than *D. variatum*, while *D. polygonium* differs from the latter in having a much more restricted size range (27–31  $\mu\text{m}$ ) and the consistent presence of 'a small raised granule in the centre of each polygon'.

### *Dictyotidium* sp. A

Plate 5, figures 15, 16

*Description*. Vesicle circular to subcircular in outline. Wall conspicuously reticulate with relatively narrow, low muri enclosing polygonal lacunae, of which 20–24 occupy a given hemisphere. Muri psilate, 2.5–5  $\mu\text{m}$  broad at base, tapering regularly to acute crest; height of muri averages 2.5–3  $\mu\text{m}$ . Polygonal outlines of muri with both rounded and sharp angles; maximum width 10–30  $\mu\text{m}$ . Floors of lacunae scabrate; flat or gently concave. Wall 4–5  $\mu\text{m}$  thick, muri excluded. No excystment structure observed.

*Dimensions* (2 specimens). Overall diameter 83, 96  $\mu\text{m}$ .

*Comparison*. In comparison with the above specimens, *Cymatiosphaera labyrinthica* Wicander, 1974 (p. 13; Pl. 6, figs. 4–6; Upper Devonian, Ohio) has a markedly lesser number of lacunae per hemisphere (6–7). A German Givetian form, *C. magnata* Pilcher, 1971 (p. 326–327; Pl. 4, figs. 52–58; Fig. 3) is characterized by a rounded elevation subcentrally sited on the floor of each lacuna, and is thus distinct from the Moose River Basin specimens here termed *Dictyotidium* sp. A.

### Genus *Diexallophasis* Loeblich, 1970

*Type species*. *Diexallophasis remota* (Deunff) comb. nov. (described below); originally designated, as *D. denticulata* (Stockmans and Willièrè) Loeblich, 1970, by Loeblich (1970, p. 714).

*Generic characters*. Vesicle originally spherical or sub-spherical; circular to subcircular or polygonal in outline; hollow; wall one-layered, relatively thin, and commonly granulate. Processes few to fairly numerous, hollow, with simple or ramose (bifurcant or multifurcant) distal termini, communicating freely with vesicle cavity, and sculptured with small spines. Excystment by simple rupture of vesicle wall, After Loeblich (1970, p. 714).

*Comparison*. *Diexallophasis* Loeblich, 1970 is distinguishable from *Multiplicisphaeridium* Staplin emend. Staplin, Janzonius and Pocock, 1965 in its development of sculptural elements on vesicle and processes. *Baltisphaeridium* Eisenack emend. Eisenack, 1969 differs from *Diexallophasis* insofar as its processes are seemingly unsculptured and have a tendency to be partly or completely closed at their proximal ends (i.e., at junctions with vesicle).

### *Diexallophasis remota* (Deunff) comb. nov., emend.

Plate 6, figures 12–14; Plate 7, figures 1–11; Figure 8

- 1955 *Veryhachium remotum* Deunff, p. 146; Pl. 4, fig. 8.  
 1959 *Baltisphaeridium longispinosum* (Eisenack); Downie (*pars*), p. 58; Pl. 10, figs. 1, 2 (*non* fig. 6).  
 1963 *Baltisphaeridium denticulatum* Stockmans and Willièrè, p. 458 (June 1963); Pl. 1, fig. 4; Fig. 13.  
 1963 *Baltisphaeridium granulatispinosum* Downie, p. 640–641 (December 1963); Pl. 91, figs. 1, 7; Fig. 3c.  
*non* 1969 *Baltisphaeridium furcatispinosum* Górka, p. 47–48; Pl. 5, fig. 12.  
 1970 *Evittia granulatispinosa* (Downie) Lister, p. 67–69 (November 1970); Pl. 4, figs. 2, 3, 5–9, 12; Pl. 5, fig. 2; Figs. 17a, 20b.  
 1970 *Evittia remota* (Deunff) Lister, p. 69–70 (November 1970); Pl. 4, figs. 10, 11, 13–15; Pl. 5, fig. 1.  
 1970 *Diexallophasis denticulata* (Stockmans and Willièrè) Loeblich, p. 715 (December 1970); Figs. 8A–E, 9 A–C.  
 1972 *Baltisphaeridium rojensis* Jankauskas and Vaitiekuniene, p. 121; Pl. 17, figs. 10, 11; Fig. 3.  
 1973 *Multiplicisphaeridium denticulatum* (Stockmans and Willièrè) Eisenack and Cramer, p. 587–603, 653.  
 1973 *Multiplicisphaeridium remotum* (Deunff) Eisenack and Cramer, p. 773.

*Original diagnosis*. Translated from the French text, Deunff's (1955, p. 146) original description of *Veryhachium remotum* is as follows: "Shell deformed, forming a swelling at junctions with 6 long processes. Processes hollow, spinose, ramifying, 50  $\mu\text{m}$  long and 8  $\mu\text{m}$  in basal diameter". This circumscription appears to be based on a single specimen (i.e., Deunff, 1955, Pl. 4, fig. 8).

*Emended diagnosis*. Vesicle originally spherical or nearly so; outline variable—circular, subcircular, square, triangular, rectangular, or polygonal. Wall of vesicle single-layered, up to 1.5  $\mu\text{m}$  thick (average 0.7  $\mu\text{m}$ ); almost smooth to faintly granulate or scabrate under the light microscope; microgranulate, granulate, microgranulate to micropunctate, microrugulate, or microreticulate under scanning electron microscope. Long, slender,  $\pm$ flexible processes distributed fairly regularly on vesicle; number variable, usually 4–12, average 6–7, rarely as many as 18–20. Processes hetero-

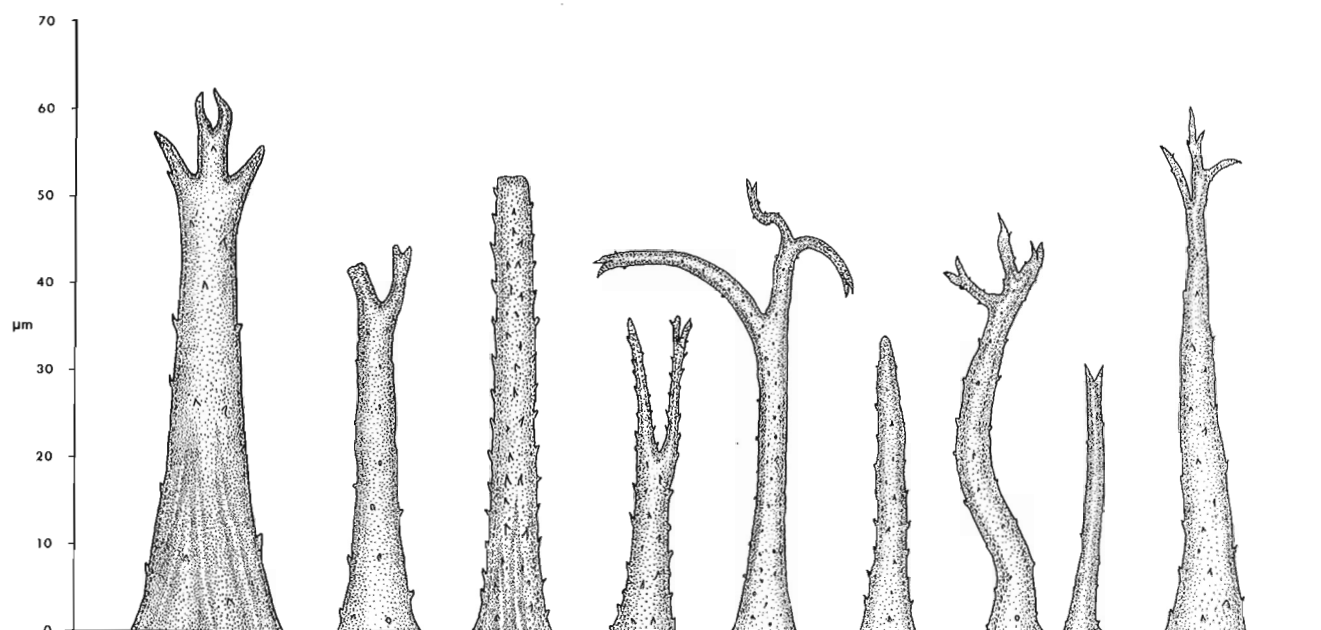


Figure 8. Processes of *Diexallophasis remota* (Deunff) comb. nov., emend.; lateral view.

morphic or near-homomorphic, with essentially hollow interiors, and constituting drawn-out, basically subcylindrical extensions of vesicle wall, freely communicating with vesicle cavity. At proximal ends, processes have curved to angular contacts with wall of vesicle; distal extremities simple or, more typically, branched (bifurcant to first, second or rarely third order; or digitate). Branching often somewhat asymmetrical. Length of processes variable, from about 0.8 to 2.0 times vesicle diameter. Processes sculptured sparsely to moderately densely with echinate to granulate elements and, in some specimens, with discontinuous, fine, subparallel (longitudinal) ridges that are usually developed proximally as a type of substrate subsidiary sculpture. Spines on processes up to 2  $\mu\text{m}$  long, usually about 0.5–1  $\mu\text{m}$ . Excystment, rarely observed, is by simple rupture of vesicle wall.

*Dimensions* (250 specimens). Diameter of vesicle 16 (32) 47  $\mu\text{m}$ .

*Remarks.* This species is the most consistently occurring and abundant element in the samples of this study. Previous authors, most notably Cramer (1971, p. 135–141), have documented considerable variation in its morphology; this is amply confirmed by the numerous specimens studied herein by means of both light and scanning electron microscopes. Cramer (1971, p. 138–141) distinguished five subspecific taxa ('varieties') within his *Baltisphaeridium denticulatum* group and Cramer and Diez (1972, p. 149–150) named an additional one. Jardíné *et al.* (1972, p. 297–298) also described three subspecies of *Evittia remota* (Deunff) Lister, 1970 and a further one was added to the species by Jardíné *et al.* (1974, p. 116–117). In the latter paper the specific combination cited was '*Diexallophasis remotum* (Deunff 1955) Loeblich 1970' although such combination did not formally exist. Lister (1970, p. 67–70) and Thusu (1973b, p. 811–812)

also recognized wide morphological variation which they found impractical, as does the author, to subdivide infraspecifically.

Previous arguments about the species name have concerned the applicability of either *denticulatum* Stockmans and Willière, 1963 or *granulatispinosum* Downie, 1963. Although Martin (1967, p. 310), and possibly Loeblich (1970, p. 715), implied some difference between the two, Cramer (1971), Lister (1970), Thusu (1973b) and Eisenack and Cramer (1973) shared the view that they have a synonymous relationship. With the exception of Lister, the latter group of authors endorsed the priority of *denticulatum* over *granulatispinosum*. Lister (1970, p. 68) attempted to invoke Article 38 of the International Code of Botanical Nomenclature as a reason for suppressing Stockmans and Willière's species name in favour of Downie's.

The author accepts that *denticulatum* and *granulatispinosum* are indeed synonymous and, further, regards *Veryhachium remotum* Deunff, 1955 and *Baltisphaeridium rojensis* Jankauskas and Vaitiekuniene, 1972 as possessing the essential morphological attributes of the same species. Lister (1970) described *Evittia granulatispinosa* (Downie) Lister and *E. remota* (Deunff) Lister separately but established no obvious grounds for distinction between them; certainly none is evident from Deunff's (1955) original description or illustration. Accordingly, *Diexallophasis remota* (Deunff) comb. nov., as senior synonym, is here regarded as the appropriate designation for the species.

*Comparison.* *Hystrichosphaeridium spiciferum* Deunff, 1955 (p. 146; Pl. 3, fig. 1), from the Devonian of Ontario, might perhaps be regarded as an unbranched variant of *Diexallophasis remota*, but more information is needed about its morphology. *Baltisphaeridium ravum*, described by Downie (1963, p. 643; Pl. 91, fig. 6; Fig. 3e) from the English



Wenlock, has digitate processes which are, however, psilate. Loeblich's (1970, p. 714–715; figs. 7A–G) species, *D. caperoradiola*, from the Middle Silurian of New York State, is obviously close to *D. remota* in its morphology and could well constitute an additional synonym. From the Spanish Silurian-Devonian, *B. sanpetrensis* (Cramer) Cramer, 1966 differs from *D. remota* in bearing relatively short and stout branching processes that have coarse echinate sculpture (see Cramer, 1971, p. 141; Pl. 10, fig. 159; Pl. 12, figs. 175, 181, 182; Fig. 43i). *B. denticulatissimum*, instituted by Cramer and Diez (1972, p. 149; Pl. 31, figs. 8, 9) from upper Wenlock sediments of Kentucky, was said to be distinguishable by 'its thick, plump processes and the dense cover of the large echinae'.

*Previous records.* *Diexallophosis remota*, as circumscribed herein, has been reported widely from northern hemisphere strata (see Cramer, 1971, Fig. 44), in which its stratigraphic range is Lower Silurian to Middle Devonian.

#### Genus *Divetipellis* Wicander, 1974

*Type species.* *Divetipellis robusta* Wicander, 1974; by original designation.

*Generic characters.* Spherical vesicle with two-layered, cavate wall. Outer layer thin, totally enveloping thicker, finely granulate, inner layer. Excystment by simple splitting of vesicle wall layers. After Wicander (1974, p. 19).

#### *Divetipellis ventricosa* sp. nov.

Plate 6, figures 7–11

*Diagnosis.* Vesicle originally spherical; outline circular to subcircular with irregular margin (due to crumpling of outer wall layer by compression). Vesicle wall two-layered, cavate; outer layer transparent, very thin ( $<0.5\ \mu\text{m}$ ), psilate, commonly  $\pm$  finely folded; inner layer much thicker (2–4  $\mu\text{m}$ ), psilate. Excystment by simple splitting of vesicle wall.

*Dimensions* (32 specimens). Overall diameter 37 (53) 76  $\mu\text{m}$ ; diameter of inner layer 24 (42) 66  $\mu\text{m}$ .

*Holotype.* Slide 8105-3, 32.9  $\times$  104.8, GSC 48332; Plate 6, figure 8. Outline subcircular, overall diameter 72  $\mu\text{m}$ ; very thin, diaphanous outer layer much folded; darker, thicker (2  $\mu\text{m}$ ), inner layer exhibiting several arcuate compression folds; diameter of inner body (formed by inner layer) 64  $\mu\text{m}$ .

*Type locality.* Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 681–683 feet; GSC loc. 8105.

*Name derivation.* Lat., *ventricosus*, bulging, swollen.

*Comparison.* *Divetipellis ventricosa* sp. nov. differs from *D. robusta* Wicander, 1974 (p. 19–20; Pl. 8, fig. 3: Upper Devonian, Ohio) by having a thicker walled and psilate inner body.

Strict application of Wicander's generic diagnosis, with respect to the inner wall layer's granulate surface, could exclude *ventricosa* from *Divetipellis*. However, Wicander's species does not display any conspicuous granulation, so far as one can judge from the single illustration he provided (i.e., of the genus and the species).

#### Genus *Duvernaysphaera* Staplin emend. Deunff, 1964

1961 *Duvernaysphaera* Staplin, p. 414–415.

1964 *Duvernaysphaera* Staplin emend. Deunff, p. 211.

1964 *Helios* Cramer, p. 329 (1964b).

1967 *Veliferites* Brito, p. 477 (1967a).

*Type species.* *Duvernaysphaera tenuicingulata* Staplin, 1961; by original designation.

*Generic characters.* Vesicle hollow, somewhat inflated, commonly lenticular or ellipsoidal in overall shape. Outline variable—circular, subcircular, quadrangular, polygonal or stellate. Peripherally (equatorially or subequatorially) the vesicle is surrounded by a thin, transparent, membranous flange, the outer margin of which conforms generally with the vesicle outline. Flange includes spokelike thickenings emanating radially from vesicle; these rodlike structures are confined to the membrane and, therefore, commonly to the equatorial plane. After Staplin (1961, p. 414–415), Deunff (1964, p. 211).

*Discussion.* Cramer and Diez (1972, p. 162) formally established *Helios* Cramer, 1964 as a junior synonym of *Duvernaysphaera* Staplin, 1961. *Veliferites* Brito, 1967 is here regarded as an additional synonym, particularly so in light of the revised *Duvernaysphaera* circumscription by Deunff (1964).

It is appropriate, therefore, to formally transfer *Veliferites tenuimarginatus* Brito (type species) to *Duvernaysphaera*. New combination: *Duvernaysphaera tenuimarginata* (Brito) comb. nov. Basionym: *Veliferites tenuimarginatus* Brito, 1967a, p. 477; Pl. 1, figs. 4–8.

*Comparison.* *Pterospermella* Eisenack, 1972 (p. 597) and *Duvernaysphaera* are structurally similar genera, but differ insofar as the peripheral membrane of the former lacks prominent spokelike elements.

#### *Duvernaysphaera tenuicingulata* Staplin, 1961

Plate 8, figures 1–6

1961 *Duvernaysphaera tenuicingulata* Staplin, p. 415–416; Pl. 49, figs. 10, 11.

*Description.* Vesicle with circular, subcircular, to roundly polygonal outline. Vesicle wall 1–2  $\mu\text{m}$  thick; scabrate to almost psilate under both light and scanning electron microscopes. Peripheral membrane very thin, diaphanous, psilate; reinforced by 8–15 narrow radial, spine- or rod-shaped co-planar extensions from vesicle wall, which are irregularly spaced. Excystment structure consists of a simple slit in vesicle wall.

*Dimensions* (54 specimens). Overall diameter 28 (37) 46  $\mu\text{m}$ ; diameter of vesicle 20 (28) 35  $\mu\text{m}$ .

*Remarks, previous records.* The Moose River Basin specimens are in close agreement with those described by Staplin (1961) from the lower Upper Devonian of Alberta, although many show an excystment split in the vesicle wall not mentioned by Staplin. Specimens devoid of the delicate flangelike membrane are fairly common (as Staplin found), the narrow spokelike projections remaining to indicate its former attachment.

A few of the present specimens, almost quadrangular in outline, approach the morphology of *Duvernaysphaera*

*tenuimarginata* (Brito) comb. nov.; but in these the projections supporting the membranes are not strictly confined to the corners as in Brito's (Brazilian, Middle Devonian) species.

Genus *Goniolopadion* gen. nov.

*Type species* (here designated). *Goniolopadion prolixum* sp. nov.; described below.

*Diagnosis.* Vesicle conspicuously star-shaped in outline, with about 5–7 acutely angled projections in the same plane, and single-walled hollow interior. One hollow, typically spinelike process emanates radially from each of the vesicle's acute projections in the same plane as the latter. Processes homomorphic with simple (acuminate), closed tips; interiors separated from vesicle cavity by basal pluglike structure. Simple split, approximately bisecting vesicle and extending from base of one process to that of a diametrically opposite one, constitutes excystment aperture.

*Name derivation.* Gr., *gonia*, angle, corner; Gr., *lopadion*, small plate. Gender neuter.

*Comparison.* *Goniolopadion* gen. nov. differs from *Ozotobranchion* Loeblich and Drugg, 1968 (p. 130) in its distinctly stellate vesicle outline, unbranched processes, and different excystment mechanism; and from *Tyligmasoma* gen. nov. also in its stellate vesicle outline together with more numerous processes, each characterized by development of a distinct basal plug. Further, *Goniolopadion* is distinguishable from other stellate genera (viz. *Stellinium* Jardiné *et al.*, 1972, p. 298; *Estiastra* Eisenack, 1959, p. 201; *Palacanthus* Wicander, 1974, p. 30) by having, *inter alia*, basal obstructions clearly separating process interiors from vesicle cavity.

*Goniolopadion prolixum* sp. nov.

Plate 8, figures 7–11

*Diagnosis.* Vesicle of symmetrically stellate outline; with 5–7, co-planar, acutely angled projections (about 45–50°), from each of which a long slender process extends also in the same plane. Vesicle sides (i.e., connecting apices of adjacent vesicle projections) obtusely angled (i.e., not forming a smooth curve). Vesicle hollow; wall single-layered, 1–1.7  $\mu\text{m}$  thick; sculpture granulate under light and scanning electron microscopes; with the latter, grana are seen to be irregular in form, up to 1  $\mu\text{m}$  and 0.5  $\mu\text{m}$  in basal breadth and height respectively, and spaced about 0.5  $\mu\text{m}$  apart; sculpture tends to become finer and sparser towards outer margin of vesicle. Processes psilate, 25–45  $\mu\text{m}$  long (subequal on same specimen), homomorphic, hollow except for basal portion, very thin walled (0.5  $\mu\text{m}$  or less in thickness); gradually tapering in width from base (1.5–3  $\mu\text{m}$  wide) to simple, pointed distal extremities. Base of processes invariably infilled by solid, pluglike structure, 2.5–4  $\mu\text{m}$  long, which serves to completely close off process interiors from vesicle cavity. Additionally, some processes contain one or several, smaller, discrete, globulelike structures, of similar substance, to the plug in the proximal third or less of their interiors. A simple, slightly curved slit in vesicle wall, which extends from a process base

to the diametrically opposite one, constitutes excystment aperture.

*Dimensions* (14 specimens). Overall diameter 67 (75) 86  $\mu\text{m}$ ; diameter of vesicle 16 (21) 27  $\mu\text{m}$ .

*Holotype.* Slide 8060-4, 41.4  $\times$  110.7, GSC 48356; Plate 8, figures 10, 11. Vesicle diameter 18  $\mu\text{m}$ ; granulate wall 1.2  $\mu\text{m}$  thick; one slender, sharp-tipped, psilate process (average length 25  $\mu\text{m}$ ) arises from each of the five acute vesicle corners; plug, constituting basal infilling of each process, precludes communication between process interior and vesicle cavity; small, solid, spheroidal bodies are lodged within proximal process interiors, immediately adjacent to main plug; excystment opening consists of a simple curved slit crossing vesicle from one process base to diametrically opposed one.

*Type locality.* Ontario, Moose River Basin; Williams Island Formation, Middle Devonian (Givetian); Jaab Lake No. 1 well, core, 187.5–189.5 feet; GSC loc. 8060.

*Name derivation.* Lat., *prolixus*, extended, spread out.

*Remarks.* The relatively delicate, hollow processes are often partly or completely broken, sometimes to the extent that only their plugged bases remain attached to the comparatively robust vesicle wall projections.

*Comparison.* From its general appearance, albeit only from a line drawing, and brief description, *Veryhachium stelligerium* Deunff, 1957 (p. 10; Fig. 10) merits comparison with *Goniolopadion prolixum* gen. et sp. nov. Deunff's species, from a Middle, or perhaps, Lower Devonian sample from Ontario, differs from *G. prolixum* in its differently shaped vesicle and shorter processes, the interiors of which do communicate with the vesicle cavity.

Genus *Gorgonisphaeridium* Staplin, Jansonius, and Pocock, 1965

*Type species.* *Gorgonisphaeridium spicatum* (Staplin) Staplin, Jansonius, and Pocock, 1965; by original designation.

*Generic characters.* Vesicle single-walled, hollow, originally spherical or subspherical; outline circular to subcircular. Vesicle wall usually relatively thick, firm; psilate or finely sculptured. Numerous processes developed  $\pm$ regularly on vesicle wall. Processes solid, straight to sinuous, slender or broad, with simple or branched apices. Excystment by simple splitting of vesicle wall. After Staplin *et al.* (1965, p. 192–193).

*Gorgonisphaeridium cumulatum* sp. nov.

Plate 8, figures 12–20

*Diagnosis.* Vesicle spherical; outline circular or almost so, distinct from processes. Vesicle wall thick (2–3  $\mu\text{m}$ ), psilate; bearing abundant, close-spaced, homomorphic, solid, psilate processes of spinose form. Processes straight to slightly curved in lateral profile; bases circular, 0.5–2  $\mu\text{m}$  in diameter, occasionally coalescent, up to 4  $\mu\text{m}$  apart (average 1–2  $\mu\text{m}$ ); length 1–3.5  $\mu\text{m}$ ; terminating in blunted acuminate tips. Processes have curved proximal contacts. Excystment (rarely seen) by simple splitting of vesicle wall.



*Dimensions* (25 specimens). Diameter of vesicle 26 (34) 44  $\mu\text{m}$ .

*Holotype*. Slide 7851-5, 52.4  $\times$  96.2, GSC 48360; Plate 8, figure 20. Vesicle spherical, 40  $\mu\text{m}$  in diameter; with psilate wall, 3  $\mu\text{m}$  thick, bearing crowded, distally tapering, solid processes (2–3  $\mu\text{m}$  long, 1–2  $\mu\text{m}$  broad at base, spaced up to 3  $\mu\text{m}$  apart). No excystment structure evident.

*Type locality*. Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 935–937 feet; GSC loc. 7851.

*Name derivation*. Lat., *cumulatus*, heaped-up, filled.

*Comparison*. The thick vesicle wall and its uniform, dense cover of relatively short, solid, acuminate processes render this species distinct from others of the genus, or at least those that have been adequately described and illustrated.

*Gorgonisphaeridium disparatum* sp. nov.

Plate 9, figures 8–16; Figure 9

*Diagnosis*. Vesicle spherical or approximately so; outline circular, subcircular or oval, clearly distinct from processes. Vesicle wall 1.5–2.5  $\mu\text{m}$  thick; psilate to scabrate under light microscope; microstriate or microrugulate to punctate under scanning electron microscope. Numerous, stout to slender processes, uniformly tapering from subcircular bases, are closely spaced or rather sparsely distributed over vesicle surface. Processes solid, heteromorphic, psilate, straight to curved in profile. Bases of processes 1.5–5  $\mu\text{m}$  in diameter; length of processes 3–12  $\mu\text{m}$ ; adjacent processes 1–10  $\mu\text{m}$  apart; proximal process contacts—slightly curved to angular, occasionally constricted. On given specimens, processes are mostly bifurcant (to second rank) or trifurcant; division usually occurs near distal end, but may begin nearer the proximal end (i.e., base). A minority of processes are simply acuminate. Ultimate tips of processes are bluntly rounded. Excystment structure not observed.

*Dimensions* (27 specimens). Diameter of vesicle 49 (59) 74  $\mu\text{m}$ ; overall diameter 59 (69) 79  $\mu\text{m}$ .

*Holotype*. Slide 7851-10A, 35.8  $\times$  104.2, GSC 48367; Plate 9, figure 9. Vesicle circular in outline; wall 1.5  $\mu\text{m}$  thick, scabrate; solid, discrete, heteromorphic, psilate processes spaced 1–8  $\mu\text{m}$  apart (average 4  $\mu\text{m}$ ); basal width of processes 1.5–4.5  $\mu\text{m}$ , length 3–12  $\mu\text{m}$ ; processes predominantly bifurcated distally, bases somewhat bulbous.

*Type locality*. Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 935–937 feet; GSC loc. 7851.

*Name derivation*. Lat., *disparatus*, divided, separated.

*Comparison*. Two Upper Devonian species from North America are comparable to *Gorgonisphaeridium disparatum* sp. nov. These are *G. spicatum* (Staplin) Staplin, Jansonius and Pocock, 1965 (p. 193; Pl. 19, fig. 14) and *G. separatum* Wicander, 1974 (p. 26; Pl. 13, figs. 1–3). Both of these are distinct from *G. disparatum* in having thinner vesicle walls (about 1  $\mu\text{m}$ ) and pointed spinelike processes of less variable morphology.

An as yet undescribed Late Silurian form from the Sahara subsurface, '*Baltisphaeridium* sp. 5' of Jardiné and Yapaudjian (1968, Pl. 3, figs. 5, 10), could perhaps be close to *G. disparatum*.

*Gorgonisphaeridium granatum* sp. nov.

Plate 9, figures 1–7

*Diagnosis*. Vesicle originally spherical or almost so; outline circular to subcircular, well demarcated from processes. Vesicle wall 1–2.5  $\mu\text{m}$  thick, with dense, uniform, finely granulate sculpture. Processes usually discrete, solid, homomorphic, straight to bent, essentially psilate; spinose in gross form, with uniform taper from subcircular bases (diameter 1–3  $\mu\text{m}$ ) to acuminate, sharp to slightly rounded tips. Length of processes 2.5–12  $\mu\text{m}$ ; basal separation also variable among specimens (2–12  $\mu\text{m}$ ); processes very rarely coalescent at base. Curved proximal process contacts. Scanning electron microscopy reveals minor modification of process surfaces by faint longitudinal striations. Excystment mechanism (rarely seen): simple rupture of vesicle wall.

*Dimensions* (125 specimens). Diameter of vesicle 22 (37) 54  $\mu\text{m}$ ; overall diameter 33 (50) 71  $\mu\text{m}$ .

*Holotype*. Slide 8104-2, 33.0  $\times$  103.3, GSC 48362; Plate 9, figure 2. Vesicle of subcircular outline; wall distinctly and densely sculptured with fine grana; processes homomorphic, solid, with simple, slightly blunted apices; distribution of processes  $\pm$  regular (5–10  $\mu\text{m}$  apart), length 7.5–9  $\mu\text{m}$ , basal diameter 2–3  $\mu\text{m}$ ; no excystment structure visible.

*Type locality*. Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 671–673 feet; GSC loc. 8104.

*Name derivation*. Lat., *granatus*, seedy, grainy.

*Remarks*. The main morphological variables (i.e., among rather than within specimens) are size of processes coupled with their density of distribution over the vesicle wall.

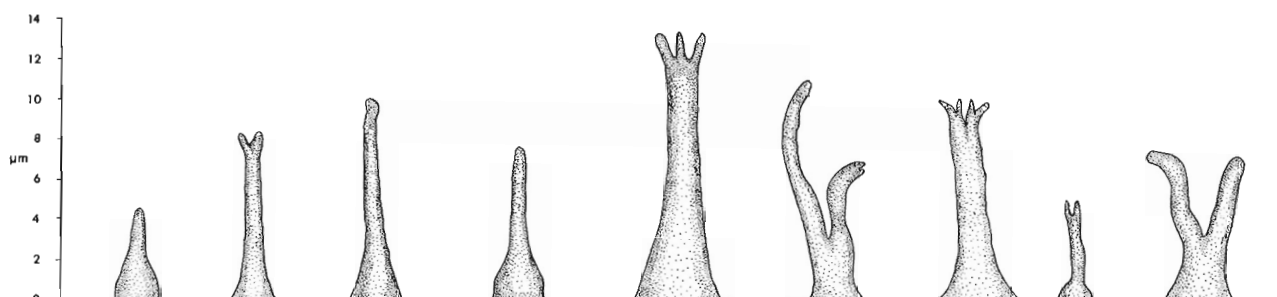


Figure 9. Processes of *Gorgonisphaeridium disparatum* sp. nov.; lateral view.

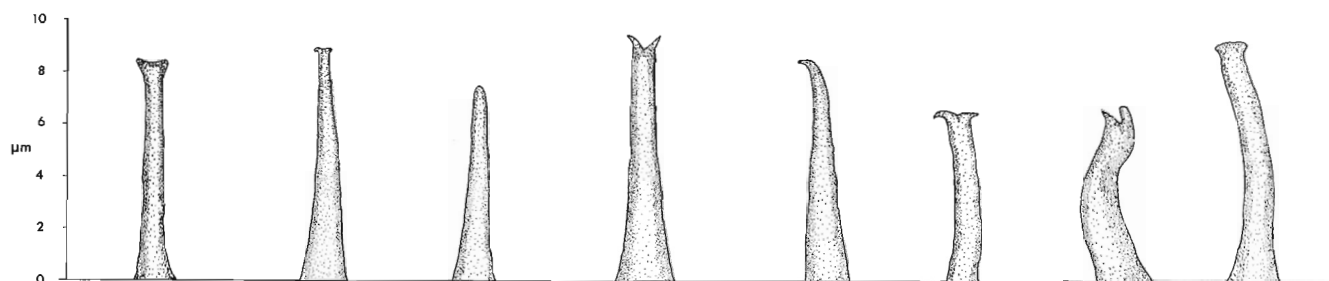


Figure 10. Processes of *Gorgonisphaeridium* sp. A; lateral view.

*Gorgonisphaeridium* sp. A

Plate 12, figure 12; Figure 10

Intensity of vesicle wall granulation, as evident under both light and scanning electron microscopes, also shows some variation.

**Comparison.** An Ohio Late Devonian species, *Gorgonisphaeridium plerispinosum* Wicander, 1974 (p. 26; Pl. 13, figs. 1–3), shows some resemblance to specimens of *G. granatum* sp. nov. having relatively fine and close-spaced processes. However, Wicander's species has a scabrate, not granulate, vesicle wall, about 1  $\mu\text{m}$  thick.

*Gorgonisphaeridium* sp. cf. *Michrhystridium sericum*  
Deunff, 1961

Plate 9, figures 17–21

Cf. 1954 *Michrhystridium sericum* Deunff, fig. 16 (nom. nud.) (1954b).  
Cf. 1961 *Michrhystridium sericum* Deunff, p. 218.

**Description.** Vesicle spherical to spheroidal. Vesicle wall 1–1.5  $\mu\text{m}$  thick, sculpture indistinct (scabrate or finely granulate); covered with diminutive, solid, upright, psilate processes with acuminate distal termini and of homomorphic character. Proximal process contacts are angular to slightly curved. Dimensions of processes—length 1–3.5  $\mu\text{m}$ , basal diameter 0.5–1  $\mu\text{m}$ . Processes crowded but mostly discrete, usually 2–3  $\mu\text{m}$  apart. Excystment by simple splitting of vesicle wall.

**Dimensions** (12 specimens). Diameter of vesicle 20 (26) 34  $\mu\text{m}$ .

**Comparison.** This species, a relatively infrequent one in the present material, could not confidently be assigned to Deunff's (1961) species *sericum*, because the extremely brief description of the latter (apparently founded on only one specimen) provides no adequate basis of reference.

**Previous records.** Deunff's (1954b, 1961) source of *Michrhystridium sericum*, with which the above specimens are comparable, was an imprecisely dated, Early or Middle Devonian sample from Ontario.

**Description.** Vesicle originally spherical; outline circular to subcircular, well-defined from processes. Vesicle wall 1.5–2.5  $\mu\text{m}$  thick, densely granulate. Numerous, subcylindrical, solid processes developed  $\pm$  evenly over vesicle wall; processes taper gently towards distal extremity which may be simply acuminate, but in most instances is divided into two very short, equal, echinate furcations, or is incipiently bifurcate. Processes psilate; bases subcircular, 1–3  $\mu\text{m}$  in diameter; length 6–10  $\mu\text{m}$ ; spaced 1–8  $\mu\text{m}$  apart. No excystment structure observed.

**Dimensions** (6 specimens). Diameter of vesicle 30 (40) 47  $\mu\text{m}$ ; overall diameter 40 (48) 54  $\mu\text{m}$ .

**Comparison.** *Michrhystridium alloiteau* and *M. cf. alloiteau*, described by Deunff (1955, 1957) from imprecisely dated Devonian rocks of Ontario, are superficially very similar to the specimens described above. However, whereas the latter have solid processes, Deunff maintained that the processes are hollow in his species.

Another of Deunff's taxa from Ontario, *M. paucispinum* Deunff, 1961 (p. 218), could well be conspecific with the present specimens, but the description and illustration given by Deunff (1954b, 1961) are insufficient for comparative purposes.

*Gorgonisphaeridium* sp. B

Plate 12, figures 10, 11; Figure 11

**Description.** Vesicle spherical; outline circular, distinct from processes. Vesicle wall 1.7–2  $\mu\text{m}$  thick, finely and uniformly granulate; with numerous discrete, solid, psilate processes that are dominantly homomorphic and distally branched. Processes subcylindrical and relatively short (3–6  $\mu\text{m}$ ); bases

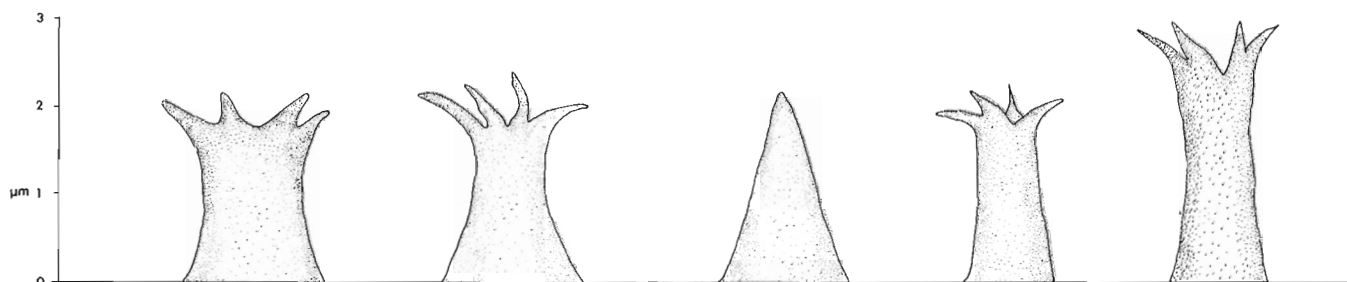


Figure 11. Processes of *Gorgonisphaeridium* sp. B; lateral view.

circular, 1.5–2.2  $\mu\text{m}$  broad, and 3–8  $\mu\text{m}$  apart; tapering only slightly to multifurcate distal extremities whence 4–6 short, subequal, spinelike branches project. An occasional acuminate (unbranched) process may be interspersed among the characteristic branched processes. Excystment by simple splitting of vesicle wall.

*Dimensions* (4 specimens). Diameter of vesicle 28–39  $\mu\text{m}$ .

*Comparison*. No closely comparable form appears to have previously been described.

### Genus *Hapsidopalla* gen. nov.

*Diagnosis*. Vesicle hollow, apparently single-layered, originally spherical to ellipsoidal; outline circular to subcircular or oval, clearly differentiated from processes. Numerous,  $\pm$ evenly spaced, hollow, essentially homomorphic and smooth processes project from vesicle wall and branch distally; tips closed. Though discrete from one another, adjacent processes are interconnected proximally by muri that form a distinct  $\pm$ uniform reticulum sculpturing the vesicle surface; processes characteristically project from junctions of muri, never from lacunae. Lacunae typically triangular to polygonal. Interior of processes in free communication with vesicle cavity. Excystment by splitting of vesicle wall.

*Name derivation*. Gr., *hapsidos*, meshed, netted; Gr., *palla*, ball. Gender feminine.

*Type species* (here designated). *Hapsidopalla sannemannii* (Deunff) comb. nov., emend.; described below.

*Other species*. 1. *Hapsidopalla exornata* (Deunff) comb. nov., emend.; described below.

2. *Hapsidopalla reticulata* (Pöthe de Baldis) comb. nov. Basionym: *Tylotopalla reticulata* Pöthe de Baldis, 1975 (1975a, p. 500, 503; Pl. 2, figs. 4, 6). Occurrence: Middle Silurian (Wenlock); San Juan Province, Argentina.

3. *Hapsidopalla venusta* (Sannemann) comb. nov. Basionym: *Hystrichosphaeridium venustum* Sannemann, 1955 (p. 345; Pl. 5, figs. 11a, 11b; Fig. 15). Occurrence: Middle Devonian (upper Givetian); Schübelebene, Frankenwald, Germany.

*Comparison*. Insofar as the species here allocated to *Hapsidopalla* gen. nov. display  $\pm$ equifurcate distal termini to the processes, the genus is closely comparable to *Ammonidium*

Lister, 1970 (p. 48–49). However, the chief difference between the two genera lies in the character of the vesicle wall sculpture: viz. reticulate in *Hapsidopalla* vs. smooth to granulate or rugulate in *Ammonidium*. Vesicle sculpturing also serves to distinguish the new genus from *Tylotopalla* Loeblich, 1970 (p. 737: granulate, rugulate, scabrate) and *Diaphorochroa* Wicander, 1974 (p. 18: granulate). The vesicle of *Acriora* Wicander, 1974 (p. 15–16) has corrugate–foveolate, not reticulate, sculpture; moreover the process interiors do not communicate with the vesicle cavity as they freely do in *Hapsidopalla*.

The type species of *Pterosphaerula* Cramer, 1967, *P. astrala* Cramer, 1967 (p. 29–30; Pl. 2, fig. 20), has a reticulate sculpture on its ‘central body’ that is somewhat similar to the overall reticulation of *Hapsidopalla* specimens. However, Cramer’s form possesses only simple (nonfurcate) supra-reticulate protrusions; further, its central body is circumscribed by a psilate lamellar structure.

### *Hapsidopalla exornata* (Deunff) comb. nov., emend.

Plate 10, figures 1–6, Figure 12

1967 *Baltisphaeridium exornatum* Deunff, p. 260; Figs. 1, 3, 4, 19.

