THE MIDDLE CAMBRIAN, UPPER CAMBRIAN, AND LOWER TREMADOC ACRITARCHS OF RANDOM ISLAND, TRINITY BAY, SOUTHEASTERN NEWFOUNDLAND

CENTRE FOR NEWFOUNDLAND STUDIES

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MARION GRACE PARSONS

THE MIDDLE CAMBRIAN, UPPER CAMBRIAN, AND LOWER TREMADOC ACRITARCHS OF RANDOM ISLAND, TRINITY BAY, SOUTHEASTERN NEWFOUNDLAND

by

© Marion Grace Parsons, B.Sc., M.U.N.

A thesis submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

In the Random Island area on the west side of Trinity Bay, eastern Newfoundland, there are three NNE-SSW oriented Lower Palaeozoic basins. The southern part of the westernmost basin underlies the northern end of Random Island; it includes, apart from minor fault-bounded remnants of Lower Cambrian rocks, an almost complete succession of Middle Cambrian to lowermost Ordovician (Tremadoc) rocks. Outcrops are largely confined to coastal cliffs.

Two sections were sampled for acritarchs. The first, on the west side of the island in rocks of Middle Cambrian to early Tremadoc age, extends from Cock and Hen Point northward for 6.5 km to an unnamed point 2.5 km beyond the village of Elliott's Cove. The second, on the east side of the island, is a short section (a few hundred metres in length) in Upper Cambrian rocks 2 km north of Snooks Harbour. The Upper Cambrian rocks of this section complement those present in the section north of Cock and Hen Point where the former are unrepresented due to faulting. Descriptions are given of 102 species, belonging to 33 genera; 38 species and one genus are new finds. A second new genus represents a reassignment of a previously-known species.

The acritarch microfloras of the Middle Cambrian to Tremadoc rocks on Random Island have been divided, on the basis of the successive first appearances of distinctive species, into a series of nine acritarch assemblages, RI 1 to RI 9. Two of the assemblages, RI 6 and RI 7, in rocks of late Upper Cambrian age, have not previously been found

elsewhere, and asssemblage RI 8, in rocks of latest Upper Cambrian age, has until now been recorded only from the Obolus Beds of the northwestern part of the Russian Platform and the Obolus Zone of northern Norway. These Obolus-bearing beds, although presently included in the Tremadoc, are shown to be of latest Upper Cambrian age.

The Middle Cambrian to Tremadoc acritarch assemblages of Random Island are compared with those that have been distinguished in rocks of comparable age in England and Wales, Belgium, Spain, northern Norway, the Russian Platform, North Africa, and elsewhere. This comparison shows that those successions are incomplete due to stratigraphic breaks. Furthermore, many of the acritarch assemblages (or zones) erected elsewhere have not been accurately dated using established trilobite zones; most of the Random Island acritarch assemblages have been directly related to such zones. Thus, outside Random Island, none of the sequences of acritarch assemblages (or zones) established for Middle Cambrian to Tremadoc rocks is as complete, or has as many of its assemblages as accurately dated, as that described in this study. The succession of acritarch assemblages on Random Island should, therefore, become the standard, as far as rocks of Middle Cambrian to early Tremadoc age are concerned, for purposes of biostratigraphic correlation.

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Special thanks go to Roy Ficken of the Department of Biology, for helping me to photograph most of my acritarch specimens and for preparing the final prints for the plates presented in this thesis, to Wilf Marsh of the Department of Earth Sciences, who made countless "final" copies of tables and maps, and to Carolyn Emerson of the Department of Biology, who showed an interest in my microfossils and manipulated the scanning electron microscope so that I obtained good quality photographs.

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CHAPTER ONE

INTRODUCTION: LOCATION OF PROJECT, SECTIONS STUDIED, PREVIOUS GEOLOGICAL WORK IN THE REGION

1.1 LOCATION OF PROJECT; SECTIONS STUDIED

The acritarch assemblages studied for this thesis were isolated from Middle Cambrian to lowermost Tremadoc rocks cropping out on the coast of the northwestern part of Random Island, Trinity Bay, southeastern Newfoundland (Fig. 1.1).

Random Island is approximately 200 kilometers by road from St. John's, the capital city of Newfoundland, and the point of departure for these studies. The northwestern part of the island is separated from the mainland by the waters of Smith Sound to the north and of Northwest Arm to the south. A causeway connects the northern extremity of the island to the mainland. The nearest town is Clarenville, 5 km south of the causeway on the west side of Northwest Arm (Fig. 1.1).

Random Island is densely forested except for small areas in the immediate vicinity of widely separated coastal villages. The interior of the island is, therefore, almost inaccessible. However, since the bedrock inland is almost everywhere concealed by Pleistocene glacial deposits, it is rarely exposed, even in streams. Thus, accessible outcrops are limited to cliffs along the coast, low in some places but over 50 m high in others, and to a few roadcuts and quarries inland. Even along the coast, exposures are not continuous because, apart from being locally concealed by glacial

Figure 1.1. Outline map of the northwestern part of Random Island showing localities mentioned in the text. Inset shows the position of Random Island.

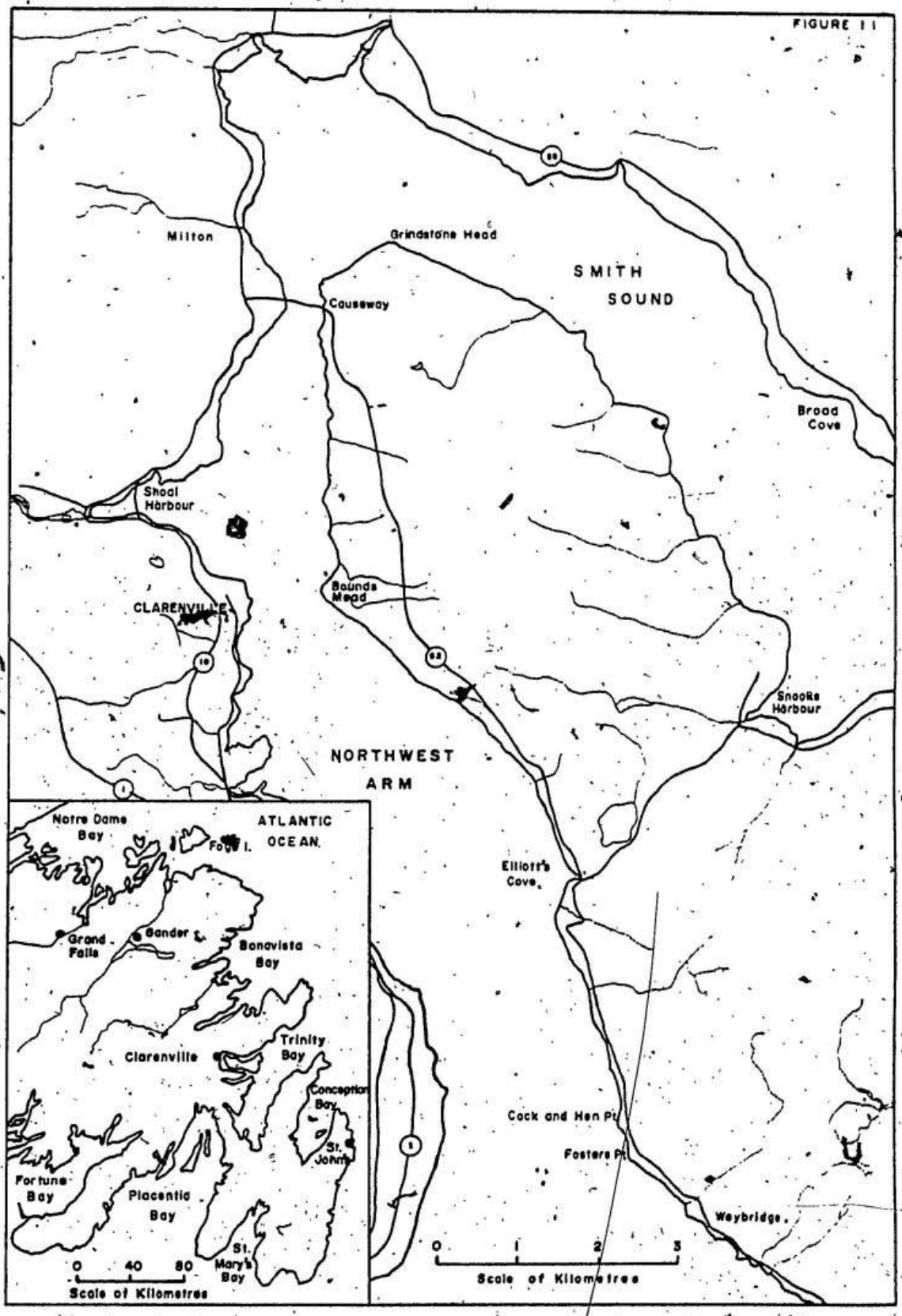
FIGURE 11
Milton
Grindstone Head
SMITH
SOUND
Causeway
Broad
Cove
Shoal
Harbour
Bounds
Head
CLARENVILLE
Snooks
Harbour
NORTHWEST
ARM
ATLANTIC
OCEAN
Notre Dame
Bay
Fogo I.
Elliott's
Cove
Grand
Falls
Gander
Bonavista
Bay
Trinity
Bay
Clarenville
Conception
Bay
St.
John's
Cock and Hen Pt.
Fosters Pt.
Fortune
Bay
Placentia
Bay
St.
Mary's
Bay
Weybridge
0 40 80
Scale of Kilometres
0 1 2 3
Scale of Kilometres

deposits, the cliffs are unstable and have, over the years, collapsed at a number of places.

A preliminary study was made which involved sampling all the coastal exposures of Middle Cambrian to Tremadocian rocks of the entire northwestern part of the island; i.e. from just north of Cock and Hen Point (near the village of Weybridge) on Southwest Arm almost to Snooks Harbour on Random Sound (Fig. 1.1); inland exposures in quarries were also sampled. Examination of the material collected showed that, within a limited time-frame, it would not be possible to study the acritarchs from all the rocks that had been sampled. Further work was, therefore, restricted, on the western side of the island, to the Middle Cambrian to lowermost Tremadoc rocks cropping out between Cock and Hen Point and a point about 2.5 kilometers northwest of Elliott's Cove, and on the eastern side of the island, to a short, isolated section of Upper Cambrian rocks exposed in low coastal cliffs about 2 km north of Snooks Harbour. Beyond the northern limit of the study area on the western side of the island, part of the Upper Cambrian section present south of Elliott's Cove is repeated, either by folding or faulting; on the eastern side of the island the Upper Cambrian section exposed north of Snooks Harbour is separated from the next exposed part of the section, which is of Tremadoc age, by a long stretch of coast where the bedrock is entirely concealed by superficial deposits.

The coastal exposures can be reached at a number of points along the coast, easiest access being at Elliott's Cove, Weybridge, Snooks Harbour, and the cable crossing 1.4 km north of Elliott's Cove (Fig. 1.1).

1.2 PREVIOUS GEOLOGICAL WORK IN THE REGION

Little was known of the geology of the Random Island area prior to the pioneer work of Matthew, 1899, who studied a section of Lower and Middle Cambrian rocks on the north shore of Random Sound and provided a description of the Etcheminnian (Lower Cambrian) fossils he found there. In the following year Walcott, 1900a, published a brief account of the Random Formation (which he called Random Terrane and regarded as Precambrian), a series of white cross-bedded orthoquartzites with intercalations of grey to green siltstone that is overlain unconformably by Lower Cambrian strata in the Random Island area. In the same year, 1900b, he described the succession of Lower Cambrian rocks east of Broad Cove (Fig. 1.1) on the north shore of Random Sound and divided it into three 'units' but named only the middle one, a prominent limestone 8 m thick, the Smith Point Limestone.

Further knowledge of the geology of the area resulted from a series of three expeditions sent from Princeton University in 1912, 1913, and 1914 under the leadership of Professor Gilbert van Ingen; other members of these expeditions were A. F. Buddington, A.O. Hayes, B.F. Howell, and N.C. Dale. Professor van Ingen gave a short description in 1914 of the Cambrian and Ordovician faunas of southeastern Newfoundland and in the same year, 1914b, also published a "Table of the Geological Formations of the Cambrian and Ordovician Systems about Conception and Trinity Bays, Newfoundland, and their Northeastern American and Western-European equivalents" (reproduced in part in Table 1.1). In his table, van Ingen named the sequence of Lower

TABLE 1.1: SHOWING WAYS IN WHICH DIFFERENT AUTHORS HAVE CLASSIFIED THE CAMBRIAN AND LOWEST ORDOVICIAN ROCKS OF SOUTHEASTERN NEWFOUNDLAND

		VAN INGEN 1914b		HOWELL 1926		HUTCHINSON 1962		JENNESS 1963	
		SERIES	FORMATION	SERIES	ZONE	GROUP	FORMATION	GRP	FORMATION
LOWER ORDOVICIAN		CLARENVILLE	RIDERS BROOK MAIDMENT APSEY BROWN MEAD	TREMADOCIAN AND OLDER CLARENVILLE SERIES	BEDS WITH BRYOGRAPTUS, SHUMARDIA, PARABOLINA, NIOBE AND PRINCETONIA	NOT STUDIED		HARCOURT GROUP	CLARENVILLE
CAMBRIAN	UPPER	ELLIOTT COVE	ELLIOTT COVE	?	ORUSIA LENTICULARIS	ELLIOTT COVE			ELLIOTT COVE
				UPPER CAMBRIAN ELLIOTT COVE SERIES	AGNOSTUS PISIFORMIS OBESUS & OLENUS AGNOSTUS PISIFORMIS				
	MIDDLE	MANUELS	MANUELS	?	Age unknown		MANUELS RIVER		MANUELS RIVER
				MIDDLE CAMBRIAN NEWFOUNDLAND SERIES	PARADOXIDES DAVIDIS				
					PARADOXIDES HICKSII				
					PARADOXIDES BENNETTII		CHAMBERLAIN'S BROOK	ADEYTOWN GROUP	CHAMBERLAIN'S BROOK
	LOWER	HANFORDIAN	HANFORD	LOWER CAMBRIAN	CATADOXIDES		BRIGUS		BRIGUS
		ETCHEMINIAN	SMITH POINT		PROTOLENUS		SMITH POINT		SMITH POINT
			BRIGUS		CALLAVIA		BONAVISTA		BONAVISTA
			BONAVISTA		?PRE-CALLAVIA				

Ordovician rocks exposed in the Random Island area the Clarenville Series and divided it into four formations, oldest to youngest, the Brown Mead, Apsey, Maidment, and Rider's Brook Formations. Three of van Ingen's names for Cambrian formations are still in use. Most of the results of work undertaken during the Princeton expeditions were published by van Ingen's co-workers. Dale, 1915, described the manganese-bearing beds at the top of the Lower Cambrian succession north of Smith sound. Buddington, 1919, gave an account of the Precambrian rocks of southeastern Newfoundland in which he mentions that dikes and sills intrude the Cambrian and Ordovician rocks of the Smith Sound and Random Sound areas, and Howell, 1925, published his classic work on the faunas of the Middle Cambrian Paradoxides beds of the Manuels River section, Conception Bay, and also, 1926, a paper on the Cambrian-Ordovician stratigraphic column of southeastern Newfoundland. In his 1925 work, Howell divided the Middle Cambrian beds on the east shore of Conception Bay into three rock units, in ascending order, the Chamberlin's Brook, Long Pond, and Kelligrew Brook Formations. However, in his stratigraphic column of 1926 he omitted formational names and, while retaining the Elliott Cove and Clarenville Series' names of van Ingen, introduced the Newfoundland Series (= the Newfoundland Beds of Walcott, 1888), to replace van Ingen's Manuels Series' for Middle Cambrian strata; the Middle to Upper Cambrian beds he divided into trilobite faunal zones (Table 1:1). Howell was uncertain of the age of the beds between the Middle Cambrian Newfoundland Series and the Upper Cambrian Elliott Cove Series and between the latter and the Clarenville Series. In the former he found no fossils and in the latter

only the brachiopod Orusia lenticularis. It is also evident from Table 1.1 that Howell thought the older part of the Clarenville Series might be of late Upper Cambrian age.

A bulletin of the Newfoundland Geological Survey published in 1948 contains two papers on the Bonavista region (Fig. 1.1) by Hayes and Rose together with a map produced jointly by them. Hayes introduced the terms Connecting Point Group and Musgravetown Group for the older and younger Precambrian rocks, respectively, of the region and recognized that, northwest of the Random Island area, the two groups are separated by an angular unconformity. He also described a section of Lower Cambrian rocks in a slate quarry west of Burn Point on the north shore of Random Sound, and reported the presence of Middle Cambrian rocks with Paradoxides davidis near Brittania on the north side of Random Island, and also, on the opposite side of Smith Sound, at Burgoyne's Cove (see Fig. 2.1). In the map by Hayes and Rose, the distribution of Cambrian and Tremadocian strata is inaccurately portrayed, and they have shown the Brigus Formation as including the Random Formation and strata of both Lower Cambrian and Middle Cambrian age.

Christie, 1950, in his Geological Survey of Canada Paper on the Bonavista Map Area, relied on previous work for descriptions of the Cambrian and Tremadocian rocks on Random Island (reproducing the earlier work of van Ingen and Walcott), and his map, with respect to the northwestern part of Random Island, is inaccurate as it shows Middle Cambrian rocks extending into areas underlain by Upper Cambrian strata, and the outcrop of the Tremadoc rocks as being of more limited extent than is actually the case. Christie commented on the

extension by Hayes and Rose, 1948, of the Brigus Formation to include underlying and overlying strata previously placed in separate formations, stating that he believed it was unjustified, and that van Ingen's original definition of the Brigus should be retained.

In 1962, Hutchinson published a comprehensive account of the statigraphy and trilobite faunas of the Cambrian System in southeastern Newfoundland. He named and listed the formations present (see below), described their distribution in the region, and provided measured sections for each area in which they occur that show the lithology and thickness of the individual beds and the horizons that contain trilobites. Systematic descriptions of most of the trilobites recorded (predominantly of Lower and Middle Cambrian age) were given in a separate chapter. Hutchinson made two important discoveries: (1) that younger Middle Cambrian beds than those of the Paradoxides davidis Zone are present in Highland Cove on the east side of Trinity Bay, where they contain a fauna representative of the Paradoxides forchhammeri Zone, and (2) that the youngest Upper Cambrian rocks in southeastern Newfoundland, those of the Peltura Zone, are preserved only in the northwestern part of Random Island and on the adjacent shore of Random Sound.

Hutchinson's table of formations (Table 1.1) differs significantly from the earlier tables of van Ingen (1914b) and Howell (1925), and although the names of some of the formations are the same, the formations themselves have been redefined. The Smith Point Limestone is placed between the Bonavista and Brigus Formations (mistakenly placed above the latter by van Ingen), thereby eliminating the need for van

Ingen's Hanford Formation (since the Hanford and Brigus Formations as originally defined are of similar lithology), and restoring the order of the Lower Cambrian Formations to that recognized by Walcott in 1900. The Middle Cambrian is divided into two formations, a lower; the Chamberlain's Brook Formation, and an upper, the Manuels River Formation. The former includes the manganese-bearing beds previously forming the uppermost part of the Lower Cambrian succession, and Howell's Chamberlin's Brook Formation, while the latter incorporates Howell's Long Pond and Kelligrew Pond Formations as the lithological differences used by Howell to separate them in the Conception Bay area cannot be recognized in other parts of southeastern Newfoundland. The Elliott Cove Formation is given group status.

The last regional study to include the Random Island area was that of Jenness, 1963, on the geology of the Terra-Nova and Bonavista Map-Areas. His regional map of the Bonavista area, and two text-figures (1963, p.60, fig. 5; p.61, fig. 6) that show, respectively, the approximate distribution of Cambro-Ordovician lithostratigraphic and biostratigraphic units in the Random Island area, are still the most accurate maps of the Random Island area available. However, Jenness had difficulty in the field separating Upper Cambrian and Lower Ordovician rocks because of their similar lithology, and mapped them together so that their distribution as separate formations is only shown on his Figure 6 depicting the distribution of biostratigraphic units (Fig. 2.1). He also reduced the status of the Elliott Cove Group of Hutchinson, 1962, and the Clarenville Series of van Ingen, 1914b, to that of formations. In addition, to facilitate mapping, Jenness

divided the entire Cambro-Ordovician succession of the Bonavista map area into two groups, based on lithology and colour: a lower, Adeyton Group, for the red and green shales with intercalations of pink, green or grey limestone of the Bonavista, Smith Point Limestone, Brigus, and Chamberlain's Brook Formations, and an upper, Harcourt Group, for the grey to black shales with intercalations of siltstone of the Manuels River, Elliott Cove, and Clarenville Formations (Table 1.1). Jenness provided descriptions of the Random and Cambro-Ordovician formations that augment those of Hutchinson, 1962, and earlier workers; he also found a number of new fossil localities and named the trilobites and other fossils present at each of them.

In 1970, Dean described a new Lower Ordovician trilobite faunule that he found in the Clarenville Formation just south of Elliott's Cove; it provides good evidence for faunal affinities with Argentina.

A major work on the geology and Lower to Middle Cambrian trilobite faunas of the southwest Avalon (Cape St. Mary's Peninsula) by Fletcher, 1972, although not directly concerned with the Random Island area, is important for two reasons, firstly because he provides much new information on Lower and Middle Cambrian sections in other parts of southeastern Newfoundland including the Random Island area (as well as evidence for Lower and Middle Cambrian sequences in the Cape St. Mary's Peninsula area that are unrepresented in the areas studied by Hutchinson, 1962, showing that hitherto unrecognized disconformities exist in the latter), and secondly because he found many previously unrecorded trilobites so that his section dealing with the systematics of

the Lower and Middle Cambrian trilobites largely supercedes that of Hutchinson.

Poulsen and Anderson (1975) showed that a thin layer of conglomerate (mainly phosphatic clasts) present above the beds containing a Paradoxides davidis fauna in Manuels River and on the west side of the northwestern part of Random Island marks a disconformity within the upper part of the Middle Cambrian succession in both areas (a temporary regression of the sea also recognized in Sweden). They found that (1) the trilobite faunal zones of Goniagnostus nathorsti and Solenopleura brachymetopa are unrepresented by strata in either section, and (2) trilobites representative of the Lejopyge laevigata Zone (the uppermost of the Middle Cambrian trilobite zones) are present in beds immediately above the conglomerate (those noted by Howell, 1926, at that stratigraphic level as barren and of uncertain age). Thus, the boundary between the Middle and Upper Cambrian beds at Manuels River and on Random Island is transitional (overlying beds contain Agnostus pisiformis), and the lowest part of the Elliott Cove Formation is of latest Middle Cambrian age.

A short, fault-bounded section on the west side of Random Island south of Cock and Hen Point and north of Fosters Point was described by Nautiyal, 1976. He considered, on the basis of the acritarchs (named but not described or illustrated) and the algal and fungal remains he found in it, that it belonged in part to the Chamberlain's Brook Formation and in part to the Random Formation. Nautiyal concluded from his identification of the algae (formally named in a later publication, 1982) that the Random Formation is of late Precambrian age.

In 1981, Anderson published a paper on the Random Formation aimed at establishing its age and relationship to bounding formations. He showed, from the stratigraphic and palaeontological evidence presented, that the lower part of the Bonavista Formation, the whole of the Random Formation (including the entire fault-bounded section on Random Island described by Nautiyal, 1976) and at least the upper part of the Chapel Island Formation (which conformably underlies the Random, and is represented only in the southern part of the Burin Peninsula and north of Fortune Bay) are of earliest Cambrian (Tommotian) age. The Lower Cambrian succession of southeastern Newfoundland was thus 'enlarged' from three to five formations. Anderson's findings were subsequently confirmed by Bengtson and Fletcher, 1983, from their study of small shelly fossils in the lower part of the Bonavista Formation and the upper part of the Chapel Island Formation.

Martin and Dean (1981; 1984) studied the acritarch microfloras of the Middle Cambrian - Tremadoc succession on Random Island and divided them into eight assemblages. Martin described the acritarchs of each assemblage, and Dean correlated the assemblages with the established trilobite zones. Their work is considered in more detail in appropriate places in chapters five to fourteen.

The four formations of van Ingen's, 1914b, Clarenville Series that would, if they had been retained, now have to be considered as members of the Clarenville Formation, were described in more detail by Martin and Dean, 1981, but as their boundaries were never defined, and they are biostratigraphic rather than lithostratigraphic units, they are considered unacceptable as members and are not considered

further here.

CHAPTER TWO

LOCAL GEOLOGICAL SETTING AND STRATIGRAPHY

2.1 LOCAL GEOLOGICAL SETTING AND STRATIGRAPHY

The rocks of the present study constitute part of the westernmost of three NNE-SSW oriented Lower Palaeozoic basins in the Random Island area that are underlain, and separated by Late Precambrian rocks of the Connecting Point and Musgravetown Groups. Two of the basins extend across Random Island while the third and by far the smallest, the easternmost, lies adjacent to the north shore of Random Sound immediately west of Burn Point (Fig. 2.1). The folded and much faulted rocks of these basins are all marine; they represent the remnants of a formerly widespread cover of Lower Palaeozoic rocks in the region. The rocks in the westernmost basin are virtually unmetamorphosed, whereas those of the other two basins are slightly to more strongly metamorphosed; in some places, notably in the easternmost basin, shales have been altered to slates. Cleavage is obvious only where the rocks have been metamorphosed, elsewhere it is rarely apparent.

The westernmost basin, bounded on its western side by a major N-S striking fault, contains a succession of Lower, Middle, and Upper Cambrian strata together with some Lower Ordovician strata. In the next basin to the east, Lower Ordovician strata are unrepresented, and in the easternmost basin, only Lower Cambrian strata are present. The rocks of

Figure 2.1. Map showing the distribution of Precambrian, Cambrian, and Lower Ordovician strata on Random Island and the adjacent mainland.

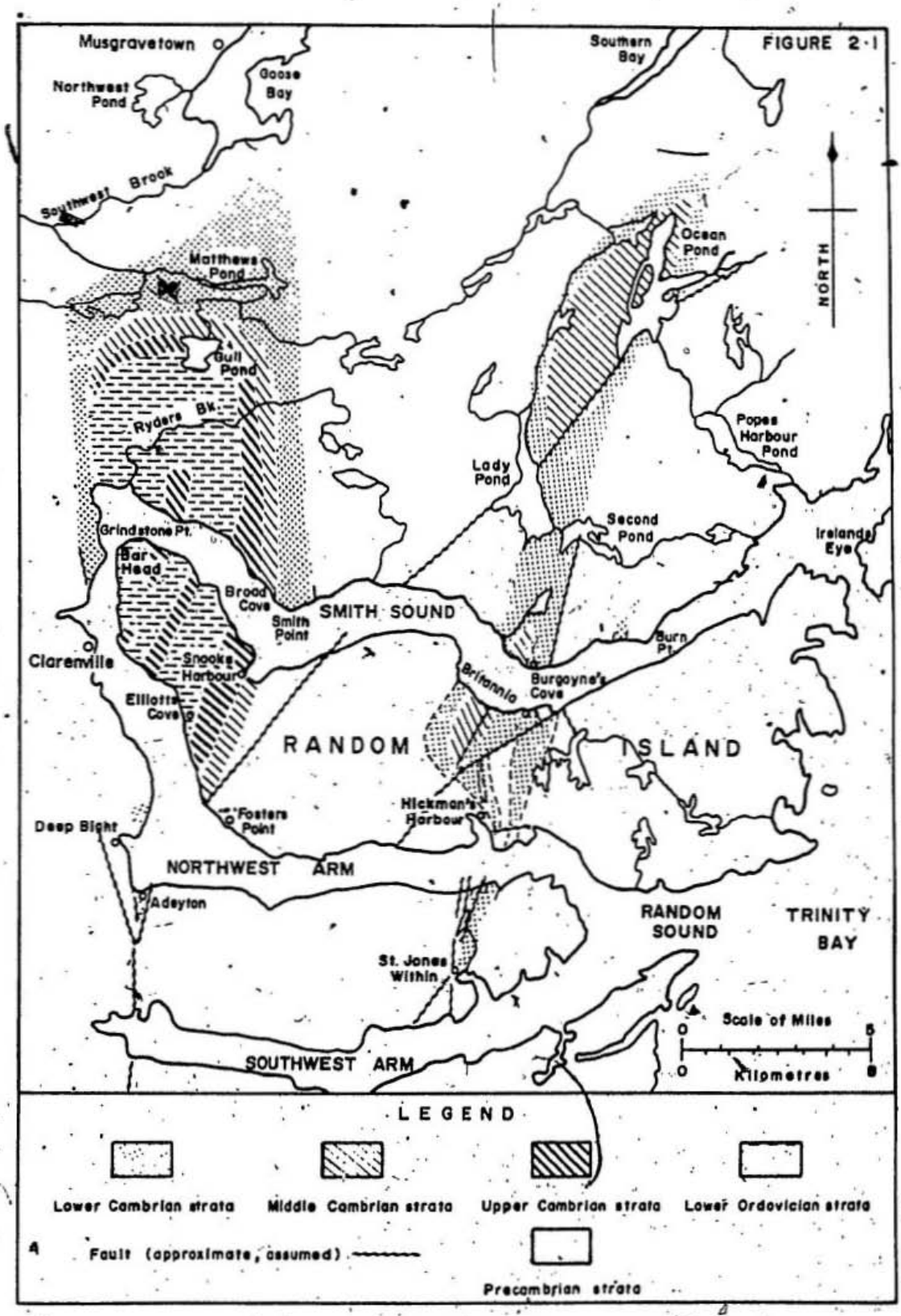
FIGURE 2·1
Musgravetown
Northwest Pond
Goose Bay
Southwest Brook
Southern Bay
NORTH
Ocean Pond
Matthews Pond
Gull Pond
Ryders Bk.
Lady Pond
Popes Harbour Pond
Second Pond
Grindstone Pt.
Bar Head
Broad Cove
Smith Point
SMITH SOUND
Ireland's Eye
Burn Pt.
Clarenville
Snooks Harbour
Elliotts Cove
Britannia
Burgoyne's Cove
RANDOM ISLAND
Hickman's Harbour
Fosters Point
Deep Bight
NORTHWEST ARM
Adeyton
RANDOM SOUND
TRINITY BAY
St. Jones Within
Scale of Miles
0 5
0 8
Kilometres
SOUTHWEST ARM
LEGEND
Lower Cambrian strata
Middle Cambrian strata
Upper Cambrian strata
Lower Ordovician strata
Fault (approximate, assumed)
Precambrian strata

the westernmost basin underlie the northwestern part of Random Island, the adjacent mainland to the north of Smith Sound, where they have their greatest areal extent, and two small areas south of the island on the western shore of Northwest Arm, one just northeast of Deep Bight and the other at Adeytown (Fig. 2.1). These two small areas of Lower Cambrian rocks, as remnants of the southern part of the basin, indicate that uplift of the area west of Northwest Arm has led to the removal by erosion of the Lower Ordovician, and the greater part of the Cambrian, sedimentary sequences that formerly occupied the area, and that one or more faults, not shown on existing maps, lie concealed beneath the sea in the northern part of Northwest Arm.

Only that part of the westernmost basin which occupies the northwestern part of Random Island is considered further here. The strike of the Cambrian and Lower Ordovician beds in this part of the basin is generally NNE-SSW, but deviations occur locally, and in the northernmost part of the island it changes to NW-SE. The predominant direction of dip is to WNW except in the northernmost part of the island where it is mainly to the WSW. However, the lower part of the Elliott Cove Formation has been gently folded so that the dip is reversed locally, and higher up in the succession towards the centre of the basin, the rocks of the Elliott Cove and Clarenville Formations are considerably crumpled and closely folded making it virtually impossible to establish the true dip of the beds. Dips are low to moderate in some parts of the succession but steep to overturned in others, especially where the beds are closely folded. Minor faults are relatively common.

On existing maps, the oldest Cambrian beds on the eastern side of the basin (of early Middle Cambrian age according to Jenness, 1963: see Fig. 2.1) are underlain by late Precambrian rocks of the Connecting Point Group. However, the only known contact between them is just west of Foster's Point on the north shore of Northwest Arm. There, quartzites of the Random Formation (the outcrop of which is not shown on existing maps) are in fault contact with siliceous argillites of the Connecting Point Group; elsewhere, the 'boundary' is concealed and therefore unknown. A few tens of metres to the northwest of the fault contact (just south of Cock and Hen Point), southeast dipping siltstones of the Random Formation are faulted against a north-northwest dipping sequence of red and green shales, with bands of pink limestone nodules and interbeds of limestone, belonging to the Lower Cambrian Bonavista Formation. These beds crop out at Cock and Hen Point, where they are intruded by dikes of basalt, and beyond it to the north in low cliffs (parallel to the strike of the beds) for about ninety metres before being cut off by a fault which separates them from red shales of the Middle Cambrian Chamberlain's Brook Formation. Thus, apart from the Bonavista Formation being incomplete, the Lower Cambrian Smith Point Limestone and Brigus Formations, and the lowermost part of the early Middle Cambrian Chamberlain's Brook Formation, are unrepresented in the Random Island part of the westernmost basin.

The formations encountered in the succession of Middle Cambrian to Lower Ordovician rocks cropping out north of the fault and south of Elliott's Cove on the west side of the island, namely, the Chamberlain's Brook, Manuels River,



Fig. 2.2 Splintery cleavage fragments of olive green shales from the Chamberlain's Brook Formation.

Elliott Cove, and Clarenville Formations, are described below.

The Chamberlain's Brook Formation consists mainly of slightly metamorphosed, highly cleaved (Fig. 2.2) olive green shales alternating with red shales; toward the top of the formation the shales darken to grey-green or dark grey, and thin beds of grey to pinkish limestone make their appearance in the succession which has an overall exposed thickness of approximately seventy-eight metres. The formation is separated from the overlying Manuels River Formation by a fault and, immediately adjacent to the fault, shales and a thin bed of limestone of the Chamberlain's Brook Formation have been tightly folded.

The base of the Manuels River Formation is marked by a thin layer of metabentonite preserved in a recess just above the fault plane; this layer corresponds to the "unctuous white clay" of Howell (Bed 36, 1925, p.50) at the base of the formation in the Manuels River Section on the southeast side of Conception Bay. The metabentonite layer has also been recorded by Fletcher, 1972, at the same stratigraphic level in the cliffs at Weymouth, northern Smith Sound, and at Deep Cove, St. Mary's Bay (Fig. 1.1), which indicates that it is an important marker bed in the Middle Cambrian succession of southeastern Newfoundland. However, it represents only a short-lived volcanic episode and the beds above it resemble those below it, indicating that the junction between the Chamberlain's Brook and Manuels River Formations is transitional and conformable.

The Manuels River Formation is a succession of unmetamorphosed dark grey to black mudstones and shales with a few thin interbeds and lens-shaped concretions of dense grey



Fig. 2.3 Interbedded shale and siltstone, with thin to fairly thick siltstone beds, of the Elliott Cove Formation exposed south of Pt. III.



Fig. 2.4 Siltstones with shale partings, exposed in a broad, flat-crested anticline south of Pt. VII (Elliott Cove Formation).

to black limestone. Cleavage is well-developed and intersects the bedding at a high angle. The thickness of the formation is about twenty-one metres. The junction of the Manuels River Formation with the overlying Elliott Cove Formation is marked by a conglomeratic layer (3 to 10 cm thick) of mainly phosphatic clasts underlain by a conspicuous yellow-weathering band of shale. As noted earlier, the conglomerate provides evidence of a regional break in sedimentation during the late Middle Cambrian.

The Elliott Cove Formation is several hundreds of metres thick and, as Hutchinson, 1962, noted, "comprises a somewhat heterogeneous sequence of clastic sedimentary rocks" (Hutchinson, p.25). Since details of the lithology of those parts of the sequence the thickness of which could be measured are provided in Appendix One, only a brief account of the main features of the formation are given here. Shales dominate the succession but they are variable in nature. Some are soft, grey, pyritiferous paper thin shales, others are thinly bedded and micaceous, or micaceous and silty, shales, and still others are hard and dark-grey to black. Interbedded with the shales, particularly in the middle part of the succession but rarely absent altogether, are beds of siltstone (or fine-grained sandstone) generally only a few millimetres to several centimetres thick but occasionally up to 30 cm thick. At some places in the succession thin siltstones become the dominant lithology and strictly speaking, the shales are then the interbeds (Figs. 2.3 and 2.4). Some of the beds of siltstone are homogeneous, while others are laminated, but most commonly they are current-bedded and their upper surfaces bear symmetric to asymmetric linguoid ripple marks (Figs. 2.5

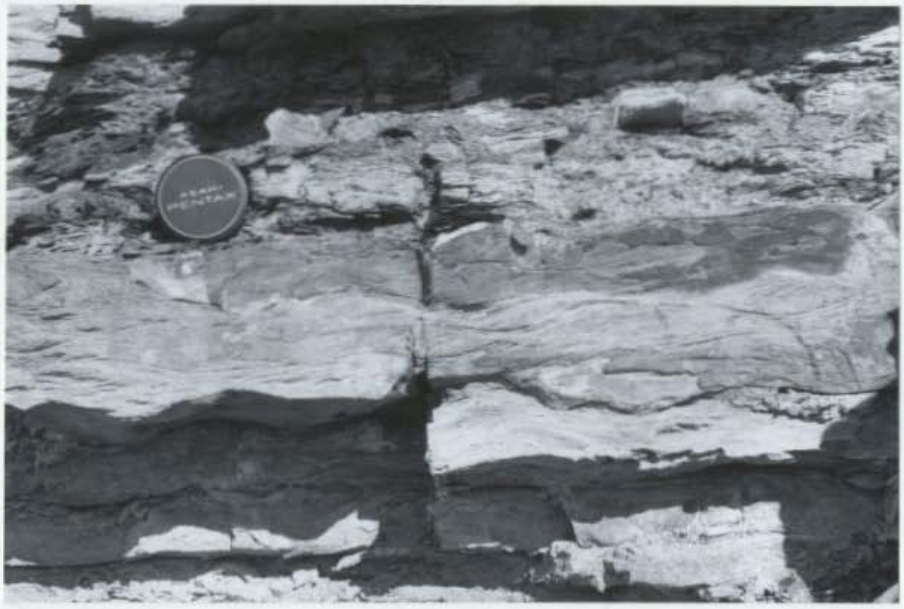

Fig. 2.5 Current bedding developed in siltstones of the Elliott Cove Formation south of Pt. VII.



Fig. 2.6 Linguoid ripple marks exposed on a number of bedding planes north of Pt. VI.

and 2.6). Judging from the current direction, the source of the sediments lay to the eastsoutheast. At some stratigraphic levels in the Elliott Cove Formation, the surfaces of thin beds of fine-grained sandstone display primary current lineation, whereas at other stratigraphic levels, the undersurfaces of beds of siltstone or fine-grained sandstone (separated from one another by shale) bear load casts (more rarely, pillows) or sole markings (flute casts, groove casts). The presence of the sole markings indicates that active current scouring of the underlying mud occurred before the overlying silt or sand was deposited.

Small to large more or less spherical to disc or lens-shaped limestone concretions are associated with the shales in some parts of the succession; some show cone-in-cone structure or, more rarely, shrinkage fractures lined or filled with calcite crystals. The thickness of the Elliott Cove Formation cannot be determined with any degree of accuracy because some parts of the section are concealed, other parts are complexly folded, and minor faults interrupt the sequence. The most recent estimate of 500 metres by Dean and Martin, 1981, represents only those parts of the section they were able to measure so that the true thickness is obviously greater than that.

The boundary between the Elliott Cove Formation and the succeeding Clarenville Formation is indistinguishable in the field as the shales at the stratigraphic level in the section where it should be are of uniform lithology. Separation of the two units, named by van Ingen, 1914b, was based on their fossil content, so that they are, in fact, biostratigraphic units. Jenness, 1963, as noted earlier, found the two units



Fig. 2.7 Chevron folding in rocks of ?Upper Cambrian/Tremadoc age between Pt. VIII and Pt. IX.



Fig. 2.8 Large lenticular concretions with cone-in-cone structure in the Clarenville Formation.

to be one indivisible lithostratigraphic unit, and mapped them together. Palaeontological data show that the boundary lies about 1 km south of Elliott's Cove. However, the latter provides only an indication of its position as a considerable thickness of shales separates the uppermost bed of the Elliott Cove Formation yielding trilobites of the Upper Cambrian Peltura Zone from the first beds in the section that contain diagnostic Lower Ordovician (Tremadocian) trilobites. Furthermore, since there is no evidence for a break in sedimentation, and younger Upper Cambrian beds than those of the Peltura Zone are known in the Cambrian succession of some parts of Scandinavia, shales of part of the intervening sequence should represent those of the youngest Cambrian trilobite zone, that of Acerocare. Despite repeated searches by the writer and Professor M. M. Anderson, no diagnostic trilobites have been found in the intervening sequence (Fig. 2.7). Thus, in the section south of Elliott's Cove, the position of the top of the Peltura Zone, the presence of the Acerocare Zone, and the position of the boundary between the Elliott Cove and Clarenville Formations (marking the position of the Cambrian-Ordovician boundary in southeastern Newfoundland) have yet to be determined.

The Clarenville Formation consists of soft, grey, micaceous shales, darker grey silty shales, and minor beds of siltstone. The shales frequently contain disc-shaped limestone concretions ranging between 30 cm and a metre in diameter. Many of the latter exhibit cone-in-cone structure (Fig. 2.8). The exposed thickness of the Clarenville Formation (no stratigraphic top has been observed) in the Elliott Cove section was estimated by Martin and Dean, 1981,



Fig. 2.9 Sills exposed in the core of a small anticline in the Elliott Cove Formation (locality 15 B).

to be 200 metres. However, as the position of the base of the formation is uncertain, parts of the formation are unexposed, and the top of the section is concealed, the true thickness of the Clarenville Formation is undoubtedly greater than 200 metres.

North of Elliott's Cove and south of the causeway linking the island to the mainland, the Upper Cambrian rocks of the Elliott Cove Formation reappear twice within the succession, which otherwise consists of younger rocks of the Clarenville Formation (Fig. 2.1). Whether the repetitions are due to faulting or to folding has not been established. A similar alternation between rocks of the Elliott Cove and Clarenville Formations occurs on the east side of the island (Fig. 2.1).

Intrusive rocks are present in the section between Fosters Point and Elliott's Cove not only in the Bonavista Formation at Cock and Hen Point but also in the Elliott Cove Formation. Buddington, 1919, reported finding several dikes and sills (augite porphyrites or basalts) intruding Cambro-Ordovician rocks of Smith and Random Sounds (the latter is situated south of the eastern end of Random Island). However, he made no finds on Northwest Arm, and the sills were not recognized by Martin and Dean, 1981, in their study of the same section; they referred to them as thick beds of sandstone. There are at least three sills low in the Elliott Cove Formation, two of which are responsible for the presence of small headlands (more resistant to erosion than the shales enclosing them), and three, possibly four, sills higher up in the formation. The latter are exposed in a small anticline at about the mid-point of the coastal section (Fig. 2.9). The intrusive rocks are all of basaltic composition. The age of

the intrusions, apart form being post-Lower Ordovician, is unknown. Greenough, 1984, established that basaltic sills intruding Cambrian rocks in the southern part of the Cape St. Mary's Peninsula, described earlier by Fletcher, 1972, are of Silurian age. However, this area lies far to the south of Random Island and the intrusive episode there may or may not be related.

CHAPTER THREE

MACROFAUNA

3.1 MACROFAUNA

Trilobites of the Acado-Baltic or Atlantic faunal realm dominate the fossil macrofauna of the Cambrian and Tremadocian sequences of the northwest part of Random Island. Inarticulate brachiopods, particularly lingulellids, are present throughout both sequences, although they are less common in the Tremadocian strata. The only articulate brachiopod so far recorded from either sequence, Orusia lenticularis Wahlenberg, is restricted to, and abundant in, part of the Upper Cambrian Elliott Cove Formation. Ostracodes are commonly associated with inarticulate brachiopods in Upper Cambrian shales. In some of the beds in which they occur together, trilobites are absent, which suggests that at times, environmental conditions on the sea floor were inimical to bottom dwelling trilobites but not to the other two groups of organisms. Hyolithids are present at a number of stratigraphic levels in the Cambrian and Tremadocian successions. Ostracodes and hyolithids have not previously been reported from the Lower Palaeozoic rocks of Random Island. Dendroid graptolites and gastropods have also been found in strata of Tremadoc age in the Random Island area, but not by the writer.

Finds of the dendroid graptolite Dictyonema in the Clarenville Formation were made by van Ingen, 1914a, b, who recorded it as Bryograptus, and by Christie (reported in

TABLE 3.1. PREVIOUS FINDS OF MACROFOSSILS IN MIDDLE CAMBRIAN, UPPER CAMBRIAN, AND LOWEST ORDOVICIAN STRATA OF THE NORTHWESTERN PART OF RANDOM ISLAND.

		TRILOBITE ZONES	VAN INGEN 1914b	BEAN 1976 BEAN AND MARTIN 1981, 1984	CHRISTIE in JENNESS 1963	HUTCHINSON 1962	POULSEN & ANDERSON 1975
TREMADOC	CLAREINVILLE FM.	PARABOLINA ARGENTINA	Bryograptus sp. Dictyonema flabelliforme Shumardia sp. → Conophrys Niobe bowsii ? → Niobella sp. Priscotelus torrensvicus → Bellella sp. Parabolina harrisia → Parabolina argentina	Ariolaptoura boothi ? Parabolina argentina	Dictyonema cf. flabelliforme Shumardia sp. Niobe beggreyi Plethometopus cf. microphthalmus Parabolina andina		
UPPER CAMBRIAN	ELLIOTT COVE FORMATION	ACEROCARE					
		PELTURA		Peltura sp.	Sphaerophthalmus alatus Peltura scarabaeoides Cloacopyge sp.	Peltura Cloacopyge postus	
		LEPTOPLASTUS		Leptoplastus sp.			
		PARABOLINA SPINULOSA	Orusia lenticularis	Parabolina spinulosa Orusia lenticularis	Parabolina sp.	Parabolina spinulosa	
		OLENUS	Olenus sp.	Olenus sp. Grandagnostus fatonensis Homagnostus obesus	Olenus cf. gibbosus Phalacroma sp. Homagnostus sp.	Olenus sp.	
		AGNOSTUS PISIFORMIS		Agnostus pisiformis	Agnostus pisiformis	Agnostus pisiformis	
		PARAGOXIDES FORCHHAMMERI					Lejopyge laevigata Paramapola laciglata
		Lower Part of Zone Unrepresented					
MIDDLE CAMBRIAN	MANUELS RIVER FM.	PARADOXIDES DAVIDIS	Paradoxides sp. Liostracus sp. Conocoryphe sp. Micmacca sp. Agnostus sp.	Paradoxides davidis	Clarella venosta	Paradoxides davidis	
		PARADOXIDES HICKSII	Paradoxides sp.	Paradoxides bioti Eodiscus cancrinus Clarella venosta Bellella laevicauda Agraulos sp.	Paradoxides bioti Bellella cf. nequalis Agraulos sp.		
	C.B. FM.*	PARADOXIDES BENNETTI		Paradoxides sp.			

C.B. FM. = Chamberlain's Brook Formation

* nomina nuda

Jenness, 1963). According to Dean (in Dean and Martin, 1981), Christie's specimen has not been traced in the Geological Survey of Canada's collections. However, Dean did find a specimen labelled "Random Island, Newfoundland" in the geology department at Princeton University that was determined by R. B. Rickards as a Dictyonema of the flabelliforme group. Thus, Dictyonema is undoubtedly present in the Clarenville Formation but recent attempts to recover additional specimens have been unsuccessful. The gastropod Bellerophon randomi (nomen nudem) was found by van Ingen in what he regarded as the uppermost beds of the Clarenville Formation (his Clarenville Series) in the Rider's Brook area on the north shore of Smith Sound (due north of the northernmost point of Random Island).

Van Ingen, 1914a, b, was the first to find trilobites and other fossils in the Lower Palaeozoic rocks of the northwestern part of Random Island and the adjacent north shore of Smith Sound. He listed the fossils for each of the formations he named, and gave new species names to several of the trilobites but the latter are invalid as he did not provide published descriptions of them. However, van Ingen's trilobite identifications have since been revised by Dean (in Martin and Dean, 1981) and both their old and new names are shown in Table 3.1, which shows the fossils that have been found to date in each formation of the Lower Palaeozoic succession.

Hutchinson, 1962, in his study of the Middle and Upper Cambrian strata of the section north of Foster's Point and south of Elliott's Cove, described much of the Elliott Cove Formation as being unfossiliferous. He found no trilobites in

TABLE 3.2: CORRESPONDING MIDDLE AND UPPER CAMBRIAN TRILOBITE ZONES OF SCANDINAVIA AND EASTERN NEWFOUNDLAND. SCANDINAVIAN TRILOBITE ZONES FROM MARTINSSON 1974; EASTERN NEWFOUNDLAND TRILOBITE ZONES FROM HUTCHINSON 1962.

	SCANDINAVIA			EASTERN NEWFOUNDLAND
	STAGES	ZONES		ZONES
UPPER CAMBRIAN		*Acerocare*	Four[1] subzones	*Acerocare*
		Peltura Zones: *Peltura scarabaeoides*	Four subzones	*Peltura*
		Peltura minor	Four subzones	
		Protopeltura praecursor	Five subzones	
		Leptoplastus	Six subzones	*Leptoplastus*
		Parabolina spinulosa	Two subzones	*Parabolina spinulosa*
		Olenus Zones: *Homagnostus obesus*	Six subzones	*Olenus*
		Agnostus pisiformis		*Agnostus pisiformis*
MIDDLE CAMBRIAN	*Paradoxides forchhammeri*	*Lejopyge laevigata*		*Paradoxides forchhammeri*
		Jincella[2] *brachymetopa*		
		Goniagnostus nathorsti		
	Paradoxides paradoxissimus	*Ptychagnostus punctuosus*		*Paradoxides davidis*
		Hypagnostus parvifrons		
		Tomagnostus atavus & *Ptychagnostus atavus*		*Paradoxides hicksii*[5]
		Triplagnostus[3] *gibbus*		*Paradoxides bennettii*
	Eccaparadoxides[4] *oelandicus*	*Eccaparadoxides*[4] *pinus*		
		Eccaparadoxides[4] *insularis*		

1: in Sweden; 2: formerly Solenopleura; 3: formerly Ptychagnostus; 4: formerly Paradoxides; 5: in some recent publications placed in Hydrocephalus

the Chamberlain's Brook Formation, three species in the Manuels River Formation, and a further three in the Elliott Cove Formation. The last are zonal guide fossils (Agnostus pisiformis, Parabolina spinulosa, and Peltura sp.), and as Hutchinson found them (individually) at widely separated localities he was able to infer that all the Upper Cambrian trilobite zones recognized elsewhere (eastern Canada and Europe), with the exception of the uppermost, the Acerocare Zone, which he did not mention, are represented in the section. Table 3.2 shows the Middle and Upper Cambrian trilobite faunal zones referred to in this study.

A number of new fossil localities were reported by Christie (in Jenness, 1963), most of them north of Elliott's Cove and north of Snooks Harbour (fig. 1.1); his trilobite finds included several species not recorded by van Ingen or by Hutchinson. The next two studies involving trilobites, those of Dean, 1970, and Poulsen and Anderson, 1975, were limited to parts of the section south of Elliott's Cove. Dean described a trilobite faunule of Lower Ordovician age collected from a thin band of shales in the Clarenville Formation just south of Elliott's Cove. Poulsen and Anderson found a sparse fauna representative of the Lejopyge laevigata Zone (the youngest Middle Cambrian faunal zone) in shales immediately overlying the conglomerate at the base of the Elliott Cove Formation, formerly considered barren; they showed that the conglomerate marks a hiatus in the succession, as a result of which the two preceding Middle Cambrian trilobite zones, those of Solenopleura brachymetopa and Goniagnostus nathorsti are missing.

Prior to the present study, the most recent search for

trilobites in the section south of Elliott's Cove (and to a more limited extent north of it) was that undertaken by Dean (in Martin and Dean, 1981) in order to determine the distribution of trilobite zones so that Martin, a specialist in acritarchs, could correlate acritarch assemblages - extracted from rock samples collected from the same sections - with those zones. Dean found Leptoplastus and other trilobites, mostly in beds considered earlier by Hutchinson, 1962, to be unfossiliferous, that enabled him to establish the approximate position of several of the zonal boundaries. However, some parts of the section, notably those in which the zonal boundaries should lie, did not yield trilobites. The most significant of the barren, or apparently barren, intervals recorded by Dean were (1) between the highest beds containing trilobites of the Olenus Zone and the lowest beds, higher in the succession, containing Orusia lenticularis indicative of the Parabolina spinulosa Zone (separated by nearly a kilometre of section along the shore), and (2) between the highest Upper Cambrian beds containing Peltura and the lowest beds of the Clarenville Formation yielding Lower Ordovician (Tremadocian) trilobites. In the latter case, since there is no evidence that sedimentation was interrupted, the intervening strata belong, at least in part, to the Acerocare Zone, the youngest of the Upper Cambrian trilobite zones.

To ensure that correlation of the acritarch assemblages of the present work with the trilobite zones would be as accurate as possible, Professor M. M. Anderson assisted by the writer, reexamined the entire section south of Elliott's Cove, firstly to confirm previously recorded fossil

localities; and secondly to find new ones in those parts of the section in which Dean failed to find them. Previous finds were confirmed and many new ones made in the Upper Cambrian part of the section. The latter greatly reduced the "collecting gaps" between the trilobite zones, including the major one noted above between the Olenus and Parabolina spinulosa Zones, so that the position of the Cambrian zonal boundaries in the section is now known to within a few metres. However, no diagnostic fossils were found in the critical part of the section referred to above in which strata of undoubted Upper Cambrian and Lower Ordovician age are separated from one another.

Map 1 (in back pocket) shows the distribution of trilobite zones in the coastal section sampled for acritarchs on the west side of Random Island between Cock and Hen Point and Elliott's Cove. The roman numerals on Map 1 indicate the small headlands that were used (in the absence of features bearing names) as the main reference points for establishing the geographic position of rocks sampled for acritarchs, macrofossil localities, and the boundaries of the trilobite zones. This scheme was devised by Dean and Martin, 1981.

CHAPTER FOUR

THE NATURE, AND CHARACTERISTIC FEATURES OF, ACRITARCHS

4.1 The Group Acritarcha

The Group Acritarcha includes a variety of microfossils of uncertain affinity, formerly called hystrichospheres, that occur in Precambrian to recent sediments. Acritarchs are, however, most abundant and diverse in early Palaeozoic rocks. They range in diameter from 500 μm down to 5 μm, and some Precambrian specimens are even smaller (1 to 2 μm). (Tappan 1980); Lower Palaeozoic acritarchs generally have a diameter of 10 μm to 50 μm (Downie 1973). The walls of these microfossils are made up of a condensed fatty acid material similar in composition to sporopollenin, the substance of which algal spores and cysts, and the spores of vascular plants, are composed (Eisenack 1963; Kjellström 1968). The name of the group is derived from the Greek words acritos = uncertain, and archae = origin. It was introduced by Evitt in 1963 because the designation 'hystrichosphere', then still in use, ceased to be valid for the majority of organic-walled microfossils grouped under that name when he showed (1961) that the type species of the genus Hystrichosphera belonged to the dinoflagellate genus Gonyaulax. The genus Hystrichosphaera, and other genera that have likewise been shown to have definite affinity with a particular group of algae, have been removed from the Acritarcha. Others, the affinities of which are less certain, have retained their acritarch status. At present,

most acritarchs are believed to individually represent the encysted stage of some form of phytoplankton, whether of one of the extant algal divisions or of a group now extinct (Tappan 1980, p.149).

The Group Acritarcha was divided by Downie, Evitt, and Sarjeant, 1963, into thirteen subgroups based on gross morphology. Other authors subsequently created additional groups or subgroups. Some of them have since been transferred to other algal divisions. None of the remaining groups or subgroups has any legal taxonomic status, and they are no longer widely used; it is now current practise in publications describing acritarchs, to arrange the genera alphabetically. Nevertheless, the subgroup concept has been retained in the present work because the author feels that, for ease of comparison, genera of similar morphology should, as far as possible, be kept in the same chapter.

