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MIDDLE AND UPPER CAMBRIAN AND LOWER ORDOVICIAN ACRITARCHS FROM RANDOM ISLAND, EASTERN NEWFOUNDLAND

F. Martin
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PREFACE

Cambro-Ordovician acritarchs described in this report record a succession of six microfloras and associated trilobite faunas of the Atlantic Realm. The microfloras show marked affinities to similar assemblages from south-western Europe and parts of North Africa a fact that supports the theory of plate tectonics and the supposition that the proto-Atlantic Ocean developed during early Paleozoic time.

Paleontological studies such as this are used to establish the biostratigraphic standards by which rocks are dated and correlated. In eastern Canada the study of early Paleozoic floras and faunas provides information necessary to understand the structural evolution of the eastern part of North America and thus such studies have a direct bearing on the assessment of the hydrocarbon potential of the sedimentary basins that lie east of the present continental margin.

D.J. McLaren
Director General
Geological Survey of Canada

OTTAWA, June 1980

CONTENTS

MIDDLE AND UPPER CAMBRIAN AND LOWER ORDOVICIAN ACRITARCHS FROM RANDOM ISLAND, EASTERN NEWFOUNDLAND

Abstract

The history and validity of various lithostratigraphic units proposed in 1914 by Van Ingen for strata of Cambrian and Ordovician age in the Random Island area, Trinity Bay, eastern Newfoundland are reviewed. A succession of six acritarch microfloras, A1 to A6, is described from the higher Middle Cambrian, Upper Cambrian and lowest Ordovician (Tremadoc Series in part) at Random Island. The vertical distribution of 21 genera and 42 species of acritarchs is recorded with reference, where possible, to corresponding Scandinavian and Anglo-Welsh trilobite zones. New species include: *Adara alea, Arbusculidium rommelaerei, Cristallinium randomense, Timofeevia microretis* and *Vulcanisphaera turbata*. The major palynological change in the succession A1 to A6 occurs in A5, in the *Peltura* Zone of the Upper Cambrian. Previously described taxa include species reported mainly from the Cambrian of Spain, Belgium and Czechoslovakia and from the Tremadoc of Bell Island (Conception Bay, eastern Newfoundland), England, Belgium, southwestern France, Algeria, Libya and Morocco.

Résumé

L'historique et la validité des différentes unités lithostratigraphiques proposées, en 1914, par Van Ingen pour des dépôts cambriens à ordoviciens de la région de Random Island, Trinity Bay, en Terre-Neuve orientale, sont revues. A Random Island, une succession de six microflores à acritarches, A1 à A6, est décrite dans la partie supérieure du Cambrien Moyen, dans le Cambrien Supérieur et à la base de l'Ordovicien (Série de Tremadoc, p.p.). La distribution verticale de 21 genres et de 42 espèces d'acritarches est établie en indiquant autant que possible la corrélation avec les zones scandinaves et anglo-galloises à trilobites. Les nouvelles espèces sont: *Adara alea, Arbusculidium rommelaerei, Cristallinium randomense, Timofeevia microretis* et *Vulcanisphaera turbata*. Le changement palynologique le plus important dans la succession A1 à A6 est situé dans A5, contenue dans les dépôts cambriens supérieurs appartenant à la Zone à *Peltura*. Les taxa connus sont décrits principalement dans le Cambrien d'Espagne, de Belgique et de Tchécoslovaquie et dans le Trèmadoc de Bell Island (Conception Bay, Terre-Neuve orientale), d'Angleterre, de Belgique, du sud-ouest de la France, d'Algérie, de Lybie et du Maroc.

Introduction

W.T. Dean, F. Martin

Lower and Middle Cambrian rocks occur in several parts of the Avalon Platform, the easternmost of the structural units into which Newfoundland was divided by Williams (1964, 1979), but Upper Cambrian strata are known from only three places. The largest development is found at Random Island, on the west side of Trinity Bay; others occur in the Manuels River area of Conception Bay, and at the northern end of Fortune Bay. The present paper is concerned with the first of these (Fig. 1), together with the underlying Middle Cambrian and overlying Lower Ordovician rocks.

Collections of samples for palynological examination were obtained from rocks correlated in part with the Middle Cambrian (or St. David's Series), Upper Cambrian (or Merioneth Series) and Lower Ordovician (Tremadoc Series) by the writers in the course of visits to Newfoundland in the summers of 1975, 1976 and 1977 as part of Geological Survey of Canada Project 690006. Further studies on the Cambro-Ordovician stratigraphy and trilobites of Random Island by Valdemar Poulsen and W.T. Dean are in progress. The present paper is concerned mainly with F. Martin's descriptions of the acritarch microfloras and their stratigraphic distribution. It is also, however, an appropriate place for briefly reviewing past research on the area, and for commenting on certain lithostratigraphic terms which, although published, have never been adequately documented.

Acknowledgments

At the geology department, Princeton University, Mrs. Phyllis Hasson and Dr. Ida Thompson kindly made available notes belonging originally to Gilbert Van Ingen. WTD is indebted to Professor B.F. Howell for comments on the Princeton expeditions to eastern Newfoundland. Professor V. Poulsen and Dr. A.W.A. Rushton generously gave unpublished data from, respectively, Random Island and northwest Wales, and Dr. R.B. Rickards examined dendroid graptolites from Random Island. FM is indebted to Professor C. Downie for critically reviewing the manuscript and to Dr. M. Vanguestaine, University of Liège, for his co-operation during the examination of type specimens from the Cambrian of Belgium. At the Institut royal des Sciences naturelles de Belgique, where processing of the acritarchs was carried out, Mr. H. de Potter is thanked for his technical help and Mr. G. Van der Veken for printing the photographs. At the Rijks Universiteit-Gent, scanning electron microscope photographs were obtained through the courtesy of Professor A. Lagasse and Mr. A. Bielen.

Review of stratigraphic terminology

W.T. Dean

Historical background

Pioneer work by Matthew (1899) on the Cambrian section along the north shore of Smith Sound, opposite the north side of Random Island, helped to elucidate the stratigraphy of some of the Lower and Middle Cambrian rocks, but it was not until later that the sequence of Upper Cambrian and Lower Ordovician strata in the area was recognized. This resulted from a series of three expeditions which were sent from Princeton University in 1912, 1913 and 1914, and included A.F. Buddington, A.O. Hayes and B.F. Howell; they were led by Gilbert Van Ingen, whose subsequently published contributions on these rocks were limited to a short abstract and a stratigraphic table (Van Ingen, 1914a, 1914b). In this table the Middle Cambrian rocks, equated with the Acadian of the Saint John Group in New Brunswick, were shown as represented by a Manuels Series, in turn corresponding to a Manuels Formation. This last unit was subdivided into two parts: D 1. phosphorite, with index fossil Lower *Paradoxides;* succeeded by D 2. black, brown and olive shales, thin sandstone and kalk-ballen with index fossils *Paradoxides, Conocoryphe, Liostracus, Agnostus* and *Microdiscus*. All of the Upper Cambrian was equated with the Johannian, represented by an Elliott Cove Series and an equivalent Elliott Cove Formation. The rocks,correlated with the Lingula Flags of Wales, were listed as: E. grey and black shale with cone-in-cone concretions and thin bedded sandstone, with index fossils *Olenus, Orusia lenticularis* (Wahlenberg, 1821), and *Lingulella ferruginea* (a *nomen nudum*).

The succeeding Lower Ordovician succession was shown as beginning with the Clarenville Series (Van Ingen, 1914b; now used as a formation, for example by Jenness, 1963), equated in its entirety with the Tremadoc Series of western Europe and subdivided into four formations as below. Of the index fossils, all the listed species and the genus *Princetonia* were *nomina nuda*.

Formation	No.	Rock Type	Index Fossils
Riders Brook	F.6	Shale	
	F.5	Grey sandy limestone	*Bellerophon randomi*
Maidment	F.4	Shales	*Niobe howelli*
Apsey	F.3	Shales	*Princetonia terranovica* *Parabolina harrieta*
	F.2	Brown Shales	*Shumardia*
Brown Mead	F.1	Grey Shales	*Bryograptus*

A short account of the Cambro-Ordovician succession by Howell (1926) was essentially a repetition of Van Ingen's table but the term Newfoundland Series was used for all the strata of known Middle Cambrian age, separated from the Elliott Cove Series by "Dark sandy shales" of unknown age. In this interpretation the Elliott Cove Series was shown to include only dark shale and thin sandstone of the *Agnostus pisiformis* Zone and the Zone of *Agnostus pisiformis obesus* and *Olenus,* whereas overlying shale with *Orusia lenticularis* had a question mark placed by it and was set beneath the succeeding Clarenville Series, said to be "Tremadocian and older" in age.

The formations listed originally by Van Ingen (1914b) were omitted from Howell's 1926 paper but at a later date Howell (*in* Christie, 1950, p. 31) gave brief notes on these subdivisions and their location which may be summarized as follows. Brown Mead Formation - exposed at Brown Mead (Bounds Mead) and contains an unidentifiable graptolite, either *Bryograptus* or *Dictyonema* (only one imperfect specimen found). Apsey Formation - exposed along the western shore of Random Island north of Brown Mead, the *Shumardia* Zone being exposed not far north of Brown Mead and the *Princetonia-Parabolina* Zone about "half a sea mile" north of the same point. Maidment Formation - exposed from 0.42 to 0.8 km north of the best exposures of Apsey Formation and thence northwards to Bar Mead. Riders Brook Formation - exposed at Riders Brook (Ryder's Brook).

It is doubtful whether any of the above subdivisions will prove acceptable for modern use, even as members of the Clarenville Formation, but the following comments may serve to clarify certain related points.

Brown Mead Formation The name Brown Mead refers to what is shown on present-day maps as Bounds Mead, a subtriangular area of storm beach deposits some 1.5 km long from north to south, which projects westward directly towards Clarenville from the west coast of Random Island. Shale of Tremadoc age forms extensive outcrops along the coast north of Bounds Mead, though the continuity of the section is obscured by cliff falls. It was at a point approximately 250 m north of the northernmost part of Bounds Mead that Van Ingen (personal notebook) first recorded *Dictyonema*, a determination subsequently changed by him to *Dichograptus*. The locality was revisited by the writers and is noted under GSC loc. 94436.

Apsey Formation The promontory known now as Aspey Point is situated 3.5 km north of Clarenville, and lies on the west shore of the channel separating the northwest coast of Random Island from the mainland (Fig. 1). No Ordovician outcrops are known there and it is apparent that as noted by Howell (*in* Christie, 1950, p. 31), the name was used in a broad sense to include the shale exposed in the cliffs of Random Island, clearly visible across Northwest Arm. *Shumardia* sp. and *Dictyonema* cf. *D. flabelliforme* Eichwald, 1840 were reported by Jenness (1963, p. 169 and text-fig. 6), on the basis of unpublished notes by A.M. Christie, from a locality (F-37) situated about 0.8 km north of Bounds Mead, but the material has not been traced in the Geological Survey of Canada's collections. The *Shumardia* of Van Ingen's table is probably *Conophrys*, specimens of which have been collected by V. Poulsen and the writer.

Of the other "index species" recorded from the Apsey Formation by Van Ingen (1914b), *Parabolina harrieta* remains a *nomen nudum.* Specimens assignable to the genus are abundant in the neighbourhood and in other parts of Random Island, as well as on the shore of the mainland north of Smith Sound (Fig. 1). In some cases the trilobite present is *Parabolina argentina* (Kayser, 1876), a species name considered as a senior subjective synonym of *P. andina* (Hoek, 1912), under which name it was recorded also by Jenness (1963, p. 169, 170).

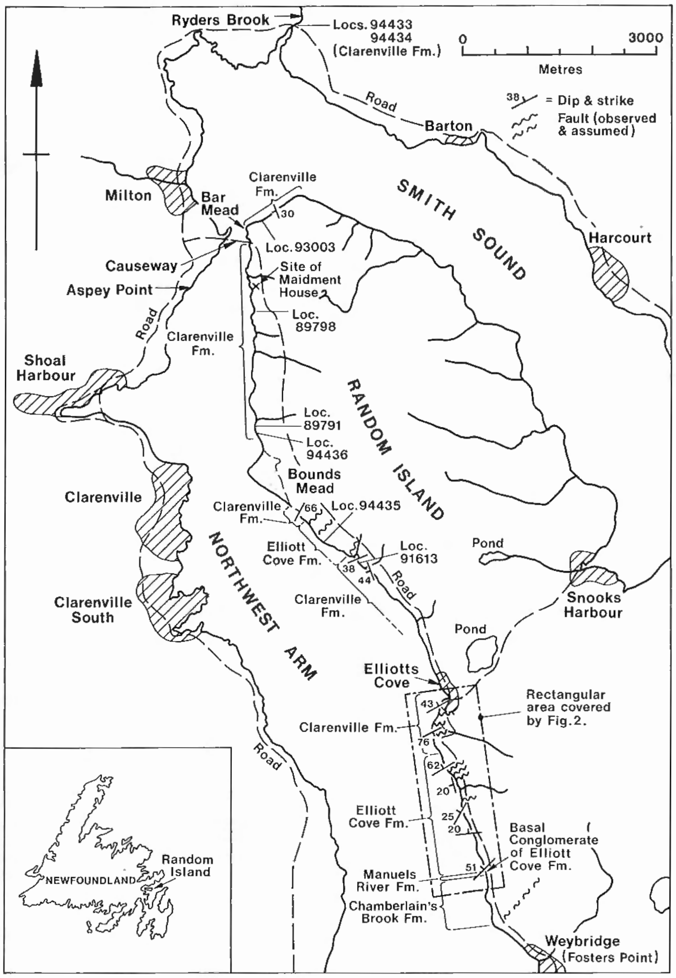

FIGURE 1. Outline map of northwestern end of Random Island and adjacent mainland showing place names mentioned in text. Small inset map shows position of Random Island in relation to Newfoundland.

Princetonia terranovica also is a *nomen nudum*, but W.H. Poole has kindly drawn my attention to a recent Princeton University newsletter in which is reproduced the front page of the newspaper *Public Ledger*, Philadelphia, dated July 4th, 1915. The latter contains an account of Van Ingen's Newfoundland expeditions and a facsimile of a trilobite named as *Princetonia*, though without giving a species. That the name represents a species of *Beltella* is supported by photographs among Van Ingen's papers at Princeton; for the present, the material may conveniently be compared with *B. ulrichi* (Kayser, 1897) from the Lower Tremadoc Series of Argentina.

Maidment Formation The subdivision was named after Maidment House, a building formerly situated near the northwest coast of Random Island and on the grass covered flat area of a onetime storm beach, partly cultivated, which extends southwards from Bar Mead, near the present-day Causeway (Fig. 1).

Although Maidment House stood on Recent deposits, shale of Tremadoc age is extensively exposed in the neighbourhood, particularly near the east side of the road about 0.5 km south of the Causeway, as well as in the adjacent large quarries, some 0.5 km farther south, from which shale is still excavated and taken to Milton, 5 km north of Clarenville, for brick manufacture. Van Ingen's (1914b) index fossil *Niobe howelli* is a *nomen nudum* but probably refers to a species of *Niobella*, a genus recorded from the area (Dean, 1976, p. 233); specimens are not uncommon in the Tremadoc rocks of Random Island and the adjacent mainland north of Smith Sound. The Anglo-Welsh Lower Tremadoc species *Niobella homfrayi* (Salter, 1866) was recorded by Jenness (1963, p. 169, 170) from the northwest part of Random Island but has not yet been confirmed there; the species has been reported from shale of Upper Tremadoc age (McLeod Brook Formation) on Cape Breton Island, Nova Scotia (Hutchinson, 1952, p. 103). No undoubtedly post-Lower Tremadoc faunas have yet been documented from Random Island.

Riders Brook Formation Uppermost of Van Ingen's (1914b) subdivisions of the Clarenville Series, the unit was further subdivided into two parts as follows: F 5 Grey sandy limestone, index fossil *Bellerophon randomi* nov. (a *nomen nudum*); and F 6 Shale, no index fossil listed. The eponymous stream, now known as Ryders Brook, is situated on the mainland and enters Smith Sound 2.5 km north of the northwest tip of Random Island (Fig. 1). No persistent limestone or siltstone horizon meriting separate recognition has been found in the vicinity, and the term is best allowed to lapse. Shale, sometimes strongly folded, is exposed along the shore southeast of the inlet at the mouth of Ryders Brook, and along the southeast side of the inlet, where it yielded *Parabolina* and *Geragnostus*. Similar trilobites were collected by the present authors in 1976 from shale exposed at the top of the then new cutting excavated where the road from Milton to Barton and beyond crosses Ryders Brook (Fig. 1); acritarchs from nearby (GSC loc. 94433) examined by F. Martin proved to be both rare and undeterminable. An adjacent outcrop of massive siltstone, GSC loc. 94434, yielded no microfossils.

A bulletin of the Newfoundland Geological Survey published in 1948 contains two papers on the Bonavista region by Hayes and by Rose, together with a map produced jointly by them. Hayes's paper includes a review of previous work on the Cambro-Ordovician rocks of the Avalon Peninsula and reproduces Van Ingen's (1914b) table which was not generally available; it does not give a detailed account of strata younger than Middle Cambrian, but various brick-pits in Cambro-Ordovician shale of the Random Island area are noted. The map by Hayes and Rose (1948) shows the northwestern portion of Random Island underlain by Clarenville Formation, with Elliott Cove Formation outcropping for only a short distance north and south of Elliott's Cove. Much of the section regarded here as being occupied by Elliott Cove Formation is shown as outcrop of the Brigus Formation, of Early Cambrian age.

The Elliott Cove Formation and Clarenville Formation, and the problem of distinguishing between the two, were noted briefly by Christie (1950, p. 29) in his account of the Bonavista map area. As noted earlier, a personal communication from B.F. Howell mentioned in the same publication (p. 31) commented on the probable type sections of Van Ingen's "Formations" of the Clarenville "Series" and pointed out that the lower and upper limits of these subdivisions had never been defined. The map accompanying Christie's paper uses a stratigraphic table which includes a mixture of rock-stratigraphic and chronostratigraphic terms. For example, the outcrop of the Elliott Cove Formation is shown to extend a short distance south of Elliott's Cove, covering parts of the section known now to consist of Clarenville Formation; still farther south the subjacent strata were mapped as "Middle Cambrian. Grey shale" and they, too, occupied part of what is now regarded as the outcrop of the Elliott Cove Formation.

The most recent general account of the Cambro-Ordovician rocks of Random Island is that of Jenness (1963, p. 57-74, 107-110) who also provided a geological map as part of a study of the Bonavista region and noted (p. 108) the difficulties of accounting for the structural occurrence of the various Upper Cambrian and Lower Ordovician outcrops in the western part of the island. Jenness did not share the opinion of previous workers who had found it possible to differentiate in the field between subdivisions on the scale of Van Ingen's (1914b) formations and series, and preferred (Jenness, 1963, p. 30, 58) to erect two new terms, in ascending order Adeyton Group and Harcourt Group, to accommodate the local Cambrian and Ordovician rocks. The Harcourt Group was mapped as an undifferentiated unit and comprised three formations, Manuels River, Elliott Cove and Clarenville, said to total more than 914 m (3000 ft.) of heterogeneous strata. Jenness (1963, p. 58-59, 72) stated that the Elliott Cove and Clarenville formations were, in part, biostratigraphic units and therefore described them together as he considered them inseparable lithologically. To some extent this criticism was justified in that Van Ingen appears to have relied a good deal on fossil evidence for separating the formations while stressing the general similarity of rock types, and no mention of standard sections was made until Hutchinson (1962, p. 25) formally designated that of the Elliott Cove Group as being the coastal section south of the eponymous settlement.

Macrofossil zonation of the Middle and Upper Cambrian

The standard macrofossil zones recognized at Random Island concern only the Middle and Upper Cambrian. Subdivision of the Middle Cambrian on the basis of trilobites is founded on the work of Westergård (1946) in Sweden and has been reviewed by Cowie and others (1972, p. 10, 11) and by Poulsen and Anderson (1975, p. 2067). Both *Paradoxides hicksii* Salter, 1865 and *P. davidis* Salter, 1863 are traditional zonal indices from the Middle Cambrian, Menevian "Stage", of southwest Wales but are not known from Sweden, where Westergård (1946) established three successive "Stages" (sometimes termed "Zonal Groups") characterized by *Paradoxides oelandicus* Sjögren, 1872, *P. paradoxissimus* (Wahlenberg, 1821) and *P. forchhammeri* Angelin, 1852. The Swedish "Stages" were subdivided by Westergård into several zones, based mainly on agnostid trilobites, and Cowie and others (1972, table 1) have shown the approximate correlation of these with the Welsh *Paradoxides* Zones. Briefly, the *P. hicksii* Zone was considered to be equivalent to Westergård's *Ptychagnostus atavus* and *Tomagnostus fissus* Zone; the lower part of the *P. davidis* Zone corresponds to the *Hypagnostus parvifrons* Zone; and the upper part of the *P. davidis* Zone corresponds to the *Ptychagnostus punctuosus* Zone. The *P. forchhammeri* "Stage" or zonal group was shown by Westergård to correspond to three zones, in ascending order: *Goniagnostus nathorsti* Zone, *Solenopleura brachymetopa* Zone, and *Lejopyge laevigata* Zone; the first of these was considered to be of doubtful status by Poulsen and Anderson (1975, p. 2067).

The Upper Cambrian zonation appropriate to eastern Newfoundland was founded originally on Scandinavian successions and is equally applicable to the Anglo-Welsh area. Index fossils are mostly olenid trilobites, with some agnostids, and the zonal scheme followed here is that used by Henningsmoen (1957). The ascending sequence of zones is as follows: *Agnostus pisiformis; Olenus* (sometimes jointly with *Homagnostus obesus*); *Parabolina spinulosa; Leptoplastus; Peltura; Acerocare*. Although certain of the Upper Cambrian strata at Random Island lack macrofossils, the succession is well developed and at least the first five of the above zones are represented. Problems connected with the Cambro-Ordovician boundary and the recognition of the *Acerocare* Zone in relation to the fauna of the *Dictyonema flabelliforme* Zone, lowest subdivision of the type Tremadoc Series (*see* Cowie et al., 1972 for review), are discussed later.