*Emended diagnosis*. Vesicle originally spherical or almost so; outline circular to subcircular. Vesicle with distinctive finely reticulate sculpture consisting of numerous, interconnected, rosettelike series of radiating, low, narrow muri (0.7  $\mu\text{m}$  or less wide and 0.5–1  $\mu\text{m}$  high) that enclose sharply defined triangular lacunae (0.5–1.3  $\mu\text{m}$  across). The centre of each series, where muri converge, is either a low, smooth, rounded elevation, or marks the base of a process. Processes homomorphic, projecting  $\pm$ regularly and discretely from reticulate vesicle surface, gradually tapering to terminate distally with rounded or slightly concave distal ends from which arise, as a single series, 2–6 fine, simple, often bent, spinose projections (up to 6  $\mu\text{m}$  long, usually 2–3  $\mu\text{m}$ ; subequal on given process). Processes otherwise psilate to sparsely microgranulate; walls of approximately same thickness as lacunate vesicle (i.e., 0.5  $\mu\text{m}$  or less); bases of processes circular to subcircular in outline, 1.5–4  $\mu\text{m}$  broad, and spaced 2–12  $\mu\text{m}$  apart; curved contact with vesicle (i.e., in lateral view); length of processes, 5–13  $\mu\text{m}$ . Hollow process interiors communicate freely with vesicle cavity. Excystment by simple splitting of vesicle wall.

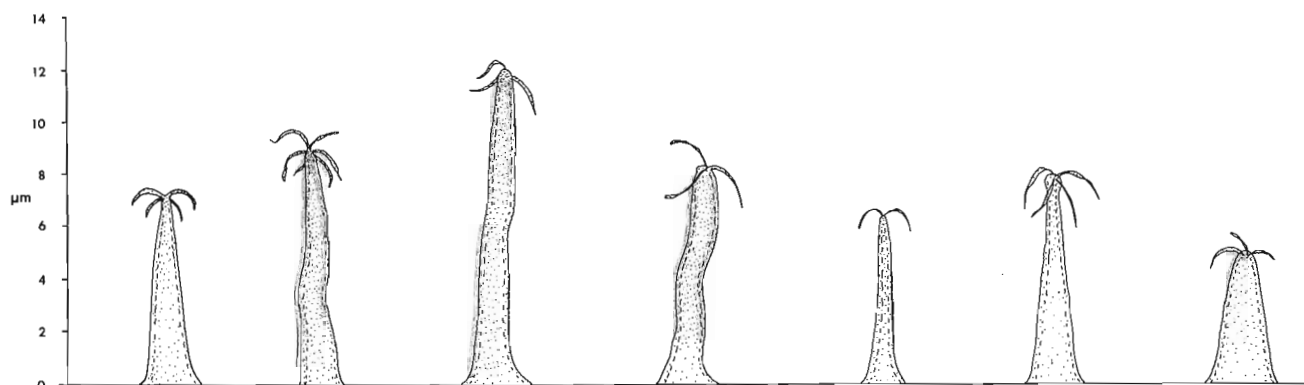


Figure 12. Processes of *Hapsidopalla exornata* (Deunff) comb. nov., emend.; lateral view.

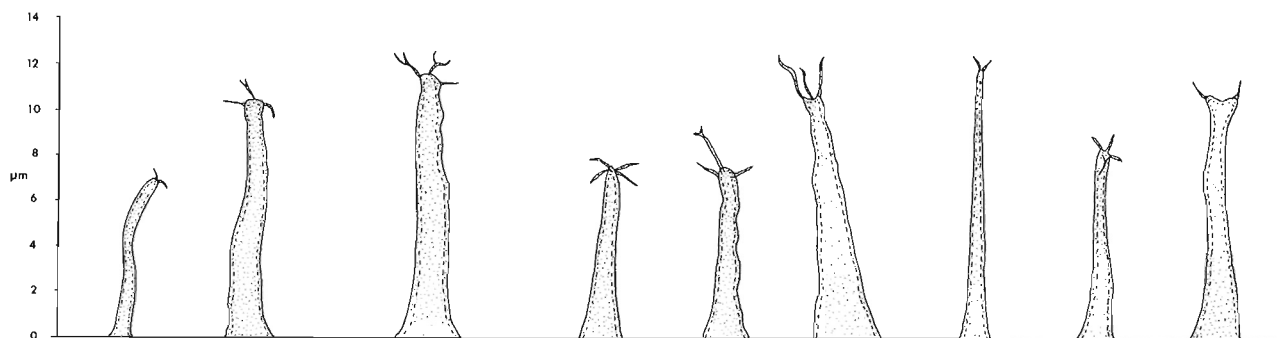


Figure 13. Processes of *Hapsidopalla sannemannii* (Deunff) comb. nov., emend.; lateral view.

**Dimensions** (15 specimens). Diameter of vesicle 25 (38) 51  $\mu\text{m}$ ; overall diameter 38 (55) 74  $\mu\text{m}$ .

**Previous records.** *Hapsidopalla exornata* (Deunff) comb. nov. has been reported previously from probable Frasnian chert exposed at Kettle Point, southern Ontario (Deunff, 1967).

*Hapsidopalla sannemannii* (Deunff) comb. nov., emend.

Plate 10, figures 7–13; Figure 13

1957 *Michrhystridium sannemanni* Deunff, p. 6; Pl. 13, fig. 1.

**Emended diagnosis.** Vesicle originally spherical or almost so; outline circular, subcircular, or oval. Vesicle wall very thin (0.5  $\mu\text{m}$  or less), bearing well-defined reticulate sculpture consisting of: numerous, interconnected, rosettelike series of radiating, low muri (about 0.5–2  $\mu\text{m}$  wide and 1–1.5  $\mu\text{m}$  high) that enclose triangular (or occasionally rectangular or polygonal) lacunae. Lacunae 3–10  $\mu\text{m}$  in maximum dimension and distinctly concave (surface view). Arising from 'rosette' centres (i.e., from junctions of muri) are hollow, homomorphic, gradually tapering processes, of similar thickness to unridged vesicle and surficially either psilate or sparsely microgranulate. Length of processes, 5–14  $\mu\text{m}$  (usually 8–9  $\mu\text{m}$ ); basal outline circular to subcircular, diameter 1.5–3.5  $\mu\text{m}$ , spaced 3–8  $\mu\text{m}$  apart; curved proximal contact with vesicle (i.e., in lateral view). Distal ends of processes rounded to somewhat flattened or gently concave, each bearing 2–4 diminutive, equal or unequal spinose projections that are 0.5–4  $\mu\text{m}$  long and are occasionally bifurcant. Vesicle cavity and process interiors in free communication. Excystment by simple splitting of vesicle wall.

**Dimensions** (30 specimens). Diameter of vesicle 26 (39) 52  $\mu\text{m}$ ; overall diameter 40 (56) 75  $\mu\text{m}$ .

**Comparison.** Despite the close similarity between *Hapsidopalla sannemannii* (Deunff) comb. nov. and *H. exornata* (described above), as evinced by their respective diagnoses, the two species can be distinguished without difficulty. The salient difference lies in the consistently much finer reticulate sculpture developed on the vesicle wall of *H. exornata*. This basic distinction is clearly shown in Deunff's original illustrations (1957, 1967), and in the illustrations of the present paper. Moreover, in *H. sannemannii* the mode of distal process branching tends to be less regular than in *H. exornata*, but this is clearly discernible only by scanning electron microscopy. It is noteworthy that the two species occur at

different stratigraphic levels in the presently studied sequence, i.e., are of mutually exclusive occurrence (see Table 2).

*Baltisphaeridium carrascum*, a species described by Cramer (1967, p. 243; Pl. 1, fig. 1) from the Spanish Lower Devonian, superficially resembles *H. sannemannii* but the vesicle of Cramer's species was stated to be psilate.

**Previous records.** Deunff (1957, 1966b) recorded *H. sannemannii* from an imprecisely dated Devonian sample from Ontario (Middle or perhaps Early Devonian).

#### Genus *Lophosphaeridium* Timofeev ex Downie, 1963

**Type species.** *Lophosphaeridium rarum* Timofeev, 1959; by subsequent designation of Downie (1963, p. 630).

**Generic characters.** Vesicle originally spherical or ellipsoidal, hollow; single-layered wall bearing simple, short, solid tubercles, e.g., grana, verrucae, bacula. After Timofeev (1959, p. 29), Downie (1963, p. 630).

**Discussion and comparison.** As currently understood, *Lophosphaeridium* Timofeev ex Downie, 1963 is a rather imprecise generic category as it embraces vesicles bearing, collectively, a variety of process types, all relatively inconspicuous and, according to Downie (1963, p. 630) and Lister (1970, p. 76), invariably solid.

However, pilate-processed forms are now attributable to *Helosphaeridium* Lister, 1970 (p. 76); and for at least some of the forms with short, spinelike processes, *Gorgonisphaeridium* Staplin, Jansonius and Pocock, 1965 (p. 192) and other genera are available.

#### *Lophosphaeridium dumalis* sp. nov.

Plate 11, figures 1–5; Figure 14

**Diagnosis.** Vesicle originally spherical or subspherical; outline circular or subcircular. Vesicle wall psilate, 0.7–1.3  $\mu\text{m}$  thick, often deformed by large-scale compression folds; bearing numerous, short, solid, discrete,  $\pm$ homomorphic processes that are of baculate form, being parallel-sided or showing slight taper to truncate (rarely rounded) distal extremities. Processes 1–1.7  $\mu\text{m}$  long, 1–3  $\mu\text{m}$  apart; bases circular to subcircular, diameter conspicuously variable on same specimen (range 0.3–1.3  $\mu\text{m}$ ). Angular proximal process contacts. Excystment by simple splitting of vesicle wall.

**Dimensions** (16 specimens). Diameter of vesicle 40 (49) 62  $\mu\text{m}$ .

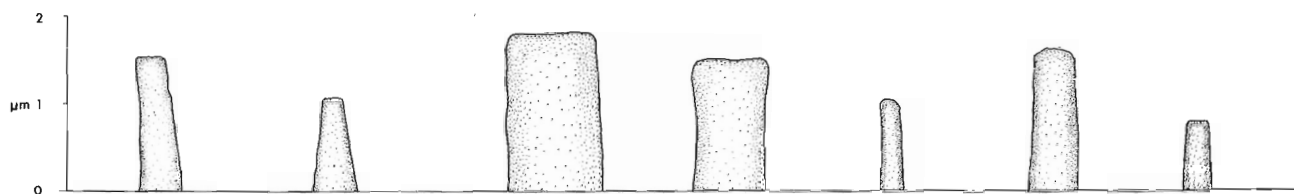


Figure 14. Processes of *Lophosphaeridium dumalis* sp. nov.; lateral view.

*Holotype*. Slide 8080-1,  $37.1 \times 113.5$ , GSC 48387; Plate 11, figure 1. Vesicle subcircular (outline distorted by compression-folds), maximum diameter  $59 \mu\text{m}$ ; psilate wall  $1.2 \mu\text{m}$  thick; processes numerous, baculate in form, averaging  $1.3 \mu\text{m}$  long, width variation  $0.5\text{--}1.3 \mu\text{m}$ .

*Type locality*. Ontario, Moose River Basin; Kwataboahagan Formation, Middle Devonian (Eifelian); Jaab Lake No. 1 well, core, 378–380 feet; GSC loc. 8080.

*Name derivation*. Lat., *dumalis*, bristly.

*Remarks and comparison*. Especially characteristic of *Lophosphaeridium dumalis* sp. nov. is the uniformity of process length, coupled with variability of process diameter, on a given specimen. A superficial resemblance exists between this species and the European Silurian species *L. microspinosum* (Eisenack, 1954, p. 209; Pl. 1, fig. 8) Downie, 1963. However more precise information, including illustrations, of Eisenack's species are needed to assess the degree of similarity.

#### Genus *Micrhystridium* Deflandre, 1937

*Type species*. *Micrhystridium inconspicuum* Deflandre, 1937; by original designation.

*Generic characters*. Vesicle hollow, subspherical to sub-polygonal; with numerous homomorphic processes of simple spinose form having closed tips and free internal communication with vesicle. No obvious differentiation in wall structure between processes and vesicle; sculpture minor or absent or both. After Staplin *et al.* (1965, p. 180).

*Discussion*. Kjellström (1971, p. 43) altered the diagnosis of *Goniosphaeridium* Eisenack, 1969 by imposing a lower size limit ( $20 \mu\text{m}$ ) on its vesicles. This was to distinguish it from *Micrhystridium* Deflandre, 1937. However, such arbitrary size limitations, in the absence of more definitive morphological criteria, are usually difficult to justify and indeed to apply (see Staplin, 1961, p. 404, 408; Staplin *et al.*, 1965; Loeblich, 1970, p. 707, 727–728). Presumably *Goniosphaeridium* could be diagnosed more cohesively around the type and related species so as to permit more meaningful and practical distinction from *Micrhystridium*.

Wicander (1974, p. 18) cited granulation on vesicle wall of his monotypic genus *Crassisphaeridium* and distinction of processes from vesicle, as distinguishing criteria in relation to *Micrhystridium*. The granulate sculpture, however, is scarcely obvious on the single photograph of *C. inusitatum* Wicander, 1974 (Pl. 6, fig. 3), and it could prove difficult to maintain *Crassisphaeridium* as a discrete generic entity without more convincing substantiation.

Some controversy surrounds the question of wall stratification in *Micrhystridium*: see Loeblich (1970, p. 727–728), Sarjeant (1973, p. 39–40).

#### *Micrhystridium stellatum* Deflandre, 1945

Plate 11, figures 6–9

1942 *Micrhystridium stellatum* Deflandre, p. 476; Figs. 7, 8. (*nom. nud.*).  
1945 *Micrhystridium stellatum* Deflandre, p. 65; Pl. 3, figs. 16–19.

*Description*. Vesicle spherical or subspherical; outline roughly circular to subcircular, being strongly modified by the numerous, hollow, homomorphic processes that are radially directed, tapering, spinelike extensions of vesicle wall. Wall of vesicle and of processes  $0.5\text{--}1 \mu\text{m}$  thick; psilate to faintly scabrate under the light microscope; psilate to evenly, densely microgranulate under the scanning electron microscope. Processes number between 12 and 22 per vesicle, are evenly distributed, about  $5\text{--}14 \mu\text{m}$  long, and taper from subcircular bases (diameter  $1.5\text{--}3.5 \mu\text{m}$ ) to sharply acute apices. Processes open freely into vesicle cavity and have curved proximal contacts with vesicle. No obvious excystment structure observed.

*Dimensions* (25 specimens). Diameter of vesicle 12 (16)  $20 \mu\text{m}$ ; overall diameter 23 (29)  $36 \mu\text{m}$ .

*Previous records*. Small acritarchs, with simple hollow spinelike processes, assignable to *Micrhystridium stellatum*, have been recorded widely from marine sediments ranging in age from Silurian to Early Mesozoic (see, for example, Lister, 1970, p. 81–82).

#### Genus *Multiplicisphaeridium* Staplin emend. Staplin, Jansonius, and Pocock, 1965

*Type species*. *Multiplicisphaeridium ramispinosum* Staplin, 1961; by original designation.

*Generic characters*. Vesicle single-walled, hollow, originally spherical to ellipsoidal; outline circular to subcircular, rarely polygonal. Processes discrete, usually slender, of variable number; distally branched, sometimes complexly so; distal tips always closed. Processes of same or similar type on given specimen, i.e., are approximately homomorphic; interiors hollow, having unobstructed communication with vesicle cavity. Vesicle and process walls unsculptured or with very minor sculpture: essentially no differentiation between walls. Excystment by simple splitting of vesicle wall. After Staplin *et al.* (1965, p. 180).

*Discussion*. Since its original institution by Staplin (1961, p. 410), the genus *Multiplicisphaeridium* has been rejected by Eisenack (1962, p. 95), Downie and Sarjeant (1963, p. 85–87), and Cramer (1971, p. 46); and redefined by Staplin *et al.* (1965, p. 180), Eisenack (1969, p. 258–259), Lister (1970, p. 83–84), and Eisenack and Cramer (1973, p. 519–520). The circumscription adopted above is essentially that of Staplin *et al.* (1965) and is considered to constitute a practical and useful morphological category.

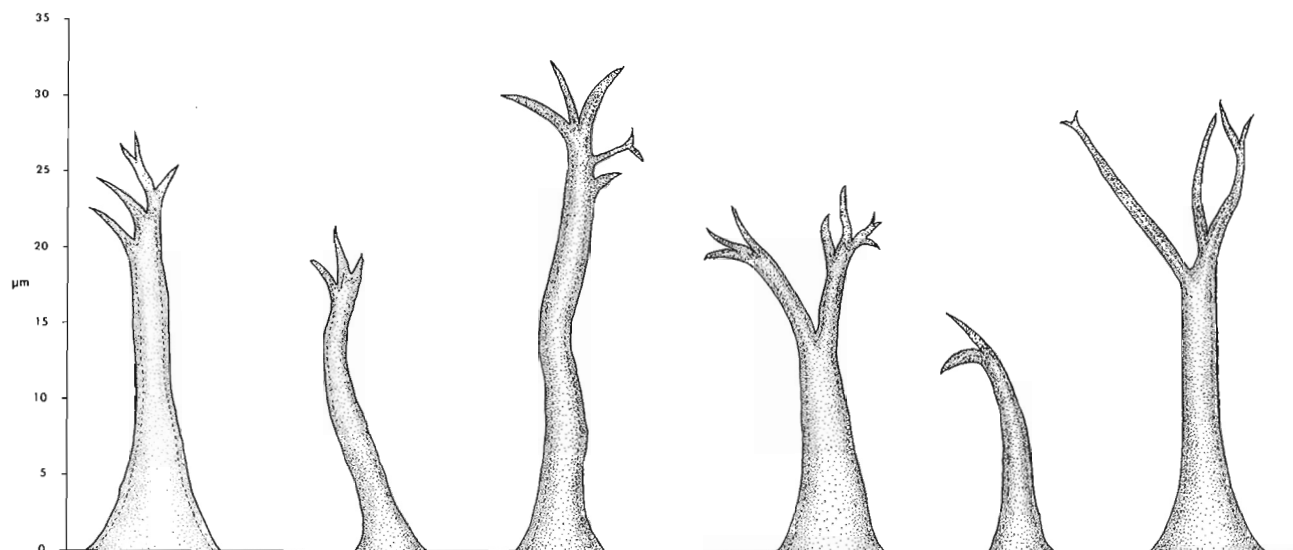


Figure 15. Processes of *Multiplicisphaeridium ampliatus* sp. nov.; lateral view.

*Comparison.* *Multiplicisphaeridium* is separable from *Baltisphaeridium* Eisenack emend. Eisenack, 1969 in having free communication between vesicle and process interiors and in lacking any structural disparity between vesicle and process walls. Note, however, that Eisenack (1969) has disputed this latter, putative distinction: see also Kjellström (1971, p. 17). *Diexallophasis* Loeblich, 1970 shows more conspicuous sculpture (i.e., on vesicle and process walls) than does *Multiplicisphaeridium*. This distinction is accepted here, albeit with some reservation (cf. Eisenack and Cramer, 1973, p. 6). *Diaphorochroa* Wicander, 1974 is a multiplicisphaerid genus, distinctive by reason of the contrasting character of its vesicle and process walls (granulate vs. psilate).

*Multiplicisphaeridium ampliatus* sp. nov.

Plate 11, figures 10–13; Figure 15

1964 *Baltisphaeridium* cf. *arbusculiferum* Downie; Cramer, Pl. 2, fig. 17 (1964b).

*Diagnosis.* Vesicle originally spherical or almost so; outline subcircular, but considerably modified by projections; wall about 0.7–1 µm thick, psilate. Curved proximal process contact with vesicle. Processes homomorphic; hollow interiors having uninterrupted communication with vesicle cavity; wall psilate. Processes display fairly irregular distal branching: bifurcant, trifurcant, to somewhat digitate, but never anastomosing; branching usually commences at least 0.5 of distance from proximal to distal extremity of process. Processes rigid, 6–10 in number; breadth at base 4–12 µm; length about 1–1.8 times vesicle diameter; distribution fairly regular. Excystment mode not observed.

*Dimensions* (16 specimens). Diameter of vesicle 16 (22) 30 µm; overall diameter 67 (77) 83 µm.

*Holotype.* Slide 8124-23, 40.6 × 108.8, GSC 48396; Plate 11, figures 11, 12. Vesicle subcircular in outline, 24 µm in diameter, with psilate wall, 1 µm thick and modified by compression-folds; eight prominent smooth-walled processes 5–10 µm broad at base, 28–40 µm long, distal quarter

or third of length shows mostly asymmetrical and bifurcant branching (up to third order).

*Type locality.* Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 925–927 feet; GSC loc. 8124.

*Name derivation.* Lat., *ampliatum*, widened, enlarged.

*Remarks.* Cramer's (1964b) specimen labelled '*Baltisphaeridium* cf. *arbusculiferum* Downie' was not specifically described, but from the photograph (Cramer, 1964b, Pl. 2, fig. 17) appears to be clearly representative of *Multiplicisphaeridium ampliatus* sp. nov.

*Comparison.* This comparatively rare species differs from *M. ramusculosum* (Downie) Lister, 1970 (described below) in having an ill-defined central body coupled with less slender and frequently less numerous processes. The Ordovician-Silurian species, *M. digitatum* (Eisenack) Eisenack, 1969 (see Eisenack and Cramer, 1973, p. 607–609), is basically similar in overall construction to *M. ampliatus* but is considerably larger and has more processes.

*Multiplicisphaeridium ramusculosum*  
(Deflandre) Lister, 1970

Plate 11, figures 14–20; Figure 16

1942 *Hystriosphæridium ramusculosum* Deflandre, p. 476; Figs. 2–6 (nom. nud.).

1945 *Hystriosphæridium ramusculosum* Deflandre, p. 63; Pl. 1, figs. 8–16; Figs. 38, 39.

1959 *Baltisphaeridium ramusculosum* (Deflandre) Downie, p. 59; Pl. 11, fig. 13.

1970 *Multiplicisphaeridium ramusculosum* (Deflandre) Lister, p. 92–93; Pl. 11, figs. 8, 11–14; Fig. 25a.

*Description.* Vesicle originally spherical or ellipsoidal; outline subcircular to oval; wall about 0.5–1 µm thick, psilate to faintly scabrate; clearly demarcated from processes. Curved proximal process contact with vesicle. Processes homomorphic or slightly heteromorphic; interiors hollow, and in free communication with vesicle cavity; wall psilate to faintly scabrate. Processes branch (bifurcate) distally from



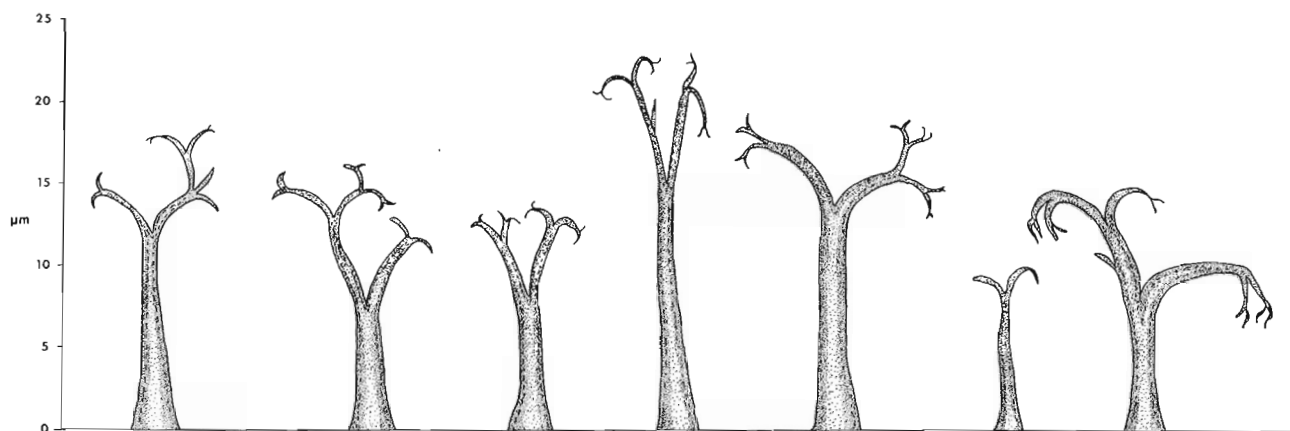


Figure 16. Processes of *Multiplicisphaeridium ramusculosum* (Deflandre) Lister, 1970; lateral view.

points 0.6 and (usually) more of distance from base to distal extremity of process; branching may be up to fourth order, variable on given specimen. Processes fairly evenly distributed and semirigid; usually numbering between 7 and 18; breadth at base 2–4  $\mu\text{m}$ ; length about 0.6 to 1.2 of vesicle diameter. Excystment, rarely evident, by simple splitting of vesicle wall.

**Dimensions** (50 specimens). Diameter of vesicle 13 (22) 34  $\mu\text{m}$ ; overall diameter 30 (45) 68  $\mu\text{m}$ .

**Remarks.** On the basis of Silurian material, this somewhat generalized category has been partly split into several infra-specific taxa ('varieties') by Cramer and Diez (1972, p. 155–157).

**Previous records.** *Multiplicisphaeridium ramusculosum* (Deflandre) Lister, 1970 appears to be a cosmopolitan form with a relatively broad stratigraphic range (Upper Ordovician to Middle Devonian): see Lister (1970, p. 93), Cramer (1971, p. 128).

#### Genus *Navifusa* Combaz, Lange, and Pansart, 1967

**Type species.** *Navifusa navis* (Eisenack) Combaz, Lange, and Pansart, 1967; by original designation.

**Generic characters.** Vesicle ellipsoidal,  $\pm$ elongate; i.e., of rodlike form with rounded ends and without processes. Wall single-layered; psilate or sculptured. Excystment mechanism not known. After Combaz *et al.* (1967, p. 295).

**Comparison.** *Navifusa* Combaz, Lange, and Pansart, 1967 is morphologically close to *Leiovalia* Eisenack, 1965 (1965b, p. 139), but the former can generally be distinguished by its ellipsoidal rather than ovoidal vesicle.

In an addendum to their paper, Combaz *et al.* (1967, p. 306–307) noted close similarity between *Navifusa* and *Quisquilites* Wilson and Urban, 1963. The latter, however, was reported (Wilson and Urban, 1963, 1971; Wilson and Skvarla, 1967) from light and electron microscopy as having a two-layered wall pierced by minute canals reminiscent of tasmanitid walls. It is possible that *Navifusa* and *Quisquilites* may prove to be congeneric.

#### *Navifusa bacillum* (Deunff) comb. nov.

Plate 12, figures 1–9

1955 *Leiofusa bacillum* Deunff, p. 148; Pl. 4, fig. 2.

1965 *Leiofusa brasiliensis* Brito and Santos, p. 7; Pl. 1, fig. 2; Pl. 2, fig. 3.  
1965 *Leiofusa brasiliensis lingula* Brito and Santos, p. 8; Pl. 1, fig. 1; Pl. 2, fig. 2.

1965 *Leiofusa cylindricum* Brito and Santos, p. 16; Pl. 1, fig. 4.

1965 *Leiofusa eisenacki* Brito and Santos, p. 17–18; Pl. 1, fig. 3.

1973 *Quisquilites widderensis* Legault, p. 60–61; Pl. 11, figs. 17–21.

1974 *Navifusa drosera* Wicander, p. 30; Pl. 15, figs. 7–9.

**Amplification of diagnosis.** Vesicle cylindrical or rodlike in form with broadly rounded ends. Wall apparently one-layered, 1–2  $\mu\text{m}$  thick; surface granulate, scabrate, to virtually psilate under light microscope; granulate to microgranulate under scanning electron microscope; grana up to 0.8  $\mu\text{m}$  in basal diameter, up to 2  $\mu\text{m}$  apart, and rarely exceeding 0.5  $\mu\text{m}$  in height. Over part or all of the surface of some specimens, grana are  $\pm$ distinctly aligned longitudinally to produce a pseudostriate effect under low magnification. No excystment structure observed.

**Dimensions** (50 specimens). Length of vesicle 63 (174) 300  $\mu\text{m}$ ; maximum width of vesicle 25 (39) 55  $\mu\text{m}$ .

**Remarks and comparison.** Breakages in vesicle walls are fairly common, but because of their inconsistency in extent and disposition they are regarded as fortuitous (i.e., preservational) rather than excystment features.

The distribution of sculptural elements (grana) varies from random to longitudinally aligned (see Pl. 12, figs. 7–9 herein; Jardiné and Yapaudjian, 1968, Pl. 5, fig. 14; Pöthe de Baldi, 1974a, Pl. 3, fig. 2). In the latter respect, some similarity to *Navifusa multistriata* (Brito) Combaz *et al.*, 1967 is evident; but Brito's species appears to have a more strongly striate appearance and the striations may be genuine grooves/ridges.

Many species attributed to *Navifusa* have been separated on slight grounds of size/shape of vesicle and their degree of granulation. In some cases only a very restricted number of specimens appear to have been studied for each species, and little or no attempt was made to gauge or document morphological variation among the categories recognized. Naviform vesicles are plentiful in many of the samples in the present material; consequently, it has been possible to study extensively, with both light and scanning electron microscopes, the variation displayed in both vesicle form and sculpture. The variation, as expressed in the above description, appears to be continuous and not unduly broad, and thus to indicate the presence of a single species. That species



is identifiable with what Deunff (1955) originally described as *Leiofusa bacillum*, and also embraces at least five other subsequently instituted species, as listed in above synonymy.

*Quisquilites widderensis* Legault, 1973 (p. 60–61; Pl. 11, figs. 17–21), from the Givetian of southwestern Ontario, was said to have a bilayered porate vesicle wall, which would of course render it distinct from *Navifusa bacillum*. However, the writer's re-examination of Legault's figured specimens indicates that the wall is of a single, externally granulate layer, entirely conformable with the specimens described above.

*Previous records.* As recognized herein, *N. bacillum* has been recorded from the Middle (and perhaps Lower) Devonian and Frasnian of southern Ontario (Deunff, 1955, 1966b, 1967; Legault, 1973); Devonian of Brazil (Brito and Santos, 1965; Brito, 1967a); Middle Devonian of Paraguay (Pöthe de Baldis, 1974a); Emsian to Upper Devonian of North Africa (Jardiné and Yapaudjian, 1968; Jardiné, 1972; Jardiné *et al.*, 1974); and Upper Devonian of Ohio (Wicander, 1974).

#### Genus *Onondagaella* Cramer, 1966 emend.

*Type species.* *Onondagaella asymmetrica* (Deunff) Cramer, 1966, here emended; by original designation.

*Emended diagnosis.* Vesicle hollow, with three processes, one developed at each apex of the invariably triangular vesicle. Vesicle wall one-layered, psilate or finely sculptured. Processes also psilate or finely sculptured; heteromorphic, to the extent that two are similar in form and size (i.e., are prominent, tapering, spinelike, subequal projections with closed tips), whilst the third is relatively short and stout and often has the appearance of being broken. Distal extremity of latter process has a circular opening or potential opening considered to be a cyclopyle (circular excystment opening: Eisenack, 1969) which in intact examples is seen to be closed by a thickened plug, subspherical or hemispherical in shape and here termed an epibystra. The interiors of all three processes open into and communicate freely with vesicle cavity.

*Discussion and comparison.* As circumscribed above, *Onondagaella* currently contains *O. asymmetrica* (Deunff) Cramer, 1966 and *O. deunffii* Cramer, 1966. Excluded from the genus now are species possessing a two-layered vesicle wall with the outer layer extended to form the processes. These displaced forms are reallocated subsequently in this paper to the genus *Tyligmasoma* nom. nov. pro *Triangulina* Cramer, 1964 (non *Triangulina* Malyavkina, 1949).

#### *Onondagaella asymmetrica* (Deunff) Cramer, 1966 emend.

Plate 12, figures 13–16; Plate 13, figures 10, 11

- 1954 *Veryhachium asymmetricum* Deunff, p. 1065 (1954b); Fig. 11 (nom. nud.).  
1955 *Veryhachium asymmetricum* Deunff, p. 143; Pl. 4, fig. 15; Fig. 6 (nom. nud.).  
1961 *Veryhachium asymmetricum* Deunff, p. 217–218.  
1966 *Onondagaella asymmetrica* (Deunff) Cramer, p. 87 (1966c); Fig. 2–15.

*Emended diagnosis.* Vesicle triangular with  $\pm$ straight sides and apices extended as three, hollow, heteromorphic pro-

cesses that communicate internally with vesicle cavity. The single layer of the vesicle wall is 0.7–1.5  $\mu$ m thick, and is scabrate, almost psilate or densely and finely rugulate to imperfectly reticulate (rugulae/muri up to 1  $\mu$ m wide and 0.5  $\mu$ m or less in height); vesicle wall usually displays strong, randomly disposed compression folds. Two processes are relatively long, tapering to bluntly acuminate or near-evexate tips (which are invariably closed), subequal on same specimen but together showing considerable variation among specimens: length 25–75  $\mu$ m, basal diameter 7–22  $\mu$ m. The third, a relatively short and stout process, is sub-cylindrical with slight taper towards distal extremity; length 9–22  $\mu$ m, basal diameter 11–25  $\mu$ m. This process evidently served as an excystment exit as it terminates distally with a circular opening or potential opening, here interpreted as a cyclopyle. In some, presumably nonexcysted specimens (about 40 per cent of those observed), partial or complete closure is effected by a distinct, spheroidal to hemispherical, thickened plug or stopperlike structure—here termed an epibystra—5–8  $\mu$ m in maximum dimension; when hemispherical, the epibystra's convex side always points inwards (i.e., is directed towards process base). The  $\pm$ flat top of the epibystra, where present, is either flush with the distal end of the process or just below it. Process walls generally display even more subdued sculpture than vesicle wall and are usually slightly thinner. The shorter/stouter process, in particular, is susceptible to breakage.

*Dimensions* (35 specimens). Diameter of vesicle 51 (80) 133  $\mu$ m.

*Remarks.* The emended diagnosis of this species takes account especially of the morphology of the third, shorter process, which appears to embody an excystment mechanism.

*Previous records.* The original specimens of *Onondagaella asymmetrica* (Deunff) Cramer, 1966 emend. were extracted from sediment-infilling of a tabulate coral collected in Ontario from Middle, or possibly Lower Devonian strata (Deunff, 1954b, 1955, 1961, 1966b). Subsequently, Jardiné and Yapaudjian (1968), Jardiné (1972) and Jardiné *et al.* (1974) have reported the species from Lower Devonian (upper Siegenian–Eifelian) and possibly older (Ludlow–Gedinnian) sediments of the Algerian Sahara.

#### Genus *Ozotobrachion* Loeblich and Drugg, 1968

*Type species.* *Ozotobrachion palidodigitatus* (Cramer) comb. nov. (see below); originally designated, as *Ozotobrachion dactylos* Loeblich and Drugg, 1968, by Loeblich and Drugg (1968, p. 130).

*Generic characters.* Vesicle hollow, typically triangular in outline; less commonly ovate, subquadrangular, or polygonal; wall one-layered or possibly of two layers closely adpressed, surface psilate or finely sculptured. A hollow, thin-walled process arises from each vesicle angle; i.e., a total of three from a triangular vesicle; four from a rectangular one (if plane of compression includes all four process bases). At proximal ends, process interiors are closed off from vesicle cavity by development of internal basal plug; distal extremities typically branched dichotomously or digitately. Excystment structure consists of a  $\pm$ linear slit in

vesicle wall running from near base of one process to an adjacent one, typically along lateral margin of vesicle. After Loeblich and Drugg (1968, p. 130).

**Discussion.** *Ozotobranchion* Loeblich and Drugg, 1968, which is sometimes misspelt as *Ozotobranchion* (Cramer, 1971; Eisenack and Cramer, 1973), was regarded by Eisenack and Cramer (p. 857) as being synonymous with *Multiplicisphaeridium* Staplin emend. Eisenack, 1969, although was not formally included in the extensive synonymy list they attached to the latter genus (Eisenack and Cramer, 1973, p. 520). Earlier, Cramer (1971, p. 161) had regarded *Ozotobranchion* as congeneric with *Baltisphaeridium* Eisenack emend. Cramer, 1971. However, the author considers Loeblich and Drugg's taxon to constitute a reasonably discrete generic entity by reason of the form and relationships of the vesicle and processes, as expressed in the above circumscription.

**Comparison.** The genera *Ozotobranchion* and *Tyligmasoma* gen. nov. are similar in construction, but the latter is characterized by simple (unbranched) processes. *Goniolopadion* gen. nov. differs from both of these genera chiefly in its distinctly stellate outline.

*Ozotobranchion furcillatus* (Deunff) comb. nov.

Plate 13, figures 1–9; Plate 14, figures 13–16

- 1955 *Veryhachium furcillatum* Deunff, p. 146; Fig. 18.  
 1966 *Veryhachium vipereum* Deunff, p. 80–81 (1966b); Pl. 6, figs. 69, 71; Pl. X, fig. 78.  
 1968 *Ozotobranchion dicros* Loeblich and Drugg, p. 132; Pl. 2, figs. 1–7.  
 1971 *Baltisphaeridium dicros* (Loeblich and Drugg) Cramer, p. 170; Pl. 13, fig. 189; Fig. 52k.  
 1973 *Multiplicisphaeridium dicros* (Loeblich and Drugg) Eisenack and Cramer, p. 605–606.  
 1973 *Multiplicisphaeridium furcillatum* (Deunff) Eisenack and Cramer, p. 649.

**Amplification of diagnosis.** Vesicle usually triangular in outline, less commonly ovate, rectangular, or polygonal; wall 0.5–1.2  $\mu\text{m}$  thick; psilate to minutely granulate or echinate under the light microscope; scabrate, microgranulate, microreticulate or, rarely, completely psilate under the scanning electron microscope. Processes  $\pm$ homomorphic, typically three in number, less commonly two, four, five or six; one process normally arising from each vesicle corner. Processes hollow, thin-walled (0.3  $\mu\text{m}$  or less), transparent, psilate or sparsely microechinate or microgranulate; gradually tapering from base; normally bifurcately branched up to third order, the branching usually  $\pm$ terminal but may begin as little as one third of distance from base to distal extremity. Process interiors closed off from vesicle cavity by distinct basal plug, about 0.7–1.5  $\mu\text{m}$  thick. Dimensions of processes: length 18–48  $\mu\text{m}$  (usually 35–40  $\mu\text{m}$ ), basal diameter 2–5  $\mu\text{m}$ . Excystment mechanism (rarely seen): a simple,  $\pm$ linear split in vesicle wall, almost connecting base of one process with an adjacent one.

**Dimensions** (74 specimens). Diameter of vesicle 10 (21) 33  $\mu\text{m}$ .

**Remarks.** In *Ozotobranchion furcillatus* (Deunff) comb. nov., the processes are almost always well and regularly separated from each other, but very rarely two may arise from the same angular position on the vesicle. Scanning electron microscopy reveals considerable diversity in sculptural modification of

vesicle and process surfaces. In general, the latter is the less conspicuously sculptured. Process branches, particularly the narrow tenuous branchlets of ultimate bifurcations, are readily dissociated from remainder of process. Apparently simple (unbranched) processes commonly result from such preservational deficiencies. Nevertheless it must be pointed out that a minority of specimens appear to be equipped with one or more genuinely unbranched processes that terminate with simple acute tips. Tips of branches are invariably closed.

Close study of a large number of Moose River Basin specimens, as documented above, supports Deunff's (1966b, p. 81) intimation of close relationship between his species *Veryhachium furcillatum* and *V. vipereum*, to the extent that they are here regarded as synonymous with each other and with *Ozotobranchion dicros* Loeblich and Drugg, 1968.

**Comparison.** *Baltisphaeridium distentum* sp. nov. (described above) differs from *Ozotobranchion furcillatus* by having more processes (6–23) and a spherical vesicle. The single alleged specimen of *O. dicros* (= *O. furcillatus*) illustrated by Cramer (1971, Pl. 13, fig. 189; Fig. 52k) appears to lack the tenuous bifurcations normally associated with *O. furcillatus*; it might possibly be a representative of *O. palidodigitatus* (Cramer) comb. nov. However, as discussed below, the two species could well intergrade sufficiently to justify merging them.

**Previous records.** Described originally from an imprecisely dated Devonian sample from Ontario (Deunff, 1955), *O. furcillatus* has been reported subsequently as follows: from Lower Devonian (upper Gedinian) of Oklahoma (Loeblich and Drugg, 1968), Ludlow of Spain and Florida (Cramer, 1971; Cramer and Diez, 1972), Wenlock of Argentina (Pöthe de Baldi, 1975a) and probable Gedinian of Algerian Sahara (Jardiné *et al.*, 1974).

*Ozotobranchion palidodigitatus* (Cramer) comb. nov.

Plate 14, figures 11, 12

- 1967 *Baltisphaeridium palidodigitatum* Cramer, p. 25; Pl. 1, fig. 8; Fig. 3:5.  
 1968 *Ozotobranchion dactylos* Loeblich and Drugg, p. 130, 132; Pl. 1, figs. 1–6.  
 1971 *Baltisphaeridium palidodigitatum* Cramer emend. Cramer, p. 168–170; Pl. 13, fig. 192; Fig. 52j.  
 1973 *Multiplicisphaeridium palidodigitatum* (Cramer) Eisenack and Cramer, p. 709–711.