4.2 Characteristic features of acritarchs

The acritarch test, or shell, comprises a hollow central body, or vesicle, that may or may not bear on its outer surface large projections (processes) and smaller projections (ornamentation or surface sculpture). Membranous veils and/or ridges may also arise from the central body; very rarely a nebula may surround the body. The arrangement of ridges, processes, and membranes on the vesicle of some acritarchs commonly corresponds to the boundaries of the polygonal plates making up the vesicle of such acritarchs. Loss of one or more of these plates may occur forming an excystment opening. There are several

other types of excystment structures (see below). However, many species show no excystment opening. Acritarchs generally occur singly, but occasionally they are associated in monospecific clusters (see Pl.6, fig.14; Pl.14, fig.1). (For definitions of the descriptive terms applied to acritarchs, see Appendix 3; text-fig. 4.1 illustrates a generalized acritarch test.)

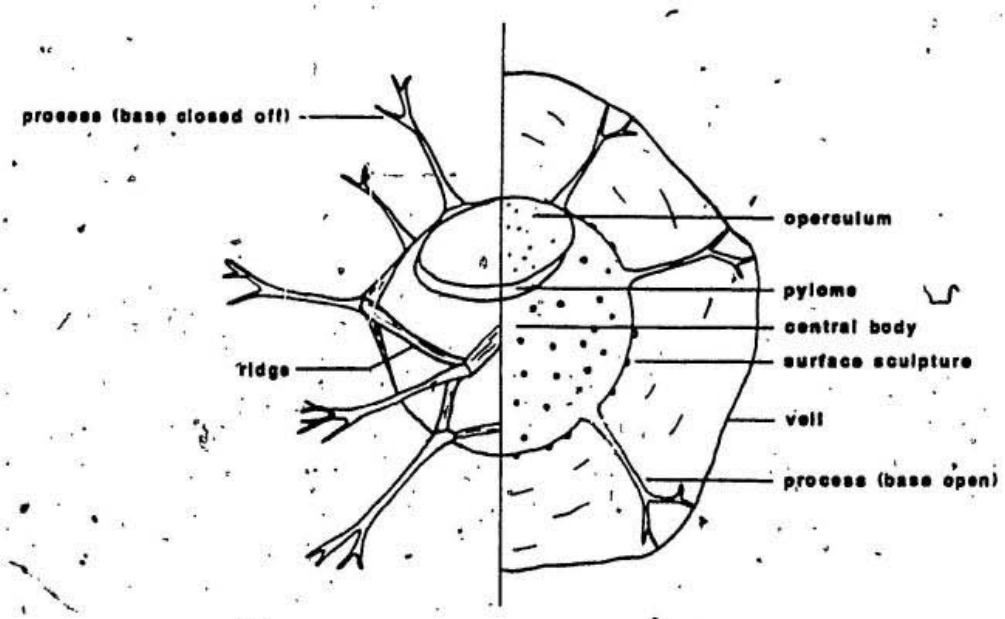

Figure 4.1. Generalized structure of the acritarch test.

Classification of the acritarchs (into genera and species) has been based largely on the following morphological features visible under the light microscope: (1) size of the central body and test, (2) shape of the central body, (3) type and distribution of processes, (4) presence or absence of veils, (5) presence or absence of an excystment opening, (6) nature of surface sculpture, if present. This last feature has, with the greater use in

recent years of the scanning electron microscope (S.E.M.) for examining acritarchs, assumed a greater importance than hitherto in the creation of new genera (e.g. Tappan and Loeblich 1971).

The first criterion, body size, is used to a limited extent in defining Lower Palaeozoic species and, more rarely, in defining genera of that age. One genus defined by many workers partly on the basis of size is the genus Micrhystridium (Deflandre 1937) Lister 1970; this genus is given an upper size limit of 20 µm. Micrhystridium is a rather extensive genus, no doubt including several genera, but it does provide a convenient grouping for most of the 'small' acritarchs whose size has been an impediment to detailed light microscope study. Here again the S.E.M. may prove valuable in providing additional morphological information that can be used as a basis for subdividing this rather cumbersome genus. In general, Lower Palaeozoic taxa are not defined on the basis of size. However, in the Precambrian, where species are simpler and fewer of them exhibit ornamentation, size is more important as a criterion for classification.

The main features used to define the acritarch subgroups are body shape and the presence and distribution of processes. The shape of the central body is usually expressed in simple terminology. Thus, Tappan (1980, p.149) used the terms "spherical, elliptical, or ovoid to discoid, arcuate, crescentic, fusiform, cylindrical, or flasklike" to describe the basic shape of the acritarch vesicle. Cramer and Diez, 1968, proposed a more formal system of geometric terminology for describing body form, but most authors still

use simple terms that, where possible, indicate the three-dimensional shape of the uncompressed body.

When processes are present on the central body, their arrangement may follow one of several basic patterns - (1) they may be distributed more or less regularly over the entire body as, for example, in the genus Baltisphaeridium Eisenack (1958) 1969, (2) they may arise from the angles of a polygonal central body as in the genus Veryhachium (Deunff 1954) Downie and Sarjeant 1963, (3) they may follow a linear arrangement defining a polygonal network as in the genus Cymatiogalea Deunff 1961, (4) they may arise from the gonal

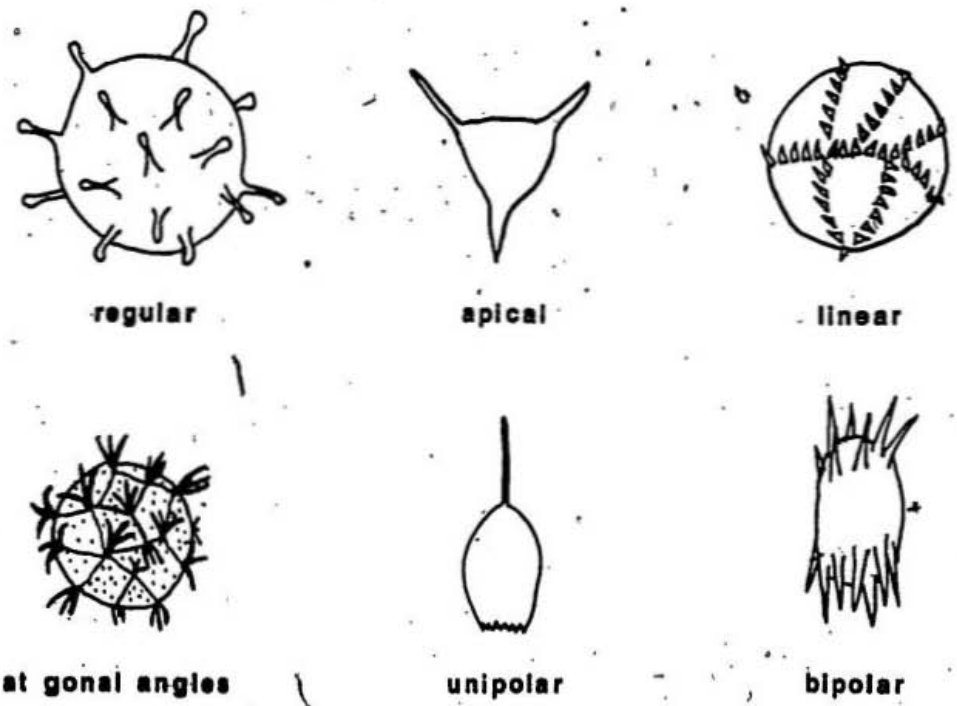

Figure 4.2. Common patterns of process distribution in acritarchs.

angles of a polygonal network on the central body as is the case with some vulcanisphaerids, (5) they may arise from a single pole as they do in the genus Volkovia Downie 1982, or (6) they may have a bipolar arrangement as in the genera Acanthodiacrodium (Timofeev 1958) Deflandre and Deflandre-Rigaud 1962 and Arbusculidium Deunff 1968. Text-figure 4.2 illustrates the main patterns of process distribution.

Not all processes on a given specimen are necessarily alike. The amount of variation in types of processes is of taxonomic significance. Four basic conditions exist: homo-

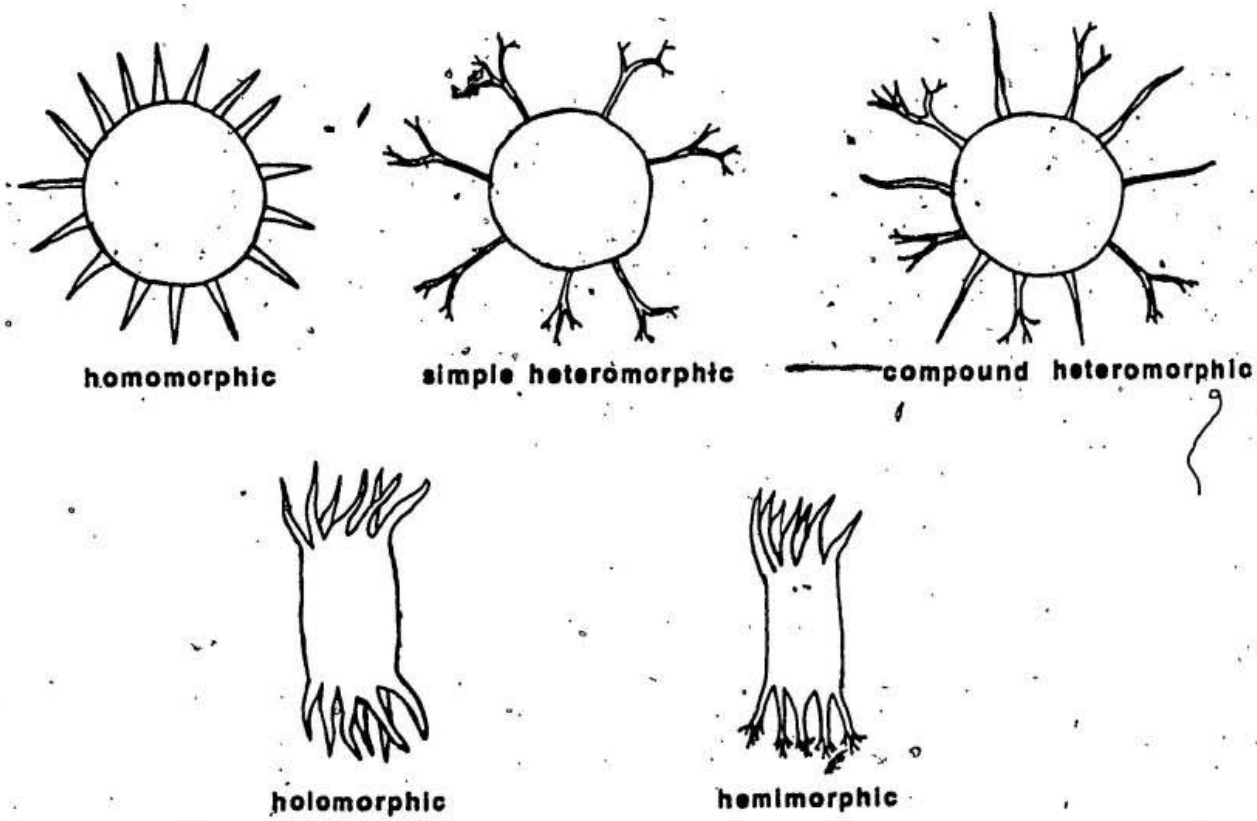

Figure 4.3. The degree of variability in types of processes in acritarchs.

morphic (all the processes of one type), heteromorphic (either simple heteromorphic, with all the processes branching, or compound heteromorphic, with some processes branching, some not), holomorphic (a bipolar arrangement in which the processes at the two poles are alike, e.g. the genus Acanthodiacrodium), and hemimorphic (a bipolar arrangement in which the processes at one pole are different from those at the other pole, e.g. the genus Arbusculidium). The species Arbusculidium rommelaeri Martin 1981 illustrates the artificial nature of these categories. It has simple processes at one pole and simple processes plus shorter interconnected processes at the other. Text-figure 4.3 illustrates the different conditions described above.

A major criterion used in the definition of genera and species is the type of processes borne by the central body. Here are considered such factors as (1) nature of the contact between process and central body, (2) communication or non-communication of process and central body cavity, (3) shape of process shaft, (4) type of process termination (see text-figures 4.4 - 4.7). A number of genera have been established on the basis of the nature of the processes of



Figure 4.4. Nature of contact between process and central body cavity.

their constituent species. For example, the genus Multiplicisphaeridium (Staplin 1961) Lister 1970 is characterized by its branching processes.

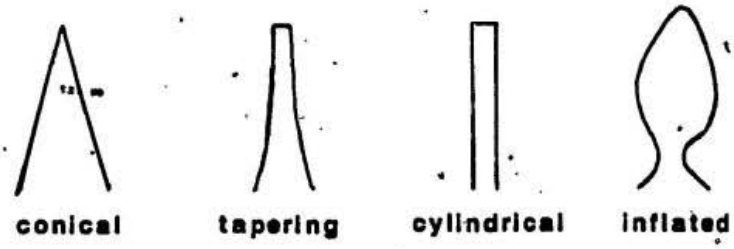

Figure 4.5. Shapes of process shafts.

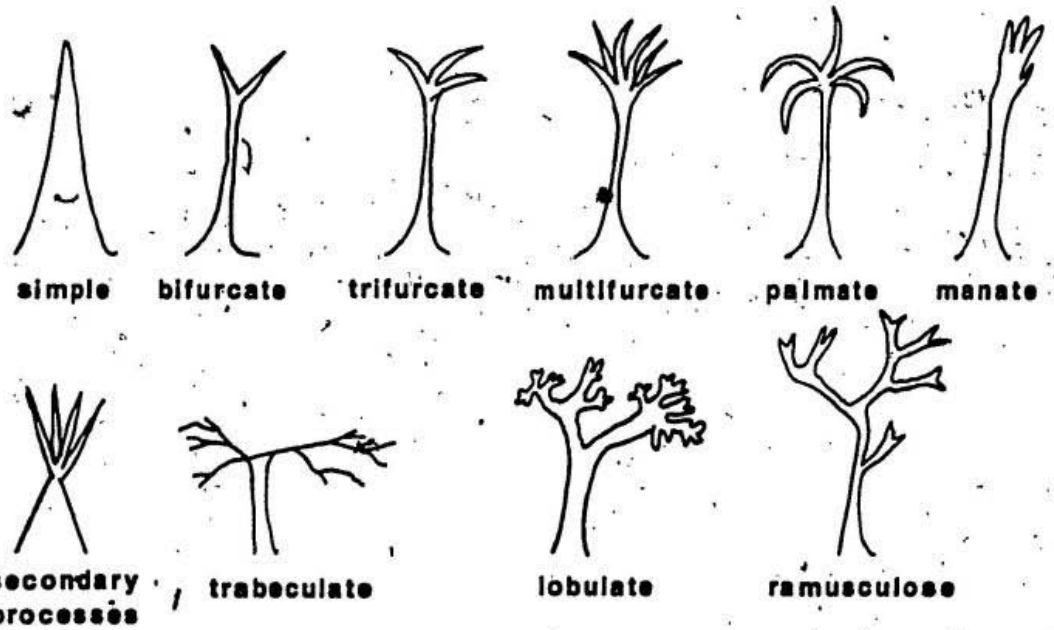

Figure 4.6. Branching patterns in processes.

Intergrading in size with processes are sculptural elements, or ornamentation, which may be present on either the central body or the processes, or on both. A problem

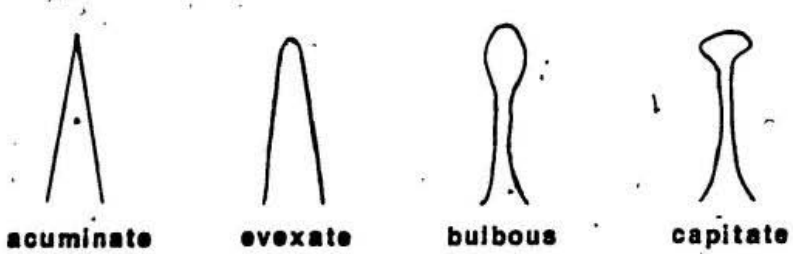

Figure 4.7. Types of termination of processes.

arises as to where to draw the line between the two types of prominences. Cramer, 1970, defined sculpture as "all kinds of small outgrowths of the ectodermal side of the vesicle wall (such as spines, ridges, hairs) which do not considerably modify the outline of the vesicle cavity" (Cramer, p.36); nevertheless, he considered the dividing line between sculpture and processes to be arbitrary. He suggested that the division between the two be set at 5 μm, those projections from the central body 5 μm or more in size being considered processes and those less than 5 μm being considered sculpture. Downie (in a laboratory manual compiled for use at the University of Sheffield) advocated a flexible 2 μm cut-off point. He felt that the latter would be more useful than one of 5 μm, especially for the separation of the process-bearing acanthomorphs from the ornamented sphaeromorphs. Text-figure 4.8 illustrates some of the common types of surface sculpture.

Most of the terminology used in describing surface sculpture has been derived, sometimes with modifications, from light microscope study of spore exines. Tappan and Loeblich (1971) conducted detailed research on the surface

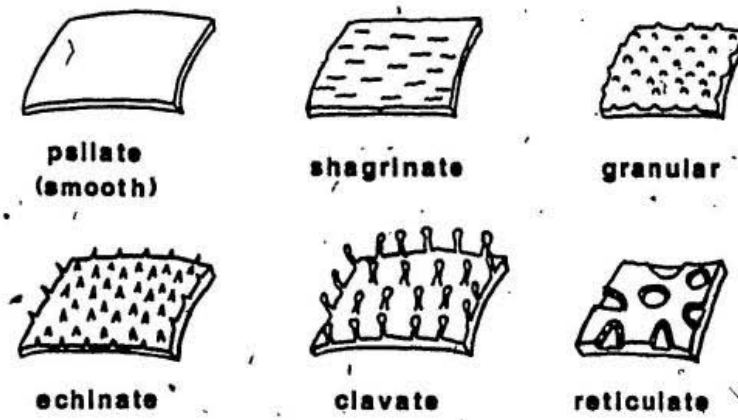

Figure 4.8. Common types of surface sculpture (from Kjellstrom 1971a).

sculpture of Lower Palaeozoic acritarchs, defining and illustrating twelve basic types of surface sculpture visible under the S.E.M. (granulate, rugulate, etc.). For sculptural elements less than 1 μm in size, they added the prefix 'micro'. A species may exhibit only one kind of ornamentation, or two or more kinds may be present on the one specimen producing a compound surface sculpture. The latter can arise by the superimposition of one kind of ornamentation on another, or through the development, on separate areas of the body, of different types of ornamentation.

In addition to processes and sculptural elements, other features may be prominent either within, on, or around the test. Occasionally the central body encloses a second body, as is the case with the genera Nucellosphaeridium Timofeev 1963 and Pterosphermopsis Timofeev 1966. Often a membrane,

or veil, may extend from the central body as is the case with many of the species of the genus Cymatiogalea (Deunff 1961) Deunff, Górka, and Rauscher 1974. Rarely, a granular to fibrous nebula envelops the test, the only reported occurrance being in the genus Granomarginata (Naumova 1961) Volkova 1968.

Another prominent feature of many acritarch tests is a relatively large opening or pylome that may be circular, oval, subpolygonal or subquadratic. The pylome is considered to be an excystment opening, comparable in function to the archaeopyle of dinoflagellate cysts. The opening may or may not have a collar of some kind and prior to excystment it is closed by a pluglike operculum. There are other kinds of excystment openings but unlike pylomes they are not preformed. Lister, 1970b, provided a comprehensive review of previous research on this feature. The main types of excystment structures are illustrated in text-figure 4.9.

One form of excystment not included in Lister's review but since reported by several authors is excystment by the loss of one or more plates. Vanguestaine, 1978, reported this phenomenon for his new genus Timofeevia; Martin, 1981, noted plate rupture as an excystment mechanism for Vulcanisphaera aff. turbata Martin 1981. In the present work, V. turbata frequently showed rupture along sutural lines, involving a loss of as much as half the shell (see pl.7, figs.4-9). Loss or partial detachment of one or several plates has also been observed in Cristallinium ovillense (Cramer and Díez 1972) Martin 1981 and in C. cambriense (Slavíková 1968) Vanguestaine 1978 (see pl.27,

figs. 1 and 8; pl.28, fig.1).

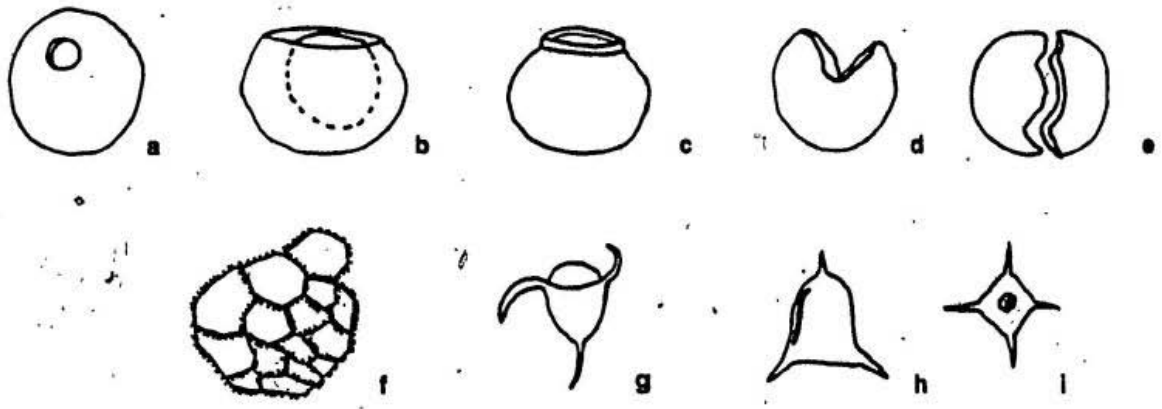

Figure 4.9. Types of excystment structures: (a) cyclopyle, (b) macropyle (large cyclopyle), (c) pylome with collar (lipped cyclopyle), (d) partial rupture, (e) median split, (f) partial detachment of plate, (g) epityche, (h) marginal split, or rupture, (i) stigma.

One feature of the acritarch test that has received limited attention is the composition of the wall. Most acritarchs seem to have walls of similar chemical composition. The few studies that have been done indicate that the walls are composed of a sporopollenin-like material.

The structure of the acritarch wall has been investigated by only a few workers. Downie, 1973, drew attention to the four types of wall structure that had been described by various authors up to that time: (1) Tasmanitid - uniform with narrow radial pores, (2) Micrhystridian - simple, homogenous, usually thin, (3)

Diacrodian - similar to the preceding, but often splits into angular plates when damaged, (4) Visbysphaerid - similar to Micrhystridian but has the capacity to develop an inner body, which gives a double wall. Jux (1971, 1975) and Martin and Kjellström (1973) studied wall structure in the genera Baltisphaeridium, Goniosphaeridium, Peteinosphaeridium, Veryhachium, Ordovicidium (as Peteinosphaeridium majorfurcatum Kjellström 1971), and Acanthodiacrodium. On the basis of their work, Tappan (1980) suggested that it may be possible to divide the acritarch genera into two broad groups: (1) those that have a "single-layered wall penetrated by two size classes of winding radial ducts, whose spacings, size, and abundance result variously in a dense (Baltisphaeridium) to a spongy appearance (Goniosphaeridium)", and (2) those that have a very thin, dense wall (appearing porous at high magnification), that may be double-layered with a pore zone between the layers. (Tappan 1980, p.152). Of the genera named above, only Acanthodiacrodium has a group (2) wall structure. The first type of wall structure is similar to that of the Prasinophyceae whereas the second type is closer to that of some dinoflagellates. However, until the wall structure of many more acritarch genera has been studied, it is premature to suggest that all acritarchs are likely to have a wall structure corresponding to that of one or another of the two kinds described by Tappan.

Ordinary light microscope observation of most acritarch walls yields little information about the wall structure other than whether it is thick or thin, double or single (this may be observable), or, on disaggregated specimens,

whether there is an underlying plate pattern (this may be determined for complete specimens if the underlying plate pattern is reflected in a polygonal arrangement of surface features). The single or double nature of the wall has been used as a diagnostic feature in the definition of some genera. The development of an inner wall, or endoderm (endophragm) adpressed to the outer wall (ectoderm, or periphragm) results in the closing off of the central body cavity from the process cavities in the genus Baltisphaeridium. This is considered a 'usual' feature of the genus, that is, the genus has a tendency to develop an endoderm, although it may be absent. Cramer (1970) considered the development of an endoderm to be a secondary feature as some, but not all, specimens of certain species show it. In his studies of selected Silurian taxa he found that populations of a particular species taken from different localities often differed drastically in the percentage of specimens which possessed an endoderm. Tappan (1980) noted that a third layer, a mesophragm, has been reported by some acritarch workers.

More detailed consideration of morphological features and their significance is included in the taxonomic chapters that follow. The acritarchs are arranged alphabetically by genus and species within the subgroups of Downie, Evitt, and Sarjeant, 1963.

The processing techniques used to isolate acritarch material and prepare it for examination are given in Appendix 2. The salient features of the Elliott's Cove section are described in Appendix 1 which also includes lists of the locations from which samples were taken. The

sample localities are shown on Map 1.

CHAPTER FIVE

ACRITARCH TAXONOMY- GROUP ACRITARCHA- SUBGROUP ACANTHOMORPHITAE

Group ACRITARCHA Evitt 1963

Diagnosis: Unicellular or apparently unicellular microfossils consisting of a test composed of organic substances and enclosing a central cavity. Shape of the test spherical, ellipsoidal, discoidal, elongate or polygonal; test surface smooth, granular, punctate or perforate. Spines or other processes, raised ridges (crests), flanges, wings or other outgrowths present or absent; where present, distributed regularly or irregularly. Inner capsule present or absent; where present, connected to the test by varied means or lacking such connection. Shell opens by rupture, splitting, or formation of a simple circular pylome. Rarely, a number of tests loosely associated in a chain. (Downie, Evitt, and Sarjeant 1963, p.7)

Subgroup ACANTHOMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having a spherical or ellipsoidal test, without an inner body and without crests. Processes isolate, simple or branching, solid or hollow, distributed arbitrarily or regularly. Without observed opening or with a simple circular pylome. (Downie, Evitt, and Sarjeant 1963, p.7)

5.1 Genus BALTISPHAERIDIUM Eisenack 1958; emend. Eisenack 1969

1958 Baltisphaeridium Eisenack gen. nov., p.398

1963 Baltisphaeridium Eisenack; emend. in Downie and Sarjeant, p.85

1965 Baltisphaeridium Eisenack; restrict. in Staplin, Jansonius, and Pocock, p.188-189

1969a Baltisphaeridium Eisenack; emend. in Eisenack, p.246-250

Type species: (Lost. holotype) Baltisphaeridium (ex-Ovum hispidium) longispinosum Eisenack 1931, p.110; pl.5, fig.10. (Neotype) Baltisphaeridium longispinosum (ex-filifera) longispinosum Eisenack 1959, p.194; pl.15, fig.1. Lower Caradoc, Aland.

Diagnosis: Shell spherical, not divided into fields, with ± numerous radial standing, mostly well separated processes, generally homogenous and hollow, the ends of which are always closed. Mostly the processes are unbranched, but on the same example there may arise branched processes beside the unbranching ones. Only rarely are all the processes branched. The cavity of the central body generally is not in communication with that of the processes. The processes are regularly (symmetrically) distributed, and are also small in number; the diameter of the body is generally more than 30 µm (most about 40-60 µm) and can be 70 µm; the overall diameter exceeds 300 µm. The (rare) pylomes are circular (normal pylome). (Trans. of Eisenack 1969)

Remarks: The genus Baltisphaeridium was created by Eisenack in 1958 through the splitting of the genus Hystrichosphaeridium. The latter, established by Deflandre in 1937, was set up to include microplankton having a test diameter greater than 20 µm, while the genus Micrhystridium, created at the same time, comprised those species with a test diameter less than 20 µm. In the case of species with a test diameter greater than 20 µm, Eisenack retained in Hystrichosphaeridium the ones that have processes with tips open at their outer ends and introduced the designation Baltisphaeridium for those in which the processes are closed distally.

Staplin in 1961 rejected the size difference between Baltisphaeridium and Micrhystridium as a generic distinction and dropped the former genus. He included all forms with simple processes, regardless of test size, in Micrhystridium and created a new genus, Multiplicisphaeridium, for species with "forked or otherwise modified processes with closed tips" that are "generally uniform within a single species". (Staplin 1961, p.404)

Downie and Sarjeant in 1963 reinstated the 20 µm size limit as a valid diagnostic difference between Micrhystridium and Baltisphaeridium and, at the same time, they rejected the validity of Multiplicisphaeridium because, as they pointed out, simple and branching processes sometimes occur together on specimens of many species.

In 1965 Staplin, Jansonius and Pocock reintroduced the genus Baltisphaeridium in a restricted sense to include forms in which there is a structural difference between the wall of the vesicle and that of the processes, as well as a tendency

for the luminae of the processes to close. In Micrhystridium the nature of the process and vesicle walls does not differ.

Eisenack, in his 1969 rediagnosis of Baltisphaeridium, did not accept the existence of any structural difference between process and vesicle walls; he did accept, however, that there is a blocking of the base of the spines on many specimens and stated that the lack of communication between the interiors of the processes and the central body cavity is a usual feature of the genus.

Kjellström, in his 1971a review of the genus, reported structural differences between the vesicle and process walls in his material from Sweden but he did not consider this feature a generic difference at the time and, therefore, retained Eisenack's emendment of the genus. That emendment is accepted here as it appears to be the diagnosis in most common usage.

Baltisphaeridium crinitum Martin 1978

Pl.1, figs.1-3, 5; Pl.31, figs.1, 2

1978 Baltisphaeridium crinitum Martin sp. nov. (in Dean and Martin), Table 2; p.7; pl.3, fig.5

1981 Baltisphaeridium crinitum Martin; Martin and Dean, p.13; pl.3, fig.1

1982 Baltisphaeridium crinitum Martin; Martin, pl.1, fig.8

Diagnosis: Vesicle globular, covered with about 100 hollow processes, the internal cavities of which do not open into the vesicle cavity. Processes conical, tapered, simple, and

pointed at the distal extremities. Surfaces are covered with fine 'hairs'; vesicle surface is slightly granulose. (Dean and Martin 1978)

Description: This form consists of large spheres, sometimes with folds, bearing in optical section approximately one hundred slightly tapering processes which do not communicate with the vesicle interior. The processes are hollow, usually truncated, and those which are entire show acuminate to evexate terminations. They vary in length from 4 µm to a recorded maximum of 20 µm; for the many specimens exhibiting truncated processes, determination of the true length of their processes is impossible. The processes are covered in weakly to strongly developed granules and in one case a 4 µm long branch was seen to arise from the base of one of the processes. (The branch was about 0.5 µm in width.) The surface of the central body is slightly to strongly granular.

Dimensions: Diameter of central body: 42-64 µm
Length of processes: 4-20 µm
Basal width of processes: 1-2.5 µm
Spacing of processes: 1-2 µm

Specimens measured: 12

Remarks: Of the twelve specimens observed, only two showed any evidence of possible excystment, and that took the form of a partial split. These specimens differ from Baltisphaeridium brevifilicum Kjellström 1971 in not possessing an excystment structure with a large operculum, and from B. magnoporatum

Kjellström 1971 in having generally longer and wider processes, and in the absence of a large excystment structure. Furthermore, Kjellström's species do not show granulation. Process length and density fall within the range defined for B. multipilosum Eisenack (1931) 1958 but the processes of that species lack the granulation present on the Random Island specimens.

Some of the Random Island specimens have much shorter processes than those of B. crinitum. Nevertheless, these specimens, as well as the long process forms, are assigned to B. crinitum on the basis of the density of processes and the presence of granules covering the processes and the central body. These granules are presumed to be the truncated 'hairs' which Martin described as being present on her Bell Island material.

Occurrence: ?Upper Cambrian/Tremadoc: AC-1, Z-5, ABC 10, AC-W, Z-4, ABC 9, 19 C, Z-3, ABC 8; Tremadoc: Z-2, Z-1, 37 C, 39 C, 40 C, 42 C, EC 5, E-C 8, E-C 7, E-C 6

Previous occurrences: Tremadoc, Bell Island, Newfoundland (Dean and Martin, 1978); Tremadoc, Random Island (Martin and Dean 1981); (?) lower Arenig, Bell Island, Newfoundland (Martin 1982)

Baltisphaeridium sp. A

Pl.1, fig.4

Description: The central body is spherical in shape and

usually shows a number of intersecting folds. Many specimens show cracking, generally with a radial pattern. The forty to fifty short, tapering, often threadlike processes visible in optical section are widely spaced. Granulation may be present on the processes, but this is difficult to determine as the processes do not generally extend beyond the perimeter of the central body and the granulation may be that of the central body superimposed on the processes. Frequently the processes are truncated. The body surface may be smooth or sparsely granular.

Dimensions: Diameter of central body: 48-59 µm
Length of processes: 3-12.5 µm
Basal width of processes: 1.5-2 µm
Spacing of processes: 2-6.5 µm

Specimens measured: 5

Remarks: Several specimens show a quadrangular pattern of folding which, in some cases, gives the effect of a pylome. In dimensions, this species resembles Baltisphaeridium trichophorum Eisenack 1965 as described by Kjellström in 1971a (p.40): "Vesicle diameter: 50 µm; process length: 7 µm; process breadth (at the base): 1 µm; process separation: 5 um. Range: vesicle diameter: 48-58 µm; process length: 7-8 um process breadth: 1 µm; process separation: 4-6 µm." However, the illustrations of that species show the processes to be less sinuous than those of Baltisphaeridium sp. A. B. brevifilicum Kjellström 1971 exhibits greater process separation - 10 µm according to the definition of the species

- but Kjellström's one illustration seems to indicate closer spacing. The basal diameter of the processes, 1.5 µm, and their more sinuous nature suggest affinity with Baltisphaeridium sp. A. Examination of the type material would be necessary before assigning these specimens to either species. B. crinitum has significantly more processes, about twice the number of Baltisphaeridium sp. A.

Occurrence: ?Upper Cambrian/Tremadoc: 19 C; Tremadoc: ?E-C 7

5.2 Genus MICRHYSTRIDIUM Deflandre 1937; emend. Lister 1970

1937 Micrhystridium Deflandre gen. nov., p.79
1961 Micrhystridium Deflandre; emend. in Staplin, p.404
1963 Micrhystridium Deflandre; emend. in Downie and Sarjeant, p.92
1965 Micrhystridium Deflandre; Staplin, Jansonius, and Pocock, p.180
1967 Micrhystridium Deflandre; emend. in Sarjeant, p.204
1970b Micrhystridium Deflandre; emend. in Lister, p.77

Type species: Hystrichosphaeridium inconspicua Deflandre 1935, p.223; pl.9, figs.11, 12. Upper Cretaceous, France.

Diagnosis: Cysts with subspherical to polygonal vesicles; processes are closed at the tips, generally homomorphic, simple, capitate, or with brief branches. Vesicle small, mean and modal diameter of vesicle generally less than 20 µm;

processes communicate freely with vesicle cavity; an inner wall, if present, is highly appressed to the outer wall. Excystment by cryptosuture, dehiscence gradual by stages; position of suture apical or near-equatorial. (Lister 1970b)

Remarks: The genus Micrhystridium has been emended frequently, with the 20 µm upper size limit being removed by Staplin (1961) and reinstated by Downie and Sarjeant (1963) when a size analysis of most acanthomorph species then recognized indicated a modal separation at 20 µm. Lister (1970b) reviewed the emendments that have been made to the genus. The 20 µm size limit provides a convenient separate category for the small forms whose structure may not be discernable because of their size until such time as better examination techniques (e.g. S.E.M.) make a further refinement of the genus possible.

Micrhystridium multiangularis Umnova 1971

PL.1, fig.6; Text-fig. 3.1

1971 Micrhystridium multiangularis Umnova sp. nov. (in Umnova and Vanderflit), p.58; pl.1, figs.12-14

Original diagnosis: Shell compressed, outline with numerous sides, thick. Every angle bears a single thin, pointed, straight or curved process. Central part of the shell folded, with one or several short narrow folds. Projections never observed in the middle part of the shell. In addition to shells bearing quite long sharp processes, there are others

that have short, blunt pillars arising from the apices of the angles (pl.1, fig.14). The latter perhaps represent the bases of broken spines. Diameter of shell 13-21 µm, number of processes 7-9, rarely 12, length of processes 3-10 µm. (Trans. of Umnova, in Umnova and Vanderflit 1971)

Description: The central body is octagonal in outline and bears 8-9 short, spine-like processes. Generally, each angle of the octagon bears a single process but occasionally two may arise from the same angle. On some specimens, pairing of processes may occur as illustrated in text-fig. 5.1 and Pl.1, fig.6, the processes constituting these pairs delimiting the four shorter sides of the octagon. The body surface is smooth. Small folds may occur.

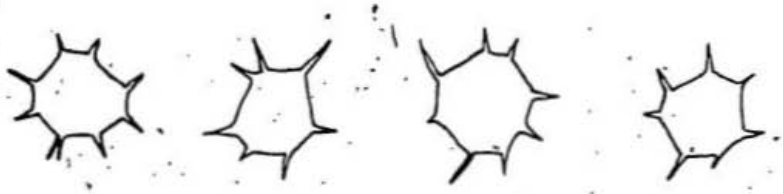

Figure 5.1. Body shape in Micrhystridium multiangularis.

Dimensions: Diameter of central body: 8.5-15.5 µm
Length of processes: 1-6.5 µm

Specimens measured: 6

Remarks: These specimens resemble Impluviculus lenticularis Martin 1977 in outline but the processes are shorter and no operculum was observed. Martin distinguishes her species from Micrhystridium multiangularis by the presence of an operculum,

a greater length for the processes, and the absence of small spines ornamenting the surface. No operculum was reported for the Random Island specimens, and the processes are very short, generally just below the lower 3 μm limit proposed by Umnova, and much shorter than the 9-12 μm range for I. lenticularis. Although Martin uses the presence of small spines on the body surface as one feature distinguishing M. multiangularis from I. lenticularis, Umnova's diagnosis of the former species does not mention an ornamentation of small spines and her illustrations of the species show unornamented as well as ornamented forms; Since the length ranges for the processes of the two species overlap, the only true difference between them is the presence of an operculum in Martin's species. In the genus Impluviculus, the presence of an operculum is not in fact a stable feature, e.g. I. milonii (Deunff 1968) Loeblich and Tappan 1969 may or may not show a dehiscence structure, so that, depending on the constancy of the presence or absence of this feature in the two species, the two may or may not be synonymous.

Vanguestaine 1973c (MS.) assigned M. multiangularis to the genus Impluviculus on the basis of Belgian material which showed an operculum. However, most of the material illustrated by Vanguestaine appears to be the same as specimens assigned to I. circularis sp. nov. in the present work. M. multiangularis does show the restriction of processes to the periphery of the shell which is characteristic of the lenticular-shaped genus Impluviculus, so Vanguestaine may indeed be correct in assigning the species to that genus. However, his material and that assigned to I. circularis in this work appears to have a rhombohedral pattern of process distribution whereas M. multiangularis has a less

regular arrangement of processes.

Occurrence: Upper Cambrian: 11 A, 8 B, 10 B, 21 B, 24 B; Tremadoc: AC-B, 37 C, E-C 7, E-C 8

Previous occurrences: lower Tremadoc, U.S.S.R. (Umnova and Vanderflit 1971)

Micrhystridium shinetonensis Downie 1958
Pl.1, figs.7-16

1958 Micrhystridium shinetonensis Downie sp. nov., p.342; fig.5a-g

1963 Micrhystridium shinetonensis Downie; Cramer, p.216

1963 Micrhystridium shinetonensis Downie; Downie and Sarjeant, p.92

?1963 Micrhystridium shinetonensis Downie; Stockmans and Willière, p.469; pl.3, fig.14; pl.2, fig.20; text-fig. 30 (considered to be of questionable synonomy by Eisenack et al., 1979)

1964 Micrhystridium shinetonensis Downie; Downie and Sarjeant, p.92

1967 Micrhystridium shinetonense Downie; Lister and Downie, p.173

1969 Micrhystridium shinetonense Downie; Martin, p.78-79; pl.1, figs.15, 58, 59, 64; text-figs. 27, 28

1970 Micrhystridium shinetonensis Downie; Cramer, p.103-104; fig.28

1971 Micrhystridium shinetonensis Downie; Gardiner and

Vanguestaine, p.178, 190

1971 Micrhystridium shinetonense Downie; Sheshegova, p.41; pl.XI, figs.9, 14

1972 Micrhystridium shinetonensis Downie; Beju, p.717

1972 Micrhystridium shinetonensis; Combaz and Peniguel, p.132; pl.1, fig.23

1973 Micrhystridium shinetonensis Downie; Martin, p.11; pl.5, fig.9

1973b Micrhystridium shinetonense Downie; Vanguestaine, p.31

1973c Micrhystridium shinetonense Downie; Vanguestaine (MS.), p.154-155; pl.XI, figs.11-16; pl. XXI, fig.7; pl.XXV, figs.8-10

1974a Micrhystridium shinetonense Downie; Potter (MS.); p.77-78; pl.20, figs.1, 2; pl.33, fig.1; text-fig. 25.18

1974 Micrhystridium shinetonensis Downie; Rauscher, p.62; pl.1, fig.9

1977 Micrhystridium shinetonensis Downie; Martin, p.24

1982 Micrhystridium shinetonense Downie; Marhoumi, Rauscher, and Vanguestaine, pl.II. fig.8

1982 Micrhystridium shinetonensis Downie; Cocchio, Table 1

Original diagnosis: Very variable; test spherical, ellipsoidal, or polygonal, length from 4-15 μm; test wall thin, glabrous, colourless and transparent in small individuals, greenish yellow in larger forms; processes simple, hollow, tapering but vary greatly and may fork or have bulbous bases; length 40-170% diameter of test, mode 60%; number in optical section 4-17, mode 8. (Downie 1958)

Description: The central body varies in shape from spherical to subpolygonal and bears from 14-27 processes in optical section. The processes may be slender and hair-like, with bases <0.5 μm wide, gently tapering, with bases about 0.75-1.0 um wide, or may consist of a triangular base up to 2 μm wide from which arises a hair-like part. (see text-fig. 5.2) Rarely, bifurcation of processes occurs distally. The surface of the central body may be smooth to slightly shagrinate.

Dimensions: Diameter of central body: 8-20 μm
Length of processes: 4-10 μm

Specimens measured: 17

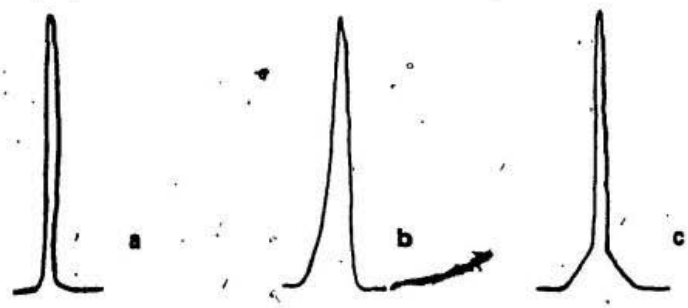

Figure 5.2. Types of processes on Micrhystridium shinetonensis: (a) hair-like, (b) tapering, (c) triangular base with hair-like extension.

Remarks: The morphology of forms considered here under Micrhystridium shinetonensis is quite variable. Downie, when he created the species in 1958, admitted that it might comprise several species, but the degree of intergradation rendered a separation unfeasible. M. shinetonensis in its various forms may resemble other Palaeozoic species - M.

stellatum Deflandre 1945, M. parinconspicuum Deflandre 1945, and M. imitatum Deflandre 1945, but Downie notes that it may occasionally show features not observed in these forms. He states, "Although it may be difficult to distinguish certain individuals from M. stellatum, M. parinconspicuum or M. imitatum it is nevertheless thought necessary to erect one new species to include all these Tremadocian forms, otherwise several new and quite artificial groups would have to be established." (Downie 1958, p.342) Thus, in the Tremadoc there are definite M. stellatum forms characterized by sturdier processes, generally few in number, that create the distinctive star-like outline of the species, as well as stellatum-like forms of M. shinetonensis.

Occurrence: Upper Cambrian: 1 A, 5 A, 6 A, 11 A, 6 B, 8 B, 10 B, 18 B, 20 B, 21 B, 22 B-2, 24 B, 30 B, 3 C, ABC 14, 5 C, ABC 13, ABC 12, Z-10, Z-7, Z-6, AC-A, AG-2, SH 13z, SH 13, SH 13y, SH 13x; ?Upper Cambrian/Tremadoc: AC-1, Z-5, Z-4, 19 C, ABC 8, 24 C; Tremadoc: Z-2, Z-1, 30 C, 32 C, 37 C, 38 C, 39 C, 40 C, 42 C, EC 5, EC 4, EC 2, EC 1, E-C 9, E-C 8, E-C 7-8, E-C 7, E-C 6

Previous occurrences: Tremadoc, Shropshire, England (Downie 1958); Tarrannonian, Silurian, Belgium (Stockmans and Williere 1963); La Vid Formation, Siegenian / Emsian (part), Lower Devonian, N.W. Spain (Cramer 1963); matrix of echinoid Myriastiches gigas, Lower Ludlovian, Silurian, England (Lister and Downie 1967); Tremadocian and Lower Arenigian, Belgium (Martin 1969); Tremadoc or Early Arenig, Ireland (Gardiner and Vanguestaine 1971); Silurian, Podolia, Siberia (Sheshegova

1971); Tremadoc - Arenig, Moesian Platform, Roumania (Beju 1972); Arenig - Llandeilo, Canning Basin, Australia (Combaz and Peniguel 1972); Tremadoc, Montagne Noire, Herault, France (Martin 1973); Upper Cambrian, Stavelot area, Belgium (Vanguestaine 1973b); Upper Cambrian - Tremadoc, Stavelot area; Upper Cambrian, Rocroi, France (Vanguestaine (MS.) 1973c); Upper Cambrian, Britain (Potter (MS.) 1974a); Tremadoc, Montagne Noire, Herault, France (Rauscher 1974); lower Tremadoc, Brabant, Belgium (Martin 1977); Arenig-Llanvirn, Morocco (Marhoumi, Rauscher, and Vanguestaine 1982); Tremadoc - Arenig, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

5.3 Genus MULTIPLICISPHAERIDUM Staplin 1961; emend. Lister 1970

1961 Multiplicisphaeridium Staplin gen. nov., p.410

1963 Multiplicisphaeridium Staplin; Downie and Sarjeant, p.87

1965 Multiplicisphaeridium Staplin; emend. in Staplin, Jansonius, and Pocock, p.180-181

1969 Multiplicisphaeridium Staplin; emend. in Eisenack, p.258-259

1970 Multiplicisphaeridium Staplin; Cramer, p.46

1970b Multiplicisphaeridium Staplin; emend. in Lister, p.83-86

1979 Multiplicispaheridium Staplin; Cramer (in Eisenack, Cramer, and Díez), p.xviii

Emended diagnosis: Vesicle hollow, spherical to ellipsoidal, single-walled; processes with closed tips, heteromorphic simple or compound branching, wall smooth or with minor ornamentation; no differentiation between vesicle wall and processes; process cavity in open connection with vesicle interior. Excystment by cryptosuture, apical or near-equatorial. (Lister 1970b)

Remarks: Staplin, when he created the genus Multiplicisphaeridium in 1961, included in it all forms with processes closed and modified distally, the processes being, for a given species, all of one type, or variations of the one type.

Downie and Sarjeant in 1963 rejected Multiplicisphaeridium as a valid genus because (1) individual specimens of many species possess both simple and multifurcate processes, and (2) different individuals of the same species may show all simple, all furcate, or simple and furcate processes. In their view, many apparently related species would be split into different genera, some going to Baltisphaeridium, some going to Multiplicisphaeridium.

In 1965, Staplin, Jansonius, and Pocock redefined the genus, and added two criteria for distinguishing it: (1) there should be no differentiation between the process and vesicle walls, and (2) the cavities of the processes and central body should be in communication with one another.

In 1969 Eisenack, who had originally rejected the genus, accepted it without making any significant modification to the diagnosis.

Cramer in 1970 totally rejected the genus on the grounds

that the closing off of the central body cavity is a result of the development of endoderm in the form of an internal cyst, a feature which he considers to be 'incidental', the result of biological age, environment, or other non-taxonomic variables. He also considered the development of surface sculpture to be a secondary characteristic.

Lister made further emendments to the diagnosis of Multiplicisphaeridium in 1970 to allow for a heteromorphic nature to the process terminations, as well as to introduce a reference to excystment. These inclusions appear valid as many species do show cryptosutural excystment and variability in the way their processes terminate.

Cramer, in Eisenack, Cramer, and Díez 1979, changed his position on the validity of the genus, distinguishing it from Baltisphaeridium on the basis of "maximum attainable process complexity" (p.xviii), rather than on the basis of separation or not of the process and central body cavities; however, he noted that such a separation due to the development of an endodermal body is almost always present in Baltisphaeridium and rare in Multiplicisphaeridium.

The genus still appears to be in common usage by most acritarch workers, although the evidence presented by Cramer for the non-diagnostic value of the closing off of the central body cavity from the process cavities is worthy of consideration. For the present, Multiplicisphaeridium is a convenient form genus.

Multiplicisphaeridium martae Cramer and Díez 1972

Pl.2, fig.1

1972 Multiplicisphaeridium sp. II; Cramer, p.2; pl.2, fig.3

1972 Multiplicisphaeridium martae Cramer and Díez sp. nov., p.42-43; pl.1, figs.5, 9; pl.2, fig.3; text-fig. 2

?1977 Multiplicisphaeridium? martae Cramer and Díez; Martin, p.7; pl.1; figs.14, 19, 23

1978 Multiplicisphaeridium martae Cramer and Díez; Fombella, p.247-248; pl.1, figs.10, 11; pl.3, fig.14

1979 Multiplicisphaeridium martae Cramer and Díez; Fombella, pl.I, fig.10; pl.II, figs.32, 35; pl.III, figs.41, 52, 55; pl.IV, fig.67; pl.V, fig.74, 77, 78

1983 Multiplicisphaeridium martae Cramer and Díez; Vanguestaine and Van Lody, pl.2, fig.7

1984 Multiplicisphaeridium sp.; Martin (in Martin and Dean), p.437; pl.57.3, fig.8

Original diagnosis: Central body spherical, clearly differentiated from the numerous processes. Processes radially oriented, columnar and fairly stiff. They vary from simple to distally manate with two or three very short pinnae; they rarely bear two dichotomous pinnulae. The processes, pinnae and occasional pinnulae are hollow. The central body cavity and the process cavities are in direct and simple connection with each other. About twenty-five to thirty-five processes visible in equatorial view.

The surface of the processes and the body is psilate; the ectoderm is about one micron thick. There is no differentiation in structure between the processes and the central body. No internal cysts or other endodermal structures observed. The mode of opening is not known. (Cramer and Díez 1972)

Description: The central body is subspherical to oval in outline and bears, in optical view, 21 to 42 slightly tapering processes which communicate freely with the central body cavity. The processes generally bifurcate distally, although some may be simple, trifurcate, or may show second order bifurcation. The terminations may be very short (less than 0.5 μm) to fairly long, terminations of 4.5 μm having been recorded. The surface of the body and processes is smooth.

Dimensions: Diameter of central body: 17-22 μm
Length of processes: 7-11.5 μm

Specimens measured: 5

Remarks: The Random Island material often has longer pinnae than does the material described by Cramer and Díez (1972). Text-fig. 2 of Cramer and Díez shows a peripheral localization of the processes but their photographic illustrations show that some central processes are also present. The Random Island specimens likewise have most of the processes arising from the peripheral region and the remainder occurring centrally. The species as illustrated by Fombella 1978 (pl.1., fig.11) and 1979, most closely resembles the Random Island material in possessing longer processes with longer pinnae.

Occurrence: Middle Cambrian: 12-20'

Previous occurrences: upper Middle Cambrian, Oville Formation, Lancara de Luna, León, Spain (Cramer 1972; Cramer

and Díez 1972); (?)Upper Cambrian - Tremadoc, Thy, Brabant Massif, Belgium (Martin 1977); Middle Cambrian, Oville Formation, León, Spain (Fombella 1978); Middle Cambrian, Oville Formation, León and Asturias, Spain (Fombella 1979); Middle Cambrian, Tacheddirt Valley, Morocco (Vanguestaine and Van Looy 1983); Middle Cambrian, Random Island (Martin and Dean 1984)

. Multiplicisphaeridium sp. A

Pl.30, fig. 18

Description: The central body is circular to polygonal in outline and bears from five to twelve processes. The bases of the processes may overlap so as to obscure the outline of the central body. Each process is made up of a broad shaft which widens before bifurcating distally, with the widening preceding each subsequent subdivision of the process. Process bifurcation up to the fourth order has been observed.

Dimensions: Diameter of central body: 26-30 µm
Length of processes: 14 µm

Specimens measured: 3

Remarks: This is a distinctive species which is quite rare.

Occurrence: ?Upper Cambrian/Tremadoc: AC-W, ABC 9, Z-3

5.4 Genus PALAIOSPHAERIDIUM Rasul 1977

1977 Palaiosphaeridium Rasul gen. nov., p.120

Type species: Palaiosphaeridium kamax Rasul 1977, p.120; pl.5, figs.1, 2. Brachiopod Beds, Tremadocian, Wrekin district, Shropshire, England.

Diagnosis: Body spherical, single walled, thin, smooth; wall ornamented with distinct, hollow, cylindrical processes, variable in length and width and nature of the tips; the tips are usually round, sometimes flat, rarely pointed; tips of a few processes are occasionally forked. The inner space of the processes communicates with the body cavity. (Rasul 1977)

Remarks: This genus differs from Baltisphaeridium Eisenack 1958 in having processes that are in communication with the central body cavity. In that respect, it fits the definition of Goniosphaeridium Eisenack 1969, but the distinctive cylindrical nature of the processes distinguishes it from the latter genus.

Palaiosphaeridium? clavigerum sp. nov.
Pl.2, figs.3-6; Pl.35, figs.5, 6

Holotype: H 43/3, slide 6 A (P) [Pl.2, fig.3]

Type locality: Locality 6 A, in the Olenus Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'claviger' - club-bearing.

Diagnosis: Spherical central body bearing 30-60 inflated processes of relatively uniform size. The processes may arise as simple drop-like projections, rounded distally and constricted at the base, or as stalked droplets borne on short, narrow 'necks'. In the former case, the processes appear to communicate freely with the central body cavity. The 'stalked' forms appear to have a plug of solid material in the narrow connection between the 'droplet' and the central body cavity. Body surface smooth.

Description: One of the specimens observed possessed a circular opening with an irregular collar. The unevenness of the collar, and the fact that the opening was observed in only one specimen, indicate that this is probably not a true pylome, and so, at present, this form is considered as not possessing an opening. The processes may be up to twice as long as wide.

Dimensions: Diameter of central body: 20-22 µm
Length of processes: 1.25-2.75 µm
Width of processes: 1.0-1.5 µm
Number of processes: 30-60

Specimens measured: 9

Remarks: This species is tentatively assigned to Palaiosphaeridium in that it possesses hollow processes which, in some cases at least, communicate with the vesicle interior.

In those forms with plugged necks, the apparent plugging of the neck may be due to the visual effect produced by the close juxtaposition of the two walls of the neck. Rasul assigned two species to this genus, Palaiosphaeridium kamax and P. mikran; the former shows a greater resemblance to this species than does the latter. Thus, some specimens of P. kamax possess short, rounded processes, as do these specimens, but otherwise the processes in that species are fewer in number in optical section (9-20) and they are neither constricted basally or of uniform width.

Micrhystridium oligum Jankauskas 1975 shows a greater resemblance to this species in possessing short processes which bulge at the tip. However, Jankauskas' species is dissimilar in that the processes may (although rarely) show branching; no branching has been observed in Palaiosphaeridium? clavigerum. As well, the size range (7-8 um) for Micrhystridium oligum is about 1/3 that for P.? clavigerum and the width to length ratio for the processes is much less (1:5 as contrasted with 1:2, or greater).