Previous and present observations, including Tremadoc Series

Current investigation, together with as yet uncompleted studies in other parts of Random Island, suggest that the Manuels River, Elliott Cove and Clarenville formations, as typically developed, constitute distinct lithostratigraphic units that may be recognized in the field regardless of faunal content. Difficulties arise, however, at the junction of the two last formations, not so much the result of lithological similarity as the consequence of often intense folding and jointing. As part of his "lumping" of the Manuels River Formation with the Elliott Cove and Clarenville formations to produce the Harcourt Group, Jenness (1963, p. 74) stated that the Manuels River/Elliott Cove contact on Random Island appeared conformable both lithologically and structurally.

The junction of the Elliott Cove Formation with the underlying Manuels River Formation on Random Island was first described by Hutchinson (1962, p. 143-4) who gave a brief account of the section north of Weybridge (5 km south of Elliott's Cove). The Manuels River Formation there was said by Hutchinson (1962, p. 144) to be 27.5 m (91 ft.) thick. The rocks are mostly dark mudstone and shale, with occasional thin limestone beds; the topmost 16 m were sampled during the present work. Hutchinson noted a thin bed of shale conglomerate at the base of the Elliott Cove Formation and this, in conjunction with the supposed absence there of the uppermost Middle Cambrian trilobite zone, that of *Lejopyge laevigata*, led him to postulate a disconformity.

Poulsen and Anderson (1975) re-investigated the section and described the occurrence of a small trilobite faunule, said by them to include *L. laevigata* (Dalman, 1828) and *Peronopsis insignis* (Wallerius, 1895), in shale from 0.6 m (2 ft.) to 4.0 m (13 ft.) above the conglomerate. Consequently, they considered the conglomerate to indicate a hiatus, as a result of which the *Goniagnostus nathorsti* and *Solenopleura brachymetopa* Zones are missing. The same faunule was said to occur at the better known section of Manuels River, near the coast of Conception Bay, farther southeast in the Avalon Peninsula, where it included also *Andrarina costata* (Angelin, 1854). Rushton (1978, p. 248-9, 257) believed some at least of Poulsen and Anderson's specimens of supposed *L. laevigata* to be incorrectly determined, but accepted the presence of the *L. laevigata* Zone at Random Island and at Manuels River; he considered that the *Solenopleura brachymetopa* Zone may be absent from eastern Newfoundland.

Estimates of the thickness of both the Elliott Cove Formation and the Clarenville Formation vary considerably. Hutchinson (1962, p. 143) recorded from the coast north of Fosters Point (now part of Weybridge village) a measured sequence of 120 m (393 ft.) of Upper Cambrian beds belonging to the Elliott Cove Formation, and this was duly noted by Jenness (1963, p. 73), though it was not clearly indicated by either author that only a fraction of the total Elliott Cove Formation was actually involved. Jenness quoted an unpublished estimate by A.M. Christie of 305 m (1000 ft.) of Upper Cambrian and perhaps 610 m (2000 ft.) of Lower Ordovician strata on Random Island; although he considered the figures to be perhaps exaggerated, he conceded that the two sets of strata could together total 610 m (2000 ft.). North (1972, p. 237) gave a relatively low maximum thickness of nearly 200 m (660 ft.) for the Elliott Cove Formation and described the rocks as becoming progressively more silty and micaceous upwards, and containing very shallow-water features that continue upwards into the Clarenville Formation. The present work indicates that the maximum development of fine grained sandstone is in the middle Elliott Cove Formation, approximating in the main to part of the *Olenus* Zone and part of the *Parabolina spinulosa* Zone, though macrofaunal evidence of age is commonly lacking in such lithologies. The higher Elliott Cove Formation marks a return to dark shale deposition, with locally abundant remains of olenid trilobites.

The upper boundary of the Elliott Cove Formation is not yet formally defined, and attempting a detailed assessment of the formation's thickness is hazardous in view of the numerous folds and faults at Random Island. The following estimated total of some 501 m (1653 ft.) must be considered approximate and the true figure could be even higher; a "+" after the given thickness indicates that part of the included or adjacent succession was not seen, generally as the result of cliff falls and slumps.

Grey shale with minor beds of siltstone. Trilobites in thin layers. *Leptoplastus* Zone and *Peltura* Zone represented.	67 m +
Soft, dark grey shale with only occasional beds of siltstone or concretions. *Parabolina spinulosa* and *Orusia lenticularis* occur.	24 m +
Alternations of fine grained sandstone, often massive, and silty grey shale. No macrofossils found.	235 m +
Soft, dark grey shale with trilobites of *Olenus* Zone. Beds of siltstone and concretions occur occasionally.	estd. 31 m
Alternations of grey shale and fine grained sandstone. No macrofossils found.	67 m
Grey and dark grey shale with minor siltstone beds. *Agnostus pisiformis* occurs.	55 m
Poorly exposed, soft, grey shale and occasional beds of siltstone. No macrofossils found.	18 m
Grey shale with basal conglomerate. Rare fossils of *Lejopyge laevigata* Zone recorded.	4 m

Assessing the thickness of the Clarenville Formation is still more difficult, in the absence of reliable marker horizons. Some 200 m (660 ft.) of shale was observed intermittently in the cliff section from Elliott's Cove south to Promontory VIII, but this excludes strata covered by fallen cliff material and takes no account of the faults obviously present. From Elliott's Cove to the northwest tip of Random Island there are many exposures of Clarenville Formation shale interruped midway between Bounds Mead and Elliott's Cove by a repetition of part of the highest Elliott Cove Formation, involving strata of the *Peltura* Zone (including loc. 94435). The relative uniformity of lithologies, macrofaunas and microfloras suggests that no more than two or three hundred metres, or even less, would be needed in order to account for this large but highly folded outcrop. Jenness's (1963) estimate, noted earlier, of a possible 610 m (2000 ft.) for the combined Elliott Cove and Clarenville formations does not differ radically from present results, but it is likely that the Elliott Cove Formation is the thicker. Although Van Ingen (1914b) may have been correct in assigning, at least by implication, the strata at Ryders Brook to the highest Clarenville Formation, in fact no stratigraphic top has been observed. Shale exposed at and south of Ryder's Brook shows no evidence of post-Lower Tremadoc strata, and the section there ends beneath Pleistocene and Recent deposits.

The relatively uncomplicated basin of Cambrian and Ordovician rocks at and adjacent to Random Island shown on Jenness's map (1963, Sheet 2C) appears to be an oversimplification, and it is likely that a north trending fault of some magnitude is concealed by the waters of the Northwest Arm of Random Sound (Fig. 1) near the northwestern tip of the island. North-South faulting involving Precambrian rocks north and south of Clarenville was shown by Jenness (1963, Sheet 2C), and in a pioneer work on the area Buddington (1919, p. 455, fig. 1) noted "...the fault on the west side of Random Sound, which may be traced for fifteen miles and brings Cambrian beds against pre-Cambrian granite and the Conception slate series".

Macrofossils from the Clarenville Formation have generally been accepted as indicative of the Tremadoc Series. Pending international agreement on the position of the Cambro-Ordovician boundary, the Tremadoc is interpreted here as the lowest series of the Ordovician, in accordance with the general practice of the Geological Survey of Canada. Certainly Van Ingen's (1914b) records of *Bryograptus, Shumardia* (probably a *Conophrys*), *Parabolina, Princetonia* (*nomen nudum* and a subjective synonym of *Beltella*) and *Niobe* (probably a *Niobella*) accord well with Tremadoc faunas in the Anglo-Welsh area. Dean (1976, p. 232, 243) pointed out that Argentinian faunal elements, including *Araiopleura* and *Parabolina argentina* (Kayser, 1876) (probably Van Ingen's *P. harrieta,* another *nomen nudum*), are important in the Random Island faunas, and on this basis an ?early Tremadocian age was favoured.

Graptolite evidence at Random Island is still meagre, though an unlocalized *Dictyonema* of the *D. flabelliforme* group and a poorly preserved specimen of *Dictyonema?* sp., from Geological Survey of Canada loc. 94436 (q.v.) might be construed as suggesting Lower Tremadoc. *Beltella* is found in the Tremadoc Series and Upper Cambrian of England and Wales and occurs in Argentina with *Parabolina argentina*, an index fossil there for the lower of two trilobite zones into which the Lower Tremadoc was subdivided by Harrington and Leanza (1957, p. 23-26). Graptolites recorded from the *P. argentina* Zone by Harrington and Leanza (loc. cit.) include *Dictyonema flabelliforme flabelliforme* (Eichwald, 1840) and *D. flabelliforme sociale* Salter, 1866. The olenid trilobite *Angelina,* questionably present at Random Island, is represented in the Argentinian Lower Tremadoc by three species, only one of which extends upwards into the lower half of the Upper Tremadoc (Harrington and Leanza, 1957, p. 27-29); in North Wales, however, the genus includes only *A. sedgwickii* Salter, 1859, the index species of the uppermost zone of the type Tremadoc.

Information critical to the argument is now becoming available from North Wales, where faunas from a section traversing the Upper Cambrian-Tremadoc boundary in its shaly facies are now being investigated by A.W.A. Rushton. A preliminary note (Rushton, 1979) drew attention to the locality at Bryn-llin-fawr, Gwynedd, where the *Acerocare* Zone is succeeded by the early part of the *Dictyonema flabelliforme* Zone, the junction of the two being marked by a thin bed apparently composed of volcanic ash. Rushton, who guided WTD to the section in June 1978, points out that although *Acerocare* itself has not yet been found, the presence of the *Acerocare* Zone is indicated by *Parabolina heres* Brøgger, 1882 (*see* Henningsmoen, 1957, p. 119). Some of Rushton's most interesting records from Bryn-llin-fawr include *Conophrys* sp. (the genus was previously reported, as *Shumardia*, from the Upper Tremadoc in England and Wales but is known from the Lower Tremadoc of Argentina) and *Araiopleura beothuk* Dean, 1970, which he has found in both the *Acerocare* Zone and the succeeding Lower Tremadoc. Thus it is possible that the strata of the Clarenville Formation at Random Island which contain *A. beothuk* may belong to the highest Upper Cambrian as well as to the Lower Tremadoc, but definite evidence of the *Acerocare* Zone there is still lacking.

The occurrence of the *Araiopleura beothuk* assemblage at still more localities on Random Island is suggested by an entry made by A.O. Hayes in Princeton Notebook No. 62, p. 96: "Sept. 19. 1912. Rainy. Followed Random Island shore from Brown Mead northwards. Found *Shumardia, Orometopus, Agnostus* about 1 mile north of Brown Mead". The same occurrence, with the *Orometopus* queried (and it may, in fact, refer to *Araiopleura*), was indicated by Van Ingen on a loose leaf under the manuscript locality number 214 A7.

Elsewhere in the eastern part of the Canadian Appalachians, Tremadoc strata and faunas of Anglo-Welsh type have been reported, particularly by Hutchinson (1952), from part of the McLeod Brook Formation on Cape Breton Island, Nova Scotia (*see* Dean, 1976, p. 233 for summary). In that area, however, there is a close lithological comparison with the Shineton Shales and analogous strata of the Welsh Borders, and faunas of both the Lower Tremadoc (*D. flabelliforme* Zone) and Upper Tremadoc (*Conophrys* [*Shumardia*] *pusilla* Zone) are represented. None of these Upper Tremadoc faunas is yet known from Random Island.

Location of fossiliferous palynological samples

W.T. Dean, F. Martin

During the present investigation samples were obtained from the upper part of the Manuels River Formation, at intervals throughout the Elliott Cove Formation, and from selected outcrops of the Clarenville Formation. Some strata were dated by means of trilobites or brachiopods, but others yielded no macrofossils.

A persistent problem when working on coastal sections such as those of Random Island is that of localizing samples with geographic precision. Habitations are few, suitable landmarks almost nonexistent, and the cliff-tops are covered with vegetation so dense that access to the shore is restricted. Because the 1:50 000 topographic map was insufficiently detailed, an enlarged outline of the relevant stretch of coastline was prepared from aerial photographs and a series of small promontories was numbered from I to XIII (Fig. 2) so as to provide readily identifiable datum points.

A few comments are in order regarding the spelling of certain place names, which may cause confusion. The embayment known in the present-day gazetteer as Elliotts Cove is nevertheless the site of the settlement Elliott's Cove. The lithostratigraphic unit proposed by Van Ingen (1914b) was written as Elliott Cove Formation and remains as such in present-day usage.

The most obvious and convenient starting place for the measured section is the outcrop of the basal conglomerate of the Elliott Cove Formation, which overlies the Manuels River Formation in the cliff about 2.75 km (1.7 miles) south of Elliott's Cove settlement. The area of habitation shown on the 1:50 000 topographic map as Foster's Point (Weybridge P.O.) now forms part of Weybridge village. After driving south from Elliott's Cove as far as the sign marking the northern limit of Weybridge, one may cross a field to reach the shore and walk thence northwards about 400 metres, crossing outcrops of Brigus Formation and Chamberlains Brook Formation to reach the section where the basal conglomerate is well exposed in the cliff a short distance south of Promontory I (Fig. 2). The position of the GSC localities (including both fossiliferous and barren samples) in relation to rock units, macrofaunal zones and vertical distribution of acritarch assemblages (=microfloras) is summarized in Figures 3 and 4.

Manuels River Formation (in part)

GSC Locality numbers, in ascending stratigraphic order: 94427 (= 95174), 95172, 95164, 95163, 95155, 95152, 94428.

All the samples from the Manuels River Formation are localized with reference to the basal conglomerate of the Elliott Cove Formation, which here is up to 8 cm thick and has an irregular upper surface;it is composed of poorly sorted, subangular, often phosphatic shale fragments that range up to almost 4 cm in diameter and are embedded in a light brown silty matrix. The bed forms a conspicuous horizon in the cliff and immediately beneath it is an equally noticeable band of leached shale that weathers pale yellow. A small discrepancy of both dip and strike between the two may be original but could be due to tectonic causes. The position of the palynological samples in relation to the conglomerate is shown in Figure 3 and the macrofossil evidence of their age is discussed.

<ins>GSC loc. 94427 and 95174</ins>. These two samples were obtained, respectively, in 1976 and 1977 from the same level in the cliff section but at points approximately 3 m apart horizontally. The horizon is 15.5 m below the basal conglomerate and 70 cm below a bed of silty, grey limestone, up to 19 cm thick, in which the following trilobites were found: *Paradoxides hicksii* Salter, 1865 (*see* Hutchinson, 1962, p. 113 for discussion and records from

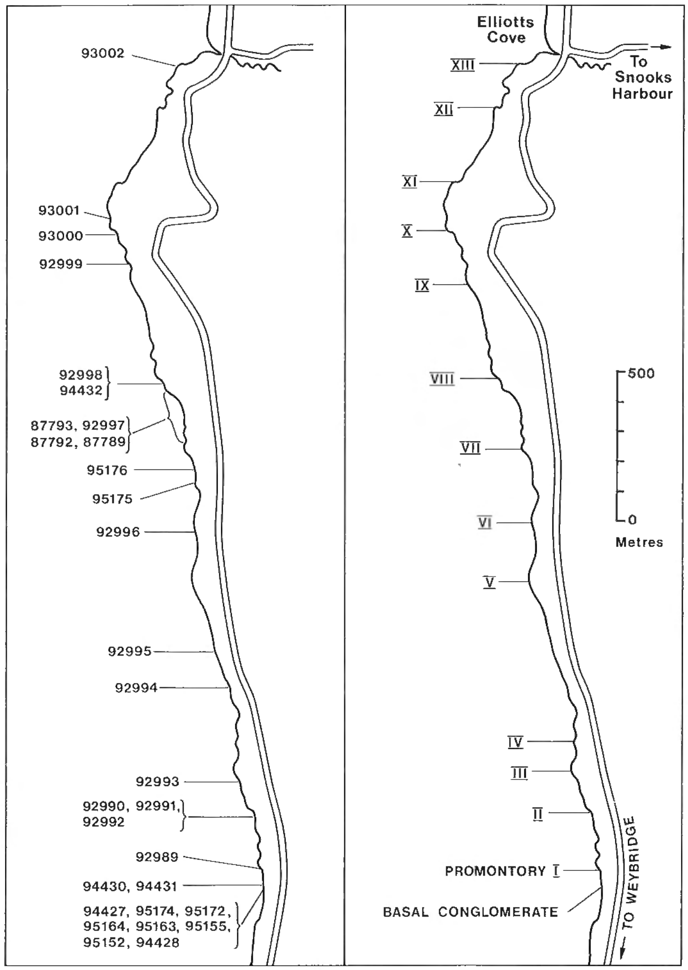

FIGURE 2. Outline map showing geographic position of GSC localities yielding palynomorphs in the Elliott Cove Formation and Clarenville Formation between Weybridge and Elliott's Cove, northwest coast of Random Island. For localities immediately below and above the basal conglomerate of the Elliott Cove Formation, see Figure 3.

Newfoundland); *Agraulos* sp., *Bailiella tenuicincta* (Linnarsson, 1879)(*see* Hutchinson, 1962, p. 105), and *Eodiscus scanicus* (Linnarsson, 1883) (discussed and illustrated by Hutchinson, 1962, p. 59). The assemblage characterizes the Welsh *Paradoxides hicksii* Zone, which is in turn equated with the Scandinavian *Ptychagnostus atavus* and *Tomagnostus fissus* Zone.

<ins>GSC loc. 95172</ins>. Dark grey shale 14.5 m below the basal conglomerate. No associated macrofossils were found but the horizon is about 30 cm below a lenticular bed of brown weathering, grey siltstone containing *Paradoxides hicksii* and rare *Clarella venusta* (Billings, 1874)(*see* Hutchinson, 1962, p. 111; Howell, 1925, table 4).

The two trilobite-bearing beds noted above probably correspond to Hutchinson's (1962, p. 144) fossil localities 20477 (the lower horizon) and 20483, though there are certain discrepancies between the present succession and that given by Hutchinson.

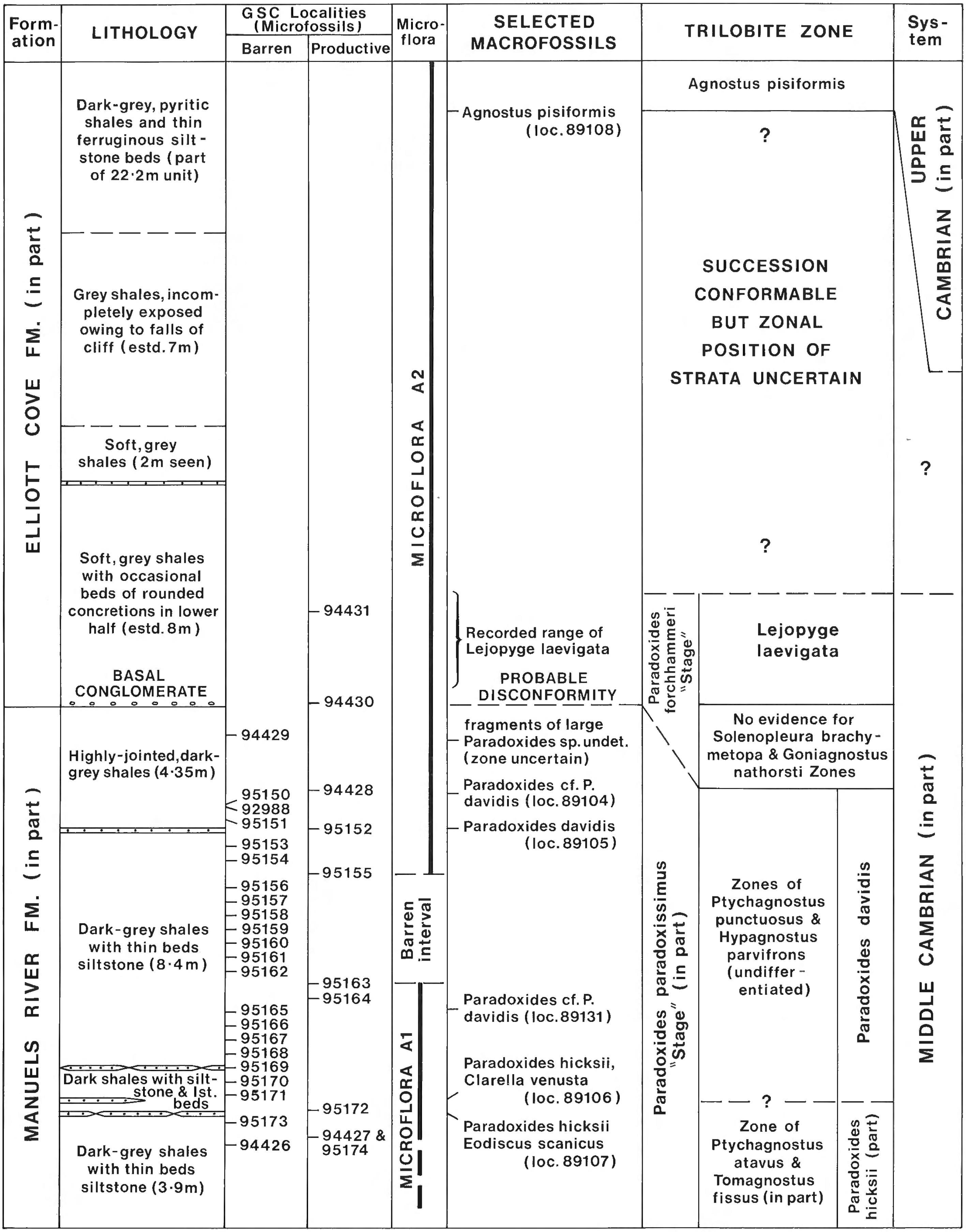

FIGURE 3. Stratigraphic section showing position of GSC localities (including both fossiliferous and barren palynomorph samples) in highest part of Manuels River Formation and lowest part of Elliott Cove Formation.