**Description and remarks.** Only a small proportion of the numerous Moose River Basin specimens assignable to the genus *Ozotobranchion* could positively be identified with its type species, *O. palidodigitatus* (Cramer) comb. nov. The particular specimens are closely similar to those identified as *O. furcillatus*, viz., in size/shape of vesicle, number/form of processes, sculpture of vesicle and processes; but differ in possessing digitate rather than bifurcating process terminations. Such difference served as the main basis for Loeblich and Drugg's (1968) separation of *O. dicros* (=junior synonym of *O. furcillatus*) from *O. dactylos* (=junior synonym of *O. palidodigitatus*: Cramer, 1971, p. 160–161, 168–169). Additionally, Loeblich and Drugg suggested that closed process tips characterize the former and open ones the latter. However, with regard to branching mode, no satisfactorily sharp distinction could be demonstrated in the present material, either within or among specimens. Further-

more, tips of well-preserved specimens (i.e., with intact processes) appear invariably to be closed. For these reasons, it would seem that continued acceptance of *furcillatus* and *palidodigitatus* as specifically distinct needs further confirmation, preferably from respective Ontario and Spanish topotypic materials.

Jardiné *et al.* (1974, Fig. 2) appear informally to have merged the two species, although they wrongly attributed the *dicros* epithet to Cramer.

*Dimensions* (12 specimens). Diameter of vesicle 16 (23) 31  $\mu\text{m}$ .

*Previous records.* *Ozotobranchion palidodigitatus* was originally described by Cramer (1967) from the upper Lower Devonian of northwest Spain. It was subsequently reported in somewhat older Lower Devonian (Gedinnian) rocks of Oklahoma (Loeblich and Drugg, 1968) and Algerian Sahara (Jardiné *et al.*, 1974), and in Wenlock strata of Argentina (Pöthe de Baldi, 1975a).

### Genus *Palacanthus* Wicander, 1974

*Type species.* *Palacanthus acutus* Wicander, 1974; by original designation.

*Generic characters.* Acritarchs with star-shaped outline; consisting of numerous prominent, simple, basally contiguous, homomorphic processes of cone- or spinelike form, and having closed tips. Processes co-planar, broad-based and diverging from common centre with the result that there is no clearly defined vesicle separate from processes. Interiors are invariably hollow so that free internal communication exists from processes into central cavity; walls single-layered, psilate. No excystment structure recorded. After Wicander (1974, p. 30).

*Comparison.* This genus is closely similar to *Estiastra* Eisenack, 1959 (p. 201) but appears to be distinguishable in having processes developed in a single plane (cf. Cramer, 1971, p. 118).

*Palacanthus ledanoisii* (Deunff) comb. nov., emend.

Plate 14, figures 1–10

- 1957 *Veryhachium le danoisi* Deunff, p. 9; Fig. 6.  
 1962 *Veryhachium stelligerum* auct. non Deunff; Stockmans and Willière, p. 85 (1962b); Pl. 1, fig. 8; Fig. 10.  
 1966 *Veryhachium* cf. *le danoisi* Deunff; Deunff, p. 23 (1966a); Fig. 7.  
 1966 *Veryhachium le danoisi* Deunff; Deunff, p. 54–55 (1966b); Pl. 10, fig. 111.  
 1966 *Veryhachium* cf. *stelligerum* of Deunff (*pars*), p. 78 (1966b); Pl. 3, figs. 32, 35, 38, 39.  
 1974 *Estiastra pentagonalis* Pöthe de Baldi, p. 371 (1974a); Pl. 2, fig. 5.

*Emended diagnosis.* Outline of acritarchs star-shaped, with 3–8 processes (average 4–5 processes) disposed  $\pm$ symmetrically in a single plane. Processes have broad (somewhat bulbous), mutually contiguous bases, 6–11  $\mu\text{m}$  in diameter; interiors hollow and opening freely into central cavity. Processes attain lengths of 20–45  $\mu\text{m}$  (subequal on same specimen) and taper to sharp or blunted, closed distal tips. Very rarely, distal extremity of one process in the radial series develops minor bifurcation or pinnate branching; otherwise processes are homomorphic. Walls single-layered, 0.5–1  $\mu\text{m}$  thick; psilate to scabrate under light microscope, psilate to microgranulate or irregularly micropunctate under

scanning electron microscope. A few examples display a broadly sinuous to almost linear split crossing vesicle subcentrally; this may either represent excystment aperture or be a fortuitous crack in wall.

*Dimensions* (65 specimens). Overall diameter 40 (62) 97  $\mu\text{m}$ .

*Remarks.* This species is plentiful in many of the Moose River Basin samples, and the above diagnosis documents continuous variation in the morphology of the numerous specimens studied. In particular, the number of processes ranges from three to eight per vesicle, the majority having either four or five. Accordingly, there seems to be no convincing reason for recognizing in the assemblages otherwise identical taxa for which either four or five had been specified as process number; viz., *Veryhachium ledanoisii* sensu Deunff, 1957 and *Estiastra pentagonalis* Pöthe de Baldi, 1974 respectively.

*Comparison.* *Palacanthus signum* (Deunff, 1968, p. 343; Fig. 7) Wicander, 1974, from the Middle Devonian of France, differs from *P. ledanoisii* (Deunff) comb. nov., emend. in having shorter processes and in being smaller overall.

*Previous records.* *P. ledanoisii* was originally described by Deunff (1957) from the Middle (or perhaps Lower) Devonian of Ontario. Subsequently recorded occurrences, as per above synonymy, are from the Devonian of Tunisia (Deunff, 1966a, b) and Brittany (Deunff, 1966b), Frasnian of Belgium (Stockmans and Willière, 1962b) and Middle Devonian of Paraguay (Pöthe de Baldi, 1974a).

### Genus *Polyedryxium* Deunff ex Deunff, 1961

*Type species.* *Polyedryxium deflandrei* Deunff, 1961; originally designated by Deunff (1954b, p. 1064, footnote 3) when the species was a *nomen nudum*; redesignated by Deunff (1961, p. 216) when valid publication of *P. deflandrei* was first achieved.

*Generic characters.* Vesicle hollow, cubic to polyhedral,  $\pm$ distinctly set off from processes or ridges, and often with numerous faces that frequently arch inwards (i.e., are superficially concave). Neighbouring sides of faces of the vesicle are separated by membranous crests or ridges often carrying denticulate or crenulate elements. Corners or angles of the vesicle are often prolonged into simple or digitate processes or angular 'fleurons'. After Deunff (1961, p. 216–217), Jansonius (1962, p. 86–87), and Deunff (1971, p. 17–19).

*Discussion.* Acritarchs of the *Polyedryxium* type, as illustrated by Deunff (1954b, 1955, 1966b, 1971), are a diverse and conspicuous feature of Lower to Middle Devonian acritarch assemblages. However, the generic circumscription of the group still appears to be in need of clarification and refinement despite Deunff's (1971) attempt to do this (cf. Legault, 1973, p. 55).

*Eisenackidium* Cramer and Diez, 1968 emend. Eisenack and Cramer, 1973 (p. 433–435) and *Crameria* Lister, 1970 (p. 61–62) are obviously morphologically akin to *Polyedryxium*. The first two taxa are congeneric, as Jardiné *et al.* (1972, p. 299) and Eisenack and Cramer (1973, p. 434) contended. In contradistinction to the latter authors, Jardiné and his collaborators claimed that *Eisenackidium* must be

rejected as a *nomen nudum*. There seems to be no valid reason for suppressing Cramer and Diez's genus on that ground, but possibly both it, and what presumably must be taken as its junior synonym (*Crameria*), should be merged as one genus with *Polyedryxium*; the latter would then take precedence as senior synonym. Clearly a re-evaluation of type species *E. triplodermum* (Cramer) Cramer and Diez, 1968 will be of critical importance in this regard: i.e., whether its vesicle is genuinely layered; also the nature of the so-called endodermal cyst and of the 'nerves' of the processes (see 'Remarks' under *P. pharaonis*, below).

*Muraticavea* Wicander, 1974 (p. 14), which was monotypically established with *M. enteicha* Wicander, 1974 (p. 14; Pl. 15, figs. 1–3), may prove difficult to maintain separately from *Polyedryxium*. According to Wicander, *Muraticavea* differs from *Polyedryxium* 'in lacking serrated edges and projections from the vesicle'; however, these are not invariable attributes of the latter genus.

### *Polyedryxium bathyaster* Deunff, 1961

#### Plate 15, figures 1, 2

1954 *Polyedryxium bathyaster* Deunff, p. 1065 (1954b); Fig. 3 (*nom. nud.*).

1955 *Polyedryxium bathyaster* Deunff, p. 142; Fig. 3 (*nom. nud.*).

1961 *Polyedryxium bathyaster* Deunff, p. 217.

**Description.** Vesicle prismatic, consisting of one set of five, equal,  $\pm$ square-outlined faces that are concave-surfaced; and two pentagonal faces, one at either end of prism and subparallel to each other, though also with concave surfaces. Wall of vesicle single-layered, 2–2.5  $\mu$ m thick, faintly sculptured with grana (up to 1  $\mu$ m in basal diameter and height) and very fine rugulae that are usually connected to grana bases, often interconnecting adjacent grana. Where each vesicle face adjoins another, vesicle wall extends outwards by a distance of 3–8  $\mu$ m, forming a seemingly  $\pm$ continuous ridge that is, in part, very thin and membranous, but partly composed of prominent strutlike elements that are of similar thickness to vesicle wall and are often hollow or digitate towards distal end. No excystment structure seen.

**Dimensions** (3 specimens). Overall diameter (diametrically across a pentagonal side) 52–62  $\mu$ m.

**Remarks.** The relatively thick, strutlike elements within the membranous ridge-extensions of the vesicle wall are durable, so that in poorly preserved specimens they may be all that remains of the extension. The same applies to *Polyedryxium deflandrei* Deunff, 1961 (described below).

**Previous records.** Deunff's (1954b, 1955, 1961, 1966b, 1971) records are all from a single sample, Middle or Early Devonian in age, from Ontario.

### *Polyedryxium carnatum* sp. nov.

#### Plate 15, figures 7–13

**Diagnosis.** Vesicle polyhedral, with polygonal to subcircular outline; wall one-layered. Vesicle surface divided into 11–22 concave faces (each 20–35  $\mu$ m in maximum width) with polygonal boundaries marked by upturned vesicle wall forming low ridges. Ridges develop very thin,  $\pm$ transparent and finely frilled crests 2–5  $\mu$ m high. Apart from crests,

vesicle wall 1.5–3  $\mu$ m thick; very finely reticulate (visible under  $\times 100$  oil-immersion objective of light microscope, as well as under scanning electron microscope) with polygonal lacunae, 1.5–5  $\mu$ m across, separated by muri about 0.5  $\mu$ m high and broad. Excystment mechanism (rarely observed): a simple split in vesicle wall.

**Dimensions** (50 specimens). Overall diameter 48 (71) 96  $\mu$ m.

**Holotype.** Slide 8124-29, 36.6  $\times$  106.9, GSC 48451; Plate 15, figure 10. Vesicle 94  $\mu$ m in diameter, rounded to polygonal in outline; 10 concave faces per hemisphere, averaging 28  $\mu$ m across, separated by 4–8  $\mu$ m wide ridges each *ca.* 7  $\mu$ m high, including very thin, finely frilled distal extremity; the 'frilling' seemingly arises from very narrow, low, parallel muri that elsewhere on vesicle form a very fine, polygonal-meshed, reticulate sculpture.

**Type locality.** Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 925–927 ft; GSC loc. 8124.

**Name derivation.** Lat., *carnatus*, fleshy, corpulent.

**Remarks.** Because of their delicate morphology, the markedly thinned and finely fluted ridge crests are only represented fully on particularly well preserved specimens. When the crestal extremities are absent, or by focussing below them, the two upturned wall segments of adjacent faces are frequently seen to be separated by a narrow slit. This slit broadens  $\pm$  abruptly to a triangular 'gape' (in surface view) at ridge junctions.

**Comparison.** *Cymatiosphaera labyrinthica*, *C. parvicarina*, and *Muraticavea enteicha*, all described by Wicander (1974, p. 13, 14) from the Ohio Upper Devonian, are similar to *Polyedryxium carnatum* sp. nov., but differ in the morphology of the vesicle-wall ridges. Two species described by Deunff (1957, p. 8; 1966b, p. 93–94) from the Middle or perhaps Lower Devonian of Ontario, *P. mirum* and *P. robustum*, are respectively considerably smaller and larger than *P. carnatum*.

### *Polyedryxium decorum* Deunff, 1955

#### Plate 15, figures 4–6; Plate 16, figures 5–7

1955 *Polyedryxium decorum* Deunff, p. 146–147; Pl. 2, fig. 1.

1967 *Polyedryxium* cf. *decorum* Deunff; Deunff, p. 259, Fig. 6.

**Amplification of diagnosis.** Vesicle polyhedral, consisting of 6–9 concave faces, each 25–45  $\mu$ m in maximum width, with polygonal (commonly pentagonal or hexagonal) boundaries. Boundaries marked by membranous, crenulated ridges, 4–10  $\mu$ m high, that include thicker strutlike structures that are subcylindrical, essentially hollow, and 1–4  $\mu$ m broad. These structures, modifying the otherwise thin, transparent ridges, are normally confined to the latter but may project distally beyond (by up to 16  $\mu$ m) as discrete tubular or chimneylike elements (usually at ridge junctions). In plan view, openings of structures are triangular or elliptical; the former especially at ridge junctions, the latter within a ridge. Vesicle wall single-layered; between ridges 1.5–2.5  $\mu$ m thick, scabrate or almost psilate under light microscope, micro-reticulate to microrugulate under scanning electron microscope. Excystment structure not discerned.

*Dimensions* (33 specimens). Diameter of vesicle 46 (65) 85  $\mu\text{m}$ .

*Previous records.* Deunff's (1955, 1966b, 1971) records are from an uncertainly dated Ontario sample, Middle or perhaps Early Devonian in age. In 1967 Deunff recorded the species from probable Frasnian chert at Kettle Point, Ontario. Cramer (1964b) reported the rare occurrence of *Polyedryxium decorum* Deunff, 1955 in the Spanish Lower Devonian. Jardiné *et al.* (1974) charted a dominantly Middle Devonian distribution for *P. decorum* in the Algerian Sahara and indicated possible extension into the Emsian.

*Polyedryxium deflandrei* Deunff, 1961

Plate 15, figure 3

1954 *Polyedryxium deflandrei* Deunff, p. 1065 (1954b); Fig. 8 (*non. nud.*).  
1955 *Polyedryxium deflandrei* Deunff, Pl. 1, fig. 2; p. 148; Fig. 8 (*nom. nud.*).  
1961 *Polyedryxium deflandrei* Deunff, p. 217.

*Description.* Vesicle cuboid in form with concave faces; wall single-layered, about 2  $\mu\text{m}$  thick, showing faint granulate sculpture (elements usually 0.5  $\mu\text{m}$  or less in basal diameter and height). Junctions of vesicle faces marked by mostly very thin and membranous, apparently continuous ridges, extending about 4–9  $\mu\text{m}$  beyond vesicle; maximum extension is at centre of an edge, so that overall shape of specimen is  $\pm$ square despite concavity of faces. Ridges include as many as four, strutlike, in places hollow, distally digitate/denticulate projections that represent extensions of vesicle wall of normal (2  $\mu\text{m}$ ) thickness. No excystment structure observed.

*Dimensions* (2 specimens). Sides of overall cubic form, as defined by outer margins of membranous ridges, 40, 44  $\mu\text{m}$ .

*Remarks and comparison.* Only two specimens of *Polyedryxium deflandrei* Deunff, 1961 were encountered, in only one of the samples studied. *P. deflandrei* and *P. diabolicum* Deunff, 1961 (*see* Deunff, 1971, p. 27; Pl. 1, figs. 7–9, 18) are extremely similar morphologically and have yet to receive convincing differential diagnoses.

*Previous records.* Deunff (1954b, etc.) recorded *P. deflandrei* from an insecurely dated Devonian sample (Middle or Early Devonian) of Ontario.

*Polyedryxium embudum* Cramer, 1964

Plate 16, figures 1–4

1964 *Polyedryxium embudum* Cramer, p. 318–319 (1964b); Fig. 32(5).  
1966 *Polyedryxium nudatum* Deunff, p. 91–92 (1966b); Pl. 13, fig. 150.

*Description.* Vesicle cubic, with slightly concave, planar or slightly convex faces. Vesicle wall single-layered, 1–1.7  $\mu\text{m}$  thick; finely sculptured (granulate to rugulate) to almost psilate under both light and scanning electron microscopes; if rugulate, the rugulae often display alignment and continuity parallel to, and within 4  $\mu\text{m}$  of, vesicle edge. At each of its 12 edges, the vesicle's wall extends, in a greatly thinned form (*i.e.*, <0.3  $\mu\text{m}$  thick), as a continuous membranous ridge that joins at vesicle corners with the two other adjacent ridges. Ridges 8–15  $\mu\text{m}$  high (average 10  $\mu\text{m}$ ),  $\pm$ transparent, sculpturally similar to vesicle wall, but sculpture usually becoming progressively sparser and even finer towards ridge margins. No excystment structure observed.

*Dimensions* (35 specimens). Sides of overall cubic form, as defined by outer edges of membranous ridges, 32 (48) 64  $\mu\text{m}$  long.

*Remarks.* Although Deunff (1971) included both his species *Polyedryxium nudatum* and Cramer's (1964b) *P. embudum* in his treatise on the genus *Polyedryxium* and morphologically related taxa, he made no attempt to distinguish them. Neither species has been adequately illustrated or given more than a brief description, but there appears to be no justification for their separate recognition, either from each other or, together, from the Moose River Basin specimens described above.

*Senzeillea incurvata* Stockmans and Willièrè, 1969 (p. 40; Figs. 4, 5), a Belgian Famennian form, appears to be distinct from *P. embudum* by having lower ridges and a 'multiperforate' vesicle surface.

*Previous records.* *P. embudum* has been reported hitherto from the Lower Devonian (Siegenian-Emsian) of northwest Spain (Cramer, 1964b); and from the Middle (or Lower?) Devonian of Ontario (Deunff, 1966b, 1971).

*Polyedryxium fragosulum* sp. nov.

Plate 16, figures 8–14

*Diagnosis.* Vesicle tetrahedral (triangular or quadrangular in overall outline, depending on orientation of specimen viewed) with flat, slightly concave or convex faces, the triangular outlines of which are bounded by membranous ridges; junctions of ridges usually (but not always) extended to form distinct processes (one per junction). Vesicle wall one-layered; between ridges, 1–1.5  $\mu\text{m}$  thick. Sculpture of vesicle wall (excluding membranous ridges): granulate to finely verrucate with irregularly or uniformly distributed elements, up to 2  $\mu\text{m}$  in basal diameter and 1.5  $\mu\text{m}$  in height; normally discrete but bases often interconnected by fine, narrow, irregularly disposed rugulae (clearly visible under scanning electron microscope). Ridges bounding vesicle faces are typically membranous, thin, transparent,  $\pm$ psilate (apart from fine wrinkles that are presumably preservational effects) and 8–12  $\mu\text{m}$  high; frequently prolonged at junction with other ridges (*i.e.*, at face corners) to extend beyond vesicle as a distinct, gradually tapering process. Processes homomorphic, clearly or only slightly distinguishable from ridges, *i.e.*, depending on length attained, which may be up to 60  $\mu\text{m}$  (usually considerably less, and subequal on same specimen); distal extremities bluntly acute or rounded; apparent longitudinal 'nerve' or rib represents junction between the three extended ridges. Excystment by split in face of vesicle, either adjacent and parallel to ridge or cutting across face.

*Dimensions* (40 specimens). Overall diameter 45 (72) 126  $\mu\text{m}$ .

*Holotype.* Slide 8124-3, 59.6  $\times$  95.6, GSC 48458; Plate 16, figure 8. Overall diameter 92  $\mu\text{m}$ ; vesicle 30  $\mu\text{m}$  in diameter, outline quadrangular; faces convex, granulate, about 1  $\mu\text{m}$  thick; faces separated by prominent membranous ridges, about 7  $\mu\text{m}$  high near middle of face edge, increasing progressively to 35  $\mu\text{m}$  at each corner where three ridges converge to form a conspicuous process having a blunted-acute distal extremity.



*Type locality.* Ontario, Moose River Basin; Stooping River Formation, Lower Devonian (Emsian); Jaab Lake No. 1 well, core, 925–927 ft; GSC loc. 8124.

*Name derivation.* Lat., *fragosulus*, somewhat rough, uneven.

*Comparison.* Two previously described and possibly conspecific forms are strongly reminiscent of specimens here constituting *Polyedryxium fragosulum* sp. nov. These are *P. tetraedroide* Cramer, 1964 (1964b, p. 320; Pl. 15, figs. 4–7; Fig. 32:1, 2) and *Cymatiosphaera triangularis* Pöthe de Baldi, 1974 (1974a, p. 376; Pl. 2, figs. 8, 11, 12) from the Ludlow to Siegenian of Spain and Middle Devonian of Uruguay respectively. Neither is applicable however inasmuch as the present specimens have a distinctly sculptured wall.

### *Polyedryxium pharaonis* Deunff, 1961

#### Plate 17, figures 1–12

- 1954 *Polyedryxium pharaonis* Deunff, p. 1065 (1954b); Fig. 13 (*nom. nud.*).  
 1955 *Polyedryxium pharaonis* Deunff, p. 143, Fig. 13 (*nom. nud.*).  
 1961 *Polyedryxium pharaonis* Deunff, p. 217.  
 1966 *Polyedryxium pharaonis* (Deunff) Deunff, p. 58–62 (1966b); Pl. 7, figs. 79, 80, 82–85; pl. 8, Figs. 92–94; Pl. 12, fig. 126; Pl. II, fig. 12; Pl. VI, figs. 42, 43.  
 1972 *Crameria pharaonis* (Deunff) Jardiné, Combaz, Magloire, Peniguel, and Vachey, p. 301–302; Pl. 2, figs. 6–10. (?*non Crameria pharaonis* (Deunff) subsp. *duplex* (Cramer) Jardiné, Combaz, Magloire, Peniguel, and Vachey, 1972, p. 301).

*Description.* Vesicle cubic to polyhedral with flat, slightly concave or slightly convex faces (square, rectangular or pentagonal in outline) bounded by membranous ridges, the junctions of which are prolonged to form conspicuous processes. As the vesicle form is commonly cubic, and as only one process normally projects from each corner, the vesicle commonly possesses eight processes, although as many as 10 or 12 may be developed. Vesicle wall one-layered; between ridges, 0.7–2  $\mu\text{m}$  thick ( $\pm$ uniform on same specimen), psilate to granulate or finely rugulate/striate under light microscope, microgranulate, granulate or micro-rugulate under scanning electron microscope (elements usually  $\pm$ irregular in form but of fairly uniform distribution). Vesicle ridges sharp-crested, about 1  $\mu\text{m}$  wide at base, transparent, with sparser and even finer sculpture than remainder of vesicle surface. Each process represents an extension of the three joined ridges beyond vesicle confines and shares the same inconspicuous sculptural characteristics as the ridges; length of processes 25–60  $\mu\text{m}$  (subequal on same specimen). From  $\pm$ flaring base, processes slightly to markedly taper to somewhat blunted acute apex. Excystment structure a simple split in one face of vesicle wall, either immediately adjacent and parallel to a ridge or extended diagonally across a face from one process base to another.

*Dimensions* (100 specimens). Diameter of vesicle 25 (36) 49  $\mu\text{m}$ .

*Remarks.* *Polyedryxium pharaonis* Deunff, 1961 is a distinctive, albeit variable species that is abundantly represented in the present material. Morphological features displaying the most obvious variation from specimen to specimen are: thickness and sculpture of vesicle wall (less ridges and processes); height of vesicle ridges; and length of processes.

Continuity of the variation in the Moose River Basin material precluded meaningful subspecific segregation; most of the subspecific/variety taxa of Deunff (1966b, 1971) and of Jardiné *et al.* (1972) are represented.

The apparent longitudinal ‘nerve’ discernible on most processes and commented upon by some previous authors simply constitutes the continuous junction between the three flaplike elements, constituting each process and derived from the parent ridges set originally at 120° to each other.

Jardiné *et al.* (1972, p. 301) proposed the combination *Crameria pharaonis* (Deunff). In emending the specific diagnosis, they asserted that the vesicle is two-layered and camerate; if used in the sense of Lister (1970, p. 24), the latter term means ‘that condition of a cyst in which a cavity separates the inner from the outer wall’. Neither of Jardiné and his coauthors’ propositions is tenable from the present material or indeed from previously published illustrations of specimens assignable to *pharaonis* (including those of Jardiné *et al.*, 1972). It is true that the vesicle ridges are thin and membranous; and therefore when viewed in lateral aspect around the vesicle margin (e.g., Jardiné *et al.*, 1972, Pl. 2, figs. 8–10; Legault, 1973, Pl. 12, fig. 10), the resultant optical section could easily be misconstrued as one of a two-layered wall. In fact, the vesicle ridges are localized, if conspicuous modifications of a vesicle wall that includes (a) no differential layering discernible under the light microscope and (b) no likewise discernible development of a cavity within it.

*Comparison.* ?*Baltisphaeridium duplex* Cramer, 1964 (1964b, p. 287; Pl. 5, figs. 1, 2, ?4, ?5), which was originally described from the Spanish Lower Devonian (Emsian), is obviously very close morphologically to *Polyedryxium pharaonis* Deunff, 1961. Indeed, Jardiné *et al.* (1972, p. 301) termed the former *Crameria pharaonis* (Deunff) subsp. *duplex* (Cramer). However, according to Cramer’s (1964b) description, there are ‘no crests between the processes’.

A Belgian Famennian form, *Eisenackidium martenianum* Stockmans and Willièvre, 1969 (p. 23–25; Pl. 3, figs. 8–10), is closely similar to *B. duplex* and might well prove to be synonymous with *P. pharaonis*.

*Previous records.* *P. pharaonis* has been widely reported from Devonian sediments of the northern hemisphere; viz., Devonian of Ontario (Deunff, 1954b, 1955, 1961, 1966b, 1971; Legault, 1973), Lower Devonian of Spain (Cramer, 1964b), and Devonian of North Africa (Deunff, 1966b; Jardiné *et al.*, 1974).

### Genus *Pterospermella* Eisenack, 1972

*Type species.* *Pterospermella aureolata* (Cookson and Eisenack) Eisenack, 1972; by original designation.

*Generic characters.* Vesicle ovoidal to subspherical or, rarely, spherical; outline circular to subcircular. Vesicle encompassed equatorially by a directly attached, membranous, flangelike structure of  $\pm$ uniform width and often displaying radial folds or ribs. After Eisenack (1972, p. 597).

*Discussion.* Eisenack (1972) proposed the genus *Pterospermella* essentially as a repository for all species previously allocated to the genus *Pterospermopsis* W. Wetzel, 1952 (p. 411) with the sole exception of the type species *Ptero-*

*spermopsis danica* W. Wetzel, 1952. Eisenack and Cramer (1973) undertook specific combinations with *Pterospermella* consistent with Eisenack's (1972) proposal. According to Eisenack, the new generic institution (of *Pterospermella*) was necessary because of the inadequacy of W. Wetzel's type material and illustrations (of *P. danica*): "the holotype of *P. danica* is a flint inclusion and a greatly damaged specimen" (translation from Eisenack, 1972, p. 596). Moreover, Eisenack (1972, p. 597) cited and supported Morgenroth's (1968, p. 556) contention that *P. danica* could be a *Thalassiphora* (*pelagica*?). These arguments seem fairly persuasive; but they are not necessarily compelling under the relevant ICBN provisions (Section 6: not referred to by Eisenack). Consequently, although *Pterospermella* is used herein as a generic category, it is judged to be in need of stronger justification than has so far been claimed. In particular, detailed description and clear photomicrographs of topotypic *Pterospermopsis danica* specimens, and comparison of these with *Pterospermella aureolata* (Cookson and Eisenack) Eisenack, 1972, appear to be required.

*Pterospermella circumstriata* (Jardiné, Combaz, Magloire, Peniguel and Vachey) Eisenack and Cramer, 1973

Plate 18, figures 1–6

- 1968 *Pterospermopsis* sp. 1 of Jardiné and Yapaudjian, Pl. 4, fig. 19.  
1972 *Pterospermopsis circumstriatus* Jardiné, Combaz, Magloire, Peniguel, and Vachey, p. 304; Pl. 3, figs. 13, 14.  
1973 *Pterospermella circumstriata* (Jardiné, Combaz, Magloire, Peniguel, and Vachey) Eisenack and Cramer, p. 975.

**Amplification of diagnosis.** Vesicle subspherical with circular or subcircular outline. Vesicle wall finely reticulate centrally, becoming concentrically ridged peripherally with muri 1–2  $\mu\text{m}$  in basal width, 0.5–2  $\mu\text{m}$  high, and 0.5–1  $\mu\text{m}$  apart. Thickness of vesicle wall 1–1.5  $\mu\text{m}$ , sculptural elements excluded. Equatorial flangelike membrane of  $\pm$ uniform width, but subject to corrosion and folding; mostly thin, transparent; inner portion often with discontinuous, radially arranged, rodlike thickenings and, less commonly, well-spaced concentric ridging reminiscent of outer part of vesicle. Excystment aperture consists of a simple, approximately linear split in vesicle wall; aperture diametric or somewhat off-centre.

**Dimensions** (56 specimens). Overall diameter 53 (72) 97  $\mu\text{m}$ ; diameter of vesicle 23 (35) 48  $\mu\text{m}$ .

**Remarks.** Jardiné *et al.* (1972) did not refer to the presence of any excystment structure in specimens of this species as originally described by them. The feature is clearly exhibited by some 30 per cent of the specimens examined during the present investigation.

**Previous records.** Jardiné and Yapaudjian (1968) and Jardiné *et al.* (1972, 1974) noted restriction of this distinctive species, in the Algerian Sahara subsurface, to strata they considered to be of Emsian age.

**Genus *Stellinium*** Jardiné, Combaz, Magloire, Peniguel, and Vachey, 1972

**Type species.** *Stellinium micropolygonale* (Stockmans and

Willière) comb. nov., described below; originally designated, as *S. octoaster* (Staplin) Jardiné, Combaz, Magloire, Peniguel, and Vachey, 1972, by Jardiné *et al.* (1972, p. 298).

**Generic characters.** Acritarchs polyhedral, with stellate outline, comprising about 7–12, broadly based, hollow, homomorphic processes, normally disposed in two discrete planes. Each process tapers rapidly to terminate in an acuminate, closed tip. No discrete vesicle delineable as such due to strong development, and basal contiguity, of processes, each of which displays a narrow, median, longitudinal ridge or seam. Process ridges diverge radially from central point on cyst surface. Process interiors open into and communicate freely with central cavity. Wall single-layered; psilate or finely sculptured. After Jardiné *et al.* (1972, p. 298).

**Comparison.** This genus differs from other star-shaped forms, such as *Estiastra* Eisenack, 1959 (p. 201), *Palacanthus* Wicander, 1974 (p. 30), and *Goniolopadion* gen. nov., chiefly in the disposition of the processes and in the development of radial crests on the processes.

*Stellinium micropolygonale* (Stockmans and Willière) comb. nov.

Plate 18, figures 7–9

- 1960 *Michrystidium micropolygonale* Stockmans and Willière, p. 4; Pl. 1, fig. 12.  
1961 *Veryhachium octoaster* Staplin, p. 413–414; Pl. 49, figs. 3, 4.  
1962 *Veryhachium micropolygonale* (Stockmans and Willière) Stockmans and Willière, p. 52–53 (1962a); Pl. 2, fig. 19; Figs. 9a, b.  
1962 *Veryhachium* aff. *octoaster* Staplin; Stockmans and Willière, p. 85 (1962b); Pl. 1, fig. 7.  
1962 *Veryhachium vandenbergheni* Stockmans and Willière, p. 86–87 (1962b); Pl. 2, figs. 11, 13; Figs. 5a, b.  
1972 *Stellinium octoaster* (Staplin) Jardiné, Combaz, Magloire, Peniguel, and Vachey, p. 298–299; Pl. 2, figs. 1, 2.  
1972 *Stellinium octoaster* (Staplin) var. *elongatum* Jardiné, Combaz, Magloire, Peniguel, and Vachey, p. 299; Pl. 2, figs. 3–5.  
1975 *Polyedryxium micropolygonale* (Stockmans and Willière) Jux, p. 128; Pl. 6, figs. 3a–c.

**Description.** Acritarchs polyhedral with stellate outline and consisting of eight, broadly based, homomorphic, hollow, cone-shaped processes, normally disposed in two  $\pm$ parallel planes. Each process equipped with a narrow, median, longitudinal ridge (0.5  $\mu\text{m}$  or less wide) converging with ridges of adjacent processes at central point on cyst surface. Processes thin-walled; surface psilate to scabrate under light microscope; scabrate, microgranulate or irregularly micro-rugulate under scanning electron microscope. Processes sharp to bluntly pointed distally. Interiors of processes in free communication with central cavity.

**Dimensions** (14 specimens). Overall diameter 40 (53) 70  $\mu\text{m}$ .

**Remarks.** The original illustration of *Stellinium micropolygonale* (Stockmans and Willière) comb. nov., provided by Stockmans and Willière (1960, Pl. 1, fig. 12), was apparently of an ill-preserved specimen. It has been supplemented since (Stockmans and Willière, 1969, Pl. 3, figs. 4–7) by somewhat clearer illustrations of more specimens; these leave no doubt as to the conspecificity of *micropolygonale* with *Veryhachium octoaster* Staplin, 1961, as intimated by Stockmans and Willière (1969, p. 10–11) and formally proposed by Jux (1975, p. 128). Moreover, the latter reported difficulty in separating *V. micropolygonale* from *V. vandenbergheni* Stock-



mans and Willière, 1962 (see Stockmans and Willière, 1969, p. 13; Pl. 3, figs. 1–3); and the author can see no reason for regarding these as separate specific taxa; certainly a continuous intergradation among specimens resembling each taxon exists in the Moose River Basin material.

*Previous records.* *Stellinium micropolygonale* has been reported widely from Lower Devonian to Strunian sediments of the northern hemisphere (see, for example, summary in Playford, 1976) and latterly from the latest Devonian of Western Australia (Playford, 1976).

### Genus *Tunisphaeridium* Deunff and Evitt, 1968

*Type species.* *Tunisphaeridium tentaculiferum* (Martin) Cramer, 1971; originally designated, as *Tunisphaeridium concentricum* Deunff and Evitt, 1968, by Deunff and Evitt (1968, p. 2).

*Generic characters.* Vesicle hollow, originally spherical; outline circular to subcircular, usually  $\pm$  clearly demarcated. Numerous, slender, rodlike, apparently mostly solid processes arise from vesicle. Distal extremities of processes are interconnected by: a very thin, diaphanous outer membrane alone; by a membrane that is structurally reinforced with a network of weakly to strongly developed, tendril-like, branching filaments radiating from process tips; or by such filaments with only traces of a membrane. Membrane is  $\pm$  conformable with vesicle outline. Excystment mechanism unknown. After Deunff and Evitt (1968, p. 2).

*Comparison.* *Tunisphaeridium* Deunff and Evitt, 1968 is a morphologically distinctive genus ranging from Silurian to Devonian. Amongst other described genera, *Piliferosphaera* Loeblich, 1970 (p. 735) shows slight resemblance to *Tunisphaeridium* in the form of the processes, which are, however, hollow and are not interconnected by an outer membranous structure.

*Tunisphaeridium tentaculiferum* (Martin) Cramer, 1971

Plate 18, figures 10–12

1961 'A Silurian hystrichosphere' of Evitt, Pl. 4, fig. 11.

1965 *Baltisphaeridium* sp. II of Martin, p. 363.

1966 *Baltisphaeridium tentaculaferum* Martin, p. 312; Pl. 1, fig. 23; Fig. 3.

1968 *Tunisphaeridium venosum* Deunff (1966?) of Cramer, p. 66; Pl. 1, fig. 5.

1968 *Tunisphaeridium concentricum* Deunff and Evitt, p. 3; Pl. 1, figs. 1–12.

1971 *Tunisphaeridium tentaculiferum* (Martin) Cramer, p. 192–193; Pl. 6, figs. 105, 106, 108, 109.

*Description.* Vesicle originally spherical; outline circular or subcircular; wall single-layered, thin (0.5  $\mu$ m or less); micro-rugulate to punctate under scanning electron microscope. Numerous, slender, rodlike, homomorphic processes arise, with curved to almost angular contacts, from vesicle surface; and terminate distally in a complex, if fairly regular, radiating series of fine ramifications. The ramose elements, in turn, provide areas of support/connection for a comprehensively enveloping, very thin, diaphanous membrane that is  $\pm$  conformable with vesicle. Processes solid or partly hollow, not communicating with vesicle cavity; length (fairly constant on same specimen), 20–48  $\mu$ m; basal diameter, 2–4  $\mu$ m; bases discrete, 4–25  $\mu$ m apart. Under scanning electron micro-

scope, processes have a longitudinally fibrous or striate appearance, particularly towards base. No excystment structure observed.

*Dimensions* (24 specimens). Diameter of vesicle 37 (50) 63  $\mu$ m; overall diameter 70 (95) 120  $\mu$ m.

*Remarks.* The membranous outer layer tends to be at least partly absent from poorly preserved examples. The specimens of this study are mostly larger than those reported hitherto.

*Distribution.* *Tunisphaeridium tentaculiferum* (Martin) Cramer, 1971 is well known from Silurian strata of Europe, North Africa, and U.S.A. (e.g., Martin, 1966, 1968; Deunff and Evitt, 1968; Cramer, 1971; Thusu, 1973a, b; Jardiné et al., 1974). Legault (1973) recorded the species from considerable younger sediments: the Middle Devonian Hamilton Group of southwestern Ontario.

### Genus *Tyligmasoma* gen. nov.

non 1949 *Triangulina* Malyavkina, p. 30, 47.

1964 *Triangulina* Cramer, p. 334 (1964b).

*Diagnosis.* Vesicle triangular in outline. Vesicle wall consisting of two layers that are closely adpressed except for apical corners of vesicle at each of which the thinner outer layer is extended to form a prominent, hollow, subcylindrical or spine-shaped process. Processes subequal on same specimen and with closed tips (i.e., unless damaged). Surface of vesicle, and of processes, either psilate or finely sculptured. Process interiors closed off from vesicle interior by continuous development of inner wall layer across process bases. No obvious excystment mechanism.

*Name derivation.* Gr., *tyligma*, swelling; Gr., *soma*, body. Gender neuter.

*Type species* (here designated). *Tyligmasoma alargadum* (Cramer) comb. nov.; described below.

*Other species.* (1) *Tyligmasoma cylindricum* (Jardiné, Combaz, Magloire, Peniguel, and Vachey) comb. nov. Basionym: *Onondagella cylindrica* Jardiné, Combaz, Magloire, Peniguel, and Vachey, 1972, p. 299; Pl. 1, figs. 9, 10. Occurrence: North Africa, Algerian Sahara; Upper Silurian (Ludlow) to Lower Devonian (Gedinnian) (Jardiné et al., 1972, 1974).

(2) *Tyligmasoma sanpetrensis* (Cramer) comb. nov. Basionym: *Onondagella sanpetrensis* Cramer, 1966c, p. 88; Pl. 2, figs. 14, 15; Fig. 2-14. Occurrence: northwest Spain; Upper Silurian (Ludlow) or Lower Devonian (basal Gedinnian) (Cramer, 1966c).

*Discussion.* The new generic name *Tyligmasoma* is proposed in place of *Triangulina* Cramer, 1964 because of Malyavkina's prior (1949) usage of the latter name as a spore genus.

*Comparison.* *Tyligmasoma* differs from *Onondagella* Cramer, 1966 (emended herein) in having a two-layered vesicle, the outer layer of which forms the three hollow processes. In the latter genus, but not the former, the process interiors freely communicate with the vesicle cavity, and the processes are subequal on a given specimen.

*Ozotobrachion* Loeblich and Drugg, 1968 (also recorded

herein) is similar in construction to *Tyligmasoma* but its slender processes are characteristically digitate or multifurcate.

*Tyligmasoma alargadum* (Cramer) comb. nov.

Plate 19, figures 1–6

1964 *Triangulina alargada* Cramer, p. 334–335 (1964b); Pl. 6, figs. 1, 4; Fig. 39.

1973 *Triangulina* cf. *T. alargada* Cramer; Legault, p. 58; Pl. 11, figs. 11, 12.