Occurrence: Upper Cambrian: 6 A

5.5 Genus STELLIFERIDIUM Deunff, Górka, and Rauscher 1974

1974 Stelliferidium Deunff, Górka, and Rauscher gen. nov., p.13

Type species: Baltisphaeridium striatulum Vavrdová 1966, p.411; pl.2, fig.3

Diagnosis: Hemispherical test bearing a large circular or polygonal opening, the diameter of which is equal to or greater than the radius of the test. The opening can be obstructed by an operculum, sometimes denticulated, and of the same shape as the opening and the surface of which is smooth, granular, or reticulate. The wall of the test, simple or double, is ornamented with varying processes from the base of which diverge a system of ridges in a star pattern. The outlines of the stars define a network with polygonal meshes at the surface of the test. A veil may be present. (Trans. of Deunff, Górka, and Rauscher 1974)

Remarks: The genus Stelliferidium contains most of those species of Priscogalea which remained after Deunff's redefinition of Cymatiogalea in 1964 expanded that genus to include non-membrane bearing forms possessing a large polar opening and processes defining polygonal fields. At that time, the residual Priscogalea species were assigned by Deunff to Baltisphaeridium. Deunff, Górka, and Rauscher (1974) stressed again the need to abandon the genus Priscogalea, and then assigned all species with a large polar opening to Cymatiogalea or to the new genus Stelliferidium of the Herkomorphitae or, in the case of those forms without ridges, a polygonal network, or a veil, to Cymbosphaeridium Lister 1970 of the Acanthomorphitae. Rasul (1974) reinstated and redefined Priscogalea, distinguishing it from Baltisphaeridium by (1) the large size of the pylome as contrasted with the small cyclopyle sometimes found in Baltisphaeridium, (2) the hollow nature of some of the processes, which may communicate with the central body cavity, and (3) the small size range of

the central body. Stelliferidium, when created, absorbed Priscogalea as redefined by Rasul. The stellate pattern characteristic of Stelliferidium is not always visible under light microscopy for all examples of a species.

Stelliferidium cortinulum Deunff 1961; comb. nov. in Deunff, Górka, and Rauscher 1974
Pl.2, fig.7; Pl. 18, figs.13, 14

1961 Priscogalea cortinula Deunff sp. nov., p.41; pl.1, figs.8, 10

1964 Baltisphaeridium cortinula Deunff; comb. nov. in Deunff, p.12; pl.1, fig.10

1967 Baltisphaeridium cortinula Deunff; Combaz, pl.III, fig.86

1973 Priscogalea cortinula Deunff; Martin, p.15-16; pl.1, figs.2-4, 12, 18; pl.IV, figs.13, 155; text-fig.5

?1973c Priscogalea cf. cortinula Deunff; Vanguestaine (MS.), p.60-61; pl.XII, fig.13; pl.XVIII, figs.4-8; pl.XXI, figs.13-15; pl.XXVIII, figs.1, 2

1974 Priscogalea cortinula Deunff; Rasul, p.50; pl.4, fig.2; pl.7, fig.4

1974 Stelliferidium cortinulum Deunff; comb. nov. in Deunff, Górka, and Rauscher, p.14; pl.3, figs.3, 4, 6; pl.4, fig.5

1977 Priscogalea cortinula Deunff; Martin, table 1

1977 Stelliferidium cf. cortinulum (Deunff) Deunff, Górka, and Rauscher; Vavrdová, pl.1, figs.1, 2

1978 Priscogalea cortinula Deunff; Dean and Martin, table

2; pl.3, fig.3

1981 Priscogalea cortinula Deunff; Martin and Dean, p.13

1982 Stelliferidium cortinulum (Deunff) Deunff, Górka, and Rauscher; Turner, p.132

1982 Stelliferidium cortinulum Deunff; Cocchio, Table 1, pl.2, fig.3

Emended diagnosis: Hemispherical shell from 30 µm to 40 µm in diameter largely defined by an opening of 20-27 µm. This opening is furnished with a lid or an operculum often adhering to or having slipped inside the shell; the operculum is a kind of membranous disc thinner on the margins, about 15 µm in diameter, designed to seal the opening of the shell. The shell bears processes over its whole surface, often bifurcated at the extremities. The base of the processes is star-like. Length of spines 5 to 7 µm. (Trans. of Deunff, Górka, and Rauscher 1974)

Description: The central body is spherical in outline, the upper third of the body being taken up by a pylome which is rimmed by a collar approximately 1.5 µm high. The pylome may bear a circular operculum. In most specimens the operculum is either missing or it has fallen inside the shell. On one specimen in which the operculum is in place, its surface bears several simple processes. The 12 to 35 processes visible in hemispheric view on the central body itself are sometimes simple but usually they bifurcate, the bifurcation varying in degree from rudimentary to pronounced. In some specimens the processes show second order bifurcation; a single specimen also exhibited third order bifurcation. The processes arise

from a triangular base, and generally the latter, as well as the proximal part of the cylindrical shaft of the process, is opaque. The length of the processes on a particular specimen does not vary greatly, although sometimes they are slightly shorter near the pylome; some polar concentration of processes may also be evident. A patterning covers the surface of the central body of several specimens. This resembles the star pattern at the base of the processes reported by Deunff, Górka, and Rauscher (1974).

Dimensions: Diameter of central body: 23-39 μm
Diameter of pylome: 19-25 μm
Diameter of operculum: 13-23 μm
Length of processes: 3-8.5 μm

Specimens measured: 10

Remarks: The processes of Stelliferidium cortinulum are generally shorter than those of Cymatiogalea bellicosa Deunff 1961 and their polar concentration is not so apparent. Also, they are more uniform in length and exhibit a less marked gradation in size from pylome to pole. However, forms which show some polar localization of processes and a less pronounced bifurcation resemble some examples of C. bellicosa in which the membrane has not been retained.

The operculum is ornamented with several simple processes. This observation was made (as noted above) on the only specimen with an operculum still in place. Ornamentation of the operculum for this species was not reported by Deunff 1961, 1964; Deunff, Górka, and Rauscher 1974; or Rasul 1974.

However, Martin (1973) did describe processes as being present on the operculum of the specimens that she studied from the Montagne Noire, France.

Occurrence: Upper Cambrian: 10 B, 21 B, 30 B, ABC 13, Z-10, Z-6, SH 13, SH 13x; ?Upper Cambrian/Tremadoc: 19 C, 24 C; Tremadoc: E-C 7-8

Previous occurrences: Tremadoc, Sahara (Deunff 1961, 1964); lower Tremadoc, Algeria (Combaz 1967); lower Tremadoc, Montagne Noire, Herault, France (Martin 1973); top of the middle Revinian, upper Revinian, and lower Salmian, Stavelot Area (Vanguestaine (MS.) 1973c); Tremadoc, Shineton Shales, Shropshire, England (Rasul 1974); Tremadoc, El Gassi, Sahara (Deunff, Górka, and Rauscher 1974); Tremadoc, Brabant, Belgium (Martin 1977); Tremadoc, Bell Island, Newfoundland (Dean and Martin 1978); Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981); Tremadoc (reworked), south Shropshire, England (Turner, 1982); Tremadoc — Arenig, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

Stelliferidium furcatum? Deunff 1961; nov. comb. and emend. in Deunff, Górka, and Rauscher 1974
Pl.2, fig.9

1961 Priscogalea furcata Deunff sp. nov., p.41; pl.1, fig.11
1964 Baltisphaeridium furcatum Deunff; comb. nov. in Deunff p.121; pl.1, fig.4
1974 Stelliferidium furcatum Deunff; comb. nov. and emend.

in Deunff, Gorka, and Rauscher, p.14; pl.7, fig.14

Emended diagnosis: Hemispherical shell, light yellow, 40 µm in diameter, furnished with a polar opening 28 µm in diameter. The shell is ornamented with short, forked processes 4 µm long. The base of the processes is star-like. (Trans. of Deunff, Górka, and Rauscher, 1974)

Description: The central body is hemispherical and is furnished with a collar 1-1.5 µm high. The operculum, when present, is circular in outline and has a granular surface. No processes are apparent on the operculum. The central body has, in hemispheric view, from 45(?)-70 narrow processes (0.5-1.0 µm wide) which show first order, and sometimes second order, bifurcation. The bifurcation is very regular, the branches of any one process being of equal length. The processes taper slightly from a triangular base. A number of processes surround the pylome. Patterning on the body surface resembles the star pattern described by Deunff, Górka, and Rauscher (but this could not be ascertained for certain as the three specimens studied were viewed only under the light microscope.)

Dimensions; Diameter of central body: 28-36 µm
Diameter of pylome: 23-28 µm
Diameter of operculum: 18 µm
Length of processes: 2-7 µm
Length of main branches: 0.75-5.5 µm
Length of secondary branches: 0.4-0.8 µm

Specimens measured: 3

Remarks: The operculum apparently lacks processes centrally and peripherally, but as the operculum was observed on only one specimen, where it was folded and in hemispheric view, it was difficult to view the periphery of the disc, and some short denticulation could have been present. This species is slightly smaller than in the diagnosis of Deunff 1961, 1964; and Deunff, Górka, and Rauscher 1974; however, the specimen figured by Deunff 1964, pl.1, fig.4, has comparable dimensions (diameter central body 35 µm, diameter pylome, 30 µm). The short, bifurcated processes suggest that this species is assignable to Stelliferidium furcatum, but as neither the original nor emended diagnosis mentions secondary bifurcation, these specimens are only tentatively assigned to that species. S. apertum Burmann 1970 does show secondary bifurcation of processes, but also exhibits trifurcation, which was not observed on the Random Island specimens. Also, the branching pattern for S. apertum appears to be more irregular and the density of processes much less (Martin 1973 quotes twenty processes for this species). S. striatulum Vavrdová 1966 has fewer processes, shows a less regular pattern of furcation, and may have multifurcate tips. S. stelligera Górka 1967, emended by Martin in 1973 to take account of the second order ramification of some of the processes, appears to have a large number of simple processes as well, and the bifurcation in general seems to be less pronounced, while the star pattern on the central body appears to be much more conspicuous. S. cortinulum Deunff 1961 generally has longer processes that are less numerous and far scarcer in the vicinity of the pylome.

Occurrence: Upper Cambrian: 21 B, 30 B, Z-10

Previous occurrences: Tremadoc, Sahara (Deunff 1961, 1964; Deunff, Górka, and Rauscher 1974)

Stelliferidium gautieri Martin 1973; comb. nov.
Pl.2, figs.10-17; Pl.3, figs.1, 2

1973 Priscogalea gautieri Martin sp. nov., p.21-22; pl.III, fig.13; pl.V, fig.21; pl.VI, fig.3; pl.VII, figs.9, 10; pl.X, figs.1-6; pl.XI, figs.1-6

1977 Priscogalea gautieri Martin; Martin, p.24; pl.IV, figs.22, 29

1981 Priscogalea gautieri Martin; Martin and Dean, p.13

Original diagnosis: Central body nearly spherical, 24 to 37 µm.

Opening: generally present, of a more or less circular outline and of a diameter falling between half and two-thirds of that of the central body.

Operculum: Outline circular to almost polygonal with a diameter of 16 to 23 µm. The central portion, 13 to 17 µm across, is scabrate. The border of the operculum is formed first by a transparent band, which is fragile, often detached, about 1 to 2 µm wide and which itself is surrounded by a second opaque band from 1 to 1.5 µm wide that has a scabrous outline. On the scanning electron microscope it appears that on complete specimens this peripheral band is narrowly attached to the rim of the opening, so that the two structures

form a collar. When the contact between the two is broken, one sinks into the plane of the central body while the other sinks into that of the operculum.

Processes: They number thirty or forty and have bases which are distinctly separated from each other. Total length from 4 to 11 µm, width at the base from 1 to 1.5 µm. They are cylindrical and hollow, the process cavities being separated from the body cavity by what appears, under the light microscope, to be an oaque zone at the base of the processes. S.E.M. photographs of broken processes show clearly a partition between the cavities. There are branchings of the first, second, and third order, of a total length of 2 to 4 µm and with thin and airy terminations. Certain processes may be simply forked with their three to eight pinnae in a rosette.

Sculpture: a network of fine 'nerves' covers the surfaces of the central body; this reticulum is irregular except around the bases of the processes where the folds (or muri) tend to be accentuated and radially arranged. This reticulum gives the body wall a scabrate aspect, when seen in profile, here and there a bit granular. The edge of the opening is ornamented with transversal grooves, more or less parallel and of varying importance. The border area may be folded over and then gives, under the light microscope, the impression of a thickening. (Trans. of Martin 1973, in Eisenack et al. 1976; p.637-638)

Description: the central body is sphèrical except for the upper 1/6 to 1/3 of the shell which is occupied by the pylome. The operculum may be attached, partly inside the shell, or missing altogether. The operculum is polygonal in shape with

a simple or ramifying process at each corner of the polygon. Specimens in which the operculum is in place when viewed from the side show no processes on the operculum. The 20-60 processes of the central body visible in hemispheric view are generally solid in appearance, sometimes hollow distally, and slightly expanded at the base. Several may join proximally to form short ridge-like structures. Distally they may show bifurcation up to the fourth order or may bear 3 or 4 very short pinnae in the rosette pattern reported by Martin; these may arise directly from the main cylindrical stem, or after primary or secondary bifurcation, or first order trifurcation, of the stem. The processes are spaced evenly over the entire shell, with the exception of the operculum, and there may be a reduction in size of the processes at or near the pylome rim. The surface of the central body is shagrinate to granular in appearance on most specimens, while several show a faint radiating star pattern at the base of the processes. Often a strongly developed, but very irregular, ridge or fold pattern delimits roughly polygonal areas.

Dimensions: Diameter of central body: 23-34 μm
Diameter of pylome: 12-28 μm
Diameter of operculum: 14-18.5 μm (from 5 specimens only)
Length of processes: 2.5-11.5 μm

Specimens measured: 17

Remarks: This species is transferred to the genus Stelliferidium on the basis of the radially arranged series of

'nerves' at the base of the processes. This species generally shows a more ramifying branching pattern to the processes than other members of the genus Stelliferidium. The ridge-like patterning may be strongly to weakly developed and may occur in combination with the stellate pattern, although not always. Sometimes the ridges are incomplete, as in Martin's illustration of the species. At other times they enclose irregular polygonal areas. Whether these are true ridges or merely folds is difficult to determine. They are most strongly developed in those forms with sturdy, thick proccesses with short multifurcate terminations arising from the main stem or after an initial bifurcation of the stem. (See pl.2, fig.17) These forms may be a separate species, but the difficulty of distinguishing these forms from folded specimens of S. gautieri proper (if indeed a valid distinction exists) has led the author to retain them, for the time being, in S. gautieri.

Occurrence: Upper Cambrian: 11 A, 8 B, 10 B, 21 B, 22 B-2, 24 B, 30 B, 3 C, ABC 14, ABC 13, ABC 12, Z-10, Z-8, ABC 11, AC-2, SH 13, SH 13x

Previous occurrences: Tremadoc, Montagne Noire, Herault, France (Martin 1973); Tremadoc, Brabant Massif, Belgium (Martin 1977); Upper Cambrian-Tremadoc, Random Island, (Martin and Dean 1981)

Stelliferidium striatulum Vavrdová 1966; comb. nov.
Deunff, Górka, and Rauscher 1974

Pl.3, figs.3, 5, 6

1966 Baltisphaeridium striatulum Vavrdová sp. nov., p.411-412; pl.1, fig.2; pl.2, fig.3; text-fig.3a

1966 Baltisphaeridium hydraferum Stockmans and Willière 1962; Martin, p.427; text-figs.2, 3 (assigned to B. striatulum by Martin 1969)

1969 Baltisphaeridium striatulum Vavrdová; Martin p.64-65; pl.I, figs.33, 42, 45; pl.V, figs.246, 247; pl.VI, figs.255, 259, 303, 304; text-fig.18

1970 Priscogalea striatula Vavrdová; comb. nov. in Paris and Deunff, p.30-31; pl.11, figs.5, 9

1974 Stelliferidium striatulum Vavrdová; comb. nov. in Deunff, Górka, and Rauscher, p.16; pl.6, figs.2, 19, 20

1978 Priscogalea striatula (Vavrdová) Paris and Deunff; Dean and Martin, Table 2; pl.2, fig.11

1980 Stelliferidium striatulum (Vavrdová) Deunff, Górka, and Rauscher; Wolf, p.69

Original diagnosis: Shell with circular, rarely oval or subpolygonal outline, with large circular or subpolygonal opening (pylome). Number of radial processes relatively high (about 35). Processes very variable in size and shape, usually with thinner walls than the central body, with a rather thickened narrow base. Surface of shell sculptured with low ridges, connected together at the base. Diameter of central body: 35 40 40 40 40 42 42 42 44 44 46 55 68 µ. Length of processes: 6 6 6 8 9 3 6 9 6 12 12 15 5 µ. (Vavrdová 1966)

Description: The central body is circular in outline with a pylome occupying the upper 1/3 to 1/4 of the shell. From the central body arise, in hemispheric view, twenty-five to thirty-five hollow, cylindrical processes which are closed off from the central body cavity. The processes are often truncated, but complete ones show multifurcate terminations. There is no polarization of process distribution, although one specimen shows a reduction in size of processes at the pylome rim. The operculum, present on two specimens, bears two processes. A star-like pattern of radiating lines extending outward from the bases of the processes is observed on some specimens, while a granular surface is visible on others.

Dimensions: Diameter of central body: 29-36.5 μm
Diameter of pylome: 12.5-35 μm
Length of processes: 2-12.5 μm

Specimens measured: 6

Remarks: This species resembles Stelliferidium stelligerum Górka 1967 in possessing a pattern of lines radiating from the bases of the processes. It differs in that its processes are multifurcate distally rather than simple or bifurcate, and in having a less pronounced stellate pattern.

Occurrence: Upper Cambrian: 21 B, 22 B-2, 30 B, ABC 11, AC-2, SH 13z, SH 13, SH 13x; ?Upper Cambrian/Tremadoc: 19 C

Previous occurrences: Arenig, Klabava Shales, Central Bohemia (Vavrdová 1966; Deunff, Górka, and Rauscher 1974); Arenig,

Llandeilo, Sart-Bernard, Belgium (Martin 1966); Tremadoc, Arenig-upper Llanvirn, Caradoc, Belgium (Martin 1969); Llanvirn, Roche-au-Merle, France; (Paris and Deunff 1970); Arenig, Bell Island, Newfoundland (Dean and Martin 1978); Tremadoc, Celtiberia, northeastern Spain (Wolf 1980)

5.6 Genus TIMOFEEVIA Vanguestaine 1978

1978 Timofeevia Vanguestaine gen. nov., p.272

Type species: Multiplicisphaeridium lancarae Cramer and Diez 1972, p.42; pl.1, figs.1-4, 6, 8; text-fig.1

Diagnosis: Hollow shell, polygonal, made up of a grouping of polygonal facets. According to the number of facets, the outline of the shell is either polygonal or rounded. Thin membrane, apparently composed of a single layer. The facets are delimited by thickened sutures, sometimes protuberant as membranous ridges. Often, they are incurved towards the centre of the shell. Processes simple, bifurcated, or ramifying, hollow or partially hollow and communicating freely with the central cavity of the shell. They are carried by the sutures of the facets, distributed on these last or confined to their points of convergence. Dehiscence structure apparently constitutes the loss of a number of polygonal facets. (Trans. of Vanguestaine 1978)

Remarks: This genus differs significantly from the genus Cymatiogalea Deunff 1961, which also has a system of polygonal

fields, in the nature of the dehiscence structure. In Timofeevia, it consists of one or more plates of the same size as those forming the rest of the shell, whereas Cymatiogalea has a single large operculum with a diameter greater than that of the normal plates. Moreover, the presence of an opercular opening is an almost constant feature in Cymatiogalea whereas it is rare in Timofeevia. The nature of the proximal part of the processes of the two genera also provides a means of distinguishing one from the other. In Timofeevia the processes open into the central body cavity, whereas in Cymatiogalea they are nearly always closed proximally.

Timofeevia bifurcata sp. nov.

Pl.3, figs.7-10

Synonymous with:

1973c Timofeevia brevibifurcata Vanguestaine (MS.) sp. nov., p.253-254; pl.XII, figs.15-18; pl.XXII, figs.4-6

1974a Timofeevia brevibifurcata Vanguestaine (MS.); Potter (MS.) p.178-180; pl.22, figs.10-12; pl.34, fig.9

Holotype: ST 43, slide 21 B 20-150 µm (1) [Pl.3, fig.9]

Type locality: Locality 21 B, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'bi' - two - and 'furcatus' - forked.

Diagnosis: Central body spherical in outline and divided by a series of ridges into approximately thirty to forty-five polygonal, generally hexagonal, fields in optical view. At the gonal angles, and occasionally intergonally as well, the ridges bear short processes that are usually simple but which may show first order, and, more rarely, second order, bifurcation. Bifurcations vary in length from 0.75 to 1.5 μm. Stem of the processes is cylindrical and varies from 0.75 to 1.0 μm. in width. Surface of the central body is smooth.

Dimensions: Diameter of central body: 27-38 μm
Length of processes: 1-3 μm
Diameter of fields: 5-8 μm

Specimens measured: 7

Remarks: This species differs from Timofeevia phosphoritica Vanguestaine 1978 in possessing a greater number of polygonal fields, thirty to forty-five on the Random Island specimens as contrasted with fifteen to twenty-five in Vanguestaine's diagnosis of T. phosphoritica and eleven to eighteen on the Random Island representatives of that species. Vanguestaine does not state the number of polygonal fields for his unpublished species T. brevibifurcata which is synonymous with T. bifurcata. He just states that it has a greater number than does T. phosphoritica. Vanguestaine also notes that the diameter of the fields is smaller on T. brevibifurcata, 4.5-7.5 μm, as contrasted with 10-12 μm on T. phosphoritica. The Random Island specimens of Timofeevia bifurcata have fields from 5 to 8 μm in diameter.

Furthermore, the processes are shorter and have simpler terminations than in Timofeevia phosphoritica. The specimens here are generally larger than those reported by Vanguestaine. Potter 1974a (MS.) noted a similar size variation in his material, with approximately half his specimens being above the upper limit of Vanguestaine's range. One specimen of the Random Island material shows a slight rupture in the shell (see pl.3, fig.10) but this may represent damage to the shell rather than being an excystment structure. Vanguestaine reports a polar opening on some specimens but attributes it to the removal of a plate corresponding to several polygonal fields rather than to the loss of a single opercular plate as occurs in Cymatiogalea.

Occurrence: Upper Cambrian: 21 B, 3 C, ABC 14, ABC 13, ABC 12, Z-10

Previous occurrences: (?)late Middle Cambrian, Revinian, top of Rn2b, Stavelot; Tremadoc, top of lower Salmian Sm1b, Stavelot, Belgium (Vanguestaine (MS.) 1973c); Upper Cambrian, England (Potter (MS.) 1974a)

Timofeevia? cf. bifurcata sp. nov.

Pl.3, fig.11

Description: The central body is roughly oval in outline and is divided into approximately fourteen polygonal fields by low ridges. From the ridges arise bifurcating processes (these may show rudimentary secondary bifurcation, but this is

difficult to determine for certain), single processes occur gonally and intergonally. Some proceses arise from the middle of the polygonal fields with no apparent connecting ridges. The body surface is smooth.

Dimensions: Diameter of central body: 25.5 µm
Diameter of fields: 6-8 µm
Length of processes: 2.5-3.5 µm

Specimens measured: 1

Remarks: This specimen resembles Timofeevia bifurcata Vanguestaine 1973c (MS.) in possessing polygonal fields bearing bifurcating processes gonally and intergonally. However, the number of polygonal fields is much smaller and they are less regular in outline, than in that species. T. phosphoritica Vanguestaine 1978 has a comparable number of polygonal fields but rarely shows intergonal processes, and it has a more varied branching pattern. There is an opening at one end of the shell, so it is possible that this specimen may belong to the genus Cymatiogalea rather than Timofeevia, but the opening seems to be less regular than is the case for Cymatiogalea.

Occurrence: Upper Cambrian: 21 B

Timofeevia? cuspidata sp. nov.
Pl.6, figs.10-14; Pl.35, fig.2

Holotype: N26, 6 A 10-20 [Pl.6, fig.10]

Type locality: Locality 6 A, in the Olenus Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'cuspidatus' - bearing points.

Diagnosis: Polygonal to subpolygonal body divided into fields by ridges which bear short processes (broad triangular points), one or two processes occur intergonally and a single processes is present at each gonal angle. The processes are about 1 μm high and up to 2 μm wide at the base. Body surface smooth. Tests occur singly or in clusters.

Description: This species commonly occurs in clusters of 2 or 3, and groupings of up to 8 have been observed.

Dimensions: Diameter of central body: 20-33 μm
Diameter of fields: 9-13 μm
Number of fields: 5-10

Specimens measured: 11

Remarks: This species is tentatively assigned to Timofeevia as the central body is divided into polygonal fields and the 'processes' are borne gonally and intergonally; they do not, however, resemble the processes of other species of Timofeevia. This form resembles some specimens of T. pentagonalis in which the processes have been truncated, but

no ramifying processes have been observed on T.? cuspidata.

T.? cuspidata is restricted to one sample, whereas T. pentagonalis, present in the same sample, has also been found at higher stratigraphic levels. Electron microscope comparison of the two species shows T. pentagonalis specimens from this level to have a pronounced granular surface while T.? cuspidata has a smooth surface. Truncated processes of T. pentagonalis observed under S.E.M. are square rather than triangular as they are in T.? cuspidata and they are narrower basally.

Occurrence: Upper Cambrian: 6 A

Timofeevia lancarae Cramer and Díez 1972; comb. nov. Vanguestaine 1978

Pl.3, fig.12; Pl.4, figs.1-4; Pl.33, fig.2

1972 Multiplicisphaeridium sp. I; Cramer, pl.1, figs.1-3

1972 Multiplicisphaeridium lancarae Cramer and Díez sp. nov., p.42; pl.1, figs.1-4, 6, 8; text-fig.1

1974a Timofeevia sp. B; Potter (MS.) p.189-190; pl.8, figs. 9-11; pl.11, figs.16, 17; pl.13, figs.16, 17; pl.14, figs.8, 9b pl.16, fig.17; pl.31, figs.11-13; pl.34, fig.12

1976 Multiplicisphaeridium lancarae Cramer and Díez; Vavrdová, p.61; pl.4, fig.7; text-fig.3

1976 Baltisphaeridium vilnense Jankauskas, p.188; pl.XXV, figs.1, 2?, 3, 6

1978 Timofeevia lancarae Cramer and Díez; comb. nov. in

Vanguestaine, p.272

1978 Multiplicisphaeridium lancarae Cramer and Díez; Fombella, pl.2, figs.6, 7

1979 Timofeevia lancarae (Cramer and Díez) Vanguestaine; Fombella, pl.V, figs.70, 71, 73, 76

1981 Timofeevia lancarae (Cramer and Díez) Vanguestaine; Martin and Dean, p.20-21; pl.2, figs.1-3, 8, 9, 11, 12, 19, 20; pl.6, figs.1; 2 (aff.), 3, 5, 7, 8

1982 Timofeevia lancarae (Cramer and Díez) Vanguestaine; Martin, pl.1, fig.20

1983 Timofeevia lancarae (Cramer and Díez) Vanguestaine; Vanguestaine and Van Looy, pl.2, figs.10-13

Original diagnosis: Central body subspherical, clearly differentiated from the processes. Processes radially oriented, columnar, and somewhat flexible. They are regularly bi- or trifurcated and may bear pinnulae of up to the fourth order. The processes and basal portions of some of the thickest pinnae are hollow; the remaining portions are solid. From ten to twenty processes are visible in equatorial view. The central body cavity and the process cavities are in direct, simple connection with each other.

The surface of the body and the processes is psilate. The ectoderm is about one micron thick; there is no differentiation in structure between the processes and the central body. No internal cysts or other endodermal structures. The mode of opening of the ectoderm is not known.

Dimensions: Diameter of the central body twenty-five to forty microns; process length thirty to fifty percent of the body diameter. (Cramer and Díez 1972)

Description: The specimens have a spherical to polyhedral central body bearing sixteen to twenty-one hollow irregularly branching processes that communicate freely with the central body cavity. Branching up to the fourth order has been observed. The process stems are columnar, the pinnulae fine and often intertwined. The surface of the central body is divided by membranous ridges into poorly to more clearly defined polygonal fields which often look like folding of the body wall. Often the ridges are incurved towards the centre of the shell, giving them the appearance of membranes connecting the processes. The body surface is smooth, shagrinate, or slightly granular.

Dimensions: Diameter of central body: 30-39 μm
Length of processes: 10-30 μm
Width of processes (at mid-length): 1-2.5 μm
Ratio of process length to body diameter: 0.39-0.88 to 1.0

Specimens measured: 12

Remarks: Cramer amd Díez reported ridges and folds connecting the bases of the processes but ascribed them to deflation of the central body prior to fossilization. Vanguestaine in 1978 created the genus Timofeevia and made Multiplicisphaeridium lancarae the type species. He described the folds and ridges as defining a polygonal network on the surface of the shell. These ridges, when incurved, cause the species to resemble members of the genus Cymatiogalea Deunff (1961) 1964.

However, Vanguestaine notes that for Timofeevia the processes arise from the distal part of the apparent membrane whereas for Cymatiogalea the processes arise from the base of the membrane. In addition, the processes in the former genus are in communication with the central body cavity whereas those of most species of the latter genus are closed proximally.

This species differs from Timofeevia phosphoritica in possessing longer, more ramusculose processes. However, some forms with intermediate characteristics are difficult to assign with certainty to either species.

Occurrence: Upper Cambrian: C+11, 1 A, 5 A, 6 A, 7 A, 11 A, 8 B, 10 B, 20 B, 21 B, 22 B-1, 22 B-2, 24 B, 3 C, C-10, SH 13z

Previous occurrences: upper Middle Cambrian, Oville Formation, Lancara de Luna, León, Spain (Cramer and Díez 1972); Upper Cambrian, England (Potter (MS.) 1974a); Lower Cambrian, Prebaltic area (Jankauskas 1976); Middle Cambrian, Jince Formation, Skryje, Czechoslovakia (Vavrdová 1976); Middle Cambrian, Oville Formation, León, Spain (Fombella 1978); upper Middle Cambrian, Oville Formation, León and Asturias, Spain (Fombella 1979); upper Middle Cambrian and Upper Cambrian, Random Island (Martin and Dean 1981); Upper Cambrian, Random Island (Martin 1982); Middle Cambrian, Tacheddirt Valley, Morocco (Vanguestaine and Van Looy 1983)

Timofeevia microretis Martin 1981

Pl.4, figs.5, 6; Pl.5, figs.1, 4

1981 Timofeevia microretis Martin sp. nov. (in Martin and Dean), p.21; pl.2, figs.4, 10, 13, 16, 17

1982 Timofeevia microretis Martin; Martin, pl.1, fig.15

Original 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 percent 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. (Martin 1981)

Description: The central body is roughly spherical and covered by approximately one hundred (in one case ~fifty) processes in optical view; these subdivide distally into fine pinnae and pinnulae and give an overall 'woolly' appearance to the test. The processes are hollow and in communication with the central body cavity. The proximal part of each process is a broad shaft. Shafts vary considerably in width (from 1.0-3.5 μm) and they may or may not subdivide distally before giving rise to the more delicate final terminations.

Dimensions: Diameter of the central body: 30-48 μm
Length of processes: 7-16 μm

Specimens measured: 9

Remarks: The dense crowding of the processes makes it difficult to determine the precise nature of the branching pattern. Ridges delimiting polygonal areas are also obscured by the crowding. In those specimens in which it was possible to observe isolated processes, the main shafts of the latter are of uniform width. However, in some cases there is either a slight distal tapering, or a distal expansion of the shaft.

This species was found to be fairly common in sample 6 A, and here, all examples showed the close spacing of processes. One specimen was recorded from the slightly higher sample 11 A, and that one showed many fewer processes (~fifty in optical view).

Occurrence: Upper Cambrian: 5 A, 6 A, 11 A, 1 B

Previous occurrences: lower part Elliott Cove Formation, early Upper Cambrian, Random Island (Martin and Dean 1981); Upper Cambrian, Random Island (Martin 1982)

Timofeevia pentagonalis Vanguestaine 1974; comb. nov. in Vanguestaine 1978

Pl.5, figs.2-13; Pl.35, fig.1; ?Pl.18, fig.12

1968 cf. Cymatiogalea sp. 1; Vanguestaine, p.364; pl.1, figs.6, 7

1970 Archaeohystrichosphaeridium cf. pentagonum Timofeev 1959; Vanguestaine, p.594

1973b Archaeohystrichosphaeridium cf. pentagonum Timofeev 1959; Vanguestaine, p.31

1973c Timofeevia pentagonalis; Vanguestaine (MS.); p.255-257; pl.IX, figs.23-25; pl.X, figs.26-28; pl.XII, figs.21-24; pl.XX, figs.22-23; pl.XXI, fig.11; pl.XXII, figs.16-19

1974 Polyedryxium? pentagonalis sp. nov.; Vanguestaine, p.75-76; pl.II, fig.1

1974a Timofeevia pentagonalis; Potter (MS.), p.183-185; pl.8, figs.1-3; pl.11, fig.13; pl.13, figs.13-14; pl.16, fig.14; pl.22, figs.13-16; pl.31, figs.5, 6; pl.34, fig.10

1978 Timofeevia pentagonalis Vanguestaine; comb. nov. in Vanguestaine, p.272; pl.III, figs.17-21, 23-25

1981 Timofeevia pentagonalis Vanguestaine; Martin and Dean, p.21; pl.5, figs.7, 9

Probable synonyms (as stated by Vanguestaine 1974):

1959 Archaeohystrichosphaeridium pentagonum Timofeev sp. nov., p.46; pl.II, fig.7O; pl.XXIII, fig.10

1966 Archaeohystrichosphaeridium pentagonum Timofeev; Timofeev, pl.XXIX, fig.13; pl.XXXI, fig.13; pl.LXXXVII, fig.9; pl.LVII, fig.14

Original diagnosis: Central body: polyhedral, or more commonly with a pentagonal outline. Diameter: 20.5-30 µm. Facets ± flat or incurved towards the interior, from 7-10 in number according to the specimens. They are pentagonal or quadrangular in shape and are bounded by thickened or projecting sutures. Their diameter varies between 9-16 µm.

Membrane: 0.25-0.5 µm in thickness, apparently made of a single layer. Processes: 3 or 4 in number per ridge, 2 at the intersection of the sutures, 1 or 2 between the nodes of the network. Slender in form, 2.5-6 µm in height, with a trunk 0.3 µm wide. Base slightly widened on the shell. Distal extremity bifurcated or ramified by successive bifurcations. Sometimes they are hollow and open proximally, but most often solid at their greatest height. Ornamentation: membrane indistinctly smooth, shagreen or microgranular. Dehiscence structure: not visible. (Trans. of Vanguestaine 1974)

Description: The central body is polygonal, or, more commonly, sub-pentagonal (somewhat heart-shaped), in outline, and its surface is divided into six to ten polygonal fields by a series of ridges. Arising from the ridges are from thirty to fifty processes in optical view, one to two processes occurring intergonally and one at each gonal angle. The processes appear to be solid. They comprise a cylindrical proximal part and an expanded, often multifurcate, distal termination. The termination may simply consist of a fan-shaped widening of the end of the process, with no actual branching occurring, or the process may divide distally into three or more short branches. An initial bifuration of the cylindrical stem may precede this multifurcate branching. The surface of the central body may be smooth, shagrinate, or granular.

Dimensions: Diameter of central body: 23-28 µm

Length of processes: 3-4.5 µm

Specimens measured: 16

Remarks: This species overlaps Timofeevia phosphoritica Vanguestaine 1978 in nearly all aspects of its morphology. Vanguestaine (1978) distinguished the two species from one another by the number of polygonal fields that each of them typically possesses: seven to ten for T. pentagonalis and ±fifteen to twenty-five for T. phosphoritica. However, there are, as Vanguestainé recognized, transitonal forms with an intermediate number of fields. The difficulty of making an accurate count of the fields on some specimens also renders their identification difficult. T. phosphoritica generally has no intergonal processes, but as there are exceptions, that distinction is of limited use. Clearly, oval-pentagonal forms with a low number of polygonal fields can be readily assigned to T. pentagonalis, whereas more spherical specimens with intergonal processes and an intermediate number of polygonal fields cannot be assigned with certainty to either species.

Occurrence: ?Middle/Upper Cambrian: C+11; Upper Cambrian: 1 A, 5 A, 6 A, 7 A, 10 A, 11 A, 1 B, 6 B, 8 B, 10 B, 20 B, 21 B, 22 B-1, 22 B-2, 24 B, 30 B, 3 C, ABC 14, ABC 13, ABC 12, Z-10

Previous occurrences: Cambrian, Grand Halleux, Belgium (Vanguestaine 1968, 1970, 1972, 1973c (MS.), 1978); Upper Cambrian, Belgium and the French Ardennes (Vanguestaine 1974); Middle Cambrian, Spain; Upper Cambrian, British Isles (Potter (MS.) 1974a); Middle-Upper Cambrian, Random Island (Martin and Dean 1981)

Timofeevia phosphoritica Vanguestaine 1978

Pl.5, figs.14, 15; Pl.6, figs.1-6

1968 Archaeohystrichosphaeridium ianischewkyi Timofeev 1959; Vanguestaine, p.365; pl.1, figs.10-12

1970 Archaeohystrichosphaeridium ianischewkyi Timofeev 1959; Vanguestaine p.593-594

1973c Timofeevia phosphoritica; Vanguestaine (MS.), p.258-261; pl.VII, figs.24-30; pl.VIII, figs.1-5, 7, 8; pl.IX, figs.21, 22, 26; pl.X, figs.34-37; text-fig.68

1974a Timofeevia phosphoritica; Potter (MS.), p.185-188; pl.8, figs.4-6; pl.11, figs.14-15; pl.13, fig.15; pl.14, figs.6, 7; pl.16, fig.15; pl.22, fig.17; pl.23, fig.1; pl.28, fig.16; pl.31, figs.7, 8; pl.34, fig.11; pl.43, figs.3, 4

1978 Timofeevia phosphoritica Vanguestaine sp. nov.; Vanguestaine, p.272-274; pl.III, figs.1-8, 10-12; text-fig.II

1981 Timofeevia phosphoritica Vanguestaine; Martin and Dean, p.21-22; pl.2, figs.7, 15; pl.4, fig.1; pl.5, figs.2, 10

1982 Timofeevia phosphoritica Vanguestaine; Turner, p.134

Possible synonyms (as listed by Vanguestaine 1978):

1959 Archaeohystrichosphaeridium ianischewkyi Timofeev sp. nov.; p.33; pl.III, fig.2; pl.XX, fig.7

1959 Archaeohystrichosphaeridium minor Timofeev sp. nov., p.33, pl.III, fig.3

1964 Archaeohystrichosphaeridium cf. minor Timofeev; Davies and Downie, fig.2k

1966 Archaeohystrichosphaeridium ianischewkyi Timofeev; Timofeev, pl.XXVII, fig.18; pl.LVI, fig.21

1971 Archaeohystrichosphaeridium ianischewkyi Timofeev; Gardiner and Vanguestaine, p.182; pl.2, fig.3

1973b Archaeohystrichosphaeridium cf. minor Timofeev; Vanguestaine, p.31

Original diagnosis: Central body: shell hollow, polyhedral, with rounded outline. Diameter between 18 and 30 µm (25 µm). Surface divided into polygonal fields, from ±15 to ±25 in number, bounded by sutures that are slightly raised in relation to the surface of the shell. The majority of the fields have a diameter approaching 10-12 µm; some are larger, up to 14 µm, others are smaller, up to 6 µm. Generally they have 5 or 6 sides, rarely 4 or 7. Membrane: thin, made of only one layer. Processes: numerous, implanted at the angles of the facets and sometimes between the latter, on the sutures. Height 4 to 6 um. Form conic or tubular. Base at contact with the shell rounded, hollow, and communicating freely with the cavity of the central body. The distal extremity is solid, simple, bifurcated or ramified by successive bifurcations up to the 4th order. Ornamentation: membrane indistinctly smooth or shagreen. Dehiscence structure: generally not visible, but evident in some specimens from one stratigraphic level (Sonnage de Grand-Halleux-2953) where they are particularly well preserved in phosphatic nodules. In some of these specimens a variable proportion of the shell has disappeared. The opening occupies the place of a single, or of several, facets. Its outline usually presents the form of a broken line that faithfully

follows the trace of the sutures outlining the polygonal fields. On some specimens with an opening occupying a limited number of facets, there are, around its margin, cracks between adjacent facets, and some of the latter are displaced. Some complete specimens appparently exhibit the same feature (cracks) at the probable site of the zone of dehiscence. In addition, isolated facets are common in the preparations. Clearly, the loss of these facets of the shell corresponds to the dehiscence mechanism of the species because we have never observed specimens showing facets detached from other parts of the surface of the shell, which would be proof of the disruption of the latter. From these observations, it follows that dehiscence is carried out, in all probability, by the separation of the facets of the 'apical' area of the shell producing an opening of a size varying according to the number of detached facets. The maximum size of the opening would correspond to the 'apical' hemisphere of the shell. (Trans. of Vanguestaine 1978)

Description: The central body is roughly circular to subpolygonal in outline and is divided into eleven to eighteen polygonal (generally hexagonal or pentagonal) fields by ridges that may be accentuated by incurving towards the centre of the shell; this incurving creates the impression that membranes interconnect the processes. On some specimens the ridges are very faint and only one or two ridges may be visible on a specimen. From the angles of the polygonal fields, arise hollow processes with cylindrical stems about 0.75 to 1.25 µm wide; the processes exhibit bifurcation up to the fourth order. Some trifurcation may ocur. Terminations may be

stubby and short or finer and ramusculose. Splitting along suture lines is sometimes evident and, rarely, a single plate is missing from a shell. The body surface is shagrinate.

Dimensions: Diameter of central body: 25.5-34 μm
Diameter of fields: 4-11 μm
Length of processes (total): 4.5-9.5 μm
Length of terminations: 0.5-4.5 μm

Specimens measured: 17

Remarks: Many of the specimens included here have processes and terminations longer than specified by Vanguestaine in the diagnosis of the species. Very few of the specimens have processes with the stubbier type of termination. More ramifying lancarae-type processes generally predominate. However, it is often difficult to decide on the specific identity of the forms with processes of intermediate length that show distal subdivisions of the 3rd and 4th order. Timofeevia lancarae Cramer and Diez 1972 has a pattern of branching that intergrades with that of T. phosphoritica. The end members are quite different, T. phosphoritica showing very short, T. lancarae showing very long, often interlacing, terminations. This gradation is apparent in specimens obtained from successively higher stratigraphic levels on Random Island. In samples 6 A and 11 A, the branching pattern for T. lancarae is quite elaborate and the process lengths are usually greater than half the diameter of the central body. At successively higher stratigraphic levels the degree of ramification and process length decreases, and many of the

specimens have processes equal in length to those of T. phosphoritica. Nevertheless, the processes still exhibit a complex pattern of furcation and an interlocking of their distal branches. There is also the added difficulty of determining whether or not the abbreviated branches are an original feature or a result of damage to the specimens. The author has decided, for the time being, to give these intermediate forms the designation T. phosphoritica-lancarae.

Martin, 1981, in her work on Random Island, gives a process length of 5 to 8 µm for T. phosphoritica and 14 to 29 um for T. lancarae. Many of the forms viewed by the present author fall between these two ranges and are also intermediate in degree of ramification to the specimens figured by Martin. Few show the typical phosphoritica-type branching of Martin's specimens. T. acremonia Rasul 1979, as illustrated, closely resembles these intermediate forms although Rasul describes it as having thirty to forty polygonal areas, and it is of Tremadoc age rather than Upper Cambrian.

Signs of dehiscence, such as a split along suture lines (see pl.5, fig.14) or the loss of a plate, are rare. Vanguestaine stated that such features are rarely present, and, therefore, their absence is not significant.

Occurrence: ?Middle/Upper Cambrian: C+11; Upper Cambrian: 1 A, 5,A, 6 A, 7 A, 10 A, 11 A, 6 B, 8 B, 10 B, 21 B, 22 B-1, 22 B-2, 24 B, 30 B, 3 C, ABC 14, ABC 13, ABC 12, Z-10, Z-7, Z-6, ABC 11, SH13z; ?Upper Cambrian/Tremadoc: Z-5, Z-4, Z-3; Tremadoc: 40 C

Previous occurrences: Cambrian, Grand Halleux, Belgium

(Vanguestaine 1968, 1970, 1973c (MS.), 1978); Middle Cambrian, Spain and Upper Cambrian, British Isles (Potter (MS.) 1974a); Middle-Upper Cambrian, Random Island (Martin and Dean 1981); Tremadoc (reworked), south Shropshire, England (Turner 1982)

?Timofeevia raquelinae Cramer and Díez 1972; comb. nov. in Fombella 1978

Pl.2, fig.2

1972 Multiplicisphaeridium sp. III; Cramer, p.4

1972 Multiplicisphaeridium raquelinae Cramer and Díez sp. nov., p.43-44; pl.1, fig.7; text-fig.3

1978 Multiplicisphaeridium raquelinae Cramer and Díez; Fombella, p.247; pl.II, figs.8, 10, 11, 14, 18

1979 Timofeevia raquelinae Cramer and Díez; Fombella, pl. V, fig.81

Original diagnosis: Central body subspherical, clearly differentiated from the processes. Processes short, plump, and radially oriented, the processes are distributed in an irregular manner over the vesicle. They are simple to irregularly manate with the pinnae mainly at the distal portions of the processes. The shortest processes tend to be simple, the longer ones manate. The processes and the occasional pinnae are hollow. The central body cavity and the process cavities are in direct connection with each other. About ten processes visible in equatorial view; however, as the number and position of the processes is variable, by consequence the number of processes visible in equatorial view

may be as low as three or as high as twelve. The surface of processes and body is psilate. The ectoderm is about one micron thick. There is no differentiation in structure between the processes and the central body. No internal cysts or other endodermal structures observed. The mode of opening is not known. (Cramer and Díez 1972)

Description: The central body is polygonal in outline and bears approximately 18 short, thick (~ 1.5 μm wide) processes, the cavities of which are in communication with the central body cavity. The processes taper slightly above their bases and then expand into bifurcate or trifurcate distal terminations. Many of the processes are truncated. There is a rough arrangement into an inner and an outer ring of processes, with the inner ring somewhat staggered with respect to the outer ring. However, the pattern shows considerable variation: processes of one ring may overlap those of the other, and two or three processes may arise quite close to one another. The body surface is smooth.

Dimensions: Diameter of central body: 32 μm
Length of processes: 4.5-6.5 μm

Specimens measured: 1

Remarks: The specimens illustrated by Cramer and Díez (1972) have a more rounded central body and more rounded processes than does the Random Island specimen. (The same tendency was noted for Multiplicisphaeridium martae Cramer and Díez 1972.) The angularity observed in the Random Island specimen is

evident in one of the specimens of the species illustrated by Fombella, 1978: pl.II, fig.10. That specimen, as is the case with the one Random Island specimen, does not show the division into polygonal fields that is present in the other specimens that she illustrated, and in Cramer and Diez's photographic illustration; the opaqueness of the Random Island specimen may be masking a poorly developed polygonal field pattern, but that does not appear to be the case. Presumably, variation in the degree of development of the polygonal field pattern exists.

This species is distinguished from M. martae on the basis of its shorter, less numerous, processes, and its larger size.

Occurrence: Middle Cambrian: 12-20'

Previous occurrences: upper Middle Cambrian, Oville Formation, León, Spain (Cramer and Díez 1972); Middle Cambrian, Oville Formation, León, Spain (Fombella 1978); upper Middle Cambrian, Oville Formation, León and Asturias, Spain (Fombella 1979)

5.7 Genus VULCANISPHAERA Deunff 1961; emend. Rasul 1976; emend.

1961 Vulcanisphaera Deunff gen. nov., p.42
1976 Vulcanisphaera Deunff; emend. in Rasul, p.479

Type species: Vulcanisphaera africana Deunff, 1961; p.42;

pl.2, figs.1, 2; Tremadoc, Sahara

Diagnosis as emended by Rasul 1976: Body spherical to ellipsoidal in outline, sometimes polygonal. Body wall has conical projections (processes) which sometimes are separated into hollow conical primary processes with flat or crater-like tops and secondary processes; the latter arise from the edge of the primary process top like a tuft of branches, which vary from two to five in number. These secondary processes may be slender, tapering, or curved, with tips sometimes bifurcated or ramified into numerous filamentous threads. Processes may be solid, erect or curved, short or long; body wall smooth to punctate.

Additions to Rasul's emended diagnosis: Sometimes the conical protuberances are absent and single tapering processes arise directly from the body wall. The body surface may be divided into polygonal areas which determine a ridge pattern. The central body may be ornamented with granules.

Remarks: Rasul's emendments were made "to include forms with variable processes and variable shapes of central body and to exclude reference to color" (Rasul 1976, p.479). Both Deunff and Rasul state that the processes occur in groups of two to five. However, some of Rasul's species from the Tremadoc of Shropshire have isolated processes. One of the additions made above to the diagnosis is intended to stress this condition. The reference to single process forms is applicable to Vulcanisphaera disjunctospinata sp. nov., described later in this section, possessing only single processes,

Vulcanisphaera? mougnoanum Martin 1973, doubtfully assigned to the genus because it possesses single processes as well as groupings of two or three, and the species Vulcanisphaera capillata Jardiné et al. 1974 and Vulcanisphaera turbata Martin 1981, which commonly show both isolated and clustered processes on the one specimen. A second emendment to Rasul's diagnosis introduced here is to allow for the presence in vulcanisphaerids of a polygonal field pattern.

Difficulty exists in drawing a clear distinction between Timofeevia Vanguestaine 1978 and Vulcanisphaera. Timofeevia may bear singly occurring, gonally restricted, processes, and although the latter usually display multifurcate terminations, they may be simple, and Vulcanisphaera may show a polygonal field pattern with single processes occurring gonally; the processes of the latter genus generally arise from a conical protuberance, but not always. No Timofeevia species show a predominance of simple tapering processes; most of the processes on a given specimen do show branching. Vulcanisphaera does not exhibit complex branching; it may have secondary processes arising from a shaft or a conical projection, or complex thread-like ramifications may arise from the tips of the secondary processes, or the latter show simple bifurcation. Thus, the distal terminations of the processes of Vulcanisphaera and Timofeevia are generally quite different from one another.

The genus Vulcanisphaera appears to intergrade with the genus Cristallinium Vanguestaine 1978 (see 'Remarks: Cristallinium'). Both possess polygonal plates bearing simple processes at the margins, but they differ in the way the processes are distributed. In Vulcanisphaera the processes

are restricted to the gonal angles whereas in Cristallinium they are disposed along the plate margins.

Where plate separation occurs in Upper Cambrian vulcanisphaerids exhibiting a polygonal field pattern, it is apparent that, at a plate junction, each of the processes of a cluster is associated with a single plate (see V. turbata, Form A, pl.7; fig.9.). Many of the Upper Cambrian and Tremadoc species bear only a single process at plate junctions (which would preclude association of one process with each plate at separation) or have no polygonal fields. This may reflect a tendency towards the loss of the underlying sutural pattern.

Vulcanisphaera africana Deunff 1961

Pl.7, fig.1

1958 Hystrichosphaeridium sp.; Downie, p.340; pl.16, fig. 10

1961 Vulcanisphaera africana Deunff sp. nov., p.42; pl.2, figs.1, 2

1964 Vulcanisphaera africana Deunff; Downie and Sarjeant, p.153

1967 Vulcanisphaera africanum Deunff; Górka, p.1, 4

1969 Vulcanisphaera africana Deunff; Martin, p.83; pl.1, fig.10; fig.33

1973 Vulcanisphaera africana Deunff; Martin, p.11; pl.2, fig.14

1973 Vulcanisphaera africana Deunff; Rauscher, p.62; pl.1, figs.12, 13

1975 Vulcanisphaera africana Deunff; Deunff and Massa, pl.1, fig.1

1976 Vulcanisphaera africana Deunff; Rasul, p.480; pl.1, fig.3, text-fig.1-2

1977 Vulcanisphaera africana Deunff; Martin, pl.II, figs.25, 27

1978 Vulcanisphaera africana Deunff; Dean and Martin, pl.3, fig.4

1981 Vulcanisphaera africana Deunff; Martin and Dean, p.23; pl.1, fig.1; pl.4, fig.3; text-fig.5

1982 Vulcanisphaera africana Deunff; Martin, pl.1, fig.10

1982 Vulcanisphaera africana Deunff; Turner, p.135

Original diagnosis: Shell light brown, from 40 to 45 µm in diameter, spherical, possessing on the surface little cones carrying processes about 10 µm high, grouped in threes, and the extremities of which are finely ramified. (Trans. of Deunff, p.42)

Description: The central body is subpolygonal to spherical. The solid, apparently tapering processes arise in clusters of three, occasionally one or two. Fine ramifications extend from the processes. The processes may be short and stubby to longer and more slender. Body surface shagrinate.

Dimensions: Diameter of central body: 25.5-28 µm
Length of processes: 2.5-16 µm

Specimens measured: 4

Remarks: This species is poorly preserved. The central body is usually distorted or torn and the processes broken, so that the process lengths given above are possibly less than their true values although the shortest and longest, most complete, processes were measured. Folding of the body wall gives an appearance of polygonal fields, such that the specimens resemble Vulcanisphaera turbata Martin 1981. The process groupings are frequently difficult to detect as the specimens are often fragmented. The presence or absence of polygonal fields may be indeterminable for the same reason. V. africana often appears to be more distorted than other species in the same sample. In the samples collected by the author, the species is not as abundant as it is in the samples obtained by Martin, 1981, from the same section.

Occurrence: Upper Cambrian: AC-F, Z-7, AC-D, Z-6, ABC 11, AC-2, SH 13z; ?Upper Cambrian/Tremadoc: Z-5, Z-4, ABC 9, 24 C; Tremadoc: AC-B, 37 C, 40 C, 42 C, E-C 4, E-C 9, E-C 8, E-C 7

Previous occurrences: upper Tremadoc, Shineton Shales, England (Downie 1958); Tremadoc, Sahara (Deunff 1961; Deunff and Massa 1975; Combaz 1967); upper Tremadoc, Kielce, Montagne de Ste. Croix, Poland (Górka 1967); lower Tremadoc, Belgium (Martin 1969); Tremadoc, Montagne Noire, France (Martin 1973); Tremadoc, Roquemaillère, France (Rauscher 1973); lower Tremadoc, Brabant Group, Belgium (Martin 1977); Tremadoc, Shineton Shales, England (Rasul 1976); Tremadoc, Bell Island, Newfoundland (Dean and Martin 1978); upper Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981);

(?)lower Arenig, Bell Island, Newfoundland (Martin 1982); ?Tremadoc (reworked), south Shropshire, England (Turner 1982)

Vulcanisphaera capillata Jardiné et al. 1974

Pl.7, figs.2, 3; Pl.31, fig.3

1974 Vulcanisphaera capillata Jardiné et al. sp. nov., p. 119; pl.II, fig.8

1981 Vulcanisphaera capillata Jardiné et al.; Martin and Dean, p.23; pl.1, fig.9

Original diagnosis: Spherical body with a thin scabrate to microgranulate wall. The processes are slender, long, flexuous, and digitate in the form of long thin filaments which are curved back and clathrate. The processes occur in groups of one to three; they are supported by a conical base which is not strongly marked or may even be absent. (Trans. of Jardiné et al. 1974)

Description: The central body is spherical in shape and bears hollow, tapering processes sometimes curved distally, which are closed off from the central body cavity; a tangled series of fine filaments arises from the processes. The processes are generally truncated. They arise singly or sometimes in groups of two or three, and delimit polygonal fields bordered by ridges. The ridges may be poorly developed on some specimens. Often, the pattern of process distribution cannot be determined, but on specimens with fewer polygonal fields, the processes are seen to arise from the corners of the fields

and occasionally from inside the fields. The body surface is shagrinate to granular.