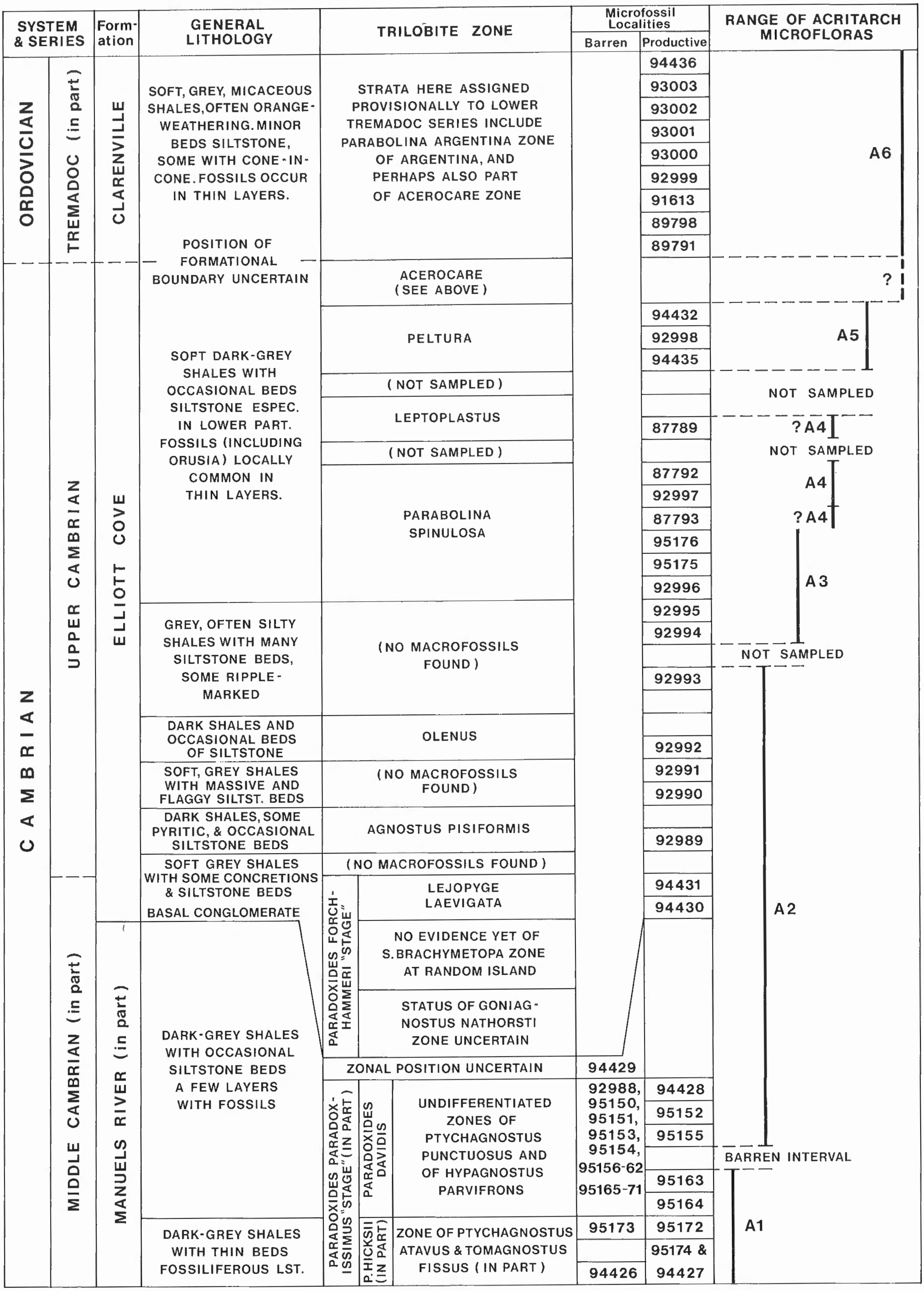

FIGURE 4. Summary of vertical distribution of acritarch assemblages (= microfloras) in relation to rock units and macrofaunal zones. NOTE: The downward extension of microflora 1 into older strata and the upward extension of microflora 6 into younger strata are not yet known. GSC locality numbers for barren samples from the *Paradoxides davidis* Zone and for productive samples from the Clarenville Formation are arranged consecutively not stratigraphically.

GSC loc. 95164. Dark shale 10.5 m below the basal conglomerate. Although no macrofossils were found at this level, a thin, fossiliferous layer of shale 50 cm lower in the sequence yielded fragments of *Paradoxides* cf. *P. davidis* Salter, 1863. Owing to lack of macrofossils, the boundary between the *P. hicksii* Zone and the *P. davidis* Zone could not be drawn precisely.

GSC loc. 95163. Dark shale without macrofauna 10 m below the basal conglomerate.

GSC loc. 95155. Dark grey shale without macrofauna 6 m below the basal conglomerate.

GSC loc. 95152. About 4.3 m below the basal conglomerate is a 13 cm resistant bed of dark grey siltstone, the lowest part of which yielded fragments of *Paradoxides davidis*, as did a layer of dark shale immediately beneath. The palynological sample came from the last-named shale at a level 4.5 m below the conglomerate.

GSC loc. 94428. Dark grey mudstone 3 m below the basal conglomerate and 1.3 m above the 13 cm siltstone bed noted in the description of loc. 95152. No macrofossils were associated with the sample, but fragments of *Paradoxides* cf. *P. davidis* were found in shale 3.15 m below the conglomerate.

At a point 1.2 m below the basal conglomerate of the Elliott Cove Formation, fragments of a large *Paradoxides* sp. undet. were found, and the age of the uppermost part of the Manuels River Formation is not yet precisely known.

Elliott Cove Formation

As far as possible the following GSC Locality numbers, mostly from the coast south of Elliott's Cove, are arranged in ascending stratigraphic order: 94430, 94431, 92989, 92990, 92991, 92992, 92993, 92994, 92995, 92996, 95175, 95176, 87793, 92997, 87792, 87789, 92998, 94432, 94435. An exception is locality 94435 which, though not the youngest according to the acritarch evidence, occurs at a different coastal section and is here considered after the others.

GSC loc. 94430. The sample was taken from the basal conglomerate of the formation and its age is accepted as *Lejopyge laevigata* Zone on the basis of Poulsen and Anderson's (1975) description of trilobites from 0.6 m higher in the sequence and Rushton's (1978) re-interpretation of it noted earlier.

GSC loc. 94431. Shale without macrofauna at a level 3.30 m above the basal conglomerate. The horizon falls within the range of trilobites indicative of the *Lejopyge laevigata* Zone as recorded by Poulsen and Anderson (1975).

GSC loc. 92989. Dark grey shale estimated at approximately 37 m above the basal conglomerate. Although the horizon yielded no macrofossils it is dated as *Agnostus pisiformis* Zone, the eponymous index fossil having been found both 2.5 m below and 0.9 m above. The level of the sample is estimated as being 6 m below strata on the south side of Promontory I, where the continuity of the succession is interrupted by a cliff fall.

GSC loc. 92990, 92991 and 92992. These three localities are considered together because they are most easily pinpointed stratigraphically by reference to a set of easily recognized index strata, comprising a 14.5 m unit of dark shale, separated by three underlying beds of brown-weathering, flaggy siltstone from a still lower shale unit, 16 m (estimated) thick, the whole being exposed in the cliff immediately south of Promontory II, where about 5 m of the overlying beds are obscured by falls of cliff. Both shale units include thin layers which contain trilobites, including *Olenus* spp., *Grandagnostus falanensis* (Westergård, 1947) (=*Phalacroma bairdi* Hutchinson, 1962) and *Homagnostus obesus* (Belt, 1867), indicative of the *Olenus* Zone. Loc. 92992 is 1.5 m below the top of the 16 m unit; loc. 92991 is in dark shale an estimated 30.5 m below the base of the same unit; and loc. 92990 is in a unit of grey shale with minor bands of siltstone approximately 36.5 m below loc. 92991. Thus, although 92992 is dated as *Olenus* Zone, the age of 92990 and 92991 is not known in terms of trilobite zones. Loc. 92990 may additionally be localized with reference to a conspicuous unit, 1.15 m thick, composed of massive siltstone beds, including one 45 cm thick at the base, which occurs about 19.5 m higher in the succession.

GSC loc. 92993. Promontory III is formed essentially by a prominent bed of massive, resistant siltstone, 80 cm thick. Sample 92993 is from a level 3.8 m below the base of the siltstone, in a unit of regressive, finely laminated, grey shale in which several thin siltstone beds occur, some of them ripple-marked. The horizon, though undated by macrofossils, is between 43 and 44 m above the highest record of *Olenus*, found 2.0 m below the top of the 14.5 m unit discussed for loc. 92992 (q.v.).

GSC loc. 92994. The portion of the Elliott Cove Formation exposed in the cliff section between Promontories IV and V essentially comprises alternations of grey shale and beds of siltstone, the latter massive in many places. Particularly noteworthy is an anticlinal fold, with axis almost east to west, involving some 14 m of silty shale and thick siltstone beds, which constitutes a convenient datum. The southeastern edge of the anticline is marked by a gap in exposures and may be faulted; southeast of this gap is a succession of northwesterly-dipping strata, and sample 92994 is from dark shale 21 m+ below the top of this succession, and 20 cm below the base of a conspicuous 17 m unit of flaggy and massive siltstone. Macrofossils are lacking. The horizon is estimated to lie about 46 m above a massive siltstone bed that forms Promontory IV and approximately 120 m above the highest strata from which *Olenus* was collected.

GSC loc. 92995. The succession on the northwest side of the anticline noted above is interrupted by fallen cliff material which extends about 18 m along the shore. The sequence then recommences with a 6 m shale unit and the sample is from a level approximately 10.8 m higher in the succession, in dark shale forming part of a unit which is approximately 25 m thick and is partly obscured by cliff debris. Although lacking macrofossils, the horizon is estimated to lie some 78 m below that of locality 92996 (see later) which occurs in beds containing the brachiopod *Orusia lenticularis* (Wahlenberg, 1821).

GSC loc. 92996. Promontory V is formed by a unit of flaggy and massive siltstone beds with shale partings, totalling an estimated 13 m; these are succeeded by approximately 14 m of brown weathering, grey, silty shale, the lowest 8 m or so of which is gently folded and obscured by fallen cliff material. Sample 92996 is from a point 1.5 m below the top of the unit, of which at least the uppermost 3 m contain abundant *Orusia lenticularis,* the crowded valves of which sometimes cover the bedding planes, though trilobite remains are rare or absent in this assemblage. Henningsmoen (1958, p. 188) reported *O. lenticularis* only from the *Parabolina spinulosa* Zone, and Spjeldnaes (1967, p. 55) noted that species of the genus, like certain other brachiopods found in numbers in black shales which lack an infauna, may have lived attached to floating seaweeds.

GSC loc. 95175 and 95176. Immediately north of Promontory VI is an outcrop, much obscured by cliff falls, of grey shale and thin siltstone beds totalling an estimated 11 m. To the north, and apparently faulted against the shale, is a conspicuous unit, 6.25 m thick, of massive and flaggy, brown grey siltstone which forms an anticline with flattened crest and often displays ripple marks and current bedding. The siltstone is succeeded, in order, by 17.5 m of dark grey shale and a 35 cm unit of flaggy siltstone with shaly partings, followed by grey soft shale, the outcrop of which extends northwest to and beyond Promontory VII, a thickness of approximately 16 m being exposed south of that feature. Sample 95175 is from shale 5.4 m below the 35 cm unit, and 95176 is from shale 2.7 m above it. The strata at Promontory VII, including both shales and a siltstone nodule, yielded *Orusia lenticularis.*

The outcrop of regressively weathering grey shale extends northwards from Promontory VII to Promontory VIII, where there is a break in continuity owing to substantial falls of cliff. The shale is folded or cut by small faults and some of the higher beds, often containing many small olenid trilobites of the *Peltura* Zone, are involved in a large landslip, so that the following measurements of thickness must be regarded as approximate.

GSC loc. 87793. In grey shale an estimated 2 m above that at Promontory VII. Macrofossils include *Parabolina spinulosa.*

GSC loc. 92997. Grey shale 5.3 m above that of locality 87793. *P. spinulosa* present.

GSC loc. 87792. A thin layer of dark shale with abundant, well preserved *P. spinulosa,* 1.8 m above 92997.

Shale of the *P. spinulosa* Zone, containing both *P. spinulosa* and *O. lenticularis,* extends at least 3.5 m above the strata of locality 87792, where it is cut by a fault of undetermined displacement. Hutchinson's (1962, p. 28) record of *P. spinulosa* from a thin bed of black shale "in a small cove about a mile south of Elliott's Cove" almost certainly refers to the shore section between Promontories VII and VIII.

GSC loc. 87789. In dark grey shale an estimated 11.5 m higher than the fault of undetermined throw noted earlier. The beds, in which *Leptoplastus* sp. was found uncommonly, weathers to form a scree of small, soft fragments, and horizons of concretions or flaggy siltstone occur only occasionally.

GSC loc. 92998 and 94432. South of Promontory VIII the following section was measured in the higher part of the exposed shale succession:

Recent deposits and fallen cliff material.	
Dark grey, silty shale with occasional impersistent beds of siltstone.	4 m +
Persistent, thin siltstone horizon.	0.20 m
Dark grey shale, some silty, others of silty appearance.	3.30 m
Persistent, thin siltstone horizon.	0.12 m
Dark grey shale.	3.10 m
Persistent, thin siltstone horizon.	0.15 m
Dark grey shale, incompletely exposed owing to fall of cliff.	5 m seen

GSC loc. 92998 is 2 m above the base of the 3.10 m shale unit; GSC loc. 94432 is 3 m above the base of the 4 m + shale unit. Both localities are in the *Peltura* Zone.

GSC loc. 94435. Dark grey shale of the *Peltura* Zone exposed in the lower part of the cliff approximately 1800 m southeast of the southeastern end of Bounds Mead. Elsewhere in this area, strata of the *Peltura* Zone were recorded by Jenness (1963, p. 169, loc. F-28 in fig. 6) southeast of Bounds Mead.

Clarenville Formation

Geological Survey of Canada Locality numbers, arranged in the following numerical order: 89791, 89798, 91613, 92999, 93000, 93001, 93002, 93003, 94436. For comments on their relative ages, see later.

The above, all of which contain microflora A6, are listed in numerical order for convenience. The macrofaunal evidence of age, though in general indicative of Lower Tremadoc Series, is often inconclusive and in one instance at least the beds may correspond to part of the *Acerocare* Zone, Upper Cambrian.

GSC loc. 89791. Bounds Mead, classified as a "point" in the gazeteer of place names in Newfoundland, is a conspicuous, flat promontory composed of Recent beach deposits which continue almost to a small headland 300 m north of the Mead, where grey shale of the Clarenville Formation is poorly exposed at a few places. The fossil locality, which yielded a few trilobite fragments including *Beltella?* sp., lies between the tip of the headland and the mouth of a small stream a short distance to the north. An adjacent area of cleared ground in this otherwise tree-covered terrain marks the location of a now vanished sawmill known as Pelley's Mill.

GSC loc. 89798. Almost 1 km south of the causeway linking Random Island with the mainland, a large quarry beside the shore is reached from the road leading south to Elliotts Cove. Shale of the Clarenville Formation is still excavated there for brick manufacture at Milton and has yielded macrofossils at several places, but exploitation of the strata by mechanical excavator means that most localities are short-lived. The present sample is from a thin (less than 1 cm) level in the uppermost part of the quarry, about 50 m north of the stream that marks the quarry's southern limit. Associated trilobites comprise *Parabolina argentina* (Kayser, 1876) and *Beltella* sp.

GSC loc. 91613. Grey shale exposed in the lower part of the cliff approximately 1.25 km southeast of the southeastern limit of Bounds Mead. In summer 1974 V. Poulsen (personal communication, 1974) found there an abundant fauna including *Araiopleura beothuk* Dean, 1970, *Conophrys* sp. and *Geragnostus* sp. In 1976 the locality was found to have been covered by a rock fall.

GSC loc. 92999. About midway between Promontories IX and X grey, micaceous shale with some siltstone beds and cone-in-cone concretions is well exposed in an anticline overturned to the northwest, associated with a number of smaller folds. Trilobites, including *Parabolina* cf. *P. argentina* and *Niobella* sp., were found at two levels, and the palynological sample came from the lower of these, at a point 12 m above the lowest strata involved in the overfold.

GSC loc. 93000. Immediately south of Promontory X a 53 m unit of grey shale with only occasional siltstone beds is exposed in the cliff. A generally steep northwesterly dip decreases towards the northern end of the outcrop. The sample was taken from a level 2 m above the base of the section. Rare macrofossils from 36 m higher in the section included *Niobella* sp. The horizon is estimated to lie at least 52 m stratigraphically higher than GSC loc. 92999, part of the intervening section being covered by a cliff fall.

GSC loc. 93001. Immediately north of Promontory X silty, grey shale forms two unequal, asymmetric anticlinal folds, the smaller lying southeast of the other. The sample is from the highest beds constituting the smaller fold. No macrofossils were found, and preparation of a detailed measured section proved impracticable owing to small-scale faulting in the vicinity.

GSC loc. 93002 (catalogued also as GSC loc. 89404). Dark finely laminated shale in the lower part of the low cliff about 137 m southeast of the mouth of the stream at Elliott's Cove settlement. This is the type locality for *Araiopleura beothuk* Dean (1970) and associated macrofossils include *Parabolina* cf. *P. argentina* and *Niobella* sp. For comments on the age of this and other localities, see end of section.

GSC loc. 93003 (catalogued also as GSC loc. 89149). Brown weathering, grey, micaceous shale in low outcrop beside shore approximately 200 m north of the curved sandbar situated just north of the east end of the causeway linking Random Island to the mainland near Milton. Associated macrofossils include *Parabolina argentina* and *Beltella* aff. *B. ulrichi* (Kayser, 1897).

GSC loc. 94436. Poorly exposed grey shale at base of bank forming base of cliff on first promontory on coast north of Bounds Mead. The shore at the tip of the promontory is the site of a large (2 m diameter), erratic boulder of reddish igneous rock and the locality is found approximately 18 m south of the boulder. The locality is of some historic interest as it yielded fragmentary dendroid graptolites identified as *Dictyonema?* sp. by R.B. Rickards; according to B.F. Howell (oral communication to W.T.D., 1971) material from there probably formed the basis of Van Ingen's record of *Bryograptus*, listed by him as index fossil for his Brown Mead Formation (now obsolete; see earlier). A few associated macrofossils included *Beltella?* sp. and undetermined hyolithids.

A dendroid graptolite (No. 2653) labelled "*Dictyonema flabelliforme*, Upper Cambrian, Random Island, Newfoundland" was found in an old collection in the geology department at Princeton University. The specimen, kindly loaned by Mrs. Phyllis Hasson, was subsequently determined by R.B. Rickards as *Dictyonema* of the *flabelliforme* group and yielded no helpful evidence of age other than indicating Tremadoc Series.

Location of barren palynological samples

W.T. Dean, F. Martin

Manuels River Formation

Most samples from this unit proved to be barren of microfossils. After the initial reconnaissance work of 1975, 25 samples at 0.5 m intervals were collected in 1977 from many of the higher strata in an attempt to locate a precise boundary between microfloras A1 and A2. Only six of these later samples contained acritarchs, and a barren gap of 4 m still separates A1 and A2. The horizons of the barren samples are shown below (as GSC locality numbers) with stratigraphic distance (in m) below the overlying basal conglomerate of the Elliott Cove Formation in the cliff section north of Weybridge (*see* Fig. 2 for geographic location of section; *see* Fig. 3 for correlation with corresponding trilobite zones).

Locality numbers with distance below basal conglomerate of Elliott Cove Formation (in metres)

94429 - 1.0 m	95157 - 7.0 m	95166 - 11.5 m
95150 - 3.6 m	95158 - 7.5 m	95167 - 12.0 m
92988 - 3.7 m	95159 - 8.0 m	95168 - 12.5 m
95151 - 4.1 m	95160 - 8.5 m	95169 - 13.0 m
95153 - 5.0 m	95161 - 9.0 m	95170 - 13.5 m
95154 - 5.5 m	95162 - 9.5 m	95171 - 14.0 m
95156 - 6.5 m	95165 - 11.0 m	95173 - 15.0 m
		94426 - 15.8 m

Elliott Cove Formation

None of the nineteen shaly samples from this formation was barren of palynomorphs.

Clarenville Formation

Of the eleven localities sampled, only two proved barren of palynomorphs; both occur in the section by the north side of the road from Milton to Barton, along the north coast of Smith Sound (*see* Fig. 1), at a point about 50 m east of the east bank of Ryders Brook. A conspicuous bed of siltstone 3.10 m thick outcrops there and GSC loc. 94434 denotes the basal few centimeters. The second barren sample, GSC loc. 94433, was collected from a level 0.60 m below the base of the siltstone bed, and acritarchs there proved rare and undeterminable, so that the sample may be conveniently grouped with those completely barren. The purpose of examining the rocks near Ryders Brook was to assess the relevance of Van Ingen's (1914b) lithostratigraphic term "Riders Brook Limestone"; as noted earlier the term is now considered obsolete. Macrofossils from shale of the Clarenville Formation in the vicinity of Ryders Brook, both near the road/stream junction mentioned above and farther south, yielded trilobites, including *Geragnostus* sp. and *Parabolina* cf. *P. argentina*.