**Amplification of diagnosis.** Vesicle triangular in outline with straight sides and broadly rounded apices. Vesicle wall two-layered with layers closely adpressed and essentially homogeneous except at each apex of vesicle triangle where outer layer is separated from thicker, and usually somewhat darker, inner layer to form a conspicuous, tapering, spinelike or subcylindrical process. The three processes are homomorphic and transparent, hollow, with rounded to sharply acute, closed tips. At proximal ends, process interiors are closed from hollow vesicle interior by inner wall layer of vesicle. Outer wall layer psilate to scabrate or finely striate under light microscope; psilate to irregularly microgranulate under scanning electron microscope. Inner wall layer 1–1.5  $\mu\text{m}$  thick; outer layer about half or less as thick ( $<0.5 \mu\text{m}$ ) and thus usually displaying irregular compression folds where constituting processes. Dimensions of processes: length 20–60  $\mu\text{m}$ , basal diameter 10–23  $\mu\text{m}$ . Excystment mechanism unknown.

**Dimensions** (20 specimens). Diameter of vesicle 28 (44) 60  $\mu\text{m}$ .

**Remarks.** The chief morphological variations of this species are size and form of processes, among specimens and also to some extent on a given specimen. The processes, being hollow and thin-walled, are liable to preservational or preparation damage so that distally incomplete processes are not uncommon.

**Comparison.** *Tyligmasoma cylindricum* (Jardiné et al., 1972) comb. nov. is possibly distinct from *T. alargadum* (Cramer) comb. nov. in bearing somewhat shorter processes and in having thickenings at process bases. However, the differences between the two species appear to be rather less unequivocal than was implied by Jardiné et al. (1972, p. 299). *T. sanpetrensis* (Cramer) comb. nov. differs from *T. alargadum* in being smaller and in having a concavely subtriangular vesicle outline and different sculptural features.

**Previous records.** Following Cramer's (1964b) original description of *Tyligmasoma alargadum* from Spanish Emsian sediments, the species has been further reported as follows: Lower Devonian of Brazil (Brito, 1967a, 1969); Emsian of North Africa (Jardiné and Yapaudjian, 1968; Jardiné et al., 1974); and Givetian of Ontario (Legault, 1973). Possible examples of *T. alargadum* were recorded by Moreau-Benoit (1974) from the Silurian of France.

Genus *Veryhachium* Deunff ex Downie, 1959

**Type species.** *Veryhachium trisulcum* (Deunff) Deunff, 1959; by subsequent designation of Downie (1959, p. 62).

**Generic characters.** Vesicle hollow, triangular to polygonal in outline, with corners ('angles') smoothly extended as

hollow tapering processes that terminate with simple (acuminate) closed distal extremities and have unobstructed internal communication with vesicle cavity. Processes usually number between three and eight per vesicle. Vesicle and process walls psilate to granulate. Epityche constitutes excystment structure. After Staplin, Jansonius, and Pocock (1965, p. 184), Loeblich and Tappan (1969, p. 55–56).

**Discussion.** Loeblich and Tappan (1969, p. 55–56; 1976, p. 306) have provided a useful commentary on the typification of this genus and their ideas on the characteristic mode of excystment.

**Comparison.** Chief distinguishing features of morphologically comparable genera vis-à-vis *Veryhachium* Deunff ex Downie, 1959 are as follows: *Wilsonastrum* Jansonius, 1962 (one or several grouped minute bristles additional to 'normal' processes); *Impluviculus* Loeblich and Tappan, 1969 (quadrangular or rounded pylome, situated centrally between processes, serving as excystment mechanism); *Dateriocradus* Tappan and Loeblich, 1971 (multifurcate processes); *Neoveveryhachium* Cramer, 1971 (additional membranous wall layer to vesicle); and *Villosacapsula* Loeblich and Tappan, 1976 (spinose sculpturing of vesicle, and usually of processes also).

*Veryhachium downiei* Stockmans and Willièrè, 1962

Plate 20, figures 4–13

1962 *Veryhachium downiei* Stockmans and Willièrè, p. 47–48 (1962b); Pl. 2, figs. 20–22; Fig. 2.

**Description.** Vesicle of triangular outline with slightly convex to slightly concave, equal sides. Each triangular apex of vesicle drawn out as simple, hollow, tapering, acuminate process, 8–44  $\mu\text{m}$  long; an additional, similar, though usually shorter process is developed elsewhere on vesicle surface of some specimens, perpendicular to the plane of the three major processes. Interior of processes and of vesicle in free communication. Process and vesicle walls about 0.4–1  $\mu\text{m}$  thick; psilate or almost so under light microscope. Under scanning electron microscope, however, specimens display considerable variation in nature and density of sculpturing elements on process and vesicle walls: microgranulate, microechinate, psilate, micropunctate (see Pl. 20, figs. 5, 8–13). This variation is evident both within a given specimen and from one specimen to the next. Epityche (excystment structure) rarely discernible.

**Dimensions** (85 specimens). Diameter of vesicle (i.e., from base of one process to centre of opposite side) 12 (21) 30  $\mu\text{m}$ .

**Remarks and comparison.** The majority of the Moose River Basin specimens conform, in their diagnostic, light-microscopic characters, with *Veryhachium downiei* Stockmans and Willièrè, 1962. Several authors (e.g., Cramer, 1964b, p. 306; 1971, p. 95; Wicander, 1974, p. 36) have noted that *V. downiei* intergrades with other essentially psilate species, notably with *V. trispinosum* (Eisenack) Deunff, 1954, such that it is difficult to pinpoint meaningful criteria for separation of them. Certainly, a small proportion of specimens observed in the present material appears to approach the morphology of *V. trispinosum* as described by Eisenack (1938, p. 14–15; figs. 2, 3).

Further, many of the present specimens could readily be accommodated in Wicander's (1974, p. 35–36; Pl. 19, figs. 4–7) species *V. roscidum* in terms of both light and scanning-electron microscopy. *V. roscidum* was diagnosed on the basis of its microgranulate wall, but this is difficult to maintain as a distinguishing attribute in a taxonomy that is based routinely upon light-microscopic observations. It is noteworthy that Jux (1975, p. 126–127; Fig. 2; Pl. 6, figs. 1a–j) described and illustrated specimens he identified with *V. downiei* that display microgranulate ornament. In an assiduous and critical appraisal of the whole complex of *Veryhachium* species of the *V. trispinosum/V. downiei* type—beyond the scope of the present study—*V. roscidum* would presumably be merged as a junior synonym of *V. downiei*.

**Previous records.** Acritarchs that are either identical or closely comparable with *V. downiei* are known widely from Silurian, Devonian and Lower Carboniferous sediments.

### *Veryhachium lairdii* Deflandre ex Deunff, 1959

Plate 20, figures 1–3

1959 *Veryhachium lairdi* (Deflandre) Deunff, p. 28; Pl. 8, figs. 75–79.

1970 *Veryhachium lairdii* (Deflandre) ex Deunff; Loeblich, p. 741–742.

**Description.** Vesicle typically square or rectangular, with concave sides and a spinelike, hollow process developed at each corner; sometimes an additional (fifth) process projects elsewhere from vesicle surface. Processes constitute tapered extensions of vesicle wall and terminate distally with simple, sharp tips; process and vesicle walls are similarly thin (0.5  $\mu\text{m}$  average) and ornamented (psilate–faintly scabrate). Vesicle cavity has unobstructed communication with process interiors. Proximal process contacts curved. Excystment mechanism not observed.

**Dimensions** (20 specimens). Overall diameter 35 (54) 80  $\mu\text{m}$ ; diameter of vesicle 12 (28) 42  $\mu\text{m}$ .

**Remarks.** The specimens are in agreement with the simple, generalized category established by Deunff (1959). See Loeblich (1970, p. 742) for discussion on effective publication of the species name and combination.

**Previous records.** Though infrequent in the samples studied here, *Veryhachium lairdii* Deflandre ex Deunff, 1959 has been widely recorded from Silurian–Devonian deposits in the northern hemisphere (viz. Stockmans and Willièrè, 1969; Cramer, 1971; Thusu, 1973b; Martin, 1974), though as Loeblich (1970, p. 744–745) pointed out the specific epithet has been loosely applied and some of the forms are more appropriately assigned to *V. valiente* Cramer, 1964.

### *Veryhachium polyaster* Staplin, 1961

Plate 19, figures 7–10

1961 *Veryhachium polyaster* Staplin, p. 413; Pl. 49, figs. 19, 20.

**Description.** Vesicle subrectangular to polygonal, wall 0.7–1.2  $\mu\text{m}$  thick; with 5–6 (rarely 7 or 8), simple, acuminate, hollow, homomorphic processes,  $\pm$ evenly spaced and representing long, drawn-out extensions of vesicle wall. Proximal process contacts curved; communication between

process interiors and vesicle cavity unobstructed. Processes normally between 20 and 50  $\mu\text{m}$  in length, and between 4 and 9  $\mu\text{m}$  broad at base. Process and vesicle walls psilate to scabrate under light microscope; sparsely to fairly densely microgranulate to microechinate under scanning electron microscope. Excystment structure not observed.

**Dimensions** (67 specimens). Diameter of vesicle 14 (25) 34  $\mu\text{m}$ .

**Remarks and comparison.** Most of the Moose River Basin specimens of the foregoing description conform with the somewhat generalized provisions of Staplin's (1961, p. 413) circumscription of *Veryhachium polyaster*, including his variety *hexaster*. Moreover, some appear to be closely comparable with *V. laevatum* Deunff, 1966 (1966b, p. 71–72; Pl. 13, fig. 141); the latter could well prove to be synonymous with Staplin's species. *V. laevatum* was said to be characterized by regular disposition of two sets of three, 25  $\mu\text{m}$  long, tapering, spinelike processes.

*V. eisenackii*, another of Deunff's species from the Ontario Devonian (Deunff, 1955, Fig. 7; 1961, p. 217), differs from the above specimens by having a 'microperforate' wall and having a generally larger vesicle and larger processes.

**Previous records.** Staplin's description of *V. polyaster* was based on Alberta Frasnian material. The possibly synonymous *V. laevatum* Deunff, 1966 is a North American Devonian form for which Deunff provided no exact geographic or stratigraphic data.

### *Veryhachium radiosum* sp. nov.

Plate 19, figures 11–13

**Diagnosis.** Vesicle typically of triangular or rectangular outline; with 3 or 4 (rarely 5 or 6), hollow, gently tapering, homomorphic processes, each extending from a vesicle angle and terminating with a slightly bulbous or evexate distal end (characteristically the former). Processes constitute prolongations of vesicle walls, 20–40  $\mu\text{m}$  long and internal communication is unobstructed; process/vesicle wall 0.5–1  $\mu\text{m}$  thick, scabrate under light microscope, microrugulate to microgranulate under scanning electron microscope. Excystment structure (rarely seen) consists of a simple split in vesicle wall between processes.

**Dimensions** (18 specimens). Diameter of vesicle 23 (35) 46  $\mu\text{m}$ .

**Holotype.** Slide 8135-28, 34.5  $\times$  103.0, GSC 48493; Plate 19, figure 13. Vesicle subtriangular in outline, diameter 41  $\mu\text{m}$ ; wall 0.7  $\mu\text{m}$  thick, scabrate, drawn out at triangular apices to form three prominent, subequal, hollow, processes (one broken on specimen); the two intact processes have blunted distal ends.

**Type locality.** Ontario, Moose River Basin; Stopping River Formation, Lower Devonian (Siegenian); Jaab Lake No. 1 well, core, 1031–1033 ft; GSC loc. 8135.

**Name derivation.** Lat., *radius*, ray, rod.

**Comparison.** The specimens described above, all confined to the stratigraphically lowest three samples of the Stopping River Formation, could not be matched with any previously published species of *Veryhachium* or related genus.

## Composition and Stratigraphic Significance of the Acritarch Assemblages

In general, most of the Jaab Lake well samples used in this study yielded an abundance of well-preserved acritarchs, especially from the Stooping River Formation and the succeeding lower half (110 feet thickness) of the Kwataboahagan Formation. Profuse assemblages were also obtained from both samples of the Murray Island Formation and from lowermost and uppermost samples of the Williams Island Formation. Elsewhere in the sequence, acritarch recovery was either meagre or nonexistent, i.e., in the Kenogami River Formation, the upper third of the Kwataboahagan Formation, the Moose River Formation and the middle portion of the Williams Island Formation (lower member). Accordingly, in terms of previously established datings summarized earlier in this paper, the acritarch-containing sediments are late Siegenian, Emsian, Eifelian and Givetian in age. The main intervals devoid of acritarchs, or virtually so, are late Gedinnian to early Siegenian (Kenogami River Formation, upper member) and part of the Eifelian (Moose River Formation). As mentioned previously, the Moose River Formation is a very sparsely fossiliferous unit, in both microfossils and megafossils. The spore yields of McGregor and Camfield (1976) were poor or lacking from the Moose River and Murray Island formations and from all but the lower 70 feet of the Kwataboahagan Formation.

As documented in the foregoing systematic section, 53 species of acritarchs are recognized and are distributed among 24 genera, 4 of which are newly instituted herein. Of the species, 29 are identified with previously established species; 17 are new; 5 are regarded as probably new species but are given informal epithets ('sp. A', 'sp. B') because of numerical insufficiency of specimens; and 2 are compared, but not decisively identified, with previously established species. Simple, spherical bodies of tasmanitid type, and also chitinozoan and scolecodont fragments, occur erratically through the sequence; these are not systematically treated or recorded in the present account.

The occurrence of the acritarch species in the samples from the Jaab Lake well section is shown in Table 2, and the taxa are listed in order of initial stratigraphic appearance. It should be noted that the vertical axis of Table 2 is not to scale, although accurate footages are listed alongside GSC sampling levels. Figure 2 depicts the levels in scaled sequence.

Twelve of the species range throughout the sequence studied. Of these, the most persistently represented and abundant is *Diexallophasis remota*. The other long-ranging forms are: *Polyedryxium pharaonis*, *Multiplicisphaeridium ramusculosum*, *Cymatiosphaera cornifera*, *C. canadensis*, *C. sp. cf. C. pavimenta*, *Michrystidium stellatum*, *Veryhachium downiei*, *V. polyaster*, *V. lairdii*, *Gorgonisphaeridium cumulatum* and *Baltisphaeridium microfurcatum*. Although many of these species are known from elsewhere in North America, and beyond, to range from Silurian into Middle or even Upper Devonian strata (see respective previous records cited in systematic section), their collective presence clearly signifies an Early to Middle Devonian age, confirmatory of the age-range of the formations established on other paleontological grounds.

The remaining 41 species show varying degrees of vertical confinement to one or more of the formations delineated in the Jaab Lake well section. How significant these local ranges in a wider stratigraphic context are will obviously depend on further work, regionally and elsewhere. Clearly, a single local section, as studied here, can scarcely in itself serve as a basis for formal zonation and accordingly no acritarch zonal scheme is here proposed. For the present, the distribution of the commoner or more distinctive species showing apparent vertical restriction is discussed below, under headings of formations in which they occur or in which they show first or last appearances.

### Stooping River Formation

The following species are confined to parts of the Stooping River Formation; respective depth intervals and previously inferred datings in Jaab Lake well are parenthesized.

*Veryhachium radiosum* (1035–1027 feet; late Siegenian)

*Baltisphaeridium crebrum* (1035–745 feet; late Siegenian–mid Emsian)

*Gorgonisphaeridium disparatum* (974–909 feet; ?late Siegenian–early Emsian)

*Polyedryxium fragosulum* (974–681 feet; ?late Siegenian–Emsian)

*Onondagaella asymmetrica* (974–627 feet; ?late Siegenian–Emsian)

*Multiplicisphaeridium ampliatus* (927–765 feet; early Emsian)

*Dictyotidium cavernosulum* (927–725 feet; Emsian)

*Baltisphaeridium stamineum* (786–699 feet; mid Emsian)

*Hapsidopalla sannemannii* (767–671 feet; mid Emsian)

*Baltisphaeridium juliae* (727–639 feet; late Emsian)

Several species begin their range in the lower portion of the Stooping River Formation and extend upwards into the overlying Kwataboahagan Formation or younger units. These are *Pterospermella circumstriata*, *Baltisphaeridium anfractum*, *Tunisphaeridium tentaculiferum*, *Costatilobus undulatus*, *Palacanthus ledanoisii*, *Cymatiosphaera multisepta*, *C. winderi*, *Polyedryxium embudum*, *Navifusa bacillum*. The entrance levels of *Pterospermella circumstriata* and *Navifusa bacillum* are, from previously published data, of particular chronological significance. *P. circumstriata* ranges throughout strata believed to be wholly Emsian in the Algerian Sahara subsurface; whereas in the latter area and in the Americas, the range of *N. bacillum* is adduced as earliest Emsian to latest Devonian (Strunian). These data imply that the Siegenian–Emsian boundary lies within the 974–935 feet depth-interval, and thus corroborate McGregor and Camfield's (1976) placement of that boundary at 960–962 feet.

### Kwataboahagan Formation

The Kwataboahagan Formation, second thickest unit in the Jaab Lake well (after the underlying Stooping River Formation), contains an acritarch palynoflora that does not differ sharply from that of the latter unit. As previously mentioned, the upper third of the Kwataboahagan Formation proved to be impoverished in both numbers and variety of acritarchs preserved. This probably reflects inimical environmental conditions, as would also appear to be the case with the overlying Moose River Formation. Thus the absence of certain species in this part of the section should be viewed

with conservatism as not necessarily indicating extinction of those forms. With this qualification in mind, the only species exclusive to the Kwataboahagan Formation are *Lophosphaeridium dumalis* and *Polyedryxium bathyaster*. The former species is the more abundant and extends through about two thirds of the unit, from near its base (535 feet depth) to a depth of 371 feet. Some species extend, from the Stooping River Formation, no higher than the lower third of the Kwataboahagan Formation; these include *Polyedryxium carnatum*, *Pterospermella circumstriata*, and *Costatolobus undulatus*. Extending somewhat higher, to within the middle of the formation, are *Ozotobrachion furcillatus*, *Divetipellis ventricosa*, *Baltisphaeridium anfractum*, and *Polyedryxium embudum*. Newly introduced into the sequence and extending upwards from the Kwataboahagan Formation into younger units are *Duvernaysphaera tenuicingulata* and *Polyedryxium decorum*.

As mentioned earlier, the Kwataboahagan Formation is regarded as dominantly Eifelian in age. The acritarchs present provide little independent evidence as to the formation's precise age, mainly because of a paucity of information on the acritarch content of similar-aged sediments elsewhere. However, the presence of *Pterospermella circumstriata* (to, but not higher than, the 523 feet level) supports the view of McGregor and Camfield (1976) that the lower part of the Kwataboahagan Formation in Jaab Lake well is late Emsian in age.

#### Moose River Formation

One sample only of this presumably Eifelian unit yielded acritarchs. The yield was a very meagre one in which only one species, *Diexallophasis remota*, was positively identifiable.

#### Murray Island Formation

Both samples of this relatively thin unit, judged to be late Eifelian in age from paleozoological evidence, yielded well preserved acritarchs.

Species observed in one or both of these samples, but not elsewhere in the sequence, are: *Polyedryxium deflandrei* (at 211–213 feet) and *Gorgonisphaeridium* sp. cf. *M. sericum* (at 211–213 feet and 197–199 feet). Three species, *Tyligmasoma alargadum*, *Ozotobrachion palidodigitatus* and *Dictyotidium variatum*, extend into the Murray Island sequence, but not into overlying sediments of the Williams Island Formation. One distinctive component of the latter unit begins its range in the Murray Island Formation, namely *Hapsidopalla exornata*; this species is known, from Kettle Point, Ontario, to occur as high as the Frasnian.

#### Williams Island Formation

As noted previously, only the lower member of the Givetian Williams Island Formation is represented in the Jaab Lake well section. Only two of the four available samples, from the local bottom (at 211–213 feet) and top (at 147–149 feet), yielded acritarchs.

Two rare forms, *Goniolopadion prolixum* and *Dictyotidium* sp. A are the only ones not observed lower in the well sequence, and both of these occur only in the lower sample, at 211–213 feet. Thus the Williams Island Formation's acritarch flora, though diverse, is not a distinctive one in terms of newly introduced elements.

*Gorgonisphaeridium granatum*, *Baltisphaeridium distentum*, and *Tunisphaeridium tentaculiferum* apparently terminate their range at the level of the lower Williams Island sample.

Common and distinctive components of both samples are *Duvernaysphaera tenuicingulata* and *Hapsidopalla exornata*. Both species are known, however, to occur also in the Kwataboahagan and Murray Island formations respectively; and hitherto had been recorded only from the Frasnian of Canada.

### Comparison of the Acritarch and Spore Assemblages

The distribution patterns of acritarch species in the Jaab Lake well section bear no close relationship with those of the spores preserved in the same section (cf. Table 2 herein with Fig. 21 of McGregor and Camfield, 1976). This is not perhaps unexpected in view of the contrasting biotopes represented by these two groups of palynomorphs. The acritarchs were indigenous to the marine environment reflected fairly uniformly by the host strata (excepting the evaporitic Moose River Formation). The spores, on the other hand, were derived from the vegetation of the terrestrial environment adjacent to the marine depositional basin. Abundant preservation of both groups points to high levels of productivity for each, and their taxonomic diversities are roughly comparable at a given stratigraphic horizon.

However, viewing the composite palynostratigraphic sequence, a considerably higher proportion of the acritarch species (and genera) persist through the stratal section, or a large part of it, than do the spore taxa. This could imply, for instance, greater climatic effects or stresses on the land



TABLE 2.  
DISTRIBUTION OF ACRITARCH  
SPECIES IN CORE SAMPLES FROM  
JAAB LAKE NO. 1 WELL.

				ACRITARCH SPECIES	
STAGE	FORMATION	GSC LOCALITY	DEPTH IN FEET		
GIVETIAN	WILLIAMS ISLAND	8056	147-149	Veryhachium radium	Baltisphaeridium crebrum
		8060	187.5-189.5	Ozobrachion furcillatus	Dicelapellis ventricosa
	MURRAY ISLAND	8061	197-199.6	Dicelapellis ventricosa	Dicelapellis ventricosa
	MOOSE R.	8062	211-213	Gorgonospira granatum	Baltisphaeridium granatum
BIFELIAN	KWATA-BOAHEGAN	8068	283-285	Baltisphaeridium granatum	Baltisphaeridium granatum
		8073	324-326	Baltisphaeridium granatum	Baltisphaeridium granatum
		8075	340-341	Baltisphaeridium granatum	Baltisphaeridium granatum
		8076	344-346	Baltisphaeridium granatum	Baltisphaeridium granatum
		8077	350-352	Baltisphaeridium granatum	Baltisphaeridium granatum
		8078	360-362	Baltisphaeridium granatum	Baltisphaeridium granatum
		8079	371-372	Baltisphaeridium granatum	Baltisphaeridium granatum
		8080	378-380	Baltisphaeridium granatum	Baltisphaeridium granatum
		8081	390-392	Baltisphaeridium granatum	Baltisphaeridium granatum
		8083	436-437	Baltisphaeridium granatum	Baltisphaeridium granatum
		8084	439-441	Baltisphaeridium granatum	Baltisphaeridium granatum
		8085	451-453	Baltisphaeridium granatum	Baltisphaeridium granatum
		8086	461-463	Baltisphaeridium granatum	Baltisphaeridium granatum
		8087	471-473	Baltisphaeridium granatum	Baltisphaeridium granatum
		8088	487-488	Baltisphaeridium granatum	Baltisphaeridium granatum
		8089	493-495	Baltisphaeridium granatum	Baltisphaeridium granatum
		8090	509-511	Baltisphaeridium granatum	Baltisphaeridium granatum
		8091	523-526	Baltisphaeridium granatum	Baltisphaeridium granatum
		8092	533-535	Baltisphaeridium granatum	Baltisphaeridium granatum
		8093	555-557	Baltisphaeridium granatum	Baltisphaeridium granatum
EMSIAN	STOOPING RIVER	8095	571-573	Baltisphaeridium granatum	Baltisphaeridium granatum
		8096	589-591	Baltisphaeridium granatum	Baltisphaeridium granatum
		8097	599-600	Baltisphaeridium granatum	Baltisphaeridium granatum
		8098	609-610	Baltisphaeridium granatum	Baltisphaeridium granatum
		8099	617-619	Baltisphaeridium granatum	Baltisphaeridium granatum
		8100	627-629	Baltisphaeridium granatum	Baltisphaeridium granatum
		8101	639-641	Baltisphaeridium granatum	Baltisphaeridium granatum
		8102	649-650	Baltisphaeridium granatum	Baltisphaeridium granatum
		8103	657-659	Baltisphaeridium granatum	Baltisphaeridium granatum
		8104	671-673	Baltisphaeridium granatum	Baltisphaeridium granatum
		8105	681-683	Baltisphaeridium granatum	Baltisphaeridium granatum
		8106	691-693	Baltisphaeridium granatum	Baltisphaeridium granatum
		8107	699-700	Baltisphaeridium granatum	Baltisphaeridium granatum
		8108	723-727	Baltisphaeridium granatum	Baltisphaeridium granatum
		8109	735-737	Baltisphaeridium granatum	Baltisphaeridium granatum
		8110	745-747	Baltisphaeridium granatum	Baltisphaeridium granatum
		8111	755-757	Baltisphaeridium granatum	Baltisphaeridium granatum
		8112	765-767	Baltisphaeridium granatum	Baltisphaeridium granatum
		8113	775-777	Baltisphaeridium granatum	Baltisphaeridium granatum
SIEGENIAN		8114	785-786	Baltisphaeridium granatum	Baltisphaeridium granatum
		8115	815-817	Baltisphaeridium granatum	Baltisphaeridium granatum
		8116	833-834	Baltisphaeridium granatum	Baltisphaeridium granatum
		8117	860-862	Baltisphaeridium granatum	Baltisphaeridium granatum
		8118	871-873	Baltisphaeridium granatum	Baltisphaeridium granatum
		8119	885-886	Baltisphaeridium granatum	Baltisphaeridium granatum
		8120	896-898	Baltisphaeridium granatum	Baltisphaeridium granatum
		8121	898-900	Baltisphaeridium granatum	Baltisphaeridium granatum
		8122	909-911	Baltisphaeridium granatum	Baltisphaeridium granatum
		8123	915-917	Baltisphaeridium granatum	Baltisphaeridium granatum
		8124	925-927	Baltisphaeridium granatum	Baltisphaeridium granatum
		8125	935-937	Baltisphaeridium granatum	Baltisphaeridium granatum
		8126	944-945	Baltisphaeridium granatum	Baltisphaeridium granatum
		8127	960-962	Baltisphaeridium granatum	Baltisphaeridium granatum
		8128	972-974	Baltisphaeridium granatum	Baltisphaeridium granatum
		8134	1027-1029.6	Baltisphaeridium granatum	Baltisphaeridium granatum
		8135	1031-1033	Baltisphaeridium granatum	Baltisphaeridium granatum
		8136	1034-1035	Baltisphaeridium granatum	Baltisphaeridium granatum
				Baltisphaeridium granatum	Baltisphaeridium granatum

vegetation causing phytogeographic changes of greater magnitude; or it may be that the acritarch phytoplankton were then inherently more conservative or tolerant than the land flora. As Chaloner (1970) and others have pointed out, the land plant record of the Devonian was one of increasing diversity of successfully innovating vascular plants, becoming progressively well adapted to the terrestrial environment. Accordingly, the record of the dispersed spores would be expected to display concomitant morphological diversification, as indeed is the case.

In distinct contrast to the Lower and Middle Devonian acritarch assemblages reported herein, assemblages of latest Devonian to earliest Carboniferous age (Wicander, 1974, 1975) display a pronounced increase in extinction rates. The lowest Carboniferous suite, in particular, connotes drastic reductions, both qualitatively and quantitatively. Tappan and Loeblich (1970, and other separately authored and joint papers) have explored possible consequences of fluctuating phytoplankton productivity with respect to other components of the marine ecosystem.

## Selected Bibliography

- Audretsch, A.P.  
1968: Middle Devonian microflora from the Great Slave Lake area, Northwest Territories, Canada; Int. Symp. on the Devonian System, 1967, Proc., v. 2, p. 837-847.
- Bain, A. and Doubinger, J.  
1965: Etude d'un microplancton (Acrirarches) du Dévonien supérieur des Ardennes; Alsace-Lorraine, Serv. Carte Geol., v.18, p. 15-30.
- Baschnagel, R.A.  
1942: Some microfossils from the Onondaga Chert of central New York; Buffalo Soc. Nat. Sci., Bull., v. 17, p. 1-8.
- Becker, G., Bless, M.J.M., Streel, M., and Thorez, J.  
1974: Palynology and ostracod distribution in the Upper Devonian and basal Dinantian of Belgium and their dependence on sedimentary facies; Rijks Geol. Dienst., Meded., n.s., v. 25, p. 9-99.
- Beju, D.  
1967: Quelques spores, acritarches et chitinozoaires d'âge Dévonien inférieur de la plateforme Moésienne (Roumanie); Rev. Palaeobot. Palynol., v. 5, p. 39-49.
- Boalch, G.T. and Parke, M.  
1971: The prasinophycean genera (Chlorophyta) possibly related to fossil genera, in particular the genus *Tasmanites*; II Planktonic Conf., Roma (1967), Proc., p. 99-105.
- Brito, I.M.  
1967a: Silurian and Devonian Acritarcha from Maranhão Basin, Brazil; Micropaleontology, v. 13, p. 473-482.  
1967b: Novo Subgrupo de Acritarcha do Devoniano do Maranhão; Acad. Bras. Cienc., An., v. 39, p. 163-166.  
1967c: Contribuição ao conhecimento dos microfósseis Devonianos de Pernambuco. II—Acritarcha Pteromorphitae; Acad. Bras. Cienc., An., v. 39, p. 285-287.  
1967d: Os Acritarcha; Braz., Div. Geol. Mineral., Notas Prelim. Estud., no. 138, 21 p.  
1968: Contribuição ao conhecimento dos microfósseis Silurianos e Devonianos da Bacia do Maranhão. III—O gênero *Vervhachium* (Acritarcha); Rio de J., Univ. Fed., Inst. Geocienc., Geol., Bol., no. 2, p. 11-17.  
1969: Un nouveau sous-groupe d'Acritarche; Rio de J., Univ. Fed., Inst. Geocienc. Geol., Bol., no. 4, p. 11-13.  
1971: Contribuição ao conhecimento dos microfósseis Silurianos e Devonianos da Bacia do Maranhão. V—Acritarcha Herkomorphitae e Prismatomorphitae; Acad. Bras. Cienc., An., v. 43 (suppl.), p. 201-208.
- Brito, I.M. and Santos, A.S.  
1965: Contribuição ao conhecimento dos microfósseis Silurianos e Devonianos da Bacia do Maranhão; Braz., Div. Geol. Mineral., Notas Prelim. Estud., no. 129, 23 p.
- Chaloner, W.G.  
1970: The rise of the first land plants; Biol. Rev., v. 45, p. 353-377.
- Chibrikova, E.V.  
1970: Plant microfossils from the Lower Devonian of the western slope of the Urals and Uralia; Akad. Nauk S.S.S.R., Izv., Ser. Geol., v. 5, p. 113-124 (in Russian).  
1972: Plant microfossils from the South Urals and Cisuralia; Bashkir. Filial, Inst. Geol., Acad. Nauk S.S.S.R., Moscow, 220 p. (in Russian).
- Combaz, A., Lange, F.W., and Pansart, J.  
1967: Les "Leiofusidae" Eisenack, 1938; Rev. Palaeobot. Palynol., v. 1, p. 297-307.
- Combaz, A. and Streel, M.  
1970: Microfossiles végétaux du Tournaisien inférieur dans le 'core drill' de Brévillers (Pas-de-Calais, France); Univ. Liège, Congrès et Colloques, v. 55, p. 227-241.
- Córna, O.  
1969: Bemerkungen zu Verbreitung palynologischer Mikrofossilien vom Präkambrium bis zum Unterkarbon; Geol. Zb. (Slov. Akad. Vied), v. 22, p. 399-416.
- Cramer, F.H.  
1963: Nota provisional sobre la presencia de microplancton y esporomorfos en las rocas sedimentarias del Devónico Inferior en las Montañas Cantábricas; Estud. Geol. (Inst. Invest. Geol. "Lucas Mallada"), v. 19, p. 215-218.  
1964a: Some acritarchs from the San Pedro Formation (Gedinien) of the Cantabric Mountains in Spain; Soc. Belg. Geol., Paleontol. Hydrol., Bull., v. 73, p. 33-38.  
1964b: Microplankton from three Paleozoic formations in the Province of León, NW-Spain; Leidse Geol. Meded., v. 30, p. 253-361.  
1966a: Additional morphographic information on some characteristic acritarchs of the San Pedro and Furada Formations (Silurian Devonian boundary) in Leon and Asturias, Spain; Inst. Geol. Mineral. España, Notas Comuns., v. 83, p. 27-48.  
1966b: Palynomorphs from the Siluro-Devonian boundary in NW Spain; Inst. Geol. Mineral. España, Notas Comuns., v. 85, p. 71-82.  
1966c: Hoegispheres and other microfossils incertae sedis of the San Pedro Formation (Siluro Devonian boundary) near Valporquero, Leon, NW Spain; Inst. Geol. Mineral. España, Notas Comuns., v. 86, p. 75-94.  
1967: Palynology of Silurian and Devonian rocks in northwest Spain; Inst. Geol. Mineral. España, Bol., v. 77, p. 223-286.  
1968: Palynologic microfossils of the Middle Silurian Maplewood Shale in New York; Rev. Micropaleontol., v. 11, p. 61-70.  
1971: Distribution of selected Silurian acritarchs; Rev. Espan. Micropaleontol., Num. Extra., 203p. (publication date vide Loeblich and Tappan, 1976, p. 302).
- Cramer, F.H. and Diez, M. del C.R.  
1968: Consideraciones taxonómicas sobre las acritarcas del Silúrico Medio y Superior del Norte de España: Las acritarcas acantomorfiticas; Inst. Geol. Mineral. España, Bol., v. 79, p. 541-574.  
1972: North American Silurian palynofacies and their spatial arrangement: Acritarchs; Palaeontographica, Abt. B, v. 138, p. 107-180.
- Daemon, R.F., Quadros, L.P., and da Silva, S.A.  
1967: Devonian palynology and biostratigraphy of the Paraná Basin in Bigarella, J.J. (ed.), Problems in Brazilian Devonian geology; Bol. Paranaense Geocienc., nos. 21/22, p. 99-132.
- Deflandre, G.  
1942: Sur les Hystrichosphères des calcaires siluriens de la Montagne Noire; Acad. Sci., C.R., Paris, v. 215, p. 475-476.  
1945: Microfossiles des calcaires siluriens de la Montagne Noire; Ann. Paleontol., v. 31, p. 39-75.



- 1954: Systematique des hystrichosphaeridés: sur l'acception de genre *Cymatiosphaera* O. Wetzel; Soc. Geol. Fr., C.R. somm., v. 1954/12, p. 257-258.
- Dettmann, M.E.  
1973: Angiospermous pollen from Albian to Turonian sediments of eastern Australia; Geol. Soc. Aust., Spec. Publ., no. 4, p. 3-34.
- Deunff, J.  
1954a: Micro-organismes planctoniques (Hystrichosphères) dans le Dévonien du Massif armoricain; Soc. Geol. Fr., C.R. somm., v. 1954/11, p. 239-242.  
1954b: Sur un microplancton du Dévonien du Canada recélant des types nouveaux d'Hystrichosphaeridés; Acad. Sci. Paris, v. 239, p. 1064-1066.  
1955: Un microplancton fossile dévonien à hystrichosphères du continent Nord-Américain; Bull. Micros. Appl., ser. 2, v. 5, p. 138-149.  
1957: Micro-organismes nouveaux (Hystrichosphères) du Dévonien de l'Amérique du Nord; Soc. Geol. Mineral. Bretagne, Bull., new ser., v. 1957/2, p. 5-14.  
1959: Micro-organismes planctoniques du Primaire armoricain. I—Ordovicien du Verrucosus (presqu'île de Crozon); Soc. Geol. Mineral. Bretagne, Bull., new ser., v. 1958/2, p. 1-41.  
1961: Quelques précisions concernant les Hystrichosphaeridés du Dévonien du Canada; Soc. Geol. Fr., C.R. somm., v. 1961/8, p. 216-218.  
1964: Le genre *Duvernaysphaera* Staplin; Grana Palynol., v. 5, p. 210-215.  
1965: Acritarches du Dévonien supérieur de la presqu'île de Crozon; Soc. Geol. Fr., C.R. somm., v. 1965/5, p. 162-164.  
1966a: Acritarches du Dévonien du Tunisie; Soc. Geol. Fr., C.R. somm., v. 1966/1, p. 22-24.  
1966b: Recherches sur les microplanctons du Dévonien (Acritarches et Dinophyceae); Rennes, the author, 168 p.  
1967: Présence d'Acritarches dans une série dévonienne du lac Huron (Canada); Soc. Geol. Fr., C.R. somm., v. 1967/6, p. 258-260.  
1968: Sur une série à Acritarches dans le Dévonien moyen du Finistère; Fr., Bur. Rech. Geol. Minières, Mem., v. 33, p. 341-348.  
1971: Le genre *Polyedryxium* Deunff—révision et observations in Microfossiles organiques du Paléozoïque, fasc. 3, Commission Internationale de Microflore du Paléozoïque, p. 7-49.
- Deunff, J. and Evitt, W.R.  
1968: *Tunisphaeridium*, a new acritarch genus from the Silurian and Devonian; Stanford Univ. Publ., Geol. Sci., v. 12, p. 1-13.
- Deunff, J. and Paris, F.  
1972: Présence d'un paléoplancton à Acritarches, Chitinozoaires, Spores, Scolécodontes et Radiolaires dans les formations Siluro-dévonniennes de la région de Plourach (Côtes-du-Nord); Soc. Geol. Mineral. Bretagne, Bull., ser. C, v. 3, p. 83-88.
- Downie, C.  
1959: Hystrichospheres from the Silurian Wenlock Shale of England; Palaeontology, v. 2, p. 56-71.  
1963: 'Hystrichospheres' (acritarchs) and spores of the Wenlock Shales (Silurian) of Wenlock, England; Palaeontology, v. 6, p. 625-652.  
1973: Observations on the nature of acritarchs; Palaeontology, v. 16, p. 239-259.
- Downie, C. and Sarjeant, W. A. S.  
1963: On the interpretation and status of some hystrichosphere genera; Palaeontology, v. 16, p. 83-96.
- Dricot, E.M.  
1968: Evolution et distribution paléogéographique du microplancton (Acritarches) dans le Frasnien de la Belgique; Int. Symp. on the Devonian System, 1967, Proc., v. 2, p. 855-859.
- Eisenack, A.  
1938: Hystrichosphaerideen und verwandte Formen im baltischen Silur; Z. Geschiebeforsch. Flachlandsgeol., v. 14, p. 1-30.  
1954: Hystrichosphären aus dem baltischen Gotlandium; Senckenberg., v. 34, p. 205-211.  
1955: Chitinozoen, Hystrichosphären und andere Mikrofossilien aus dem Beyrichia-Kalk; Senckenb. Lethaea, v. 36, p. 157-188.  
1959: Neotypen baltischer Silur-Hystrichosphären und neue Arten; Palaeontographica, Abt. A, v. 112, p. 193-211.  
1962: Einige Bemerkungen zur neueren Arbeiten über Hystrichosphären; Neues Jahrb. Geol. Palaeontol., Monatsh., Jg. 1962, H. 2, p. 92-101.  
1965a: Mikrofossilien aus dem Silur Gotlands. Hystrichosphären, Problematika; Neues Jahrb. Geol. Palaeontol., Abh., v. 122, p. 257-274.  
1965b: Die Mikrofauna der Ostseekalke. Chitinozoen, Hystrichosphären; Neues Jahrb. Geol. Palaeontol., Abh., v. 123, p. 115-148.  
1969: Zur systematik einiger paläozoischer Hystrichosphären (Acritarcha) des baltischen Gebietes; Neues Jahrb. Geol. Palaeontol., Abh., v. 133, p. 245-266.  
1972: Kritische Bemerkung zur Gattung *Pterospermopsis* (Chlorophyta, Prasinophyceae); Neues Jahrb. Geol. Palaeontol., Monatsh., Jg. 1972, H. 10, p. 596-601.  
1974: Beiträge zur Acritarchen-Forschung; Neues Jahrb. Geol. Palaeontol., Abh., v. 147, p. 269-293.
- Eisenack, A. and Cramer, F.H.  
1973: Katalog der fossilen Dinoflagellaten, Hystrichosphären und verwandten Mikrofossilien, Band III, Acritarcha 1 Teil, Stuttgart, 1104 p.
- Evitt, W.R.  
1961: Observations on the morphology of fossil dinoflagellates; Micropaleontology, v. 7, p. 385-420.  
1963: A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs, I, II; Natl. Acad. Sci., Proc., v. 49, p. 158-164, p. 298-302.  
1967: Dinoflagellate studies II. The archeopyle; Stanford Univ. Publ., Geol. Sci., v. 10, p. 1-83.
- Górka, H.  
1969: Microorganismes de l'Ordovicien de Pologne; Palaeontol. Pol., no. 22, 102 p.  
1974a: Les Acritarches de concrétions calcaires du Famennien supérieur de Lagów (Monts de Sainte Croix, Pologne); Acta Palaeontol. Pol., v. 19, p. 225-250.  
1974b: Quelques informations sur une association d'Acritarches du Famennien de Pologne; Rev. Palaeobot. Palynol., v. 18, p. 131-135.
- Jankauskas, T.V. and Vaitiekuniene, G.K.  
1972: Silurian Acritarcha from the Baltic area; Palaeontol. Zh., v. 1972/2, p. 113-121 (in Russian).
- Jansonius, J.  
1962: Palynology of Permian and Triassic sediments, Peace River area, western Canada; Palaeontographica, Abt. B, v. 110, p. 35-98.
- Jardiné, S.  
1972: Microplancton (Acritarches) et limites stratigraphiques du Silurien terminal au Dévonien supérieur; 7th Congr. Int. Strat. Geol. Carb., Krefeld (1971), C.R., v. 1, p. 313-323.
- Jardiné, S., Combaz A., Magloire, L., Peniguel, G., and Vachey, G.  
1972: Acritarches du Silurien terminal et du Dévonien du Sahara algérien; 7th Congr. Int. Strat. Geol. Carb., Krefeld (1971), C.R., v. 1, p. 295-311.
- Jardiné, S., Combaz, A., Magloire, L., Peniguel, G., and Vachey, G.  
1974: Distribution stratigraphique des Acritarches dans le Paléozoïque du Sahara algérien; Rev. Palaeobot. Palynol., v. 18, p. 99-129.
- Jardiné, S. and Yapaudjian, L.  
1968: Lithostratigraphie et palynologie du Dévonien-