Dimensions: Diameter of central body: 37-53 μm
Length of processes: 6-11 μm (the maximum length is probably >11 μm as most of the processes were truncated)

Specimens measured: 12

Remarks: Although the original diagnosis of the species does not mention polygonal fields, Martin, 1981, introduces this feature in her species description and draws attention to its presence in the original illustration of the species by Jardiné et al., 1974. Some distorted specimens of Vulcanisphaera are difficult to assign with certainty to either V. capillata or V. africana Deunff 1961 as the processes are separated by tearing of the central body and their arrangement cannot be determined. This tearing also disrupts any polygonal pattern. The arrangement of generally isolated processes arising from the angles of polygonal fields recalls the stratigraphically lower species V. disjunctospinata. On V. capillata, the conical bases from which the processes arise may not be visible and the filaments are often missing due to truncation of the processes. V. disjunctospinata never shows filamentous threads arising from the processes and the polygonal fields have a greater diameter.

Occurrence: Upper Cambrian: SH 13; Tremadoc: 37 C, 40 C, 42

C, EC 2, E-C 7-8, E-C 7

Previous occurrences: lower Tremadoc, Algerian Sahara (Jardiné et al. 1974); Tremadoc, Random Island (Martin and Dean 1931)

Vulcanisphaera disjunctospinata sp. nov.

Pl.9, figs.6-8; Pl.10, figs.2, 3

Holotype: L 48, slide 6 A 20-150 μm (1) [Pl.9, fig.8]

Type locality: Locality 6 A, in the Olenus Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'disjuncto' - disjunct - and 'spinatus' - spined.

Diagnosis: Subpolygonal body divided, in optical view, into eleven to twenty-four polygonal fields by ridges approximately 2 μm high. From the points of junction of the ridges arise single processes - simple, rarely bifurcated, spine-like processes that taper rapidly from a 1-1.5 μm wide base and are solid throughout their length (fourteen to twenty present in optical view). Processes sometimes show what looks like granulation. This may represent rudimentary branching. Body surface shagrinate.

Description: The tops of the ridges sometimes show a slight serration resembling the toothed pattern on the ridges of

Cristallinium, although not as pronounced. Rarely, two processes appear to arise from the same junction.

Dimensions: Diameter of central body: 28-48 μm

Length of processes: 3-6 μm

Specimens measured: 9

Remarks: This species is comparable in size and process shape with Archaeohystrichosphaeridium cellulare Timofeev 1959 which has a diameter of 25-40 μm and bears spine-like processes. However, one of Timofeev's two drawings of the species shows the processes as being hollow and in communication with the central body cavity (pl.III, fig.4) whereas the other shows solid looking processes (pl.XX, fig.18) comparable to those of V. disjunctospinata. The species diagnosis describes them only as "short pointed spines" (Timofeev 1959, p.33). Timofeev reported this species from the Lower Cambrian Eophyton beds and the Middle Cambrian Izhora Formation. (The age of the latter, according to Jankauskas (1976a) is incorrect; he believes that the sample was obtained from beds of Lower Ordovician age in the Moscow Syneclise.) Timofeev, German, and Michailova (1976) illustrated specimens of A. cellulare from sediments of Lower Ordovician age in the Lenningrad region. The illustrations are line drawings, and these all show the processes to be hollow and in communication with the central body cavity (Pl.XXXIII).

V. disjunctospinata superficially resembles specimens of Timofeevia phosphoritica that bear simple processes, or processes in which the distal ramifications have been lost.

However, it never shows the ramifying processes associated with T. phosphoritica and its processes are solid, unlike those of the latter species which are hollow and in communication with the central body cavity. The diameter of the central body is also generally larger than it is in T. phosphoritica.

The processes on this species are like those of the vulcanisphaerids, but the lack of clustering of processes precluded its inclusion in the genus as emended by Rasul (1976). The additions presented earlier to the diagnosis of the genus Vulcanisphaera extend the scope of the genus to cover forms with singly occurring processes and allow for inclusion of this species in Vulcanisphaera.

Occurrence: Upper Cambrian: 6 A

Vulcanisphaera turbata Martin 1981

Pl.7, figs.4-11; Pl.8, figs.1-8; Pl.9, figs.1-5

1981 Vulcanisphaera turbata Martin sp. nov. (in Martin and Dean), p.23; pl.1, figs.2-4; text-fig.6

1982 Vulcanisphaera turbata Martin; Martin, pl.1, fig.19

Original 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 in 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. (Martin and Dean 1981)

Description: The central body may be circular, subpolygonal, or polygonal in outline. Ridges define the polygonal fields which bear at their angles clusters of processes with filamentous terminations. Where individual groupings can be distinguished, they are made up of three processes. On some specimens the density of processes is so great that the number per grouping cannot be determined. The body surface is granular.

A wide range in the length of the processes and in their density is included under this species designation. Three basic intergrading forms occur: (1) Form A - polygonal, sometimes spherical, forms with a low number of processes, fifteen to thirty tufts being observed, and a low number of polygonal fields, from ten to fifteen in optical view. The processes may be extremely short to long, and the filamentous terminations are very reduced or not visible at all. The granulation is very pronounced. These specimens are generally incomplete as separation occurs readily along the plate margins. Where separation has occurred it can be seen that each angle of the polygonal plates carries one process which retains that association after plate separation. Often the central body is curled up and the processes on opposite sides become entangled; (2) Form B - subpolygonal to circular forms

with a medium number of processes (~thirty to forty tufts). Here the polygonal fields, from fifteen to twenty in number, are somewhat masked by the processes. Again the length of the processes varies from extremely short to long and the terminations are somewhat more pronounced. Frequently, these processes are recurved distally. The body surface is granular; (3) Form C - subpolygonal to circular forms with a high density of processes. The processes are generally fairly long with conspicuous filaments forming a net-like mass on some specimens, and their density is so high as to partially or completely mask their polygonal arrangement. Counts of from forty to eighty tufts of processes were made, but generally the density was so high that an accurate count could not be made. The body surface is concealed by the processes.

Dimensions: Diameter of central body: 33-56 μm
Length of processes: 2.5-28 μm

Specimens measured: 46

Remarks: The three forms described here intergrade with one another. Form A appears to be the same as Vulcanisphaera aff. turbata Martin 1981; it is included here under V. turbata as it fits the species description for V. turbata and intergrades with Form B, which is V. turbata as illustated by Martin in 1981. Form C resembles in general appearance V. cirrita Rasul 1976 in bearing long, densely-crowded, processes from which arise interwoven filaments forming a net-like structure, but it differs in having a polygonal arrangement of processes. Specimens from the lower part of the species range

(sample 6 A) constitute a distinct grouping of Form B in which the processes are short (2.5-6 μm), generally recurved, and have a 'tuft-like' aspect. The present work extends the range of process length from the 6-20 μm range given by Martin in 1981. The processes, while occurring in groups, often appear to have expanded triangular bases which are distinctly separate from one another, as can be seen where slight plate separation has occured and each of the three plates (formerly forming a junction bearing a cluster of processes) carries one process from that cluster. This is especially evident in Form A. Sometimes the processes appear to have a common base, the 'protuberances' described by Martin, but the actual fusion of these bases is not certain. Forms B and C, which show little and no plate separation respectively, may perhaps show a greater frequency of basal fusion of the processes although in B the bases, where observable, are generally separate. Due to the density of the processes in form C, the basal region is obscured and its nature cannot be determined with the light microscope.

Occurrence: Upper Cambrian: 5 A, 6 A, 7 A, 9 A-2, 11 A, 8 B, 10 B, 17 B, 20 B, 21 B, 22 B-1, 22 B-2, 24 B, 30 B, 3 C, ABC 14, ABC 13, ABC 12

Previous occurrence: Middle-Upper Cambrian, Random Island (Martin and Dean 1981); Upper Cambrian, Random Island (Martin 1982)

Vulcanisphaera sp. A

Pl.8, fig.12

Description: The central body is subpolygonal in outline and bears about forty to fifty clusters of processes in optical view. Where discernable, the processes occur in groups of two (possibly three, as the clearest groupings are visible at the perimeter of the central body where the third process may not be visible), each process comprising a slender, hollow, hair-like projection arising from an opaque triangular base; the processes in a cluster apparently have separate bases. Some ramification of the processes occurs distally. The body surface seems to be smooth.

Dimensions: Diameter of central body: 18 μm
Length of processes: 3-3.5 μm

Specimens measured: 1

Remarks: The small size of this specimen, and obscuring of parts of the central area of the body by debris, makes a more accurate description impossible with the equipment available. No polygonal fields were visible on the specimen, but the possibility that they are present cannot be ruled out. This form is less than half the size of most Vulcanisphaerids observed on Random Island and is considered a separate species for the time being. Its delicate nature and small size give it the appearance of an immature stage.

Occurrence: Upper Cambrian: 21 B

Vulcanisphaera sp. B

Pl.8, fig.9

Description: The central body is roughly circular in outline, although it is somewhat distorted on the one specimen observed, and its surface is divided into irregular polygonal fields. Near the corners of the polygonal fields arise broad-based tapering processes (2.5 µm wide at the base) generally, if not always, occurring in groups of two. The processes appear to be separate basally but joined at their tips, with one or both of the tips of an individual pair being bent towards the other. One process of a pair commonly appears to be more slender than the other, but this may be due to orientation only. The triangular basal portions of the processes are opaque but some of the processes are less opaque distally. The body surface is granular.

Dimensions: Diameter of central body: 34 µm

Length of processes: 6-6.5 µm

Specimens measured: 1

Remarks: This species is assigned to Vulcanisphaera on the basis of the clustering of tapering processes at the corners of the polygonal fields. The species differs from the genus as described by Deunff in 1961 in that the processes apparently arise directly from the body wall rather than from conical protuberances, although the general form of the processes is conical. Other species of Vulcanisphaera show processes arising directly from the body wall in combination with others

arising from triangular prominences. The simple spine-like shape of the processes and the absence of conical protuberances recalls Vulcanisphaera disjunctospinata, but it differs from that form in having processes grouped in twos, rather than occurring singly.

Occurrence: Upper Cambrian: 21 B

Vulcanisphaera? sp. C

Pl.8, fig.11

Description: The central body is ellipsoidal in outline and divided by ridges into approximately thirty-five very irregular polygonal fields in optical view. At the angles of the fields are borne two (sometimes only one) short processes with a cylindrical shaft and a 'splayed' termination. The processes arise from 'crater-like' bases. There appear to be occasional rudimentary processes occurring intergonally. The body surface is shagrinate. A small split occurs on one side of the central body.



Figure 5.3. Types of processes on Vulcanisphaera? sp. C.

Dimensions: Diameter of central body: 46.5 um

Length of processes (including terminations): 1.5-3.5 um

Specimens measured: 1

Remarks: This species resembles Cristallinium randomense Martin 1981 in bearing very short, often clustered, processes arising from protuberances, although it differs in that (1) the protuberances are 'crater-like' rather then triangular, (2) the processes are almost entirely restricted to the gonal angles, and (3) they are splayed distally. The processes are Cristallinium-like, and the possible presence of intergonal rudimentary processes (their nature makes it difficult to ascertain for certain if these really are processes) makes Vulcanisphaera? sp. C even closer in morphology to that genus. This species is not included in Vulcanisphaera turbata Martin 1981 because it has generally two (sometimes one) processes at the gonal angles, and its processes are splayed, not filamentous, distally.

Occurrence: Upper Cambrian: 21 B

CHAPTER SIX

ACRITARCH TAXONOMY- SUBGROUP DIACROMORPHITAE

Subgroup DIACROMORPHITAE Downie, Evitt, and Sarjeant 1963

(Equivalent to the Family Diacrodiaceae Timofeev 1958; Family Diornatosphaeridae Downie 1958; Family Trachydiacrodidae Deflandre and Deflandre-Rigaud 1962)

Acritarchs having a spherical to ellipsoidal test, without an inner body. Equatorial zone smooth or slightly wrinkled, polar areas ornamented with punctae, tubercles or spines. No openings observed. (Downie, Evitt, and Sarjeant 1963, p.10)

6.1 Genus ACANTHODIACRODIUM Timofeev 1958; emend. Deflandre and Deflandre-Rigaud 1962

1958 Acanthodiacrodium Timofeev gen. nov., p.831

1962 Acanthodiacrodium Timofeev; emend. in Deflandre and Deflandre-Rigaud, p.194

Type species (assigned by Deflandre and Deflandre-Rigaud 1962): Acanthodiacrodium dentiferum Timofeev 1958, p.831; pl.I, fig.2; pl.III, fig.2

Emended diagnosis: Globular-ellipsoidal micro-organisms; equatorial zone smooth or folded; poles similiar, ornamented with hairs, spines or horns; transverse wrinkles present or absent; membrane thin or with double outline. (Trans. of

Deflandre and Deflandre-Rigaud 1962)

Remarks: Deflandre and Deflandre-Rigaud, 1962, in their emendation of the Diacromorph genera established by Timofeev in 1958 and 1959, combined those genera in which the ornamentation was of the same type but which otherwise differed only in the presence or absence of folding or in the possession of a single or double outline. They accepted Downie's view (given in a personal communication to the authors) that the presence or absence of folding, the supposed difference between the genera Lophodiacrodium and Lophorytidodiacrodium, is a secondary characteristic and applied it to other Diacromorph genera as noted above; the presence or absence of a double body outline is likewise considered to be of no diagnostic significance. Thus, the genus Acanthodiacrodium was emended to include Timofeev's genera Acanthodiacrodium (which shows no folding), Acanthorytidodiacrodium (which shows transverse folds), and Acanthozonodiacrodium (which has a double outline).

Acanthodiacrodium abortivum Timofeev 1959

1959 Acanthodiacrodium abortivum Timofeev sp. nov., p.57; pl.VI, fig.22

Diagnosis: Shell oval in outline, thick-walled, with curved pointed spines on the poles (up to 14-15 on each pole). Sculptural background shagreen. Colour pale yellow-grey. 45-55 µm (with spines 50-60 µm). (Trans., of Timofeev 1959)

Acanthodiacrodium cf. abortivum Timofeev 1959

Pl.10, fig.6

Description: The ellipsoidal central body bears approximately fifteen processes at each pole. The processes are spine-like, with a base about 0.5-0.75 μm wide. The equatorial zone is broad, 9.5 μm wide. The body surface is shagrinate.

Dimensions: Length of central body: 28 μm
Width of central body: 26 μm
Length of processes: 4-5 μm

Specimens measured: 1

Remarks: This specimen, in process shape, spacing of processes, and length of processes relative to that of the central body, resembles Acanthodiacrodium abortivum Timofeev 1959. Timofeev's species is, however, larger than A. cf. abortivum which has a central body length from 2/3 to 1/2 that of the Russian material. Since a similiar discrepancy in proportions exists between other Random Island and Russian species (see, for example, Ooidium rossicum) in which the conspecificity is certain, that difference is not considered significant. Timofeev considered his species to be of Middle Cambrian age, whereas A. cf. abortivum is of Tremadoc age. However, some authors have questioned Timofeev's dating of certain strata as Middle Cambrian, and, therefore, the age difference may not be significant either. Only one specimen of this form was observed; for this species, which is similar to a number of other Acanthodiacrodium species, that is not

considered an adequate sample on which to base a positive identification.

Occurrence: Tremadoc: E-C 7

Acanthodiacrodium achrasi Martin 1973
Pl.10, figs.5, 7, 8; Pl.12, fig.10

1973 Acanthodiacrodium achrasi Martin sp. nov., p.30-31; pl.V, fig.11; pl.VI, figs.8, 11, 19; pl.VIII, figs.1, 2, 4

1977 Acanthodiacrodium achrasi Martin; Martin, pl.I, figs. 8, 22; pl.II, fig.9

1978 Acanthodiacrodium achrasi Martin; Dean and Martin, Table 2; pl.3, fig.9

1981 Acanthodiacrodium achrasi Martin; Martin and Dean, p.13; pl.3, fig.15

1982 Acanthodiacrodium achrasi Martin; Cocchio, Table 1, pl.1, fig.28

Original diagnosis: Central body: polygonal outline, 22 to 30 µm long and 15 to 25 µm wide. Processes: from five to twelve in number per pole; length from 3 to 9 µm. Conic form with simple distal extremity. Internal cavity in communication with that of the central body. Ornamentation: fine hairs 0.5 to 1.0 µm long cover the surface of the central body and the processes. (Trans. of Martin 1973)

Description: The central body is polygonal in outline and may

be rectangular, inflated rectangular (convex sides), or very irregularly polygonal. From four to eight processes are present at each pole although on most specimens several additional processes also arise from the mid-region. The slightly sinuous processes are hollow and in communication with the central body cavity. They taper slightly and are evexate to acuminate distally. The tips of the more slender processes are generally missing. Short projections up to 0.75 µm long cover the processes and the central body. On most specimens these appear as triangular to granular prominences < 0.5 µm high, but in some cases they are accompanied by longer, slender, hair-like projections.

Dimensions: Length of central body: 25.5-34.5 µm
Width of central body: 22.5-31 µm
Length of processes: 4-11 µm (one specimen had shorter processes 1.5-2 µm long)

Specimens measured: 12

Remarks: These specimens have been assigned to Acanthodiacrodium achrasi Martin 1973 on the basis of the polygonal outline of the central body and the presence of the same kind of ornamentation (fine hairs) on the central body and processes. The hair-like ornamentation is not as well developed as described by Martin in her original diagnosis but it does closely resemble that depicted in her S.E.M. photographs (pl.VIII, figs.1, 2, and 4). It is assumed that most of the hairs of the Random Island specimens have been broken off. A. ubui Martin 1969 is similar to A. achrasi

but differs from it in possessing a more robust ornamentation that is restricted to the processes.

Occurrence: Upper Cambrian: Z-6; ?Upper Cambrian/Tremadoc: 19 C, ABC 8; Tremadoc: Z-2, Z-1, 32 C, 42 C, E-C 7-8

Previous occurrences: Tremadoc, Montagne Noire, Hérault, France (Martin 1973); Tremadoc, Brabant Massif, Belgium (Martin 1977); Tremadoc, Bell Island, Newfoundland (Dean and Martin 1978); Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981); Tremadoc, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

Acanthodiacrodium aff. achrasi Martin 1973
Pl.10, fig.10; Pl.11, fig 1; Pl.33, figs.4, 6, 7

Description: The central body is circular to polygonal in outline and bears from nine to nineteen tapering processes; each process has a broad triangular base. On some specimens a bipolar arrangement of processes may be apparent. Frequently, the broad bases of the processes overlap to such an extent as to obscure the outline of the central body. The processes may emerge from the central body at a variety of angles. Both the processes and central body have a dense covering of stout spines, up to 0.5 µm long.

Dimensions: Length of central body: 22-31 µm
Width of central body: 16-28 µm
Length of processes: 6.5-18.5 µm

Specimens measured: 12

Remarks: This species resembles Acanthodiacrodium achrasi in possessing ornamentation on the processes and central body and in the shape of its central body. The ornamentation, however, is more robust than on A. achrasi (more like that of A. ubui Martin 1969) and the processes are usually broad-based and markedly tapering rather than narrow-based and of fairly uniform diameter as in A. achrasi.

Several specimens in sample SH 13z have a circular body outline and narrow-based processes resembling those of A. achrasi proper. However, their ornamentation is very strongly developed and similar to that of A. aff. achrasi in the same sample, broad points with no hair-like terminations visible.

A. aff. achrasi is distinguished from A. ubui Martin 1969 by its broad-based processes and the presence of ornamentation on the central body. The bipolar forms sometimes resemble specimens of Acanthodiacrodium complanatum (Deunff 1961) Vavrdová 1965 (occurring at the same stratigraphic level) that show a well developed spinosity; such 'look-alikes' may, therefore, be difficult to assign with certainty to either species.

Occurrence: Upper Cambrian: AC-F, Z-7, ABC 11, SH 13z, SH 13, SH 13y, SH 13x

Acanthodiacrodium andersoni sp. nov.

Pl.11, figs.13, 15-17, 19, 20; Pl.37, figs.5, 6

Holotype: F/G 44/3/1, slide SH 13 (P) [Pl.11, fig.15]

Paratype: UV 14, slide SH 13 (P) [Pl.11, fig.16]

Type locality: Locality SH 13, in the Peltura Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: Named for Professor M. M. Anderson.

Diagnosis: Circular to ellipsoidal body outline. Twenty to thirty conical protuberances from 1.5-5 µm high (mean 2.5 µm) at each pole (lateral view) with no protuberances at the equator. Central body and protuberances covered in short spines.

Description: The processes vary in shape from triangular with rounded tops to semi-ellipsoidal (dome-shaped). On some specimens the ornamentation is like that of Buedingiisphaeridium Schaarschmidt 1963: rounded cones with solid tips. Such specimens differ from Buedingiisphaeridium in lacking protuberances in the equatorial zone. The barren equatorial zone itself is narrow (maximum width 8 µm), and in some cases it is not visible, possibly being masked by the overhanging protuberances. Neighbouring protuberances frequently appear to be locally interconnected by their bases to form short ridges.

Dimensions: Length of central body: 27-39 µm
Width of central body: 22-30 µm
Length of protuberances: 1.5-5 µm

Specimens measured: 13

Remarks: This species resembles several of Timofeev's species of Lophorytidodiacrodium described in 1959 from the Baltic region. Lophorytidodiacrodium lutkevischi has rounded protuberances similar to the semi-ellipsoidal ones of this species, but the processes of Timofeev's species are more closely spaced and shorter and none of them is triangular. In Lophorytidodiacrodium tuberculatum and Lophorytidodiacrodium turulosum the protuberances appear to be more widely spaced than in Acanthodiacrodium andersoni and they do not show the range of height observed in the latter species. Timofeev's species are more quadrangular, less oval, in shape and the protuberances appear to be aligned with the longitudinal axis rather than radiating from the centre, giving a rather smooth lateral outline. Surface sculpture differs as well, the Baltic specimens all showing a shagreen surface while those from Random Island have a spinose surface. Folding, apparent in Timofeev's species, was not observed in A. andersoni.

Occurrence: Upper Cambrian: SH 13z, SH 13, SH 13y, SH 13x

Acanthodiacrodium complanatum Deunff 1961; comb. nov. in Vavrdová 1965

Pl.11, figs.2-5, 7; Pl.33, figs.4, 5

1961 Priscotheca complanata Deunff sp. nov., p.43; pl.3, fig.7

1964 Priscotheca complanata Deunff; Downie and Sarjeant, p.141

1965 Acanthodiacrodium complanatum Deunff; comb. nov. in Vavrdová, p.351

1972 Priscotheca complanatum Deunff; Vavrdová, p.80

1974 Priscotheca complanata Deunff; Rasul and Downie, p.3

1977 Priscotheca complanata Deunff; Vavrdová, table 1

1977 Acanthodiacrodium complanatum (Deunff) Vavrdová; Martin, p.19; pl.XXX

1978 Acanthodiacrodium complanatum (Deunff) Vavrdová; Dean and Martin, Table 2

1981 Acanthodiacrodium complanatum (Deunff) Vavrdová; Martin and Dean, p.13

1982 Acanthodiacrodium complanatum (Deunff) Vavrdová; Cocchio, Table 1; pl.1, fig.27

Diagnosis: Shell light yellow to dark brown, 34 µm long and 37 µm wide. Ornamented with long processes enlarged at the base and oriented at angles to the shell. Length of the processes: 17 µm. (Trans. of Deunff 1961)

Description: The central body is rectangular in outline although it may sometimes assume a pentagonal or hexagonal appearance while maintaining a bipolar character; the longitudinal axis always exceeds the transverse axis in length. There are from six to eleven sturdy tapering processes at each pole that are from 2/3 to 6/7 the length of the central body. The processes are concentrated at the poles but on some specimens several processes may occupy the equatorial region. The surface of the processes and central body is shagrinate in appearance or it bears scattered spines, some of which may be hair-like. These are most obvious on the

processes.

Dimensions: Length of central body: 19-30 µm
Width of central body: 15-22.5 µm
Length of processes: 11-20 µm

Specimens measured: 20

Remarks: This species is assigned to Acanthodiacrodium complanatum (Deunff 1961) Vavrdová 1965 on the basis of the long tapering processes directed at an angle to the body. It is somewhat smaller than Deunff's specimens and the species as described by Martin 1977 (length 32-48 µm; width 24-33 µm). Deunff does not report ornamentation of the processes and central body. Martin, in her 1977 description of the species, however, states that the processes and central body are covered in hairs from 1.0-1.5 µm long. The short spines and occasional hairs observed on some of the Random Island specimens may correspond to that ornamentation, although many specimens show only a shagrinate type of surface with no definite spines visible under the light microscope. A number of forms which resemble A. complanatum but are otherwise intermediate between the genus Acanthodiacrodium and the genus Polygonium Vavrdová 1966 (now included under Goniosphaeridium Eisenack 1969) have been included with this species as have some specimens, suggestive of the genus Tectitheca Burmann 1968, which show a more strongly developed apical spine at one pole.

A. complanatum (as described by Martin) resembles A. achrasi in having an ornamentation of hairs 1.0-1.5 µm long

covering the processes and central body. However, the former can be distinguished from the latter by its less pronounced ornamentation and thicker processes.

Occurrence: Upper Cambrian: AC-D, SH 13z, SH 13, SH 13x, SH 13z; ?Upper Cambrian/Tremadoc: AC-1, Z-5, AC-W, Z-4, ABC 9

Previous occurrences: Tremadoc, Sahara (Deunff 1961); Arenig, Klabava Shales, Central Bohemia (Vavrdová 1965, 1972); Tremadoc, Shineton Shales, Shropshire, England (Rasul and Downie 1974); Arenig - Llanvirn, Šárka Formation, Central Bohemia (Vavrdová 1977); lower Tremadoc, Brabant Massif, Belgium (Martin 1977); Tremadoc, Bell Island, Newfoundland (Dean and Martin 1978); Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981); Tremadoc - Arenig, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

Acanthodiacrodium discigerum sp. nov.

Pl.12, figs.8, 9, 11, 12, 16

1967 Acanthodiacrodium gr. 1; Vanguestaine, p.592; pl.III, figs.24-29

1974 'Lophodiacrodium' sp.; Vanguestaine, pl.II, fig.3

Holotype: T 41, slide 19 C >10 um (1) [Pl.12, fig.8]

Type locality: Locality 19 C in ?Upper Cambrian/Tremadoc strata, Random Island.

Derivation of name: From the Latin 'discus' - disc - and 'gero' - bearing.

Diagnosis: Ellipsoidal central body with narrow, smooth equatorial zone. The poles individually bear from forty-five to one hundred processes. Each process has a dome-like base, 1.5 to 3 µm in diameter and 0.75 to 2.5 µm high, from which arises a much narrower, uniformly cylindrical distal part, 1.5-3 µm long and 0.3-0.7 µm in diameter, that is rounded to slightly pointed at the tip. The contact between the dome-like base and the cylindrical portion of a process is generally abrupt but sometimes the two merge. These exceptional processes, lacking a division into distinct proximal and distal portions, taper uniformly from base to rounded tip.

Description: On most specimens there is a very slight equatorial constriction, and on some, the equatorial zone is obscured by a fold. The process bases stand out as dark areas on the central body giving the poles the appearance of being covered in large disks or granules.

Description: Length of central body: 32.5-39 µm
Width of central body: 25.5-32.5 µm
Width of equatorial zone: 4-8 µm

Specimens measured: 10

Remarks: This species is considered synonymous with Vanguestaine's species on the basis of the bipolar

distribution of numerous bulbous-based processes with stick-like distal extremities. There may be some difficulty in distinguishing specimens of A. discigerum with small process bases and no obvious equatorial zone from specimens of Lophosphaeridium sp. A with large bases to the processes. The latter species is generally somewhat smaller in diameter.

Occurrence: 19 C, ABC 9

Previous occurrences: Zone 6, Upper Cambrian, Stavelot Massif, Belgium (Vanguestaine 1967, 1974)

Acanthodiacrodium lanatum Timofeev 1959; comb.nov. in Martin 1977
Pl.11, figs.8-12

1959 Acanthorytidodiacrodium lanatum Timofeev sp. nov., p.87; pl.VII, fig.32; pl.XXIII, fig.30
1977 Acanthodiacrodium lanatum Timofeev; Martin, p.20; pl.II, fig.22; pl.IV, fig.19

Original diagnosis: Shell oval-elliptical in outline, bulging, densely covered with thin fibre-like curved processes, with two arched transverse secondary folds, also with a covering of fibres; the secondary folds have their concave sides towards each other and come into contact at their ends. Colour yellow-grey. (Trans. of Timofeev 1959)

Description: The central body is circular to oval in outline,

rarely with an equatorial constriction, and may have from two to five transverse folds; additional, usually less prominent, folds of different orientation may also be present. Sometimes the folds are paired with either the concave or convex sides facing one another, depending on the specimen. Hundreds of short, thread-like processes spaced 0.5 to 0.75 µm apart cover the body. (In one specimen an unornamented zone about 3 µm wide is present centrally, but whether this zone is real or only apparent is uncertain.) Each process appears to arise from a circular base, but the small size of the processes makes further analysis impossible. One of the measured specimens has slightly larger processes that seem to be hollow and closed off from the central body cavity. On many specimens processes appear to be truncated.

Dimensions: Length of central body: 22.5-26.5 µm
Width of central body: 17-25 µm
Length of processes: 1-2 µm

Specimens measured: 6

Remarks: The Newfoundland specimens are smaller than the Russian material described by Timofeev (1959) and they exhibit a more variable fold pattern. However, neither the presence or absence of folds, nor their pattern when present, is considered by Deflandre and Deflandre-Rigaud (1962) to be of diagnostic or taxonomic significance. Archaeohystrichosphaeridium papillosum Timofeev 1959 has the same fibre-like processes but they are much more crowded. Baltisphaeridium microspinosum Eisenack 1954 has more spine-like, less

fibre-like, processes.

This species is assigned to the genus Acanthodiacrodium. The genus Lophodiacrodium has ornamentation of a similar size range but it comprises solid tubercles. Downie (1963) did, however, provisionally include some Wenlockian forms with short, solid spines with rounded or capitate ends in Lophodiacrodium. Deflandre and Deflandre-Rigaud included in the genera Acanthodiacrodium and Lophodiacrodium species that possess either a folded or smooth equatorial zone and ornamentation of 'hairs, spines, or horns' for Acanthodiacrodium and 'punctations, buttons, warts, or tubercles' for Lophodiacrodium. The ornamentaton on A. lanatum is close to that just described for Acanthodiacrodium. Only one Newfoundland specimen showed an apparently unornamented equatorial zone; the other specimens showed equatorial folding, suggestive of bipolarity.

Occurrence: ?Upper Cambrian/Tremadoc: AC-1, 19 C; Tremadoc: E-C 7

Previous occurrences: Tremadoc, U.S.S.R. (Timofeev 1959); lower Tremadoc, Chevlipont-Bois de l'Ermitage, Brabant, Belgium (Martin 1977)

Acanthodiacrodium randomense sp. nov.

Pl.10, figs.11-16; Pl.36, figs.1, 3

Possible synonym:

1973 Acanthodiacrodium aff. ubui Martin 1969; Martin, p.36; pl.III, fig.19

Holotype: F 32/1, slide 37 C >10 µm (3) [Pl.10, fig.14]

Type locality: Locality 37 C, in the Parabolina argentina Zone, Tremadoc, Clarenville Formation, Random Island.

Derivation of name: Named for the locality of Random Island.

Diagnosis: Central body ellipsoidal in outline bearing from thirty to fifty short processes at each pole (lateral view). The processes are columnar to slightly tapering and are covered in hairs each of which arises from a triangular base. These have lengths of up to 1.5 µm. Short hairs cover the surface of the central body.

Description: Generally the hairs are represented as triangular prominences with the fine terminations missing. The ornamentation of the central body appears as granules or short spine-like projections. The equatorial zone is from 4 to 10 µm wide and, on one specimen, shows possible longitudinal ridges.

Dimensions: Length of central body: 24-34 µm
Width of central body: 22.5-35 µm
Length of processes: 2-5 µm

Specimens measured: 10

Remarks: This species resembles Acanthodiacrodium aff. ubui (Martin 1969) in Martin 1973 in possessing numerous short processes, and in having both the processes and the central body covered in hairs. The processes on Martin's specimens are somewhat longer, 5-7 µm as contrasted with 2-5 µm for A. randomense, and Martin's forms are usually larger, 33-52 µm wide and 25-40 µm long. The two forms are, nevertheless, similar and may belong to the same species. A. ubui Martin 1969 has more robust ornamentation, which is restricted to the processes, and a smaller number of processes (eight to twenty-five). A. achrasi Martin 1973 has a polygonal rather than ellipsoidal central body and fewer processes (five to twelve) per pole, although it is similar in having an ornamentation of fine hairs covering both the processes and the central body.

Occurrence: Upper Cambrian: AC-2; ?Upper Cambrian/Tremadoc: AC-1, Z-5, AC-W, ABC 9, 19 C, Z-3, ABC 8; Tremadoc: Z-2, AC-B, Z-1, 30 C, 32 C, 37 C, 38 C, 39 C, 40 C, 42 C, E2, EC 5, EC 4, EC 2, EC 1, E-C 9, E-C 8, E-C 7-8, E-C 7, E-C 6

Acanthodiacrodium ubui Martin 1969

Pl.12, figs.1-3, 5, 6, 13

1969 Acanthodiacrodium ubui Martin sp. nov., p.127-128; pl. I, fig.51; text-fig.81

1970 Acanthodiacrodium ubui Martin; Lister, p.47-54; pl.5; text-fig.1

1971 Acanthodiacrodium ubui Martin; Rauscher, p.293; fig.

20

1973 Acanthodiacrodium ubui Martin; Martin, p.36

1977 Acanthodiacrodium ubui Martin; Martin, p.22; pl.II, figs.6, 10, 21; pl.III, figs.2, 3, 9

1981 Acanthodiacrodium ubui Martin; Martin and Dean, p.13, 16; pl.4, figs.2, 4

Original diagnosis: based on the description of 4 examples. Central body: oval outline with poles largely rounded; length from 40 to 45 µm; width from 30 to 35 µm. Processes: about 8 to 25 in number at each pole; length from 7 to 9 µm. Form slightly conic and slender, tapering gradually to a simple extremity. Ornamentation: the surface of the equatorial zone shows fine longitudinal ridges. The surface of the processes is covered with robust hairs, crowded and about 1.5 µm long. (Trans. from Martin 1969)

Description: The central body is rectangular to ellipsoidal in outline and bears at each pole (in lateral view) from seven to thirty slightly tapering processes with conspicuous lateral branches up to 0.75 µm long. The body surface is smooth or occasionally striated.

Dimensions: Length of central body: 25-46.5 µm
Width of central body: 22-33.5 µm
Length of processes: 4.5-14 µm

Specimens measured: 19

Remarks: This species differs from Acanthodiacrodium achrasi

Martin 1973 in having sturdier projections on the processes and no ornamentation of the central body. Acanthodiacrodium andersoni sp. nov. has much shorter, less sturdy processes that are more numerous, and it also has hairs ornamenting the central body.

Only one specimen with definite A. ubui type processes showed striations on the equatorial zone, these presumably corresponding to the fine longitudinal ridges of the original diagnosis. Martin (Martin and Dean 1981), in her description of the species from Random Island, states that the longitudinal wrinkles are either poorly developed or absent. A number of ellipsoidal forms in sample 24 C lie within the range of body size and process number for A. ubui but, although there is some indication of lateral branches, these are not so pronounced as to allow a positive placement in this species. Several of these forms show equatorial striation.

Occurrence: Upper Cambrian: AC-H, (?) Z-8, AC-G, AC-F, Z-7, AC-E, AC-D, Z-6, AC-A, ABC 11, AC-2; ?Upper Cambrian/Tremadoc: AC-1, Z-5, Z-4, ABC 9, 19 C, Z-3, ABC 8, 24 C; Tremadoc: Z-2, Z-1, 37 C, 40 C, EC 3, EC 1, E-C 9, E-C 7-8, E-C 7, E-C 6

Previous occurrences: lower Tremadoc, Belgium (Martin 1969); Tremadoc, Habberley Shales, Shropshire, England (Lister 1970); Lower Ordovician, Montagne Noire, France (Rauscher 1971; Martin 1973); Tremadoc, Brabant Massif, Belgium (Martin 1977); upper Cambrian-Tremadoc (Martin and Dean 1981)

Acanthodiacrodium sp. A

Pl.11, figs.14, 18, 21; Pl.12, fig.4; Pl.33, figs. 11, 12; Pl.34, fig.9

Description: The central body is rectangular in outline, with straight to convex sides; occasionally the convexity is pronounced giving it an inflated appearance. Seven to seventeen processes occur at each pole. They commonly appear as low, opaque triangles, but these are assumed to have been truncated. Complete processes taper from a triangular base to a whip-like, sometimes hair-like, distal part. On most specimens the proximal base, and generally the distal portion, of the processes is markedly opaque. Occasionally the opaqueness starts part way up the process as though the hollow base of the process were still an extension of the central body. However, several specimens show some finer processes with circular bases that are opaque only at the junction with the central body. (See text-fig. 6.1 for illustration of process types.) A number of examples show longitudinal splitting. The body surface is smooth to shagrinate.

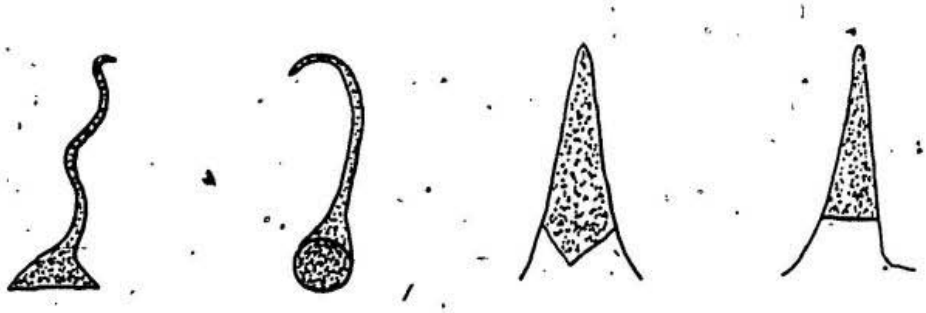

Figure 6.1. Process types in Acanthodiacrodium sp. A.

Dimensions: Length of central body: 23-34 µm
Width of central body: 19-32 µm
Length of processes: 6.5-11 µm

Specimens measured: 23

Remarks: This species resembles Acahthodiacrodium sp. (pl.1, fig.11) illustrated by Martin 1982 from the (?)lower Arenig of Bell Island in possessing opaque processes, but the dimensions of the latter species are greater. Only one example is illustrated by Martin, and there is no description. A. scytotomillei Martin 1977 has dimensions comparable to those for A. sp. A, and in general shape and the opaqueness of its processes it resembles that species, but the ornamentaton of fine, widely spaced hairs on the processes which characterizes A. scytotomillei was not observed for A. sp. A.

Occurrence: ?Upper Cambrian/Tremadoc: 24 C; Tremadoc: Z-2, E-C 7-8

6.2 Genus ARBUSCULIDIUM Deunff 1968

1968 Arbusculidium Deunff gen. nov., p.101-102

Type species: Arbusculidium destombesii Deunff 1968, p.101-102; figs.1- 3, 5-9, 11-14; Tremadoc, Morocco

Diagnosis: Vesicle subcylindrical or slightly prismatic, elongated, smooth or finely reticulate, bearing at opposite ends tufts of different processes. Occasionally, one or several processes present in the median part of the vesicle. One of the poles bears infrequent simple spines which are widened at their bases and taper distally; the other pole

bears thick prolongations which are ramified, and often interconnected by filaments which might perhaps support a membrane. Total length 30 to 90 µm. (Trans. of Deunff 1968 in Eisenack et al. 1976, p.63).

Remarks: This genus differs from Acanthodiacrodium Timofeev 1958 in the dissimilarity of the ornamentation of the two poles.

Arbusculidium destombesii Deunff 1968
Pl.12, figs.7, 14, 15; Pl.13, fig.1

1968 Arbusculidium destombesii Deunff sp. nov., p.102; figs.1-3, 5-9, 11-14
1972 Arbusculidium destombesii Deunff; Vavrdová, p.79
1975 Arbusculidium destombesii Deunff; Deunff and Massa, p.22; fig.3
1977 Arbusculidium destombesii Deunff; Martin, p.23; pl.IV, fig.17
1978 Arbusculidium destombesii Deunff; Dean and Martin, Table 2, pl.3, fig.12
1981 Arbusculidium destombesii Deunff; Martin and Dean, p.13

Original diagnosis: The shell is elongated, subcylindrical to prismatic, smooth or microreticulate from 20 to 50 µm long and 15 µm wide; it bears from 4 to 8 simple processes 10 to 20 µm in length at one extremity, and, at the other one, 5 to 10 ramifying processes 10 to 25 µm in length terminating in filamentous florets, often interconnected. (Trans. of Deunff

1968)

Description: The roughly rectangular central body bears eight to ten simple processes at one pole and approximately ten ramifying processes at the other pole. The ramifying processes show a palmate pattern of branching, with the branches intertwining to form a tangled mass on many specimens, although they do not form a ring or a net-like structure as neither arrangement is apparent in those specimens that have less densely crowded processes. The non-tapering to slightly tapering trunk of the processes may be up to 2.0 μm in diameter. The body surface is shagrinate.

Dimensions: Length of central body: 24-39 μm
Width of central body: 19-34 μm
Length of simple processes: 7-15 μm
Length of ramifying processes: 9-17 μm

Specimens measured: 5

Remarks: The number of ramifying processes is an approximation as their close spacing on most specimens made it impossible to make an accurate count. This species differs from Arbusculidium frondiferum Deunff 1968 in possessing branching processes which do not unite to form a ring and in having a larger number of simple processes (8 to 10 as contrasted with 4 to 5 for Arbusculidium frondiferum). The number of simple processes is slightly greater than that given in Deunff's original diagnosis, but the number of branching processes is not at variance.

Occurrence: ?Upper Cambrian/Tremadoc: Z-3; Tremadoc: Z-2, AC-B, 40 C, E-C 9, E-C 7

Previous occurrences: Tremadoc, Zagora argillites, Morocco (Deunff 1968); Arenig, Klabava Shales, Central Bohemia (Vavrdová 1972); Tremadoc, Libya (Deunff and Massa, 1975); lower Tremadoc, Brabant Massif, Belgium (Martin 1977); Tremadoc, Bell Island, Newfoundland (Dean and Martin 1978); Tremadoc, Random Island (Martin 1981)

Arbusculidium? penicillum sp. nov.

Pl.30, figs.1-3

Possible synonym:

1976 Arbusculidium sp.; Vavrdová, pl.III, figs.3, 4

Type species: B 24/2, slide Z-5 > 10 (1) [Pl.30, fig.3]

Type locality: Locality Z-5, in ?Upper Cambrian/Tremadoc strata, Random Island.

Derivation of name: From the Latin 'penicillum' - tuft.

Diagnosis: Central body rectangular to inflated rectangular showing faint to prominent longitudinal striations. At one pole are from two to five tapering processes while at the other are from eight to twelve or more simple, more slender processes that are interconnected by a tangled filamentous

mass. The non-filamentous processes may project at an angle to the long axis of the body, whereas the filamentous processes are nearly always parallel, or nearly so, with the long axis.

Dimensions: Length of central body: 28-32.5 µm
Width of central body: 15-26.5 µm
Length of non-filamentous processes: 5.5-15 µm
Length of filamentous processes: 6-12.5 µm

Specimens measured: 12

Remarks: This species resembles Arbusculidium sp. illustrated, but not described by Vavrdová (1976) from the Tremadoc, Shineton Shales, England. No striations were observable on Vavrdova's illustrations, but as the striations on A. penicillum are sometimes very faint, that is not significant.

The species is provisionally assigned to the genus Arbusculidium on the basis of the bipolar nature of the body, with simple processes at one pole and processes connected by filaments at the other pole. The filamentous processes are, however, simple, not ramified as is stated in the diagnosis of Arbusculidium.

Occurrence: ?Upper Cambrian/Tremadoc: AC-1, ABC 10, Z-5; Tremadoc: E-C 7-8

Arbusculidium rommelaerei Martin 1981
Pl.13, figs.2-7; Pl. 29, fig.9

1981 Arbusculidium rommelaerei Martin sp. nov.; Martin and Dean, p.16; pl.3, figs.6, 8, 21, 23; pl.5, fig.1

1982 Arbusculidium rommelaerei Martin; Martin, pl.1, fig.16

Original 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. (Martin, in Martin and Dean, 1981)

Description: The central body is roughly rectangular in shape with straight to convex sides parallel to the longitudinal axis and slightly convex to acutely convex poles. One pole may, in some specimens, be pointed rather than rounded in outline. Occasionally, the body is wider at one pole than at the other, giving a trapezoidal outline. Often the sides become so convex as to produce an ellipsoid. In lateral view one pole bears from five to eleven hollow, tapering processes (which may be opaque distally or entirely) while the other pole has three to six processes of this type surrounding a group of ten to twenty more thread-like processes. On some specimens the latter appear as slender columns, whereas on others they appear to taper from a circular base to a columnar or thread-like distal part. Some of the columns show a very slight distal expansion. The body surface is smooth to

shagrinate.

Dimensions: Length of central body: 27-37 µm
Width of central body: 22-31 µm
Length of tapering processes: 3.5-9 µm
Length of columnar processes: 1-3 µm

Specimens measured: 13

Remarks: In her species diagnosis, Martin describes one pole as having simple processes which are echinate. This ornamentation was not observed by the present author and may be visible only under S.E.M. or better resolution light microscopy. In addition, several simple processes of the same type were observed to flank the thread-like processes at the other pole and the number of the latter in lateral view was ten to twenty as contrasted with the forty to fifty recorded by Martin. As Martin's number appears to refer to a polar rather than a lateral count, the two numbers are comparable. The nature of the interconnections of these processes could not be determined. Generally the processes appear as columns, sometimes as a tangled mass of threads. This species can be distinguished from Arbusculidim destombesii Deunff 1968 by its much shorter and much more numerous anastomosing processes. In those specimens of A. destombesii observed by the author from Random Island the processes are stouter and show very pronounced ramification.

One form resembling A. rommelaerei has unusually long processes (up to 7.5 µm) that exceed the upper limit of length (5 µm) set by Martin, and greatly exceed the maximum length (3

µm) recorded for other specimens of A. rommelaerei from the same sample. In size, it is slightly smaller than the specimens of A. rommelaerei associated with it (25 µm x 17 µm), and almost as large as the smallest specimens measured by Martin (27-40 µm x 18-30 µm). Its longest simple processes are at the upper limit of length recorded by the present author for A. rommelaerei and within the 5-10 µm range quoted by Martin. This form is designated A. aff. rommelaerei (pl.13, fig.8).

Occurrence: Upper Cambrian: Z-7, AC-D, AC-A, ABC 11; ?Upper Cambrian/Tremadoc: ABC 10, AC-W, 19 C, ABC 8, 24 C; Tremadoc: Z-2, AC-B, Z-1, 32 C, 37 C, 38 C, 39 C, 40 C, 42 C, EC 4, E-C 9, E-C 8, E-C 7-8, E-C 7

Previous occurrences: Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981); Upper Cambrian, Random Island (Martin 1982)

6.3 Genus DASYDIACRODIUM Timofeev 1959; emend. Deflandre and Deflandre-Rigaud 1962

1959 Dasydiacrodium Timofeev gen. nov., p.88

1962 Dasydiacrodium Timofeev; emend. in Deflandre and Deflandre-Rigaud, p.194

Type species (assigned by Deflandre and Deflandre-Rigaud 1962): Dasydiacrodium eichwaldi Timofeev 1959; p.91; pl.VIII, fig.8; pl.XXIII, fig.33; Tremadoc, Vologda, U.S.S.R.

Emended diagnosis: Ellipsoidal or more or less elongate-polygonal micro-organisms; smooth equatorial zone; poles dissimiliar, one being ornamented with hairs, spines or horns, in number clearly superior to the other; transverse wrinkles present or absent; membrane thin in the known species, possibly with double outline. (Trans. of Deflandre and Deflandre-Rigaud 1962 in Eisenack et al. 1976, p.171)

Remarks: When Deflandre and Deflandre-Rigaud redefined this genus in 1962, they made Dasyrytidodiacrodium Timofeev 1959 synonymous with it. These two genera are identical except for the presence or absence of secondary folding; the former lacks secondary folds while the latter shows this characteristic. Deflandre and Deflandre-Rigaud ascribed the secondary folding to mode of preservation rather than to any generic difference.

Species of the genus Dasydiacrodium usually bear several spines at each pole. One species, however, D. caudatum Vanguestaine 1973 bears a single process, rarely two, apically, rather than a number of processes. In that respect it resembles the genus Alliumella Vanderflit 1971 as redefined by Vanguestaine 1973c (MS.) (this emendation was never validated). Vanguestaine expanded Alliumella to include not only spherical forms with a single apical process, but spherical forms with antapical spines as well (he further extended the genus to include specimens which showed equatorial splitting). However, D. caudatum has an ellipsoidal body outline, and far more numerous processes (six to fourteen) at the antapical pole than does Vanguestaine's species of Alliumella. However, the two genera do, by definition, overlap, except with respect to body shape.

Some of the specimens from Random Island have only an apical spine while others have, in addition, one to several antapical spines. These last are placed in D. caudatum because, despite having fewer antapical spines than the number stated in Vanguestaine's diagnosis of that species, they are quite similar to an example he illustrates which shows only one antapical spine (Vanguestaine 1973c (MS.), pl.XIV, fig.17). The forms with an apical spine and no antapical spines are also included here in D. caudatum because they are very similar to the specimens which have a low number of antapical spines. In process number and arrangement the forms with few or no antapical spines resemble Alliumella, but they have an ellipsoidal rather than a spherical body, shape. In that respect they fit the definition of Dasydiacrodium but while some of these specimens have unequal numbers of spines at the two poles as does that genus, others have spines at only one pole and thus fall outside the definition of the genus. Clearly, some of these specimens do not properly fit either the species or the genus diagnosis, but they do grade morphologically into specimens (described from Belgium) which undoubtedly do.

The new species D. longispinatum (described later in this section) is included in the genus because of unequal polar distribution of spines, even though the shape of its body, which varies from round to inflated triangular to U-shaped, does not fit the genus definition. However, it is morphologically closer to Dasydiacrodium than to any of the other established genera.

Clearly, with further study, new genera may have to be created for some bipolar forms.

Dasydiacrodium caudatum Vanguestaine 1973

Pl.32, figs.1, 3-6, (?) 7-9, 11

1973a Dasydiacrodium caudatum Vanguestaine sp. nov., p.30, pl.I, figs.9, 13

1973c Dasydiacrodium caudatum Vanguestaine; Vanguestaine (MS.), p.222-223; pl.XI, fig.5, pl.XIII, figs.9, 13; pl.XIV, fig.4-7, 13, 17

non 1981 Dasydiacrodium caudatum Vanguestaine; Martin (in Martin and Dean) p.18-19; pl.1, figs.10, 11, 15

Diagnosis: Rounded triangular, sometimes oval central body. Diameter 21 to 32 µm. Apex with one process (exceptionally two), antapex with 6 to 14 processes. Processes conical, each with acute distal extremity and base distinct from the central body, generally simple though on some specimens one or two may be forked, hollow and communicating freely with the vesicle cavity. Wall surface of both central body and processes covered with 0.25 to 0.5 µm wide granules. Wall thickness; 0.25 µm. (Vanguestaine 1973a)

Description: The central body is inflated triangular to ellipsoidal in outline and bears one or two apical processes and zero to ten antapical processes. The central body and processes are covered in granules.

Dimensions: Height of central body: 20-32 µm
Width of central body: 16-25 µm
Length of apical processes: 4.5-10 µm
Length of antapical processes: 6.5-10 µm

Specimens measured: 8

Remarks: Those specimens which are 'typical' D. caudatum as described by Vanguestaine come from a sample that also yielded Trunculumarium revinium, Veryhachium dumontii, and Leiofusa stoumonensis, the characteristic species of Vanguestaine's Zone 5 in Belgium (Vanguestaine 1973a). Several larger specimens (central body 35-39 µm x 26-28 µm; apical processes 16-17 µm long and antapical processes 9-12.5 µm long) from a single sample in the next lowest assemblage on Random Island are questionably assigned to D. caudatum as they closely resemble Vanguestaine's material, but are slightly larger than his specimens and are distinctly larger than the other unequivocal examples from Random Island. Furthermore, they show four or five processes at the apical end, or interspersed between the apex and antapex. The latter arrangement of processes recalls that found in the genus Tectitheca Burmann 1968 which has four or more processes in this intermediate area. These specimens intergrade with ellipsoidal to rounded polygonal forms in which there is no evident polarization of processes. It is possible that some degree of polarity may be masked by the orientation of the body.

A further sample from a stratigraphic level just below that containing the D. caudatum - T. revinium assemblage, yielded, in some abundance, a group of ellipsoidal specimens with one apical process and zero to two antapical processes; those without an antapical process are more common than those with such processes. As noted above under 'Remarks: Dasydiacrodium', the latter resemble one of Vanguestaine's illustrated specimens of D. caudatum (Pl.XIV, fig.17,

Vanguestaine 1973c). Vanguestaine did not comment on these marginal types. As they occur only slightly lower stratigraphically than the other representatives of D. caudatum from Random Island, they are included here in that species. (A single example with no antapical processes was observed in a still lower sample within the same assemblage.)

Martin (in Martin and Dean 1981) describes specimens which she designates D. caudatum. However, the three specimens she illustrated do not belong to that species (as described in this work). The present author would assign them to Dasydiacrodium longispinatum sp. nov. They show shorter, generally narrower processes, and a less rounded central body, than those in Vanguestaine's illustrations and than does the material from Random Island described in the present work. The specimens illustrated by Martin are all from her highest Tremadoc assemblage (A6) which this author has found to be separated from the assemblage containing T. revinium (A4) by three assemblages not previously reported from Random Island, as well as an assemblage containing some elements of Martin's assemblage A5. Neither of the three new assemblages contain representatives of D. caudatum as described by Martin, or as described in this work. It is probable that the specimens reported from Martin's A4 assemblage, and possibly A5, are equivalent to D. caudatum as described here, but in the absence of any illustrations of those specimens, that cannot be stated for certain.

Occurrence: Upper Cambrian: ?24 B, 3 C, ABC 14, 5 C, ABC 13, ABC 12, Z-10

Previous occurrences: Rn2b, Upper Middle Revinian, Upper Cambrian, Stavelot Area, Belgium (Vanguestaine 1973a)

Dasydiacrodium longispinatum sp. nov.
Pl.13, figs.17-21; Pl.14, figs.1-16; Pl.33, fig.13; Pl.37, figs.1, 4

Holotype: O 31/32, slide E-C 7 >10 µm (1) [Pl.14, fig.2]

Paratypes: H 24/3, slide E-C 7 >10 µm (1) [Pl.13, fig.21]; D 47/4, slide E-C 7-8 >10 µm (2) [Pl.14, fig.15]

Type locality: Locality E-C 7, in the Parabolina argentina Zone, Tremadoc, Clarenville Formation, Random Island.

Derivation of name: From the Latin 'longus' - long - 'spina' - spine - and 'atus' - provided with.

Diagnosis: Central body circular to inflated triangular to U-shaped in outline bearing one long process (rarely more) apically and 2 to 5 shorter processes basally. Body surface is smooth, shagrinate, or granular.

Description: Some specimens are perfectly spherical, others U-shaped, while still others are of an intermediate inflated triangular (generally isosceles) appearance. The basal processes are usually extremely short, stubby spines but they may develop into longer, more slender projections that are, in most cases, associated with the more globular specimens. The

U-shaped types bear the short stubby spines oriented at approximately a 120 degree angle to the base line. The inflated triangular forms may show either type of basal process and intergradations between the two. Very rarely additional apical processes are present. (One specimen with three apical processes was observed)

Dimensions: Length of central body: 22-30 μm
Width of central body: 16-22 μm
Length of apical processes: 6.5-15 μm
Length of basal processes: 0.5-12.5 μm

Specimens measured: 27

Remarks: Although three basic forms of shape exist for this species, intergradation is so widespread as to render the use of shape as a species distinction invalid. Intermediate forms between this species and Veryhachium sp. B do occasionally occur in which the three main processes begin to approach one another in length and the triangular shape becomes less isosceles. The globular forms may show reduction of the basal processes, and on some examples, no basal processes are visible, which makes them indistinguishable from Alliumella baltica Vanderflit 1971.