Paleontology

F. Martin

Material and method

Approximately 30 grams of each of the 51 samples was treated using a standard palynological technique (Martin, in press). With the exception of two from the allegedly highest part of the Clarenville Formation (GSC loc. 94433, 94434), all the residues contained abundant, unidentifiable sapropelic debris; none contained chitinozoa. Twenty-two of the thirty samples from the Manuels River Formation proved to be either poor in blackish, incomplete acritarchs or barren; exceptions were samples from horizons situated 15.50 m (GSC loc. 94428, 95174) and 14.5 m (GSC loc. 95172) below the top of the formation, in which most specimens were transparent and well preserved. The nineteen samples from the Elliott Cove Formation and nine of the eleven from the Clarenville Formation contained acritarchs in varying quantity, estimated as being between 10 and 4000 per gram of rock. Specimens are generally better preserved in the Elliott Cove Formation than in the Clarenville Formation; however, in a single assemblage, preservation may vary considerably either between species or within a species. In the most favourable cases only about half the specimens could be identified. Consequently the terminology used to indicate the frequency of taxa in Table 1 uses the following convention for the number of specimens determined in any one sample: ○ = 1; ● = 2-19; ◯ = 20-100; ⬤ = more than 100. Known taxa for which no new observations are made are not discussed in the Systematic Descriptions. The figured specimens, accompanied by co-ordinates established by means of the England Finder Graticule, are in the National Type Fossil Collection, Geological Survey of Canada, Ottawa. Palynological preparations from each sample are also deposited in the Institut Royal des Sciences Naturelles de Belgique, Brussels.

List of acritarch taxa

Genera and species are presented below in alphabetical order. All are also listed according to their stratigraphic appearance in Table 1. Taxa marked with an asterisk are described in the text.

Acanthodiacrodium achrasi Martin, 1973
Acanthodiacrodium angustum (Downie) Combaz, 1967
Acanthodiacrodium complanatum (Deunff) Martin, 1977
**Acanthodiacrodium ubui* Martin, 1969
**Adara alea* sp. nov.
Arbusculidium destombesii Deunff, 1968
**Arbusculidium rommelaerei* sp. nov.
Baltisphaeridium crinitum Martin, 1978
**Cristallinium cambriense* (Slavíková) Vanguestaine, 1978
**Cristallinium ovillense* (Cramer and Diez de Cramer) comb. nov.
**Cristallinium randomense* sp. nov.
Cymatiogalea bellicosa Deunff, 1961
Cymatiogalea bouvardi Martin, 1973
**Cymatiogalea* cf. *C. cylindrata* Rasul, 1974
Cymatiogalea? membranula Martin, 1978
Cymatiogalea velifera (Downie) Martin, 1969
**Dasydiacrodium caudatum* Vanguestaine, 1973
**Eliasum* cf. *E. asturicum* Fombella, 1977
**Eliasum llaniscum* Fombella, 1977
Goniosphaeridium uncinatum (Downie) Kjellström, 1971
Leiofusa simplex (Combaz) Martin, 1977
**Leiofusa stoumonensis* Vanguestaine, 1973
Leiosphaeridia sp.
**Multiplicisphaeridium?* cf. *M? furcatum* (Deunff) Eisenack et al., 1973
**Ooidium?* sp. A
Poikilofusa squama (Deunff) Martin, 1977
Priscogalea cortinula Deunff, 1961
Priscogalea cuvillieri Deunff, 1961
Priscogalea gautieri Martin, 1973
Priscogalea multarea Deunff, 1961
**Pterospermopsimorpha* sp.
Saharidia fragile (Downie) Combaz, 1967
**Timofeevia lancarae* (Cramer and Diez de Cramer) Vanguestaine, 1978
**Timofeevia microretis* sp. nov.
**Timofeevia pentagonalis* (Vanguestaine) Vanguestaine, 1978
**Timofeevia phosphoritica* Vanguestaine, 1978
**Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976
**Veryhachium dumontii* Vanguestaine, 1973
**Veryhachium* sp. A
**Vulcanisphaera africana* Deunff, 1961
**Vulcanisphaera capillata* Jardiné et al., 1974
**Vulcanisphaera turbata* sp. nov.

Systematic descriptions

Genus *Acanthodiacrodium* Timofeev, 1958 ex and emend. Deflandre and Deflandre-Rigaud, 1962

Type species: *Acanthodiacrodium dentiferum* Timofeev, 1958, by original monotypy

Acanthodiacrodium ubui Martin, 1969

Plate 4, figures 2, 4

Acanthodiacrodium ubui Martin, 1969, p. 127, Pl. 1, fig. 51; text-fig. 81.

Table 1. List of acritarch genera and species and their vertical distribution in microfloras A1 to A6. Locality numbers for the Clarenville Formation arranged in the following numerical order.

ACRITARCHS FROM RANDOM ISLAND

SPECIMENS PER SAMPLE: ○ = 1 (V. RARE); ● = 2 - 19 (RARE); ◯ = 20 - 100 (COMMON); ⬤ = > 100 (V. COMMON)

GSC LOCALITIES	94427	95174	95172	95164	95163	95155	95152	94428	94430	94431	92989	92990	92991	92992	92993	92994	92995	92996	95175	95176	87793	92997	87792	87789	94435	92998	94432	89791	89798	91613	92999	93000	93001	93002	93003	94436
Series	MIDDLE CAMBRIAN (in part)										UPPER CAMBRIAN																	TREMADOC SERIES (in part)								
Formation	MANUELS RIVER FM. (in part)								ELLIOTT COVE FM.																			CLARENVILLE FM.								
MICROFLORAS	A1					A2										A3					? A4	A4		? A4	A5 a	A5 b		A6								
LEIOSPHAERIDIA SP.	◯	◯				○	○																								●					
CRISTALLINIUM CAMBRIENSE	◯	◯	●		●	●	●	●		●	●	●										○			●	●						○		○		
ADARA ALEA	⬤	⬤	⬤																																	
PTEROSPERMOPSIMORPHA SP.	○																																			
ELIASUM CF. E. ASTURICUM	○	○	○		○																															
ELIASUM LLANISCUM	●	◯	◯	●	●	○																														
TIMOFEEVIA PHOSPHORITICA						●	●	●	●	◯	◯	◯	◯	●	◯	●	○	○	●	●	●	●	●	●	○		●									
TIMOFEEVIA LANCARAE								●	●	⬤	⬤	⬤	⬤	●	⬤	○			●																	
TIMOFEEVIA PENTAGONALIS										●	●	◯	◯		○			●		◯							○									
VULCANISPHAERA TURBATA										○	◯	◯	◯		◯	⬤	●	●	●	●		○ cf.	●	●												
TIMOFEEVIA MICRORETIS											●	⬤																								
LEIOFUSA STOUMONENSIS															○	●	◯	◯	◯	●	◯	●														
CRISTALLINIUM OVILLENSE																●																				
VERYHACHIUM SP. A.																○								◯	○	●	◯						●			
VERYHACHIUM DUMONTII																◯		⬤	◯	◯	●	◯	◯	●	○	●	●									
CRISTALLINIUM RANDOMENSE																●	●	◯	●	⬤	◯	●	●	◯	◯	●	◯					○				
TRUNCULUMARIUM REVINIUM																						⬤	⬤													

DASYDIACRODIUM CAUDATUM																					●	●	○			○		●			●	●	◯	●	◯	◯
CYMATIOGALEA CF. C. CYLINDRATA																			●		●			●		●	●				○	○		●		
CYMATIOGALEA? MEMBRANULA																									○									○		○
OOIDIUM ? SP. A.																									●											
PRISCOGALEA CORTINULA																									○		○			●	●		●			●
VULCANISPHAERA AFRICANA																									●	◯	●	●	●	●	◯	●	◯	●	●	○
ARBUSCULIDIUM ROMMELAEREI																									⬤	⬤	⬤			●	◯		◯	◯		
ACANTHODIACRODIUM ACHRASI																							● cf.	● cf.	○	○	●		●	○	●			●	●	●
PRISCOGALEA GAUTIERI																										○		●						○		
CYMATIOGALEA BOUVARDI																										●	○					○				
GONIOSPHAERIDIUM UNCINATUM																										●	●			●	○	●		○		●
ACANTHODIACRODIUM UBUI																										●	○	●			●		○			
ACANTHODIACRODIUM COMPLANATUM																										○		○	●	●	●		◯	●	●	
SAHARIDIA FRAGILE																										●	●			●	◯		○			
MULTIPLICISPHAERIDIUM ? CF. M. FURCATUM																											●			●			●			
ACANTHODIACRODIUM ANGUSTUM																													●							○
ARBUSCULIDIUM DESTOMBESII																													●		◯			●	●	●
VULCANISPHAERA CAPILLATA																												●		●	○	○	●	●		
CYMATIOGALEA BELLICOSA																												●			○		○	○		
PRISCOGALEA MULTAREA																												●			○					●
CYMATIOGALEA VELIFERA																														●	●		●	●	○	
LEIOFUSA SIMPLEX																															●					
POIKILOFUSA SQUAMA																															●					
BALTISPHAERIDIUM CRINITUM																													●	○	●		●	●		
PRISCOGALEA CUVILLIERI																												●	○	○			○		●	●

Acanthodiacrodium ubui Martin, 1969. Martin, 1977, p. 22, Pl. 2, fig. 6, 10, 21; Pl. 3, fig. 2, 3, 9 (includes detailed synonymy).

Figured specimen. GSC 57831 (Pl. 4, fig. 2, 4).

Dimensions. Based on twenty-five specimens. Length of vesicle from 30 to 38 µm; width of vesicle from 24 to 32 µm; length of processes from 7 to 12 µm; length of spines on surface of processes from 0.5 to 2 µm.

Remarks. Based on thirty-seven specimens. Parallel longitudinal wrinkles poorly developed or absent on the vesicle. No opening like those observed by Lister (1970) on the vesicle wall. The relatively thick wall of both vesicle and processes and the occasional presence of an excystment opening, as recorded by Lister (1970) exclude the species from *Actinotodissus* Loeblich and Tappan, 1978.

Occurrence. Rare or very rare in the upper part (*Peltura* Zone) of the Elliott Cove Formation and in the Clarenville Formation.

Genus *Adara* Fombella, 1977, emend.

Type species: *Adara matutina* Fombella, 1977

Emended diagnosis. Vesicle circular in outline. Numerous stout, short, conical processes lack obvious polygonal pattern of distribution; they are hollow, with their internal cavity opening into that of the vesicle, and the distal ends are usually rounded and simple. Vesicle and wall of processes are smooth, chagrinate, granulate, echinate or costate. Thin, translucent membranes may extend between processes from proximal to distal ends. No opening in the vesicle wall.

Remarks. The original diagnosis is modified to include the variability of the wall ornamentation and the possible presence of a thin membrane stretched between the processes. The genus is distinguished from *Cymatiogalea* Deunff, 1961 by having more conical, simple processes, the cavities of which open into that of the vesicle; and from *Palaiosphaeridium* Rasul, 1977 by having more numerous, shorter, conical processes occasionally linked by translucent membranes.

Adara alea sp. nov.

Plate 1, figures 20-22; Plate 4, figures 7,9,10

Holotype. GSC 57782 (Pl. 1, fig. 21).

Paratypes. GSC 57781 (Pl. 1, fig. 20), GSC 57783 (Pl. 1, fig. 22), GSC 57835 (Pl. 4, fig. 7), GSC 57836 (Pl. 4, fig. 9), GSC 57837 (Pl. 4, fig. 10).

Type locality. GSC loc. 94427, Manuels River Formation, in mudstone 15.5 m below the basal conglomerate of the Elliott Cove Formation at cliff section north of Weybridge, Random Island. The age is Middle Cambrian, Zone of *Ptychagnostus atavus* and *Tomagnostus fissus*.

Diagnosis. Based on five hundred specimens. Vesicle spherical in outline, sometimes ellipsoidal if compressed; laevigate to chagrinate surface with very variably developed radiating ridges around the base of the processes. About forty to sixty processes, conical in form and approximately as long as wide with tips rounded and simple or with few and reduced spines; the processes are hollow with the internal cavity opening into that of the vesicle. Thin, translucent membranes are sometimes preserved, and stretch between the processes from proximal to distal ends. No opening in the vesicle wall.

Dimensions. Based on thirty specimens. Vesicle diameter from 33 to 44 µm; length of processes from 3 to 6 µm. Length of spines is 1 µm or less.

Comparison. *Adara matutina* Fombella, 1977 has less well developed processes than *A. alea* and no wall ornamentation.

Occurrence. Abundant in the Manuels River Formation at levels 15.5 m (GSC loc. 94427 and 95174) and 14.5 m (GSC loc. 95172) below the basal conglomerate of the Elliott Cove Formation; these strata are correlated with the Zone of *Ptychagnostus atavus* and *Tomagnostus fissus*. Absent from the remainder of the Manuels River Formation at Random Island.

Genus *Arbusculidium* Deunff, 1968

Type species: *Arbusculidium destombesii* Deunff, 1968

Arbusculidium rommelaerei sp. nov.

Plate 3, figures 6, 8, 21, 23; Plate 5, figure 1

Holotype. GSC 57818 (Pl. 3, fig. 8).

Paratypes. GSC 57817 (Pl. 3, fig. 6), GSC 57819 (Pl. 3, fig. 21), GSC 57820 (Pl. 3, fig. 23), GSC 57839 (Pl. 5, fig. 1).

Type locality. GSC loc. 94435, Random Island. The horizon is in the Elliott Cove Formation, Upper Cambrian, *Peltura* Zone.

Diagnosis. Based on approximately six hundred specimens. Vesicle ellipsoidal and squat with psilate to chagrinate surface. Processes conical, simple and hollow with the internal cavity opening into that of the vesicle. Six to seventeen stout processes with echinate surface occur at one pole. At the opposite pole there are about forty to fifty shorter, more slender processes which are interconnected along all their length by very fine, anastomosing, net-like ramifications. No opening in the vesicle wall.

Dimensions. Based on eighty specimens. Length of vesicle from 27 to 40 µm; width of vesicle from 18 to 30 µm; length of processes from 2 to 5 µm at one pole, and from 5 to 10 µm at the other.

Discussion. *A. rommelaerei* has processes which are more numerous and much shorter and thinner than those of *A. stephanum* Vavrdová, 1976; in both species the net-like ramifications of the processes are similar. In *A. destombesii* Deunff, 1968 (*see* Pl. 1, fig. 14, 19 of the present paper) the processes at one of the poles are interconnected only distally and have more strongly-developed bases.

Occurrence. Very common in the upper part of the Elliott Cove Formation, in strata assigned to the *Peltura* Zone. Its frequency is variable in the succeeding Clarenville Formation.

Genus *Cristallinium* Vanguestaine, 1978

Type species: *Cristallinium cambriense* (Slavíková) Vanguestaine, 1978

Cristallinium cambriense (Slavíková) Vanguestaine, 1978

Plate 3, figures 4, 5, 9, 11;
Plate 5, figures 3, 5, 8, 11.

Dictyotidium cambriense Slavíková, 1968, p. 201, Pl. 2, fig. 1, 3.
Dictyotidium cambriense Slavíková. Gardiner and Vanguestaine, 1971, p. 195, Pl. 2, fig. 4, 5.
Cymatiosphaera ovillensis Cramer and Diez de Cramer, 1972, p. 44, Pl. 2, fig. 4, 7, 10.
Dictyotidium cambriense Slavíková. Martin, 1973, p. 42, Pl. 2, fig. 13; Pl. 6, fig. 4.
Staplinia cambriense (Slavíková) Vanguestaine. Vavrdová, 1976, Pl. 1, fig. 1, 3, 5, 8.
Cymatiosphaera favosa Jankauskas, 1976b, p. 190, Pl. 25, fig. 7, 15 (non fig. 13).
Cymatiosphaera lazdynica Jankauskas,1976b, p. 190, Pl. 25, fig. 4, 5, 8, 10.
Dictyotidium cambriense Slavíková. Martin, 1977, text-fig. 13, Pl. 4, fig. 12.
Dictyotidium? *cambriense* Slavíková. Martin *in* Dean and Martin, 1978, text-fig. 4, 5.
Cymatiosphaera ovillensis Cramer and Diez. Fombella, 1978, Pl. 1, fig. 20.
Cristallinium cambriense (Slavíková) comb. nov. Vanguestaine, 1978, p. 271, Pl. 2, fig. 16, non fig. 17; Pl. 3, non fig. 16, ?fig. 26.

Figured specimens. GSC 57813 (Pl. 3, fig. 4), GSC 57814 (Pl. 3, fig. 5), GSC 57815 (Pl. 3, fig. 9), GSC 57816 (Pl. 3, fig. 11), GSC 57842 (Pl. 5, fig. 3, 5), GSC 57843 (Pl. 5, fig. 8, 11).

Dimensions. Based on forty specimens. Diameter of vesicle from 30 to 43 µm; diameter of polygonal fields from 10 to 17 µm; height of septa from 0.5 to 3 µm; height of granules 0.7 µm or less, exceptionally up to 1 µm.

Discussion. Based on approximately six hundred single specimens and fifty clusters of three to six specimens. *Cristallinium cambriense* exhibits great variation in the number of polygonal fields (estimated at between 10 and 25) and in the height of the septa; the granules are always poorly developed. Owing to frequent folding and compression, the shape of the specimens appears even more variable, as is shown by a cluster of four specimens illustrated here (Pl. 3, fig. 11). The variability of the taxon was not completely described or illustrated by Slavíková (1968). Cramer and Diez de Cramer (1972) did not take Slavíková's publication into account when they erected *Cymatiosphaera ovillensis* (here considered a junior subjective synonym of *Cristallinium cambriense*, as indicated by Vanguestaine, 1978, p. 271) and noted the important variability of the species. Jankauskas (1976b), unaware of Slavíková's 1968 paper, described four new species of *Cymatiosphaera*: *C. favosa*, *C. lazdynica*, *C. cristata* and *C. nerisica*. Misprints in the text and in the explanation of plate 25 were corrected by Jankauskas in a letter sent to FM in January, 1978. The modifications relating to the foregoing taxa are as follows: *C. favosa*, fig. 7, 15 (not 13); *C. cristata*, fig. 18, 21 (not 17, 20); *C. nerisica*, fig. 11, 19 (not 14, 18). The four species described by Jankauskas (1976b) are here transferred to *Cristallinium*, and in my opinion the supposed differences between *C. favosum* and *C. lazdynicum* are due to preservation. In the cluster of four specimens illustrated in the present paper (*see* Pl. 3, fig. 11), the two lower specimens resemble the holotype of *C. favosum* (Jankauskas, 1976b, pl. 25, fig. 7), while the upper two are similar to *C. cambriense*, of which *C. lazdynicum* is a junior subjective synonym. Most of the Belgian Cambrian specimens attributed to *C. cambriense* by Vanguestaine (1978) have much more strongly developed ornamentation on both the vesicle and the septal walls; they should be considered in part as a separate species.

Occurrence. At Random Island *Cristallinium cambriense* was found to be variably abundant in the Manuels River Formation, rare in the Elliott Cove Formation, and very rare in the Clarenville Formation (see Table 1 for localities).

Previous records. Very rare in the Tremadoc Series as represented by part of the Bell Island Group, exposed at Bell Island, eastern Newfoundland (Martin in Dean and Martin, 1978).

Relatively abundant at one level in the Vergalsky Horizon, eastern U.S.S.R., which, on the basis of palynological data, is attributed to the Lower Cambrian, *Holmia* Zone (Jankauskas, 1976b). Variably abundant in the Middle Cambrian (*Eccaparadoxides pusillus* Zone to *Hydrocephalus lyelli* Zone inclusive) as represented by the Jince Formation in Czechslovakia (Slavíková, 1968; Vavrdová, 1976). Present in the Middle and Upper Cambrian, or possibly Lower Tremadoc, in the Oville Formation of northern Spain (Cramer and Diez de Cramer, 1972; Fombella, 1978). Rare in the Middle? Cambrian of the Booley Formation in southeast Ireland (Gardiner and Vanguestaine, 1971). Recorded as being common in most of the Upper Cambrian of England and Wales in a preliminary paper by Potter (1974). Very rare in the early Tremadoc of the "Quartzophyllades de Chevlipont" in central Belgium (Martin, 1977) and of the "Ecailles de Cabrières" in Hérault, France (Martin, 1973). The species was recorded, but not illustrated, under the name *Staplinium cambriense* by Jardiné et al. (1974) from palynological zones B1 and B2 of Algeria, which are correlated with the middle and upper parts of the Tremadoc Series.

Cristallinium ovillense (Cramer and Diez de Cramer) comb. nov.

Plate 3, figure 16

Zonosphaeridium ovillensis Cramer and Diez de Cramer, 1972, p. 44, Pl. 2, fig. 5, 8, 11.

Figured specimen. GSC 57826.

Discussion. Based on four specimens. Excystment by rupture of the vesicle along the sides of the polygonal fields. General shape, characteristics of the ornamentation and excystment permit the transfer of the species from *Zonosphaeridium* Timofeev, 1956 ex Timofeev, 1959 to *Cristallinium*. *Zonosphaeridium* is mainly characterized by a narrow fringe devoid of polygonal fields.

Dimensions. Based on three specimens. Diameter of vesicle from 35 to 48 μm; diameter of polygonal fields from 6 to 12 μm; height of septa from 1 to 1.5 μm.

Occurrence. Very rare in the Elliott Cove Formation, in deposits devoid of macrofossils between the *Olenus* Zone and the *Parabolina spinulosa* Zone.

Cristallinium randomense sp. nov.

Plate 3, figures 2, 10, 12, 17, 20, 24, 26; Plate 6, figures 4, 6

Holotype. GSC 57806 (Pl. 3, fig. 10).

Paratypes. GSC 57805 (Pl. 3, fig. 2), GSC 57807 (Pl. 3, fig. 12), GSC 57808 (Pl. 3, fig. 17), GSC 57809 (Pl. 3, fig. 20), GSC 57810 (Pl. 3, fig. 24), GSC 57811 (Pl. 3, fig. 26), GSC 57851 (Pl. 6, fig. 4), GSC 57852 (Pl. 6, fig. 6).

Type locality. GSC loc. 92998, Random Island. The horizon is in the Elliott Cove Formation, Upper Cambrian, *Peltura* Zone.