- Gothlandien gréseux du bassin de Polignac (Sahara); Inst. Fr. Pet., Rev., v. 23, p. 439-469.
- Jux, U.  
1975: Phytoplankton aus dem mittleren Oberdevon (Nehden-Stufe) des südwestlichen Bergischen Landes (Rheinisches Schiefergebirge); Palaeontographica, Abt. B, v. 149, p. 113-138.
- Kjellström, G.  
1971: Ordovician microplankton (baltisphaerids) from the Grötlingbo borehole no. 1 in Gotland, Sweden; Sver. Geol. Unders., Aarsb., v. 65, p. 1-75.
- Lange, F.W.  
1967: Biostratigraphic subdivision and correlation of the Devonian in the Paraná Basin in Bigarella, J.J., (ed.), Problems in Brazilian Devonian geology; Bol. Paran. Geoscienc., nos. 21/22, p. 63-98.
- Lanzoni, E. and Magloire, L.  
1969: Associations palynologiques et leurs applications stratigraphiques dans le Dévonien supérieur et Carbonifère inférieur du Grand Erg occidental (Sahara algérien); Inst. Fr. Pet., Rev., v. 24, p. 441-469.
- Legault, J.  
1973: Chitinozoa and Acritarcha of the Hamilton Formation (Middle Devonian), southwestern Ontario; Geol. Surv. Can., Bull. 221, 103 p.
- Lele, K.M.  
1972: Observations on Middle Devonian microfossils from the Barrandian Basin, Czechoslovakia; Rev. Palaeobot. Palynol., v. 14, p. 129-134.
- Lister, T.R.  
1970: A monograph of the acritarchs and Chitinozoa from the Wenlock and Ludlow series of the Ludlow and Millchope areas, Shropshire—Part 1; Palaeontogr. Soc., Monogr., v. 124, p. 1-100.
- Loeblich, A.R., Jr.  
1970: Morphology, ultrastructure and distribution of Paleozoic acritarchs; North Am. Paleontol. Conv., Chicago (1969), Proc., pt. G, p. 705-788.
- Loeblich, A.R., Jr. and Drugg, W.S.  
1968: New acritarchs from the Early Devonian (late Gedinian) Haragan Formation of Oklahoma, U.S.A.; Tulane Stud. Geol., v. 6, p. 129-137.
- Loeblich, A.R., Jr. and Tappan, H.  
1969: Acritarch excystment and surface ultrastructure with descriptions of some Ordovician taxa; Rev. Espan. Micropaleontol., v. 1, p. 45-57.  
1970: *Thysanoprobolus*, a new acritarch genus from the Early Devonian (late Gedinian) Haragan Formation of Oklahoma, U.S.A.; Biol. Soc. Wash., Proc., v. 83, p. 261-266.  
1976: Some new and revised organic-walled phytoplankton microfossil genera; J. Paleontol., v. 50, p. 301-308.
- Loeblich, A.R., Jr. and Wicander, E.R.  
1974: New Early Devonian (late Gedinian) microphytoplankton: *Demorhethium lappaceum* n.g., n. sp., from the Bois d'Arc Formation of Oklahoma, U.S.A.; Neues Jahrb. Geol. Palaeontol., Monatsh., Jg. 1974, H. 12, p. 707-711.
- Mädler, K.  
1963: Die figurierten organischen Bestandteile der Posidonienschiefer; Geol. Jahrb., Beih., v. 58, p. 287-406.
- Magloire, L.  
1968: Etude stratigraphique par la Palynologie, des dépôts argilo-gréseux du Silurien et du Dévonien inférieur dans la Région du Grand Erg Occidental (Sahara algérien); Int. Symp. on the Devonian System, 1967, Proc., v. 2, p. 473-491.
- Malyavkina, V.S.  
1949: Identification of spores and pollen of the Jurassic and Cretaceous; Vses. Neft. Nauchno-Issled. Geologorazved. Inst., Tr., v. 33, 137 p. (in Russian).
- Martin, F.  
1965: Les Acritarches du sondage de la Brasserie Lust, à Kortrijk (Courtrai) (Silurien belge); Soc. Belg. Geol., Paleontol. Hydrol., Bull., v. 74, p. 354-402.  
1966: Les Acritarches du parc de Neuville-sous-Huy (Silurien belge); Soc. Belg. Geol., Paleontol. Hydrol., Bull., v. 75, p. 306-335.  
1968: Les Acritarches de l'Ordovicien et du Silurien belges; Inst. R. Sci. Nat. Belg., Mem., no. 160, 175 p.  
1974: Ordovicien supérieur et Silurien inférieur à Deerlijk (Belgique); Inst. R. Sci. Nat. Belg., Mem., no. 174, 71 p.
- Martinez-Macchiavello, J.C.  
1968: Quelques Acritarches d'un échantillon du Dévonien inférieur (Cordobés) de Blanquillo, Département de Durezo, Uruguay; Rev. Micropaleontol., v. 11, p. 77-84.
- McGregor, D.C. and Camfield, M.  
1976: Upper Silurian? to Middle Devonian spores of the Moose River Basin, Ontario; Geol. Surv. Can., Bull. 263, 63 p.
- McGregor, D.C., Sanford, B.V., and Norris, A.W.  
1970: Palynology and correlation of Devonian formations in the Moose River Basin, northern Ontario; Geol. Assoc. Can., Proc., v. 22, p. 45-54.
- Moreau-Benoit, A.  
1967: Quelques microplanctontes du Dévonien inférieur de l'Anjou; Rev. Micropaleontol., v. 10, p. 200-208.  
1969: Etude palynologique des formations schisto-gréseuses associées au Calcaire de Chalonnès aux carrières Saint-Charles et Tarare en Chateaufonds (Maine-et-Loire); Soc. d'Etudes Scientifique de l'Anjou, Bull., n.s., v. 7, p. 93-99.  
1972: Palynologie stratigraphique du Silurien et du Dévonien dans le sud-est du Massif Armoricain; 7th Congr. Int. Strat. Geol. Carb., Krefeld (1971), C.R., v. 1, p. 285-293.  
1974: Recherches de palynologie et de planctonologie. Sur le Dévonien et quelques formations siluriennes dans le sud-est du Massif Armoricain; Soc. Geol. Mineral. Bretagne, Mem., v. 18, 248 p.
- Morgenroth, P.  
1968: Zur Kenntnis der Dinoflagellaten und Hystrichosphaeriden des Danien; Geol. Jahrb., v. 86, p. 533-578.
- Nadler, Yu. S.  
1973: Phytoplankton and spores from Devonian deposits of Salair, in Lower and Middle Devonian stratigraphy, Trudy 3rd. Int. Symp. Silurian-Devonian boundary and stratigraphy of Lower and Middle Devonian, Leningrad (1968), v. 2, p. 168-172 (in Russian).
- Oliver, W.A., Jr., de Witt, W., Jr., Dennison, J.M., Hoskins, D.M., and Huddle, J.W.  
1969: Correlation of Devonian rock units in the Appalachian Basin; U.S. Geol. Surv., Oil and Gas Invest. Chart, no. OC-64.
- Pilcher, R.  
1971: Mikrofossilien aus dem Devon der südlichen Eifeler Kalkmulden; Senckenb. Lethaea, v. 52, p. 315-357.
- Playford, G.  
1976: Plant microfossils from the Upper Devonian and Lower Carboniferous of the Canning Basin, Western Australia; Palaeontographica, Abt. B, v. 158, p. 1-71.
- Pöthe de Baldi, E.D.  
1974a: El microplancton del Devónico medio de Paraguay; Rev. Espan. Micropaleontol., v. 6, p. 367-379.  
1974b: Microplancton adicional del Silurico superior de Santiago del Estero, Republica Argentina; Ameghiniana, v. 11, p. 313-327.  
1975a: Microplancton del Wenlockiano de la Precordillera Argentina; Rev. Espan. Micropaleont., v. 7, p. 489-505.  
1975b: Microplancton de la formacion Los Espejos, provincia de San Juan, Republica Argentina; Rev. Espan. Micropaleontol., v. 7, p. 507-518.

- Rauscher, R.  
1969a: Présence d'une forme nouvelle d'Acrotarches dans le Dévonien de Normandie; Acad. Sci., C.R., Ser. D, v. 268, p. 34-36.  
1969b: Analyse palyno-planctologique du Silurien supérieur du Pas-de-Calais; Soc. Geol. Nord, Ann., v. 89, p. 317-322.
- Rauscher, R. and Doubinger, J.  
1968: Etude palyno-planctologique dans le bassin de Sainte-Mère-Eglise (Normandie); Alsace-Lorraine, Serv. Carte Geol., v. 21, p. 315-320.
- Rauscher, R., Doubinger, J., and Manche-Bain, A.  
1965: Spores et acrotarches du Dévonien inférieur (Siegénien) du Cotentin; Alsace-Lorraine, Serv. Carte Geol., v. 18, p. 307-317.
- Reigel, W.  
1974: Phytoplankton from the upper Emsian and Eifelian of the Rhineland, Germany—a preliminary report; Rev. Palaeobot. Palynol., v. 18, p. 29-39.
- Sanford, B.V. and Norris, A.W.  
1973: The Hudson Platform in McCrossan, R.G. (ed.), The future petroleum provinces of Canada, their geology and potential; Can. Soc. Pet. Geol., Mem., no. 1, p. 387-409.
- Sanford, B.V. and Norris, A.W.  
1975: Devonian stratigraphy of the Hudson Platform; Geol. Surv. Can., Mem. 379, 124 p. (pt. 1) plus 248 p. (pt. 2).
- Sannemann, D.  
1955: Hystrichosphaeriden aus dem Gotlandium und Mittel-Devon des Frankenwaldes und ihr Feinbau; Senckenb. Lethaea, v. 36, p. 321-346.
- Sarjeant, W.A.S.  
1973: Acrotarches and tasmanitids from the Mianwali and Tredian Formations (Triassic) of the Salt and Surghar Ranges, West Pakistan in Logan, A. and Hills, L. V. (eds.), The Permian and Triassic systems and their mutual boundary; Can. Soc. Pet. Geol., Mem., no. 2, p. 35-73.
- Sheshigova, L.I.  
1971a: The acrotarches of the Paleozoic in Vozzhennikova, T.F. (ed.), Algae of the Paleozoic and Mesozoic of Siberia; Nauka, Moscow, p. 9-35. (in Russian).  
1971b: The Upper Devonian acrotarches of the Augerian region of Kuzbass in Vozzhennikova, T.F. (ed.), Algae of the Paleozoic and Mesozoic of Siberia; Nauka, Moscow, p. 50-60 (in Russian).
- Sommer, F.W. and van Boekel, N.M.  
1963: Some new Tasmanaceae from the Devonian of Para; Acad. Bras. Cienc., An., v. 35, p. 61-65.  
1966: Revisão das Tasmanáceas Paleozóicas Brasileiras; Acad. Bras. Cienc., An., v. 38, p. 53-64.
- Staplin, F.L.  
1961: Reef-controlled distribution of Devonian microplankton in Alberta; Palaeontology, v. 4, p. 392-424.
- Staplin, F.L., Jansonius, J., and Pocock, S.A.J.  
1965: Evaluation of some acrotarchous hystrichosphere genera; Neues Jahrb. Geol. Palaeontol., Abh., v. 123, p. 167-201.
- Stockmans, F. and Willière, Y.  
1960: Hystrichosphères du Dévonien belge (Sondage de l'Asile d'aliénés à Tournai); Senckenb. Lethaea, v. 41, p. 1-11.  
1962a: Hystrichosphères du Dévonien belge (Sondage de l'Asile d'aliénés à Tournai); Soc. Belg. Geol., Paleontol. Hydrol., Bull., v. 71, p. 41-77.  
1962b: Hystrichosphères du Dévonien belge (Sondage de Wépion); Soc. Belg. Geol., Paleontol. Hydrol., Bull., v. 71, p. 83-99.  
1963: Les hystrichosphères ou mieux les Acrotarches du Silurien belge. Sondage de la Brasserie Lust à Courtrai (Kortrijk); Soc. Belg. Geol., Paleontol. Hydrol., Bull., v. 71, p. 450-481.  
1969: Acrotarches du Famennien inférieur; Acad. R. Belg., Cl. Sci., Mem., v. 38, p. 1-63.
- 1974: Acrotarches de la 'Tranchée de Senzeille' (Frasnien supérieur et Famennien inférieur); Acad. R. Belg., Cl. Sci., Mem., v. 41, p. 1-79.
- Tappan, H. and Loeblich, A.R., Jr.  
1970: Geobiologic implications of fossil phytoplankton evolution and time-space distribution in Kossan, R.M. and Cross, A.T. (eds.), Symposium on palynology of the Late Cretaceous and Early Tertiary; Geol. Soc. Am., Spec. Pap., v. 127, p. 247-340.  
1971: Surface sculpture of the wall in Lower Paleozoic acrotarches; Micropaleontology, v. 17, p. 385-410.  
1973: Evolution of the oceanic plankton; Earth-Sci. Rev., v. 9, p. 207-240.
- Thusu, B.  
1973a: Acrotarches provenant de L'Ilion Shale (Wenlockien), Utica, New York; Rev. Micropaleontol., v. 16, p. 137-146.  
1973b: Acrotarches of the Middle Silurian Rochester Formation of southern Ontario; Palaeontology, v. 16, p. 799-826.
- Timofeev, B.  
1959: The ancient flora of the Baltic region and its stratigraphic significance; Vses. Neft. Nauchno-Issled. Geologorazved. Inst., Tr., v. 120, 320 p. (in Russian).
- van Boekel, N.M.  
1968: Microfósseis Devonianos do Rio Tapajós, Para; Braz., Div. Geol. Mineral., Notas Prelim. Estud., no. 145, 15 p.
- Wetzel, O.  
1933: Die in organischer Substanz erhaltenen Mikrofossilien des baltischen Kreditefeuersteins; Palaeontographica, Abt. A, v. 77-78, p. 141-186 plus p. 1-100.
- Wetzel, W.  
1952: Beitrag zur Kenntnis, des Dan-zeitlichen Meeresplanktons; Geol. Jahrb., v. 66, p. 391-420.
- Wicander, E.R.  
1974: Upper Devonian-Lower Mississippian acrotarches and prasinophycean algae from Ohio, U.S.A.; Palaeontographica, Abt. B, v. 148, p. 9-43.  
1975: Fluctuations in a Late Devonian-Early Mississippian phytoplankton flora of Ohio, U.S.A.; Palaeogeogr. Palaeoclimatol. Palaeoecol., v. 17, p. 89-108.
- Williams, G.L., Sarjeant, W.A.S., and Kidson, E.J.  
1973: A glossary of the terminology applied to dinoflagellate amphiesmae and cysts and acrotarches; Am. Assoc. Stratigr. Palynol., Contrib. Ser., no. 2, 222 p.
- Wilson, L.R. and Skvarla, J.J.  
1967: Electron-microscope study of *Quisquilites* and *Tasmanites*; Okla. Geol. Notes, v. 27, p. 54-63.
- Wilson, L.R. and Urban, J.B.  
1963: An incertae sedis palynomorph from the Devonian of Oklahoma; Okla. Geol. Notes, v. 23, p. 16-19.
- Wilson, L.R. and Urban, J.B.  
1971: Electron microscope studies of the marine palynomorph *Quisquilites*; Micropaleontology, v. 17, p. 239-243.
- Winder, C.G.  
1968: Micropalaeontology of the Devonian in Ontario; Int. Symp. on the Devonian System, 1967, Proc., v. 2, p. 711-719.
- Winslow, M.R.  
1962: Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio; U.S. Geol. Surv., Prof. Pap., no. 364, 93 p.

## Plates 1 – 20

All figures are from unretouched negatives and prints.

Transmitted light photomicrographs were taken under bright field illumination, except where indicated by letters IC (=interference contrast illumination).

The majority of specimens photographed under the scanning electron microscope (SEM) were remounted and preserved in glycerine jelly slides (e.g., 8135-S1) as cited in the plate explanations.

Plate 1

Figures 1–8. *Baltisphaeridium anfractum* sp. nov.; figure 1, holotype, slide 8111-6,  $59.5 \times 111.6$ , GSC 48266,  $\times 500$ ; figure 2, slide 8127-4,  $62.0 \times 104.3$ , GSC 48267,  $\times 500$ ; figure 3, slide 8127-36,  $32.6 \times 105.1$ , GSC 48268,  $\times 500$ ; figure 4, slide 8108-5,  $42.2 \times 101.8$ , GSC 48269,  $\times 500$ ; figures 5, 6, slide 7851-S1,  $42.8 \times 106.7$ , GSC 48270, SEM,  $\times 500$  and  $\times 2500$  respectively; figure 7, slide 7851-S2,  $38.9 \times 103.6$ , GSC 48271, SEM,  $\times 750$ ; figure 8, slide 7851-S1,  $41.6 \times 107.0$ , GSC 48272, SEM,  $\times 2500$ .

Figures 9–12. *Baltisphaeridium crebrum* sp. nov.; figure 9, holotype, slide 8124-11,  $36.5 \times 103.1$ , GSC 48273,  $\times 1000$ ; figure 10, slide 8114-1,  $48.0 \times 95.3$ , GSC 48274,  $\times 750$ ; figures 11, 12, slide 8121-5,  $41.5 \times 96.1$ , GSC 48275, high and median foci respectively,  $\times 750$ .

Figures 13, 14. *Baltisphaeridium distentum* sp. nov.; figure 13, slide 8099-1,  $28.1 \times 107.5$ , GSC 48276,  $\times 1000$ ; figure 14, slide 8127-73,  $37.9 \times 104.3$ , GSC 48277,  $\times 750$ .

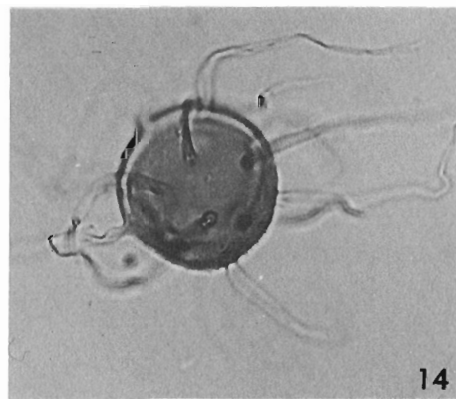
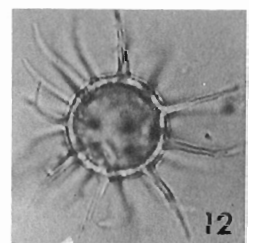
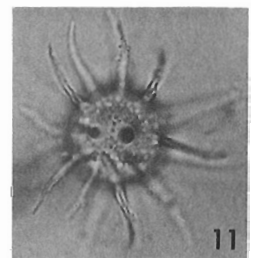
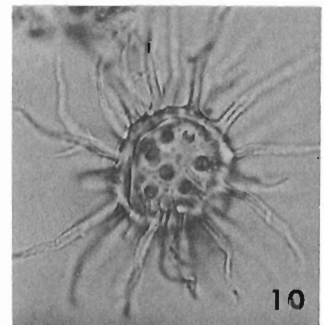
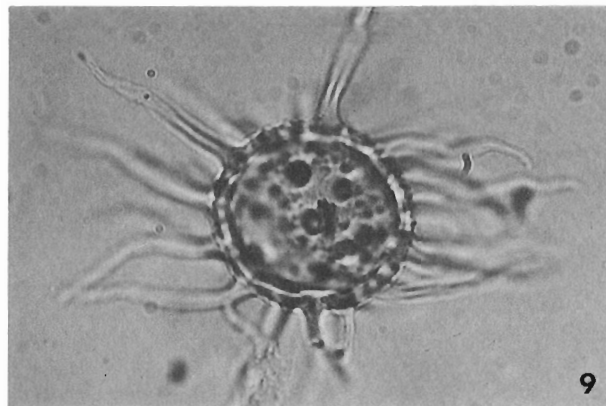
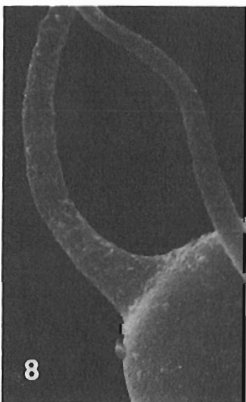
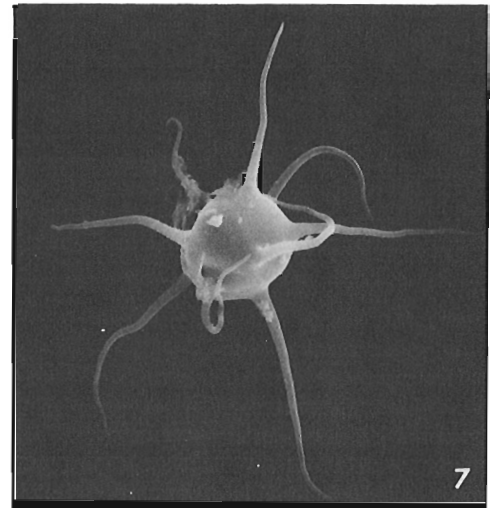
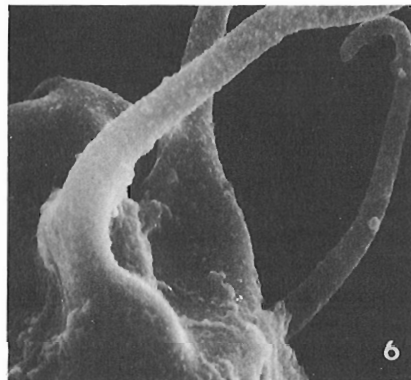
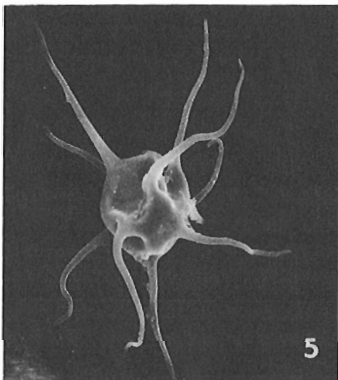
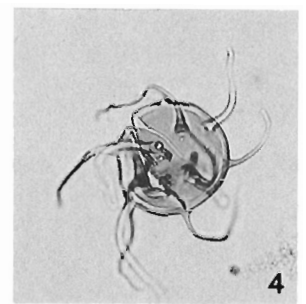
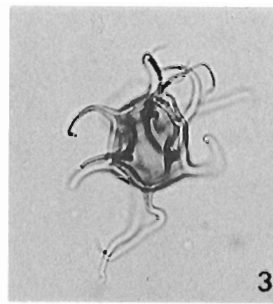
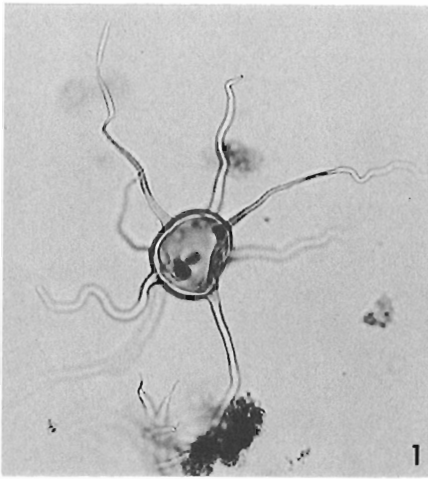


Plate 2

Figures 1–5. *Baltisphaeridium distentum* sp. nov.; figure 1, holotype, slide 8127-18,  $34.1 \times 102.5$ , GSC 48278,  $\times 750$ ; figures 2, 3, slide 7851-S2,  $37.0 \times 102.8$ , GSC 48279, SEM,  $\times 750$  and  $\times 2500$  respectively; figure 4, slide 7851-S2,  $37.4 \times 102.8$ , GSC 48280, SEM,  $\times 750$ ; figure 5, slide 7851-S1,  $42.7 \times 105.1$ , GSC 48281, SEM,  $\times 2500$ .

Figures 6–11. *Baltisphaeridium juliae* Cramer, 1964; figures 6, 7, slide 8108-S1,  $51.0 \times 105.7$ , GSC 48282, SEM,  $\times 1000$  and  $\times 2500$  respectively; figures 8, (IC), 9, slide 8108-1,  $34.3 \times 98.3$ , GSC 48283,  $\times 750$ ; figure 10, slide 8108-1,  $61.0 \times 106.8$ , GSC 48284,  $\times 750$ ; figure 11, slide 8108-1,  $36.6 \times 107.7$ , GSC 48285,  $\times 750$ .

Figures 12–15. *Baltisphaeridium microfurcatum* (Deunff) Stockmans and Willièvre, 1962; figure 12, slide 8122-2,  $39.0 \times 94.8$ , GSC 48286,  $\times 750$ ; figure 13, slide 8111-10,  $38.5 \times 105.5$ , GSC 48287,  $\times 750$ ; figures 14, 15, slide 8123-8,  $48.3 \times 98.6$ , GSC 48288, high and median foci respectively,  $\times 750$ .



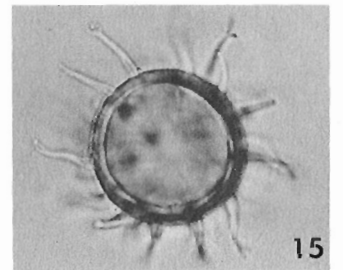
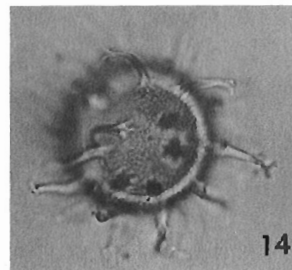
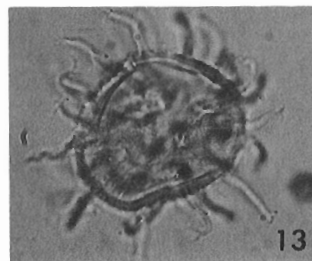
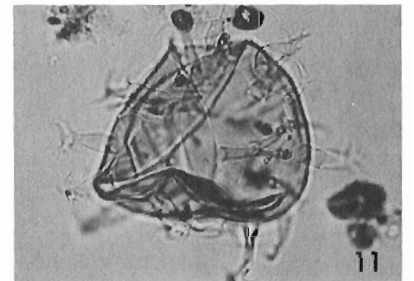
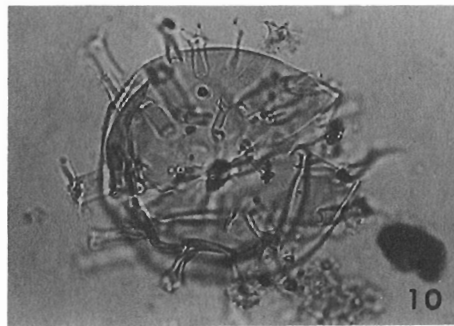
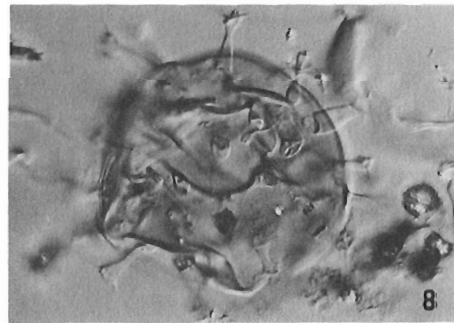
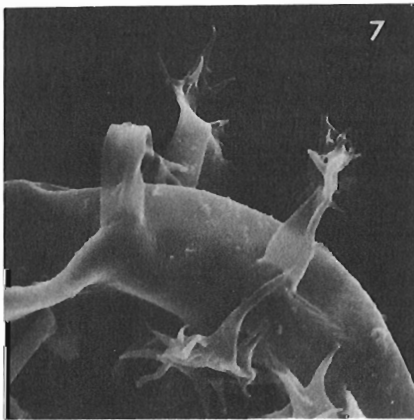
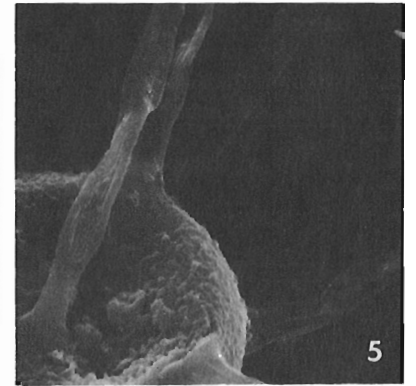
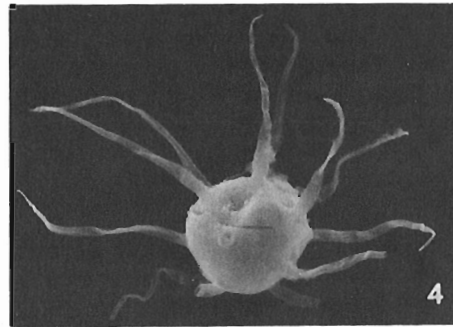
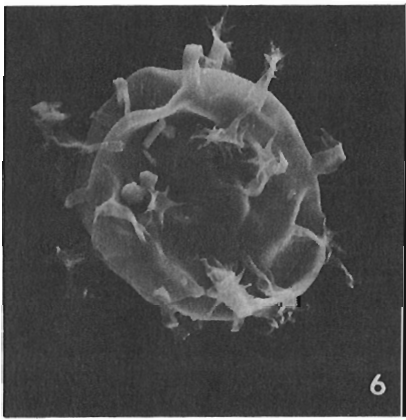
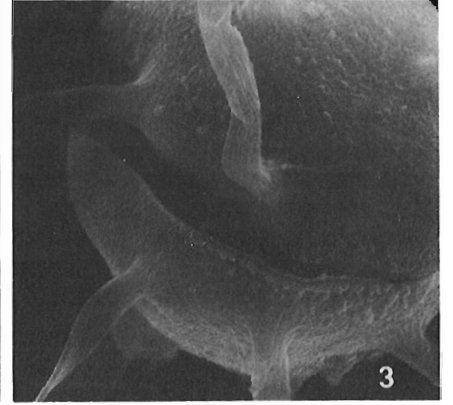
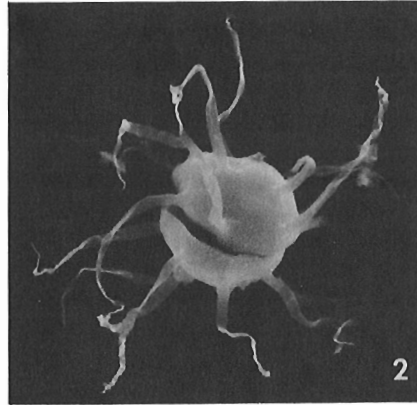
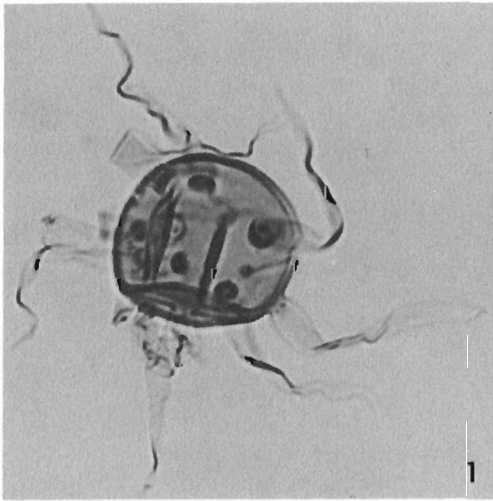


Plate 3

Figures 1–3. *Baltisphaeridium stamineum* sp. nov.; figure 1, holotype, slide 8111-3,  $48.8 \times 113.3$ , GSC 48289,  $\times 500$ ; figure 2, slide 8109-4,  $36.2 \times 111.7$ , GSC 48290,  $\times 1000$ ; figure 3, slide 8113-4,  $47.6 \times 107.8$ , GSC 48291,  $\times 1000$ .

Figures 4–9. *Costatilobus undulatus* gen. et sp. nov.; figures 4, 5, holotype, slide 8124-13,  $32.2 \times 101.9$ , GSC 48292,  $\times 750$  and  $\times 500$  respectively; figure 6, slide 8127-4,  $32.5 \times 106.3$ , GSC 48293,  $\times 500$ ; figures 7, 8, slide 8124-S1,  $34.4 \times 103.1$ , GSC 48294, SEM,  $\times 1000$  and  $\times 2500$  respectively; figure 9, slide 7851-S1,  $41.2 \times 105.8$ , GSC 48295, SEM,  $\times 500$ .

Figures 10–12. *Baltisphaeridium microfurcatum* (Deunff) Stockmans and Willièvre, 1962; figure 10, GSC loc. 8124, SEM,  $\times 1000$ ; figure 11, slide 8124-S2,  $39.1 \times 102.5$ , GSC 48296, SEM,  $\times 2500$ ; figure 12, slide 8135-S1,  $35.3 \times 102.1$ , GSC 48297, SEM,  $\times 1000$ .

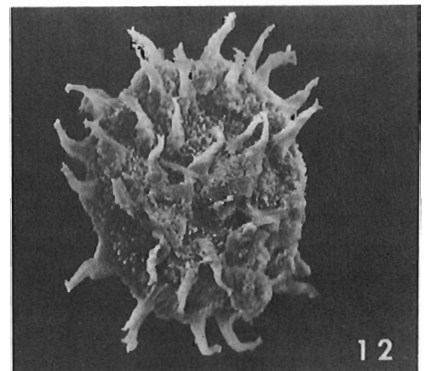
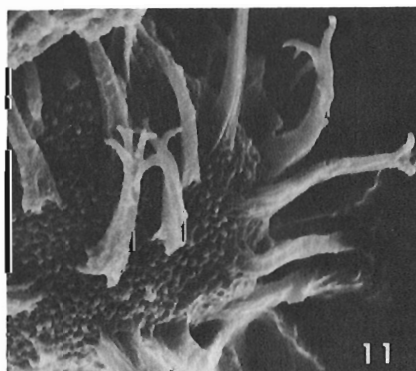
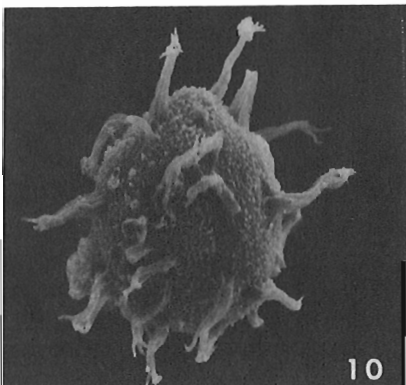
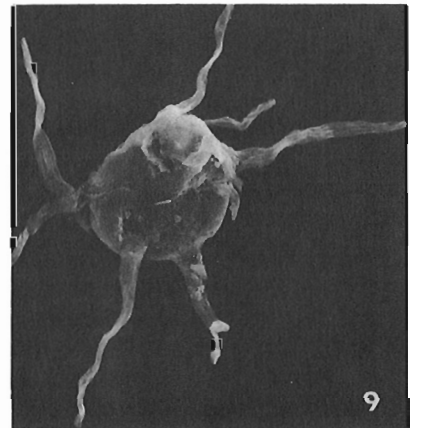
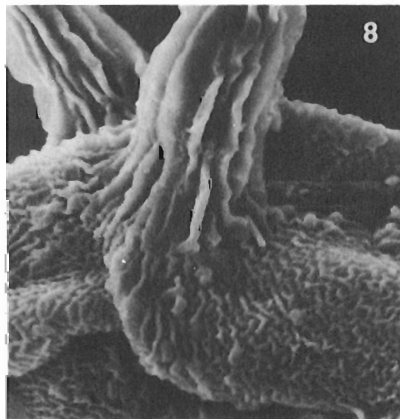
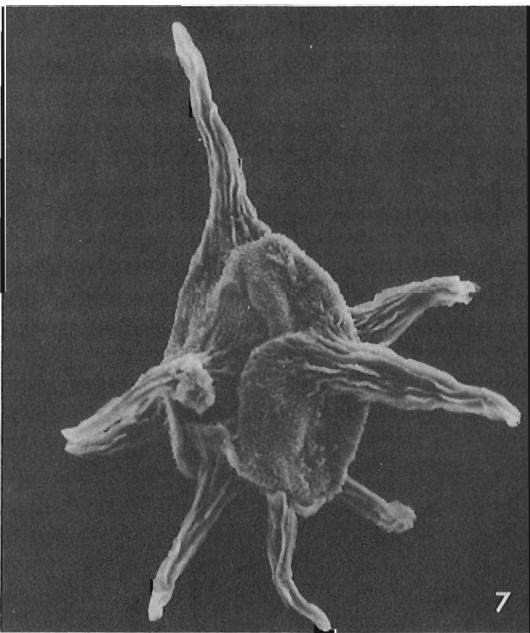
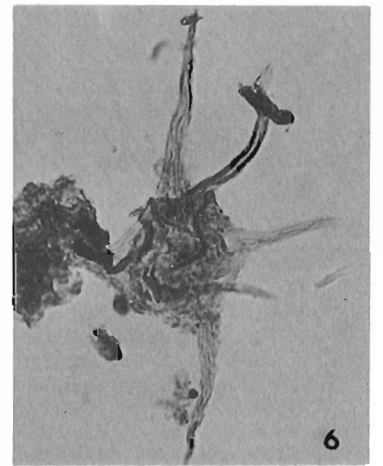
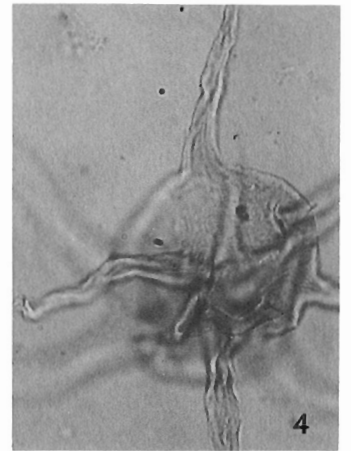
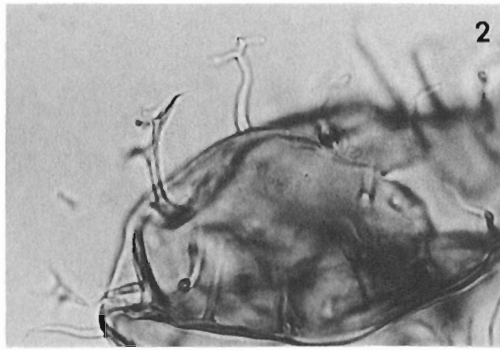
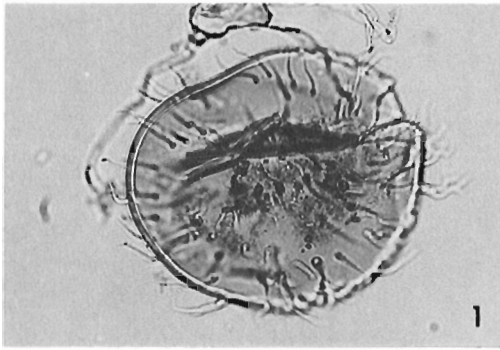


Plate 4

Figures 1, 2. *Cymatiosphaera canadensis* Deunff, 1961; figure 1, slide 8135-8,  $68.9 \times 104.5$ , GSC 48298,  $\times 500$ ; figure 2, slide 8135-12,  $32.6 \times 104.8$ , GSC 48299,  $\times 500$ .