Occurrence: Tremadoc: AC-B, Z-1, 30 C, 32 C, 37 C, 38 C, 39 C, 40 C, E2, EC 5, EC 4, EC 3, EC 2, EC 1, E-C 9, E-C 8, E-C 7-8, E-C 7, E-C 6

6.4 Genus HAMATODIACRODIUM gen. nov.

Type species: Acanthodiacrodium bucerum Umnova 1971 (in Umnova and Vanderflit), p.59-60; pl.1, figs.18, 19; Tremadoc, Russian Platform.

Derivation of name: From the Latin 'hamatus'- with hooks-, referring to the incurved basal processes.

Diagnosis: Central body trapezoidal or subtriangular to U-shaped in outline bearing zero to five straight or curved processes at the narrower apical end and two to six processes at the base. Two of the basal processes are always slightly to strongly incurved in a hook-like manner, the others may be either straight or curved.

Remarks: Two forms have been assigned to this genus- Acanthodiacrodium bucerum Umnova 1971 and Acanthodiacrodium bucerum var. aciferum Umnova 1971. Both show the pair of strongly incurving spines characteristic of this genus.

This genus, like the genus Dasydiacrodium (Timofeev) Deflandre - Deflandre/Rigaud usually has a dissimilar number of processes at the two poles. However, this is not always the case for Hamatodiacrodium. Some representatives of the genus have no processes at all at the apical pole and others have an equal number of processes at the two poles (see pl.1, fig.18, Umnova and Vanderflit, 1971); as well, in the latter genus, the type of processes at the two poles is usually different, whereas in Dasydiacrodium they are of the one type. Furthermore, the shape of the body is generally subtriangular

to U-shaped or trapezoidal in Hamatodiacrodium rather than ellipsoidal or elongate-polygonal as it is in Dasydiacrodium.

Hamatodiacrodium bucerum Umnova 1971; comb. nov.
— Pl.13, figs.9-13; Pl.37, figs.2, 3.

1971 Acanthodiacrodium bucerum Umnova sp. nov.; Umnova and Vanderflit, p.59-60; pl.1, figs.18, 19

Original diagnosis: Shell thin, trapezoidal, with smooth to finely shagrinate sculptural surface. Thin sharp spines of a variety of lengths project from the angles of the shell : from the narrow base 5-14 µm in length, from the wider one, 11-17 µm. The short spines are slightly, and the long ones strongly, bent towards one another, resembling horns. Sometimes the short spines are strongly brought together and the shell acquires a triangular shape. Very rarely specimens are met with that have the short spines totally absent and the shell on the narrow side is then rounded. In addition to the main spines, the side of the shell between the long spines often has 1-3 spine-like outgrowths with length 9-12 µm and basal width 8-10 µm. The length of the narrow base of the trapezoid varies from 14 to 19 µm, the wide base from 19-26 µm, and the length of the shell from 22-27 µm. (Trans. of Umnova, in Umnova and Vanderflit 1971)

Description: The central body is triangular to U-shaped on most specimens; only rarely is a trapezoidal specimen found. Specimens with one or other of the two basic body shapes are

considered separately here; those with a triangular to U-shaped central body are called Form 1, and those with a trapezoidal body are called Form 2. Form 1 specimens bear one, sometimes two, spine-like processes apically. (Rarely, no apical process is present.) These are very short and have a basal width of 1 μm or less. Two longer, stouter processes project backward from the basal angles, curving inward towards the midline. These have a basal width of 2 to 3 μm. A third reduced process may arise from above the base line. The body surface is smooth to slightly shagrinate. Form 2 specimens have from 3 to 4 short triangular processes (basal width 1.5 μm) at the apical end, two of which define the angles of the narrow base of the trapezoid, while the remainder are randomly oriented. At the wide base of the trapezoid are borne 3 to 4 long processes that curve towards the midline. These have a basal width of 2 to 3 μm. The surface of the central body is smooth.

Dimensions: Length of central body: 19.5-31 μm
Width of central body: 18.5-28.5 μm
Length of apical processes: 0.75-4.5 μm
Length of basal processes: 9-18.5 μm

Specimens measured: 18

Remarks: The U-shaped body and prominent backward projecting processes of many of the Form 1 specimens recall in shape that of the horseshoe crab or trilobites with large genal spines. Form 1 specimens resemble Hamatodiacrodium bucerum var. aciferum in general body shape. However, although the

illustrated specimens of H. bucerum proper are trapezoidal in shape, Umnova does, in the species description, state that the shape may become triangular to rounded in front, and apical processes may not be present; this latter variation does occur occasionally in the Random Island material. The basal processes of Form 1 bear a closer resemblance to the species proper than to the variety, comprising, on most specimens, two main backwardly projecting strongly incurved spines separated by a straight base line, while infrequently an additional but reduced process may occur between the two main processes. The apical processes for Form 1 are always spine-like.

While showing the typical trapezoidal shape of H. bucerum and the triangular shape of the apical processes as indicated in pl.1, fig.19, Umnova, 1971, Form 2 may display a much greater development of the secondary basal spines and, in that respect, resembles H. bucerum var. aciferum. However, on the basis of the trapezoidal shape, the triangular apical processes, and the greater incurving of the basal spines, it is assigned to H. bucerum. As some of the Random Island specimens do not fit exactly into either of Umnova's categories, but have characteristics of both H. bucerum and H. bucerum var. aciferum, they are included, for the moment, in the division with which they have the most features in common.

The species is removed from the genus Acanthodiacrodium because of the unequal number and dissimilar shape of the processes at the two poles. It is assigned to the new genus Hamatodiacrodium because of the markedly hooked nature of the basal processes.

Occurrence: ?Upper Cambrian/Tremadoc: 19 C; Tremadoc: AC-B, 37 C, 40 C, E 2, EC 5, EC 4, EC 3, EC 2, EC 1, E-C 9, E-C 7-8, E-C 7, E-C 6

Previous occurrences: Tremadoc, Russian Platform (Umnova and Vanderflit 1971)

Hamatodiacrodium bucerum var. aciferum Umnova 1971; comb. nov.

Pl.13, figs.14-16

1971 Acanthodiacrodium bucerum var. aciferum Umnova var. nov.; Umnova and Vanderflit, p.60; pl.1. figs.20, 21

Diagnosis: Flattened shell, thin, form irregularly oval in outline, with smooth or finely shagrinate sculptured surface. On one end of the shell two long thorn-like spines, the ends of which bend towards one another. The opposite end of the shell is drawn out into a harpoon-like spine. On the shell between two long spines are arranged 1-3 spines. Length of shell 19-22 µm, width 15-20 µm. Length of processes 12-15 µm, basal width 4-11 µm; length of spines on narrow end of shell about 3 µm. (Trans. of Umnova, in Umnova and Vanderflit 1971)

Description: The central body is U-shaped and bears one to five spine-like processes apically and four to six larger, broader-based processes basally. The basal processes are generally bent inwards and are all roughly equal in size.

Curved contacts exist between the basal processes and the central body. The body surface is smooth.

Dimensions: Length of central body: 22-26 μm
Width of central body: 21-26 μm
Length of apical processes: 1-5.5 μm
Length of basal processes: 5.5-12.5 μm

Specimens measured: 6

Remarks: This form resembles Umnova's specimens in shape and in the uniformity of size of the basal processes as well as in the curved nature of the contact between the processes and the central body. It differs in possessing as many as four processes apically, rather than the single process reported by Umnova. Also, the apical processes make more of an angular contact with the central body instead of tapering from the central body as in Umnova's illustrations. H. bucerum proper differs from the variety in showing more strongly incurved basal processes.

Occurrence: ?Upper Cambrian/Tremadoc: ABC 9, 19 C, ABC 8; Tremadoc: E-C 7

Previous occurrences: Tremadoc, Russian Platform (Umnova and Vanderflit 1971)

CHAPTER SEVEN

SUBGROUP HERKOMORPHITAE

Subgroup HERKOMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having a spherical to ellipsoidal or subpolygonal test without an inner body. Surface of the test subdivided by crests into polygonal fields of regular or irregular form: surface within these fields smooth, punctate or tuberculate. No median girdle present. Rodlike supports or projecting spines present in some at crest junctions. No observed opening or a simple, circular pylome. (Downie, Evitt, and Sarjeant 1963, p.10)

7.1 Genus CYMATIOGALEA Deunff 1961; emend. Deunff, Górka, and Rauscher 1974

1961 Cymatiogalea Deunff, p.41-42
1964 Cymatiogalea Deunff; emend. in Deunff, p.121
1974 Cymatiogalea Deunff; emend. in Deunff, Górka, and Rauscher, p.9
1974 Cymatiogalea Deunff; emend. in Rasul, p.52

Type species: Cymatiogalea margaritata Deunff 1961, p.42; pl.1, fig.1

Emended diagnosis: Subhemispherical shell having a large circular or polygonal polar opening, the diameter of which is equal to or greater than the radius of the shell. The opening

can be obscured by an operculum. The surface of the shell is divided into polygonal fields bounded by processes supported or not by a system of membranes. (Trans. of Deunff, Górka, and Rauscher 1974)

Remarks: The emendation of the diagnosis was made primarily to stress the 'constant presence' (Deunff, Górka, and Rauscher 1974, p.9) of polygonal fields in the genus Cymatiogalea. The original diagnosis, Deunff 1961, included in the genus those species with a large circular polar opening that bear processes and membranes often with a polygonal arrangement. However, the preamble to the genus stated that Cymatiogalea included forms with a large polar opening that possess processes and membranes, or simply membranes. The processes could be absent. The genus Priscogalea, also created by Deunff in 1961, contained those forms with a large circular polar opening and random processes with or without polygonal areas that did not possess membranes. The presence or absence of membranes was thus the criterion that could be used in all cases for distinguishing between species of the two genera.

In 1964, Deunff emended Cymatiogalea to include species with no membranes, only spines or granules, as well as membrane-bearing forms with or without processes supporting the membrane; he again mentioned that the processes and membranes are often arranged polygonally. Allowance was also made in the emendation for the shape of the polar opening being more variable, circular to polygonal. At the same time, the genus Priscogalea was abandoned. The expansion of Cymatiogalea to include non-membrane-bearing forms, and the failure of the diagnosis to totally restrict the genus to

membrane- and non-membrane-bearing forms with polygonally arranged ornamentation, left the genus overlapping with the genus Baltisphaeridium, as perceived by Deunff in 1964, to which those species of Prisogalea not transferred to Cymatiogalea were assigned. Deunff, in his discussion of the allocation of species to Cymatiogalea and Baltisphaeridium, indicated that of the non-membrane-bearing forms, only those with spines or granules arranged in polygonal fields were to be placed in Cymatiogalea, but the genus definition did not, in fact, make that clear. (See also 'Remarks: Stelliferidium') The emendment of 1974 by Deunff, Górka, and Rauscher (referred to above) clarified that point by making the polygonal arangement of membranes and processes diagnostic for the genus. (Their emended diagnosis allows for processes without membranes but not membranes without supporting processes). Species included in Priscogalea in 1961 and transferred to Baltisphaeridium in 1964 were then grouped in a new genus Stelliferidium. Cymatiogalea was also emended by Rasul in the same year to include, yet again, reference to the presence of polygonal areas. The latter are, according to Rasul, a reflection of an underlying pattern of tabulation.

Cymatiogalea bellicosa Deunff 1961

Pl.15, figs.1-8; Pl.17, fig.15; Pl.18, fig.1

1961 Cymatiogalea bellicosa Deunff sp. nov., p.42; pl.1, fig.13

1961 Cymatiogalea pudica Deunff; Deunff, p.42; pl.1, fig 4

1964 Cymatiogalea bellicosa Deunff; Deunff, p.122; pl.1,

figs.10-12, 16, 19-20

1972 Cymatiogalea bellicosa Deunff; Beju, p.717

1974 Cymatiogalea bellicosa Deunff; Deunff, Górka, and Rauscher, p.10; pl.4, figs.6, 7; pl.6, figs.5, 22; pl.7, fig.17

1974 Cymatiogalea bellicosa Deunff; Rasul, p.53; pl.4, fig.6

1975 Cymatiogalea bellicosa Deunff; Deunff and Massa, p.22

1977 Cymatiogalea bellicosa Deunff; Vavrdová, table 1

1981 Cymatiogalea bellicosa Deunff; Martin and Dean, p.13; pl.3, fig.18

Original diagnosis: Shell hemispherical, pale yellow to dark brown, 38 µm in diameter, opening: 30 µm. Ornamentation made up of a membrane situated principally at the opposite pole of the organism, appears as a ridge when viewed in optical section. Height of the membranous ridge: 10 µm. (Trans. of Deunff 1961)

Description: The central body is hemispherical in shape; the upper half to one-third of the body is occupied by a pylome. The pylome may be devoid of an operculum or occupied by a circular operculum; in some cases, the latter is partly attached to the pylome, in other cases it is detached and lies within the central body. (An attached operculum generally has a buckled look). A rim approximately 1.5 µm high surrounds the pylome. The central body bears from 20-40 processes located mainly in the polar region. The process distribution varies from specimen to specimen, some showing almost total localization of the processes at the pole, while others have

the majority of the processes at the pole with somewhat shorter processes being interspersed between the polar area and the pylome. On many specimens, the polar processes are markedly longer than the more equatorial processes, and on nearly all specimens there is an increase in process length poleward. Often, several very short processes occcur on the pylome rim. The processes are interconnected by a membrane which in some cases is preserved as a thick encompassing structure while in other cases all that remains is a thin partial veil, or nothing at all. The processes are cylindrical in nature, with expanded, slightly furcated, terminations. The body surface is generally shagrinate to granular, although striations have been observed, in rare cases, on the upper part of the body. The surface of the operculum is usually psilate or shagrinate, but on one specimen it showed pronounced granulation.

Remarks: Rasul (1974) reported Cymatiogalea bellicosa as possessing no decoration of the pylome margin. However, the Random Island material does show a few reduced processes ornamenting the perimeter of the pylome. Striations on the body, which were recorded by Rasul but not Deunff, have been observed on some of the Random Island specimens. Some of the C. bellicosa forms bearing short processes with fairly simple terminations, and lacking a membrane (through non preservation) are difficult to distinguish from Stelliferidium cortinulum (Deunff 1961) Deunff, Górka and Rauscher 1974 as the latter species may also show a polar concentration of processes.

Dimensions: Diameter of central body: 28-38 µm
Diameter of pylome: 23-33 µm
Diameter of operculum: 16-25 µm
Length of processes: 3-13 µm

Specimens measured: 17

Occurrence: Upper Cambrian: 11 A, 8 B, 10 B, 14 B, 18 B, 20 B, 21 B, 22 B-1, 22 B-2, 24 B, 3 C, ABC 14, ABC 13, ABC 12, Z-7, AC-A, ABC 11, AC-2, SH 13z, SH 13; ?Upper Cambrian/Tremadoc: AC-1, ABC 10, Z-5, ABC 9, 19 C, Z-3, ABC 24 C; Tremadoc: Z-2, AC-B, Z-1, 32 C, 37 C, 38 C, 39 C, 40 C, 42 C, EC 5, EC 4, EC 2, E-C 8, E-C 7-8, E-C 7, E-C 6

Previous occurrences: Tremadoc, Sahara (Deunff 1961, 1964; Deunff, Górka, and Rauscher 1974); Tremadoc - Arenig, Moesian Platform, Roumania (Beju 1972); Tremadoc, Shineton Shales, Shropshire, England (Rasul 1974); Tremadoc, Sanrhar Formation, Libya (Deunff and Massa 1975); Llanvirn, Šárka Formation, Central Bohemia (Vavrdová 1977); Tremadoc, Random Island (Martin and Dean 1981)

Cymatiogalea bouvardi Martin 1973

Pl.15, fig.9; Pl.35, fig.4; Pl.31, figs.6, 9, (cf.) 10, 11

1973 Cymatiogalea bouvardi Martin sp. nov., p.39-40; pl. III, figs.1, 4, 8, 14, 17

1981 Cymatiogalea bouvardi Martin; Martin and Dean, p.13;

pl.3, fig.14; pl.4, fig.6

Original diagnosis: Central body: nearly spherical in shape with a diameter from 26 to 30 µm. Opening always present but deformed; outline subcircular to nearly polygonal with a diameter equal to aproximately half that of the central body. Processes: about one hundred; total length from 4 to 6.5 µm. Cylindrical in form, narrow and hollow, proximal part sometimes opaque. Distal ramifications of the first, second, or third order and from 0.5 to 2 µm in length. Ornamentation: a transparent veil, fragmentally preserved, binds the processes to each other. (Trans. of Martin 1973)

Description: The central body is roughly spherical in outline with the upper 1/4th to 1/5th occupied by a circular pylome. The operculum, observed only in lateral view, is unornamented. On some specimens a bordering rim of processes is present; it was not possible to ascertain whether the processes are actually confined to the rim of the pylome or are in part or entirely associated with the operculum. The central body bears, in lateral view, approximately one hundred short, cylindrical or very slightly tapering processes, each of which arises from a broader circular base ~1.0 µm in diameter. The processes appear to be closed off basally from the central body. Distally, the processes are slightly multifurcate and may show second order bifurcation. On many specimens the distal branching is poorly developed or absent; the processes of such specimens are simple or merely 'frayed' at the ends. No veils were observed.

Dimensions: Diameter of central body: 26-35 μm
Diameter of pylome: 13-19 μm
Length of processes: 2.5-8 μm

Specimens measured: 15

Remarks: This species somewhat resembles Stelliferidium distincta Rasul 1974 but differs in possessing a greater number of processes (one hundred as compared with forty, in optical section). S. striatulum Vavrdová 1966 likewise has fewer processes (~35), and its processes are generally longer than those of either S. distincta or Cymatiogalea bouvardi. Also, Vavrdová described S. striatulum as having narrow based processes but the constriction indicated in text-fig. 3a of Vavrdová (1966) is not visible on many of the photographs of that species.

The first undoubted appearance of this species on Random Island is in assemblage RI 5 (late Upper Cambrian). Two specimens from the stratigraphically much lower assemblage RI 2 (early Upper Cambrian) resemble C. bouvardi. One specimen was viewed under the light microscope, the other under S.E.M. The first is quite dark. The S.E.M. specimen closely resembles Martin's S.E.M. illustration of C. bouvardi from Random Island (pl.4, fig.6, 1981). It displays faint lines radiating from the bases of some of the processes. In that respect the specimen resembles C. philipotti Henry 1966, but the pattern is much less pronounced than in that species. Both specimens from assemblage RI 2 are, therefore, assigned with doubt to C.? bouvardi. A single specimen from sample 30 B in assemblage RI 3 shows multifurcate terminations, in

process number it is comparable with C. bouvardi; but the processes appear to be sturdier than on other specimens of the species from Random Island (although within the limits set by the original diagnosis); also, its body outline is more hemispheric, less spherical. That specimen is designated C. cf. bouvardi here.

Occurrence: Upper Cambrian: 30 B (cf.), Z-9 (cf.), Z-8 (cf.), Z-7, AC-E, AC-D, Z-6, AC-A, ABC 11, AC-2; ?Upper Cambrian/Tremadoc: 24 C

Previous occurrences: Tremadoc, Montagne Noire, Hérault, France (Martin 1973); top Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981)

Cymatiogalea cristata Downie 1958; comb. nov. in Rasul 1974

Pl.15, figs.10-12.

1958 Hystrichosphaeridium cristatum Downie sp. nov., p.338-339; pl.16, fig.4; text-fig.4f

1958 Baltisphaeridium cristatum Downie; comb. nov. in Eisenack, p.400

non 1962 Baltisphaeridium cristatum (Downie) Eisenack; Eisenack, p.360; pl.44, fig.9

? 1967 Cymatiogalea polygonophora Górka sp. nov., p.3; pl.1, figs.5-6

1969 Priscogalea cristata Downie; comb. nov. in Martin, p.85; pl.1, figs.43, 44, 46

? 1969 Cymatiogalea polygonophora Górka; Górka, p.62-63; pl.XVI, fig.10; text-fig.24

1973 Priscogalea cristata (Downie) Martin; Martin, p.16-17; pl.V, fig.26; pl.VI, fig.21

1974 Cymatiogalea cristata Downie; comb. nov. in Rasul, p.56, 58; pl.5, figs.3, 4; pl.7, fig.1; text-fig.5

1974 Cymatiogalea cristata (Downie) Rasul; Rauscher, p.65-66; pl.I, fig.21

1977 Priscogalea cristata (Downie) Martin; Martin, p.24; pl.II, figs.4, 5, 26

1980 Cymatiogalea cristata (Downie) Rasul; Wolf, p.69

1982 Cymatiogalea cristata (Downie) Rasul; Turner, p.125-126; pl.15, fig.2

Original diagnosis: Test more or less spherical, 23-30 µm in diameter; test wall about 1 µm thick, yellow, granular; test divided into polygonal fields about 10 µm across by flanges marking suture lines; flanges low with solid processes 4 µm long, 2.5-4 µm apart, processes branch distally into 2-4 spines. Pylome present on holotype, 12 µm diameter; cover intact. (Downie 1958)

Description: The central body is subquadratic, hemispherical, or spherical in outline; in profile, about 1/6th to 1/3rd of the shell is occupied by the pylome. An operculum may or may not be attached. The body surface is divided into five to six polygonal fields by ridges (sometimes discontinuous) bearing, in hemispheric view, from twenty-four to thirty-five narrow (0.75 µm wide) processes, each arising from a slightly triangular base. Some of the processes appear to be truncated

distally; others terminate in two to four short branches. There is a 2-3.5 μm separation of processes on the ridges. Several processes surround the pylome. The body surface is granular.

Dimensions: Diameter of central body: 21-30 μm
Diameter of pylome: 18.5-26 μm
Diameter of operculum: 16-20 μm
Length of processes: 2.5-6.5 μm

Specimens measured: 4

Remarks: Rasul, 1974, includes C. polygonophora (Górka 1967, 1969) under C. cristata; examination of Górka's illustration shows that C. polygonophora has a stockier type of process that appears to be much more numerous than is apparent in Downie's 1958 illustrations of C. cristata. This author considers the synonymy of the two species to be in doubt. Rasul rejects Baltisphaeridium cristatum in Eisenack 1962 as being synonymous with C. cristata because it possesses a different type of polygonal field and more numerous processes. The specimens of C. cristata from Random Island resemble C. multarea Deunff 1961 in possessing slender processes arising from ridges that outline polygonal fields. They differ in showing furcation of the processes distally. (Although Deunff, 1961, states only that the processes of C. multarea are slender, Rasul, 1974, describes them as simple.) Some of the examples with truncated processes are difficult to distinguish from C. multarea.

Occurrence: Upper Cambrian: 21 B, 30 B, ABC 14, 5 C, ABC 13, ABC 12; ?Upper Cambrian/Tremadoc: 19 C, 24 C; Tremadoc: 37 C, E-C 9, E-C 7-8, E-C 6

Previous occurrences: Tremadoc, Shineton Shales, Shropshire, England (Downie 1958); ? Tremadoc, Poland (Gorka 1967, 1969); Tremadoc, Belgium (Martin 1969); Tremadoc, Montagne Noire, France (Martin 1973); Tremadoc, Shropshire, England (Rasul 1974); Tremadoc, France (Rauscher 1974); lower Tremadoc, Chevlipont, Brabant, Belgium (Martin 1977); Tremadoc, Celtiberia, northeast Spain (Wolf 1980); Tremadoc (reworked), South Shropshire, England (Turner 1982)

Cymatiogalea cuvillieri Deunff (1961) 1964
Pl.15, fig.13-15; Pl.16, figs.1, 4, 5

1961 Priscogalea cuvillieri Deunff sp. nov., p.41; pl.1, fig.2

1964 Cymatiogalea cuvillieri Deunff; comb. nov. in Deunff, p.124; pl.1, figs.2, 3

1970 Cymatiogalea cuvillieri Deunff; Martin, Michot, and Vanguestaine, p.346; pl.1, fig.1

1973 Priscogalea cuvillieri Deunff; Martin, p.17-18; pl.III, figs.11, 15; pl.IV, figs.3, 4, 11, 17, 19; pl.V, figs.23, 28; pl.VI, fig.5; pl.IX, fig.6; text figs.6, 7

1973c Cymatiogalea cuvillieri Deunff; Vanguestaine (MS.) p.237; pl.XXVIII, figs.12-14

1973 Cymatiogalea cuvillieri Deunff; Rauscher, p.66; pl.1,

fig.27

1974 Cymatiogalea cuvillieri Deunff; Deunff, Górka, and Rauscher, p.11; pl.6, figs.6-8

1974 Cymatiogalea cuvillieri Deunff; Rasul, p.53-54; pl.5, fig.1, 2; pl.7, fig.2

1975 Cymatiogalea cuvillieri Deunff; Deunff and Massa, p.22

1980 Cymatiogalea cuvillieri Deunff; Wolf, p.69

1981 Priscogalea cuvillieri Deunff; Martin and Dean, p.13

1982 Cymatiogalea cuvillieri Deunff; Martin, pl.1, fig.12

1982 Cymatiogalea cuvillieri Deunff; Cocchio, Table 1, pl. 2, fig.2

Diagnosis: Shell spherical, from 20-25 µm, light yellow to dark brown, having at one-pole a circular opening of about 16 µm, furnished with an opercular disc from 10 to 12 µm in diameter. The surface of the shell is covered in polygonal fields, the partitions of which possess short irregularities 1 µm high, 3-5 per partition. Peculiar to Priscogalea is the possession of a network similar to that displayed by Cymatiosphaera. (Trans. of Deunff 1961)

Description: The central body is spherical to hemispherical in outline with a pylome that occupies 1/3rd to 1/2 of the upper part of the body. The rim of the pylome may bear five to eight very short (<0.5 µm) triangular prominences or triangular based spines up to 3 µm long. The surface of the central body is divided into polygonal fields by triangular projections (about twenty-five to forty in hemispheric view) with four to five projections, 1 to 2.5 µm apart, to a side of a field. The surface of the central body varies from smooth

to shagrinate to coarsely granular.

Dimensions: Diameter of central body: 23-30 µm
Diameter of pylome: 22-26 µm
Height of processes: 0.75-2 µm (up to 3 µm on pylome)
Basal width of processes: 0.75-1.5 µm

Specimens measured: 7

Remarks: The processes on the Random Island material show more variation in height than those on Deunff's specimens, but are comparable in that respect with those reported by other authors. Martin, 1973, gives a height range for 'warts' of 1 to 2 µm, and for spines, of 1.5 to 3.5 µm. Rasul, 1974, gives a range of 1 to 2 µm for the length of the spines.

Occurrence: Upper Cambrian: 24 B, ABC 14, Z-6, AC-2; ?Upper Cambrian/Tremadoc: ABC 10, Z-5, Z-4, 19 C, Z-3, ABC 8, 24 C; Tremadoc: Z-2, AC-B, Z-1, 32 C, 37 C, 38 C, 39 C, 40 C, 42 C, EC 5, EC 4, EC 3, EC 2, EC 1, E-C 9, E-C 8, E-C 7-8, E-C 7, E-C 6

Previous occurrences: Tremadoc, Sahara (Deunff 1961, 1964; Deunff, Gorka, and Rauscher 1974); lower Caradoc, Condroz, Belgium (Martin, Michot, and Vanguestaine 1970); Tremadoc, Montagne Noire, Hérault, France (Martin 1973); Silurian/Ordovician, France (Rauscher 1973); lower Tremadoc (lower Salmian), Stavelot Area, Belgium (Vanguestaine (MS.) 1973c); Tremadoc, Shineton Shales, Shropshire, England (Rasul 1974);

Tremadoc, Libya (Deunff and Massa 1975); Tremadoc, Celtiberia, northeast Spain (Wolf 1980); Tremadoc, Random Island (Martin and Dean 1981); lower Tremadoc, Salta Province, Argentina (Martin 1982); Tremadoc, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

Cymatiogalea aff. cuvillieri (1) Deunff (1961) 1964

Pl.16, fig.2

Description: This specimen has a spherical shell, a large part of which is taken up by the pylome. The surface of the shell in hemispheric view is divided into three or four large polygonal fields by rows of short, solid, conic processes (about four per partition) bearing hair-like extensions. The operculum is subpolygonal in shape and bears short (~ 1 µm long) pointed processes on its perimeter.

Dimensions: Diameter of central body: 22 µm
Diameter of operculum: 17 µm
Height of processes: 1-1.5 µm (conic part): 3-4 µm (hair-like extension)
Basal width of processes: 2 µm
Spacing of processes: 1-1.5 µm

Specimens measured: 1

Remarks: This specimen fits the definition of Cymatiogalea cuvillieri in possessing a broad pylome plus an operculum, and a surface divided up into polygonal fields by very short

processes. However, it differs from C. cuvillieri in possessing fine extensions projecting from the triangular basal part of each of its processes. Other species of Cymatiogalea bear much longer processes. C. multiclaustra Deunff (1961) 1964, which shows a similar pattern of polygonal fields, has longer processes (8-10 µm), but they are connected by a membrane rather than occurring as isolated cones.

Occurrence: Upper Cambrian: 21 B

Cymatiogalea aff. cuvillieri (2) Deunff (1961) 1964

Pl.16, fig.3

Description: The central body is hemispherical, with its upper part occupied by a pylome. The rim of the pylome is largely unornamented as it bears only one or two very short spines. The surface of the central body in hemispheric view is divided into polygonal fields by about forty-five needle-like spines, three to five to each side of a field, that are widely spaced (2 to 4.5 µm (average 3 µm) apart). The spines have triangular bases and taper distally to a point. Often, only the bases remain. The spines may be slightly curved or even flexed. The body surface is smooth. The sub-circular operculum of the measured specimen lies inside the shell.

Dimensions: Diameter of the central body: 37 µm

Diameter of pylome: 31 µm

Diameter of operculum: 18 µm

Height of processes: 3.5 µm

Basal width of processes: 0.5-0.75 µm

Specimens measured: 1

Remarks: This form is much larger in diameter than Cymatiogalea cuvillieri or C. aff. cuvillieri (1) from Random Island, and it is also larger than Deunff's specimens. The cuvillieri pattern of spine-like processes delimiting polygonal fields is present, but the spines, instead of being low and equidimensional, are long, narrow, and needle-like, i.e., their lengths are much greater than their widths. The processes are also more widely spaced than in C. cuvillieri.

Occurrence: ?Upper Cambrian/Tremadoc: 19 C

Cymatiogalea digitata sp. nov.

Pl.17, figs.11-13; Pl.34, fig.8

Holotype: H 41/42, slide 21 B 20-150 µm (1) [Pl.17, fig.13]

Type locality: Locality 21 B, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'digitatus' - having fingers.

Diagnosis: Spherical central body bearing, in polar view, thirty to fifty short processes with clavate or digitate

terminations; the clavigerous terminations sometimes carry very short spiny prominences. Ridges interconnect the processes (at least partially) and veils extend between the processes. The subpolygonal pylome is approximately half the diameter of the central body. It bears a collar and is surrounded by processes that are comparable in length to the processes at the opposite pole. The operculum bears several processes. The surface of the central body is smooth.

Description: The ridges are low, often difficult to see as the body is generally preserved in polar view (pylome uppermost) with the ridges appearing to radiate from the pylome. The processes are of approximately equal length all over the central body and operculum. The veil is well developed and complete on some specimens; on others it is poorly preserved (incomplete) or missing.

Dimensions: Diameter of central body: 23-33 µm
Diameter of pylome: 10-18 µm
Length of processes: 2-6 µm

Specimens measured: 8

Remarks: This species is similar to Cymatiogalea membranispina Deunff 1961 in possessing processes interconnected by ridges and veils. Rasul, 1974, describes the processes of the latter species as being "slender, pillar-like with round tips. Sometimes they grade into swollen, club-shaped tips, rarely forked" (Rasul 1974, p.53). However, there is no mention of digitate terminations, and the

degree of distal expansion of the processes of specimens of C. membranispina from Random Island is much less. The pylome of the Random Island specimens of C. membranispina is much larger than that of C. digitata.

C. digitata also resembles short process specimens of C. bellicosa Deunff 1961. The two species have processes that are sometimes digitate, and both have veils interconnecting the processes; C. bellicosa does not have a system of ridges, but then in C. digitata the ridges are not always apparent. The most obvious difference between the two is the polarization of processes in C. bellicosa, with the longer, more numerous processes concentrated at the pole opposite the pylome, and few, if any, processes in the pylomar region; where present, those near the pylome are greatly reduced in size. Rasul (1974) reports no decoration of the pylome in C. bellicosa, and Deunff's illustrations seem to indicate an undecorated pylome rim. The Random Island specimens of C. bellicosa sometimes show reduced ornamentation of the pylome rim. C. digitata on the other hand has well developed pylomar processes. Furthermore, in C. digitata the processes are generally shorter than is the case for C. bellicosa, and all the specimens of C. bellicosa illustrated by Deunff, Górka, and Rauscher (1974) indicate a larger pylome than is present in C. digitata. Rasul (1974) gives the diameter of the pylome for C. bellicosa as being 50-85% of that of the central body, while for C. digitata it is always 50% or slightly less.

Occurrence: Upper Cambrian: 21 B, 24 B, 3 C, SH 13

Cymatiogalea diversata Rasul 1974

Pl.16, fig.6, 7

1974 Cymatiogalea diversata Rasul, sp. nov., p.60, 62; pl.6, figs.6, 7

1980 Cymatiogalea diversata Rasul; Wolf, p.69

Original diagnosis: Spherical to hemispherical body, divided into polygonal fields by linear arrangement of processes, or by faint to prominent sutural ridges. Processes appear closed to the interior of the body, slender, variable in nature; some are simple, some forked near the tips or halfway towards the tips; others are multifurcate. All these variations are present in a single specimen. Body wall thick, microgranular. (Rasul 1974)

Description: The central body is hemispherical in outline, the upper portion being occupied by a large pylome. In hemispheric view approximately thirty to thirty-five processes, 0.75 to 1.0 µm thick, divide the body into polygonal fields, four to five processes to a side of a field. The processes appear to be solid. Proximally, each process widens out to form a slightly triangular base; bases are generally separate from one another, but, locally, may coalesce laterally to form a short ridge. Distally, fine multifurcations arise. On one specimen, a subpolygonal operculum has fallen inside the shell. The body surface is granular.

Dimensions: Diameter of central body: 28-31 µm

Diameter of pylome: 25-26 µm

Diameter of operculum: 16 µm

Length of processes: 4.5-8.5 µm

Specimens measured: 2

Remarks: These specimens differ slightly from the forms reported by Rasul (1974) in that nearly all, instead of some, of the processes are multifurcate. This species resembles Cymatiogalea multiclaustra Deunff (1961) 1964 in possessing a shell divided into polygonal fields by slender processes, but it differs in that the processes are distally multifurcate rather than simple. The processes of C. cristata Downie 1958 differ in possessing two to four distal spines rather than numerous multifurcations.

Occurrence: Upper Cambrian: 21 B

Previous occurrences: Tremadoc, Shineton Shales, Shropshire, England (Rasul 1974); Tremadoc, Celtiberia, northeast Spain (Wolf 1980)

Cymatiogalea irregularis sp. nov.

Pl.18. figs.4-8

Holotype: L 45 2/4, slide 21 B (P)2-2 [Pl.18, fig.8]

Type locality: Locality 21 B, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'irregular' - irregular.

Diagnosis: Hemispherical central body divided into very irregular polygonal fields by low ridges. From twenty-two to forty processes arise from the ridges (hemispheric view), one from each gonal angle and one, sometimes none, intergonally. Rarely, two processes arise from one point. Pylome present, furnished with a few short processes or none at all. Polygonal operculum. The processes show a somewhat polar concentration, with the area immediately surrounding the pylome having a low density of processes. The processes appear to be hollow and have a cylindrical shaft with digitate terminations. Occasionally, distal bifurcation of the shaft precedes the multifurcation. The body surface is shagrinate to granular.

Description: Two specimens were observed with an operculum present. This was devoid of processes in each case. The ridges on the body surface are very low and appear as faint, thin, lines. Some specimens show fragments of veil-like material on the processes, but it is not certain if these are remnants of true veils or just pieces of debris entangled in the processes.

Dimensions: Diameter of central body: 26.5-34 μm
Diameter of pylome: 18.5-32.5 μm
Diameter of operculum: 17 μm
Length of processes: 1-7 μm

Specimens measured: 6

Remarks: In the nature of its processes, this species resembles some specimens of Stelliferidium gautieri Martin 1973. S. gautieri may show what appear to be ridges connecting some of the processes. These are higher and wider than those of C. irregularis and may represent folding (some of Martin's photographs of S. gautieri show this feature). Those specimens of S. gautieri that exhibit these ridges show, in addition to the ridges, a pattern of lines radiating from the bases of the processes. C. irregularis never shows a stellate pattern of lines associated with the bases of its processes. Furthermore, in the latter the pylomar area is almost devoid of processes whereas in S. gautieri the processes are distributed equally over the entire body.

C. cristata Downie 1958 has polygonal fields and processes with multifurcate distal terminations but the latter are quite different from those of C. irregularis. The polygonal fields of C. cristata are much more regular, and no localization of processes occurs. In addition, in C. irregularis the central body is hemispheric in shape (on those specimens which have lost their operculum) due to the large size of the pylome. C. cristata has a smaller pylome, so the loss of the operculum gives an overall body shape which is nearly subquadratic to circular in outline for that species.

Occurrence: Upper Cambrian: 10 B, 21 B, 24 B

Cymatiogalea cf. irregularis

Pl.18, figs.9, 10, (?)11, 15

Description: The central body is hemispherical in outline and is divided into irregular polygonal areas by low ridges that bear from eighteen to twenty-eight short, hollow multifurcate or simple (possibly truncated) processes in hemispheric view. The shaft of the processes tapers from a triangular base and is usually curled. Often no distal subdivision is observable, the processes then recalling those of Cymatiogalea multarea Deunff 1961 as illustrated by Rasul 1974. This may be due to truncation, as other processes show short multifurcations distally. Generally, a single process occurs gonally, with one or none present intergonally. Very few processes, or none, occur on the pylome rim. A subpolygonal operculum may lie inside the shell. The body surface is granular.

Dimensions: Diameter of central body: 25-39 μm
Diameter of pylome: 24-37 μm
Length of processes: 1.5-4 μm

Specimens measured: 4

Remarks: This species resembles Cymatiogalea irregularis in possessing an irregular ridge pattern, but the processes of the latter are approximately twice the length of those of the former, and generally more numerous. C. multarea Deunff 1961 as described by Rasul (1974) has more regular fields and more processes per ridge, and its processes are always simple. C. cf. multiclaustra Deunff 1961, illustrated by Deunff, Górka, and Rauscher (1974, pl.6, fig.23), although similar, has more regular fields. The irregularity of the ridge pattern in C. irregularis and in C. cf. irregularis is possibly due to

folding but the author considers that the ridges are more continuous than would be the case if folding were responsible.

Occurrence: Upper Cambrian: 21 B

Cymatiogalea membrana Rasul 1974

Pl.16, figs.8-12

1974 Cymatiogalea membrana Rasul sp. nov., p.58, 59; pl.5, fig.9.

Original diagnosis: Spherical to hemispherical body having large, thick processes of Baltisphaerid type, with strong veils stretching out between the processes. The bases of the processes are thickened, the tips furcated; opening circular to subpolygonal. Margin of the opening decorated by processes and membranes. The processes follow rather a linear arrangement indirectly producing polygonal areas on the test surface, but the tabulation pattern is difficult to work out; test wall infrareticulate. (Rasul 1974)

Description: The central body is spherical; the upper 1/6 of the body is occupied by a pylome; from the central body arise, in hemispheric view, forty-five to fifty-five short, sturdy processes (~1.0 µm wide) which show short multifurcate terminations, sometimes of the second order. The processes are distributed over the entire body, often with slightly shorter processes surrounding the pylome. They are interconnected by a membrane that, in some specimens, also

links the processes of the pylome. The length of the processes is from 14-30% of the diameter of the central body. The body surface appears to be reticulate in nature, but this was difficult to determine for certain.

Dimensions: Diameter of the central body: 23-32.5 μm
Length of processes: 4-8.5 μm

Specimens measured: 10

Remarks: These specimens are virtually identical to those of Cymatiogalea membrana as described by Rasul (1974). Thus they possess thick, multifurcate processes interlinked by membranes, and processes surrounding the pylome. They differ slightly in that (1) the processes are generally shorter, 14 to 30% of the body diameter in length as compared with 24-49% for Rasul's specimens, and (2) the processes over the greater part of the body appear to be more numerous than on Rasul's specimens. However, the processes surrounding the pylome appear to be less numerous than on the English material. These minor differences are not considered significant as populations of the same species from widely separated localities are unlikely to be identical in every aspect of their morphology.

C. membrana, which somewhat resembles C. bellicosa Deunff 1961, can be distinguished by the more pronounced processes surrounding the pylome, the lack of polar concentration of processes, the greater uniformity in size of the processes at the pylome and elsewhere on the central body, and the extension of the membrane to the pylome region.

Occurrence: Upper Cambrian: SH 13, SH 13y

Previous occurrences: Tremadoc, Shineton Shales, Shropshire, England (Rasul 1974)

Cymatiogalea membranispina Deunff 1961

Pl.16, figs.13-15; Pl.17, figs.1-3

1961 Cymatiogalea membranispina Deunff sp. nov., p.42; pl.1, fig.6

1964 Cymatiogalea membranispina Deunff; Deunff, p.121; pl.1, figs.9, (?) 18

1974 Cymatiogalea membranispina Deunff; Deunff, Górka, and Rauscher, p.12; pl.6, fig.15

1974 Cymatiogalea membranispina Deunff; Rasul, p.52-53; pl.4, figs.3, 8; pl.7, fig.5

1975 Cymatiogalea membranispina Deunff; Deunff and Massa, p.22

Diagnosis: Spherical shell 44 µm in diameter possessing a polygonal opening from 25 µm to 30 µm across. The surface of the shell bears a membranous netwbrk 10 µm high supported by thickenings in the form of pillars. (Trans. of Deunff 1961)

Description: The shell is subpolygonal in outline, varying from subquadratic to subhexagonal. The surface of the shell, in hemispheric view, is divided up into polygonal to oval shaped fields by twenty to sixty-five columnar processes from

1-1.5 μm wide (0.75 μm on one specimen). On most specimens, the processes are linked to one another by a membrane, and they are also, in some specimens, connected by ridges; other specimens lack ridges. The processes are simple, with rounded, slightly expanded (club-like), tapered, or truncated-looking terminations. The surface of the shell is smooth. An operculum is generally present. The rim of the pylome bears processes, although the operculum itself appears to have none.

Dimensions: Diameter of central body: 23-32 μm
Diameter of pylome: 19-28 μm
Diameter of operculum: 20-23 μm (from 3 specimens)
Length of processes: 2-11 μm

Specimens measured: 13

Remarks: Some of these specimens, like many of those described by Rasul (1974) possess shorter processes than those of Deunff's material (1961, 1964). On other Random Island specimens the processes attain the 10 μm height given by Deunff for the species. Some of the longer processes with club-shaped terminations have opaque bases and the latter then resemble the shorter processes referred to above. It is possible, therefore, that the shorter processes observed on the Random Island material are just the bases of longer processes.

This species resembles Cymatiogalea multiclaustra Deunff 1961 in possessing polygonal fields defined by processes, but in the latter species, the processes are finer and less

columnar and no membrane is present. C. multarea Deunff 1961 also possesses polygonal fields defined by processes, but again the processes are more slender and no membrane is present. Many of the Random Island specimens do not show a membrane but the similarity of these individuals to others in the same sample which do show a membrane enables one to assign them to C. membranispina, especially as the columnar nature of the processes is distinctive. Deunff's 1964 description of C. membranispina provides for the inclusion in his species of specimens that have lost their membranes.

Occurrence: ?Upper Cambrian/Tremadoc: ABC 10, AC-W; Tremadoc: Z-2, AC-B, Z-1, 32 C, 37 C, 38 C, 39 C, 42 C, E2, EC 5, EC 4, EC 2, EC 1, E-C 9, E-C 8, E-C 7-8, E-C 7

Previous occurrences: Tremadoc, Sahara (Deunff 1961, 1964; Deunff, Górka, and Rauscher 1974); Tremadoc, Shineton Shales, Shropshire, England (Rasul 1974); Tremadoc, Sanrhar Formation, Libya (Deunff and Massa 1975)

Cymatiogalea? membranula Martin 1978

Pl.17, figs.4-6; Pl.33, fig.13

1978 Cymatiogalea? membranula Martin sp. nov. (in Dean and Martin), p.7-8; pl.1, fig.8; pl.3, figs.29, 31

1981 Cymatiogalea? membranula Martin; Martin and Dean, p.13

Original diagnosis: Vesicle globular to discoidal, covered with numerous hollow processes, the internal cavities of which

do not open into the cavity of the vesicle and the distal extremities of which are simple or divided into two or three short spines. The processes support low membranes, the proximal edges of which delimit polygonal fields and the distal edges of which are delicately spinose. The surface of the vesicle and of the appendices are irregulaly rugulate. No opening observed on the vesicle. (Martin, in Dean and Martin 1978)

Description: The vesicle is circular to subpolygonal in outline, and is divided by a series of membranes into a network of approximately ten to fourteen polygonal fields. The membranes may show irregular margins; they are supported by apparently solid processes (up to 1.5 μm in diameter) which extend beyond the membranes themselves. One specimen showed short (maximum ~0.8 μm) projections from the shafts of several of the processes. The processes may terminate simply (often giving the appearance of having being truncated) or may bear several short furcations. The surface of the central body is smooth.

Dimensions: Diameter of central body: 22-35.5 μm
Diameter of fields: 7-11 μm
Length of processes: 3-17 μm

Specimens measured: 16

Remarks: The specimens from Random Island observed by the author differ from the species as described by Martin (1978) from Bell Island in that the spinose nature of the membrane is not readily apparent, although the irregular distal margin of

the membrane observed on occasional specimens may correspond to that feature. In addition, the body surface, under the light microscope, is smooth rather than rugulate. No S.E.M. photographs were taken due to the low frequency of occurrence of the species. The lack of spines on the membrane may be because of poor preservation as the membranes themselves are often missing on the Random Island material.

This species resembles Cymatiosphaera pavimenta Deflandre 1945 but is somewhat larger and the pillars in the latter species do not furcate or extend beyond the membrane distally. It also looks very much like specimens of Timofeevia phosphoritica Vanguestaine 1978 in which the processes are truncated and in which incurving of the ridges defining the polygonal fields produces the effect of membranes connecting the processes.

Martin distinguishes C.? membranula from other species of Cymatiogalea by the fact that the processes extend beyond the membrane. This species does not entirely fit the definition of Cymatiogalea in that no large polar opening has been observed on the vesicle, and it is closer in appearance to the genus Cymatiosphaera. However, the ramifications of the processes distally and their extension beyond the membrane exclude it from the latter genus.

Occurrence: Upper Cambrian: AC-H, (?)Z-8, AC-G, AC-F, Z-7, AC-E, AC-D, Z-6, AC-A, ABC 11, AC-2, SH 13z; ?Upper Cambrian/Tremadoc: AC-1, Z-5, ABC 10, AC-W, ABC 9, 19 C, Z-3, ABC 8

Previous occurrences: Tremadoc-?Arenig, Bell Island Group,

Bell Island, Newfoundland (Dean and Martin 1978); Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981)



Cymatiogalea radiata sp. nov.

Pl.17, fig.14

Holotype: K 29, slide E-C 7-8 >10 (2) [Pl.17, fig.14].

Type locality: Locality E-C 7-8, in the Parabolina argentina Zone, Tremadoc, Clarenville Formation, Random Island.

Derivation of name: From the Latin 'radiatus' - bearing spokes or rays.

Diagnosis: Subpolygonal body divided into polygonal fields by solid, thin, stiff, spoke-like processes that are simple or expanded distally into triangular (possibly furcated) terminations. The processes arise directly from the body wall or, more commonly, from ridges about 1.5 to 2 µm high. They support a well developed membrane. The body surface is shagrinate.

Description: The processes are slender (0.4-1.0 µm wide) and, in some cases, their bases form triangular expansions. On specimens where the basal contact is clear, they appear to be closed off from the central body cavity. The ridges bearing the processes are not always present; no pylome has been observed. The membrane appears to be finely granulose but this is difficult to determine for certain.

Dimensions: Diameter of central body: 25-30 µm
Length of processes: 5-10.5 µm

Specimens measured: 4

Remarks: This species is similar to Cymatiogalea membranispina Deunff 1961 in possessing columnar processes interconnected by membranes defining polygonal fields. However, it has stiffer, much more slender processes and a more prominent membrane. This species is somewhat similar in appearance to C. cf. membranispina Górka 1969, but the processes on Górka's species show bi- or tri-furcation distally. C. velifera Downie 1958 and C. gorkae Rauscher 1973 also have fine processes interconnected by membranes but again they show distal bi- or tri-furcation and the processes are more flexuous.

Occurrence: ?Upper Cambrian/Tremadoc: Z-5, AC-W; Tremadoc: E-C 7-8, E-C 7

Cymatiogalea velifera Downie 1958; comb. nov. Martin 1969
Pl.17, figs.7-10

1958 Hystrichosphaeridium veliferum Downie, sp. nov., p.340; pl.17, fig.2; text-fig.4c, e
1964 Baltisphaeridium veliferum Downie; comb. nov. in Downie and Sarjeant, p.168
1969 Cymatiogalea velifera Downie; comb. nov. in Martin,

p.133; pl.I, figs.8, 9

1974 Cymatiogalea velifera (Downie) Martin; Rasul, p.52; pl.4, figs.4, 5

1974 Cymatiogalea velifera (Downie) Martin; Deunff, Górka, and Rauscher, p.13

1981 Cymatiogalea velifera (Downie) Martin; Martin and Dean, p.13

1982 Cymatiogalea velifera (Downie) Martin; Turner, p.126; pl.15, fig.1

Original diagnosis: Test spherical, 25-35 µm in diameter; test wall relatively thick, colour yellowish-brown, infra-reticulate structure; processes about 30% of test diameter in length, about 30 in the optical plane, hollow, bifurcating or trifurcating at tips; thin veils with horizontal striations are stretched between processes, test wall thickened where veils join it so that surface of test is divided into more or less polygonal fields. (Downie 1958)

Description: The outline of the central body is circular to subcircular and the surface of the body is divided into irregular fields by ridges approximately 2-2.5 µm high. In optical view, thirty-five to fifty thin processes 0.5-0.75 µm in diameter arise from the ridges, one at each gonal angle and one, sometimes two, intergonally; each has a slightly expanded base, a cylindrical somewhat flexible stem, and a simple, or a bifurcated, or a trifurcated distal extremity. Sometimes the subdivision occurs half-way along the process but generally it is more distal. Often the branches are slightly recurved. Veils link the processes, and one specimen showed a dashed

pattern of parallel lines on the veil concentric to the perimeter of the central body. The body surface is smooth or infrareticulate.

Dimensions: Diameter of central body: 23-27 μm
Length of processes: 3-8 μm

Specimens measured: 6

Remarks: This species resembles Cymatiogalea membranispina Deunff 1961 in having membrane linked processes borne on ridges. It differs in that its processes are much more slender and often subdivide distally. The Random Island specimens also differ in their shape, C. velifera being more spherical, less polyhedral, in appearance. Furthermore, the ridges and fields of C. velifera are, respectively, more pronounced and less quadratic in shape than are those of C. membranispina.

C. gorkea Rauscher 1973 closely resembles C. velifera as the central body of the former is also divided into polygonal fields by ridges bearing processes, with bifurcated or trifurcated distal extremities, that are connected laterally by veils; the veils do not, however, show horizontal striations, although these are not always distinguishable on C. velifera either. C. gorkea has a granular surface, and Rauscher's illustration (text-fig. 23) indicates a more clearly defined polygonal network than is the case for C. velifera.

Baltisphaeridium veliferum was transferred by Martin (1969) to the genus Cymatiogalea on the basis of the polygonal

distribution of its processes and the interlinking of the processes by veils. Martin reports one specimen with a polar opening, but no polar opening was observed on any of the Random Island material examined by this author.

Occurrence: Upper Cambrian: 10 B, 18 B, 20 B, 21 B, 22 B-2, 30 B, ABC 14, Z-8, Z-7; ?Upper Cambrian/Tremadoc: AC-1, ABC 10; Z-5, ABC 9; Z-3, ABC 8; Tremadoc: Z-2, AC-B, Z-1, 37 C, 42 C, EC 2, E-C 9, E-C 7-8

Previous occurrences: Tremadoc, Shineton Shales, Shropshire, England (Downie 1958; Rasul 1974); lower Tremadoc, Belgium (Martin 1969); Tremadoc, Sahara (Deunff, Górka, and Rauscher 1974); Tremadoc, Random Island (Martin and Dean 1981)

Cymatiogalea sp. A

Pl.18, fig.2

Possible synonym:

1981 Cymatiogalea cf. cylindrata (Rasul 1974) Martin 1981, p.18; pl.3, figs.7, 22

Description: The central body is spherical and bears twenty-five to thirty processes (in optical view) that are distally multifurcate or bifurcate with second order multifurcation. The processes are solid proximally but sometimes appear to be hollow distally. Ridges interconnect the processes, and they are further linked by membranes. The

length of the processes is from 28-42% of the diameter of the central body. The central body shows a patterning, the nature of which is difficult to determine. The processes appear to be slightly granular to spinose. No pylome was observed.

Dimensions: Diameter of central body: 26.5-28.5 μm
Length of processes: 8-11 μm

Specimens measured: 2

Remarks: These specimens may be synonymous with Cymatiogalea cf. cylindrata described by Martin (in Martin and Dean, 1981). The globular vesicle is divided into polygonal fields by membrane-linked processes interconnected by ridges. The apparent granular nature of some of the processes may be due to poor preservation of the spinose ornamentation of the processes. The number of processes is, however, somewhat less than the fifty recorded by Martin, even if a total process count is considered, rather than a count in optical view.

Occurrence: Upper Cambrian: SH 13

CHAPTER EIGHT

SUBGROUP NETROMORPHITAE

Subgroup NETROMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having an elongate to fusiform test, without an inner body. Surface generally smooth, rarely granular. One or more spines, closed distally, may be present at one or both poles. Openings not observed. (Downie, Evitt, and Sarjeant 1963, p.9)

8.1 Genus ELIASUM Fombella 1977

1977 Eliasum Fombella gen. nov., p.118

Type species: Eliasum llaniscum Fombella 1977; p.118; pl.1, fig.6; fig.1:1; lower Middle Cambrian, Oville Formation, León, Spain

Diagnosis: Vesicle elongate, subprismatic, with rounded poles and a thin membrane. Made up of five or six longitudinal ridges which are arranged in a regular and equidistant manner. These can be smooth or ornamented by short spines, denticles or similar elements. The ridges are well defined and often accentuated by secondary folds; can also be notched, bearing one or more rows of denticulate elements. The areas between the ridges may be smooth or ornamented by a sculpture of a smaller size than that of the ridges. The vesicle fractures along the length of the ridges, showing these to be weak

structural zones. (Trans. of Fombella 1977)

Remarks: Some species of Leiovalia Eisenack 1965 resemble Eliasum in shape, but they do not bear longitudinal ridges. The genus Eupoikilofusa Cramer 1970 has longitudinally arranged elements, but these are borne on ridges which are less prominent towards the poles, and the vesicle has pointed rather than rounded poles.