Diagnosis. Based on approximately one thousand specimens. Vesicle globular, slightly polygonal in outline, with chagrinate to granulate surface; when present, the granules are connected by low, narrow, discontinuous ridges. Low, sometimes discontinuous septa perpendicular to the vesicle surface delimit polygonal fields. The upper part of each septum bears numerous, slender processes, each formed by a small, conical base that is usually opaque and out of which one to three narrow, sinuous and distally simple spines emerge. Rarely, single processes may develop directly from the vesicle surface. Excystment occurs by rupture of the vesicle along the sides of the polygonal fields.

Dimensions. Based on fifty specimens. Diameter of vesicle from 36 to 55 μm; diameter of polygonal fields from 7 to 15 μm; height of septa from 0.5 to 4 μm; length of processes from 4 to 6 μm, of which 3.5 to 5 μm is occupied by the sinuous spines; height of the granules on the vesicle wall is less than 0.5 μm.

Discussion. Owing to the state of preservation, the ornamentation may be observed only locally on a particular specimen (Pl. 3, fig. 20, 26). *Cristallinium randomense* differs from *C. cambriense* and *C. dentatum* (Vavrdová) comb. nov. in the ornamentation of the upper part of the septa. In *C. cambriense* the latter bear more reduced, simple projections; in *C. dentatum* they are ornamented with small processes resembling cylindrical posts, with slightly expanded ends which are divided distally into two to five spines less than 1 μm long. Differences between *C. cristatum* (Jankauskas, 1976b) comb. nov. and *C. nerisicum* (Jankauskas, 1976b) comb. nov. are small (*see* p. 17 of the present paper for corrected numbers of illustrations in Jankauskas's publication). According to Jankauskas (1976b, p. 191), in *C. nerisicum* the septa are present only on one side of the vesicle, which does not appear in his illustrations. However, judging from their diagnoses, both taxa have a zigzag ornamentation of small, simple protuberances on the upper part of the septa.

Occurrences. Variably abundant, but often common, in the Elliott Cove Formation, where the species ranges upwards from strata undated by macrofossils (see GSC loc. 92994) which occur stratigraphically between shales dated as *Olenus* Zone and *Parabolina* Zone. Very rare in the Clarenville Formation.

Genus *Cymatiogalea* Deunff, 1961

Type species: *Cymatiogalea margaritata* Deunff, 1961

Cymatiogalea cf. *C. cylindrata* Rasul, 1974

Plate 3, figures 7, 22

Cymatiogalea cylindrata Rasul, 1974, p. 59, Pl. 6, fig. 1-5.

Figured specimens. GSC 57821 (Pl. 3, fig. 7), GSC 57822 (Pl. 3, fig. 22).

Description. Based on thirty-one specimens. Vesicle globular, slightly polygonal in outline; vesicle wall granulate. There are about fifty hollow processes, with spinose walls and with a length between thirty and fifty per cent of the vesicle diameter; the processes are cylindrical with short, digitate tips, and do not open into the vesicle cavity. Low, solid ridges join the bases of the processes and delimit polygonal areas. On well-preserved specimens thin, translucent membranes link the processes along the whole of their length. No opening was observed in vesicle wall.

Dimensions. Based on twelve specimens. Diameter of vesicle from 25 to 28 μm; length of processes from 8 to 12 μm.

Discussion. The specimens from Random Island differ from those of *C. cylindrata* described by Rasul (1974) from the Tremadoc Series (Transition Beds) of Shropshire in having slightly longer processes, the bases of which are linked by solid ridges formed by the vesicle wall. The spines on the walls of the processes are similar to those noted by Rasul (1974, Pl. 6, fig. 3) for *C. cylindrata* forma 2.

Occurrence. Very rare in both the Elliott Cove Formation, where it ranges upwards from the *Parabolina spinulosa* Zone, and in the Clarenville Formation.

Genus *Dasydiacrodium* Timofeev, 1959 ex and emend. Deflandre and Deflandre-Rigaud, 1961

Type species: *Dasydiacrodium eichwaldi* Timofeev, 1959 designated by Deflandre and Deflandre-Rigaud, 1961, p. 194

Dasydiacrodium caudatum Vanguestaine, 1973

Plate 1, figures 10, 11, 15

Dasydiacrodium caudatum Vanguestaine, 1973, p. 30, Pl. 1, fig. 9, 13.

Figured specimens. GSC 57771 (Pl. 1, fig. 10), GSC 57772 (Pl. 1, fig. 11), GSC 57773 (Pl. 1, fig. 15).

Description. Based on fifty-five specimens. Outline of vesicle more or less in the form of an isosceles triangle with convex sides. Four to fifteen processes present, conical in shape, slender and distally simple; they are hollow and the internal cavity opens into that of the vesicle. Three processes extend in the same plane as the angles of the vesicle. One supplementary process occurs rarely at the apex of the triangle; other processes, one of them generally in the middle, may be located on the opposite side. The vesicle and the wall of the processes are covered with short spines which have slightly bulbous bases.

Dimensions. Based on twenty specimens. Length of sides of vesicle from 23 to 31 μm; length of processes from 4 to 10 μm; length of spines less than 0.5 μm.

Discussion. *Dasydiacrodium caudatum* differs from *Veryhachium dumontii* Vanguestaine, 1973 in having a smaller vesicle, more numerous, equally developed processes, and a relatively reduced ornamentation of the wall. *D. caudatum* is distinguished from *V. primaevum* Deunff, 1966 by its more numerous processes and by the ornamentation of the wall. The Belgian material of *D. caudatum* described by Vanguestaine (1973) has the wall ornamented with granules which are here considered to be spine bases. The presence of processes at the two poles of the vesicle excludes the species from *Trunculumarium* Loeblich and Tappan, 1976.

Occurrence. Rare in the upper part of the Elliott Cove Formation, from the *Parabolina spinulosa* Zone to the *Peltura* Zone. Variably abundant in the succeeding Clarenville Formation.

Genus *Eliasum* Fombella, 1977

Type species: *Eliasum llaniscum* Fombella, 1977

Eliasum cf. *E. asturicum* Fombella, 1977

Plate 2, figure 6

Eliasum asturicum Fombella, 1977, p. 118, Pl. 1, fig. 1; Fig. 1:2a.

Figured specimen. GSC 57800.

Dimensions. Based on ten specimens. Length and width of vesicle from 65 to 80 μm and from 28 to 30 μm respectively. Length of spines from 0.5 to 2.5 μm.

Discussion. Based on fifteen specimens. The examples from Random Island have more strongly developed ornamentation than those described from the Middle Cambrian of Spain by Fombella (1977).

Occurrence. Rare in the Manuels River Formation between 15.5 m and 10 m below the basal conglomerate of the Elliott Cove Formation.

Eliasum llaniscum Fombella, 1977

Plate 2, figure 14

Leiosphaeridia sp. 2 Cramer and Diez de Cramer, 1972, Pl. 2, fig. 9.
Leiosphaeridia sp. Varvrdová, 1976, p. 60, Pl. 1, fig. 4.
Eliasum llaniscum Fombella, 1977, p. 118, Pl. 1, fig. 6; Fig. 1 : 1.

Figured specimen. GSC 57803.

Dimensions. Based on twenty specimens. Length and maximum width of vesicle from 70 to 78 μm and from 30 to 34 μm respectively.

Discussion. Based on approximately three hundred specimens. A few vesicles exhibit at one pole a more or less circular opening, the diameter of which is about one third the width of the vesicle.

Occurrence. Variably abundant in the Manuels River Formation at Random Island, between 15.5 m and 5 m below the basal conglomerate of the Elliott Cove Formation.

Genus *Leiofusa* Eisenack, 1938

Type species: *Leiofusa fusiformis* (Eisenack, 1934) Eisenack, 1938

Leiofusa stoumonensis Vanguestaine, 1973

Plate 1, figures 16, 17

Leiofusa stoumonense Vanguestaine, 1973, p. 29, Pl. 1, fig. 7, 11, 12.
Leiofusa stoumonensis Vanguestaine. Vanguestaine, 1974, p. 79.

Figured specimens. GSC 57778 (Pl. 1, fig. 16), GSC 57779 (Pl. 1, fig. 17).

Dimensions. Based on forty specimens. Length of vesicle from 50 to 55 μm; width of vesicle from 25 to 27 μm; length of processes from 50 to 60 μm; height of surface ornamentation is 0.5 μm or less.

Discussion. Based on approximately five hundred specimens. The granules on the vesicle and the wall of the processes tend to be more variably developed than those described by Vanguestaine (1973).

Occurrence. Abundance variable in the Elliott Cove Formation at Random Island. The lowest record is from strata undated by macrofossils at a level (*see* GSC loc. 92993) about 42.5 m above shales of the *Olenus* Zone; the species ranges upwards into the *Parabolina spinulosa* Zone.

Genus *Multiplicisphaeridium* Staplin, 1961 emend. Eisenack, 1969

Type species: *Multiplicisphaeridium ramispinosum* Staplin, 1961

Multiplicisphaeridium? cf. *M*? *furcatum* (Deunff) Eisenack, Cramer and Diez Rodriguez, 1973.

Plate 3, figures 19, 25

Figured specimens. GSC 57828 (Pl. 3, fig. 19), GSC 57829 (Pl. 3, fig. 25).

Description. Based on ten specimens. Vesicle globular, slightly polygonal in outline, with chagrinate wall. Numerous short, hollow processes open into the vesicle cavity. The processes are pillar shaped, regularly and dichotomously divided at the tips, and the first order ramifications are more or less parallel to the outline of the vesicle. No opening in the vesicle wall.

Dimensions. Based on six specimens. Diameter of vesicle from 32 to 39 μm; length of pillar like processes from 3 to 4 μm; length of distal ramifications from 3 to 5 μm.

Discussion. The specimens differ from *M.*? *furcatum* (Deunff) Eisenack, Cramer and Diez Rodriguez, 1973 from the Tremadoc Series of the Sahara in having processes which are more divided distally. The type of ramification of the processes justifies the doubtful generic attribution.

Occurrence. Very rare in the upper part (*Peltura* Zone) of the Elliott Cove Formation, and in the Clarenville Formation.

Genus *Ooidium* Timofeev, 1957 ex Norris and Sarjeant, 1965

Type species: *Ooidium rossicum* Timofeev, 1957, designated by Norris and Sarjeant, 1965, p. 45

Ooidium? sp. A

Plate 1, figure 13

Figured specimen. GSC 57775.

Description. Based on three poorly preserved specimens. Vesicle stout, ovate in outline. Anastomosing, short, narrow trabeculae, supported by few processes, are confined to one pole. Surface psilate. No opening in the vesicle wall.

Dimensions. Length of vesicle from 39 to 45 µm; width of vesicle from 30 to 38 µm; length of processes and trabeculae from 6 to 9 µm.

Discussion. Generic attribution is questionable because of the short processes supporting the trabecula. Representatives of the genus are known from the Obolus Beds, Lower Tremadoc Series, of the U.S.S.R. (Timofeev, 1957; Loeblich, 1970).

Occurrence. Rare at one horizon (GSC loc. 94435) in the Elliott Cove Formation correlated with the *Peltura* Zone.

Genus *Pterospermopsimorpha* Timofeev, 1962 ex Timofeev, 1969

Type species: *Pterospermopsimorpha pileiformis* Timofeev, 1969 designated by Timofeev, 1969, p. 16

Pterospermopsimorpha sp.

Plate 3, figure 13

Figured specimen. GSC 57823.

Description. Based on a single, folded specimen. External and internal vesicles concentric and elliptical in outline. External membrane chagrinate.

Dimensions. Length and width of external vesicle 42 µm and 30 µm respectively; length and width of internal vesicle 25 µm and 13 µm respectively.

Occurrence. Very rare in the Manuels River Formation at GSC loc. 94427, situated 15.5 m below the basal conglomerate of the Elliott Cove Formation at Random Island (*see* Fig. 3).

Genus *Timofeevia* Vanguestaine, 1978

Type species: *Timofeevia lancarae* (Cramer and Diez de Cramer, 1972) Vanguestaine, 1978

Discussion. When Timofeev (1954) proposed *Archaeohystrichosphaeridium* he did not designate a type species and the name was thus invalid; he briefly described the genus and clearly included therein a number of dissimilar and sometimes inadequately illustrated forms belonging to different genera, as was noted by Loeblich and Tappan (1976). In a paper read on April 16th, 1975, but not published until March, 1976, Vavrdová designated *A. vologdense* Timofeev, 1959 as type species of *Archaeohystrichosphaeridium*, but did not give an appropriate diagnostic description of the genus. In March, 1976 there also appeared a paper by Loeblich and Tappan, whose manuscript had been submitted on June 30th, 1975, in which they selected *A. bifurcatum* Timofeev, 1959 as type species of *Archaeohystrichosphaeridium*, the latter being considered by them as a junior subjective synonym of *Cymatiogalea* Deunff, 1961, even though the latter genus differs in not having the cavities of the processes opening into the vesicle cavity. Vanguestaine (1978), in introducing *Timofeevia*, gave a clear diagnosis of the genus, which clearly includes some species of *Archaeohystrichosphaeridium* that are not yet satisfactorily described.

In considering the Cambrian acritarchs from Random Island I find it convenient to use Vanguestaine's genus, which may be distinguished from a number of superficially similar genera as follows:

from *Cymatiogalea* Deunff, 1961 by the presence of hollow processes which always open into the vesicle cavity, and by the absence of thin translucent membranes linking the processes;

from *Multiplicisphaeridium* Staplin, 1961 emend. Eisenack, 1969 by the presence of polygonal fields accentuated by more or less discontinuous septa;

from *Ordovicidium* Tappan and Loeblich, 1971 by the presence of polygonal fields and the possible presence of a polygonal opening in the vesicle wall;

from *Peteinosphaeridium* Staplin, Jansonius and Pocock, 1965 emend. Eisenack, 1969 by the absence of a circular opening, the nature of the ramifications of the processes, and the presence of polygonal areas, often clearly developed; and

from *Priscogalea* Deunff, 1961 emend. Martin, 1973 by the hollow processes, the cavities of which always open into that of the vesicle, and by the septa, which are discontinuous and not solid.

Timofeevia lancarae (Cramer and Diez de Cramer) Vanguestaine, 1978

Plate 2, figures 1-3, 8, 9, 11, 12, 19, 20;
Plate 6, figures 1, 2(aff.), 3, 5, 7, 8

Multiplicisphaeridium lancarae Cramer and Diez de Cramer, 1972, p. 42, Pl. 1, fig. 1-4, 6, 8; Text-fig. 1.
Multiplicisphaeridium lancarae Cramer and Diez de Cramer. Vavrdová, 1976, p. 61, Pl. 4, fig. 7; Text-fig. 3.
Baltisphaeridium vilnense Jankauskas, 1976, p. 118, Pl. 25, fig. 1, 2?, 3, 6.
Timofeevia lancarae (Cramer and Diez) comb. nov. Vanguestaine, 1978, p. 272.
Multiplicisphaeridium lancarae Cramer and Diez. Fombella, 1978, Pl. 2, fig. 6, 7.

Figured specimens. GSC 57784 (Pl. 2, fig. 1), GSC 57785 (Pl. 2, fig. 2), GSC 57786 (Pl. 2, fig. 3), GSC 57787 (Pl. 2, fig. 8), GSC 57788 (Pl. 2, fig. 9), GSC 57789 (Pl. 2, fig. 11), GSC 57790 (Pl. 2, fig. 12), GSC 57791 (Pl. 2, fig. 19), GSC 57792 (Pl. 2, fig. 20), GSC 57846 (Pl. 6, fig. 1), GSC 57847 (Pl. 6, fig. 2, aff.), GSC 57848 (Pl. 6, fig. 3, 5), GSC 57849 (Pl. 6, fig. 7), GSC 57850 (Pl. 6, fig. 8).

Description. Based on more than one thousand specimens. Vesicle globular, slightly polygonal in outline; vesicle wall is chagrinate to granulate and the granules tend to form radially distributed costae around the bases of the processes. More than fifteen polygonal areas are delimited by septa or folds of very variable development which extend between the bases of the processes. There are approximately thirty to fifty processes which have a chagrinate to spinose wall and a length which is between fifty and seventy per cent of the vesicle diameter. The processes are hollow, cylindrical, with cavity opening into the vesicle cavity, and the distal third of each bears ramifications up to the fourth order; the ramifications are variably developed and may terminate in fine anastomosing filaments which form a loose, discontinuous network, sometimes linking adjacent processes. Rarely, a polygonal opening is observed, its diameter equal to two-thirds that of the vesicle.

Dimensions. Based on fifty specimens. Diameter of vesicle from 28 to 44 µm; length of processes from 14 to 29 µm.

Discussion. *Timofeevia lancarae* differs from *T. phosphoritica* Vanguestaine, 1978 in having relatively longer processes, the distal ramifications of which are more strongly developed. *Baltisphaeridium vilnense* Jankauskas, 1976 is considered a junior subjective synonym of *T. lancarae;* however, one paratype figured by Jankauskas (1976b, Pl. 25, fig. 2) appears to be much smaller and to have processes of simpler type, but its magnification is not indicated.

Occurrence. Found in the uppermost Manuels River Formation and part of the Elliott Cove Formation at Random Island. The lowest record there is in the Middle Cambrian, *Ptychagnostus punctuosus* Zone (*see* Table 1), and the species ranges upwards into the Upper Cambrian, *Parbolina spinulosa* Zone.

Timofeevia microretis sp. nov.

Plate 2, figures 4, 10, 13, 16, 17

Holotype. GSC 57794 (Pl. 2, fig. 10).

Paratypes. GSC 57793 (Pl. 2, fig. 4), GSC 57795 (Pl. 2, fig. 13), GSC 57796 (Pl. 2, fig. 16), GSC 57797 (Pl. 2, fig. 17).

Type locality. GSC loc. 92990, Random Island; in shales of the Elliott Cove Formation estimated to be approximately 92 m above the basal conglomerate. The horizon lacks megafossils and lies between strata dated as *Agnostus pisiformis* Zone and as *Olenus* Zone.

Diagnosis. Based on two hundred and fifty specimens. Vesicle circular to polygonal in outline. Wall of vesicle chagrinate to slightly granulate; ridges which delimit polygonal areas between the bases of the processes are weakly developed and often absent. About sixty to one hundred processes present, their length equal to between thirty and seventy per cent of the diameter of the vesicle. The processes, which open into the vesicle cavity, are of cylindrical to conical form and their distal two-thirds are divided into numerous, thin, anastomosed filaments which form a loose network around the whole vesicle. No opening observed.

Dimensions. Based on fifty specimens. Diameter of vesicle from 22 to 35 µm; length of processes from 9 to 20 µm.

Discussion. *Timofeevia microretis* is distinguished from *T. lancarae* and *T. phosphoritica* Vanguestaine, 1978 by its more numerous processes, which are provided with a continuous network of anastomosed filaments all around the vesicle, and by its less distinct polygonal fields.

Occurrence. *Timofeevia microretis* was found at two localities in the lowest part of the Elliott Cove Formation at Random Island. GSC loc. 92989, where the species was very rare, is in shales belonging to the *Agnostus pisiformis* Zone at a level estimated at 37 m above the basal conglomerate of the formation. The species was very common at the type locality, GSC loc. 92990, estimated to be about 55 m higher in the succession, and in grey shales undated by macrofossils.

Timofeevia pentagonalis (Vanguestaine, 1974) Vanguestaine, 1978

Plate 5, figures 7, 9

Polyedryxium? pentagonale Vanguestaine, 1974, p. 75, Pl. 2, fig. 1.

Timofeevia pentagonalis (Vanguestaine, 1974) comb. nov. Vanguestaine, 1978, p. 272.

Figured specimen. GSC 57841.

Dimensions. Based on fifty specimens. Diameter of vesicle from 22 to 29 µm; length of processes from 6 to 8 µm.

Discussion. Based on one hundred and thirty specimens. Probably owing to their poorer state of preservation, the Belgian specimens described by Vanguestaine (1974) exhibit less complex distal divisions of the processes. *T. pentagonalis* differs from *T. phosphoritica* Vanguestaine, 1978 in having shorter processes, the length of which does not exceed one-third of the vesicle diameter, and fewer polygonal fields, the number of which is usually less than twelve.

Occurrence. Variably abundant in the lower and middle parts of the Elliott Cove Formation at Random Island. The lowest record there is from shales assigned to the Middle Cambrian, *Lejopyge laevigata* Zone, and the species ranges upwards into the Upper Cambrian, *Peltura* Zone, where it is very rare.

Timofeevia phosphoritica Vanguestaine, 1978

Plate 2, figures 7, 15; Plate 4, figure 1; Plate 5, figures 2, 10

Timofeevia phosphoritica Vanguestaine, 1978, p. 272, Pl. 3, fig. 1-12.

Figured specimens. GSC 57801 (Pl. 2, fig. 7), GSC 57802 (Pl. 2, fig. 15), GSC 57830 (Pl. 4, fig. 1), GSC 57840 (Pl. 5, fig. 2, 10).

Description. Based on more than one thousand specimens. Vesicle globular with slightly polygonal outline. Vesicle wall smooth, chagrinate to slightly granulate; sometimes the granules tend to form radial costae around the bases of the processes. There are more than fifteen polygonal areas, delimited by variably developed septa or folds which extend between the bases of the processes; the septa are more apparent on compressed than on uncompressed specimens. About fifty processes are present, their length between thirty and fifty per cent of the vesicle diameter; they are of cylindrical form and open into the vesicle cavity. The tips of the processes are subdivided to form short ramifications up to the fourth order. No opening observed.

Dimensions. Based on fifty specimens. Diameter of vesicle from 19 to 32 μm; length of processes from 5 to 8 μm.

Discussion. The Belgian Cambrian specimens described by Vanguestaine (1978) are usually poorly preserved but their processes, even though often incomplete, tend to be slightly shorter than those described here.