Figure 3. *Cymatiosphaera multisepta* Deunff, 1955; slide 8056-3,  $68.4 \times 108.9$ , GSC 48300,  $\times 750$ .

Figures 4–14. *Cymatiosphaera cornifera* Deunff, 1955; figure 4, slide 7851-10,  $53.7 \times 113.2$ , GSC 48301,  $\times 750$ ; figure 5, slide 8117-1,  $31.4 \times 103.3$ , GSC 48302,  $\times 750$ ; figure 6, GSC loc. 8124, SEM,  $\times 1000$ ; figure 7, slide 8102-2,  $32.5 \times 98.8$ , GSC 48303,  $\times 750$ ; figures 8, 9, slide 8128-7,  $33.0 \times 109.9$ , GSC 48304, high and median foci respectively,  $\times 750$ ; figure 10, slide 8090-4,  $39.0 \times 102.2$ , GSC 48305,  $\times 750$ ; figures 11, 12, slide 8135-S1,  $35.6 \times 103.4$ , GSC 48306, SEM,  $\times 1000$  and  $\times 2500$  respectively; figure 13, slide 8135-S1,  $34.9 \times 102.4$ , GSC 48307, SEM,  $\times 1000$ ; figure 14, GSC loc. 8124, SEM,  $\times 2500$ .

Figures 15–21. *Cymatiosphaera winderi* Deunff, emend.; figure 15, slide 8124-7,  $54.3 \times 101.2$ , GSC 48308,  $\times 500$ ; figure 16, slide 8109-6,  $57.8 \times 106.1$ , GSC 48309,  $\times 500$ ; figure 17, slide 7851-9,  $44.6 \times 108.4$ , GSC 48310,  $\times 500$ ; figure 18, slide 8109-4,  $42.2 \times 98.8$ , GSC 48311,  $\times 500$ ; figures 19, 20, slide 8124-S1,  $34.0 \times 103.8$ , GSC 48312, SEM,  $\times 1000$  and  $\times 2500$  respectively, note excystment opening; figure 21, slide 8114-2,  $59.7 \times 99.0$ , GSC 48313,  $\times 1000$ .

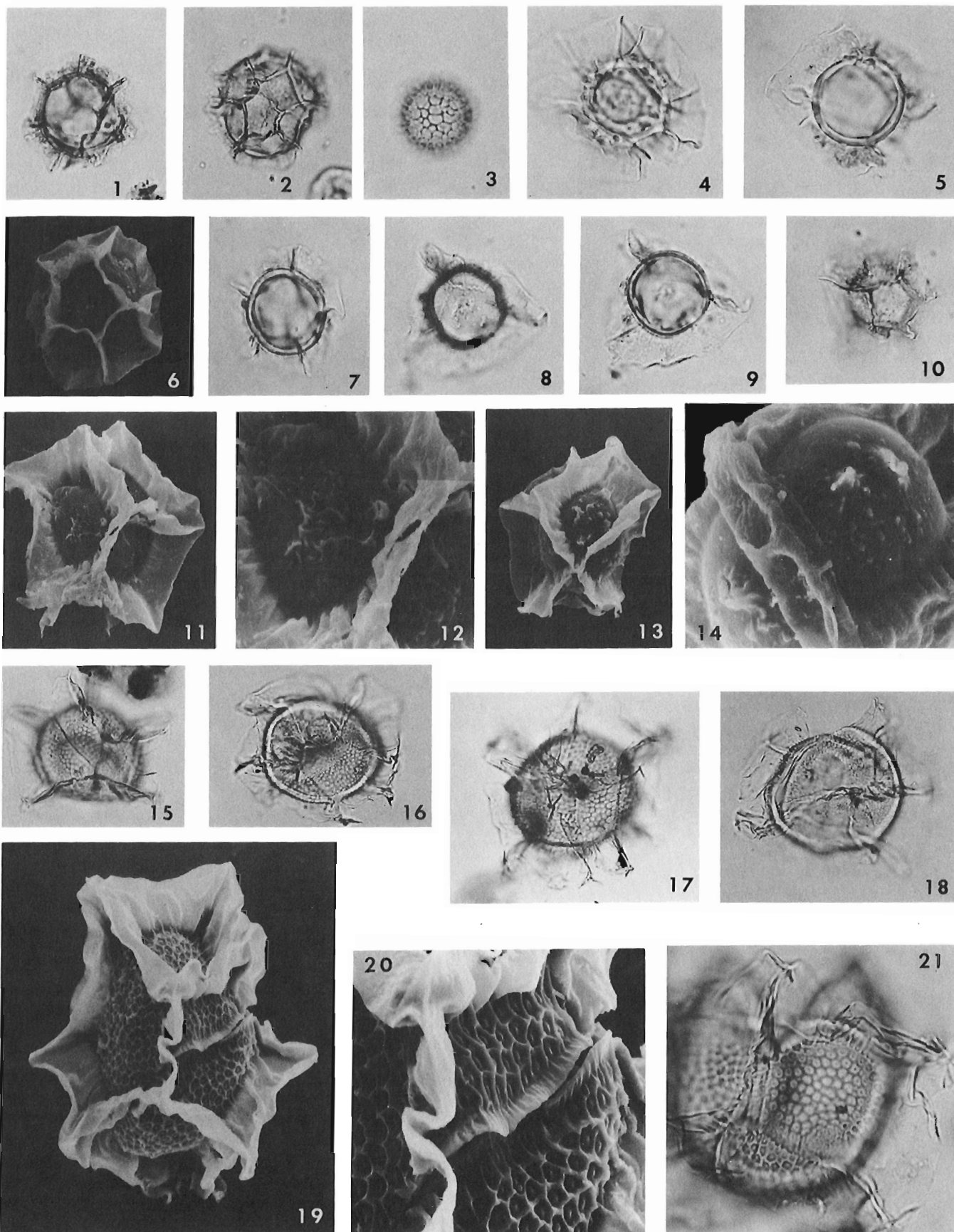


Plate 5

Figure 1. *Dateriocradus* sp. A; slide 8121-8,  $55.6 \times 94.8$ , GSC 48314,  $\times 500$ .

Figures 2-4. *Dictyotidium variatum* sp. nov.; figure 2, slide 7851-9,  $68.9 \times 95.0$ , GSC 48315,  $\times 750$ ; figure 3, slide 8122-1,  $36.7 \times 101.3$ , GSC 48316,  $\times 750$ ; figure 4, slide 8122-2,  $50.0 \times 95.0$ , GSC 48317,  $\times 500$ .

Figures 5-8. *Dictyotidium cavernosulum* sp. nov.; figure 5, holotype, slide 8124-9,  $56.4 \times 103.9$ , GSC 48318,  $\times 500$ ; figure 6, slide 8124-1,  $65.8 \times 107.3$ , GSC 48319,  $\times 500$ ; figure 7, slide 8108-1,  $33.6 \times 105.8$ , GSC 48320,  $\times 500$ ; figure 8, slide 7851-S2,  $39.0 \times 102.4$ , GSC 48321, SEM,  $\times 750$ .

Figures 9-11. *Cymatiosphaera* sp. cf. *C. pavimenta* (Deflandre) Deflandre, 1954; figure 9, slide 8056-3,  $62.6 \times 106.8$ , GSC 48322,  $\times 500$ ; figure 10, slide 8056-3,  $50.8 \times 93.6$ , GSC 48323,  $\times 500$ ; figure 11, slide 8056-3,  $62.6 \times 108.7$ , GSC 48324,  $\times 500$ .

Figures 12-14. *Dateriocradus* sp. B; figures 12, 13, slide 8056-S1,  $47.6 \times 105.6$ , GSC 48325, SEM,  $\times 750$  and  $\times 2500$  respectively; figure 14, slide 8111-S1,  $40.9 \times 103.0$ , GSC 48326, SEM,  $\times 1000$ .

Figures 15, 16. *Dictyotidium* sp. A; figure 15, GSC loc. 8060, SEM,  $\times 500$ ; figure 16, slide 8060-3,  $50.6 \times 106.9$ , GSC 48327,  $\times 500$ .



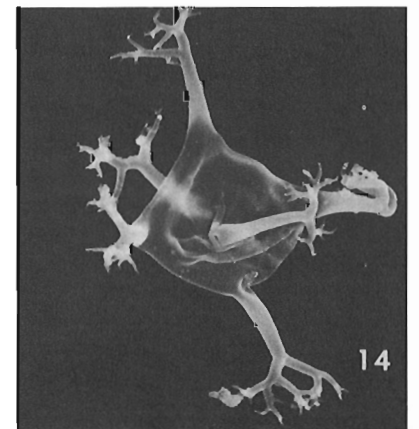
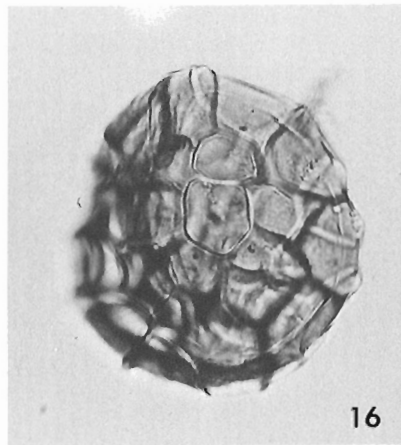
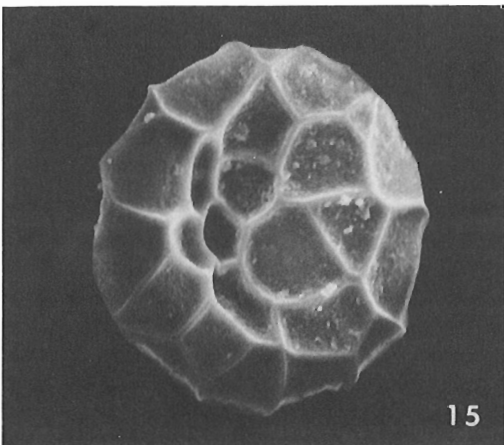
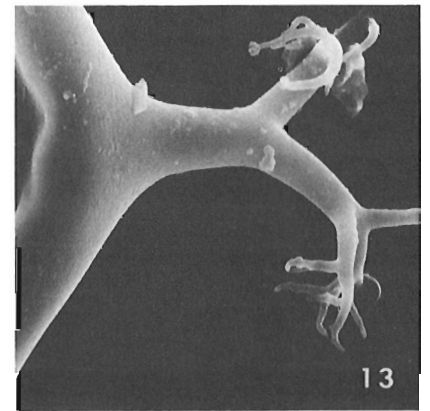
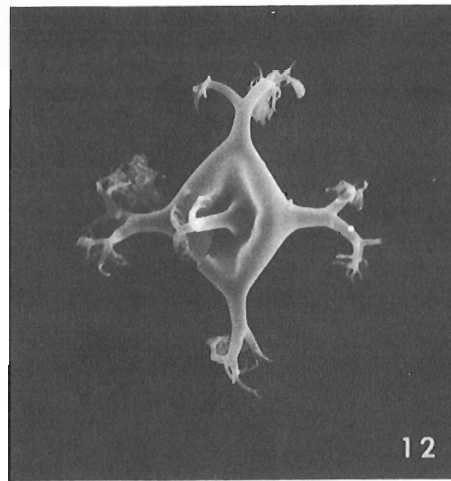
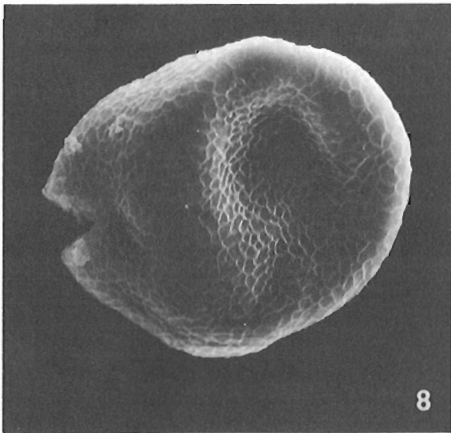
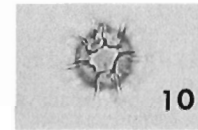
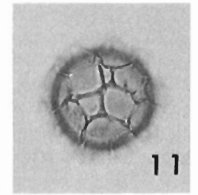
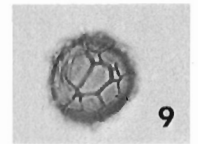
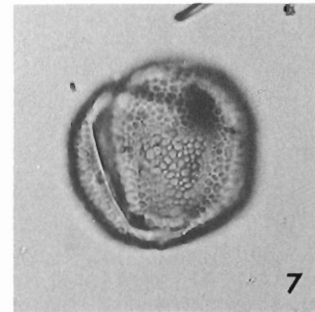
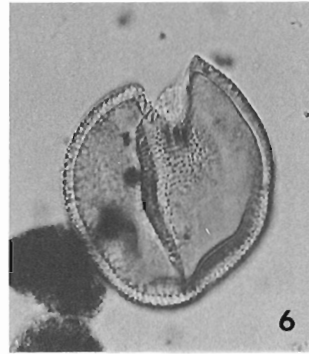
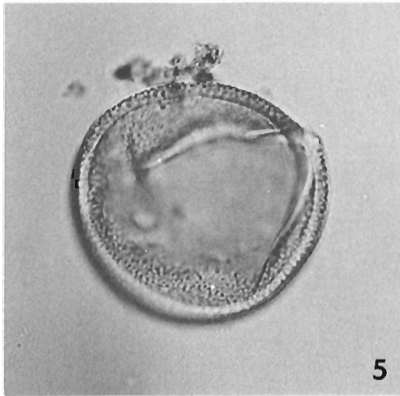
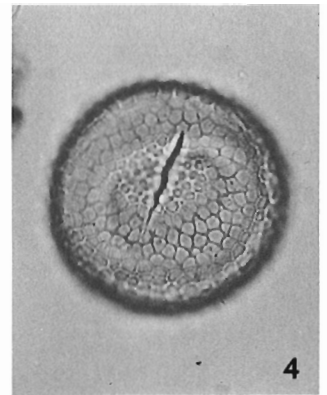
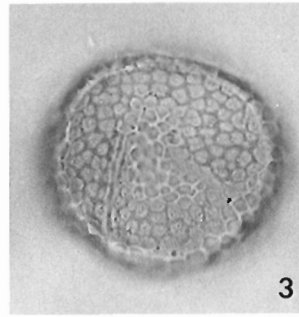
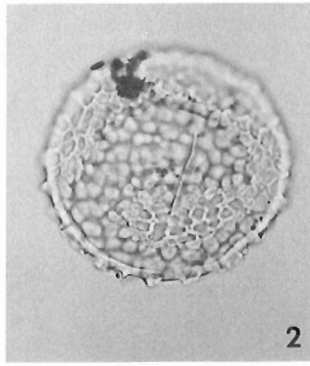
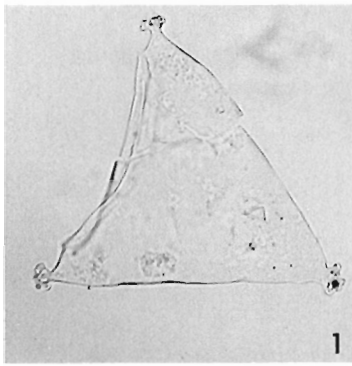


Plate 6

Figures 1–6. *Dictyotidium variatum* sp. nov.; figure 1, GSC loc. 8124, SEM,  $\times 500$ ; figure 2, GSC loc. 8124, SEM,  $\times 1000$ ; figure 3, holotype, slide 8124-3,  $42.8 \times 99.8$ , GSC 48328,  $\times 500$ ; figure 4, slide 7851-1,  $27.3 \times 104.3$ , GSC 48329,  $\times 750$ ; figure 5, GSC loc. 8124, SEM,  $\times 2500$ ; figure 6, slide 8124-S2,  $38.3 \times 102.6$ , GSC 48330, SEM,  $\times 2500$ .

Figures 7–11. *Divetipellis ventricosa* sp. nov.; figure 7, slide 8135-S1,  $37.3 \times 103.6$ , GSC 48331, SEM,  $\times 1000$ ; figure 8, holotype, slide 8105-3,  $32.9 \times 104.8$ , GSC 48332,  $\times 500$ ; figure 9, slide 8118-1,  $49.6 \times 95.3$ , GSC 48333,  $\times 500$ ; figure 10, slide 8080-2,  $52.3 \times 94.2$ , GSC 48334,  $\times 500$ ; figure 11, slide 8114-2,  $60.9 \times 115.3$ , GSC 48335,  $\times 500$ .

Figures 12–14. *Diexallophasis remota* (Deunff) comb. nov., emend.; figure 12, slide 8118-3,  $45.3 \times 98.1$ , GSC 48336,  $\times 500$ ; figure 13, slide 8123-11,  $36.4 \times 104.5$ , GSC 48337,  $\times 500$ ; figure 14, slide 8116-5,  $37.8 \times 107.9$ , GSC 48338,  $\times 500$ .

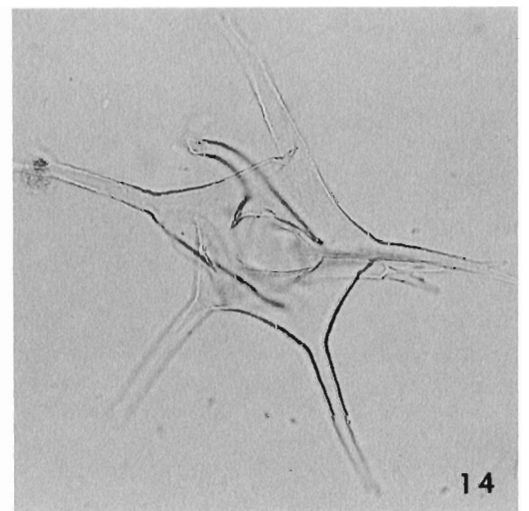
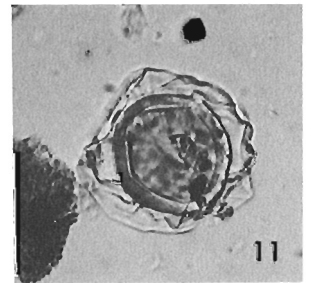
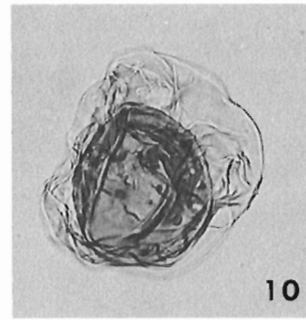
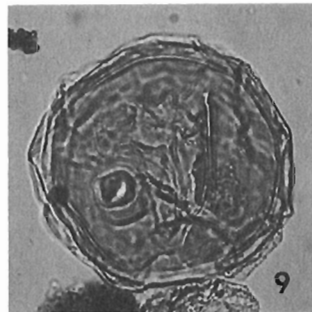
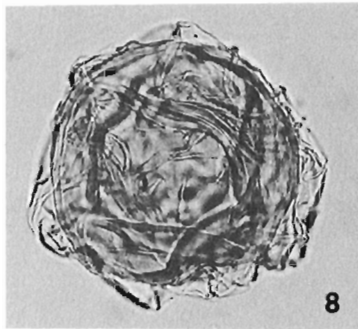
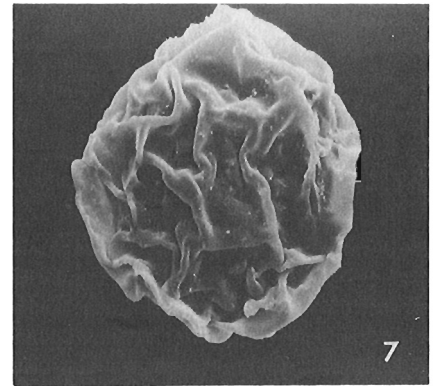
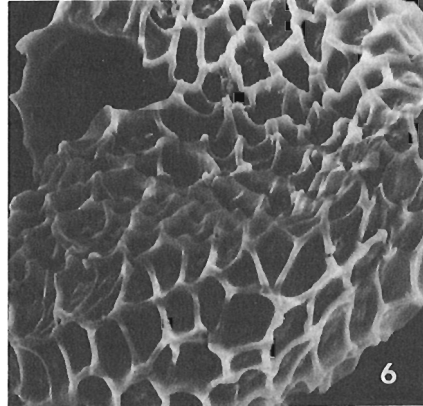
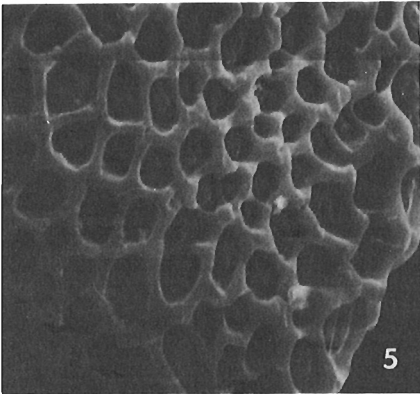
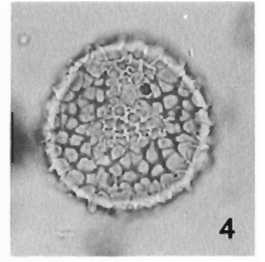
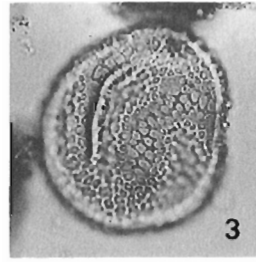
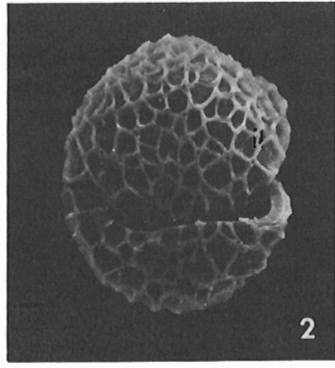
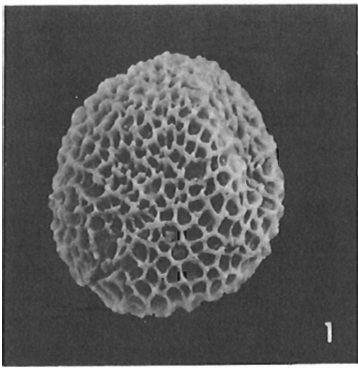


Plate 7

Figures 1–11. *Diexallophasis remota* (Deunff) comb. nov., emend.; figure 1, slide 8127-75,  $34.8 \times 103.2$ , GSC 48339,  $\times 500$ ; figure 2, slide 8127-44,  $39.0 \times 107.3$ , GSC 48340,  $\times 500$ ; figure 3, slide 8123-10,  $36.4 \times 104.9$ , GSC 48341,  $\times 500$ ; figure 4, slide 8124-43,  $37.2 \times 103.3$ , GSC 48342,  $\times 500$ ; figure 5, slide 8096-1,  $51.3 \times 115.0$ , GSC 48343,  $\times 500$ ; figures 6, 7, slide 8124-S2,  $37.8 \times 103.1$ , GSC 48344, SEM,  $\times 500$  and  $\times 2500$  respectively; figure 8, slide 8124-S2,  $37.8 \times 103.0$ , GSC 48345, SEM,  $\times 1000$ ; figure 9, slide 8124-S2,  $37.3 \times 103.2$ , GSC 48346, SEM,  $\times 2500$ ; figure 10, slide 8124-S1,  $34.7 \times 101.1$ , GSC 48347, SEM,  $\times 2500$ ; figure 11, slide 8124-S2,  $38.2 \times 102.1$ , GSC 48348, SEM,  $\times 2500$ .

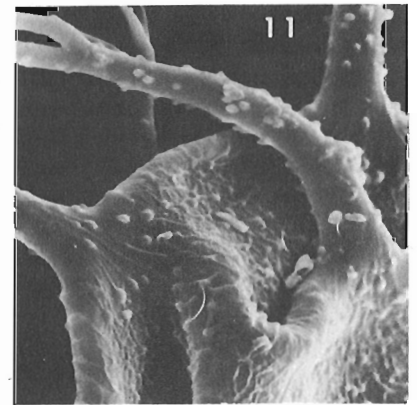
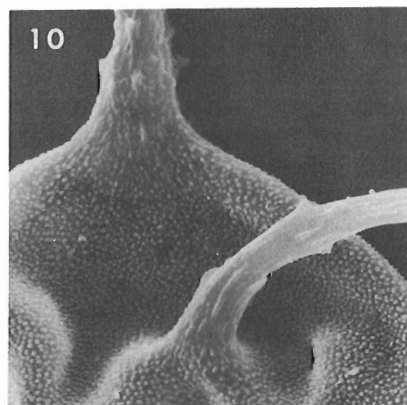
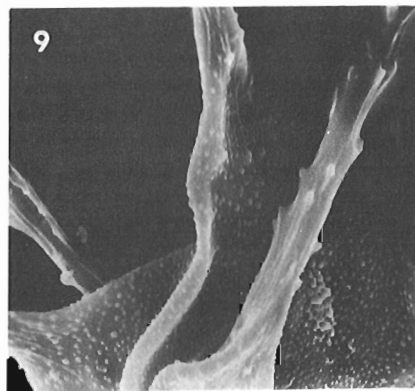
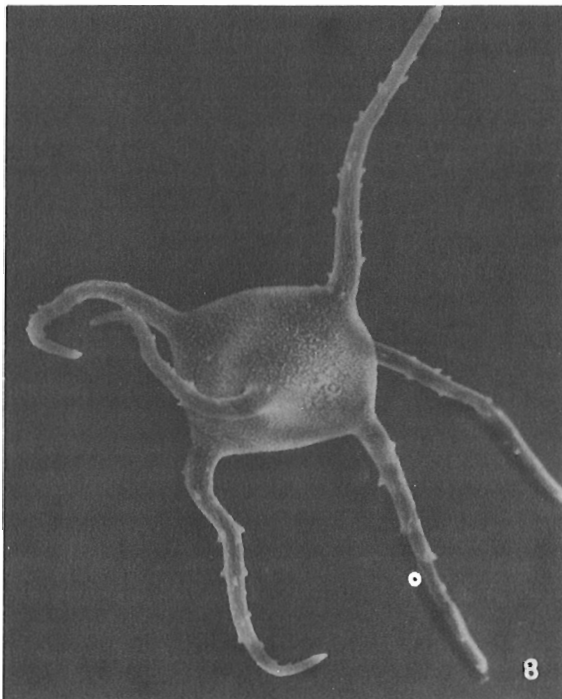
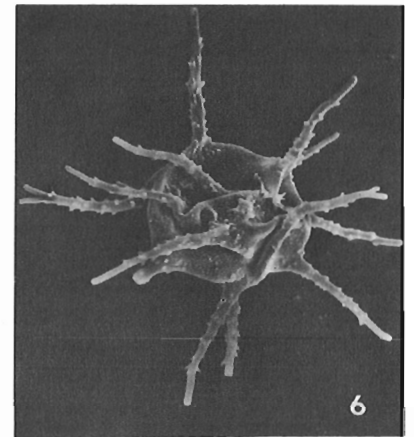
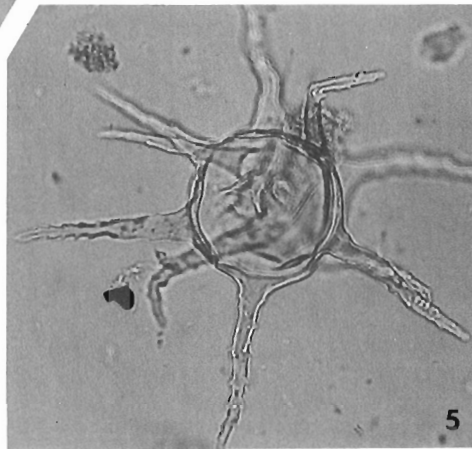
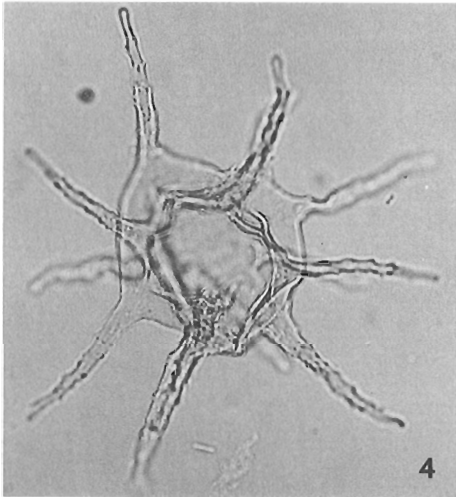
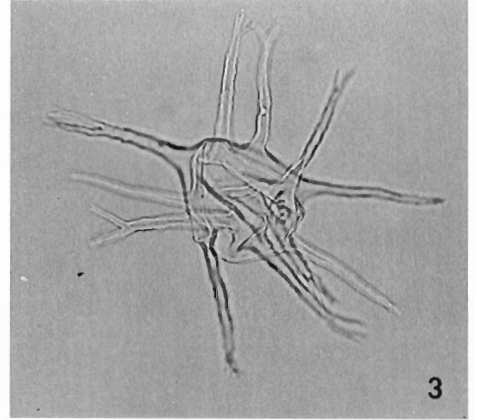
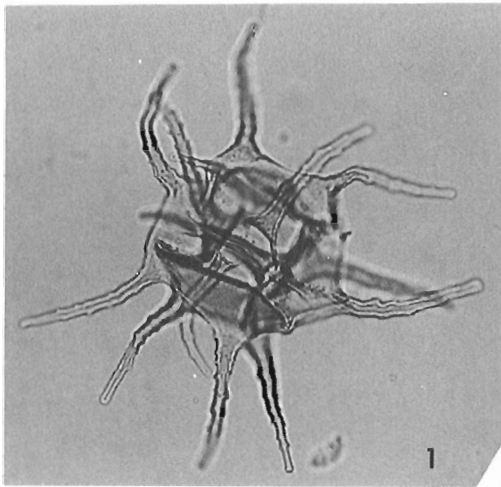


Plate 8

Figures 1–6. *Duvernaysphaera tenuicingulata* Staplin, 1961; figure 1, slide 8060-2,  $54.2 \times 95.1$ , GSC 48349,  $\times 750$ ; figure 2, slide 8060-2,  $60.6 \times 112.5$ , GSC 48350,  $\times 750$ ; figure 3, slide 8061-1,  $30.9 \times 103.5$ , GSC 48351,  $\times 750$ ; figure 4, slide 8062-4,  $49.3 \times 103.2$ , GSC 48352,  $\times 750$ ; figure 5, slide 8056-S1,  $47.1 \times 104.5$ , GSC 48353, SEM,  $\times 1500$ ; figure 6, slide 8056-S1,  $48.2 \times 106.7$ , GSC 48354, SEM,  $\times 1000$ .

Figures 7–11. *Goniolopadion prolixum* gen. et sp. nov.; figure 7, slide 8060-2,  $57.6 \times 108.5$ , GSC 48355,  $\times 750$ ; figures 8, 9, GSC loc. 8060, SEM,  $\times 750$  and  $\times 2500$  respectively; figures 10, 11, holotype, slide 8060-4,  $41.4 \times 110.7$ , GSC 48356,  $\times 500$  and  $\times 750$  respectively.

Figures 12–20. *Gorgonisphaeridium cumulatum* sp. nov.; figures 12, 13, GSC loc. 8124, SEM,  $\times 1000$  and  $\times 2500$  respectively; figures 14, 15, GSC loc. 8124, SEM,  $\times 1000$  and  $\times 2500$  respectively; figures 16, 17, slide 8122-2,  $63.6 \times 112.6$ , GSC 48357, high and median foci respectively,  $\times 750$ ; figure 18, slide 7851-5,  $61.3 \times 97.6$ , GSC 48358,  $\times 500$ ; figure 19, slide 7851-5,  $37.8 \times 97.6$ , GSC 48359,  $\times 750$ ; figure 20, holotype, slide 7851-5,  $52.4 \times 96.2$ , GSC 48360,  $\times 750$ .



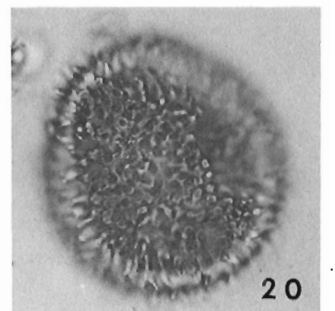
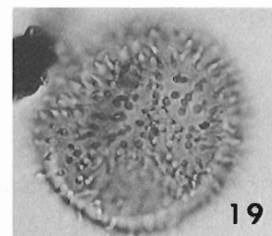
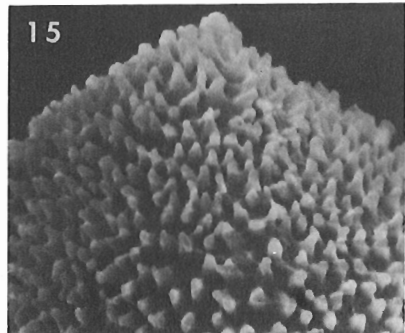
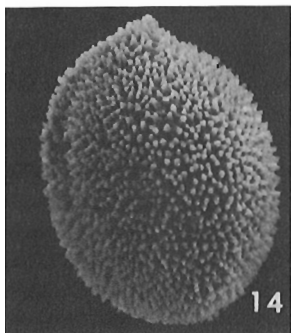
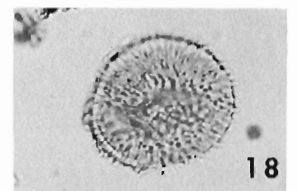
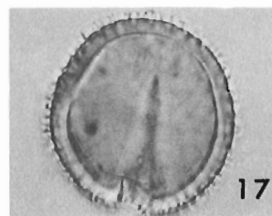
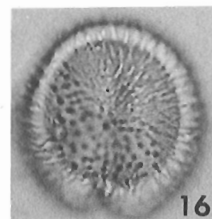
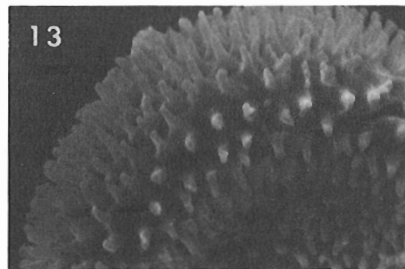
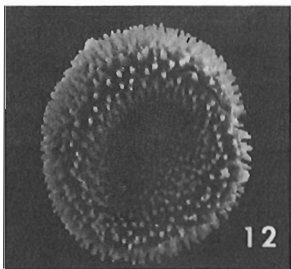
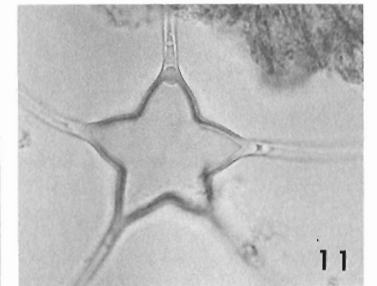
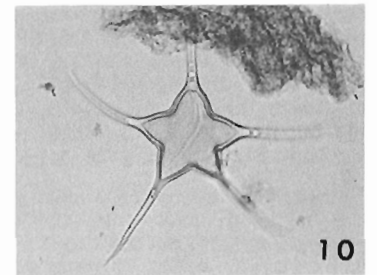
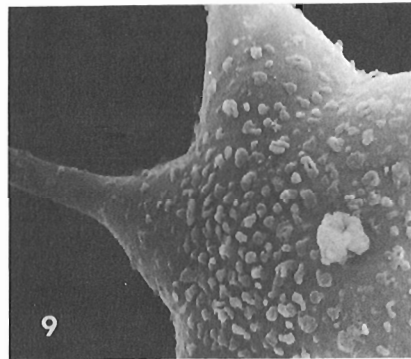
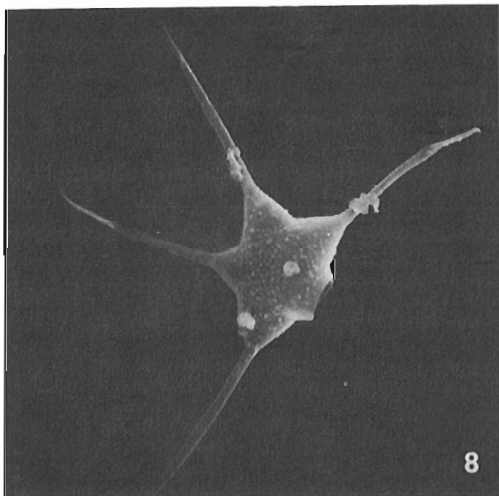
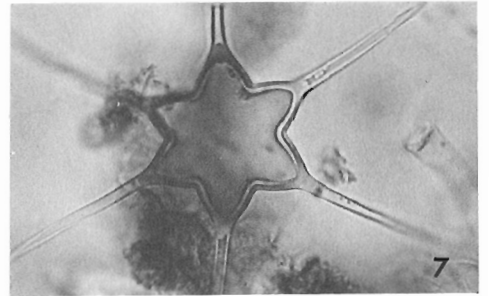
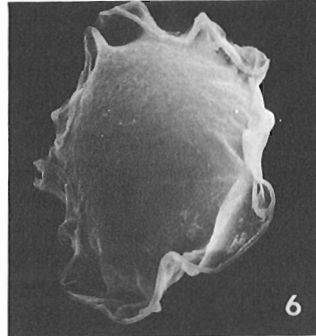
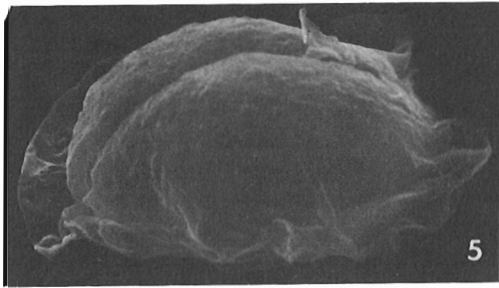
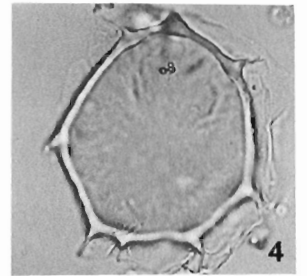
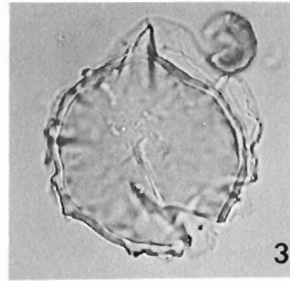
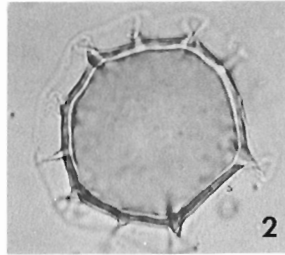
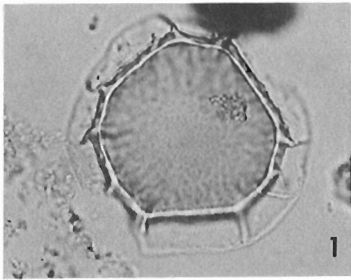


Plate 9

Figures 1-7. *Gorgonisphaeridium granatum* sp. nov.; figure 1, slide 8096-1,  $35.8 \times 103.6$ , GSC 48361,  $\times 750$ ; figure 2, holotype, slide 8104-2,  $33.0 \times 103.3$ , GSC 48362, IC,  $\times 750$ ; figure 3, slide 8098-8,  $45.2 \times 111.8$ , GSC 48363,  $\times 750$ ; figure 4, slide 8110-1,  $42.9 \times 104.3$ , GSC 48364,  $\times 750$ ; figure 5, GSC loc. 8124, SEM,  $\times 1000$ ; figures 6, 7, slide 8124-S2,  $38.8 \times 101.4$ , GSC 48365, SEM,  $\times 1000$  and  $\times 2500$  respectively.

Figures 8-16. *Gorgonisphaeridium disparatum* sp. nov.; figure 8, slide 8124-42,  $36.8 \times 103.2$ , GSC 48366,  $\times 500$ ; figure 9, holotype, slide 7851-10A,  $35.8 \times 104.2$ , GSC 48367,  $\times 500$ ; figure 10, slide 8126-19,  $36.2 \times 102.4$ , GSC 48368,  $\times 500$ ; figure 11, slide 8128-4,  $51.0 \times 98.2$ , GSC 48369,  $\times 500$ ; figure 12, slide 8126-4,  $37.8 \times 108.2$ , GSC 48370,  $\times 500$ ; figures 13, 14, slide 8124-S2,  $38.6 \times 102.3$ , GSC 48371, SEM,  $\times 1000$  and  $\times 2500$  respectively; figure 15, slide 7851-S1,  $40.5 \times 105.0$ , GSC 48372, SEM,  $\times 2500$ ; figure 16, slide 8124-S1,  $35.1 \times 103.0$ , GSC 48373, SEM,  $\times 1000$ .

Figures 17-21. *Gorgonisphaeridium* sp. cf. *Michrhystridium sericum* Deunff, 1967; figure 17, slide 8122-1,  $59.0 \times 110.1$ , GSC 48374,  $\times 750$ ; figures 18, 19, slide 8062-1,  $50.7 \times 101.7$ , GSC 48375, high and median foci respectively,  $\times 750$ ; figure 20, slide 8061-4,  $43.2 \times 104.7$ , GSC 48376,  $\times 750$ ; figure 21, slide 8062-1,  $36.3 \times 104.4$ , GSC 48377,  $\times 750$ .