Eliasum llaniscum Fombella 1977
Pl.19, figs.1,2

1972 Leiosphaeridia sp.; Cramer, pl.2, fig.4
1972 Leiosphaeridia sp. 2; Cramer and Díez, pl.2, fig.9 (assigned by Martin, in Martin and Dean 1981)
1976 Leiosphaeridia sp.; Vavrdová, p.60; pl.1, fig.4 (assigned by Martin, in Martin and Dean, 1981)
1977 Eliasum llaniscum Fombella sp. nov., p.118; pl.1, fig.6; fig.1:1
1978 Eliasum llaniscum Fombella; Fombella, pl.I, fig.3
1979 Eliasum llaniscum Fombella; Fombella, pl.I, fig.4
1981 Eliasum llaniscum Fombella; Martin and Dean, p.19; pl.2, fig.14
1982 Eliasum llaniscum Fombella; Fombella, p.20; pl.II, fig.17
1983 Eliasum llaniscum Fombella; Vanguestaine and Van Looy, pl.1, figs.9, 11; pl.2, fig.17

Original diagnosis: Species of Eliasum, the vesicle of which

has a smooth membrane, with five ridges without ornamentation. (Fombella 1977)

Description: The central body is ellipsoidal (cucumber-shaped) in outline, one pole sometimes showing a slight tapering, while remaining rounded. Frequently there are transverse to slightly oblique cracks. On some specimens one end may be missing, the break being sometimes regular, sometimes irregular. Longitudinal splitting may occur along the ridges. No ornamentation of the ridges or the areas between them was observed. Three to five ridges were observed in optical view.

Dimensions: Length of central body: 52-77.5 µm
Width of central body: 24-32.5 µm

Specimens measured: 8

Remarks: This species can be distinguished from other Eliasum species by the smoothness of the ridges and of the membrane between them. Whether or not the opening often observed at one pole is a dehiscence structure or merely a result of damage could not be determined from the specimens studied. The circular opening observed by Martin (in Martin and Dean 1981) on some of her specimens from Random Island is much smaller than it is on specimens from the same locality observed by the present author - a diameter of one third, as contrasted with three fifths, of the width of the vesicle.

Fig.2, pl.2, Vavrdová, 1966, illustrates a species of Eliasum, which may be llaniscum, but the designation is

uncertain from the photograph, and no description of the nature of the ridges is given.

Occurrence: Middle Cambrian; 12-20', C-10

Previous occurrences: upper Middle Cambrian, Oville Formation, León, Spain (Cramer 1972; Cramer and Díez 1972); Middle Cambrian, Jince Area, Bohemia (Vavrdová 1976); Middle Cambrian, Oville Formation, Spain (Fombella 1977, 1978, 1979; 1982); Middle Cambrian, Manuels River Formation, Random Island (Martin and Dean 1981); Middle Cambrian, Tacheddirt Valley, Morocco (Vanguestaine and Van Looy 1983)

Eliasum pisciforme Fombella 1977

Pl.19, figs.1, 3

1977 Eliasum pisciforme Fombella sp. nov., p.119; pl.1, fig.3; fig.1:3

1978 Eliasum pisciforme Fombella; Fombella, pl.I; fig.9; pl.III, figs.22, 23

1979 Eliasum pisciforme Fombella; Fombella, pl.III, fig:44

Original diagnosis: 'Species of Eliasum with interridge areas densely granular and ridges with a notched ornamentation, consisting of short spines or denticles, separated from one another by irregular distances. The dimensions of the elements which form the granular ornamentation of the interridge areas is invariable. (Fombella 1977)

Description: The central body is ellipsoidal in outline. Cracking of the vesicle may occur. The margins of the ridges are jagged, the serrations being very low, while the interridge areas are granular. Four to five ridges are present in optical view.

Dimensions: Length of central body: 63.5-66.5 µm
Width of central body: 28.5 µm

Specimens measured: 3

Remarks: The granulation and costal ornamentation are less pronounced than on Fombella's specimens, and some specimens are difficult to distinguish with certainty from Eliasum llaniscum, as the vesicles are dark and the edges of the ridges are indistinct. There was little residue so the sample could not be further oxidized. Nevertheless, granulation and some serration of the costal margins was evident on the three specimens that were measured.

Occurrence: Middle Cambrian: 12-20'

Previous occurrences: Middle Cambrian, Oville Formation, Spain (Fombella 1977, 1978, 1979)

8.2 Genus LEIOFUSA Eisenack 1938; emend. Gramer 1970

1938 Leiofusa Eisenack gen. nov., p.28
1967 Leiofusa Eisenack; emend. in Combaz, Lange, and

Pansart, p.297

1970 Leiofusa Eisenack; emend. in Cramer, p.71.

Type species: Ovum hispidum fusiformis Eisenack 1934, p.65; pl.4, fig.19

Emended diagnosis: Vesicle hollow, fusiform with simple pointed processes at each pole. Processes varying in length form less than one tenth to as much as 5 times the length of the body. Vesicle wall unilayered, psilate to microgranulate. Sculptural elements not arranged in longitudinal rows. The long axis of the vesicle coincides with the longitudinal vesicles symmetry axis. Vesicle symmetry longitudinal, holomorphic. Longitudinal axis straight or essentially so. Pylome circular, slit-shaped, or formed by equatorial splitting. (Cramer 1970)

Remarks: This genus is distinguished from the genus Poikilofusa (Staplin, Jansonius, and Pocock 1965) Loeblich and Tappan 1978 by the random arrangement of its ornamentation as contrasted with the arrangement of ornamentation in long rows in the latter genus.

Leiofusa oculina sp. nov.

Pl.19, fig.11; Pl.20, figs.1, 12; Pl.34, figs.1, 2

Holotype: OP 39, 11A 20-150 µm (2) [Pl.34, figs.1, 2]

Type locality: Locality 11 A, in the Olenus Zone, Upper

Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'oculus' - eye - and 'ina' - like.

Diagnosis: Slightly fusiform body, with extremities drawn out into gently rounded points, or bearing a short spine at one or both poles. Membrane thin, body surface shagreen to granular and usually finely wrinkled, the wrinkling often producing a scalloped pattern on the body surface, especially at the poles.

Description: Most of the specimens are roughly oval with slightly pointed extremities. However, several of the specimens show a small spine at one or both poles (3 μm and 12 μm long for one specimen), and in some cases the spines and the area around the spines are covered with what appear to be 'granules'; the 'granules' on the spines of some specimens are particularly large (up to 2 μm). These prominences are formed by curved wrinkles on the surface of the body and spines that simulate granules. Several specimens show a cross-shaped pattern of folding. The fine wrinkling of the surface makes surface sculpture difficult to determine on some examples.

Dimensions: Total body length: 87-129 μm
Width of central body: 39-70 μm

Specimens measured: 8

Remarks: In size and general appearance, this species

resembles Leiovalia tenera Kir'yanov 1974, but the slightly pointed extremities and the frequent presence of short spines at the poles distinguish it from that species.

Occurrence: Upper Cambrian: 11 A

Leiofusa stoumonensis Vanguestaine 1973

Pl.19, fig.12; Pl.20, figs.2, 3, 5-8; Pl.34, fig.5

1973a Leiofusa stoumonense Vanguestaine sp. nov., p.29; pl.1, figs.7, 11, 12

1973c Leiofusa stoumonensis; Vanguestaine (MS.) p.217-218; pl.XIII, figs.7, 11, 12; pl.XIV, figs.1-3; pl.XV, fig.1

1974a Leiofusa stoumonense Vanguestaine; Potter (MS.), p.138-140; pl.10, figs.15, 16; pl.15, fig.7; pl.16, fig.7; pl.21, figs.11, 12, 13; pl.30, fig.13; pl.33, fig.15

1974 Leiofusa stoumonensis Vanguestaine; Vanguestaine, p.79

1981 Leiofusa stoumonensis Vanguestaine; Martin and Dean, p.19; pl.1, figs.16, 17

Original diagnosis: Elliptical central body, 40 to 60 µm long and 20 to 34 µm wide. One simple spindle-shaped process at each pole, with rounded tip and base distinctly differentiated from the central body, 40-68 µm long, 2-4 µm wide at mid-length, hollow and communicating freely with the vesicle cavity. Membrane finely microgranulate (almost at the limit of resolution with the light microscope), 0.3 µm thick. (Vanguestaine 1973a)

Description: The central body is fusiform and tapers to a long process at either pole. Generally, the processes are fairly distinct from the central body, but on some specimens the transition is less clearly defined. The tips of the processes may be evexate or acuminate and are missing on many specimens. The body surface is smooth, shagrinate, or slightly granular. Granulation, when present, is often more pronounced on the processes than on the central body.

Dimensions: Length of central body: 32-60 µm
Width of central body: 14-32 µm
Length of processes: 23-98 µm
Total body length: 75-248 µm
% central body width is of central body length: 42-66
% central body length is of total length: 18-43

Specimens measured: 19

Remarks: Some specimens of Léiofusa stoumonensis from Random Island have smaller central bodies than do those described by Vanguestaine. The length of the processes ranges from considerably shorter to considerably longer than that recorded for the Belgian material. Not all specimens showed microgranulation, but the similarity in size, shape and occurrence of smooth, shagreen, and microgranulate forms has led the author to assign all these types to L. stoumonensis.

Some of the smaller specimens with granulation resemble the species Poikilofusa? dubiostriata sp. nov. However, the latter species shows a more pronounced ornamentation,

especially on the central body, and its processes are shorter relative to the length of the body. A few examples were difficult to assign with certainty to either species and they may, in fact, be transitional forms. Occasionally there is a form with a globular body and long flagelliform processes (see pl.20, fig.2) approximating L. flagellaris Burmann 1970 in its proportions. However, Burmann's species is twice the size of these forms. The Middle Silurian species L. granulacutis Loeblich 1970 shows a greater degree of ornamentation, which tends to die out at the distal ends of the processes. In L. stoumonensis the granulation is most obvious on the processes. L. tumida Downie 1959 is always psilate and has a more globular central body, the width being approximately 73% of the length as contrasted with a maximum of 66% for the Random Island forms of L. stoumonensis.

Occurrence: Upper Cambrian: 5 A, 11 A, 6 B, 8 B, 10 B, (?)15 B, (?)17 B, 18 B, 20 B, 21 B, 22 B-1, 22 B-2, 24 B, 30 B, 3 C, ABC 14, 5 C, ABC 13, ABC 12, Z-10, Z-8

Previous occurrences: Middle Revinian, top of Rn2b, Upper Cambrian, Stavelot, Belgium (Vanguestaine 1973a, 1973c (MS.), 1974); Upper Cambrian, England (Potter (MS.) 1974a); Upper Cambrian, Random Island (Martin and Dean 1981)

Leiofusa sp. A

Pl.20, fig.10

Description: The central body is fusiform and is clearly differentiated from the very-short processes at either pole. The processes taper slightly from a 2 μm base and are evexate at the tip. Very faint granulation covers the processes and central body.

Dimensions: Length of central body: 37-43 μm
Width of central body: 20-22 μm
Total length: 54-65 μm
Length of processes: 7-16 μm

Specimens measured: 3

Remarks: This species, in size and ornamentation, resembles Leiofusa pristina Potter (MS.) 1974, but in the three examples recorded from Random Island, the process/body junction is clearly defined, a rare occurrence in L. pristina. Other examples would have to be examined before this species could be assigned uniquivocally to L. pristina.

Occurrence: Upper Cambrian: 21 B

8.3 Genus CITROFUSA gen. nov.

Type species: Citrofusa curiosa sp. nov. [pl.29, figs.1, 3] from the Upper Cambrian Parabolina spinulosa Zone, Random Island.

Derivation of name: From the Latin 'citrus' - citrus - and

'fusus' - spindle. The name refers to the spindle-shaped body, which resembles a lemon (citrus fruit) in outline.

Diagnosis: Fusiform body extended at the poles into extremely short, rounded processes. These in turn bear a short, rod-like termination from 1/4 to 3/4 the length of the processes. Ratio of body width to body length varies from 0.52-0.58: 1.0. Body surface shagrinate.

Remarks: The shape of this genus is similar to that of the genus Leiovalia Eisenack 1965, but it differs in having a short rounded process at either end, and is unique in possessing stick-like projections on the processes.

Citrofusa curiosa sp. nov.

Pl.29, figs.1, 3

Holotype: S 29/30, slide 21 B 20-150 µm (1) [Pl.29, fig.1.]

Type locality: Locality 21 B, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'curiosus' - odd.

Diagnosis: Same as for the genus.

Dimensions: Length of central body: 33-50 µm
Width of central body: 18-29 µm
Length of processes: 1-4 µm (rounded part)

1-2 µm (stick)

Specimens measured: 3

Remarks: One specimen has a transparent membrane stretched over the stick-like termination at one pole.

Occurrence: Upper Cambrian: 21 B

8.4 Genus PIREA Vavrdová 1972

1972 Pirea Vavrdova gen. nov., p.83

Type species: Pirea dubia Vavrdová 1972, p.83; pl.1, fig.4; Arenig, Klabava Shales

Original diagnosis: Acritarchs with pear- to bottle-shaped shells, wall single-layered, psilate, granulate or with transversal ribs (microstriate). Apical horn clavate, capitate; antapical end broadly rounded. (Vavrdová 1972)

Remarks: This genus differs from the genera Alliumella Vanderflit 1971 and Deunffia Downie 1960 in bearing an apical process which merges with the central body rather than making a sharp angular contact, and in not having spine-like processes. In addition, the body in Pirea is much wider antapically, and as a result of tapering apically, it is characteristically bottle-shaped rather than being ellipsoidsal or circular as in Deunffia and Alliumella

respectively.

Pirea ornata Burmann 1970; comb. nov. Eisenack, Cramer, and Díez 1976

1970 Deunffia ornata Burmann sp. nov., p.320; pl.XV, figs. 9-12

1976 Pirea ornata Burmann; comb. nov. in Eisenack, Cramer, and Díez, p.565

Original diagnosis: Central body prolate, slightly stretched, bearing at the apical pole a short, hollow process which is distinctly differentiated from the central body. The process does not taper and is terminally rounded. It may also become inflated to become capitate. The entire body is covered by tiny needles, of which generally no more than expanded bases show up as warts. Dimensions: Central body length 40 µm, width 20 µm; process length 7 µm, width 3 to 4 µm; ratio of process length to central body length= 0.18:1. (Trans. of Burmann 1970 in Eisenack et al. 1976, p.565)

Pirea cf. ornata (Burmann 1970) Eisenack, Cramer and Díez 1976

Pl.20, fig.4

Description: The central body is prolate and bears apically a short process with a rounded tip which is in communication with the central body cavity. There is no constriction at the 'neck' of the process. The entire body is covered with slight

granule-like prominences <0.5 μm high.

Dimensions: Length of central body: 34 μm
Width of central body: 19 μm
Length of process: 7 μm
Width of process: 2.5 μm
Ratio of process length to central body length: 0.2:1

Specimens measured: 1

Remarks: This specimen differs from Pirea ornata in that (1) the apical process tapers only slightly distally, and (2) the base of the process is not clearly separated from the central body. The granule-like prominences on this specimen resemble the 'warts' which form the bases of the spines in Burmann's species. On the Random Island specimen a projection arises from the antapical end. The projection suggests some type of attachment structure.

Occurrence: Upper Cambrian: 21 B

8.5 Genus POIKILOFUSA Staplin, Jansonius, and Pocock 1965; emend. Loeblich and Tappan 1978

1965 Poikilofusa Staplin, Jansonius, and Pocock gen. nov., p.185

1978 Poikilofusa Staplin, Jansonius, and Pocock; emend. in Loeblich and Tappan, p.1281-1282

Type species: Poikilofusa spinata Staplin, Jansonius, and Pocock 1965, p.186; pl.18, fig.25-26. Trenton Formation, Middle Ordovician, Anticosti Island.

Emended diagnosis: Fusiform vesicle whose polar extremities are drawn out into processes; surface sculptured by grana or spinules arranged in discontinuous longitudinal rows. (Loeblich and Tappan 1978)

Remarks: This genus has undergone elimination, reinstatement, and redefinition by various authors since its creation. Poikilofusa, as originally described by Staplin, Jansonius, and Pocock in 1965 comprised "Fusiform vesicles, with small spines or muri, probably with no openings (pylomes), with firm but relatively thin walls, which are similar to those of micrhystrids". However, the genus was seen by Combaz, Lange, and Pansart (1967) to be a junior synonym of Dactylofusa Brito and Santos 1965 which was originally defined as "Navicular shaped organisms covered with claviform processes which are regularly distributed in longitudinal rows. At the end of the clavae are more digitiform appendices in regular ornament." They expanded Dactylofusa to include echinate and striate forms, but restricted it to those clavate, echinate, and striate species not bearing appendices. Striate forms with appendices were placed, together with smooth forms, in Leiofusa, while echinate forms with appendices were not included in either genus.

Cramer (1970) removed the species with longitudinally arranged striate sculpture (>1.0 μm) and ornamention from Dactylofusa and placed them in the new genus Eupoikilofusa.

Forms with striate elements <1.0 μm were assigned to Leiofusa (this included those with echinate elements arranged in striae). Forms with microgranulate elements (<0.5 μm) not arranged in longitudinal rows also went to Leiofusa. This still left those species with randomly arranged granulate elements >0.5 μm without a generic designation.

Loeblich and Tappan (1978) restored Poikilofusa, but in a restricted sense, so that it included species with longitudinally arranged microechinate elements, while striated forms without echinate elements were retained in Eupoikilofusa. Dactylofusa was left as originally created by Brito and Santos, except that it now included forms with processes. Again, species with randomly arranged echinate elements >0.5 μm were not classified.

Poikilofusa? dubiostriata sp. nov.

Pl.20, figs.9, 11, 14; Pl.21, fig.1

Holotype: J 25, slide 21 B 20-150 μm (1) [Pl.20, fig.11]

Type locality: Locality 21 B, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'dubius' - doubtful - and 'striatus' - striated.

Diagnosis: Fusiform body extending into a tapering process at either pole. Process tip may be either rounded or pointed. Body and processes covered in conical spines, generally less

than 0.5 µm high but in some cases extending to ~0.75 µm. The spines appear to be randomly arranged on most specimens but occasionally show some indication of alignment. Width of central body 57-77% of the total length of the central body. Length of central body 44-61% of the total length.

Description: The body may show longitudinal, and in some cases, transverse or oblique folds. There is no apparent reduction in size or abundance of ornamentation towards the poles. The body generally has an inflated appearance. The apparent alignment of spines cannot be confirmed under the light microscope on those specimens so far examined.

Dimensions: Length of central body: 29-45 µm
Width of central body: 20-30 µm
Length of processes: 8-26 µm
Total body length: 57-80 µm

Specimens measured: 14

Remarks: This form resembles Disparifusa hystricosa Loeblich 1970 in possessing short conical spines, but it lacks the asymmetry of that species. Leiofusa granulacutis Loeblich 1970 is larger, and the ornamentation on the processes dies out distally. This species is placed, with doubt, in the genus Poikilofusa as the ornamentation is quite pronounced, frequently exceeding 0.5 µm in height, and it sometimes appears to be arranged in rows.

Occurrence: Upper Cambrian: 11 A, 6 B, 8 B, 10 B, 15 B, 18

B, 20 B, 21 B, 22 B-2, 24 B, 30 B, ABC 14, ABC 13

Poikilofusa squama Deunff 1961; comb: nov. in Martin 1977

Pl.19, fig.4; Pl.34, figs.3, 4

1961 Leiofusa squama Deunff sp. nov., p.40; pl.2, fig.8

1967 Dactylofusa squama Deunff; comb. nov. in Combaz, Lange, and Pansart, p.297

1967 Dactylofusa squama Deunff (Combaz, Lange, and Pansart); Combaz, p.17; pl.4, fig.94

1970 Eupoikilofusa squama Deunff; comb. nov. in Cramer, p.88

1974 Dactylofusa squama Deunff (Combaz, Lange, and Pansart); Rauscher, p.63; pl.1, figs.14-15

1975 Leiofusa squama Deunff; Deunff and Massa, p.22; fig.13

1977 Poikolofusa squama Deunff; comb. nov. in Martin, p.18; pl.II, fig.23

1981 Poikilofusa squama Deunff (Martin); Martin and Dean, p.13; pl.1, fig.18

1982 Dactylofusa squama Deunff (Combaz, Lange, and Pansart); Cocchio, Table 1

Original diagnosis: Chitinous, pale yellow microorganism, the shell of which is in the form of a flattened spindle, finely striated, measuring 107 µm long and 8 to 15 µm wide. (Trans. of Deunff 1961)

Description: The elongate fusiform body has a width to length

ratio of from 1:3 to 1:8. It bears approximately twenty to thirty longitudinally arranged striae in optical section. The striae are continuous for the most part, but they may show some gaps. They appear to be made up of tiny echinate elements, but their small size makes this difficult to determine for certain under the light microscope. Some specimens show a tip at one pole, but on these the other pole is obscured so that the possible presence of this feature at both poles could not be determined. One specimen showed a longitudinal split.

Dimensions: Total length (estimated): 73-170 μm
Maximum width: 15-29 μm

Specimens measured: 12

Remarks: This species is retained in Poikilofusa because of the apparent microechinate nature of the striae and their failure to diminish distally. Only three complete specimens were found, most of the examples having one end truncated. The upper limit for length (170 μm) was estimated from a specimen of which only 140 μm remained. The Random Island specimens are wider, and often longer, than those of Deunff (1961) and they are longer than those described by Combaz (1967) and by Rauscher (1974), although comparable in width. Deunff's material shows more of a spine at the poles than do most of the Random Island forms. Some of the specimens from Random Island are more inflated centrally than others - this is evident from the width/length ratio which ranges from 1:3 to 1:8. The smaller, more inflated specimens generally have

more striations.

The species is similar to Eupoikilofusa striata Staplin, Jansonius, and Pocock 1965; comb. nov. Loeblich and Tappan 1978. However, the poles on P. squama are less rounded, the ornamentation does not fade towards the poles, and the striae are more numerous (twenty to thirty as contrasted with ten to twenty for E. striata) and appear to be more regularly arranged. Also, the body is more elongate, and less inflated centrally.

Occurrence: ?Upper Cambrian/Tremadoc: AC-1, ABC 10, Z-5, AC-W, Z-4, ABC 9, Z-3, ABC 8; Tremadoc: Z-2, AC-B, 32 C, 37 C, 39 C, 40 C, 42 C, EC 2, E-C 7-8, E-C 7

Previous occurrences: Tremadoc, Sahara (Deunff 1961); Tremadoc, Hassi-Messaoud, Sahara, Algeria (Combaz 1967); Ordovician, France (Rauscher 1974); Tremadoc, Libya (Deunff and Massa 1975); lower Tremadoc, Brabant, Belgium (Martin 1977); Tremadoc, Random Island (Martin and Dean 1981); Tremadoc, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

CHAPTER NINE

SUBGROUP OOMORPHITAE

Subgroup OOMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having a spherical to ellipsoidal test, without an inner body. Surface smooth or shagreen-like. A cluster of tubercles or short spines is present at one pole. No openings observed. (Downie, Evitt, and Sarjeant 1963, p.11)

9:1 Genus OOIDIUM Timofeev 1957; emend. Loeblich 1970

1957 Ooidium Timofeev gen. nov., p.281
1965 Ooidium Timofeev; emend. in Norris and Sarjeant, p.45
1970 Ooidium Timofeev; emend. in Loeblich, p.731-732

Type species (designated by Norris and Sarjeant 1965): Ooidium rossicum Timofeev 1957, p.281; figs.1-5

Emended diagnosis: Cysts with subcircular-ovate to elongate-ovate outline, one pole crowned with anastomosing trabeculae; wall surface commonly striate below the trabeculate portion, with lower portion of body granulate or psilate; no excystment mechanism observed. (Loeblich 1970)

Remarks: Loeblich, in 1970, on the basis of light microscope and scanning electron microscope evidence, found the polar concentration of ornamentation in Ooidium to be a network of anastomosing trabeculae rather than a concentration of

tubercles or short spines as stated by Norris and Sarjeant in their emendment of the genus in 1965. In his redefinition of the genus Loeblich also drew attention to the frequent presence of striae on the mid-portion of the cyst. In addition, Loeblich (1970) made the genus Zonoolidium, created by Timofeev at the same time (1957) as the genus Ooidium, a synonym of the latter, interpreting the 'fringe' that Timofeev used to distinguish Zonoolidium from Ooidium as a mere "reflection of the wall thickness" (Loeblich 1970, p.732).

Ooidium? clavigerum sp. nov.
Pl.30, figs.8-12, 15, 16

Type species: F 45, slide ABC 10 > 20 (1) [Pl.30, fig 12]

Paratype: FG 23, slide ABC 10 10-20 μm [Pl.30, fig.8]

Type locality: Locality ABC 10, in ?Upper Cambrian/Tremadoc strata, Random Island.

Derivation of name: From the Latin 'claviger' - club bearing.

Diagnosis: Central body ellipsoidal in outline, frequently broader at one end, sometimes showing folding at various orientations. At one pole a mass of tangled thread-like 'filaments' occupies approximately the upper 1/8 of the shell. At the other pole, two to fourteen processes visible in lateral view. Processes straight or curved, generally 'matchstick-like', with a cylindrical shaft expanding into a

bulbous distal termination. Occasionally processes divide distally into a funnel-shaped or clasp-like termination (see pl.30, fig.8). Some specimens show splitting. Body surface smooth.

Description: The folding pattern is variable when present, being transverse, oblique, or even concentric with the perimeter of the central body. The processes appear to be in communication with the central body cavity, but on most specimens the base is too narrow to determine this for certain.

Dimensions: Length of central body: 21-32.5 µm
Width of central body: 16-23 µm
Length of processes: 0.75-5.5 µm
Height of threads: 3-7 µm

Specimens measured: 18

Remarks: The tangled mass of thread-like 'filaments' at one pole may be equivalent to the trabeculae in the diagnosis of Ooidium but its exact nature has yet to be determined. The rudimentary processes at the opposite pole are a unique feature of this species. Their presence has not been reported for any other Ooidium species nor is it mentioned in the genus diagnosis. The latter could, however, as it contains only a few species, readily be expanded to include Ooidium-like species with various types of ornamentation at the non-trabeculate pole. No striations have been observed in the equatorial region of Ooidium? clavigerum. This species is

~2/3 the size of the Russian representatives of the genus Ooidium.

Occurrence: ?Upper Cambrian/Tremadoc: AC-1, ABC 10, Z-5, AC-W, Z-4

Ooidium rossicum Timofeev 1957; emend. Loeblich 1970
Pl.20, fig.13; Pl.21, figs.2-5

1957 Ooidium rossicum Timofeev sp. nov., p.281; figs.1-5
1957 Ooidium sablincaense Timofeev sp. nov., p.281; figs.6-8 (as 'sablincaene' on p.281)
1957 Zooidium guttiforme Timofeev sp. nov., p.282; figs. 15-23
1957 Zonooidium scutellatum Timofeev sp. nov., p.283; figs.26, 27
1959 Ooidium rossicum Timofeev; Timofeev, pl.XIII, fig.1
1959 Ooidium sablincaense Timofeev; Timofeev, pl.XIII, fig.2
1959 Ooidium guttiforme Timofeev; Timofeev, pl.XIII, fig.6; pl.XX, fig.15
1959 Ooidium scufellatum Timofeev; Timofeev, pl.XIII, fig.9; pl.XXII, fig.10
1962 Ooidium rossicum Timofeev; Timofeev, pl.VII, fig.2
1962 Ooidium sablincaense Timofeev; Timofeev, pl.VII, fig.3
1970 Ooidium rossicum Timofeev; emend. in Loeblich, p.732-733; figs.25 A-F; 26 A, B; 27A, B
non 1982 Ooidium rossicum Timofeev; Fombella, p.20; pl.I, figs.1, 11; pl.II, fig.23

Emended diagnosis: Inflated ovoid body, with dissimilar poles, commonly folded crosswise to the body during preservation; wall about 1 µm in thickness, lower 1/3 to 1/2 of the body ornamented by prominent grana that give the lower margin of the body a microserrate appearance; upper half of body with elevated discontinuous ridges that merge at the base of the summit into the broad bases of tiny trabeculae which crown the summit as a tangled and anastomosing series of tabeculae forming small arches; no excystment opening observed.

Length ranges from 36-42 µm and breadth from 29-35 µm. (Loeblich 1970)

Description: The oval body is frequently expanded slightly at the granulate pole. The other pole bears short, intertwining trabeculae that generally appear like short blunt spines. The inter-polar zone shows longitudinal striation.

Dimensions: Length of central body: 25-32 µm
Width of central body: 18-25 µm

Specimens measured: 8

Remarks: The Random Island material is smaller in size than Timofeev's Russian specimens. The merging of the ridges into the trabeculae cannot be seen with the light microscope. This species is distinguished from Ooidium timofeevi Loebich 1970, which resembles it, by the presence of grana on the lower part of its body and the prominence of the striae in its interpolar zone. The striae are faint on O. timofeevi and the lower

part of the body of that species is unornamented. Loeblich, in his re-examination of the species in 1970, included in Ooidium rossicum three other species described by Timofeev in 1957, namely: Ooidium sablincaense, Zonooidium guttiforme, and Zonooidium scutellatum.

Occurrence: ?Upper Cambrian/Tremadoc: AC-W, Z-4, ABC 9, 19 C, Z-3, ABC 8, 24 C; Tremadoc: Z-2, AC-B, 42 C, E-C 8

Previous occurrences; Tremadoc, U.S.S.R. (Timofeev 1957, 1959, 1962); Tremadoc, Obolus Sandstone, River Tosna area, U.S.S.R. (Loeblich 1970)

9.2 Genus TRUNCULUMARIUM Loeblich and Tappan 1976

1976 Trunculumarium Loeblich and Tappan gen. nov., p.305

Type species: Ooidium revinium Vanguestaine 1973a, p.30; pl.1, figs.3-6, 10, 14; Rn2b, (Middle Revinian) Upper Cambrian, Stavelot Area, Belgium.

Diagnosis: Vesicle oval in outline, with variable number of processes confined to one pole, processes hollow and communicating freely with the vesicle interior, commonly simple, rarely bifurcated; wall thin, surface of vesicle with grana, processes with grana, and small spinules and tubercles, excystment by simple rupture and splitting of the vesicle wall. (Loeblich and Tappan 1976)

Remarks: This genus was created for those Oomorphs which possess a crown of spines at one pole. It differs from Ooidium Timofeev 1957 in having spines, instead of trabeculae, at one pole.

Trunculumarium revinium Vanguestaine 1973; comb. nov. in Loeblich and Tappan 1976

Pl.30, figs.5-7

1973a Ooidium revinium Vanguestaine sp. nov., p.30; Pl.1, figs.3-6, 10, 14

1976 Trunculumarium revinium Vanguestaine; comb. nov. in Loeblich and Tappan, p.305

1981 Trunculumarium revinium (Vanguestaine) Loeblich and Tappan; Martin and Dean, p.22; pl.2, figs.5, 18; pl.5, figs.4, 6

1982 Trunculumarium revinium (Vanguestaine) Loeblich and Tappan; Martin, pl.1, fig.14

Original diagnosis: Oval central body. Diameter: 22.5 to 40 µm. Processes 11 to 30 in number, confined to one pole, conical, commonly simple though on some specimens some may be forked, .5 to 15 µm long, hollow and communicating freely with the vesicle cavity. Wall surface of both central body and processes densely covered with 0.25 to 0.5 µm wide granules. Small spines and tubercles on processes only, up to 0.5-1 µm. Membrane thickness about 0.3 µm. Excystment aperture appears as a slit along the main axis. (Vanguestaine 1973a)

Description: The central body is ellipsoidal in outline and bears from twenty to thirty-five processes at one pole (lateral view). The processes taper above their bases, and bear prominences up to 1 um long. The specimens are fairly dark so that the surface covering of the processes could not be determined. The central body is covered in granules. Several specimens show longitudinal splitting.

Dimensions: Length of central body: 26.5-36.5 µm
Width of central body: 18-32.5 µm
Length of processes: 8-15.5 µm

Specimens measured: 10

Remarks: This species was transferred from Ooidium by Loeblich and Tappan in 1976 because conical processes, rather than trabeculae, comprising the 'crown'. On Random Island, it is restricted almost entirely to one sample in the Upper Cambrian, with a single occurrence in a Tremadoc sample. (On that specimen, the prominences on the processes are not as pronounced as they are on those of the Upper Cambrian specimens.)

Occurrence: Upper Cambrian: Z-10; Tremadoc: E-C 7

Previous occurrences: Middle Revinian, top of Rn2b, Upper Cambrian, Stavelot, Belgium (Vanguestaine 1973a); Upper Cambrian, Elliott Cove Formation, Random Island (Martin and Dean 1981); Upper Cambrian, Elliott Cove Formation, Random Island (Martin 1982)

Trunculumarium? sp. A

Pl.27, figs.11, 12

Description: The central body is circular to ellipsoidal in outline. One pole bears what appear to be tapering processes interconnected by filamentous threads. The other pole is smooth.

Dimensions: Length of central body: 25-31 μm
Width of central body: 23-29.5 μm

Specimens measured: 6

Remarks: All six specimens of this species are poorly preserved so that the exact nature of the processes cannot be determined. They were found in only two closely spaced samples. The rather nondescript appearance of this species might cause it to be overlooked where it is present only in low abundance. It is provisionally assigned to the genus Trunculumarium because the simple tapering processes are confined to one pole. However, the filaments interconnecting the processes are not covered by the genus diagnosis.

Occurrence: Upper Cambrian: SH 13, SH 13x

9.3 Genus VOLKOVIA Downie 1982

1982 Volkovia Downie gen. nov., p.265

Type species: Deunffia dentifera Volkova 1969; p.234; pl.50, figs.29-31, Lower Cambrian, U.S.S.R.

Diagnosis: Acritarchs with small, ellipsoidal, single-walled vesicles, bearing at one pole a single prominent spine and an operculum or opening at the other. The opening may be surrounded by a corona of small spines. (Downie 1982)

Remarks: Downie (1982) transferred the species Deunffia coronifera and D. flagellata Jankauskas 1975, as well as D. dentifera Volkova 1969 to his new genus Volkovia. The two genera - Deunffia Downie 1960 and Volkovia - are similar in that both possess an ellipsoidal central body bearing a single spine at one pole. However, Deunffia, unlike Volkovia, does not possess a polar opening or operculum at the other pole. Some of the Random Island specimens are rounded at the pole opposite the spine-bearing pole. No pylome is visible on these specimens, nor can a separate operculum be distinguished. As many of the other specimens do show an opening, it is seems likely that, in those examples where it is absent, burial occurred before the opening had time to develop.

Downie, when he created the genus Volkovia in 1982, noted, "Volkovia is one of a characteristic group of Lower and Middle Cambrian oomorph. genera which includes Ovulum Jankauskas, Aranidium Jankauskas and Revinotesta Vanguestaine." (Downie, 1982, p.265). On Random Island, the genus is present in younger strata, ranging into the Upper Cambrian Parabolina spinulosa Zone.

Volkovia sp. A

Pl.21, figs.6-9

Possible synonym:

1973c Deunffia sp. A; Vanguestaine (MS.), p.216-217; pl. XII, fig.9

Description: The ovate to slightly globular test is covered in very short (≤1.5 µm) spines; the test bears a flagelliform process at one pole, the process being approximately half the length of the test. The other pole may be rounded, or open to form a pylome, in which case it bears a series of tooth-like projections giving a jagged effect.

Dimensions: Length of central body: 10-12 µm
Width of central body: 6.5-9 µm
Process length: 5-6.5 µm

Specimens measured: 12

Remarks: This form is comparable in test size to Volkovia coronifera (Jankauskas 1975) Downie 1982 but bears a much longer process that is not dilated terminally as it is in that species. It also lacks the small tubercles that decorate the unopened pylomar end of V. coronifera. V. flagellata (Jankauskas 1975) Downie 1982 differs from Volkovia sp. A in having a smaller test and a shorter process.

V. dentifera (Volkova 1969) Downie 1982 possesses a tuft at the end of the process not observed in this form and,

although, at its lower limit, the size range of V. dentifera (11-17 μm x 6-9 μm) overlaps that of V. sp. A, the former has a much longer process (13-17 μm). Only one of the four specimens studied by Volkova had a tuft, and Downie, 1982, did not observe it at all on his specimens. Also, Downie's specimens have shorter processes (4-7 μm) than those reported by Volkova, comparable in length to those of V. sp. A. The absence of a tuft, and the shorter length of the process, on V. sp. A may be the result of truncation, so that the Random Island specimens are not given a separate species designation at this time as they may belong to the species V. dentifera.

Deunffia sp. A Vanguestaine 1973 (MS.) falls within the length and width range for this species (12 μm x 7.5 μm), and although its process length is slightly longer (7.5 μm), it shows a comparable surface sculpture. Vanguestaine's single example of this species has no denticles at the non-process bearing pole. It could therefore be equivalent to the Random Island specimens in which the pylome has not opened.

Occurrence: Upper Cambrian: 11 A, 8 B, 10 B, 20 B, 21 B, 22 B-2, 24 B, 30 B, 3 C, 5 C, ABC 13.

CHAPTER TEN

SUBGROUP POLYGONOMORPHITAE

Subgroup POLYGONOMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having a pronounced polygonal test, without an inner body and without crests. Processes isolate or fusing at the bases, few in number, normally simple, rarely branching. (Downie, Evitt, and Sarjeant 1963, p.8)

10.1 Genus CORYPHIDIUM Vavrdová 1972

1972 Coryphidium Vavrdová gen. nov., p.84

Type species: Coryphidium bohemicum Vavrdová 1972, p.84-85; pl.1, figs.1, 2; text-fig.4. Arenig, Klabava Shales, Bohemia.

Original diagnosis: Acritarchs with polyhedral main body, angles rounded. Wall thin, single-layered, in places sculptured with very fine ribs. Numerous processes, equal in length, symmetrically distributed at angles of polyhedron and adjoining edges. Processes are conical, proximally opened, distally heteromorphic (truncate, bifurcate, plurifurcate). (Vavrdová 1972)

Remarks: According to Vavrdová (1972), some specimens of this genus show an opening corresponding in position to the precingular archaeopyle of fossil dinoflagellates.

Coryphidium? sp.

Pl.21, fig.10

Description: The central body is roughly subsquare in outline with rounded corners. It bears, in optical section, approximately twenty-three processes which are slightly bulbous to clavate terminally; the bulbous terminations are almost opaque relative to the semi-transparent, proximal shafts. The interiors of the processes appear to be in communication with the central body cavity. Some of the processes may bifurcate distally. The body surface is slightly shagrinate.

Dimensions: Diameter of the central body: 32.5 μm
Length of processes: 3.5-6 μm

Specimens measured: 1

Remarks: This species is tentatively assigned to the genus Coryphidium on the basis of its subsquare outline and rounded corners. On the one specimen found it was difficult to determine the pattern of process distribution and the degree of variability in the process terminations. The processes seem to be randomly arranged rather than concentrated at the angles of the polyhedron and on the adjoining edges. The species could possibly be assigned to Baltisphaeridium, but the processes do appear to be in communication with the central body cavity. Of the non-rugulate species of Coryphidium, C. tadla Cramer and Díez 1976 has capitate processes. The latter are, however, more numerous

(approximately forty), slenderer, and their terminations are generally less expanded. C. australe Cramer and Díez 1976 has even more numerous processes (approximately forty-five) that are, in most cases, shorter (up to 3 µm) and may be denticulate distally. The shorter, more clavate processes of C.? sp. resemble some of the processes of C. australe but not those of the latter that exhibit denticulate branching.

Occurrence: ?Upper Cambrian/Tremadoc: 19 C

10.2 Genus ESTIASTRA Eisenack 1959

1959 Estiastra Eisenack gen. nov., p.201
1970 Estiastra Eisenack; Loeblich, p.44

Holotype: Estiastra magna Eisenack 1959, p.201-202; pl.16, figs.17-20; Esthonus-Limestone, lowermost Silurian, Stage H, Kattentak, Estonia.

Original diagnosis: Star-shaped shells, whose broad, cornet shaped appendages arise from a common centre, yet in such fashion that the central body is not visibly distinct from the appendages, but the central cavity may be formed only from the bases of the originally very pyramidal prominences. (Trans. of Eisenack 1959 in Norris and Sarjeant 1965, p.28)

Remarks: This genus overlaps with the genera Veryhachium Deunff 1954 and Goniosphaeridium Eisenack 1969. Downie and Sarjeant (1963) distinguish the genera Veryhachium and

Estiastra on the basis of the distinct separation of the processes from the central body in the former genus and not in the latter, while noting the boundary between the two genera seems to be arbitrary. Some species included under the genus Goniosphaeridium show the stellate outline and lack of differentiation of the central body which characterize Estiastra (e.g. compare G. raczi Cramer 1964 and E. stellata Loeblich 1970). The former genus, as redefined by Kjellström in 1971a, is said to possess a spherical to polygonal vesicle. The genus should, perhaps, be restricted to species in which the vesicle outline is clearly defined and distinct from the processes, although, as was the case with Veryhachium, the boundary is again arbitrary. The genus Estiastra shows some resemblance to the genus Pulvinosphaeridium Eisenack 1954 in possessing a stellate outline and inflated processes that are indistinguishable from the central body. The two may be distinguished by the acuteness of the process contacts in the former, as contrasted with the gently undulating contacts in the latter.

Estiastra sp. A

Pl.21, figs.11, 12

Possible synonym:

1976 Goniosphaeridium connectum Kjellström 1971; Kjellström, p.30; fig.23

Description: The test has a stellate outline with five to six

processes forming an outer array while the remainder occur more centrally, giving a total of eight to twelve processes. The processes merge with the central body so that the outline of the latter is masked. Each of the funnel-shaped processes has a broad triangular base from which arises a columnar terminal part with an evexate tip. Some processes show less of a division into triangular and columnar parts; their shape, individually, then resembles that of an apically rounded cone.

Dimensions: Total diameter: 32-40 µm

Specimens measured: 4

Remarks: This species is much smaller than most members of the genus (although comparable in size to Estiastra culcita Wicander 1974). In outline, it resembles the Estiastra species illustrated by Rauscher, 1974, from the Llanvirnian of France (pl.II, fig.8) but that species is about five times as large and does not appear to have an inner array of processes.

Goniosphaeridium connectum Kjellström 1971, as illustrated in Kjellström 1976, fig.23, shows the same stellate outline and funnel-shaped processes and is comparable in size (vesicle diameter 25-28 µm; process length 12-14 µm). However, the species, as originally described by Kjellström in 1971a, is larger and has a more clearly defined central body and longer, narrower processes which taper gradually and do not show an inflated triangular base. If the 1971 and the 1976 specimens described by Kjellström are the same species, in spite of their somewhat different shape and size, then Estiastra sp. A, which is different from the 1971 specimens

illustrated by Kjellström, is probably a separate species.

Occurrence: Tremadoc: E-C 7

10.3 Genus GONIOSPHAERIDIUM Eisenack 1969; emend. Kjellström 1971

1969 Goniosphaeridium Eisenack gen. nov., p.255-256
1971 Goniosphaeridium Eisenack; emend. in Kjellström, p.43

Type species: (1) Holotype (lost)- Ovum hispidium polygonale Eisenack 1931, p.113; pl.4, fig.19.
(2) Neotype- Baltisphaeridium polygonale Eisenack 1959, p.199; pl.16, fig.8.

Emended diagnosis: Unicellular, organic-walled microplankton with spherical to polygonal vesicle greater than 20 µm, not divided into fields or plates. Process interior communicates freely with vesicle cavity, the distal terminations of the processes always simple and closed. Walls psilate or shagrinate. (Kjellström 1971a)

Remarks: This genus is distinguished from the genus Baltisphaeridium Eisenack (1958) 1969 by its processes being in communication with the central body cavity rather than being closed proximally, and from Multiplicisphaeridium (Staplin 1961) Lister 1970 in having simple instead of multifurcate process terminations. The genus Polygonium Vavrdová 1966, comprising polygonal species with a low number

(about fifteen) of long, broad-based processes, was made a partial junior synonym of Goniosphaeridium and of Micrhystridium Deflandre 1937 by Eisenack et al. in 1976. The present author retains the original 20 µm size limitation for Micrhystridium. Consequently, polygonal forms over 20 µm in diameter with simple, basally open, processes are assigned here to Goniosphaeridium.

Goniosphaeridium eisenackianum? Deunff 1958; comb. nov.

Pl.21, figs.16, 17; Pl.22, figs.1-3, 7

1958 Hystrichosphaeridium eisenackianum Deunff sp. nov., p.23-24; pl.2, figs.26, 30, 31

1963 Baltisphaeridium eisenackium Deunff; Downie and Sarjeant, p.90

1964 Baltisphaeridium eisenackianum Deunff; Downie and Sarjeant, p.90

1965 Baltisphaeridium cf. eisenackianum Deunff; Vavrdová, p.352; pl.1. figs.1-3

1969 Baltisphaeridium eisenackianum Deunff; Konzalová-Mazancová, p.84-85; fig.2

1969 Baltisphaeridium eisenackianum Deunff; Lister, Cocks, and Rushton, p.602

1970 Baltisphaeridium cf. eisenackianum Deunff; Paris and Deunff, p.29; pl.3, fig.2

1971 Baltisphaeridium eisenackianum Deunff; Moreau-Benoit, p.139-140; pl.2, fig.14

Original diagnosis: Hystrichosphere, of dark yellow or brown-black colour, with shell measuring 55-60 µm in diameter. The long, hollow, slender processes; some ten in number, communicate with the interior of the shell; their length is approximately 100 µm and their basal diameter is between 2.5 and 5 µm. (Trans. of Deunff 1958)

Description: The central body, irregularly spherical to subpolygonal in outline, bears five to ten processes that are quite distinct and do not merge with it. The hollow processes make angular contact with the central body and freely communicate with its interior. They arise from bases 3 to 8 µm in diameter, taper slightly, and have acuminate to evexate terminations. Sparse spinose ornamentation is often present on the processes. They are often truncated, and in most cases it appears that it is the longest processes that are incomplete. The shell surface is shagrinate.

Dimensions: Diameter of central body: 35-62 µm
Length of processes: 14-32 µm (lower limit)

Specimens measured: 9

Remarks: These specimens are, with doubt, assigned to Goniosphaeridium eisenackianum as none of them was found to possess processes about 100 µm in length, although truncation of many of the larger processes may account for this finding. Also, many of the specimens possess fewer processes than reported by Deunff in 1958. One specimen shows slightly narrower processes than the rest. The reported stratigraphic

range for G. eisenackianum is Caradoc to Upper Silurian, but these specimens occur in uppermost Upper Cambrian samples.

G. conjunctum Kjellström 1971 differs from this species in possessing broader based processes that make curved proximal contact with the vesicle, thereby giving the central body a polygonal outline. G. connectum Kjellström 1971, while comparable in dimensions, including basal width of the processes, has a polygonal rather than a circular to oval outline and has processes that make curved contact with the central body. The Tremadoc species Baltisphaeridium spinosum Rasul 1979 is very similar to G. eisenackianum? but has smooth processes.

Occurrence: Upper Cambrian: Z-7, AC-D, AC-A, ABC 11, AC-2, SH 13z, SH 13, SH 13y, SH 13x; ?Upper Cambrian/Tremadoc: Z-5; Tremadoc: 40 C

Previous occurrences: Upper Ordovician, Brittany (Deunff 1958); Ashgillian, Czechoslovakia (Vavrdová 1965; Konzalová-Mazancová 1969); Caradocian subsurface material, England (Lister, Cocks, and Rushton 1969); Llanvirn, Brittany (Paris and Deunff 1970); Upper Ordovician and Lower Silurian, Brittany (Moreau-Benoit 1971)

Goniosphaeridium gracilis Vavrdová 1966; comb. nov.
Pl.21, figs.13, 14; Pl.22, fig.4; Pl.31, figs.5, 8

1966 Polygonium gracilis Vavrdová sp. nov., p.43; pl.2, fig.3; pl.3, fig.1; text-figs.3b, 4b

1973 Polygonium gracile Vavrdová; Rauscher, p.75; pl.III, fig.1

1974 Polygonium gracile Vavrdová; Rauscher, p.89; pl.I, fig.17

1975 Polygonium gracilis Vavrdová; Deunff and Massa, p.22

1976 Polygonium gracile Vavrdová; Vavrdová, pl.III, fig.8

1977 Polygonium gracile Vavrdová; Vavrdová, table 1

Original diagnosis: Shells with hexagonal or pentagonal outline provided with long, usually simple smooth processes communicating with the inner cavity. Processes are regularly arranged in circles after the following pattern: 1; 5'(6'); 5''(6'''); (3'''); 1''''. Diameter of central body: 20-35 µm. Length of processes: 9-35 µm. (Vavrdová 1966)

Description: The central body has six to seven straight sides and bears ten to sixteen tapering processes that communicate freely with the interior of the central body. The processes are approximately 3 µm wide basally and have acuminate distal terminations. Six to seven processes form an outer peripheral ring while the remainder, except for a possible central process, form an inner ring, staggered with respect to the outer ring. A central process is evident in some specimens but not in others. The surface of the body is smooth to shagrinate.

Dimensions: Diameter of central body: 22-26 µm
Length of processes: 9-14 µm

Specimens measured: 6

Remarks: The lengths of the processes of the Random Island specimens of G. gracilis fall within the lower part of the length range quoted by Vavrdová (1966). The clearly defined polygonal outline and the concentric arrangement of processes distinguishes this species from G. tener Timofeev 1959. G. dentatum Timofeev 1959 exhibits a greater degree of merging of process bases with the central body and thus the polygonal outline of the latter is much less clearly defined.

This species, like many others in the genus Goniosphaeridium, shows forms gradational between that genus and the genera Acanthodiacrodium and Tectitheca.

Occurrence: Upper Cambrian: Z-8, AC-G, Z-7, Z-6, ABC 11, SH 13z, SH 13, SH 13x, AC-1; ?Upper Cambrian/Tremadoc: ABC 10, Z-5, AC-W, Z-4, ABC 9, 19 C, Z-3, ABC 8, 24 C; Tremadoc: Z-2, AC-B, Z-1, 32 C, 37 C, 39 C, 40 C, 42 C, EC 4, EC 2, E-C 9, E-C 7-8, E-C 7, E-C 6

Previous occurrences: Arenig, Klabava Shales, Central Czechoslovakia (Vavrdová 1966; 1976); Arenig, Montagne Noire, France (Rauscher 1973; 1974); Tremadoc, Sanrhar Formation, Libya (Deunff and Massa 1975); Arenig-Llanvirn, Šárka Formation, Central Bohemia (Vavrdová 1977)

Goniosphaeridium pungens Timofeev 1959; comb. nov.
Rauscher 1973
Pl.21, fig.15; Pl.31, fig.4

1959 Archaeohystrichosphaeridium pungens Timofeev sp. nov.,

p.21; pl.III, fig.33

1969 Baltisphaeridium pungens Timofeev; comb. nov. in Martin, p.60; pl.I, figs.16, 23, 24, 34; text-fig.14

1973 Goniosphaeridium pungens Timofeev; comb. nov. in Rauscher, p.62; pl.I, figs.7-8

1975 Goniosphaeridium pungens (Timofeev) Rauscher; Deunff and Massa, p.22; pl.1, fig.8

1978 Goniosphaeridium pungens (Timofeev) Rauscher; Fournier-Vinas, pl.II, figs.14, 17

1982 Goniosphaeridium pungens (Timofeev) Rauscher; Cocchio, Table 1; pl.1, fig.1

Original diagnosis: Shell rounded, thick, with 12-20 long pointed spines. Spines have an expanded base, their length is equal to 1/2 the diameter of the shell. Sculptural background shagrinate. Colour pale yellow. Diameter 25-40 µm (with spines 45-60 µm). (Trans. of Timofeev 1959)

Description: The central body is circular to subpolygonal in outline and bears fifteen to twenty-one conic processes with acuminate terminations. The processes, which internally communicate freely with the cavity of the central body, are 1.5-4.5 µm wide basally even though the contact of each process with the central body is curved. They are distinctly separated from the central body and in length they are approximately 1/3rd to 1/2 the diameter of the central body. The body surface is shagrinate.

Dimensions: Diameter of central body: 20-24 µm
Length of processes: 8-9 µm

Specimens measured: 3

Remarks: This species resembles Baltisphaeridium nanum (Deflandre 1945) Downie 1959 in outline and in process shape and length. It does have a shagrinate rather than the smooth surface which is found in the latter species, but the present author does not consider this difference to be an adequate criterion for distinguishing between them because in many species specimens can be found having one or the other of these kinds of surface. B. brevispinosum Eisenack 1931, of which B. nanum was originally a variety, shows separation of the process and central body cavities; Deflandre, when creating the variety, did not comment on the presence or absence of this feature. Other authors have given different descriptions; Lister, in emending the species in 1970, defined it as having processes which communicate freely with the vesicle cavity while Kjellström (1971) stated there is a "faintly defined separation of the interior of the process from the vesicle cavity" (Kjellström 1971a, p.36) and Rauscher, 1973, noted that the processes are without communication with the central cavity. Because of the similarity of G. pungens and B. nanum, the author feels that forms in which no separation between process and central body cavity occurs should be assigned to Timofeev's species, G. pungens, while those specimens which show a separation of the two cavities should be placed in Deflandre's species, B. nanum, in keeping with the concept of the original diagnosis of B. brevispinosum (of which B. nanum was originally a variety). The long stratigraphic range of this rather simple species - Tremadoc to Upper Devonian - may mean in fact that

it includes several species.

The classification of many of the species in the genus Goniosphaeridium is somewhat disorganized. The Random Island specimens show narrow-based, discrete processes as contrasted with the broader-based, overlapping processes of other Goniosphaeridium species. Rauscher (1973) assigns those Goniosphaeridium species with polygonal central bodies and broad-based conic processes from 8-16 µm long to either G. dentatum Timofeev 1959 or G. pungens, according to the presence or absence of ornamentation on the central body; he assigned the forms with smooth surfaces to the former species and those with shagrinate and finely granulose surfaces to the latter species. However, Timofeev's original diagnosis of the two species refers to them both as possessing shagrinate surfaces. The present author, for the time being, retains Timofeev's original species diagnosis and distinguishes G. dentatum from G. pungens on the basis of its broader-based, more overlapping processes while admitting that it may eventually prove necessary to unite several of Timofeev's 1959 species within a single species.

G. adligans Timofeev 1959 has somewhat shorter processes than G. pungens.

Occurrence: Upper Cambrian: SH 13

Previous occurrences: Tremadoc, Prebaltic (Timofeev 1959); Tremadoc and lower Arenig?, Belgium (Martin 1969); Tremadoc, Montagne Noire, France (Rauscher 1973); Tremadoc, Sanrhar Formation, Libya (Deunff and Massa 1975); Tremadoc, Monts de Lacaune, Montagne Noire, France (Fournier-Vinas 1978);

Tremadoc - Arenig, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

Goniosphaeridium symbolum Rasul 1979; nov. comb.

1979 Polygonium symbolum Rasul sp. nov., p.62; pl.1, fig.10

Original diagnosis: Body polygonal smooth, the outline of which is somewhat obscured by the broad bases of the processes which merge into the test. The processes are hollow, simple, long, smooth, tapering, sometimes end with hair-like tips. No excystment recorded. (Rasul 1979)

Goniosphaeridium cf. symbolum Rasul 1979

Pl.22, fig.6

Description: The central body is polygonal but the broad bases of the processes obscure the outline. There are from twenty-one to twenty-six processes. Generally, each process tapers rapidly from a triangular base to a narrow, almost cylindrical, but slightly tapering distal part. The exceptions lack a distinct triangular base and exhibit uniform tapering. There is considerable process overlap. The surface of the body is smooth.

Dimensions: Diameter of central body: 21-22 µm

Length of processes: 11-17 µm (this is a lower limit as most of the processes were truncated)

Specimens measured: 2

Remarks: This species fits the diagnosis for Polygonium symbolum Rasul 1979. However, the illustration of Rasul's species shows a broader-based process which tapers more uniformly throughout its length rather than showing a constriction between the basal and the more distal portions of the process.

Goniosphaeridium gracilis Vavrdová 1966 has a clearly defined hexagonal or pentagonal outline with process bases that are quite distinct from the outline of the central body. Furthermore, it generally has fewer (approximately fifteen) processes. Archaeohystrichosphaeridium pellicidum Timofeev 1959 has still fewer processes (twelve to fifteen) and they taper uniformly. Kjellström's species (1971) G. connectum and G. conjunctum likewise have fewer processes - ten and fifteen respectively - and they also taper uniformly.