Occurrence. At Random Island the species occurs rarely in the upper part of the Manuels River Formation, is often common in the lower half of the Elliott Cove Formation, and occurs rarely in the upper part of the same formation. The lowest record is from the Middle Cambrian, approximately *Ptychagnostus punctuosus* Zone; the highest record is from the Upper Cambrian, *Peltura* Zone.

Genus *Trunculumarium* Loeblich and Tappan, 1976

Type species: *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976

Trunculumarium revinium (Vanguestaine)

Loeblich and Tappan, 1976

Plate 2, figures 5, 18; Plate 5, figures 4, 6

Ooidium revinium Vanguestaine, 1973, p. 30, Pl. 1, fig. 3-6, 10, 14.

Trunculumarium revinium (Vanguestaine, 1973) comb. nov. Loeblich and Tappan, 1976, p. 305.

Figured specimens. GSC 57798 (Pl. 2, fig. 5), GSC 57799 (Pl. 2, fig. 18), GSC 57844 (Pl. 5, fig. 4), GSC 57845 (Pl. 5, fig. 6).

Dimensions. Based on forty specimens. Length of vesicle from 28 to 35 μm; width of vesicle from 23 to 30 μm; length of processes from 10 to 18 μm; length of spines on wall of processes is 1.5 μm or less; length and width of granules on wall of vesicle are both approx. 0.5 μm.

Discussion. Based on approximately four hundred specimens. Ornamentation of the vesicle wall is generally more strongly developed than was indicated in Vanguestaine's (1973) description. On well-preserved examples the granules of the vesicle wall are seen to have spinose ends which are less well-developed than those on the wall of the processes.

Occurrence. Locally abundant at some horizons in the *Parabolina spinulosa* Zone of the Upper Cambrian, as represented by part of the Elliott Cove Formation.

Genus *Veryhachium* Deunff, 1954 ex Downie, 1959 emend. Downie and Sarjeant, 1963

Type species: *Veryhachium trisulcum* (Deunff) Deunff, 1959, designated by Downie, 1959, p. 62.

Veryhachium dumontii Vanguestaine, 1973

Plate 1, figures 7, 8

Veryhachium dumontii Vanguestaine, 1973, p. 28, Pl. 1, fig. 1, 2, 8.

Figured specimens. GSC 57768 (Pl. 1, fig. 7), GSC 57769 (Pl. 1, fig. 8).

Description. Based on approximately four hundred specimens. Outline of vesicle more or less an isosceles triangle; the equal sides are the longest and slightly convex and the shortest side is straight. There are three to five conical processes, each with a simple, distal extremity and with the internal cavity opening into that of the vesicle. The three main processes extend in the same plane as the angles of the vesicle; rarely, one or two secondary processes are inserted close to the shortest side of the vesicle and between two main processes. Surface of both vesicle and processes is covered with short spines, the bases of which are granulose and bulbous; often only the bases, connected by narrow, discontinuous ridges, are preserved.

Dimensions. Based on forty specimens. Length of vesicle from 30 to 49 μm; width of vesicle from 20 to 38 μm; length of processes from 9 to 20 μm; length of spines about 1 μm but exceptionally up to 4 μm.

Discussion. The Belgian specimens described by Vanguestaine (1973) have a granulose ornamentation and often one to three secondary processes.

Occurrence. Variably abundant in the Elliott Cove Formation at Random Island, where the oldest specimens were found in strata (GSC loc. 92994) which, though not dated by means of macrofossils, lie between shales of the *Olenus* Zone and the *Parabolina spinulosa* Zone. The species ranges upwards into the *Peltura* Zone.

Veryhachium sp. A

Plate 1, figure 12; Plate 4, figure 5

Figured specimens. GSC 57774 (Pl. 1, fig. 12), GSC 57833 (Pl. 4, fig. 5).

Description. Based on sixty-five folded or incomplete specimens. Vesicle very variable in shape, with convex sides; outline circular to more or less triangular. Four to eight simple, stout processes are more or less cylindrical proximally and tapered distally. The processes are hollow, with the internal cavity opening into that of the vesicle, and their length is slightly greater than the vesicle diameter. Surface of vesicle and processes is chagrinate.

Dimensions. Based on seven specimens. Diameter of vesicle from 40 to 55 μm; length of processes from 40 to 60 μm.

Occurrence. Variably abundant, though generally rare, in the Elliott Cove Formation; the lowest record of the species is in strata undated by macrofossils which lie between the *Olenus* and *Parabolina spinulosa* Zones, and it subsequently occurs from the *Parabolina spinulosa* Zone to the *Peltura* Zone. Very rare in the Clarenville Formation.

Genus *Vulcanisphaera* Deunff, 1961 emend. Rasul, 1976

Type species: *Vulcanisphaera africana* Deunff, 1961

Vulcanisphaera africana Deunff, 1961

Plate 1, figure 1; Plate 4, figure 3; Text-figure 5

Vulcanisphaera africana Deunff, 1961, p. 42, Pl. 2, fig. 1.
Vulcanisphaera africana Deunff. Martin, 1973, p. 11, Pl. 2, fig. 14 (includes detailed synonymy).
Vulcanisphaera africana Deunff. Rauscher, 1974, p. 62, Pl. 1, fig. 12, 13.
Vulcanisphaera africana Deunff. Deunff and Massa, 1975, Pl. 1, fig. 1.
Vulcanisphaera africana Deunff. Rasul, 1976, p. 480, Pl. 1, fig. 1; Text-fig. 1.
Vulcanisphaera cirrita Rasul, 1976, p. 480, Pl. 1, fig. 3; Text-fig. 1:2.
Vulcanisphaera africana Deunff. Martin, 1977, text-fig. 4; Pl. 2, fig. 25, 27.
Vulcanisphaera africana Deunff. Martin in Dean and Martin, 1978, Pl. 3, fig. 4.

Figured specimens. GSC 57762 (Pl. 1, fig. 1; text-fig. 5), GSC 57832 (Pl. 4, fig. 3).

Dimensions. Based on approximately seventy specimens. Diameter of vesicle from 30 to 52 µm; length of processes from 12 to 25 µm.

Discussion. Based on six hundred specimens. *Vulcanisphaera africana* exhibits considerable variation in the number and length of the processes and in the density of their anastomosing threads. Rauscher (1974a) has already drawn attention to this variability, which was not noted in the original diagnosis. On the other hand the specimen figured as *V. africana* by Deunff and Massa (1975) has numerous thin, anastomosing ramifications and is similar to the holotype of *V. cirrita* Rasul, 1976, which is here considered a junior subjective synonym. According to Rasul (1976) both *V. africana* and *V. cirrita* have the same stratigraphic range within the Tremadoc succession represented by the Shineton Shales in Shropshire.

Occurrence. Variably abundant in the upper part (*Peltura* Zone) of the Elliott Cove Formation and in the Clarenville Formation at Random Island.

Vulcanisphaera capillata Jardiné, Combaz, Magloire, Peniguel and Vachey, 1974

Plate 1, figure 9

Vulcanisphaera capillata Jardiné et al., 1974, p. 119, Pl. 2, fig. 8.

Figured specimen. GSC 57770.

Description. Based on eighteen specimens. Vesicle spherical with slightly granulate to echinate surface. Processes numerous, generally isolated from each other and only rarely grouped in tufts of two; their bases delimit the angles of polygonal areas. The processes are very slender, conical and hollow, and the internal

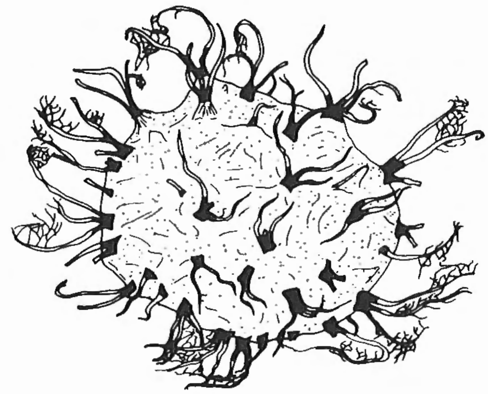

FIGURE 5. *Vulcanisphaera africana* Deunff, 1961. GSC 57762, GSC Loc. 92998, x 1000. See also Pl. 1, fig. 1.

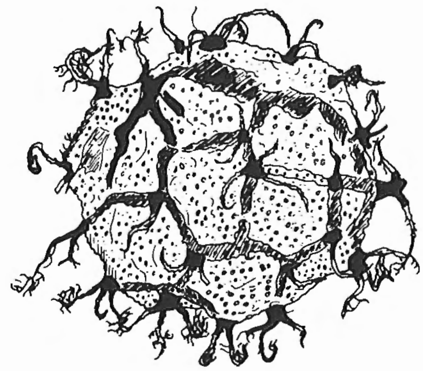

FIGURE 6. *Vulcanisphaera turbata* sp. nov. Holotype, GSC 56763, GSC Loc. 92996, x 1000. See also Pl. 1, fig. 2.

cavity does not open into that of the vesicle; they are interconnected by numerous filamentous threads which arise along the whole length of each process.

Dimensions. Based on five specimens. Diameter of vesicle from 40 to 45 µm; length of processes from 4 to 16 µm.

Discussion. The polygonal distribution of the processes, though not mentioned in the original diagnosis, is clearly visible in the illustration of the holotype.

Occurrence. Rare in the Clarenville Formation at Random Island.

Vulcanisphaera turbata sp. nov.

Plate 1, figures 2-4; Text-figure 6

Holotype. GSC 57763 (Pl. 1, fig. 2; text-fig. 6).

Paratypes. GSC 57764 (Pl. 1, fig. 3), GSC 57765 (Pl. 1, fig. 4).

Type locality. GSC loc. 92996, Random Island. The stratum is in the Elliott Cove Formation, Upper Cambrian, *Parabolina spinulosa* Zone.

Diagnosis. Based on examination of four hundred specimens. Vesicle more or less spherical, slightly polygonal in outline with granulate surface. Low, dark protuberances delimit the angles of polygonal fields on the vesicle wall.

Erect or curved processes of variable length are grouped in tufts of two or three on each protuberance; numerous, anastomosing, filamentous threads are developed from, and link, the processes along the whole of their length. Single processes may sometimes develop directly from the vesicle wall. Low ridges arising from the inflexion of the polygonal fields towards the interior of the vesicle are developed to a variable degree.

Dimensions. Based on thirty specimens. Diameter of vesicle from 35 to 55 μm; height of protuberances from 1 to 1.5 μm; length of processes from 6 to 20 μm; diameter of granules on vesicle surface is 0.5 μm or less.

Discussion. *V. turbata* is distinguished from *V. africana* Deunff, 1961 by the clearly polygonal distribution of the protuberances and processes, both of which are also usually shorter, and by the granulate surface of the vesicle. The new species differs from *Vulcanisphaera mougnoanum* Martin, 1973 by having a minimum of two processes on each protuberance; a greater development of anastomosing threads from the processes; and granulation of the vesicle surface.

A broken specimen (GSC 57766, Pl. 1, fig. 5) considered to be related to the new species and designated as *V.* aff. *V. turbata* shows that excystment occurs by means of rupture lines along the sides of the polygonal fields.

Occurrence. Rare to common in the Elliott Cove Formation at Random Island. The lowest record there is from the Middle Cambrian, *Lejopyge laevigata* Zone, and the species ranges upwards into the Upper Cambrian, *Parabolina spinulosa* Zone.

Sequence and correlations of acritarch microfloras

F. Martin

In the Middle and Upper Cambrian and Lower Tremadoc strata exposed on Random Island, six acritarch microfloras, A1 to A6, are defined on the bases of the first appearance of selected taxa and of the presence of a grouping of taxa considered as characteristic (Table 1). Not all these chosen taxa need necessarily be present at each of the localities yielding the microflora under consideration, and most may be found beyond the upper limit of the vertical range of an assemblage. The vertical ranges of the microfloras are estimated; this lack of precision is due either to the presence of relatively barren samples (as between microfloras A1 and A2) or to the fact that the sampling was intentionally limited to outcrops dated by means of macrofossils or to strata sufficiently continuous as to be able to estimate the position of acritarch horizons with reference to those containing macrofossils. These microfloras, like other Cambrian and Tremadoc acritarch assemblages, have a more or less pronounced regional character and are not to be considered as formal standard zones.

Cambrian microfloras A1 to A5 from Random Island permit only limited comparisons with assemblages published from other regions; the latter include Czechoslovakia (Slavíková, 1968; Vavrdová, 1976), eastern U.S.S.R. (Jankauskas, 1976a,b), Spain (Cramer and Diez de Cramer, 1972; Fombella, 1977, 1978), and the Belgian and French Ardennes (Vanguestaine, 1973, 1974, 1978). Except in the two last-named regions, data concerning the Upper Cambrian are practically non-existent, especially as Jankauskas (1976a) has demonstrated that the acritarchs from the Ijora Beds attributed to the Upper Cambrian by Timofeev (1959) belong to the Middle Cambrian. At present, only summary palynological notes (Davies and Downie, 1964; Potter, 1974) are available for the Cambrian of England and Wales.

The positive comparisons in the present paper concern especially isolated taxa, the order of appearance of which may vary from region to region. They have little bearing on assemblages that are different from those described here. An exception is microflora A4, which may be partially correlated with zone 5 of Vanguestaine (1974), a subdivision attributed by that author to the Upper Cambrian, in deposits devoid of macrofossils in the Massifs of Stavelot and of Rocroi in the Belgian and French Ardennes.

An overall comparison of microflora A6, of Tremadoc age, is proposed on the basis of works published for the Sahara (Deunff, 1961; Combaz, 1967; Jardiné *et al.*, 1974), England (Rasul and Downie, 1974; Rasul, 1979), France (Rauscher, 1974a, b; Martin, 1973), Belgium (Martin, 1977) and Bell Island, eastern Newfoundland (Martin *in* Dean and Martin, 1978). Rasul and Downie (1974) proposed the subdivision of the Tremadoc Series, as represented by the Shineton Shales of Shropshire, into nine provisional zones based on acritarchs. Rasul (1979), revising the succession, divided the Shineton Shales into eight zones of local application based on the first occurrence and the association of selected and mainly new taxa. Their application outside the Shineton Shales is as yet incompletely known, notably with regard to the four palynological subdivisions described from the Tremadoc of the Algerian Sahara by Jardiné *et al.* (1974).

The order of presentation of the microfloras here is as follows: stratigraphic position in the sections at Random Island and correlation, where possible, with macrofaunal subdivisions; general description of the assemblage; comparison or partial correlation with other regions, account being taken, without going into detail, of species cited in the synonymy lists of the present paper.

Microflora A1 (*Adara alea-Eliasum llaniscum* assemblage)

Stratigraphic position. At Random Island the assemblage has been found only in Middle Cambrian strata forming part of the Manuels River Formation, and its lowest record there is 0.8 m below beds with *Paradoxides hicksii* (see Fig. 3 for zones); still older strata were barren (GSC loc. 94426) or were not sampled. The upper limit lies within the stratigraphic range of *Paradoxides davidis* and is separated from the first appearance of microflora A2 by 4 m of barren shales.

Description. The assemblage contains numerous *Adara alea* sp. nov. and *Eliasum llaniscum* Fombella, 1977, rare *E.* cf. *E. asturicum* Fombella, 1977, and abundant *Cristallinium cambriense* (Slavíková) Vanguestaine, 1978. All these are restricted to microflora A1 except for *C. cambriense*, which has a longer vertical range, is found more rarely in microfloras A2 to A5, and occurs exceptionally in microflora A6. *Leiosphaeridia* sp., which is an indicator of environment rather than age, may be locally abundant. *Pterospermopsimorpha* sp. is extremely rare.

Comparison. In León Province, Spain, specimens of *Adara* and *Eliasum*, including *E. llaniscum*, are known from an outcrop that lacks macrofossils and is located in the lower part of the Oville Formation (Cramer and Diez de Cramer, 1972; Fombella, 1977). The age of the described acritarchs was stated to be late Middle Cambrian by Cramer and Diez de Cramer (1972) and early Middle Cambrian by Fombella (1977); nevertheless, according to Cramer (*in* Cramer, Lobato and Truyols, 1977, Stop 1-4) the palynological material analysed in those two publications comes from the same locality and horizon. Without giving precise information on the location of her samples Fombella (1978) recognized three acritarch assemblages in the entire Oville Formation, the successive ages of which are: early Middle Cambrian; late Middle Cambrian; and Late Cambrian to Tremadoc. According to her data *Eliasum llaniscum* occurs in all three assemblages, whereas the genus *Adara* is found only in the first. In Czechoslovakia *E. llaniscum* is found in the Jince Formation, of Middle Cambrian age, *Eccaparadoxides pusillus* Zone (Vavrdová, 1976). *Pterospermopsimorpha* is recognized from the late Precambrian to Cambrian rocks of the U.S.S.R. (Timofeev, 1969, p. 16). *Cristallinium cambriense* is known in Europe from the Middle Cambrian to the Tremadoc Series, and in U.S.S.R. from the upper part of the Lower Cambrian, if the age attribution proposed on the basis of palynological data by Jankauskas (1976b) is confirmed (see p. 17 for detailed references).

Microflora A2 (*Timofeevia phosphoritica-Vulcanisphaera turbata* assemblage)

Stratigraphic position. In the cliff section north of Weybridge the lowest occurrence (GSC loc. 95155) of microflora A2 is in the Manuels River Formation, 6 m below the top of the unit; the horizon lies within the stratigraphic range of *Paradoxides davidis* (see Fig. 3 for zones) and is separated by 4 m of barren shale from the preceding microflora A1. In the Elliott Cove Formation the assemblage was found in strata of the *Lejopyge laevigata* Zone, the *Agnostus pisiformis* Zone and the *Olenus* Zone; the highest record was from strata (GSC loc. 92993) undated by macrofossils which lie about 43 m above shale containing *Olenus*. The vertical range is estimated to be about 200 m. Although there is a progressive increase in the number of species upwards throughout this thickness of strata, the poor state of preservation of material from the upper part of the Manuels River Formation and the lowest part of the Elliott Cove Formation does not permit further subdivision of microflora A2. The nature of the boundary between the Manuels River Formation and the Elliott Cove Formation is discussed elsewhere in the present paper (p.4,5). The presence of *Lejopyge laevigata* Zone above the basal conglomerate of the Elliott Cove Formation suggests that the conglomerate itself represents only a relatively minor stratigraphic break. This conclusion is supported by the microfossil evidence; although the conglomerate (GSC loc. 94430) has yielded only a poorly preserved acritarch assemblage, the taxa recognized are those of microflora A2.

Description. Typical constituents which appear in microflora A2 are *Timofeevia phosphoritica* Vanguestaine, 1978, *T. lancarae* (Cramer and Diez de Cramer) Vanguestaine, 1978, *T. microretis* sp. nov., *T. pentagonalis* (Vanguestaine) Vanguestaine, 1978 and *Vulcanisphaera turbata* sp. nov. With the exception of *T. microretis*, which disappears below the upper limit of the assemblage's vertical range, all these taxa extend upward into younger Upper Cambrian strata of the Elliott Cove Formation, where they are less abundant. *T. lancarae* is present also in microflora A3; *V. turbata* ranges still higher, into A4; and *T. pentagonalis* and *T. phosphoritica* extend as high as A5 (see Table 1). *Leiofusa stoumonensis* Vanguestaine, 1973, which occurs in the uppermost part of the vertical range of A2, is more abundant in the two succeeding microfloras A3 and A4.

Comparison. Up to the present, the oldest known occurrence of *Vulcanisphaera* dated by macrofossils was from the *Olenus* Zone of England and Wales (Potter, 1974). The other taxa from microflora A2 are considered at the same time as those constituting microflora A3.

Microflora A3 (*Cristallinium randomense-Veryhachium dumontii* assemblage)

Stratigraphic position. Microflora A3 occurs approximately in the middle part of the Elliott Cove Formation. The oldest representatives of A3, from GSC loc. 92994, are separated from A2 by a stratigraphic gap, not yet sampled, of some 72 m. Loc. 92994 and 92995 are in the strata undated by macrofossils and lie, respectively, approximately 121 m and 77 m below a unit of grey silty shale in which *Orusia lenticularis*, indicative of the *Parabolina spinulosa* Zone, was found. All the remaining representatives of A3 are in strata of the *P. spinulosa* Zone.

Description. Of all the taxa that appear in microflora A3, only the very rare *Cristallinium ovillense* (Cramer and Diez de Cramer, 1972) comb. nov. is restricted to it. *Veryhachium dumontii* Vanguestaine, 1973 and *Cristallinium randomense* sp. nov. appear here and are variably abundant through microfloras A3 to A5. *C. randomense* occurs also, though very rarely, at one locality in the Clarenville Formation, in microflora A6. *Veryhachium* sp. A occurs rarely and its frequency is variable; *Cymatiogalea* cf. *C. cylindrata* Rasul, 1974 appears but is recorded from only one sample. The latter two taxa occur sporadically in microfloras A3 to A6 inclusive.

Comparison. Microfloras A2 and A3 are considered together here. *Timofeevia lancarae*, which appears first in microflora A2 at Random Island, and *Cristallinium ovillense*, confined to microflora A3 there, were recorded together at the same horizon in the Oville Formation in Spain (Cramer and Diez de Cramer, 1972) accompanied by specimens of *Adara* and *Eliasum llaniscum* (Fombella, 1977), taxa which in the present work have been found only in microflora A1. Fombella (1978) indicated that *Timofeevia lancarae* is present throughout the Oville Formation, from lower Middle Cambrian to Upper Cambrian-Tremadoc.

T. lancarae is reported from the Horizons of Vergalsky and of Rauousvensky in the western U.S.S.R., strata of which are devoid of macrofossils and are assigned to the Lower Cambrian (*Holmia* Zone and *Protolenus* Zone) on the basis of palynological data (Jankauskas, 1976b). In Czechoslovakia, badly preserved specimens from the Middle Cambrian (*Eccaparadoxides pusillus* Zone) have been attributed to *T. lancarae* by Vavrdová (1976). In the French and Belgian Ardennes *Timofeevia phosphoritica* (*sensu lato* including *T. pentagonalis* and *T. lancarae*) is present according to Vanguestaine (1974, 1978) in his palynological zones 3 to 6, the age of which he estimated as being from Early or Middle Cambrian to Late Cambrian.