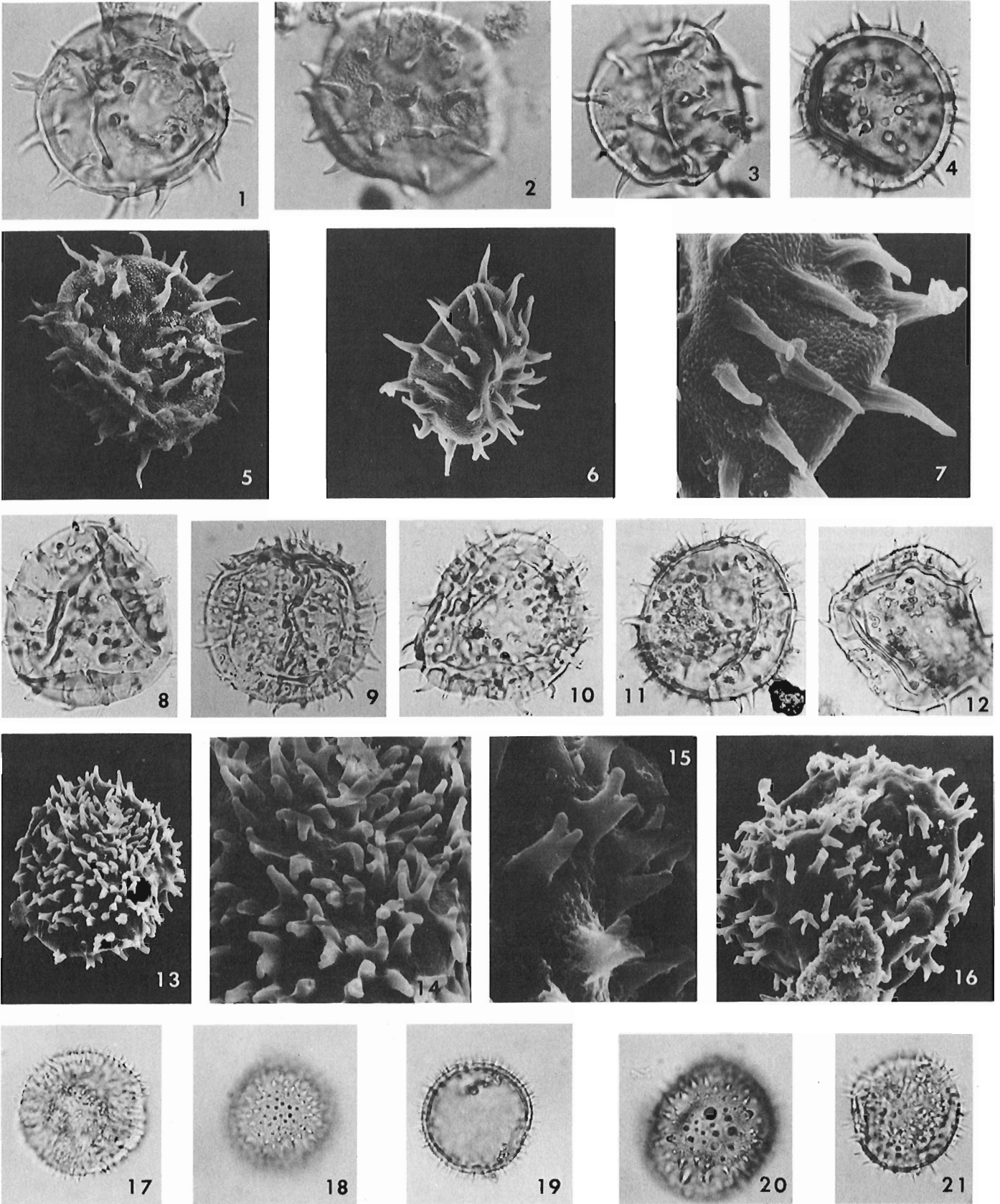


Plate 10

Figures 1–6. *Hapsidopalla exornata* (Deunff) comb. nov., emend.; figures 1, 2, slide 8056-3,  $52.8 \times 95.0$ , GSC 48378, high and median foci respectively,  $\times 750$ ; figure 3, slide 8060-4,  $47.2 \times 98.3$ , GSC 48379,  $\times 750$ ; figures 4, 5, slide 8060-S1,  $38.2 \times 101.8$ , GSC 48380, SEM,  $\times 750$  and  $\times 2500$  respectively; figure 6, slide 8060-2,  $34.5 \times 106.1$ , GSC 48381,  $\times 1000$ .

Figures 7–13. *Hapsidopalla sannemannii* (Deunff) comb. nov., emend.; figures 7, 8, slide 8109-S1,  $36.8 \times 102.1$ , GSC 48382, SEM,  $\times 1000$  and  $\times 2500$  respectively; figure 9, slide 8109-5,  $38.8 \times 112.3$ , GSC 48383,  $\times 1000$ ; figure 10, slide 8109-S1,  $36.8 \times 102.8$ , GSC 48384, SEM,  $\times 1000$ ; figure 11, slide 8104-9,  $64.6 \times 105.2$ , GSC 48385,  $\times 750$ ; figures 12, 13, slide 8111-13,  $37.6 \times 103.7$ , GSC 48386, high and low foci respectively,  $\times 750$ .

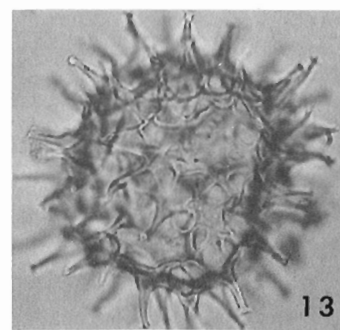
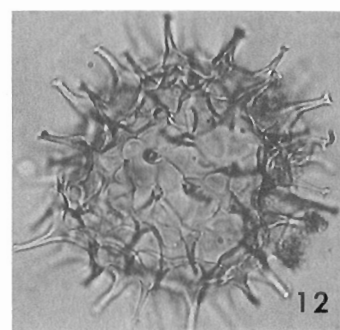
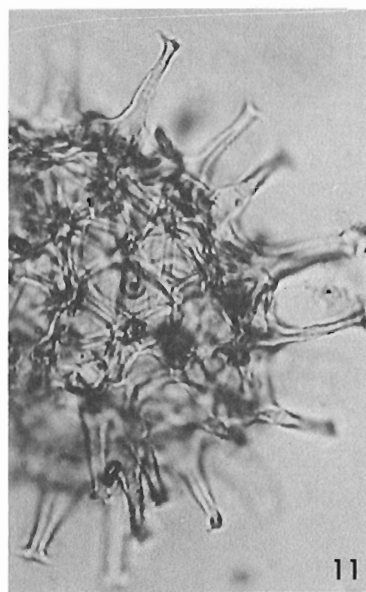
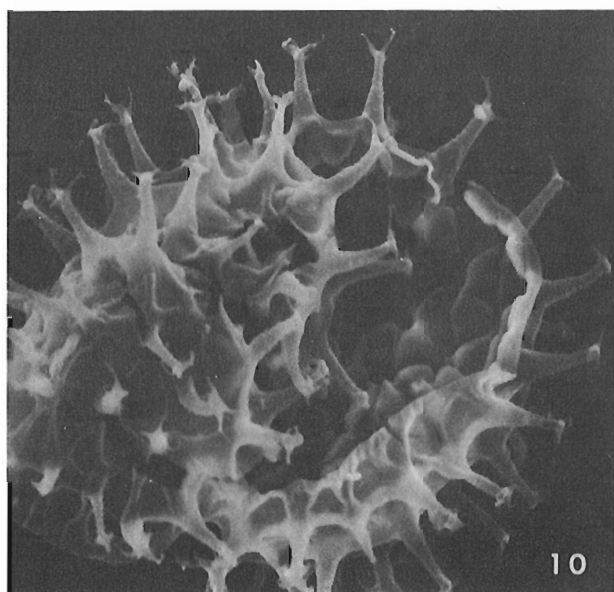
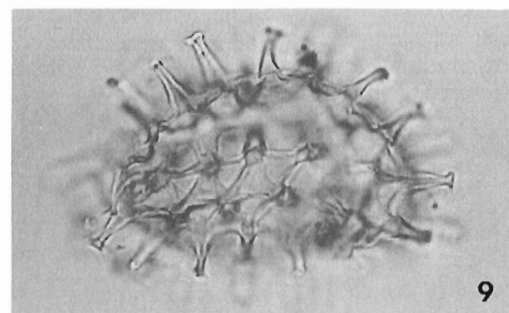
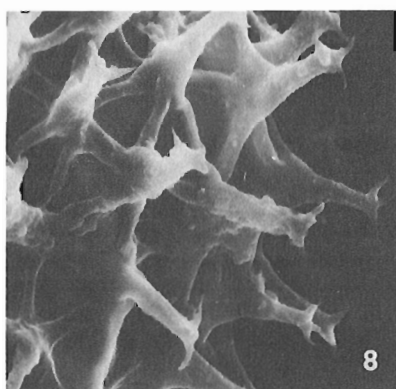
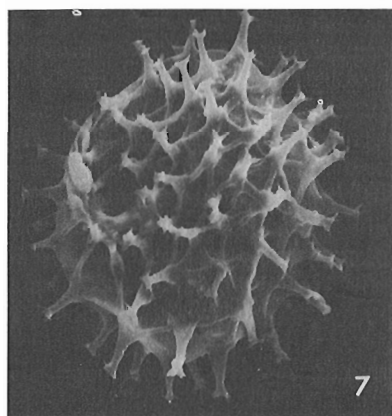
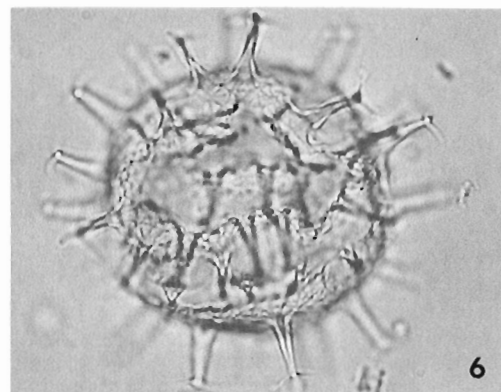
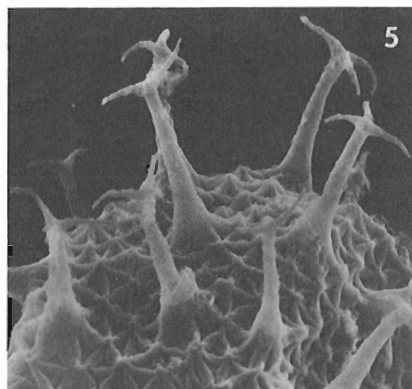
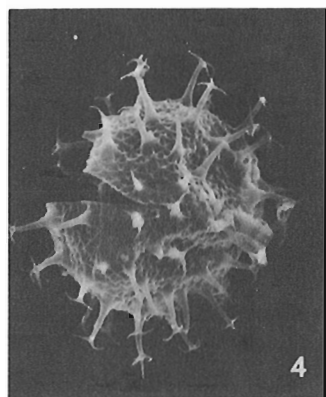
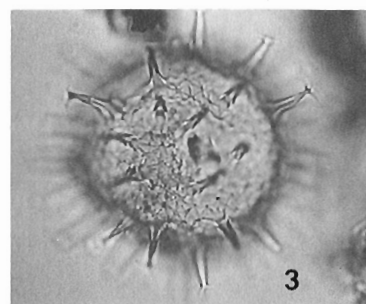
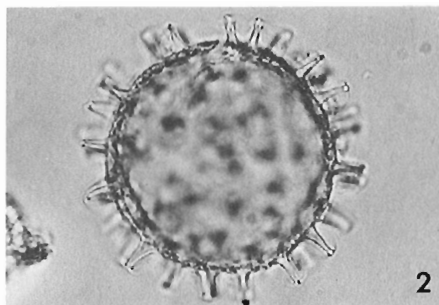
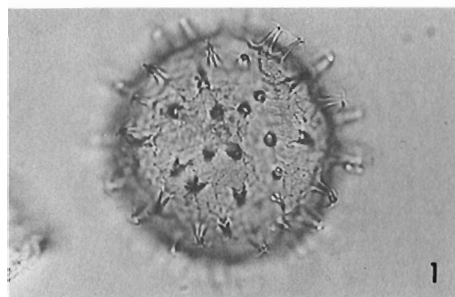


Plate 11

Figures 1–5. *Lophosphaeridium dumalis* sp. nov.; figure 1, holotype, slide 8080-1,  $37.1 \times 113.5$ , GSC 48387, IC,  $\times 750$ ; figure 2, slide 8080-2,  $44.5 \times 98.7$ , GSC 48388,  $\times 1000$ ; figure 3, slide 8080-2,  $59.9 \times 100.2$ , GSC 48389,  $\times 750$ ; figure 4, slide 8080-1,  $55.7 \times 113.5$ , GSC 48390,  $\times 500$ ; figure 5, slide 8080-1,  $43.9 \times 107.0$ , GSC 48391,  $\times 500$ .

Figures 6–9. *Micrhysstridium stellatum* Deflandre, 1945; figure 6, slide 8135-S2,  $38.7 \times 108.6$ , GSC 48392, SEM,  $\times 1000$ ; figure 7, slide 8135-S1,  $35.9 \times 104.8$ , GSC 48393, SEM,  $\times 1000$ ; figure 8, slide 8062-2,  $31.0 \times 103.7$ , GSC 48394,  $\times 750$ ; figure 9, slide 8062-1,  $39.8 \times 111.0$ , GSC 48395,  $\times 750$ .

Figures 10–13. *Multiplicisphaeridium ampliatus* sp. nov.; figure 10, GSC loc. 8124, SEM,  $\times 500$ ; figures 11, 12, (IC), holotype, slide 8124-23,  $40.6 \times 108.9$ , GSC 48396,  $\times 500$ ; figure 13, slide 8124-24,  $36.9 \times 105.6$ , GSC 48397,  $\times 500$ .

Figures 14–20. *Multiplicisphaeridium ramusculosum* (Deflandre) Lister, 1970; figure 14, slide 8121-6,  $60.4 \times 107.7$ , GSC 48398,  $\times 750$ ; figure 15, slide 8056-3,  $64.2 \times 105.7$ , GSC 48399,  $\times 750$ ; figure 16, slide 8109-6,  $46.0 \times 93.6$ , GSC 48400,  $\times 750$ ; figure 17, slide 8111-7,  $54.7 \times 104.2$ , GSC 48401,  $\times 750$ ; figure 18, slide 7851-S2,  $37.8 \times 101.4$ , GSC 48402, SEM,  $\times 750$ ; figures 19, 20, slide 7851-S1,  $42.9 \times 105.5$ , GSC 48403, SEM,  $\times 500$  and  $\times 2500$  respectively.



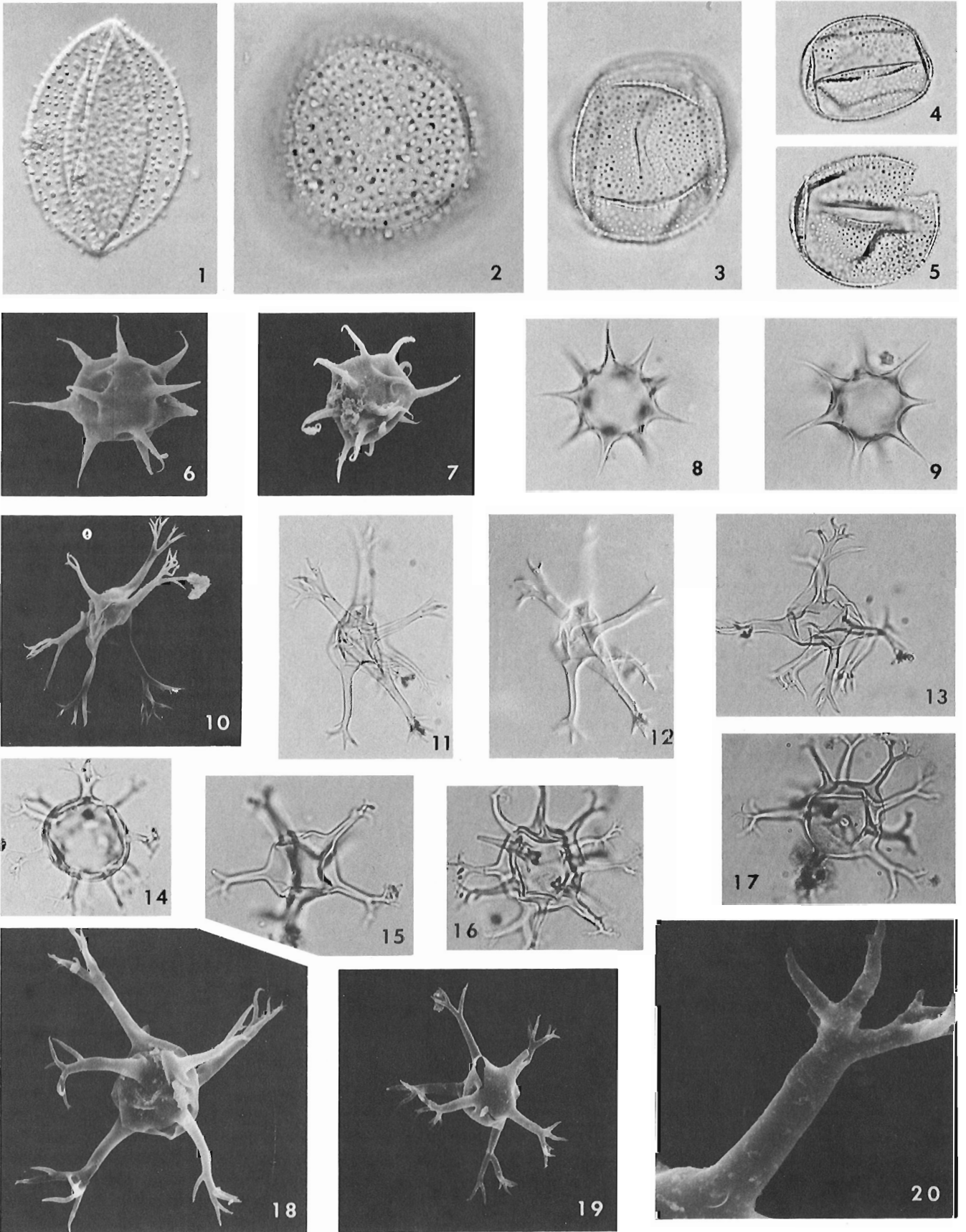


Plate 12

Figures 1–9. *Navifusa bacillum* (Deunff) comb. nov.; figure 1, slide 8117-5,  $39.7 \times 96.6$ , GSC 48404,  $\times 300$ ; figure 2, slide 8087-6,  $43.2 \times 99.3$ , GSC 48405,  $\times 300$ ; figures 3, 8, (IC), slide 8081-6,  $66.3 \times 103.8$ , GSC 48406,  $\times 300$  and  $\times 1000$  respectively; figure 4, slide 8109-5,  $61.0 \times 95.0$ , GSC 48407,  $\times 300$ ; figure 5, slide 8123-1,  $54.9 \times 108.8$ , GSC 48408,  $\times 300$ ; figure 6, slide 8124-33,  $33.8 \times 105.4$ , GSC 48409,  $\times 300$ ; figure 7, GSC loc. 8111, SEM,  $\times 1500$ ; figure 9, slide 8084-1,  $58.7 \times 97.6$ , GSC 48410,  $\times 1000$ .

Figures 10, 11. *Gorgonisphaeridium* sp. B; figure 10, slide 8062-S1,  $37.3 \times 103.5$ , GSC 48411, SEM,  $\times 1500$ ; figure 11, slide 8062-3,  $26.8 \times 99.1$ , GSC 48412,  $\times 750$ .

Figure 12. *Gorgonisphaeridium* sp. A; slide 8097-2,  $54.9 \times 111.7$ , GSC 48413,  $\times 750$ .

Figures 13–16. *Onondagaella asymmetrica* (Deunff) Cramer, 1966 emend.; figure 13, slide 8112-1,  $65.8 \times 115.0$ , GSC 48414,  $\times 500$ ; figures 14–16, showing closure (or near-closure) of cyclopyle by epibystra (i.e., plug-like structure); figure 14, slide 8113-3,  $60.8 \times 114.2$ , GSC 48415,  $\times 1000$ ; figure 15, slide 8120-1,  $51.0 \times 104.0$ , GSC 48416,  $\times 1000$ ; figure 16, slide 8123-8,  $50.6 \times 102.4$ , GSC 48417,  $\times 1000$ .

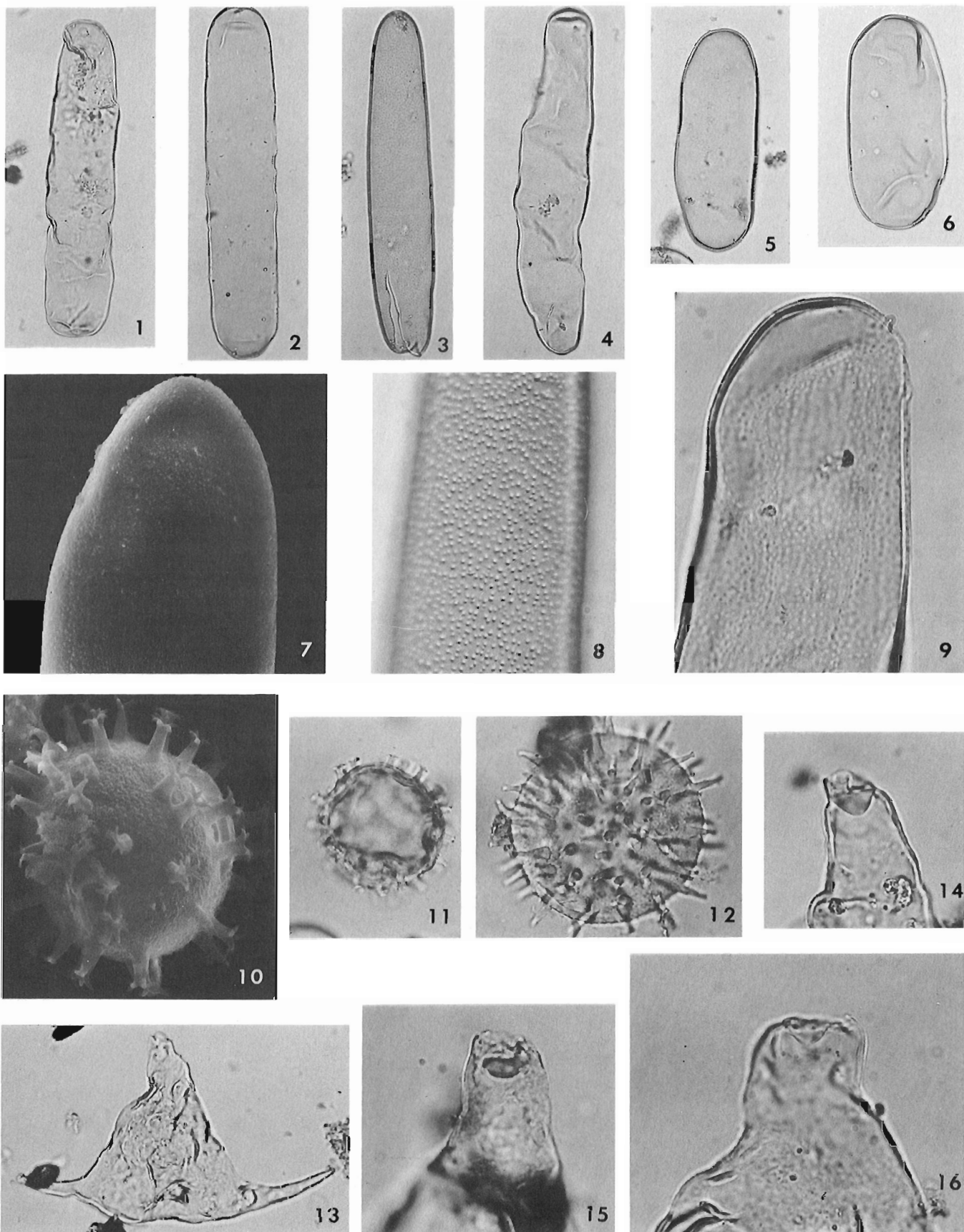


Plate 13

Figures 1-9. *Ozotobrachion furcillatus* (Deunff) comb. nov.; figure 1, slide 8111-7,  $41.6 \times 106.8$ , GSC 48418,  $\times 500$ ; figures 2, 3, slide 7851-17,  $41.4 \times 104.3$ , GSC 48419,  $\times 500$  and  $\times 750$  respectively; figure 4, slide 8128-7,  $48.3 \times 113.3$ , GSC 48420,  $\times 750$ ; figure 5, slide 8126-25,  $36.8 \times 102.8$ , GSC 48421,  $\times 500$ ; figure 6, slide 8135-S1,  $36.2 \times 103.3$ , GSC 48422, SEM,  $\times 750$ ; figures 7, 8, slide 7851-S2,  $36.8 \times 101.3$ , GSC 48423, SEM,  $\times 750$  and  $\times 2500$  respectively; figure 9, slide 7851-S1,  $42.2 \times 105.5$ , GSC 48424, SEM,  $\times 2500$ .

Figures 10, 11. *Onondagaella asymmetrica* (Deunff) Cramer, 1966 emend.; figure 10, slide 8127-48,  $37.8 \times 104.0$ , GSC 48425,  $\times 500$ ; figure 11, slide 8127-22,  $37.6 \times 98.2$ , GSC 48426, IC,  $\times 500$ .

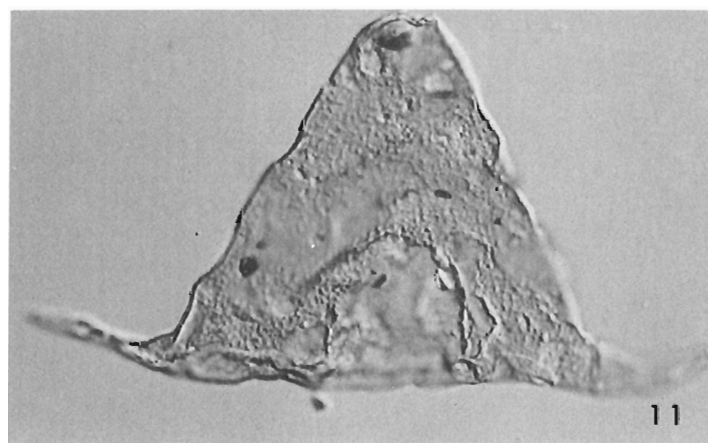
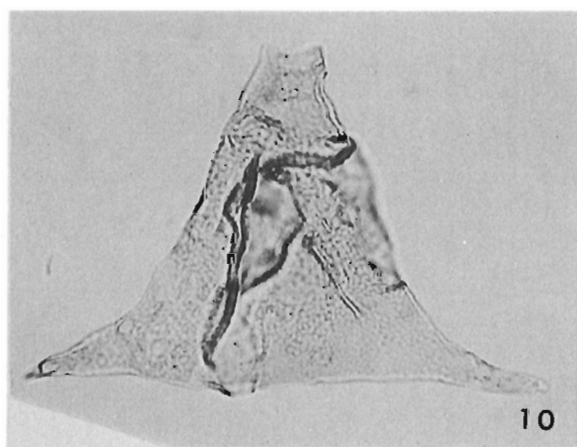
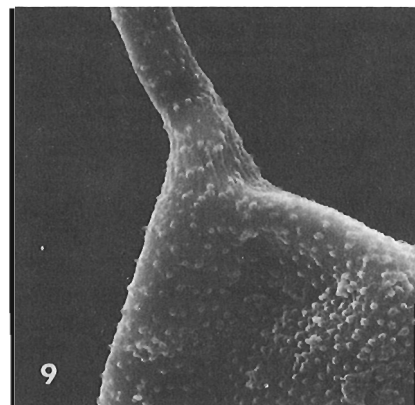
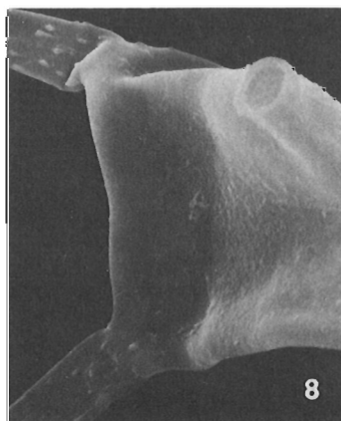
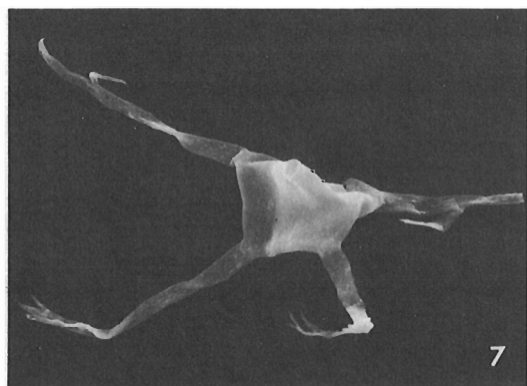
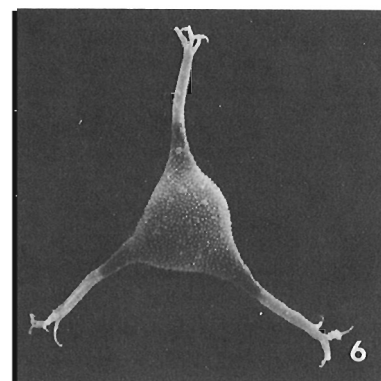
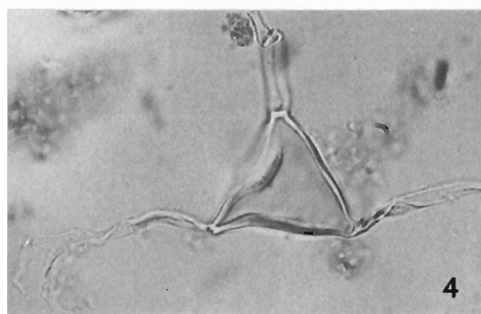
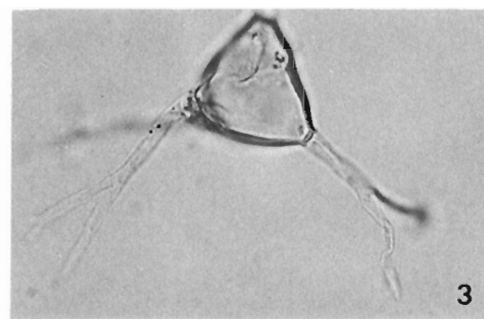
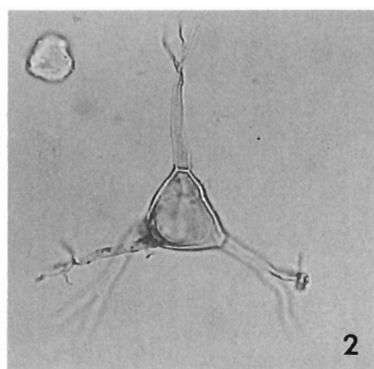
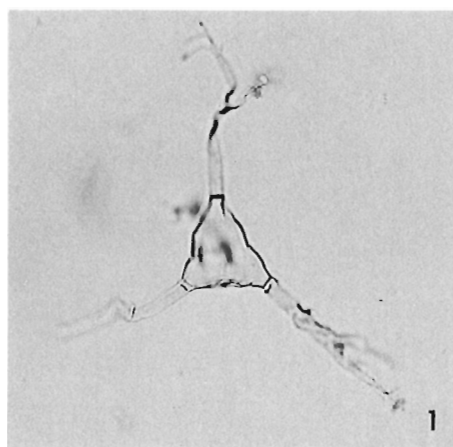


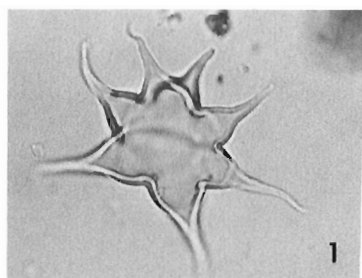
Plate 14

Figures 1–10. *Palacanthus ledanoisii* (Deunff) comb. nov., emend.; figure 1, slide 8102-2,  $45.4 \times 105.4$ , GSC 48427,  $\times 750$ ; figure 2, slide 8107-5,  $64.3 \times 103.0$ , GSC 48428,  $\times 500$ ; figure 3, slide 8112-12,  $35.8 \times 104.8$ , GSC 48429,  $\times 500$ ; figure 4, slide 7851-9,  $66.1 \times 99.8$ , GSC 48430,  $\times 750$ ; figure 5, slide 8112-15,  $38.8 \times 104.4$ , GSC 48431,  $\times 500$ ; figure 6, slide 8111-6,  $69.4 \times 103.0$ , GSC 48432,  $\times 500$ ; figure 7, slide 7851-8,  $54.8 \times 99.6$ , GSC 48433,  $\times 750$ ; figure 8, slide 7851-S1,  $40.8 \times 105.2$ , GSC 48434, SEM,  $\times 750$ ; figure 9, slide 8124-S2,  $37.0 \times 102.9$ , GSC 48435, SEM,  $\times 1000$ ; figure 10, slide 7851-S2,  $38.4 \times 101.5$ , GSC 48436, SEM,  $\times 750$ .

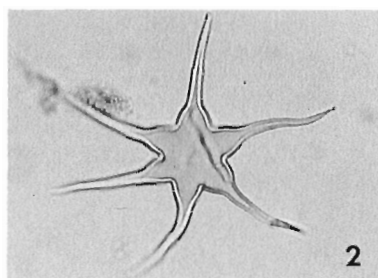
Figures 11, 12. *Ozotobrachion palidodigitatus* (Cramer) comb. nov.; figure 11, slide 8090-3,  $33.0 \times 105.2$ , GSC 48437,  $\times 750$ ; figure 12, slide 8089-2,  $48.2 \times 103.1$ , GSC 48438,  $\times 750$ .

Figures 13–16. *Ozotobrachion furcillatus* (Deunff) comb. nov.; figure 13, slide 7851-S1,  $43.2 \times 105.3$ , GSC 48439, SEM,  $\times 500$ ; figure 14, slide 8111-S1,  $41.6 \times 102.6$ , GSC 48440, SEM,  $\times 2500$ ; figure 15, slide 8109-S1,  $36.6 \times 103.0$ , GSC 48441, SEM,  $\times 2500$ ; figure 16, slide 7851-S1,  $41.7 \times 105.2$ , GSC 48442, SEM,  $\times 2500$ .

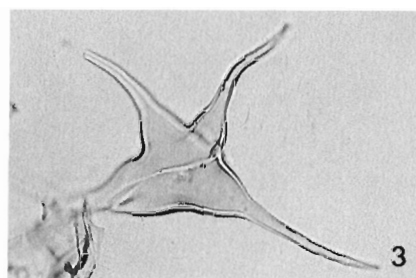




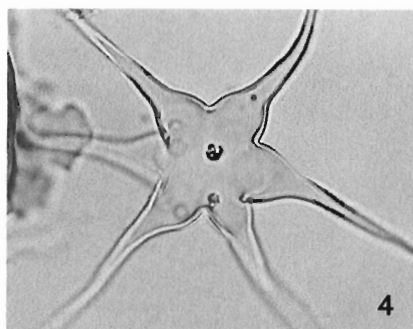
1



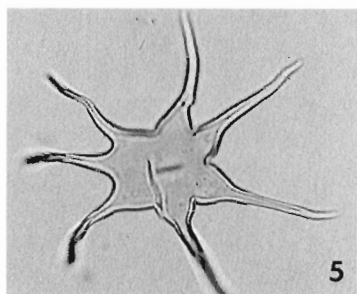
2



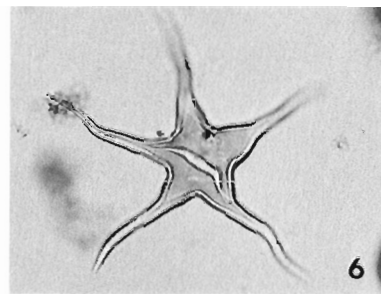
3



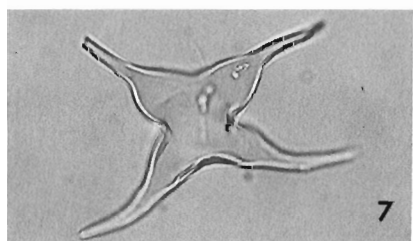
4



5



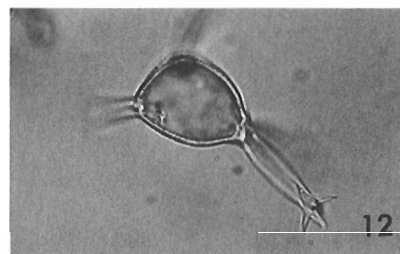
6



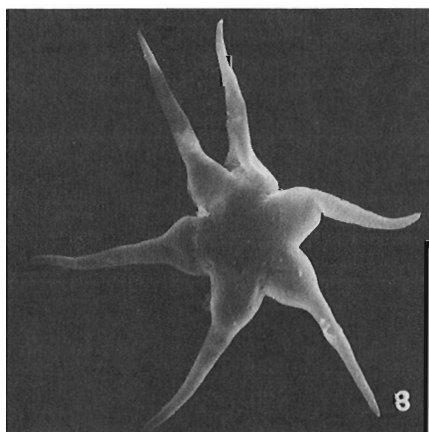
7



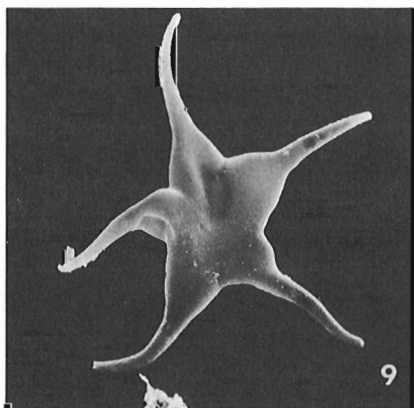
11



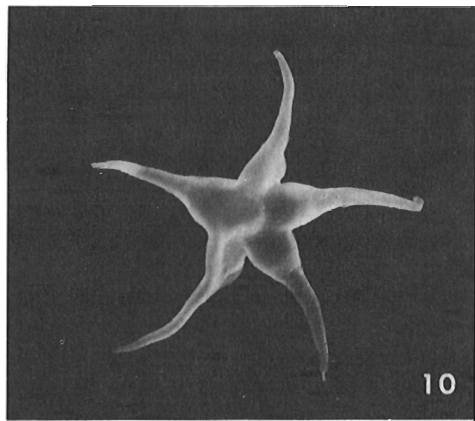
12



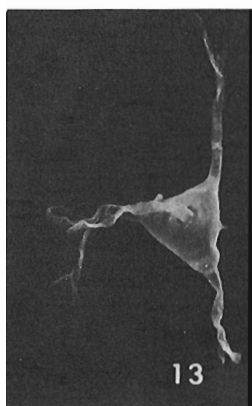
8



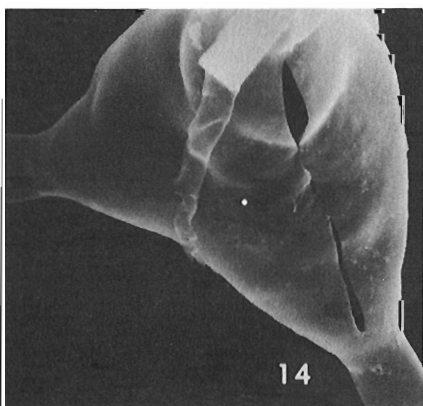
9



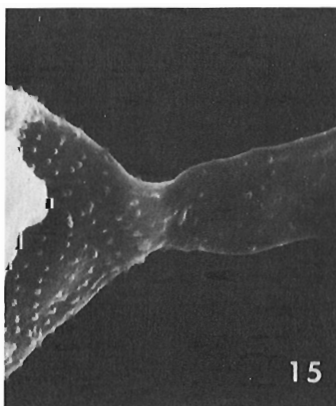
10



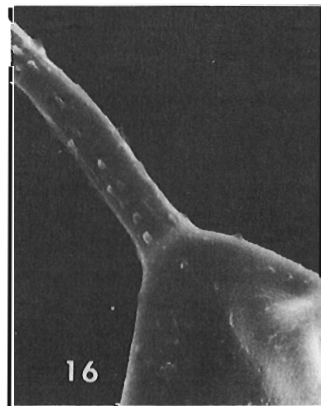
13



14



15



16

Plate 15

Figures 1, 2. *Polyedryxium bathyaster* Deunff, 1961; slide 8089-3,  $46.1 \times 108.2$ , GSC 48443, high ( $\times 500$ ) and low ( $\times 750$ ) foci respectively.