Occurrence: Tremadoc: 37 C, E-C 7

Goniosphaeridium uncinatum Downie 1958; comb. nov. in Kjellström 1971

Pl.22, fig.8; Pl.23, figs.1, 2

1951 Hystrichosphaeridium sp. ex aff. longispinosum Eisenack 1931; Eisenack, p.191; pl.3, fig.7; text-fig.1

1958 Hystrichosphaeridium longispinosum (Eisenack) var. uncinatum nov. Downie, p.337, fig.2a

1964 Baltisphaeridium longispinosum var. uncinatum

Downie; comb. nov. in Downie and Sarjeant, p.92

1965 Baltisphaeridium uncinatum (Downie) Downie and Sarjeant; Martin, p.425-426; text-fig.1

1965 Veryhachium piliferum Martin sp. nov., p.432-433; text-fig.9

non 1966 Baltisphaeridium aff. uncinatum (Downie) Downie and Sarjeant; Martin, p.310-311; pl.1, fig.5

1966 Baltisphaeridium uncinatum (Downie) Downie and Sarjeant; Martin, p.309, 326, 333

1969 Baltisphaeridium uncinatum (Downie) Downie and Sarjeant; Martin, p.66-67; pl.1, figs.17, 21; pl.2, figs.70, 96; pl.5, fig.228; pl.6, fig.267; text-fig.19

1969 Baltisphaeridium cf. longispinosum var. uncinatum (Downie) Downie and Sarjeant; Henry, p.77; pl.1, figs.8, 10

1970 Micrhystridium uncinatum Downie; comb. nov. in Cramer, p.107-108; pl.6, figs.97, 98, 101; text-fig.29d

1971b Goniosphaeridium uncinatum Downie; comb. nov. in Kjellström, p.27-28; pl.18

1973 Goniosphaeridium uncinatum (Downie) Kjellström; Martin, p.9-10; pl.VII, fig.15

1975 Goniosphaeridium uncinatum (Downie) Kjellström; Deunff and Massa, p.22; pl.1, fig.2

1977 Goniosphaeridium uncinatum (Downie) Kjellström; Vavrdová, table 1

1977 Goniosphaeridium uncinatum (Downie) Kjellström; Martin, table 1; pl.IV, fig.24; pl.V, figs.3, 14

1978 Goniosphaeridium uncinatum (Downie) Kjellström; Dean and Martin, Table 2; pl.1, figs.4, 5; pl.2,

fig.4

1978 Goniosphaeridium uncinatum (Downie) Kjellström; Fournier-Vinas, pl.II, figs.1, 9

1981 Goniosphaeridium uncinatum (Downie) Kjellström; Martin and Dean, p.13; table 1

1982 Goniosphaeridium uncinatum (Downie) Kjellström; Cocchio, Table 1; pl.1, fig.3

Original diagnosis: Test rather polygonal, thin walled; processes with numerous small lateral branches, 1-1.5 µm in length, normal to main process and giving it a barbed appearance. (Downie 1958)

Description: The central body is subpolygonal to polygonal and bears twenty to thirty-two tapering processes the cavities of which communicate freely with the interior of the central body. The processes bear numerous thorn-like lateral branches up to 5 µm long (generally 3 µm maximum length), that lie at right angles to the main process. Generally, the processes are truncated. They have curved proximal contacts with the central body. The surface of the latter is smooth to shagrinate.

Dimensions: Diameter of central body: 22-31 µm
Length of processes: 16-20 µm
Basal width of processes: 2.5-5 µm

Specimens measured: 5

Remarks: This species is distinguished from other

Goniosphaeridium species by the thorn-like lateral branches. The specimens from Random Island have generally longer lateral branches than do Downie's forms and show more numerous processes than is indicated in his illustration of the species. Cramer (1970) reports longer lateral branches than in the original diagnosis - up to 3 µm long - and a greater number of processes - from ten to more than twenty-five.

Occurrence: Upper Cambrian: Z-8, AC-G, AC-F, AC-D, Z-6, AC-A, ABC 11, SH 13; ?Upper Cambrian/Tremadoc: Z-5, 24 C; Tremadoc: Z-2, AC-B, 37 C, 40 C, EC 4, EC 2, E-C 9, E-C 7

Previous occurrences: Tremadoc, England (Downie 1958); Lower Ordovician, Jagoval, Estonia (Eisenack 1951); Tremadoc, Llanvirnian, Belgium (Martin 1965, 1969); Caradoc, Brittany (Henry 1969); doubtful occurrences in the upper Llandoverian to lower Wenlockian, Belgium (Martin 1966); Upper Ordovician (not lower Silurian) subsurface material, Libya, Saudi Arabia (cf. Cramer 1970); reworked in Lower Silurian, Almodovar del Campo, Spain (cf. Cramer 1970); Middle Ordovician (lower Viruan) subsurface material, Gotland (Kjellström 1971); Tremadoc, Montagne Noire, France (Martin 1973); Tremadoc, Sanrhar, Libya (Deunff and Massa 1975); Tremadoc and Arenig or Llanvirn, Brabant, Belgium (Martin 1977); Arenig-Llanvirn, Šárka Formation, Central Bohemia (Vavrdová 1977); Tremadoc - Arenig, Bell Island, Newfoundland (Dean and Martin 1978); Tremadoc, Monts de Lacaune, Montagne Noire, France (Fournier-Vinas 1978); Upper Cambrian-Tremadoc, Random Island (Martin and Dean 1981); Tremadoc - Arenig, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

Goniosphaeridium sp. A

Pl.22, figs.5, 9; Pl.23, fig.4

Description: The central body is round to subpolygonal in outline and bears seventeen to thirty slender, narrow-based processes that taper to a point. The processes are from 1.5 to 2 μm wide at the base and are quite distinctly separated from the outline of the central body. Many of them are truncated but those still intact are approximately half the diameter of the central body in length. The surface of the central body is smooth to shagrinate.

Dimensions: Diameter of the central body: 19-26 μm.
Length of processes: 9-14 μm (this is a lower limit due to the truncation of the processes.)

Specimens measured: 9

Remarks: This species has a greater number of processes than does Goniosphaeridium pungens Timofeev 1959 and they are also less spine-like and more sinuous than in that species. They are, in fact, more like those of B. lucidium (Deunff 1958) Downie and Sarjeant 1964. Martin, 1969, distinguishes B. lucidium from Baltisphaeridium nanum on the basis of process length, those of the former species generally being longer. As the present author distinguishes B. nanum and G. pungens on the basis of the separation or non-separation of the process and body cavities (with G. pungens having processes in communication with the body cavity), while considering them to be comparable in dimensions, then G. pungens can also be

distinguished from B. lucidium on the basis of process length. However, although G. sp. A appears to have had some long processes that have been truncated and may be equivalent to B. lucidium, the condition of preservation of the specimens makes a positive designation difficult.

Occurrence: Tremadoc: 37 C, E-C 7

10.4 Genus IMPLUVICULUS Loeblich and Tappan 1969; emend. Martin 1977

1969 Impluviculus Loeblich and Tappan gen. nov., p.48
1977 Impluviculus Loeblich and Tappan; emend. in Martin 1977; p.15

Type species: Veryhachium milonii Deunff 1968, p.47; pl.1, figs.1-8, 10-13, and 15-17., Tremadoc, Morocco.

Emended diagnosis: Central body of a more or less lenticular form, with a polygonal to nearly circular outline and a diameter generally less than 20 µm. From four to some ten conic processes of which the main ones are placed peripherally along the equatorial zone; their internal cavities communicate with that of the central body. Central opening more or less circular to polygonal in outline, with or without bordering spines or tubercles. Operculum more or less circular to polygonal in outline, ornamented or not ornamented with excrescences. The surface of the central body is smooth or bears warts, hairs, or spines. (Trans. of Martin 1977)

Remarks: Martin emended the genus to allow for greater variability in body outline and number of processes than the subquadratic form with four processes in the original diagnosis of Loeblich and Tappan.

Certain species of the genera Veryhachium Deunff 1954 and Impluviculus resemble each other, for example V. minutum Downie 1958 and I. milonii (Deunff 1968) Loeblich and Tappan 1969. The flattened nature of Impluviculus as contrasted with the more three-dimensional form of Veryhachium may not be recognizable under the light microscope, and then, unless a pylome or operculum is visible, specimens of the two genera are indistinguishable. Any deviation from the pad-like form, such as one process defining a different body plane from the others, would distinguish the specimen as being a species of Veryhachium.

Impluviculus? bibulbulus sp. nov.

Pl.23, figs.7, 8, 26, 28; Pl.24, figs.3-5; Pl.33, fig.8

Holotype: DE 18, slide 37 C > 10 (2) [Pl.24, fig.3]

Paratypes: HJ 39/40, slide 37 C 10 (2) [Pl.23, fig.28]
E 22/23 4/3, slide 37 C > 10 (2) [Pl.24, fig.5]

Type locality: Locality 37 C, in the Parabolina argentina Zone, Tremadoc, Clarenville Formation, Random Island.

Derivation of name: From the Latin 'bi' - two- and 'bulbulus' - little swellings.

Diagnosis: Central body rhombohedral with a single process at each angle of the rhombohedron, the processes communicating freely with the central body cavity. Rarely, a fifth process may arise near the base of one of the other four. The processes bifurcate distally and occasionally show secondary bifurcation. The tips of the terminal bifurcations are usually bulbous. Surface of the central body is smooth to shagrinate.

Description: The processes vary in length from shorter to greater than half the length of the sides of the central body. On some specimens the bifurcation occurs directly from the central body with no intervening 'stalk'. Some examples show a distally rounded main process from which arise two disks borne on short 'stems' (see pl.24, fig.5). Generally the terminations are expanded, but on some specimens no expansion was observed. This may be due to deflation or truncation of the terminations (although the length of the terminations makes the latter unlikely), or to variation within the species. The processes of most specimens are in a poor state of preservation, and only rarely are all four present. Several of the specimens which lack the intervening stalk show an additional branch at the point of bifurcation. An irregular opening, possibly a pylome, occurs centrally on some specimens.

Dimensions: Length of sides of central body: 8.5-14 µm
Total length of processes: 2-8 µm
Length of terminations: 0.5-3.5 µm

Specimens measured: 13

Remarks: This species, in size and shape, resembles Veryhachium minutum and also Impluviculus milonii. It differs from these two species in having processes that bifurcate and are bulbous terminally. I.? lacrimifer sp. nov. has smaller terminal expansions which occur singly. Schizocystia saharica Jardiné, Combaz, Magloire, Peniguel, and Vachey 1974 is very similar to I.? bibulbulus in form as it has a quadratic central body bearing short processes with bulbous terminations. These may be bi- or tri-furcate. However, specimens of this Devonian species are approximately twice the size of those of the Random Island species. Furthermore they have rough to microverrucate surfaces and are divided into roughly equal halves (a characteristic of the genus Schizocystia).

The generic designation of I.? bibulbulus is in some doubt. The genus Veryhachium, as emended by Downie and Sarjeant in 1963, is defined as having hollow, pointed spines whereas in this species the processes bifurcate and are expanded terminally. The genus Adorfia Burmann 1970 also shows doubly capitate terminations but the degree of branching is much more complex giving tree-like branching patterns. The genus Micrhystridium Deflandre 1937 has a greater number of processes (more than nine) than does I.? bibulbulus, although the size range of that genus is comparable, and bulbous terminations fall within the scope of the genus. I.? bibulbulus and the new species I.? lacrimifer are assigned to the genus Impluviculus on the assumption that the central openings observed on some specimens are pylomes. These are

not as definite as those on other species of the genus. Many specimens show growth of pyrite within the central body. It is possible that the observed openings are the result of the removal of pyrite crystals. If these openings are indeed accidental, then a new genus needs to be created for small polygonal forms in which the processes are modified and less than nine in number.

Occurrence: ?Upper Cambrian/Tremadoc: AC-W, Z-4, ABC 9, 19 C, ABC 8, 24 C; Tremadoc: 32 C, 37 C, 39 C, 42 C, EC 5, EC 4, EC 2, EC 1, E-C 9, E-C 8, E-C 7-8, E-C 7, E-C 6

Impluviculus circularis sp. nov.
Pl.23, figs.13, 15-21

Holotype: Q 26, slide 24 B (P)2 [Pl.23, fig.20]

Type locality: Locality 24 B, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'circularis' - round.

Synonymous with:

1973c Impluviculus multiangularis Umnova 1971; comb. nov. in Vanguestaine (MS.), p.178-180; text-fig.58 f, g, (?) h, i; pl.XI, figs. (?) 20, 21-22; pl.XXI, fig.6; pl.XXV, fig.11

1973c Impluviculus milonii (Deunff 1968) Loeblich and Tappan 1969; Vanguestaine (MS.), p.177-178, text-fig.

58e, pl.XI, figs.18, (cf.) 19

1974a Impluviculus multiangularis (Umnova 1971) Vanguestaine (MS.) 1973; Potter (MS.), p.151-154; pl.22, fig.3; pl.30, fig.15

Diagnosis: Circular to slightly subcircular central body with circular pylome or operculum. From four to eight slender processes arise singly or in pairs from the perimeter of the central body, generally forming a + pattern. Surface of central body smooth.

Description: Some specimens show small folds crossing the operculum.

Dimensions: Diameter of central body: 11-20 µm
Length of processes: 3-9 µm

Specimens measured: 17

Remarks: This species is synonymous with most specimens attributed to I. multiangularis by Vanguestaine 1973c (MS.) and some of those he assigned to I. milonii.

Occurrence: Upper Cambrian: 20 B, 21 B, 22 B-2, 24 B, 30 B, 3 C, ABC 14, 5 C, ABC 13, ABC 12, 8 C, Z-7, Z-6, AC-A, AC-2; ?Upper Cambrian/Tremadoc: AC-W, Z-4, ABC 9, 19 C, Z-3, ABC 8, 24 C; Tremadoc: Z-2, Z-1, 32 C, 37 C, EC 5, EC 4, EC 2, EC 1, E-C 9, E-C 6

Impluviculus? lacrimifer sp. nov.

Pl.23, figs.22-25, 27

Holotype: H 36 2/4, slide 24 B (P) 2 [Pl.23, fig.27]

Type locality: Locality 24 B, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Latin 'lacryma' - tear - and 'fer' - to bear.

Diagnosis: Polygonal to subpolygonal body with four to eight processes which communicate freely with the vesicle interior. Processes arise from a triangular base and taper slightly distally before expanding into a drop-like termination. The body surface is shagrinate.

Description: The shape of the central body is usually rhombohedral but in some cases it has been distorted. It appears to be two dimensional with the processes arising from the periphery. The terminations of the processes vary in size from barely perceptable expansions to prominent globules. A faint polygonal opening, possibly a pylome, is visible on some specimens.

Dimensions: Diameter of the central body: 10-18 µm
Length of processes: 4-12 µm
Diameter of terminations: 0.75-1.0 µm

Specimens measured: 9

Remarks: This species differs from Micrhystridium acum Martin 1969 in having a polygonal to subpolygonal rather than a globular central body, and in possessing a much smaller number of processes. It is tentatively assigned to the genus Impluviculus because of the possible presence of a pylome and its shape. The latter is generally rhombohedral in optical view, like that of I. milonii, with the processes arising from the periphery in one plane, suggesting a lenticular cross-section. Also, the size falls within the range for other species of the genus.

Occurrence: Upper Cambrian: 8 B, 10 B, 24 B, Z-9; Tremadoc: 32 C, 39 C, EC 5, EC 1, E-C 8, E-C 7-8, E-C 6

Impluviculus milonii Deunff 1968; comb. nov. in Loeblich and Tappan 1969
Pl.23, figs.9-12; Pl.29, fig.12

1966 Veryhachium cf. lairdi Deflandre 1946; Deunff, pl. 3, fig.40

1968b Veryhachium milonii Deunff sp. nov., p.46-47; pl.1, figs.1-8; 10-13, 15-17

1969 Impluviculus milonii Deunff; comb. nov. in Loeblich and Tappan, p.48

1973 Impluviculus milonii (Deunff) Loeblich and Tappan; Martin, p.28; pl.IV, fig.6

1973b Impluviculus milonii (Deunff) Loeblich and Tappan; Vanguestaine, p.31

1973c Impluviculus milonii (Deunff) Loeblich and Tappan;

Vanguestaine (MS.), p.177-178; pl.XI, figs.16, 17; pl.XVII, figs.8, 9; pl.XX, figs.19, 20; pl.XXI, figs.3, 5; text-fig.58a-d

1974a Impluviculus milonii (Deunff) Loeblich and Tappan; Potter (MS.), p.150-151; pl.11, figs.1-3; pl.30, fig.14

1974a Impluviculus multiangularis (Umnova 1971) Vanguestaine (MS.); Potter (MS.), p.151-154; pl.11, figs.4-7; pl. 16, fig.9

1982 Impluviculus milonii (Deunff) Loeblich and Tappan; Cocchio, Table 1

Original diagnosis: The inflated body is subquadratic to diamond- shaped, smooth or finely granular. The sides, from 7 to 15 µm long, are usually incurved towards the centre. Each angle is ornamented by a stiff or flexuous apparently hollow process from 5 to 20 µm long. The shell may or may not be provided with a circular or quadrangular opening. The dimensions of this opening vary from 1.5 to 7 µm. Some thickenings may be evident on the surface of the test or near the opening. (Trans. of Deunff 1968)

Description: The shape of the central body varies from straight-sided rhombohedral to inflated rhombohedral (see Pl.23, figs.9-12). Each angle of the rhombohedron bears a single slightly tapering process, with an occasional fifth process paired with one of the other four. On forms with more than four processes, the paired processes may be separated slightly giving an additional, but very short, side. The surface of the central body is smooth to shagrinate. A

circular to polygonal opening or an operculum is often present.

Dimensions: Diameter of central body: 9-18 μm
Length of processes: 1.5-9.5 μm

Specimens measured: 19

Remarks: The shape of this species intergrades with that of the new species Impluviculus circularis as the rhombohedral central body becomes more 'inflated'. Many specimens are intermediate in form between the two species (see Pl.23, fig.14).

Vanguestaine notes the same gradation in shape between I. milonii and rounded forms equivalent to I. circularis, most of which he assigns to Micrhystridium multiangularis Umnova 1971 (designated Impluviculus multiangularis in Vanguestaine, 1973c). However, he draws the dividing line between the two species on the basis of the number of processes, forms with five processes or less being assigned to I. milonii and forms with six or more processes being assigned to I. multiangularis. In the present work, shape is used as the diagnostic criterion as six and five process circular forms are considered to be more similar than four process rhombohedral and circular forms which differ notably in their areal extent in optical view.

The present author considers M. multiangularis Umnova 1971 as being quite different from the specimens assigned to the species by Vanguestaine.

Occurrence: Upper Cambrian: 5 A, 6 A, 11 A, 8 B, 10 B, 18 B, 20 B, 21 B, 22 B-2, 24 B, 3 C, ABC 14, 5 C, Z-10, 8 C, AC-H, Z-8, Z-7, AC-D, Z-6, AC-A, AC-2, SH 13z, SH 13; ?Upper Cambrian/Tremadoc: Z-5, Z-4, ABC 9, 19 C, Z-3, 24 C; Tremadoc: Z-2, AC-B, Z-1, 32 C, 37 C, 38 C, 42 C, E2, EC 5, EC 4, EC 3, EC 2, EC 1, E-C 9, E-C 8, E-C 7, E-C 6

Previous occurrences: Tremadoc, Morocco (Deunff 1966, 1968; Loeblich and Tappan 1969); Tremadoc, Montagne Noire, France (Martin 1973); Middle Revinian, top of Rn2b, Upper Revinian, Upper Cambrian, Stavelot; Revinian, Rv3c and Rv4, Rocroi, Belgium (Vanguestaine 1973b; 1973c (MS.); Upper Cambrian, Britain (Potter (MS.) 1974a); Tremadoc, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

10.5 Genus RETISPHAERIDIUM Staplin, Jansonius, and Pocock 1965

1965 Retisphaeridium Staplin, Jansonius, and Pocock gen. nov., p.187

Type species: Retisphaeridium dichamerum Staplin, Jansonius, and Pocock 1965, p.187-188; pl.19, figs.1-7. Middle Cambrian, Albertella Zone, Alberta, Canada.

Original diagnosis: Vesicles probably subpolygonal and transversely elliptical in polar section, outline subcircular; surface covered with a variably patterned irregular meshwork of external costae, mostly absent at the "equator"; on the type species no other sculpture; vesicle wall rather thin,

showing no structure; diameter of the type species less than 50 µm. (Staplin, Jansonius, and Pocock 1965)

Remarks: Staplin, Jansonius, and Pocock, in their diagnosis of the genus in 1965, distinguished it from the genus Dictyotidium Eisenack 1955 on the basis of the equatorial suppression of the irregular meshwork in Retisphaeridium.

Whether the costae are real, and whether the polygonal pattern is indeed suppressed at the equator, has been questioned and been suggested to be a preservational feature by Potter, in his unpublished Ph.D. thesis (1974a). He created a new genus, Plicatosphaera, the diagnosis of which is "Body hollow, outline circular to polygonal; wall single layered, smooth to granular, divided into polygonal areas by sutures; line of suture usually indicated by folds of the body wall formed by overlapping margins of the polygonal plates; no thickenings at the angles of the polygons; apart from a possibly granular surface texture, no ornament sutural or otherwise." (Potter 1974a (MS.), p.165-166) Potter considers that Retisphaeridium and Plicatosphaera may be synonymous, with the costae of the former genus representing the folds along plate margins of the latter, and the equatorial suppression of the costae being a reflection of the state of compression of the body, folds being unlikely to develop across a near circular periphery where the forces exerted may be of a tensional nature." (Potter 1974a (MS.), p.167) If indeed there are no costae present in Retisphaeridium, but only an accentuation of an underlying polygonal pattern by folding, then a new diagnosis is needed for the genus.

In the present work the concept of costae will be

retained, as a folding pattern can often be seen to overlie a series of what appear to be low ridges. The latter may simply represent secondary folds but as that has not yet been shown to be the case, they will continue to be called 'ridges' here.

Downie, in his 1982 work on Lower Cambrian acritarchs, considered that many of the Lower Cambrian forms included in the genus Cymatiosphaera O. Wetzel 1933 might be assignable to Retisphaeridium; he suggests that the folding patterns produced by collapse of the body could produce an effect of polygonal fields with bounding alae.

Retisphaeridium dichamerum Staplin, Jansonius, and Pocock 1965

Pl.23, figs.3, 5, 6; (?)Pl.34, fig.6

1965 Retisphaeridium dichamerum Staplin sp. nov. (in Staplin, Jansonius, and Pocock), p.187-188; pl.19, figs.1-7

1971 Retisphaeridium dichamerum Staplin; Sheshegova, p.27; pl.6, fig.19

1978 Retisphaeridium dichamerum Staplin; Fombella, p.248; pl.I, fig.15

1982 Retisphaeridium dichamerum Staplin; Downie, p.279; fig.11 o-p

1983 Retisphaeridium dichamerum Staplin; Vanguestaine and Van Looy, pl.2, figs.8, 9

Original diagnosis: Outline subcircular, wall sculptured with a meshwork of low costae; costae approx. 0.3 µm wide, field

areas 5-6 sided and irregular; the costae easily become involved in folding, giving the appearance of abundant taper-point folding; on smaller specimens the meshwork is only suggested by a few folds or a few partly connected raised striae; no sculpture in addition to the meshwork, but the vesicle wall may have a roughened appearance under oil immersion; wall thickness 1 µm or less. Inflated specimens seem to have a partly polygonal shape. (Staplin, Jansonius, and Pocock 1965)

Description: The central body is irregularly oval to circular in outline and its surface is divided up in optical view into eight to twenty polygonal to subpolygonal fields by a series of ridges. Sometimes the ridges occur in isolation and are seen to be quite narrow, but generally they are overlain by the 'taper-point' folding described by Staplin, Jansonius, and Pocock, the folds varying from 1.5 to 3 µm in width. The body surface is smooth.

Dimensions: Diameter of central body: 32.5-43.5 µm
Diameter of fields: 5.5-13 µm

Specimens measured: 7

Remarks: This species differs from Cristallinium ovillense Cramer and Díez 1972, which also shows a network of fairly small polygonal fields, in that it possesses less numerous fields which form a more erratic pattern. Also, on some specimens the wedge-shaped folding pattern characteristic of Retisphaeridium dichamerum is visible and termination of the

polygonal network before reaching the perimeter of the shell (i.e., the failure of the fields to cross the equator) can occasionally be observed.

Occurrence: Middle Cambrian: 12-20

Previous occurrences: Middle Cambrian, Albertella Zone, Alberta, Canada (Staplin, Jansonius, and Pocock 1965); Siberia (Sheshegova 1971); Middle Cambrian, Oville Formation, León, Spain (Fombella 1978); Lower Cambrian, Fucoid Beds, Scotland, Gog Formation, Alberta, and Holmia Shales, Norway (Downie 1982); Middle Cambrian, Tacheddirt Valley, Morocco (Vanguestaine and Van Looy 1983)

10.6 GENUS STRIATOTHECA Burmann 1970

1970 Striatotheca Burmann gen. nov., p.299-300

Type species: Striatotheca principalis Burmann 1970, p.300; pl.11, fig.1. Upper Arenig or lower Llanvirnian, D.D.R.

Original diagnosis: The central body is tetragonal or polygonal in outline, without basal constriction grading at the corners into the tapering, hollow processes which are limited in number. The processes, and in some cases the central body as well, bear a striate sculpture consisting of rib-like elements which, when intersecting, form a positive reticulum. The basic, general form of the central body is four-sided, but it may be altered resulting from concave

arching of the edges as a function of the basal width of the processes which as a rule gradually merge with the central body. Other deviations from the basic form result from shortening of the edges, reduction of a process, unequal development of processes, and development of additional processes.

The relatively close striation may be limited to the processes alone, or may extend from those onto both sides of the body as some kind of fan-shaped reticula. The ribs have a subparallel attitude to the adjacent sides of the central body. The centrally located ribs differ from the peripheral ones by a comparitively larger degree of curvature. In the middle part of the body, the ribs are partially replaced by the raised reticulum, or they become strongly divergent. (Burmann 1970)

Remarks: This genus is distinguished from the genus Veryhachium Deunff 1954 by its striate sculpture.

Striatotheca sp.

PL.30, figs.13, 14, 17

Description: The central body is very irregularly polyhedral with processes sometimes lying in one plane, sometimes projecting at various angles from the central body. Four to eight processes have been observed, but the incompleteness of the specimens makes this count an approximation only. The processes have rounded tips and often arise from a broad base, becoming cylindrical above the base and maintaining a fairly

constant width. Other processes are of fairly uniform width throughout, show no proximal expansion into a broad base. The central body is longitudinally striated, from sixteen to forty striations being counted on those specimens in which the striations are clear; the striations do not appear to extend onto the processes.

Dimensions: Length of central body: 20-29.5 µm
Width of central body: 16-21 µm
Length of processes: 2.5-16 µm

Specimens measured: 9

Remarks: Although specimens of this species make up from 13.5-25% of the identifiable material in the two samples in which it appears, complete individuals are rare. Body shape and process length are extremely variable.

Occurrence: ?Upper Cambrian/Tremadoc: AC-1, ABC 10, Z-5, AC-W, Z-4

10.7 Genus VERYHACHIUM Deunff 1954; emend. Downie and Sarjeant 1963

1954b Veryhachium Deunff gen. nov., p.306
1963 Veryhachium Deunff; emend. in Downie and Sarjeant, p.93

Type species: Hystrichosphaeridium trisculum Deunff 1951,

p.323; fig.3.

Emended diagnosis: A genus of hystrichospheres having polygonal or subpolygonal tests bearing a small number (in general 3-8) of hollow pointed spines with closed tips. Size of tests 10 um to 40 µm, rarely smaller or greater. (Downie and Sarjeant 1963)

Remarks: This genus is distinguished from the genera Micrhystridium Deflandre 1937 and Baltisphaeridium Eisenack 1958 on the basis of the number of processes, forms with more than eight processes being assigned to the latter two genera (unless the additional processes are considered 'accidental', or not the norm for the species) while forms with three to eight processes are asigned to Veryhachium.

Veryhachium? asymmetricum sp. nov.
Pl.19, figs.5-10

1974a Leiofusa scalenabullata Potter (MS.) sp. nov., p.135-136; pl.21, figs.9, 10

Holotype: H.35, slide 3 C (P)3 [Pl.19, fig.7]

Type locality: Locality 3 C, in the Parabolina spinulosa Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: From the Greek 'a' - not- and 'symmetros' - symmetrical.

Diagnosis: Central body oval to triangular in outline, the body being extended to form processes at two of the three angles of the triangle, producing an asymmetrical form. The processes are tapering and communicate freely with the interior of the central body, one process generally being longer than the other. The body surface is granular.

Dimensions: Length of central body: 25-39 µm
Width of central body: 15-30 µm
Length of longest process: 2-12 µm
Length of shortest process: 2-11 µm

Specimens measured: 12

Remarks: This form appears to be transitional between the genera Leiofusa and Veryhachium. It resembles in appearance specimens of Veryhachium in which one of the processes has been folded over. Potter [1974a (MS.)] described the same form from the Upper Cambrian of England and he noted that Timofeev (1962) recorded similar transitional forms from the Silurian of the Baltic region. V. asymmetricum closely resembles the one species of the genus Sylvanidium described by Loeblich, 1970 - S. paucibrachium - in possessing a bean-shaped body with two main polar processes. The latter generally shows secondary processes as well, although the generic definition does include forms without secondary processes. S. paucibrachium is more than twice as large as V. asymmetricum, and since the latter never shows secondary processes, it is retained for the moment in Leiofusa. The genus Unellium Rauscher 1969 is similar in possessing an

asymmetrical body with two main processes, but the body is more globular, the main processes are less pronounced, and secondary processes are present. Disparifusa Loeblich 1970 is also similar in shape but has distinctly different ornamentation as it is covered with numerous short conical spines.

Occurrence: Upper Cambrian: 24 B, 30 B; 3 C, 5 C

Previous occurrences: Upper Cambrian, Orusia Shales, Shropshire, England (Potter (MS.) 1974a)

Veryhachium dumontii Vanguestaine 1973

Pl.24, figs.1, 2, 6, 7, 9, 12-14; Pl.25, figs.1, 2, 5, 6, ?7, 8; (?)Pl.26, figs. 3, 6

1973a Veryhachium dumontii Vanguestaine sp. nov., p.28-29; pl.1, figs.1, 2, 8

1973c Veryhachium dumontii; Vanguestaine (MS.), p.188-189; pl.XIII, figs.1, 2, 8; pl.XIV, figs.3-6, 8, 9

1974a Veryhchium dumontii; Potter (MS.), p.155-156; pl.16, fig.11; pl.22, fig.4, pl.30, fig.17(?); ?pl.11, figs. 8, 9; ?pl.34; fig.3

1981 Veryhachium dumontii Vanguestaine; Martin and Dean, p.22; pl.1, figs.7, 8

1982 Veryhachium dumontii Vanguestaine; Martin, pl.1, fig. 17

Original diagnosis: Flattened central body triangular-shaped,

with convex sides. Three main processes in central body plane. Triangle height: 28.5-41 µm. The apex of the central body may be conspicuously inflated. On the antapex, 1-3 secondary processes are often intercalated between the main ones. Processes conical, simple, with acute tip, base clearly or poorly individualized; hollow and communicating freely with the vesicle cavity. Height of main processes: 7.5 to 23.5 µm. Height of secondary processes: 2.5-11 µm. Central body and processes' wall surface ornamented with granules 0.25-1 µm wide, connected by narrow ridges forming a network with meshes 0.25 µm wide. Membrane thickness: 0.25-0.5 µm. (Vanguestaine 1973a)

Description: The central body is triangular with sides that are convex, or, less commonly, nearly straight, or even slightly concave. Each angle of the triangle bears a process which communicates freely with the vesicle interior. The central body may be isosceles, with the two paired processes being of roughly equal length, or it may vary in shape from a roughly equilateral form with the processes at the angles of the triangle barely, if at all, defined to more bell-shaped forms with the paired processes poorly to clearly defined, while the third process is well defined. Granulation is generally arranged in lines radiating from the apex of the triangle. The excystment opening, when present, is a slit that, in most cases, is parallel to the longitudinal axis (axis of biláteral symmetry), but off to one side.

Dimensions: Height of triangle: 26-58 µm

Maximum width of triangle: 28-63 µm

Length of paired processes: 2.5-22 μm

Length of third process: 3-20 μm

Specimens measured: 24

Remarks: No secondary processes were observed by the author, although Martin has observed up to five such processes on her material from Random Island. On some of the Newfoundland specimens, the processes merge so imperceptably with the central body that no true processes can be defined.

The Random Island material extends the size range of the species, although only slightly.

Some of Potter's Veryhachium cf. dumontii forms appear to fall within the range of species variation observed for V. dumontii on Random Island and are placed in synonomy with the species here.

Occurrence: Upper Cambrian: 6 B, 8 B, 10 B, 14 B, 18 B, 20 B, 21 B, 22 B-1, 22 B-2, 24 B, 30 B, 3 C, ABC 14, 5 C, ABC 13, ABC 12, Z-10, Z-9, 8 C, AC-H, Z-8, AC-G, AC-F, Z-7, AC-E, AC-D, Z-6, AC-A, ABC 11, AC-2, SH 13z, SH 13, SH 13y, SH 13x; ?Upper Cambrian/Tremadoc: ABC 10, Z-5, AC-W, Z-4, ABC 9, 24 C

Previous occurrences: upper Middle Revinian, Stavelot area (Vanguestaine 1973a; (MS.) 1973c); Upper Cambrian, Shropshire, England (Potter (MS.) 1974a); Upper Cambrian, Elliott Cove Formation, Random Island (Martin and Dean 1981); Upper Cambrian, Elliott Cove Formation, Random Island (Martin 1982)

Veryhachium minutum Downie 1958

Pl.24, fig.8

1958 Veryhachium minutum Downie sp. nov., p.344; pl.17, fig.4; text-fig.3e

1963 Veryhachium minutum Downie; Downie and Sarjeant, p.94

1964 Veryhachium minutum Downie; Downie and Sarjeant. p.151

1967 Veryhachium lairdi Deflandre 1946; Combaz, p.17; pl.3, figs.89-91

1969 Veryhachium minutum Downie; Martin, p.97; pl.V, figs.14, 18, 31, 35-39, 60, 61, 63; text-figs. 45, 46

1970 Veryhachium minutum Downie; Martin, Michot, and Vanguestaine, p.344-345; pl.1, fig.8

1972 Veryhachium minutum Downie; Klavacheva, p.242

1972 Veryhachium minutum Downie; Vavrdová, p.80

1973 Veryhachium minutum Downie; Martin; p.27; pl.V, fig.5

1973 Veryhachium minutum Downie; Klavacheva and Chobanova, p.5

1974 Veryhachium minutum Downie; Klavacheva and Chobanova, figs.1, 2

1974 Veryhachium minutum Downie; Rauscher, p.63; pl.1, figs.11, 16

1977 Veryhachium minutum Downie; Vavrdová, Table 1

1977 Veryahchium minutum Downie; Martin, p.24; pl.III, fig.4; pl.V, fig.6

?1978 Veryhachium minutum Downie; Fournier-Vinas, pl.II, figs.2; 3

1982 Veryhachium minutum Downie; Marhoumi, Rauscher, and Vanguestaine, pl.II, fig.23

1982 Veryhachium minutum Downie; Cocchio, Table 1; pl.2,

fig.13

Original diagnosis: Test small, about 3 to 15 µm, formed by the united bases of the processes; test wall thin, colourless, transparent; processes conical; length 80 to 200% of test diameter, but difficult to distinguish test from processes; number 4 or 6. (Downie 1958)

Description: The rhombohedral central body has straight to convex sides and, at each corner of the rhombohedron, a process that tapers from a 1-2 µm wide base. One or two shorter processes arise from the central area at right angles to the other four. The surface of the central body and processes is smooth to shagrinate.

Dimensions: Diameter of central body: 13-14.5 µm
Length of processes: 1.5-14.5 µm

Specimens measured: 3

Remarks: This species differs from Impluviculus milonii (Deunff 1968) Loeblich and Tappan 1969 in bearing additional processes in a plane perpendicular to that containing the four main processes; I. milonii is more two-dimensional with all processes lying in the same plane. Furthermore, no operculum is present. This last feature is by itself not enough to distinguish the two species as the operculum may not be apparent on all Impluviculus specimens. Those four-process rhombohedral forms which do not show an operculum cannot be assigned with certainty to either species but are designated

I. milonii if they occur with other operculum-bearing members of that species. The small size of this species helps distinguish it from other species of Veryhachium.

Occurrence: Tremadoc: E-C 7

Previous occurrences: Tremadoc, Shropshire, England (Downie 1958); Tremadoc, Hassi-Messaoud (Combaz 1967); lower Tremadoc and Llanvirn, Belgium (Martin 1969); lower Caradoc, Belgium (Martin, Michot, and Vanguestaine 1970); doubtful upper Llandoverian-Llanvirnian or Caradocian, Iskur Gorge, Bulgaria (Kalvacheva 1972); Arenig, Klabava Shales, Bohemia (Vavrdová 1972); Tremadoc, Montagne Noire, Hérault, France (Martin 1973); late Llanvirn-Llandeilo, Iskur Gorge, Bulgaria (Kalvacheva and Chobanova 1973); Arenig, Tremadoc, Montagne Noire, France (Rauscher 1974); Arenig - Llanvirn, Šárka Formation, Central Bohemia (Vavrdová 1977); Tremadoc-Arenig or Llanvirn, Brabant, Belgium (Martin 1977); Tremadoc, Monts de Lacaune, Montagne Noire, France (Fournier-Vinas 1978); Tremadoc, Massif de Mouthoumet, Corbières, France (Cocchio 1982)

Veryhachium sp. A

Pl.25, fig.9; Pl.26, figs.1, 4

Description: The central body is triangular to inflated triangular and bears three large, slightly tapering processes which communicate with the interior of the central body. The apical process may be extremely long, up to one and a half

times the height of the central body. The body surface is shagrinate to slightly granular.

Dimensions: Height of central body: 25-38 µm
Maximum width of central body: 16-25 µm
Length of apical process: 18-47 µm
Length of basal processes: 18-40 µm

Specimens measured: 6

Remarks: These specimens may be equivalent to Veryhachium sp. A Martin (in Martin and Dean 1981) which is also a large species with extremely long processes. However, none of the six specimens observed has more than three processes, whereas Martin's species has from four to eight processes.

Occurrence: Upper Cambrian: 21 B, 24 B, ABC 11

Veryhachium sp. B

Pl.24, figs.10, 11, 15; Pl.25, figs.3,4

Description: The central body varies in shape from slightly inflated triangular to almost globular. From each angle of the triangle arises a very short tapering process which is in communication with the central body cavity. Most specimens bear only three processes, but occasionally a fourth process is present. The body surface may be shagrinate to slightly granular.

Dimensions: Height of central body: 21-26 µm
Basal width of central body: 20-24 µm
Length of processes: 0.25-2 µm

Specimens measured: 10

Remarks: These specimens are assigned to Veryhachium on the basis of the subtriangular outline of most of the specimens. The majority of the three-process forms are very similar in outline to V. reductum forme breve Deunff 1958, and forme reductum (breve) as designated by Jekowsky (1961). However, some specimens bear more than three processes and, as well, the central body is more globular than in Deunff's species. V. brevitrispinum Staplin 1961 is of comparable shape also, but again it is a three-process form.

These specimens occur stratigraphically at the same level as Dasydiacrodium longispinosum sp. nov. Some of them show a slight dominance of one spine; V. sp. B may in fact represent members of that very diverse species, D. longispinosum, in which the processes have become extremely reduced.

Occurrence: Tremadoc: Z-1, 32 C, 37 C, 38 C, 39 C, 40 C, 42 C, E2, E-C 8, E-C 7-8, E-C 7

CHAPTER ELEVEN

SUBGROUP PRISMATOMORPHITAE

Subgroup PRISMATOMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having a prismatic to polygonal vesicle with more or less sharp edges, often produced into a distinct flange, entire or serrate, with or without projections at the angles. Surface of test smooth, granular, or reticulate. No openings observed. (Downie, Evitt, and Sarjeant 1963, p.11)

11.1 Genus CRISTALLINIUM Vanguestaine 1978

1978 Cristallinium Vanguestaine gen. nov., p.270-271

Type species: Dictyotidium cambriense Slavíková 1968, p.201; pl.II, figs.1, 3. Middle Cambrian of Bohemia, Zone of Ellipsocephalus hoffi.

Diagnosis: Hollow shell, polyhedral, with a complex polygonal outline; exterior surface divided into polygonal fields by thickened and ornamented ridges. Facets more or less equidimensional, pentagonal or hexagonal, flat or slightly incurved towards the interior of the shell. Membrane apparently single-layered. External surface of the facets shagreen to granular. The ridges are ornamented with elements of reduced size - granules, cones, spines, simple rods - rarely divided or arranged in more or less distinct clusters. These ornaments are copious and densely distributed along the

different ridges. Structure at dehiscence not known. (Trans. of Vanguestaine 1978)

Remarks: Potter [1974a (MS.)] suggested a possible phylogenetic relationship between the genera Plicatosphaera (his new genus which he considers possibly synonymous with Retisphaeridium Staplin, Jansonius, and Pocock 1965), Comptofaciesphaera (his new genus now equivalent to Cristallinium Vanguestaine 1978), Timofeevia Vanguestaine 1978, Vulcanisphaera Deunff 1961, and Cymatiogalea Deunff 1961. He envisioned the unornamented plates of Retisphaeridium developing furcate processes at the plate margins, giving rise to the genus Timofeevia, with excystment in the latter genus occurring by loss of one, or several, of these ornamented plates. This trait of excysting by loss of a regular-sized plate or plates became modified in the genus Cymatiogalea, where the isolated plates which formed an opening in the preceding genus have now become one large operculum greatly exceeding in diameter any single plate. A second postulated evolutionary line led from Retisphaeridium to Cristallinium, where each plate has now developed numerous small elements along its margin, and then, by reduction of the intergonal elements and expansion in the size of the gonal elements, to Vulcanisphaera, with each plate having at each gonal angle a single process, giving rise to clusters, generally of three, at the plate junctions.

The possibility of a transition from Cristallinium to Vulcanisphaera is evident from a consideration of the Upper Cambrian species V. turbata Martin 1981 and C. randomense Martin 1981. C. randomense bears conic protuberances along the plate margins from which one to three simple spines arise,

and these protuberances are much more irregularly spaced than are the smaller, simpler elements found in C. cambriense Slaviková 1968. This clustering of processes in the former, giving them a tuft-like appearance, with intervening bare intergonal patches, suggests the beginning of Vulcanisphaerid affinities. V. turbata is divided into polygonal fields with clusters of two or three processes arising from gonal protuberances. Some of the very short process forms of this species show a 'tuft-like' aspect and recall C. randomense. One can see from C. randomense that a further reduction of intergonal elements with a concomitant increase in size of the gonal processes could easily lead to V. turbata. The polygonal suture pattern disappears in some later Vulcanisphaerid species such as V. africana Deunff 1961.

Cristallinium cambriense Slaviková 1968; comb. nov. in Vanguestaine 1978
Pl.28, figs.1-8, 10, 11; Pl.35, fig.3

1968 Dictyotidium cambriense Slaviková sp. nov., p.201; pl.2, figs.1, 3

1971 Dictyotidium cambriense Slaviková; Gardiner and Vanguestaine, p.195; pl.2, figs.4, 5

1972 Cymatiosphaera sp. 1; Cramer, pl.2, figs.1, 2, 5, 6

1972 Cymatiosphaera ovillensis Cramer and Diez sp. nov., p.44; pl.2, figs.4, 7, 10

1973 ?Dictytidium cambriense Slaviková; Martin, p.42; pl.II, fig.13; pl.VI, fig.4

1973b Dictyotidium cf. cambriense Slaviková; Vanguestaine,

p.31

1973c Staplinium cambriense Slaviková; Vanguestaine (MS.), p.249-251; pl.VI, fig.23; pl.VII, figs.31-33; pl.VIII, figs.6, 9-13; pl.X, fig.38; pl.XV, fig.7; pl.XVI, figs. 1-6

1974a Comptofaciesphaera cambriense Slaviková; Potter (MS.), p.161-163; pl.7, figs.18, 19; pl.11, fig.10; pl.13, fig. 12; pl.14, fig.5; pl.15, fig.1; pl.16, fig.13; pl.22, figs.7, 8, 9; pl.27, fig.2; pl.28, figs.5, 6; pl. 31, fig.3; pl.34, fig.8

1976 Staplinia cambriense Slaviková; Vavrdová, p.58-59, 61; pl.1, figs.1, 3, 5, 8

1976 Cymatiosphaera favosa Jankauskas sp. nov., p.190; pl. 25, figs.7, 15 (non fig.13) (transferred by Martin 1981)

1976 Cymatiosphaera lazdynica Jankauskas sp. nov., p.190; pl.25, figs.4, 5, 8, 10

1977 Dictyotidium cambriense Slaviková; Martin, text-fig.13; pl.4, fig.12

1978 Dictyotidium? cambriense Slaviková; Dean and Martin, Table 2; pl.3, fig.11

1978 Cymatiosphaera ovillensis Cramer and Díez; Fombella, pl.1, fig.20

1978 Cristallinium cambriense Slaviková; comb. nov. in Vanguestaine, p.270-271; pl.2, figs.16, 17; pl.3, figs. 16, 26

1979 Cristallinium ovillensis Cramer and Díez; comb. nov. in Fombella, pl.III, fig.43; pl.IV, figs.63, 65, 69

1981 Cristallinium cambriense (Slaviková) Vanguestaine; Dean and Martin, p.17; pl.3, figs.4, 5, 9, 11; pl.5, figs.3, 5, 8, 11

1982 Cristallinium cambriense (Slaviková) Vanguestaine; Cocchio, Table 1; pl.1, fig.17

1982 Cristallinium ovillense (Cramer and Díez) Fombella; Fombella, p.19; pl.II, fig.22

1983 Cristallinium cambriense (Slaviková) Vanguestaine; Vanguestaine and Van Looy, pl.1, figs.7, 8

Original diagnosis: Outline subpolygonal, sculpture of the walls (of) vesicle of rough appearance. Surface of the test divided by low, small costae into many irregular polygonal, 5-6 sided fields, of different size and different shape. The meshwork of the same specimen has up to 20 fields, often less. Costae are distinct and of the same breadth, mostly straight, rarely incurved. Costae project randomly and rarely in small, short spines with closed tips. Occurrence rare to common. (Slaviková 1968)

Description: The central body is subpolygonal in outline and divided into eight to fifteen polygonal fields (in optical view) by ridges approximately 1.5 µm to 2.0 µm high. The ridges may be unornamented, or they may bear evenly spaced continuous, or irregularly spaced discontinuous, rows of prominences from <0.25 µm to 2 µm in height. These prominences range from triangular in shape to more elongate finger-like projections. The general effect of the processes is to give a 'saw-tooth' appearance to the ridges. In some cases the processes are seen to form a double row, presumably each row being associated with an individual plate. One or several plates may partially separate from the remainder, forming a flap. The surface of the central body may be

smooth, shagrinate, or granular.

Dimensions: Diameter of central body: 36-55 μm
Diameter of fields: 9-20 μm

Specimens measured: 26

Remarks: The majority of specimens included here under the designation Cristallinium cambriense, when their stratigraphic position is compared with the stratigraphic distribution given by Martin (in Martin and Dean 1981) for Cristallinium randomense, appear to be synonymous with the latter species. However, none of these show two or three spines arising from a conic base which is usual for C. randomense; neither do their processes attain the 4 to 6 μm height ascribed to that species. Only those specimens which show unequivocal groupings of long slender spines are assigned to C. randomense. Martin does state, with respect to C. randomense, that in many specimens the spines of the processes are missing and only the conic bases remain; such specimens are not considered distinguishable from C. cambriense by the present author, and are included in the latter species as they do fall within the definition by various authors of C. cambriense. Slavíková, when he created the species in 1968, defined it as (rarely) bearing short spines. Cramer and Díez, in the description of their species Cymatiosphaera ovillensis in 1972 (this species is synonymous with C. cambriense), reported occasional crenulation on the ridges. Gardiner and Vanguestaine in 1971 reported sparse, small spines 0.5 to 1 μm high. Vanguestaine (1978) recorded ornamentation from 1 to 2

μm high and his S.E.M. photograph (Pl.III, fig.16) shows a digitate type of process similar to that described by the present author. Martin considers those digitate specimens from Vanguestaine's work to be a separate species from C. cambriense. It is probable that the stratigraphic range for C. cambriense is extended beyond its true limits and the range for C. randomense is shorter than is actually the case because of the difficulty of distinguishing truncated specimens of the latter species from specimens of the former.

Occurrence: Middle Cambrian: 12-20', R+1.5, C-15; Upper Cambrian: 5 A, 6 A, 7 A, 11 A, 6 B, 8 B, 10 B, 18 B, 20 B, 21 B, 22 B-1, 22 B-2, 24 B, 30 B, 3 C, ABC 14; 5 C, ABC 13, ABC 12, Z-10, Z-8, AC-F, AC-D, Z-6, AC-A, AC-2, SH 13, SH 13y, SH 13x; ?Upper Cambrian/Tremadoc: AC-1, Z-4, ABC 8, 24 C; Tremadoc: 32 C, 40 C

Previous occurrences: Middle Cambrian, Ellipsocephalus hoffi Subzone, Czechoslovakia (Slaviková 1968); the Duncannon Area, Ireland (Gardiner and Vanguestaine 1971); upper Middle Cambrian, Oville Formation, Lancara de Luna, León, Spain (Cramer and Díez 1972); Late Cambrian, Upper Rn26 of the Stavelot Area, Belgium (Vanguestaine 1973); Tremadoc, middle Revinian, Stavelot and Rocroi, Belgium (Vanguestaine (MS.) 1973c); Middle - Upper Cambrian, Britain (Potter (MS.) 1974a); Tremadoc, Montagne Noire, France (Martin 1973); Middle Cambrian, Jince Formation, Bohemia (Vavrdová 1976); Lower Cambrian, Holmia Zone, eastern U.S.S.R. (Jankauskas 1976); early Tremadoc, 'Quartzophyllades de Chevilpont', central Belgium (Martin 1977); lower and middle Revinian,

Grand-Halleux, Belgium (Vanguestaine 1978); Tremadoc, Bell Island, Newfoundland (Dean and Martin 1978); Middle Cambrian, Oville Formation, Spain (Fombella 1978, 1979, 1982); Middle Cambrian-Tremadoc, Random Island (Martin and Dean 1981); Tremadoc, Massif de Mouthoumet, Corbières, France (Cocchio 1982); Middle Cambrian, Tacheddirt Valley, Morocco (Vanguestaine and Van Looy 1983)

Cristallinium ovillense? Cramer and Díez 1972; comb. nov. Martin in Dean and Martin 1981
Pl.27, figs.1, 2, 4, 5, 7, 8

1972 Zonosphaeridium sp. I; Cramer, pl.1, figs.4, 6

1972 Zonosphaeridium ovillensis Cramer and Díez sp. nov., p.44; pl.2, figs.5, 8, 11

1978 Zonosphaeridium sp. Cramer and Díez; Fombella, pl.3, figs.16, 17

1979 Zonosphaeridium ovillense Cramer and Díez; Fombella, pl.II, fig.25; pl.IV, fig.60, 61

1981 Cristallinium ovillense Cramer and Díez; comb. nov. Martin (in Dean and Martin), p.17-18; pl.3, fig.16

Original diagnosis: Species of Zonosphaeridium characterized by a zone of two to four microns wide, and by a fairly coarse reticulum of tetragonal, pentagonal, to (rarely) hexagonal campi. The campi are separated by thickenings of the ectoderm. These 'muri' are about one micron wide at their bases and are about equally high; they are round crested.

Disregarding the muri, the vesicle wall is 0.5 micron or

less thick. The delicateness of the vesicle wall may cause the campi to collapse, thereby giving certain specimens a concavely polygonal outline. (Cramer and Díez 1972)

Description: The central body is roughly spherical and its surface is separated into approximately forty to sixty polygonal fields (optical view) by ridges from 1.0 to 1.5 µm high. The ridges bear irregularly spaced triangular projections which are generally <0.5 µm high but may attain a height of 0.75 µm. Rupturing is sometimes evident along the plate margins. The surface of the central body varies from smooth to shagrinate in texture.

Dimensions: Diameter of central body: 40-50 µm
Diameter of fields: 5-10 µm

Specimens measured: 7

Remarks: This species, although it closely resembles Cramer and Díez's illustrations, is assigned with some doubt to Cristallinium ovillense because the ridges (muri) are ornamented, a feature not reported in the original diagnosis of the species. Martin, in 1981, assigned the species to the genus Cristallinium, which is characterized by the ornamentation of the ridges, but she did not redefine the species nor mention the presence of ridge ornamentation. However, her illustration of the species appears to show the ridges bearing slight triangular prominences. As the degree of ornamentation for the genus Cristallinium does seem to vary within a given species (for example, in C. cambriense, from

unornamented ridges to markedly denticulate ridges), it is possible that the Random Island specimens show a better developed or preserved denticulation than the material studied by Cramer and Diez.

This species differs from C. cambriense Slaviková 1968 in possessing a greater number of polygonal fields, forty to sixty as contrasted with a maximum of twenty for Slavikova's species; the fields are, as a consequence, much smaller in diameter. C. randomense Martin 1981 also has fewer and larger polygonal fields than does C. ovillense, and the ridges in that species bear much longer projections - slender spines arising from conic bases.

Occurrence: Upper Cambrian: 11 A, 21 B, 22 B-2

Previous occurrences: upper Middle Cambrian, Oville Formation, Láncara de Luna, León, Spain (Cramer and Díez 1972); Middle Cambrian, Oville Formation, Spain (Fombella 1978; 1979); Upper Cambrian, Elliott Cove Formation, Random Island (Martin and Dean 1981)

Cristallinium randomense Martin 1981

Pl.27, figs.3, 6, 9, 10; Pl.28, figs.9, 12

1981 Cristallinium randomense Martin and Dean sp. nov., p.18; pl.3, figs.2, 10, 12, 17, 20, 24, 26; pl.6, figs. 4, 6

Original 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 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. [Martin (in Martin and Dean 1981)]

Description: The central body is subpolygonal in outline and divided into approximately fourteen to sixteen polygonal fields by ridges bearing irregularly spaced prominences. The prominences bear long thin spines, isolated or in clusters of two or three, attaining lengths of up to 4.5 µm. The surface of the central body is shagrinate to granular.

Dimensions: Diameter of central body: 31-43.5 µm
Diameter of fields: 8-12 µm
Length of processes: 2.5-4.5 µm

Specimens measured: 6

Remarks: On the specimens observed, the division between the conic base and the emergent spines could not be distinguished for all of the processes; most of the processes comprised clusters of long, slender spines, resembling those of a short-spined Vulcanisphaerid except for the intergonal occurrence of ornamentation. Although there is some difficulty in distinguishing between truncated specimens of Cristallinium randomense and specimens of C. cambriense Slavikova 1968, the obvious clustering and the extreme length of the spines on the forms recorded here allows one, with certainty, to assign them to C. randomense.

Occurrence: Upper Cambrian: 21 B, 22 B-1, 22 B-2, 24 B, 30 B, ABC 14, 5 C, Z-7, AC-E, AC-D, AC-A, ABC 11, AC-2, SH 13z; ?Upper Cambrian/Tremadoc: AC-1, Z-5, Z-4, ABC 9, Z-3, ABC 8

Previous occurrences: Upper Cambrian to Tremadoc, Random Island (Martin and Dean 1981)

CHAPTER TWELVE

SUBGROUPS PTEROMORPHITAE, [illegible]SPHAEROMORPHITAE, AND SPHAEROMORPHITAE

12.1 Subgroup PTEROMORPHITAE

Subgroup PTEROMORPHITAE Downie, Evitt and Sarjeant 1963

Acritarchs having a spherical to ellipsoidal or polygonal shell, frequently dorsoventrally compressed, without an inner body. A wing lamella, typically equatorial in position, surrounds the test; it may be sustained by processes or radial folds. Processes elsewhere absent: crests absent. Surface of test smooth or granular. No openings observed. (Downie, Evitt, and Sarjeant 1963, p.10)

12.1.1 Genus PTEROSPERMELLA Eisenack 1972

1972 Pterospermella Eisenack gen. nov., p.597

Type species: Pterospermopsis aureolata Cookson and Eisenack 1958, p.49; pl.9, fig.10-12, Lower Cretaceous (Upper Neocomian or Lower Aptian), Carnarvon Basin, Western Australia.