Leiofusa stoumonensis and *Veryhachium dumontii* appear, respectively, late in microflora A2 and from the entry of microflora A3 at Random Island; in Belgium they are among the characteristic elements of Vanguestaine's (1973) palynological zone 5, found in so-called Revinian (Rn2b) deposits which contain no macrofossils and were attributed by him to the Upper Cambrian.

Microflora A4 (*Trunculumarium revinium-Dasydiacrodium caudatum* assemblage)

Stratigraphic position. Both samples (GSC loc. 92997 and 87792) which contain definite representatives of microflora A4 are from dark-grey shale in the upper part of the *Parabolina spinulosa* Zone and are separated from one another by only 2 m of strata. Two further samples are referred questionably to A4 and their composition is discussed below (see Description). The older of these, loc. 87793, is from a level 5.2 m below that of loc. 92997, and also belongs to the *P. spinulosa* Zone. The younger, from loc. 87789, is from strata of the *Leptoplastus* Zone and occurs an estimated 15 m above 87792, though the section here is affected by small-scale faulting.

Description. The assemblage of A4 is distinguished from that of A3 by the appearance of *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976 and of *Dasydiacrodium caudatum* Vanguestaine, 1973; the former taxon is restricted to the assemblage, but the latter taxon has a longer range, into microflora A6. A4 contains representatives of diacrodians with homoeomorphic poles, determined here as *Acanthodiacrodium* cf. *A. achrasi* Martin, 1973, which appear for the first time in the succession; *A. achrasi* ranges upwards at least into microflora A6.

The slightly older assemblage at GSC loc. 87793 is referred questionably to A4 (see Table 1) because it contains *Dasydiacrodium caudatum* but neither *Trunculumarium revinium* nor *Acanthodiacrodium* cf. *A. achrasi*. The slightly younger sample from GSC loc. 87789, dated on trilobite evidence as *Leptoplastus* Zone, is also attributed questionably to A4 because it lacks both *Trunculumarium revinium* and *Dasydiacrodium caudatum* but contains very rare *Acanthodiacrodium* cf. *A. achrasi*.

Comparison. *Trunculumarium revinium* and *Dasydiacrodium caudatum*, together with *Leiofusa stoumonensis* and *Veryhachium dumontii*, are elements limited to and characteristic of zone 5 in the Revinian (Rn2b) of the Massif de Stavelot, Belgium (Vanguestaine, 1974). Of these taxa, *T. revinium* is limited to zone 5 and is the most characteristic; the species is present also in the Massif de Rocroi (Rv5) in the French Ardennes (Vanguestaine, 1974). At Random Island these four species were found together only in microflora A4. If their distribution is subsequently confirmed, the position of zone 5 in Belgium and the French Ardennes would be rendered more precise within the Upper Cambrian, and would probably correspond to the *Parabolina spinulosa* Zone. However, it should be noted that Vanguestaine (1974) reported the appearance of the first diacrodians with homoeomorphic poles in younger deposits, his zone 6, of the Massif de Stavelot (Revinian, Rn3), and that he attributed these strata to the Upper Cambrian or to the Tremadoc Series. According to Downie, quoting the unpublished Ph.D. thesis of T.L. Potter (*in* Vanguestaine, 1974, p. 80), *Trunculumarium revinium*, *Veryhachium dumontii* and *Dasydiacrodium caudatum* have all been recognized in the *Orusia* Shales, Upper Cambrian, of the Anglo-Welsh area.

Microflora A5 (*Vulcanisphaera africana-Arbusculidium rommelaerei* assemblage)

Stratigraphic position. Microflora A5 occurs high in the Elliott Cove Formation, in strata assigned to the *Peltura* Zone, and is subdivided into two parts, A5a and A5b. The first of these was recovered from GSC loc. 94435, on the coast between Elliotts Cove and Bounds Mead (see Fig. 1), a section from which *Peltura scarabaeoides* (Wahlenberg, 1821) was reported by Jenness (1963, p. 169, loc. F-27; see also the present paper). A5b was obtained from GSC loc. 92998 and 94432 in the cliff section south of Elliotts Cove; both localities are in soft, grey shale and are separated from one another by 7.7 m of strata. The stratigraphic relationship of A5a and A5b is not yet known from field evidence, and is postulated here on the basis of palynological data.

Description. Typical constituents that appear at the lower limit of the range of A5 are numerous *Arbusculidium rommelaerei* sp. nov. and *Vulcanisphaera africana* Deunff, 1961; relatively less abundant *Acanthodiacrodium achrasi* Martin, 1973 and *Priscogalea cortinula* Deunff, 1961; and extremely rare *Cymatiogalea*? *membranula* Martin *in* Dean and Martin, 1978. All these taxa range upwards into microflora A6, the youngest recovered at Random Island. Rare specimens of *Ooidium*? sp. A are restricted to A5a.

A5b is differentiated by the appearance of *Priscogalea gautieri* Martin, 1973, *Cymatiogalea bouvardi* Martin, 1973, *Goniosphaeridium uncinatum* (Downie) Kjellström, 1971, *Acanthodiacrodium ubui* Martin, 1969, *A. complanatum* Deunff, 1961, *Multiplicisphaeridium*? cf. *M.? furcatum* (Deunff, Eisenack *et al.*, 1973 and *Saharidia fragile* (Downie) Combaz, 1967. All these taxa range upwards into A6. The last representatives of *Timofeevia pentagonalis* and *T. phosphoritica* are found in A5b.

Comparison. Species that were of stratigraphic significance earlier in the Cambrian, such as *Cristallinium randomense, Dasydiacrodium caudatum* and *Veryhachium dumontii*, are represented in A5, but most of the other known taxa which appear in A5 have been recorded from the Tremadoc Series and not from the Cambrian. Detailed references concerning the following remarks on regional distribution have been given elsewhere (Martin, 1977, text-fig. 14; Martin *in* Dean and Martin, 1978, Table 3) and are not repeated here. In the Tremadoc Series, as represented by the Shineton Shales of Shropshire, *Vulcanisphaera africana* is present from the *Dictyonema* Beds up to the Arenaceous Beds, whereas *Priscogalea cortinula* has a more limited vertical range, from the *Dictyonema* Beds to the *Clonograptus* Beds (Rasul and Downie, 1974; Rasul, 1979). These two acritarch taxa are commonly reported from the Tremadoc of the Sahara, France and Belgium, and have been recognized in the lower part of the Bell Island Group exposed at Bell Island, eastern Newfoundland (Martin *in* Dean and Martin, 1978, p. 10-12). In the Russian literature Jankauskas (1976a) mentions them as occurring in the Ladoga Formation, which he attributes to the Lower Tremadoc. *Cymatiogalea bouvardi, Priscogalea gautieri, Acanthodiacrodium ubui* and *A. complanatum* are present in the (probably Lower) Tremadoc of the Montagne Noire, southwestern France. Except for the first named, these taxa have been determined in strata containing *Dictyonema* in Belgium. *A. ubui* is present in the Shineton Shales, from the *Dictyonema* Beds to the Brachiopod Beds (Rasul and Downie, 1974; Rasul, 1979), and *A. complanatum* is known from the (supposedly Lower) Tremadoc of the Sahara. *Cymatiogalea*? *membranula* is present in the Tremadoc Series of Bell Island, eastern Newfoundland. *Saharidia fragile* and *Goniosphaeridium uncinatum* have a vast geographic and stratigraphic distribution, covering eastern Newfoundland, western Europe and North Africa. The first of these species occurs in the Tremadoc Series; the second in the Tremadoc, Arenig and Llanvirn Series.

Microflora A6 (*Arbusculidium destombesii-Vulcanisphaera capillata* assemblage)

Stratigraphic position. Microflora A6 has been recovered from shale outcrops of the Clarenville Formation at several localities along the northwest coast of Random Island. The Lower Tremadoc Series is undoubtedly represented, and, as noted elsewhere, certain of the macrofossils may range still lower, into the *Acerocare* Zone of the Upper Cambrian, by analogy with corresponding faunas and strata in the Anglo-Welsh area. In view of the faulted and folded nature of the outcrops, the vertical range of A6 is difficult to estimate.

Description. Acritarch assemblages from the Clarenville Formation are of relatively uniform composition and may be considered together. A6 is distinguished from the preceding microflora, A5, by the appearance of the following taxa: *Arbusculidium destombesii* Deunff, 1968, *Vulcanisphaera capillata* Jardiné *et al.*, 1974, *Cymatiogalea bellicosa* Deunff, 1961, *C. velifera* (Downie) Martin, 1969, *Priscogalea multarea* Deunff, 1961, *P. cuvillieri* Deunff, 1961, *Baltisphaeridium crinitum* Martin *in* Dean and Martin, 1978, and *Acanthodiacrodium angustum* (Downie) Combaz, 1967. *Leiofusa simplex* (Combaz) Martin, 1977 and *Poikilofusa squama* (Deunff) Martin, 1977 were found in only one sample (GSC loc. 92999).

Comparison. Among the species recognized by Vanguestaine (1974) as being of Cambrian age, and which were present in A5, *Veryhachium dumontii* has completely disappeared from A6; however, *Dasydiacrodium caudatum* may be found in still greater abundance.

Most of the taxa that appear in microflora A6 are known in the Tremadoc Series of western Europe or eastern Newfoundland (see Martin *in* Dean and Martin, 1978 for list of references). They do not permit a more precise age determination, for many of them have a long vertical range or their ranges are insufficiently documented. Among them, only *Arbusculidium destombesii* and *Vulcanisphaera capillata* are more indicative of the Lower Tremadoc. *Arbusculidium destombesii* is recorded from the *Dictyonema* Beds of the Shineton Shales (Rasul and Downie, 1974), from the Quartzophyllades de Chevlipont, in the Massif du Brabant, Belgium, where it is accompanied by *Dictyonema* (Martin, 1977), and from imprecisely dated levels within the Tremadoc Series of Libya (Deunff and Massa, 1975) and Bell Island, Newfoundland (Martin *in* Dean and Martin, 1978).

According to J. Destombes (personal communication, 1979) the type material of *Arbusculidium destombesii* described by Deunff (1968) came from one horizon at a single outcrop in the central Anti-Atlas; numerous *Dictyonema* found both below and above have not been specifically determined but are certainly of Tremadoc age according to Solange Willefert. *Arbusculidium ornatum* (Combaz) Jardiné and others, 1974, a species close to *A. destombesii*, has been recognized in Algeria, in strata (zone Bo) which Combaz (1967) and Jardiné and others (1974) assigned to the Lower Tremadoc, a correlation founded as much on structural as on micropaleontological data. The vertical range of *V. capillata* is limited to zone Bo in Algeria according to Jardiné and others (1974).

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PLATES

All figured specimens are in the type fossil collection of the Geological Survey of Canada, Ottawa, and have numbers with the prefix GSC. Descriptions and photographs are by F. Martin.

All taxa illustrated are listed in Table 1; those marked with an asterisk are also described in the text.

Plate 1

Figure 1. *Vulcanisphaera africana* Deunff, 1961. GSC 57762, GSC Loc. 92998, x 700.*

Figures 2-4. *Vulcanisphaera turbata* sp. nov. Fig. 2, holotype, GSC 57763, GSC Loc. 92996. Fig. 3, GSC 57764, GSC Loc. 92989. Fig. 4, GSC 57765, GSC Loc. 92994. x 700.*

Figure 5. *Vulcanisphaera* aff. *V. turbata* sp. nov. GSC 57766, GSC Loc. 92993, x 700.*

Figure 6. *Saharidia fragile* (Downie) Combaz, 1967. GSC 57767, GSC Loc. 92999, x 700.

Figures 7, 8. *Veryhachium dumontii* Vanguestaine, 1973. Fig. 7, GSC 57768, GSC Loc. 92996. Fig. 8, GSC 57769, GSC Loc. 92998. x 700.*

Figure 9. *Vulcanisphaera capillata* Jardiné *et al.*, 1974. GSC 57770, GSC Loc. 92999, x 700.*

Figures 10, 11, 15. *Dasydiacrodium caudatum* Vanguestaine, 1973. Fig. 10, GSC 57771, GSC Loc. 92999. Fig. 11, GSC 57772, GSC Loc. 93001. Fig. 15, GSC 57773, GSC Loc. 92999. x 700.*

Figure 12. *Veryhachium* sp. A. GSC 57774, GSC Loc. 92998, x 700.*

Figure 13. *Ooidium*? sp. A. GSC 57775, GSC Loc. 94435, x 700.*

Figures 14, 19. *Arbusculidium destombesii* Deunff, 1968. Fig. 14, GSC 57776, GSC Loc. 93002. Fig. 19, GSC 57777, GSC Loc. 92999. x 700.

Figures 16, 17. *Leiofusa stoumonensis* Vanguestaine, 1973. Fig. 16, GSC 57778, GSC Loc. 92996. Fig. 17, GSC 57779, GSC Loc. 95176. x 500.*

Figure 18. *Poikilofusa squama* (Deunff) Martin, 1973. GSC 57780, GSC Loc. 92999, x 500.

Figures 20-22. *Adara alea* sp. nov. Thin, translucent membrane indicated by the arrows. GSC Loc. 94427, x 1000.* Fig. 20, GSC 57781. Fig. 21, holotype, GSC 57782. Fig. 22, GSC 57783.

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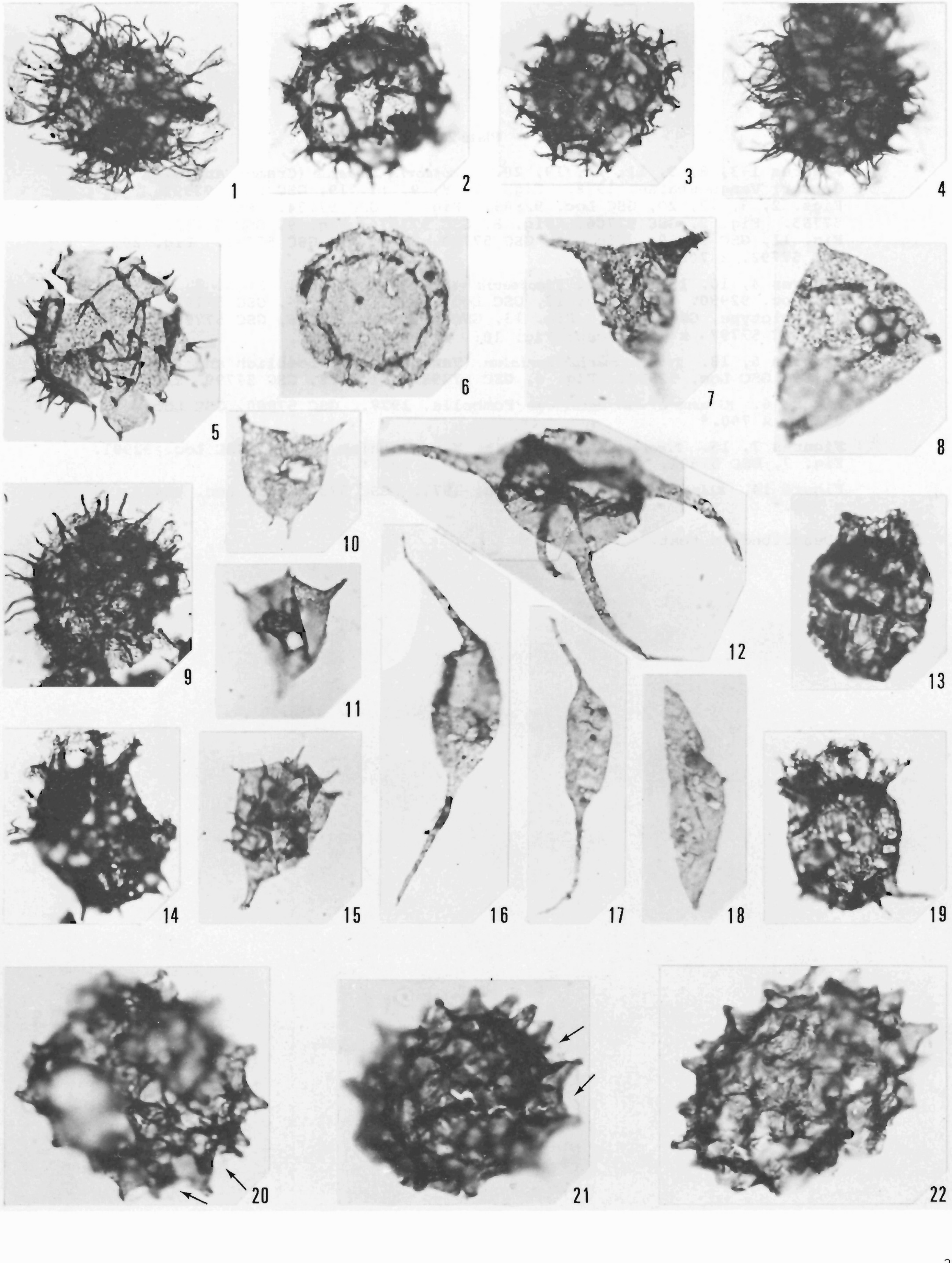
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Plate 2

Figures 1-3, 8, 9, 11, 12, 19, 20. *Timofeevia lancarae* (Cramer and Diez de Cramer) Vanguestaine, 1978. Figs. 1, 8, 9, 11, 19, GSC Loc. 92993. Figs. 2, 3, 12, 20, GSC Loc. 92989. Fig. 1, GSC 57784. Fig. 2, GSC 57785. Fig. 3, GSC 57786. Fig. 8, GSC 57787. Fig. 9, GSC 57788. Fig. 11, GSC 57789. Fig. 12, GSC 57790. Fig. 19, GSC 57791. Fig. 20, GSC 57792. x 700.*

Figures 4, 10, 13, 16, 17. *Timofeevia microretis* sp. nov. Figs. 4, 10, 16, GSC Loc. 92990. Figs. 13, 17, GSC Loc. 92989. Fig. 4, GSC 57793. Fig. 10, holotype, GSC 57794. Fig. 13, GSC 57795. Fig. 16, GSC 57796. Fig. 17, GSC 57797. x 700 except Fig. 10: x 1000.*

Figures 5, 18. *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976. GSC Loc. 92997. Fig. 5, GSC 57798. Fig. 18, GSC 57799. x 700.*

Figure 6. *Eliasum* cf. *E. asturicum* Fombella, 1977. GSC 57800, GSC Loc. 95172, x 700.*

Figures 7, 15. *Timofeevia phosphoritica* Vanguestaine, 1978. GSC Loc. 92991. Fig. 7, GSC 57801. Fig. 15, GSC 57802. x 700.*

Figure 14. *Eliasum llaniscum* Fombella, 1977. GSC 57803, GSC Loc. 94427, x 500.*

*Described in text.

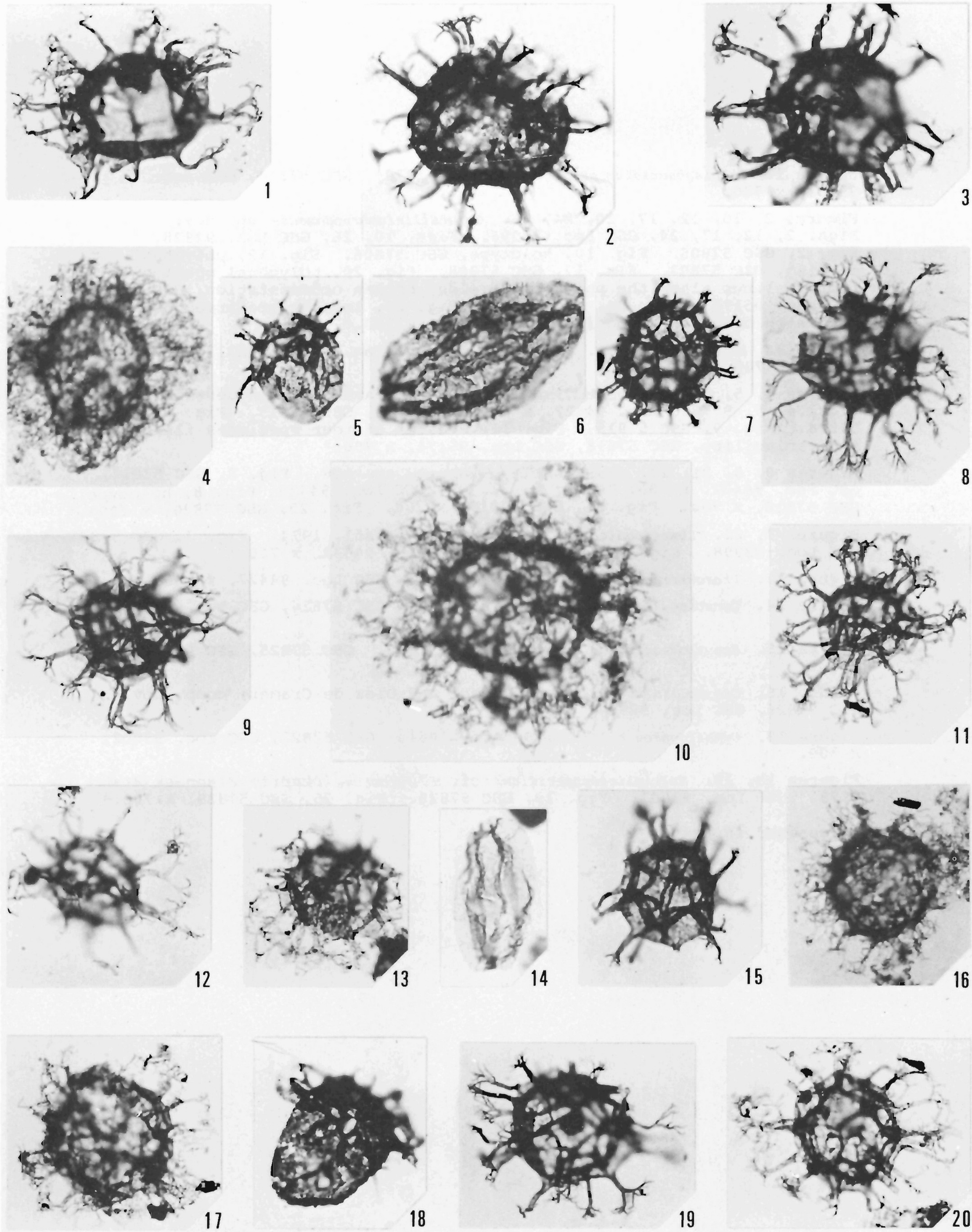
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Plate 3

Figure 1. *Baltisphaeridium crinitum* Martin, 1978. GSC 57804, GSC Loc. 93001, x 700.