Figure 3. *Polyedryxium deflandrei* Deunff, 1961; slide 8062-4,  $38.8 \times 107.7$ , GSC 48444,  $\times 750$ .

Figures 4-6. *Polyedryxium decorum* Deunff, 1955; figure 4, slide 8062-1,  $29.9 \times 101.2$ , GSC 48445,  $\times 500$ ; figure 5, slide 8080-2,  $39.0 \times 107.2$ , GSC 48446,  $\times 500$ ; figure 6, slide 8062-3,  $30.8 \times 94.7$ , GSC 48447,  $\times 500$ .

Figures 7-13. *Polyedryxium carnatum* sp. nov.; figure 7, slide 8128-4,  $50.1 \times 113.4$ , GSC 48448,  $\times 500$ ; figure 8, slide 8128-7,  $39.8 \times 108.8$ , GSC 48449,  $\times 500$ ; figure 9, slide 8124-15,  $37.0 \times 103.3$ , GSC 48450,  $\times 500$ ; figure 10, holotype, slide 8124-29,  $36.6 \times 106.9$ , GSC 48451,  $\times 500$ ; figure 11, GSC loc. 8124, SEM,  $\times 500$ ; figures 12, 13, slide 8124-S2,  $38.9 \times 102.1$ , GSC 48452, SEM,  $\times 750$  and  $\times 2500$  respectively.

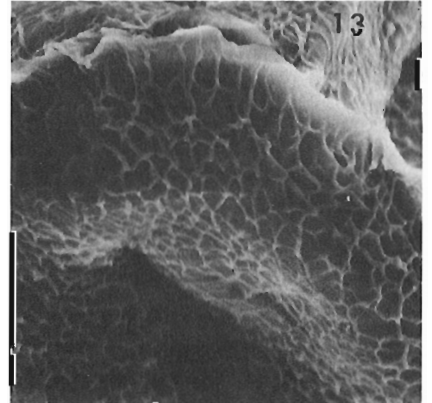
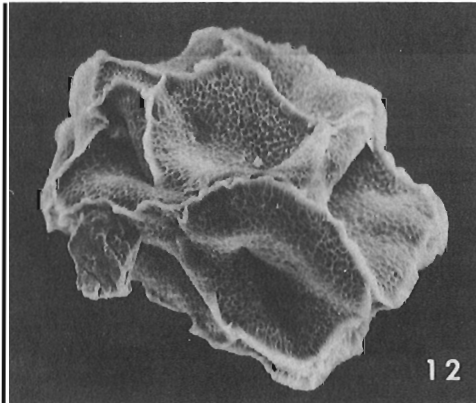
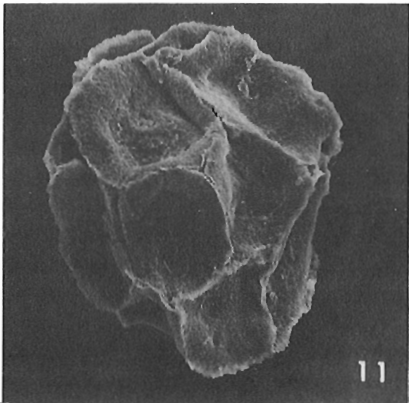
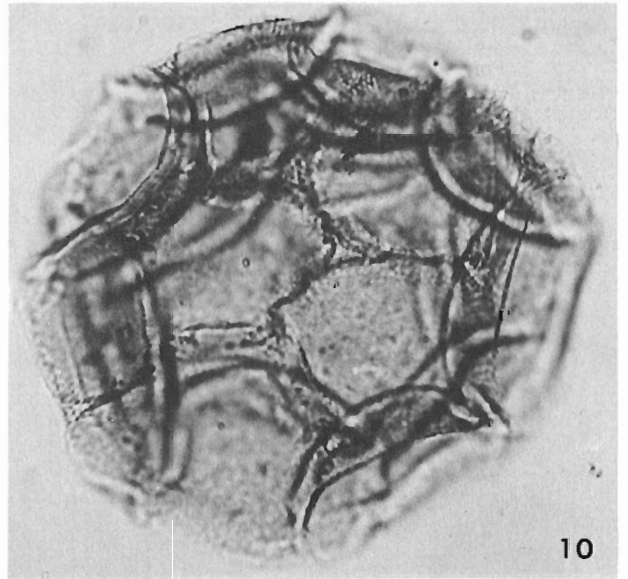
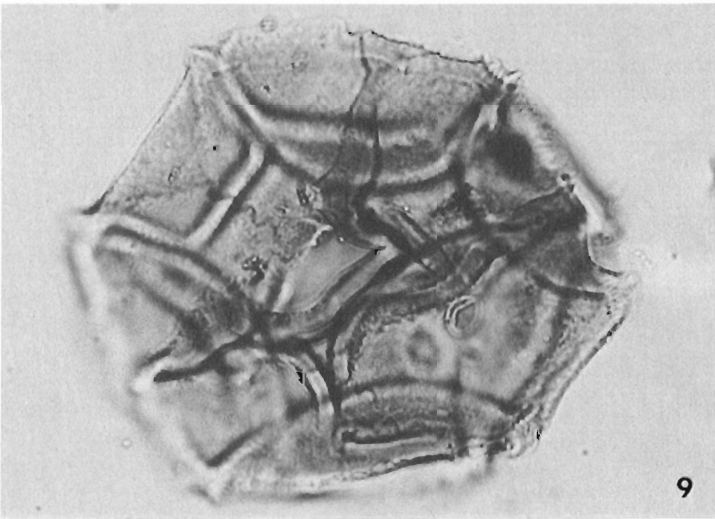
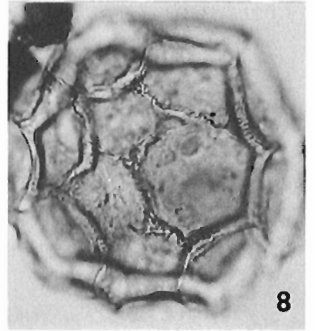
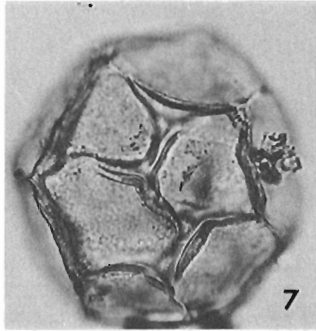
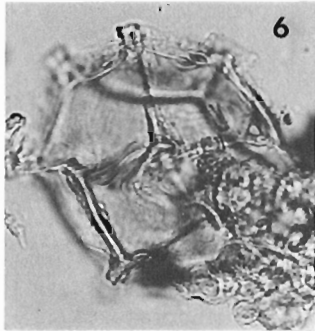
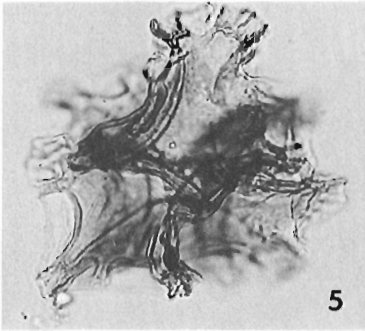
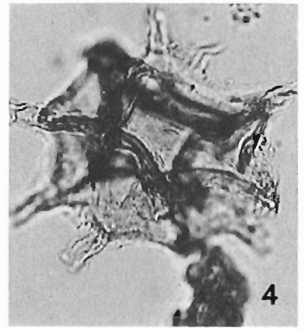
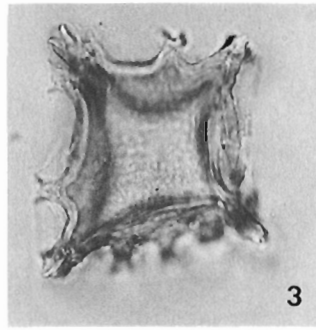
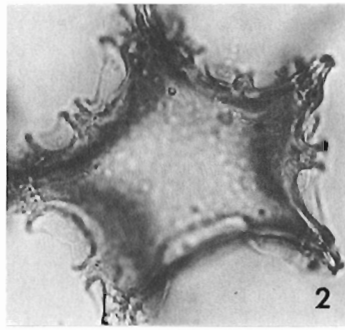
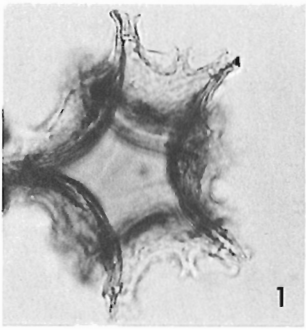


Plate 16

Figures 1–4. *Polyedryxium embudum* Cramer, 1964; figure 1, slide 8095-7,  $69.3 \times 104.2$ , GSC 48453,  $\times 500$ ; figure 2, slide 8097-2,  $61.9 \times 98.2$ , GSC 48454,  $\times 750$ ; figures 3, 4, slide 8109-S1,  $36.2 \times 102.3$ , GSC 48455, SEM,  $\times 500$  and  $\times 2500$  respectively.

Figures 5–7. *Polyedryxium decorum* Deunff, 1955; figure 5, slide 8062-S1,  $37.5 \times 102.4$ , GSC 48456, SEM,  $\times 750$ ; figures 6, 7, slide 8062-S1,  $37.7 \times 103.2$ , GSC 48457, SEM,  $\times 750$  and  $\times 2500$  respectively.

Figures 8–14. *Polyedryxium fragosulum* sp. nov.; figure 8, holotype, slide 8124-3,  $59.6 \times 95.6$ , GSC 48458,  $\times 500$ ; figure 9, slide 8126-1,  $63.2 \times 95.8$ , GSC 48459,  $\times 500$ ; figure 10, slide 8126-32,  $32.1 \times 102.0$ , GSC 48460,  $\times 500$ ; figure 11, slide 8126-7,  $34.8 \times 103.2$ , GSC 48461,  $\times 500$ ; figures 12, 13, GSC loc. 8124, SEM,  $\times 500$  and  $\times 2500$  respectively; figure 14, GSC loc. 8124, SEM,  $\times 2500$ .

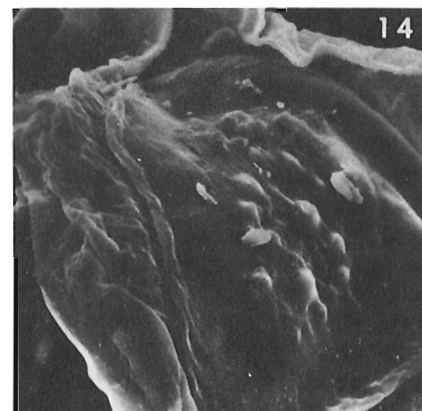
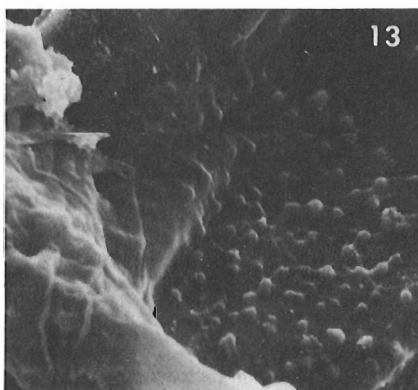
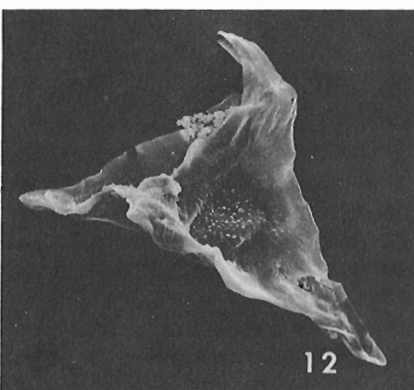
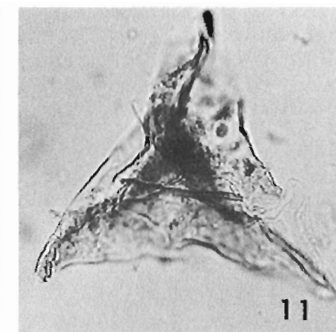
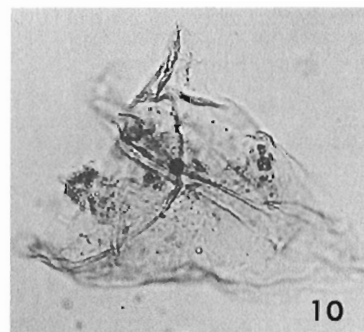
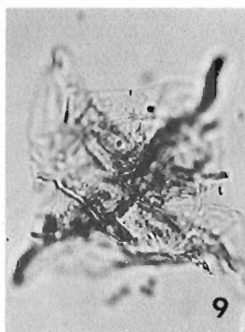
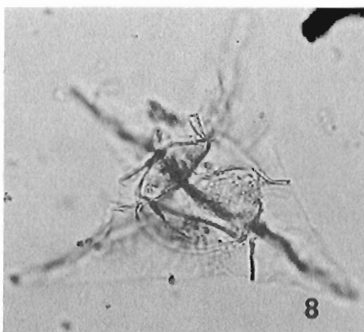
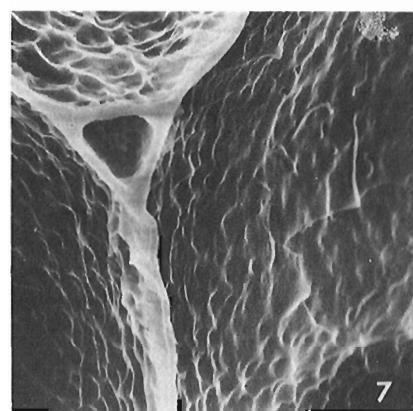
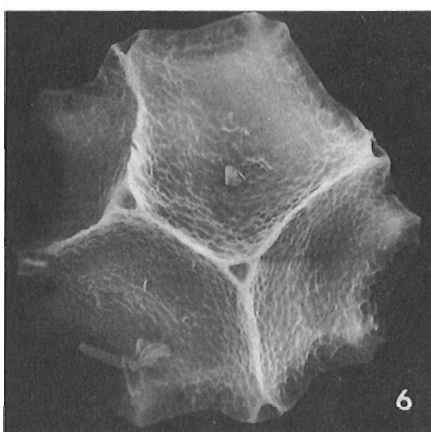
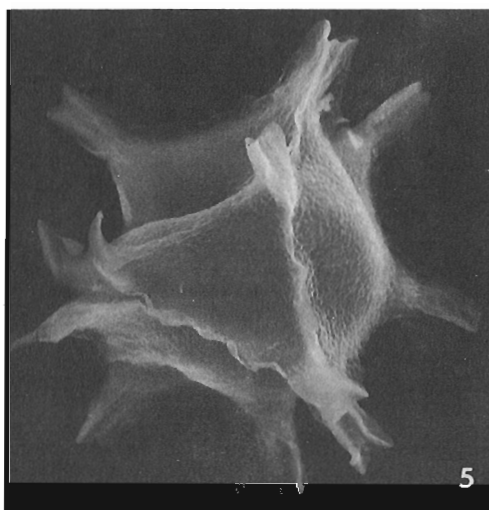
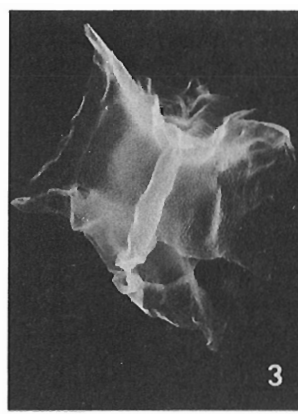
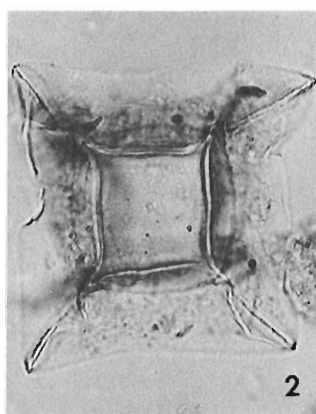
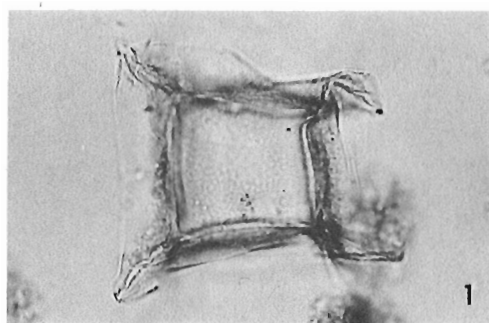


Plate 17

Figures 1–12. *Polyedryxium pharaonis* Deunff, 1961; figure 1, slide 8098-7,  $62.3 \times 94.8$ , GSC 48462,  $\times 500$ ; figure 2, slide 8112-14,  $34.3 \times 108.2$ , GSC 48463,  $\times 500$ ; figure 3, slide 8135-41,  $38.6 \times 103.4$ , GSC 48464,  $\times 500$ ; figure 4, slide 8111-S1,  $42.0 \times 104.2$ , GSC 48465, SEM,  $\times 500$ ; figure 5, slide 8126-22,  $40.6 \times 100.0$ , GSC 48466,  $\times 500$ ; figure 6, slide 8111-11,  $37.2 \times 103.8$ , GSC 48467,  $\times 500$ ; figures 7, 8, slide 8060-S1,  $39.5 \times 101.5$ , GSC 48468, SEM,  $\times 750$  and  $\times 2500$  respectively; figures 9, 10, slide 8062-S1,  $37.6 \times 103.5$ , GSC 48469, SEM,  $\times 750$  and  $\times 2500$  respectively; figures 11, 12, slide 8062-S1,  $37.5 \times 102.8$ , GSC 48470, SEM,  $\times 750$  and  $\times 2500$  respectively.



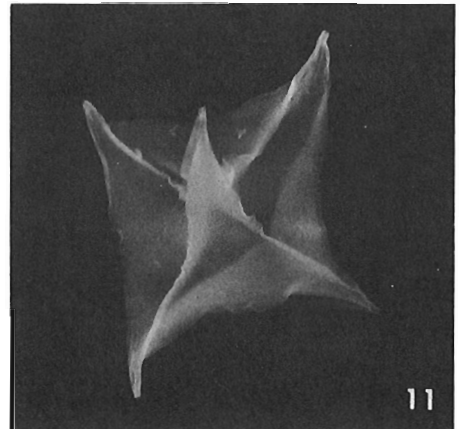
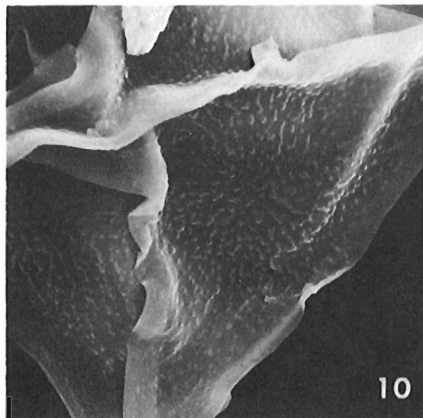
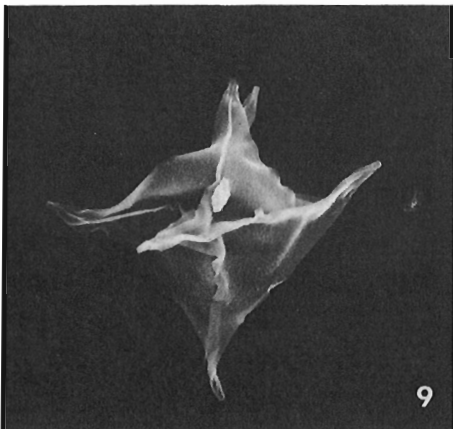
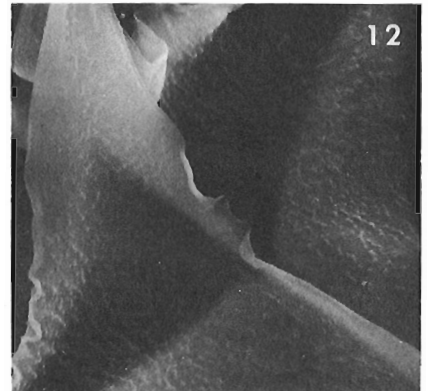
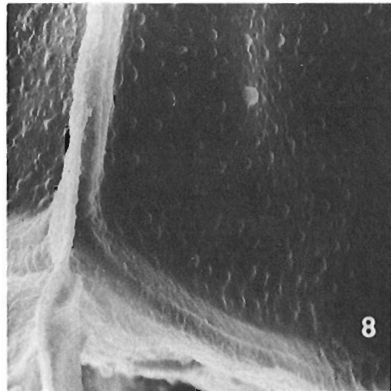
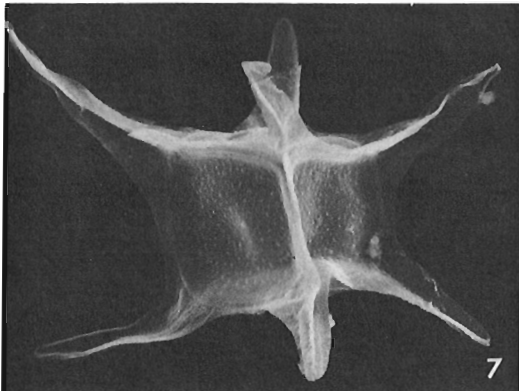
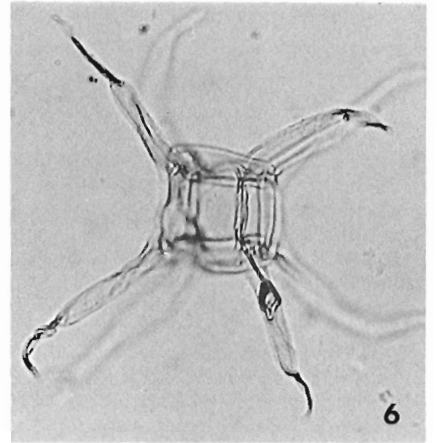
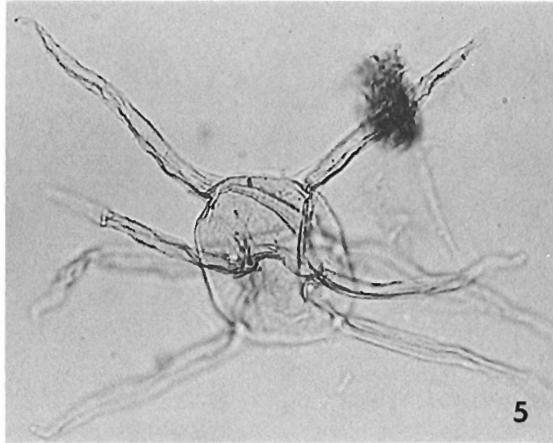
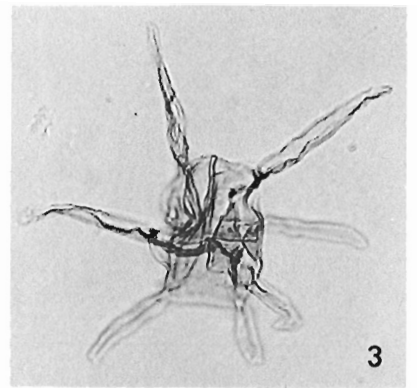
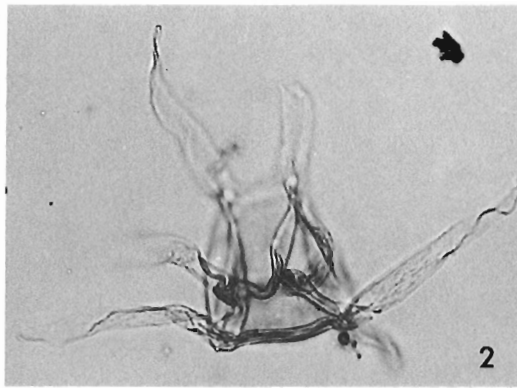
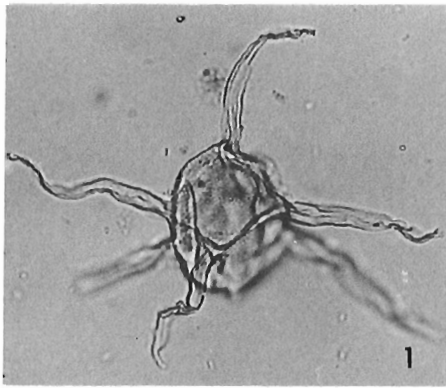


Plate 18

Figures 1-6. *Pterospermella circumstriata* (Jardiné, Combaz, Magloire, Peniguel, and Vachey) Eisenack and Cramer, 1973; figure 1, slide 7851-S2,  $37.8 \times 101.5$ , GSC 48471, SEM,  $\times 500$ ; figure 2, slide 8117-5,  $60.8 \times 105.6$ , GSC 48472,  $\times 500$ ; figure 3, slide 8115-4,  $56.6 \times 95.5$ , GSC 48473, IC,  $\times 500$ ; figure 4, slide 7851-S1,  $42.2 \times 106.7$ , GSC 48474, SEM,  $\times 750$ ; figures 5, 6, slide 8111-S1,  $41.8 \times 103.8$ , GSC 48475, SEM,  $\times 500$  and  $\times 2500$  respectively.

Figures 7-9. *Stellinium micropolygonale* (Stockmans and Willièrè) comb. nov.; figure 7, slide 8056-S1,  $48.7 \times 105.4$ , GSC 48476, SEM,  $\times 750$ ; figure 8, slide 8056-S1,  $48.7 \times 105.3$ , GSC 48477, SEM,  $\times 750$ ; figure 9, slide 8062-1,  $54.9 \times 97.2$ , GSC 48478,  $\times 750$ .

Figures 10-12. *Tunisphaeridium tentaculiferum* (Martin) Cramer, 1971; figure 10, slide 8109-S1,  $35.6 \times 103.6$ , GSC 48479, SEM,  $\times 500$ ; figure 11, slide 8111-6,  $37.1 \times 106.8$ , GSC 48480,  $\times 500$ ; figure 12, slide 8112-1,  $57.6 \times 93.2$ , GSC 48481,  $\times 500$ .

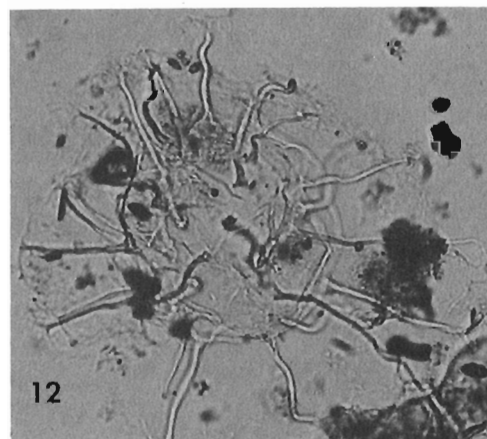
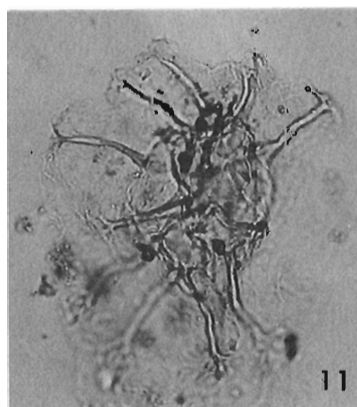
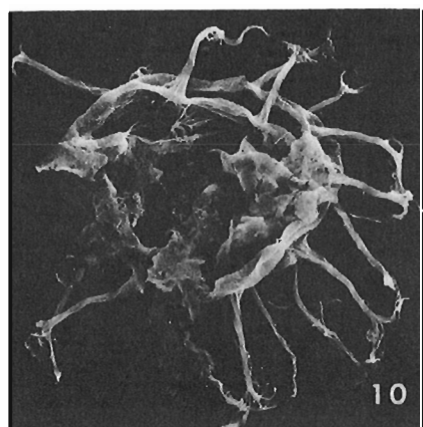
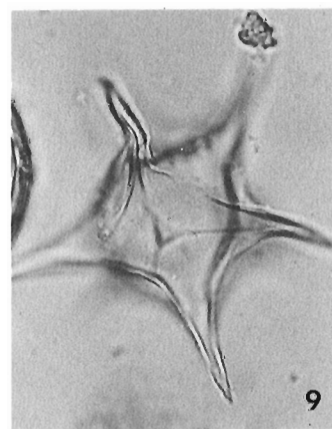
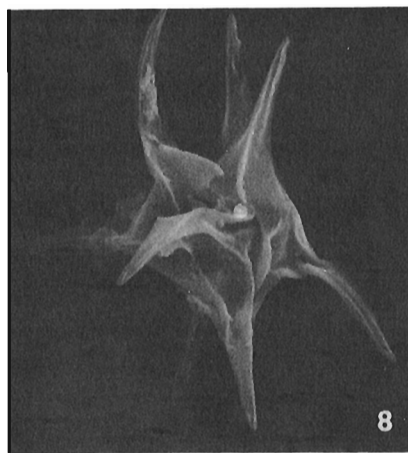
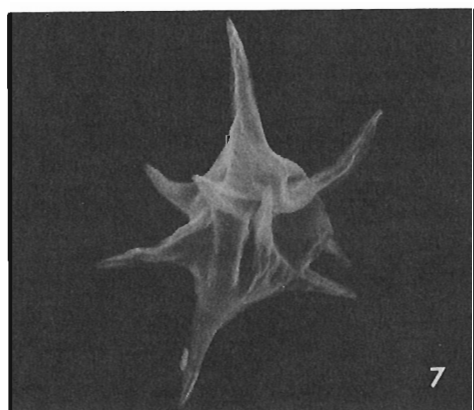
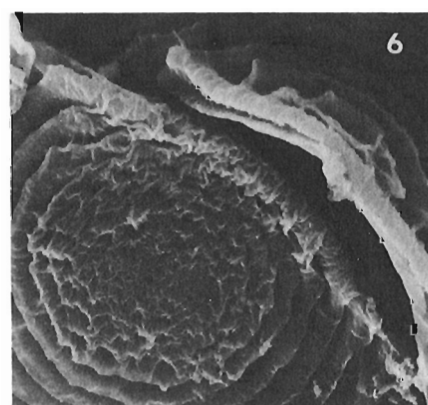
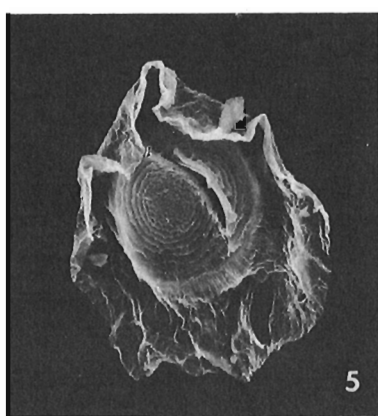
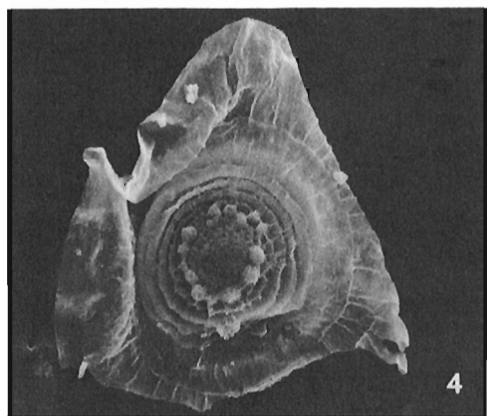
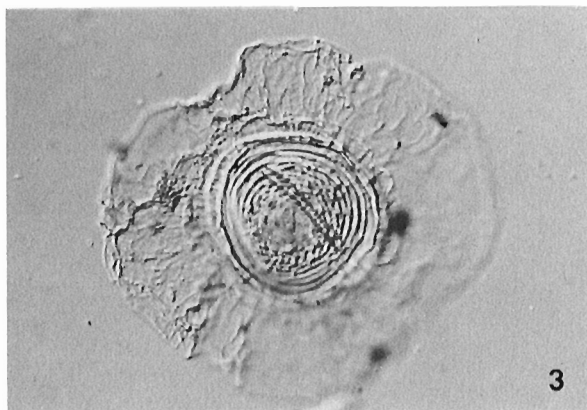
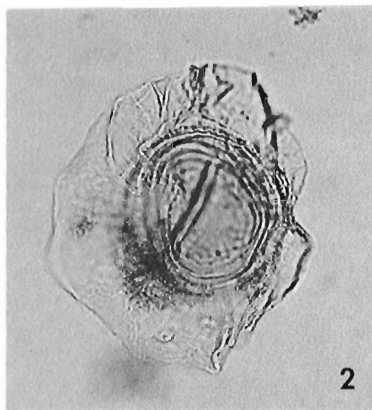
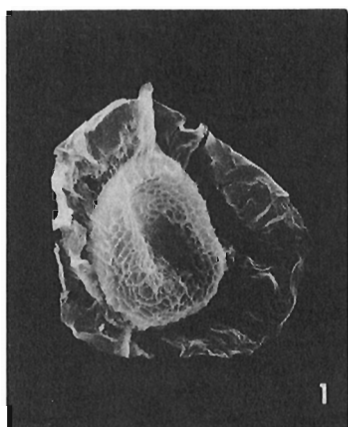


Plate 19

Figures 1–6. *Tyligmasoma alargadum* (Cramer) comb. nov.; figures 1, 2, slide 8109-S1,  $36.5 \times 103.7$ , GSC 48482, SEM,  $\times 750$  and  $\times 1000$  respectively; figure 3, slide 8115-7,  $39.9 \times 109.7$ , GSC 48483,  $\times 1000$ ; figure 4, slide 8108-1,  $54.4 \times 102.9$ , GSC 48484,  $\times 500$ ; figure 5, slide 8102-2,  $21.8 \times 93.2$ , GSC 48485,  $\times 750$ ; figure 6, slide 8106-1,  $42.3 \times 112.7$ , GSC 48486,  $\times 500$ .

Figures 7–10. *Veryhachium polyaster* Staplin, 1961; figure 7, slide 8109-S1,  $36.8 \times 103.2$ , GSC 48487, SEM,  $\times 750$ ; figure 8, slide 8111-3,  $64.7 \times 106.8$ , GSC 48488,  $\times 500$ ; figure 9, slide 8109-4,  $68.2 \times 108.8$ , GSC 48489,  $\times 500$ ; figure 10, slide 8118-4,  $53.3 \times 109.0$ , GSC 48490,  $\times 500$ .

Figures 11–13. *Veryhachium radiosum* sp. nov.; figure 11, slide 8135-S1,  $36.2 \times 104.8$ , GSC 48491, SEM,  $\times 750$ ; figure 12, slide 8134-15,  $36.8 \times 104.2$ , GSC 48492,  $\times 500$ ; figure 13, holotype, slide 8135-28,  $34.5 \times 103.0$ , GSC 48493,  $\times 500$ .

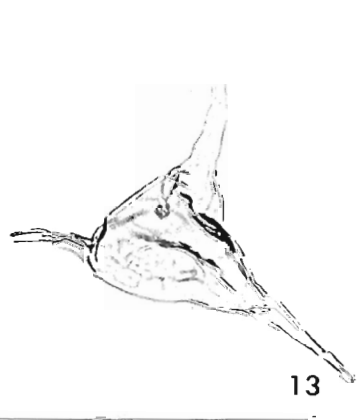
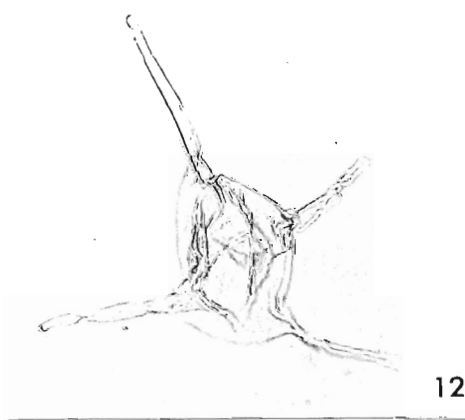
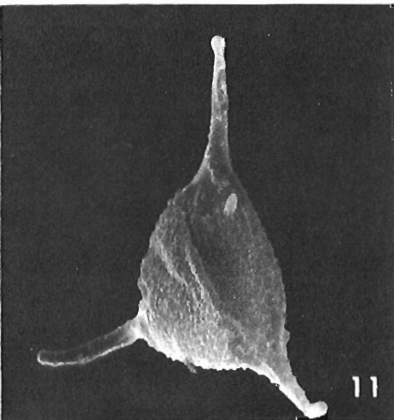
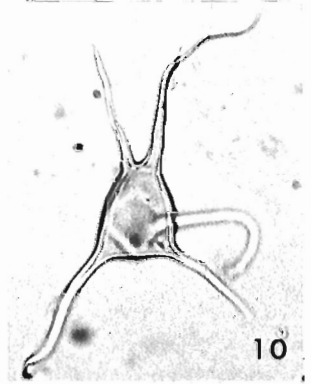
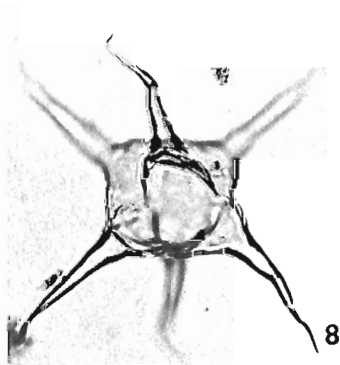
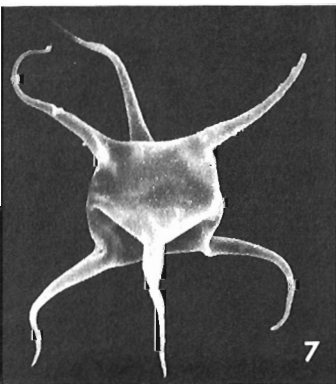
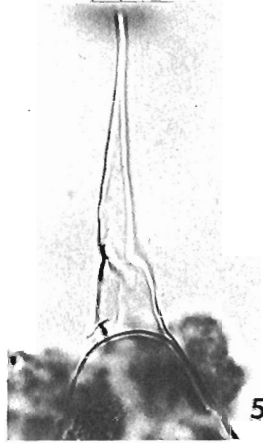
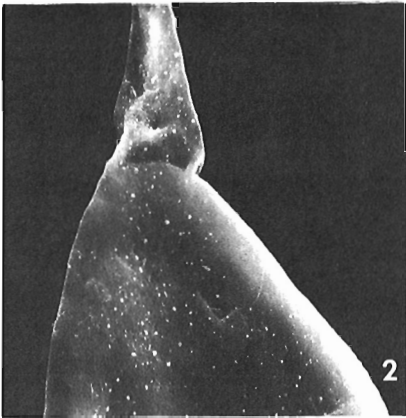
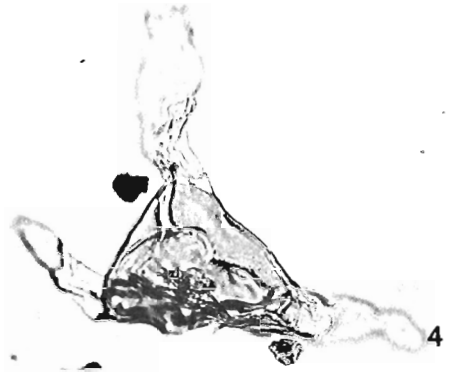
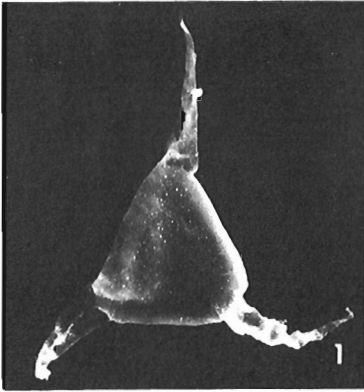


Plate 20

Figures 1–3. *Veryhachium lairdii* Deflandre ex Deunff, 1959; figure 1, slide 8056-S1,  $47.6 \times 106.0$ , GSC 48494, SEM,  $\times 750$ ; figure 2, slide 8127-5,  $34.2 \times 99.0$ , GSC 48495,  $\times 750$ ; figure 3, slide 8127-55,  $36.0 \times 101.7$ , GSC 48496,  $\times 750$ .

Figures 4–13. *Veryhachium downiei* Stockmans and Willièvre, 1962; figure 4, slide 8124-21,  $38.7 \times 103.6$ , GSC 48497,  $\times 1000$ ; figure 5, slide 8060-S1,  $39.3 \times 101.7$ , GSC 48498, SEM,  $\times 2500$ ; figure 6, slide 8108-6,  $51.6 \times 97.4$ , GSC 48499,  $\times 750$ ; figure 7, slide 8060-4,  $70.4 \times 104.3$ , GSC 48500,  $\times 500$ ; figure 8, slide 8135-S1,  $38.1 \times 104.8$ , GSC 48501, SEM,  $\times 2500$ ; figures 9, 10, slide 8135-S1,  $37.2 \times 104.8$ , GSC 48502, SEM,  $\times 1000$  and  $\times 2500$  respectively; figures 11, 12, slide 8109-S1,  $35.9 \times 102.5$ , GSC 48503, SEM,  $\times 750$  and  $\times 2500$  respectively; figure 13, slide 8056-S1,  $48.4 \times 106.2$ , GSC 48504, SEM,  $\times 2500$ .