Figures 2, 10, 12, 17, 20, 24, 26. *Cristallinium randomense* sp. nov. Figs. 2, 12, 17, 24, GSC Loc. 92996. Figs. 10, 26, GSC Loc. 92998. Fig. 2, GSC 57805. Fig. 10, holotype, GSC 57806. Fig. 12, polygonal opening, GSC 57807. Fig. 17, GSC 57808. Fig. 20, polygonal opening and rupture lines along the polygonal fields, broken ornamentation, GSC 57809, GSC Loc. 95176. Fig. 24, GSC 57810. Fig. 26, locally preserved ornamentation on compressed specimen, GSC 57811. x 700.*

Figure 3. *Leiosphaeridia* sp. with circular opening. GSC 57812, GSC Loc. 94427, x 700.

Figures 4, 5, 9, 11. *Cristallinium cambriense* (Slavíková) Vanguestaine, 1978. Figs. 4, 5, 9, GSC Loc. 94427, x 1000. Fig. 4, GSC 57813. Fig. 5, GSC 57814. Fig. 9, GSC 57815. Fig. 11, cluster of four specimens illustrating the variability, GSC 57816, GSC Loc. 95174, x 700.*

Figures 6, 8, 21, 23. *Arbusculidium rommelaerei* sp. nov. Fig. 6, GSC 57817, GSC Loc. 94432, x 700. Figs. 8, 21, 23, GSC Loc. 94435. Fig. 8, holotype, GSC 57818, x 700. Fig. 21, GSC 57819, x 700. Fig. 23, GSC 57820, x 1000.*

Figures 7, 22. *Cymatiogalea* cf. *C. cylindrata* Rasul, 1974. Fig. 7, GSC 57821, GSC Loc. 92998. Fig. 22, GSC 57822, GSC Loc. 94432. x 700.*

Figure 13. *Pterospermopsimorpha* sp. GSC 57823, GSC Loc. 94427, x 1000.*

Figure 14. *Cymatiogalea bouvardi* Martin, 1973. GSC 57824, GSC Loc. 92998, x 700.

Figure 15. *Acanthodiacrodium achrasi* Martin, 1973. GSC 57825, GSC Loc. 92999, x 700.

Figure 16. *Cristallinium ovillense* (Cramer and Diez de Cramer) comb. nov. GSC 57826, GSC Loc. 92994, x 500.*

Figure 18. *Cymatiogalea bellicosa* Deunff, 1961. GSC 57827, GSC Loc. 93002, x 700.

Figures 19, 25. *Multiplicisphaeridium*? cf. *M*? *furcatum* (Deunff) Eisenack *et al.*, 1973. GSC Loc. 93001. Fig. 19, GSC 57828. Fig. 25, GSC 57829. x 700.*

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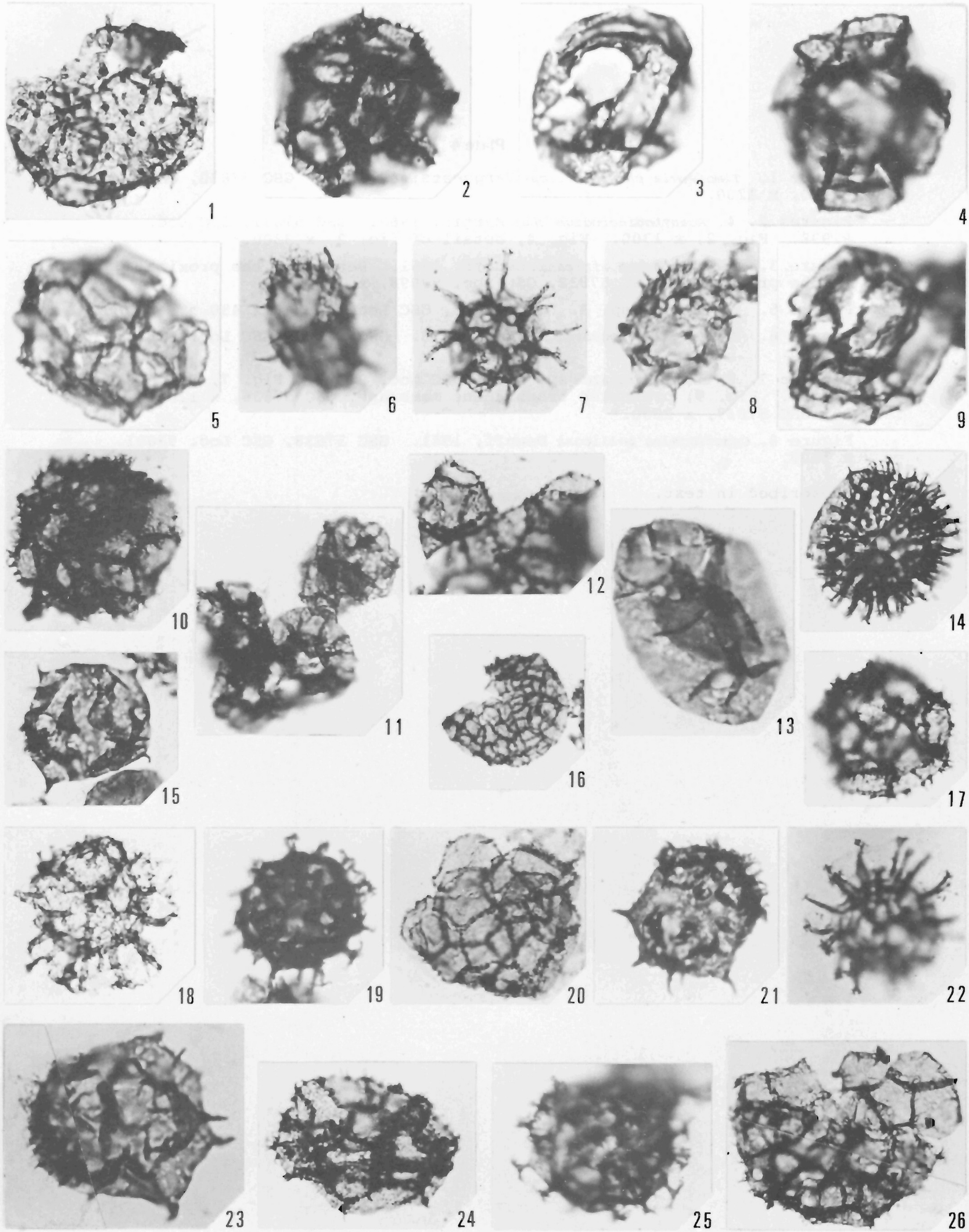
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Plate 4

Figure 1. *Timofeevia phosphoritica* Vanguestaine, 1978. GSC 57830, GSC Loc. 92990, x 1200.*

Figures 2, 4. *Acanthodiacrodium ubui* Martin, 1969. GSC 57831, GSC Loc. 92998. Fig. 2, x 1300. Fig. 4, detail of fig. 2, x 3300.*

Figure 3. *Vulcanisphaera africana* Deunff, 1961. Detail of the proximal part of the processes. GSC 57832, GSC Loc. 92998, x 2300.*

Figure 5. *Veryhachium* sp. A. GSC 57833, GSC Loc. 92998, x 450.*

Figure 6. *Cymatiogalea bouvardi* Martin, 1973. GSC 57834, GSC Loc. 92998, x 1300.

Figures 7, 9, 10. *Adara alea* sp. nov. GSC Loc. 94427. Fig. 7, GSC 57835, x 1100. Fig. 9, preserved translucent membrane, GSC 57836, x 1200. Fig. 10, GSC 57837, x 2800.*

Figure 8. *Cymatiogalea bellicosa* Deunff, 1961. GSC 57838, GSC Loc. 93001, x 1400.

*Described in text.

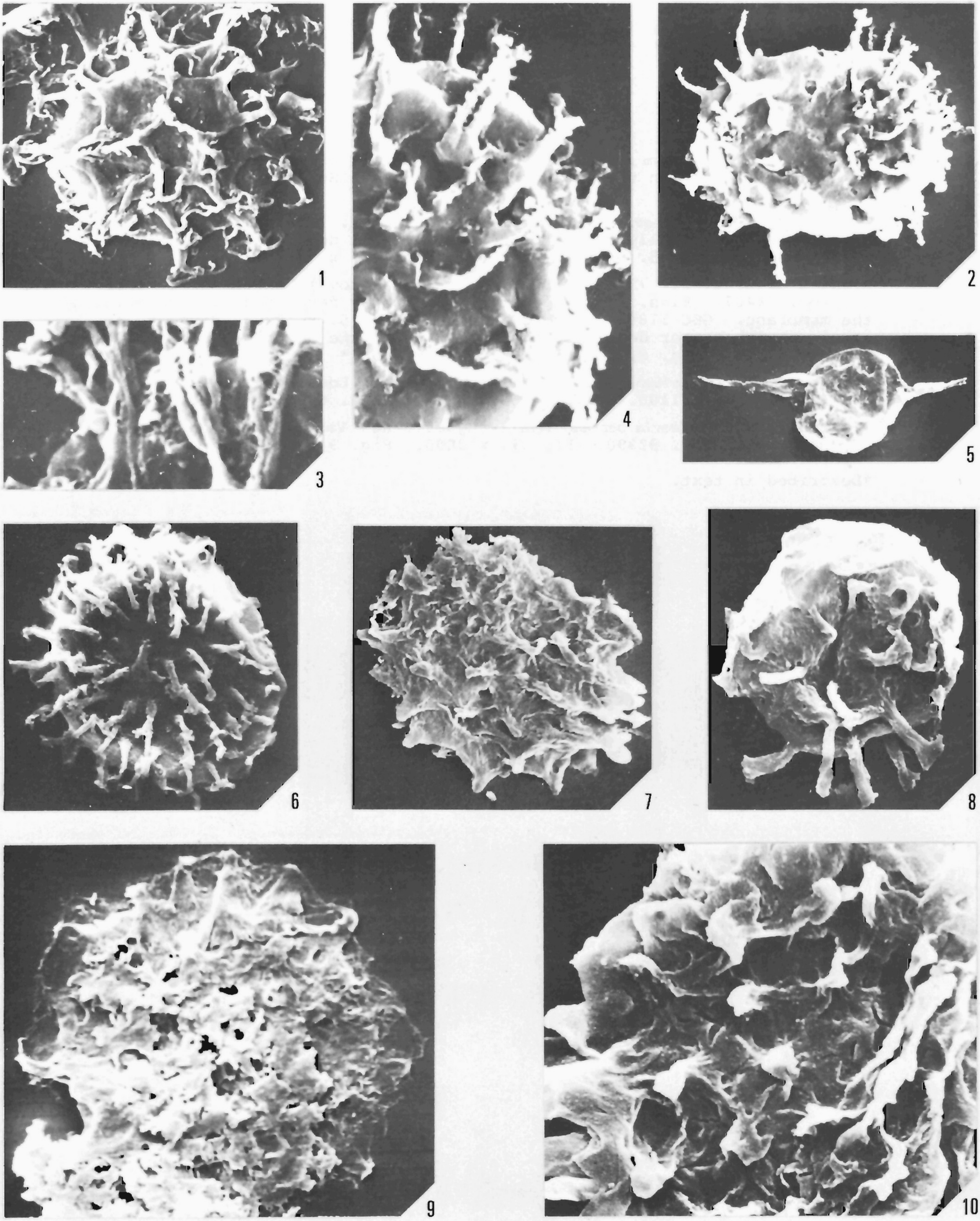
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Plate 5

Figure 1. *Arbusculidium rommelaerei* sp. nov. Detail of the anastomosing net-like ramifications on the more ornamented pole. GSC 57839, GSC Loc. 94435, x 2700.*

Figures 2, 10. *Timofeevia phosphoritica* Vanguestaine, 1978. Figs. 2, 10, specimen with partially broken processes and well developed septa. GSC 57840, GSC Loc. 94435. Fig. 2, x 2700. Fig. 10, x 1300.*

Figures 3, 5, 8, 11. *Cristallinium cambriense* (Slavíková) Vanguestaine, 1978. GSC Loc. 94427. Figs. 3, 5, specimen with poorly developed ornamentation of the membrane. GSC 57842. Fig. 3, x 5500. Fig. 5, x 1000. Figs. 8, 11, specimen with better developed ornamentation of the membrane than in Figs. 3, 5. GSC 57843. Fig. 8, x 1100. Fig. 11, x 4600.*

Figures 4, 6. *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976. GSC Loc. 92997, x 1100.* Fig. 4, GSC 57844. Fig. 6, GSC 57845.

Figures 7, 9. *Timofeevia pentagonalis* (Vanguestaine) Vanguestaine, 1978. GSC 57841, GSC Loc. 92990. Fig. 7, x 3000. Fig. 9, x 1300.*

*Described in text.

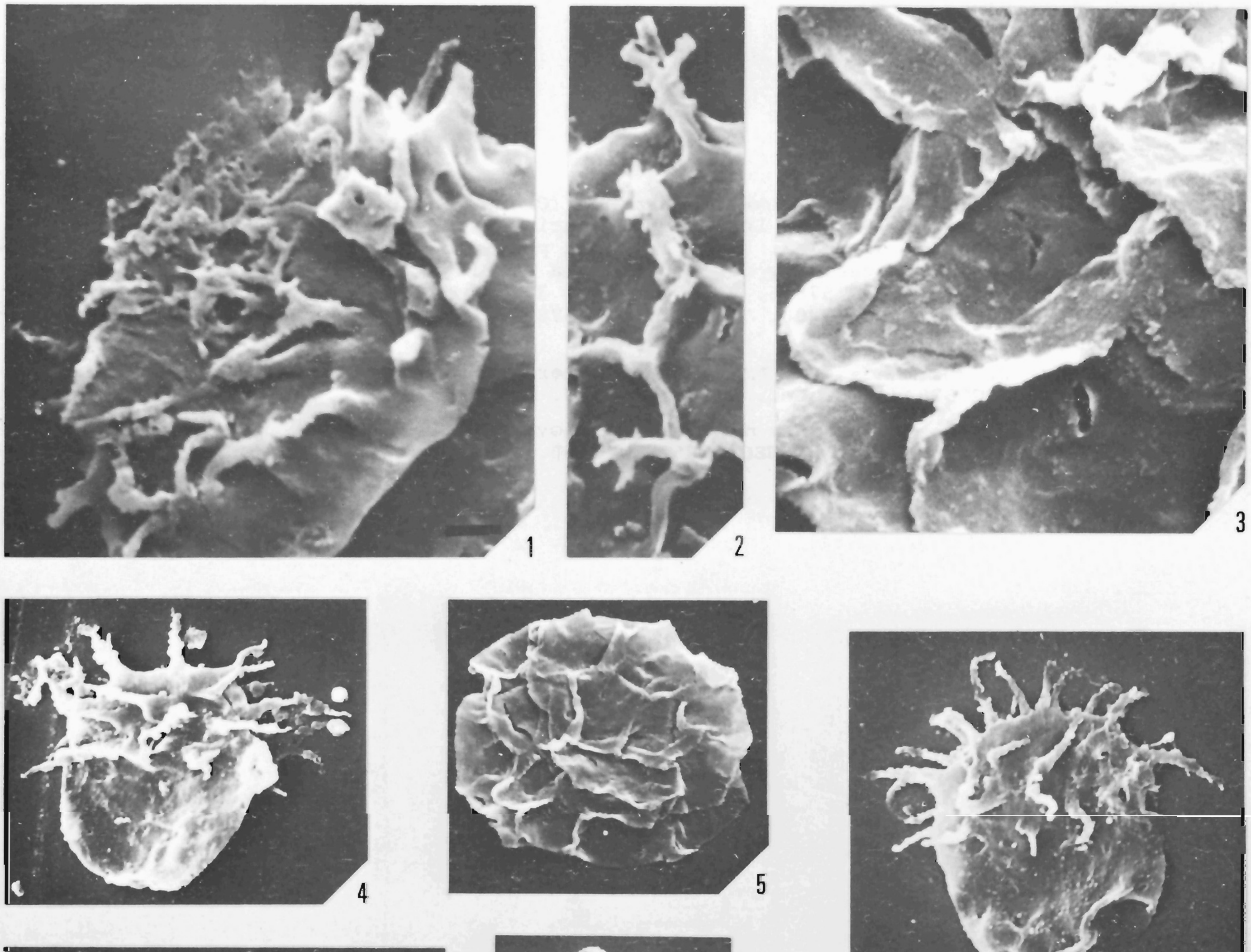
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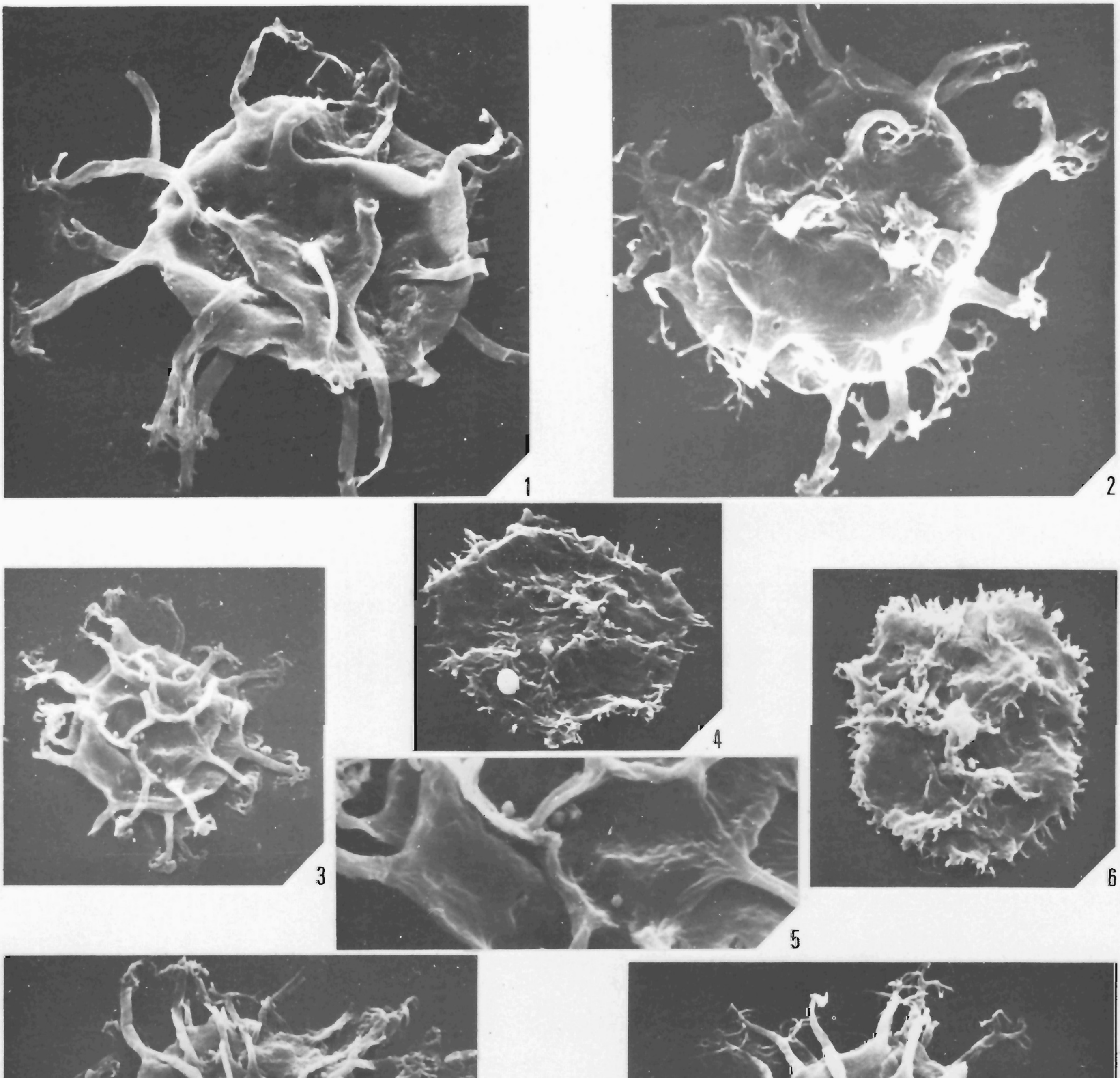
Plate 6

Figures 1, 3, 5, 7, 8. *Timofeevia lancarae* (Cramer and Diez de Cramer) Vanguestaine, 1978. GSC Loc. 92989. Variably developed radial costae around the process bases. Fig. 1, septa poorly developed locally. Figs. 3, 5, 7, 8 variably developed septa or ridges between the process bases. Fig. 1, GSC 57846, x 1400. Fig. 3, GSC 57848, x 900. Fig. 5, detail of fig. 3, x 2200. Fig. 7, GSC 57849, x 1100. Fig. 8, GSC 57850, x 1100.*

Figure 2. *Timofeevia* aff. *T. lancarae* (Cramer and Diez de Cramer) Vanguestaine, 1978. GSC 57847, GSC Loc. 92989, x 1400.

Figures 4, 6. *Cristallinium randomense* sp. nov. GSC Loc. 92996. Fig. 4, GSC 57851, x 1200. Fig. 5, GSC 57852, x 1100.*

*Described in text.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