Original diagnosis: Microfossils of an organic substance, when viewed from above consisting of a circular central body; transverse section of central body is usually long - oval, rarely circular; and in the plane of the equator is a

concentric circular flange with a smooth or serrated edge. It can be even or radially folded. (Trans. of Eisenack 1972)

Remarks: The equatorial flange, or wing, surrounding the central body is a very distinctive diagnostic feature of this genus.

Pterospermella snooksensis sp. nov.
Pl.26, figs.2, 9, 10

Holotype: V 18, slide SH 13 >20 (2) [Pl.26, fig.9].

Type locality: Locality SH 13, in the Peltura Zone, Upper Cambrian, Elliott Cove Formation, Random Island.

Derivation of name: The name 'snooksensis' refers to the abandoned brickworks at Snooks Harbour which is close to the outcrop at which this species was first found.

Diagnosis: Central body and equatorial wing circular to slightly ellipsoidal in outline. The diameter of the central body is from 54-69% of the overall diameter. The equatorial wing has a gently undulating margin, and is slightly shagrinate in texture and transparent, while the central body has a smooth surface and is for the most part darker in colour than the wing. Short ribs may occasionally extend outward from the central body.

Description: On some specimens, parts of the central body are

transparent while the rest is much darker. The lighter areas seem to be composed of only the lower surface of the central body membrane while the darker areas have both the upper and lower hemispheres of the membrane, the irregularity of the colouration being due in part to tearing of the central body. Often a darker rim occupies the margin of the central body.

Dimensions: Total diameter: 42-55 μm
Diameter of central body: 23-38 μm

Specimens measured: 4

Remarks: This species closely resembles the Ludlovian species Pterospermella martinii Cramer 1967; comb. nov. Eisenack, Cramer, and Díez 1973. However that species is diagnosed as having an equally tansparent central body and equatorial membrane whereas P. snooksensis has a transparent equatorial membrane but a darker central body. Furthermore, it shows radial wrinkles but no radial wrinkles are present on P. snooksensis. The dimensions of the two species are comparable, P. martinii having a central body diameter of 25-30 μm and an overall diameter of 40-48 μm. The Random Island species, since it is stratigraphically lower, possesses a more opaque central body, and lacks radial wrinkling is considered, for the time being to be a new species while admitting that the last two differences may be preservational in nature and the two species may be synonymous.

Occurrence: Upper Gambrian: (?)Z-8, AC-F, Z-6, ABC 11, SH 13; ?Upper Cambrian/Tremadoc: Z-5

12.2 Subgroup DISPHAEROMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having a spherical to ovoidal shell, containing a spherical to ovoidal, hollow inner body. Crests and processes absent. Surface of shell and inner body smooth or granular. Without observed opening or with a simple circular pylome. (Downie, Evitt, and Sarjeant 1963, p.11)

12.2.1 Genus NUCELLOSPHAERIDIUM Timofeev 1963, ex Timofeev 1966

1963 Nucellosphaeridium Timofeev, p.46; fig.1: 6, 7
1966 Nucellosphaeridium Timofeev, p.41

Type species: Nucellosphaeridium deunffii Timofeev, 1966, p.42; pl.VIII, fig.10. Lower Silurian, U.S.S.R.

Original diagnosis: Shells with diameter varying from 20 to 150 µm, of spherical and subspherical shape, thick walled, smooth or weakly sculptured, containing a dense nucleus. Diameter of nucleus one third to one fifth that of the shell. Colour yellow, dark-yellow. Genus contains 4 species. (Trans. of Timofeev 1966)

Remarks: Nucellosphaeridium is similar to Pterspermopsimorpha Timofeev 1962 ex Timofeev 1966 in having a spherical inner body enclosed by a spherical outer membrane. It differs from that genus in that the diameter of the inner body is from

one-fifth to one-third the diameter of the outer membrane in the former genus as constrasted with two-thirds in the latter.

Nucellosphaeridium sp.

Pl.26, fig.11

Description: The transparent spherical outer body encloses a slightly eccentric light brown inner sphere, the diameter of which is approximately two-fifths that of the outer sphere. The surface of both the inner and outer spheres is slightly shagrinate. The inner body shows several folds, and one occurs in the outer sphere associated with a notch in the side of the sphere. Several smaller irregular holes are found in the outer sphere as well.

Dimensions: Diameter of inner sphere: 10.5 µm
Diameter of outer sphere: 25 µm

Specimens measured: 1

Remarks: The openings in the outer sphere are irregular and may be damage structures rather than characteristic features.

This species is assigned to Nucellosphaeridium rather than Pterospermopsimorpha Timofeev 1962, ex Timofeev 1966, as the ratio of the diameters of the inner and the outer spheres is closer to the 1:3 to 1:5 ratio for the former genus than to the 2:3 ratio for the latter genus.

Of the four species described by Timofeev in 1966, only Nucellosphaeridium minutum has a comparable outer sphere

diameter (20-40 μm). However, its internal sphere is only one-quarter the diameter of the external sphere, as contrasted with two-fifths of the diameter of its outer sphere for the Random Island species. Nucellosphaeridium sp. A described by Martin, 1983, from Random Island is much larger as well (50-65 μm outer sphere diameter).

Occurrence: Tremadoc: E-C 7-8

12.3 SUBGROUP SPHAEROMORPHITAE

Subgroup SPHAEROMORPHITAE Downie, Evitt, and Sarjeant 1963

Acritarchs having a spherical to ellipsoidal shell lacking an inner body. Surface granular, smooth, punctate or perforate, but not otherwise ornamented. Without observed opening, with a simple circular pylome, or opening by splitting. (Downie, Evitt, and Sarjeant 1963, p.8)

12.3.1 Genus LEIOSPHAERIDIA Eisenack 1958; emend. Downie and Sarjeant 1963

1958 Leiosphaeridia Eisenack gen. nov., p.8
1963 Leiosphaeridia Eisenack; emend. in Downie and Sarjeant, p.94-95

Type species: Leiosphaeridia baltica Eisenack 1958, p.8; pl.2, fig.5. Early Ashgill, Ordovician, Baltic region.

Emended diagnosis: Spherical to ellipsoidal bodies without processes, often collapsed or folded, with or without pylomes. Walls granular, punctate or unornamented; thin. Without divisions into fields and without transverse or longitudinal furrows or girdles. (Downie and Sarjeant 1963)

Remarks: The emendment by Downie and Sarjeant (1963) was made to exclude reference to colour in Eisenack's diagnosis. In that same paper they provide a detailed account of the relationship of the genus Leiosphaeridia to the genera Leiosphaeridium Timofeev 1959, Proleiospheridium Timofeev 1959, and Leiosphaera Eisenack 1938, all of which they consider synonymous with Leiosphaeridia.

No attempt has been made in the present work to differentiate between the species of the genus Leiosphaeridia. They are lumped together under the designation 'leiospheres' in the species distribution charts. Several representatives of this group are illustrated in pl.29, figs.5, 10, and 11. Several thick-walled sphaeromorphs are illustrated in the same plate (figs.2, 4, 7).

12.3.2 Genus LOPHOSPHAERIDIUM Timofeev 1959; emend. Lister 1970

1959 Lophosphaeridium Timofeev, p.29
1963 Lophosphaeridium Timofeev; Downie, p.630
1970b Lophosphaeridium Timofeev; emend. in Lister, p.61
1974 Lophosphaeridium Timofeev; Vanguestaine, p.71-72

Type species (designated by Downie, 1963): Lophosphaeridium rarum Timofeev 1959, p.29; pl.2, fig.5. Ordovician, U.S.S.R.

Original diagnosis: Vesicle thick, tuberculose. (Timofeev 1959)

Emended diagnosis: Vesicle hollow, single-walled with ornament of solid tubercules. Excystment is by cryptosuture. (Lister 1970 b)

Remarks: Vanguestaine (1974) rejected Lister's emendment which stated that the tubercules are solid and further extended the concept of the genus to include specimens with very short projections, the height of which was not necessarily less than or equal to their width. (Such species in which the height of the prominences is greater than their width had been grouped by Timofeev in the genus Archaeohystrichosphaeridium, created at the same time.) Vanguestaine did not formally emend the genus, but he did describe and assign to the genus a number of new species in which the processes are hollow or partially hollow and which have a length : width ratio which is often > 1.

Lophosphaeridium? sp. A

Pl.33, figs.14-16; Pl.36, figs.2, 4

Description: The central body is spherical to ellipsoidal in outline, and often shows a near-equatorial fold. Approximately seventy to one hundred short processes (in

optical view) spaced 0.5 µm to 2.0 µm apart ornament the central body. The surface of the central body and processes are smooth when viewed under the S.E.M. The processes vary in shape from slightly tapering columns which are rounded distally (occasionally there is a slight terminal expansion) to more acutely tapering, more triangular processes with rounded terminations, to short distally rounded columns with expanded bases.

Dimensions: Length of central body: 25-29 µm
Width of central body: 21-28 µm
Length of processes: 1-2 µm

Specimens measured: 9

Remarks: This species is tentatively assigned to the genus Lophosphaeridium. Its processes are not solid, but it does fit the concept of the genus as discussed by Vanguestaine (1974). The equatorial folding present on many specimens suggests affinity with the genus Lophodiacrodium Timofeev 1958 as emended by Deflandre and Deflandre-Rigaud 1962; that genus has a bipolar nature with a smooth or finely folded equatorial zone. Not all specimens of L.? sp. A show folding.

The species is very similar to some specimens of the Lower or Middle Cambrian species Lophosphaeridium bacilliferum illustrated by Vanguestaine (1974). The specimens from Random Island are in general slightly larger than those of L. bacilliferum, the average length of the central body being 28 µm as contrasted with Vanguestaine's figure of 23 µm. The average width of the processes on the central body is also

slightly greater, 0.5 µm as contrasted with 0.3 µm and their length may exceed the upper limit given by Vanguestaine by 0.5 µm. The processes do, however, show the rounded columnar shape and, in many cases, the expansive base characteristic of the processes of L. bacilliferum. Lophosphaeridium? kryptoradiatum Vanguestaine 1974 (Middle or Upper Cambrian in age) has an ornamentation consisting of processes of comparable size and shape. However, that species frequently exhibits radiating striae, although this is not present on all specimens. Lophosphaeridium tentativum Volkova 1968 (with a range in Belgium corresponding to that of L. bacilliferum) is ornamented with processes of approximately the same height as L.? sp. A, but the processes are much wider, the width and length being approximately equal (according to Vanguestaine's 1974 diagrammatic illustration of the species) so that each has approximately the form of a rounded cone.

L.? sp. A resembles small specimens of A. discigerum in which the barren equatorial zone is not visible. In general, the processes are longer and and have a broader base on the latter species.

Occurrence: ?Upper Cambrian/Tremadoc: Z-4, ABC 9, Z-3, 24 C; Tremadoc: Z-2, AC-B, Z-1, 32 C, 42 C, EC 5, EC 1, E-C 8, E-C 7, E-C 6

12.3.3 Genus SAHARIDIA Combaz 1967

1967 Saharidia Combaz gen. nov., p.13

Type species: Saharidia downiei Combaz 1967, p.13; pl.2, fig.35-36. Tremadoc, Sahara.

Original diagnosis: Shell with circular outline, with a central pylome, always observable, equal to about 1/4 of the diameter, surrounded by one or several concentric circles (folds or thickenings). Tegument very thin (1 to 2 µm) and surface smooth or finely granulose. (Trans. of Combaz 1967)

Remarks: Combaz, when creating this genus, proposed a possible discoidal or lenticular shape for the body based on its concentric nature and the constant central position of the pylome. A pylome is not always apparent on specimens from Random Island.

Saharidia fragile Downie 1958; comb. nov. and emend. Combaz 1967

Pl.26, fig.8

1958 Leiosphaeridium fragile Downie sp. nov., p.344-345; pl.17, fig.6

1967 Saharidia fragile Downie; comb. nov. and emend. in Combaz, p.13; pl.2, figs.35-36

1973 Saharidia fragile (Downie) Combaz; Martin, p.30; pl.II, fig.7

1977 Leiosphaeridia fragile Downie; Vavrdová, Table 1

1978 Saharidia fragile (Downie) Combaz; Dean and Martin, Table 2; pl.3, fig.32

1981 Saharidia fragile (Downie) Combaz; Martin and Dean,

p.13; pl.1, fig.6

1982 Saharidia fragile (Downie) Combaz; Martin, pl.1, fig.7

1982 Saharidia fragile (Downie) Combaz; Turner, p.132; pl.15, fig.6

Emended diagnosis: (see the generic diagnosis) The surface, in this species, is ornamented with dispersed granules. (Trans. of Combaz 1967)

Description: The Random Island specimens have a circular central body with a granular surface. They show a concentric arrangement of folds or thickenings with an outer ring much narrower than the central ring, its width being 1/6 to 1/12 that of the entire shell. Sometimes a pylome is present.

Dimensions: Diameter of cental body: 54-95 μm
Width of outer ring: 4.5-14 μm
Diameter of pylome: 8-21 μm

Specimens measured: 8

Remarks: Generally, only segments of the central body are found, although some complete specimens were recovered. This species is distinguished from Saharidia downiei Combaz 1967 by its granular surface as opposed to the smooth surface of the latter.

Occurrence: Upper Cambrian: ABC 11; ?Upper Cambrian/ Tremadoc: Z-5, AC-W, Z-4, ABC 9, ABC 8; Tremadoc: Z-2, AC-B, Z-1, 37 C, 39 C, 40 C, E2, E-C 9, E-C 7-8, E-C 7

Previous occurrences: Tremadoc, Shineton Shales, England (Downie 1958); Tremadoc, Hassi-Messaoud, Sahara, Algeria (Combaz 1967; Tremadoc, Montagne Noire, Hérault, France (Martin 1973); Llanvirn, Šárka Formation, Central Bohemia (Vavrdová 1977); Tremadoc, Bell Island, Newfoundland (Dean and Martin 1978); Tremadoc, Random Island (Martin and Dean 1981); lower Tremadoc, Random Island (Martin 1982); Tremadoc (reworked), south Shropshire, England (Turner 1982)

Saharidia sp. A

Pl.26, fig.7; Pl.29, figs.13, 14

Description: The test is circular in outline with an outer ring, the diameter of which is from 1/4 to 1/6 that of the total test. The outer margin of the test and of the inner ring often appears to be slightly jagged. The surface of the test is shagrinate. Some very scattered granules may be present on some specimens. Rarely, a pylome is observed.

Dimensions: Diameter of central body: 31-37 μm
Width of outer ring: 6-8.5 μm
Diameter of pylome: 5.5 μm (from one specimen)

Specimens measured: 8

Remarks: This species is very similar to Saharidia downiei Combaz 1967, but it is much smaller. Although Combaz does not give a size range for his specimens, the illustrated specimens of S. downiei appear to be about the same size as S. fragile

from the same study (~70-80 μm). S. sp. A is much smaller than S. fragile from Random Island, being 1/2 the size of the latter species. (This includes a comparison of specimens of the two species from the same sample.)

Occurrence: Upper Cambrian: ABC 11; ?Upper Cambrian/ Tremadoc: AC-1; Tremadoc: Z-2, AC-B, Z-1, EC 2, E-C 9

CHAPTER THIRTEEN

MIDDLE CAMBRIAN, UPPER CAMBRIAN, AND TREMADOC ACRITARCH ASSEMBLAGES FROM RANDOM ISLAND

13.1 Definition of Assemblages

The acritarch microfloras of the Middle Cambrian to Tremadoc rocks of Random Island, as presented in this work, have been divided into a series of nine assemblages. Each assemblage is based on the presence of one or more readily distinguishable taxa that are considered as characteristic; these taxa may or may not be abundant or present together in all samples within the vertical range of the assemblage. Taxa with vertical ranges less than that of the assemblage in which they occur may also be considered characteristic. The lower boundary of an assemblage (which is thereby the upper boundary of the preceding assemblage) is defined by the first appearance of one, or of several, selected taxa. These taxa need not be restricted to the assemblage as they may range upward into younger strata. A taxon not involved in the establishing of boundaries, but the abundance of which is considered characteristic of a particular assemblage, may occur in strata below; and/or in strata above, those of that assemblage.

Because of the great thickness of the Middle Cambrian - Tremadoc section on Random Island, samples were initially taken at widely separated stratigraphic levels. Once the nature and order of the assemblages had been established, additional samples were taken from the stratigraphic intervals

between them in order to fix the positions of their boundaries as accurately as possible. However, even with additional sampling, it was not found possible in every case to determine their exact positions.

The vertical ranges of the Random Island assemblages differ considerably from one another; those of assemblages RI 3 and RI 4 are, respectively, the longest and shortest. Thus, the former is present throughout a considerable thickness of strata whereas the latter is confined to a very small thickness of strata.

Martin (in Martin and Dean 1981) described a succession of six acritarch microfloras, A1 to A6, from the higher Middle Cambrian, Upper Cambrian, and Lower Ordovician (Tremadoc Series in part) rocks of the same coastal section south of Elliott's Cove on Random Island as that studied by the writer; the youngest of the microfloras is a composite one as it is based, in part, on acritarchs found by Martin in rocks of Tremadoc age cropping out north of Elliott's Cove and south of the causeway linking Random Island to the mainland. The number of acritarch microfloras was subsequently increased to eight by Martin (in Martin and Dean 1984) as a result of a further, more comprehensive, study than previously undertaken, of the acritarchs of the older Middle Cambrian rocks at the southern end of the section south of Elliott's Cove. Thus, the succession of acritarch microfloras became AO-1, AO, A1 to A6. The section on the north side of the island (north of Snooks Harbour) studied by the writer, was not sampled by Martin and Dean.

The assemblages established by the writer are designated by the letters RI to distinguish them from the acritarch

microfloras of Martin, hereafter also called assemblages, which are prefixed by the letter A. Several of the RI assemblages and A assemblages are equivalent to one another. However, the RI assemblages contain a number of hitherto unrecorded species, some of which are new, and the stratigraphic ranges of some of Martin's assemblages have been refined by closer sampling in the present study. Furthermore, three new assemblages have been distinguished that were not recognized by Martin and Dean (1981, 1984).

Assemblages RI 1 to 9 are described separately below, and each of them is related, where possible, to one or more of the established trilobite zones. Equivalence or otherwise of each RI assemblage to one or more of Martin's assemblages is also indicated or discussed.

13.2 Description of Assemblages

The first, and oldest, of the nine assemblages (RI 1) is of Middle Cambrian age, the next five (RI 2 - RI 6) are of Upper Cambrian age, the seventh (RI 7) is of ?Upper Cambrian/Tremadoc age, the eighth (RI 8) is, in part, of undetermined Upper Cambrian/Tremadoc age and, in part, of Tremadoc age, and the youngest assemblage (RI 9) is of Tremadoc age.

13.2.1 ASSEMBLAGE RI 1: ELIASUM LLANISCUM - RETISPAERIDIUM DICHAMERUM

Assemblage RI 1, of Middle Cambrian age, occurs in the upper part of the Chamberlain's Brook Formation (Paradoxides

bennettii Zone) and in all but the uppermost 10 m of the overlying Manuel's River Formation (Paradoxides hicksii and Paradoxides davidis Zones). It is described largely from a single sample that yielded a relatively small number of species in low concentration. Three other samples contained the diagnostic species Eliasum llaniscum, but they were even more impoverished in species than the sample just referred to.

This assemblage is equivalent to assemblages AO-1 (Eliasum jennessii - Acritarch gen. et sp. nov. Martin 1984), AO (Eliasum? hutchinsonii - Cristallinium cambriense), and A1 (Adara alea - Eliasum llaniscum) of Martin (in Martin and Dean 1984). Martin's oldest assemblage, AO-1, includes, in addition to the diagnostic species named above, two other species that were not found in the lowest part of assemblage RI 1 during the present study, namely Retisphaeridium howellii Martin 1983 and Cymatiosphaera crameri Slavikova 1968. Furthermore, no finds were made of Eliasum? hutchisonii Martin 1984 and Adara alea Martin 1981, species characteristic, respectively, of Martin's AO and A1 assemblages. Consequently, no separation of assemblage RI 1 into three acritarch microfloras comparable to those of Martin has been attempted here.

The most common species in assemblage RI 1 are Retisphaeridium dichamerum Staplin, Jansonius, and Pocock 1965, Eliasum llaniscum Fombella 1977 and Multiplicisphaeridum martae Cramer and Díez 1972. ?Timofeevia raquelinae Cramer and Díez 1972, Cristallinium cambriense Slavikova 1968, Eliasum pisciforme Fombella 1977 and unidentified species of Micrhystridium and Lophosphaeridium are also present, but rarer.

13.2.2 ASSEMBLAGE RI 2: TIMOFEEVIA PHOSPHORITICA - VULCANISPHAERA TURBATA

Assemblage RI 2 is equivalent to Martin's A2 assemblage. The former, defined strictly, on the basis of the vertical distribution of acritarchs found by the writer, is confined to strata of the Agnostus pisiformis Zone and the lower part of the Olenus Zone of the Upper Cambrian part of the Elliott Cove Formation. However, Martin (in Martin and Dean 1981) found that the main species of her A2 assemblage (which are the same as those of assemblage RI 2) make their first appearance in underlying strata of Middle Cambrian age, i.e. those of the uppermost part of the Manuels River Formation (Paradoxides davidis Zone) and of the lowest part of the overlying Elliott Cove Formation (Lejopyge laevigata Zone), strata that did not yield recognizable acritarchs in the present study. The lower boundary of RI 2 is, therefore, the same as that of A2, as determined by Martin (i.e., in the uppermost part of the Middle Cambrian Manuels River Formation), and the former is not actually confined, as indicated above, to Upper Cambrian strata.

Assemblage RI 2 is characterized by an abundance of Timofeevia phosphoritica Vanguestaine 1978 and Vulcanisphaera turbata Martin 1981, species that are also abundant in the next highest assemblage, RI 3 (A3 of Martin). T. phosphoritica ranges upward into RI 6 (A5 of Martin); and V. turbata, although not recorded from strata above RI 3 in the present study, was reported by Martin from assemblage A4 (RI 4). The assemblage begins with the first appearance of T. phosphoritica. Because of the absence of productive samples

immediately below this level in the present study, two other diagnostic species, Timofeevia pentagonalis Vanguestaine (1974) 1978 and the long-process form of Timofeevia lancarae (Cramer and Díez 1972) Vanguestaine 1978, make their appearance at the same time as T. phosphoritica. Martin (in Martin and Dean, 1981) found from her more detailed sampling of the strata immediately below those of the Agnostus pisiformis Zone that the first appearance of each of the species of Timofeevia is sequential, i.e. T. phosphoritica appears first, then T. lancarae, and finally T. pentagonalis; all three are fairly common in this assemblage. V. turbata, Micrhystridium shinetonensis Downie 1958, and leiospheres are also common at this stratigraphic level. Cristallinium cambriense Slaviková 1968 ranges upward from the Middle Cambrian RI 1 assemblage into RI 2, and beyond into the Tremadoc (RI 9).

A number of species make their first appearance in assemblage RI 2. Impluviculus milonii Deunff 1968, Cymatiogalea bellicosa Deunff 1961, Stelliferidium gautieri (Martin 1973) comb. nov., and Micrhystridium multiangularis Umnova and Vanderflit 1971 are fairly rare and they also occur in higher assemblages. These species, because of their long stratigraphic range and low abundance are of little use in defining the assemblage.

Timofeevia microretis Martin 1981 is sparse, and restricted to the assemblage. Timofeevia? cuspidata sp. nov., and Vulcanisphaera disjunctospinata sp. nov. are abundant but limited in their distribution to a single sample; Leiofusa oculina sp. nov. and Palaiosphaeridium? clavigerum sp. nov. are fairly rare, and each is likewise confined to a

single sample.

Leiofusa stoumonensis Vanguestaine 1973, characteristic of the next highest assemblage, first becomes abundant near the top of assemblage RI 2, although an isolated specimen was found in a sample from the mid-part of the assemblage. Poikilofusa? dubiostriata sp. nov., Volkovia sp. A, and Cristallinium ovillense Cramer and Díez 1972, appear first in the upper part of RI 2. They range upward into RI 3 but are rare in that assemblage, as in RI 2.

13.2.3 ASSEMBLAGE RI 3: VERYHACHIUM DUMONTII - CRISTALLINIUM CAMBRIENSE

Assemblage RI 3 occurs in the upper part of the Olenus Zone and in the greater part of the succeeding Parabolina spinulosa Zone of the Upper Cambrian part of the Elliott Cove Formation. It is characterized by the common occurrence of Veryhachium dumontii Vanguestaine 1973 and Cristallinium cambriense, and the fairly common occurrence of Leiofusa stoumonensis. The assemblage is equivalent to the A3 assemblage (Cristallinium randomense - Veryhachium dumontii) of Martin. C. cambriense is used as the species diagnostic of the assemblage in the present work because the author found that most specimens of Cristallinium (excluding those of C. ovillense) from the lower and middle parts of the Upper Cambrian on Random Island possess short triangular processes more like those of C. cambriense than of Cristallinium randomense Martin 1981. (See 'Discussion: C. cambriense', Section 11.1.)

The first appearance of V. dumontii marks the beginning

of the assemblage; this species ranges upward into RI 8, but is absent from RI 9. L. stoumonensis, which first appeared near the top of RI 2, is prominent in RI 3, and persists into RI 4 where it is very common. C. cambriense is most prominent in RI 3 but appears higher and lower stratigraphically.

Several species range upward into RI 3 from the preceding assemblage. Timofeevia phosphoritica, Timofeevia lancarae, Timofeevia pentagonalis, and Vulcanisphaera turbata are generally less common than in the previous assemblage, Micrhystridium shinetonensis is again common, and Impluviculus milonii has become quite common. Unidentified leiospheres are somewhat less abundant than in the previous assemblage, and Cymatiogalea bellicosa, Stelliferidium gautieri, and Micrhystridium multiangularis are generally rare.

Appearing first at this level, and continuing into higher assemblages are Impluviculus? lacrimifer sp. nov., Stelliferidium cortinulum Deunff 1961, Cymatiogalea cristata Downie 1958, Stelliferidium striatulum Vavrdová 1966, Cymatiogalea velifera Downie 1958, Cymatiogalea cuvillieri Deunff 1961, Cristallinium randomense Martin 1981, Dasydiacrodium caudatum Vanguestaine 1973 (marginal forms with few or no antapical processes; see Section 6.3), and Impluviculus circularis sp. nov.; except for the last, all these species are present only as rare occurrences. As mentioned earlier, Poikilofusa? dubiostriata, Volkovia sp. A, and Cristallinium ovillense are present, although rare, in this assemblage.

There are a number of other species present in assemblage RI 3 but in very low abundance, and most of them are

restricted to that assemblage; these are listed in Chart 1.

13.2.4 ASSEMBLAGE RI 4: TRUNCULUMARIUM REVINIUM

The description of assemblage RI 4 that follows is based on a single sample from shales of the upper part of the Parabolina spinulosa Zone of the Upper Cambrian part of the Elliott Cove Formation. The poorly preserved acritarchs in the sample are partially or completely obscured by organic debris which it was found impossible to remove so that it is probable that only some of the species present at this stratigraphic level have been identified.

Assemblage RI 4 is equivalent to Martin's A4 (Trunculumarium revinium - Dasydiacrodium caudatum) assemblage. However, the equivalence applies only to the acritarch microflora recovered from the two samples that she included without reservation in A4; the acritarchs of two other samples that Martin assigned with doubt to A4 are known, from the present study, to belong, in one case, to the uppermost part of the preceding assemblage (RI 3) and, in the other case, to the uppermost part of the succeeding assemblage (RI 5). The proximity of Martin's two A4 sample localities to the RI 4 sample locality indicates that assemblage RI 4 is confined to strata no more than a few metres thick.

The lower boundary of assemblage RI 4 is defined by the first appearance of Trunculumarium revinium Vanguestaine 1973. This species characterizes the assemblage as it occurs not only in abundance (making up 28% of all the acritarchs present), but is virtually confined to it (one specimen was found in RI 9). Common as well in this assemblage are

Veryhachium dumontii, Timofeevia pentagonalis, Impluviculus milonii, Leiofusa stoumonensis; less common are Timofeevia phosphoritica, Timofeevia bifurcata, and unidentified leiospheres.

Dasydiacrodium caudatum is present in assemblage RI 4, but only four specimens were observed. These differed slightly from those in the preceding assemblage. (See 'Discussion: D. caudatum', Section 6.3.) Vulcanisphaera turbata was not found in the single sample from RI 4, but Martin reported it from her equivalent assemblage, A4.

Present as well in RI 4 are rare occurrences of Timofeevia lancarae, Cristallinium cambriense, Stelliferidium cortinulum, Stelliferidium gautieri, Stelliferidium furcatum? Deunff 1961, Micrhystridium shinetonensis, and unidentified Polygonium forms.

13.2.5 ASSEMBLAGE RI 5: ACANTHODIACRODIUM UBUI - CYMATIOGALEA? MEMBRANULA

Assemblage RI 5 is present in the upper part of the Elliott Cove Formation, and as it ranges through strata of the uppermost part of the Parabolina spinulosa Zone, the Leptoplastus Zone and the lower part of the Peltura Zone, it is of late Upper Cambrian age. The relationship of this assemblage to A5, the Vulcanisphaera africana - Arbusculidium rommelaeri assemblage of Martin, is discussed below.

Martin (in Martin and Dean 1981) divided assemblage A5 into two parts, A5a and A5b. The first of these subassemblages was recovered from a single sample taken from an outcrop of the Elliott Cove Formation south of Bounds Mead,

whereas the second was obtained from two closely spaced samples in strata of the Peltura Zone in the section south of Elliott's Cove. The stratigraphic relationship of A5a and A5b is not known from field evidence but Martin postulated, on the basis of the acritarch content of each of them, that A5a is older than A5b.

The nature of the acritarch microflora of assemblage RI 5 differs significantly from that of the preceding assemblage, RI 4. Thus, in RI 5, Leiofusa stoumonensis disappears, Veryhachium dumontii and Timofeevia species become insignificant, and there is an influx of Acanthodiacrodium species. Assemblage RI 5 is characterized by the first appearance of Acanthodiacrodium ubui Martin 1969 and Cymatiogalea? membranula Martin 1978. According to Martin, C.? membranula is rare and restricted to assemblage A5a, and A. ubui is present only in subassemblage A5b. However, both species are present, although in low numbers, throughout RI 5. Furthermore, strata above and below those of the locality south of Elliott's Cove from which Martin recovered the sample containing subassemblage A5b have yielded C.? membranula. (The two lowest samples assigned to RI 5 did not yield these two species. They are included in RI 5 because they contain two new species - a species resembling Cymatiogalea bouvardi and an unusual leiofusid species - that are common in the lower part of RI 5 (see below) but are unrepresented in the preceding assemblage, RI 4.)

The species Arbusculidium rommelaeri Martin 1981, the dominant element in both subassemblages of A5, is present in the upper part of RI 5 (although in lower concentration than in Martin's samples), and Vulcanisphaera africana Deunff 1961,

the other species Martin considers diagnostic of A5 (common in one sample of A5b but rare in the other two samples of the assemblage) is present in low concentration in the upper part of RI 5. The first appearance of the latter is, however, at a slightly lower stratigraphic level in strata near the top of the lower part of RI 5. Acanthodiacrodium achrasi Martin 1973, Acanthodiacrodium complanatum (Deunff 1961) Vavrdová 1965, Saharidia sp. A, and Cymatiogalea bouvardi also make their first appearance in the upper part of RI 5, the last named being the most abundant of the four, and the most characteristic species in that part of the assemblage. Martin found the first, second, and fourth of the species just referred to, together with a species of Saharidia, in subassemblage A5b; she found only the first in A5a. Species that make their first appearance in the lower part of RI 5 and range upward into its upper part are Acanthodiacrodium aff. achrasi, Goniosphaeridium eisenackianum? (Deunff 1958) comb. nov., G. gracilis Vavrdová 1966, G. uncinatum (Downie 1958) Kjellström 1971, and Pterospermella snooksensis sp. nov. These species are, with the exception of G. uncinatum, rare to relatively rare. Several species that range upward into RI 5 from RI 4 are shown in Chart 1; apart from leiospheres, common to abundant in most samples, they are present as rare occurrences.

It is apparent from the preceding discussion that Martin's subassemblages A5a and A5b, despite the apparent restriction of some species to the one or the other of them, are of the same age, and that assemblage A5, as a whole, is equivalent to the acritarch microflora of the upper part of RI 5. Martin assigned acritarchs of the single sample that

she took from strata included here in the lower part of RI 5, albeit doubtfully, to the top of the preceding assemblage, A4 (= RI 4). That sample did not yield Trunculumarium revinium, the most characteristic element of A4 (and RI 4); the other acritarchs present, with the exception of Vulcanisphaera turbata, have all been found in RI 5 and A5.

Recent sampling of the shales of the uppermost part of the Parabolina spinulosa Zone and of the succeeding Leptoplastus Zone that contain acritarchs of the lower part of assemblage RI 5 has yielded two hitherto unrecorded new species. The first of these is a species of Cymatiogalea that is common to fairly common. Although resembling C. bouvardi, it possesses sturdier processes. The second is a rather unique species resembling Leiofusa stoumonensis, but unlike that species, it has a dark central body; it is common in the lower part of RI 5 and is also represented in the upper part of the assemblage. The new finds are not described further in the present work because the taxonomic part of this thesis was completed before resampling began (for refinement of assemblage boundaries).

13.2.6 ASSEMBLAGE RI 6: ACANTHODIACRODIUM ANDERSONI - ACANTHODIACRODIUM COMPLANATUM

This assemblage has been found only on the north side of the island, 2 km north of Snooks Harbour (Fig. 2.1), in four samples from a 23 m thick sequence of shales. The latter, dipping gently to the eastnortheast, are continuously exposed for some distance along the coast but north and south of the section there are no outcrops so that the vertical range of

assemblage RI 6, i.e. the total thickness of strata in which it is represented, is presently unknown. There is no equivalent to RI 6 in the assemblages described by Martin.

The shales of the section north of Snooks Harbour contain trilobites. The most abundant form present is Sphaeropthalmus humilis Phillips 1848 (identified by Ludvigsen 1983) which is characteristic of the uppermost part of the Peltura Zone (i.e. the Peltura scarabaeoides Subzone of the Scandinavian zonal scheme). Thus, assemblage RI 6 lies stratigraphically above RI 5 as the latter ranges into at least the lower part of the Peltura Zone. The absence, south of Elliott's Cove, of strata containing an RI 6 flora is probably due to faulting - see discussion in next section - 13.2.7 (assemblage RI 7).

Assemblage RI 6 is characterized by an abundance of Acanthodiacrodium andersoni sp. nov., which is restricted to the assemblage, and by a super-abundance of Acanthodiacrodium complanatum. The latter species makes its first appearance in the preceding assemblage, RI 5, and is also present, although in very low abundance, in assemblages RI 7 and RI 8. The first appearance of A. andersoni marks the beginning of the assemblage.

A. aff. achrasi and unidentified leiospheres are also present in abundance in this assemblage. Cymatiogalea membrana Rasul 1976, Goniosphaeridium pungens (Timofeev 1959) Rauscher 1973, Cymatiogalea sp. A. and an unidentified Trunculumarium? species (T.? sp. A) are rare occurrences restricted to this assemblage. Vulcanisphaera capillata Jardiné et al. 1974 enters the succession first at this stratigraphic level.

The range of S. gautieri terminates within this

assemblage (although Martin reports that species in her A6 assemblage, which is equivalent to RI 9). Species that range upward from lower assemblages into RI 6 are listed in Chart 1.

13.2.7 ASSEMBLAGE RI 7: STRIATOTHECA SP. - OOIDIUM? CLAVIGERUM

This assemblage is described from ?Upper Cambrian/Tremadoc rocks from which no diagnostic trilobite material has been recovered. The stratigraphically lowest sample with an RI 7 assemblage was taken from strata located about 100 m north of an exposure of shales that yielded an RI 5 assemblage and trilobites of the Peltura Zone. In the intervening section, apart from two small outcrops from which an RI 5 flora was obtained, the bedrock is concealed. The northernmost of the small outcrops is 40 m distant (measured along the beach) from the southernmost outcrop containing an RI 7 assemblage. The shales of this concealed part of the section may include those belonging to assemblage RI 6 or, alternatively, a hidden fault is responsible for the juxtaposition of assemblages RI 5 and RI 7, and the absence of the RI 6 flora, in this part of the Elliott's Cove section. The latter possibility is considered more likely in view of the fact that the thickness of the strata containing an RI 6 assemblage is known to be at least 23 m and, judging from the dip of the adjacent shales, the concealed interval is almost certainly too narrow to provide room for that thickness of strata.

Assemblage RI 7 has not previously been reported from Random Island, and neither of the two main species of the

assemblage has been described from any other locality. The beginning of this assemblage is marked by the first appearance of two species - Ooidium? clavigerum sp. nov. and Striatotheca sp. - both of which are restricted to RI 7 and the lower part of RI 8; these species and leiospheres, in almost equal abundance, are the dominant elements of the assemblage.

Species first appearing in this assemblage that range upward into higher assemblages are Cymatiogalea membranispina Deunff 1961, Saharidia fragile (Downie 1958) Combaz 1967, Cymatiogalea radiata sp. nov., 1961, Poikilofusa squama (Deunff 1961) Cramer 1970, Acanthodiacrodium randomense sp. nov., Baltisphaeridium crinitum Martin 1978, Arbusculidium penicillum sp. nov., and Estiastra sp. A. A number of species continue into RI 7 from lower assemblages (see Chart 1).

13.2.8 ASSEMBLAGE RI 8: OOIDIUM ROSSICUM - ACANTHODIACRODIUM DISCIGERUM

The Ooidium rossicum - Acanthodiacrodium discigerum assemblage has not previously been reported from Random Island. It occurs for the most part in strata above those of assemblage RI 7 and below those of the Parabolina argentina Zone, an interval undated by macrofossils. However, the uppermost part of the assemblage is present in shales of the Parabolina argentina Zone that contain Niobella. Thus, assemblage RI 8 ranges into the lowest part of the Clarenville Formation and is in part of Tremadoc age.

This assemblage is characterized by an abundance of

Ooidium rossicum Timofeev 1957 which generally dominates the assemblage, making up from 20 to 45% of the identifiable material in all except the two lowest samples. (This figure may be artifically high as the distinctiveness of the species makes positive identification possible even from small fragments, whereas other species that are less distinctive may not have been included in the count because of the impossibility of identifying them in samples that contain a great deal of broken material.)

The first appearance of O. rossicum marks the beginning of the assemblage. Ooidium? clavigerum and Striatotheca sp. range upward from RI 7 into the lower part of the assemblage but then disappear entirely. O. rossicum is almost totally restricted to RI 8, as only rare specimens have been recovered from the next highest assemblage, RI 9. Acanthodiacrodium discigerum sp. nov. is also restricted to the assemblage; it is present in two samples, being quite abundant in one of them. Hamatodiacrodium bucerum var. aciferum (Umnova 1971) comb. nov., Impluviculus? bibulbulus sp. nov., and Lophosphaeridium sp. A make their first appearance in this assemblage but they also occur in RI 9. Baltisphaeridium sp. A, Coryphidium? sp., Multiplicisphaeridium sp. A, and Cymatiogalea aff. cuvillieri (2) are present as rare occurrences, and only in this assemblage. Acanthodiacrodium sp. A and Arbusculidium destombesii Deunff 1968 are present as rare occurrences in RI 8 and RI 9. The presence of the latter in RI 8 is noteworthy as its appearance is taken by Martin as indicative of her A6 (Arbusculidium destombesii - Vulcanisphaera capillata) assemblage of Tremadoc age. Its presence in RI 8 makes it of doubtful value as a lower

Tremadoc marker because the strata in which it first appears may be younger than Tremadocian (possibly belonging to the late Upper Cambrian Acerocare Zone), and of little value as an indicator of an A6 assemblage. The other species diagnostic of A6, Vulcanisphaera capillata, as well as two of the species used to mark the lower boundary of A6, namely Cymatiogalea cuvillieri and Cymatiogalea bellicosa, have also been recovered from older assemblages in the present work.

Species not already mentioned that range upward into RI 8 from lower assemblages are recorded in Chart 1. This assemblage sees the last occurrences (in this work) of the species Veryhachium dumontii, Cymatiogalea? membranula, Acanthodiacrodium complanatum, and Cristallinium randomense, among others. However, all except the first of these were recorded by Martin (in Martin and Dean 1981) from younger (A6) strata on Random Island.

13.2.9 ASSEMBLAGE RI 9: DASYDIACRODIUM LONGISPINATUM - HAMATODIACRODIUM BUCERUM

Assemblage RI 9 occurs in the Parabolina argentina Zone of the Tremadocian Clarenville Formation. It is equivalent to all except the upper part of the A6 (Arbusculidium destombesii - Vulcanisphaera capillata) assemblage of Martin.

The species Dasydiacrodium longispinatum sp. nov. characterizes the assemblage and is common throughout, its first appearance marking the beginning of the assemblage. Hamatodiacrodium bucerum Umnova (1971) comb. nov., common in the upper part of RI 9, appears at the beginning of the assemblage in low numbers and as a rare occurrence in one

sample in the preceding assemblage, but as Form A; in RI 9, only Form B is present. Veryhachium sp. B, unsatisfactory for diagnostic purposes because of its rather indeterminate nature, also appears near the beginning of the assemblage.

Several species present as rare occurrences, and only in RI 9, are Nucellosphaeridium sp., Acanthodiacrodium cf. abortivum Timofeev 1959, Goniosphaeridium cf. symbolum Rasul 1979, Goniosphaeridium sp. A, and Veryhachium minutum Downie 1958.

Most of the species present in RI 8 range upward into RI 9 (see Chart 1). Cristallinium randomense was not found at this level in the present work, but Martin reports one sample with a single specimen from her A6 assemblage. Cristallinium cambriense is very rare, both in Martin's sampling and that of the present work. Micrhystridium shinetonensis, Impluviculus milonii, and leiospheres are still present in abundance.

Acanthodiacrodium angustum (Downie 1958) Combaz 1967, a species recorded by Vanguestaine (1974) from the Tremadoc of Belgium, is not present in RI 9. However, Martin reports it from two samples north of Bounds Mead; the stratigrapic position of these samples with respect to others from A6, and to samples from RI 9, is not known. The species was also found, during the preliminary study for this work, in material from north of Elliott's Cove, and its presence may mark the beginning of a new assemblage, or an upper subunit of RI 9 (and A6).

CHAPTER FOURTEEN

BIOSTRATIGRAPHIC CORRELATION OF THE ACRITARCH ASSEMBLAGES OF RANDOM ISLAND WITH THOSE OF OTHER REGIONS

Previous work on Middle Cambrian, Upper Cambrian, and Tremadoc acritarchs has been carried out mainly in Europe, North Africa, and, more recently, in eastern Newfoundland; other, generally less extensive, studies have been carried out in mainland Canada, Argentina, China, and Australia. Random Island microfloras show most similarity with assemblages from the British Isles, western Europe, the Baltic countries, the Russian Platform, and North Africa. Individual species from the other localities mentioned above are present on Random Island. Comparisons between the Random Island assemblages and those of a number of other localities are made in the sections that follow.

14.1 BELGIUM

The Cambrian and Ordovician rocks of the Ardennes region of Belgium crop out in five small massifs that are surrounded by Devonian strata. They have been divided on the basis of their lithology into three groups, the Devillian, the Revinian, and the Salmian. Rocks of the Devillian and Revinian Groups, devoid of macrofossils except for the problematic trace fossil Oldhamia in the Devillian (Vanguestaine 1967, 1970), are present in the Rocroi, Stavelot, and Brabant massifs, and also, in the case of those

of the Revinian, in the Givonne and Serpont massifs. The rocks of the Salmian Group overlie those of the Revinian in the Stavelot and Brabant massifs.

The presence of Dictyonema flabelliforme in the lower part of the Salmian Group indicates that the latter is of Tremadoc age; the upper part of the group (overlain by Silurian strata in the Brabant massif) is of post-Tremadoc Ordovician age. A Cambrian age for the two lower groups, originally assigned on stratigraphic grounds, was confirmed by Vanguestaine (1973a, 1973b, 1973c, 1974, 1978) who studied the acritarch microfloras of the three groups of strata (excluding the upper part of the Salmian) and divided the Cambrian - Tremadoc succession into a series of nine acritarch zones (Zones 0 to 8). The ages of the zones are as follows: Zone 0 - Lower Cambrian, Zones 1 to 4 - Lower or Middle Cambrian, Zones 4 and 5 - Upper Cambrian, Zones 5 and 6 - Tremadoc. Stratigraphic breaks are present between the strata of Zones 0 and 1, 4 and 5, 5 and 6, and 6 and 7.

Most of the acritarchs of Zones 0 to 3 and much of Zone 4 (divided by Vanguestaine, 1978, into subzones 4a and 4b) have not been recovered from Cambrian rocks on Random Island. Exceptions, that make their appearance in Belgium at the base of Zone 2, are Cristallinium cambriense and Timofeevia phosphoritica sensu lato. The latter includes specimens transitional in form with Timofeevia pentagonalis, and specimens that are equivalent to short process forms of Timofeevia lancaraa. On Random Island, C. cambriense, which has a long vertical range, makes its first appearance in the lowest part of assemblage RI 1 (AO-1 of Martin) in strata of early Middle Cambrian age, whereas T. phosphoritica, T.

lancarae, and T. pentagonalis make their first appearances (in that order) at successively higher stratigraphic levels in the lower part of Martin's A2 assemblage in strata of late to latest Middle Cambrian age. In Belgium, T. pentagonalis and Vulcanisphaera turbata appear first in the upper part of Subzone 4b; on Random Island, they appear at the same stratigraphic level in assemblage A2 in strata of latest Middle Cambrian age (Lejopyge laevigata Zone). The absence in the Belgian zones of Eliasum llaniscum, which is characteristic of Martin's assemblages, AO-1, AO, and A1, suggests that the acritarchs of Zone 2 are younger than those of assemblage A1 (and RI 1). Zones 2, 3, and 4 of Belgium are, therefore, probably equivalent to the lower part of assemblage A2 (possibly excluding its lowermost beds in which E. llaniscum is still represented. The species Alliumella baltica Vanderflit 1971, present throughout Zone 4 in Belgium, appears to be endemic to that region as it has not been found elsewhere in strata of comparable age.

Zone 5, separated from Zone 4 by a stratigraphic break, is distinguished by the presence of four species, namely, Dasydiacrodium caudatum, Leiofusa stoumonensis, Veryhachium dumontii, and Trunculumarium revinium. Of the four, T. revinium is considered by Vanguestaine, 1974, to be the most characteristic of the zone. Assemblage RI 3 contains three of the four characteristic species, but it does not contain the most characteristic species. Only RI 4, in Upper Cambrian strata of the upper part of the Parabolina spinulosa Zone, includes all four species.

Other species that are common to Zone 5 and assemblage RI 4 are Micrhystridium shinetonensis, Stelliferidium

cortinulum, Impluviculus milonii, T. phosphoritica, T. pentagonalis, Cristallinium cambriense, Timofeevia bifurcata (T. brevibifurcata Vanguestaine (MS.) 1973), and Vulcanisphaera turbata (V. raribifurcata Vanguestaine (MS.) 1973, and specimens assigned to V. africana by Vanguestaine). The last of these, V. turbata, although not found in RI 4, was reported by Martin (in Martin and Dean 1981) from her A4 assemblage. Other species of the RI 4 assemblage, not reported by Vanguestaine from Belgium, make up only an insignificant proportion of the Random Island assemblage.

Zone 5 in Belgium is correlated here with assemblage RI 4 on Random Island as their species content is virtually the same. It is also evident that, as a result of non-deposition in the Belgian area, the Cambrian succession there does not include acritarch microfloras corresponding to those of assemblages RI 2 and 3 on Random Island; the missing strata represent those of the Agnostus pisiformis and Olenus Zones and those of much of the Parabolina spinulosa Zone because RI 4 is restricted to an upper part of that zone. A stratigraphic break separates Zone 5 from Zone 6.

Zone 6 is characterized by "Lophodiacrodium" spp. (in Vanguestaine 1974; illustrated as Acanthodiacrodium gr. 1 in 1967) and Ooidium sp. A; "Lophodiacrodium" is almost certainly equivalent to Acanthodiacrodium discigerum sp. nov. of the middle part of assemblage RI 8. Ooidium sp. A as illustrated and described by Vanguestaine, 1974, probably includes several species, but the mediocre preservation of the specimens, especially of their processes, made it impossible for Vanguestaine to assign them to any of the established Ooidium species. However, some of the Belgian specimens with

short spines and microgranulation at the non-spinose pole closely resemble less well-preserved specimens of Ooidium rossicum from assemblage RI 8 in which the trabeculate ornamentation has been reduced to short blunt spines, and there is little doubt that they belong to that species. Some of the other species of Zone 6 that occur also in RI 8 are Acanthodiacrodium ubui, Impluviculus circularis (as Impluviculus multiangularis), and Polygonium sp. B (several examples of which appear to belong to Goniosphaeridium gracilis).

Vanguestaine and Van Looy (1983), on the basis of the appearance of Stelliferidium cortinulum (or gautieri), Acanthodiacrodium achrasi, Goniosphaeridium uncinatum and Acanthodiacrodium ubui in Zone 6 (unpublished in the 1974 work of Vanguestaine) equated Zone 6 with Martin's A5 assemblage in strata of the Peltura Zone. However, on Random Island, those species range upward into higher assemblages, including RI 8, described only in the present work. Furthermore, A5, apart from lacking A. discigerum, contains no undoubted species of Ooidium, and Zone 6 does not include the two species most characteristic of A5 (Vulcanisphaera africana and Arbusculidium rommelaeri). A5 is equivalent to the upper part of RI 5 and the species most characteristic of the latter, Cymatiogalea bouvardi, is yet another species not represented in Zone 6. It is now apparent that the latter cannot be equated with Martin's A5 assemblage. Here, Zone 6 in Belgium is correlated with assemblage RI 8 on Random Island. The age of the latter is presently referred to as ?late Upper Cambrian/early Tremadoc because only its upper part has yielded diagnostic trilobites, i.e. those of the Tremadocian

Parabolina argentina Zone. Assemblages RI 5, RI 6, and RI 7 of Random Island are unrepresented in the Belgian Cambrian succession as a result of the stratigraphic break between Zones 5 and 6. The Upper Cambrian strata that are missing are those of the uppermost part of the Parabolina spinulosa Zone and those of the Leptoplastus and Peltura Zones.

Zone 7 is the only one of the Belgian zones in which diagnostic macrofossils have been found. The base of this zone has yielded Dictyonema flabelliforme, thus dating it as lower Tremadoc. The acritarch species most characteristic of Zone 7 are Acanthodiacrodium (Lophodiacrodium) angustum (Downie 1958) Combaz 1967 and Micrhystridium robustum Downie 1958. In the present study, neither of these species was recovered from the Elliott Cove section but the former was found during the preliminary study in rocks of Tremadoc age north of Elliott's Cove.

Vanguestaine and Van Looy suggest a correlation of the acritarch microflora of Zone 7 with the Arbusculidium destombesii - Vulcanisphaera capillata assemblage of Martin (A6) on the basis of the appearance of A. angustum and Cymatiogalea (Priscogalea) cuvillieri at the base of both assemblages. The latter species appears much earlier on Random Island (in RI 3) and A. angustum is not represented in RI 9 or in that part of A6 south of Elliott's Cove that is equivalent to RI 9. However, as neither A. destombesii or V. capillata is present in Zone 7, and A. angustum and C. cuvillieri are both known to occur higher in the Tremadoc, it is considered likely that strata equivalent to those of Zone 7 are not present in the Elliott's Cove section. This likelihood is supported by the presence of a stratigraphic

break between Zones 6 and 7 in Belgium which suggests that there, strata of earliest Tremadoc age, corresponding to those of RI 9 (A6), are missing. Zone 7 may, however, be represented in sections north of Elliott's Cove, i.e. those in which A. angustum, has been found by the writer and by Martin.

Zone 8, characterized by the first appearances of Priscogalea chevronensis Vanguestaine 1974, Priscogalea cf. striatula (Vavrdová 1966) Vanguestaine 1974, and Priscogalea stelligera (Gorká 1967) Vanguestaine 1974, (all now included in the genus Stelliferidium) and Veryhachium primaevum Deunff 1966 (in its upper part), does not resemble any of the Random Island assemblages.

A number of species, other than those already mentioned above, have been reported from the Tremadoc, and post-Tremadoc early Palaeozoic rocks of Belgium. Those that are present in Belgium and also in the Upper Cambrian and/or Tremadoc of the Elliott's Cove section on Random Island (see Chart 1) are simply listed here with the stratigraphic interval from which they were recorded.

Poikilofusa squama, Acanthodiacrodium complanatum, Acanthodiacrodium lanatum, and Arbusculidium destombesii: lower Tremadoc (Martin, 1977); Goniosphaeridium pungens and Cymatiogalea velifera: lower Tremadoc (Martin, 1969); Stelliferidium striatulum: Tremadoc to Llandovery ?Llanvirn (Martin, 1973, 1966, 1969); Cymatiogalea cristata: Tremadoc (Martin, 1969, 1977); Cymatiogalea cuvillieri: lower Caradoc (Martin, Michot, and Vanguestaine, 1970; Vanguestaine (MS.) 1973c); Acanthodiacrodium ubui: Llandovery (Martin, 1973); Goniosphaeridium uncinatum: Tremadoc to Ludlovian (Martin,

1966, 1969, 1973, 1977; Henry, 1969); and Micrhystridium shinetonensis: Tremadoc to lower Arenig (Martin, 1969); Tarranonian (Silurian) (Stockmans and Willièri, 1963).

14.2 FRANCE

Most palynological studies in France have been concerned with acritarchs of Ordovician age from the Massif Armoricain, the Massif de Mouthoumet, and the Montagne Noire. In the latter region, Lower and Middle Cambrian rocks have also yielded acritarchs.

Fournier-Vinas (1978) described acritarch assemblages of Cambrian and Lower Ordovician age from Mont de Lacaune, Montagne Noire, south of the Massif Central. The Middle Cambrian rocks of that region contain T. pentagonalis and several other species (not recorded for Random Island), but they apparently lack species of Eliasum typical of rocks of that age elsewhere. The Tremadocian strata of Mont de Lacaune yielded a number of species (G. uncinatum, G. pungens, V. africana, M. shinetonensis, A. destombesii, C. cristata, and V. minutum) most of which range through the late Upper Cambrian - early Tremadoc succession on Random Island. P. squama, which does not appear until the Arenig at Mont de Lacaune, makes it first appearance on Random Island in strata of ?late Upper Cambrian/early Tremadoc age.

Cocchio (1982), from her study of the acritarchs of an apparently unfossiliferous sequence of pre-Caradoc Lower Palaeozoic sedimentary rocks in the Massif de Mouthoumet, Corbières, southern France, established that the age of the

latter is Tremadoc to Arenig. Many of the species reported by Cocchio have not been found on Random Island but a number of others, with long stratigraphic ranges, occur in Upper Cambrian and Tremadoc strata there. These include C. cambriense, M. shinetonensis, G. uncinatum, I. milonii, C. cuvilleri, S. cortinulum, A. complanatum, A. achrasi P. squama, and G. pungens. V. minutum, definite specimens of which are rare in the Tremadoc (assemblage RI 9) on Random Island, was also recorded by Cocchio.

Martin (1973) and Rauscher (1971, 1973, 1974) found a number of species in the Tremadoc of the Montagne Noire that are also present in Cambrian and/or Tremadocian strata on Random Island. These include S. gautieri, A. ubui, Acanthodiacrodium achrasi, G. uncinatum, G. pungens, I. milonii, C. cristata, Cymatiogalea bouvardi, C. cambriense, S. cortinulum, M. shinetonensis, C. cuvillieri, P. squama, Veryhachium minutum, Vulcanisphaera africana, and species of the genera Saharidia and Impluviculus. Other species common to Random Island and France are S. striatulum, present in the Llanvirn of Brittany (Paris and Deunff, 1970), Goniosphaeridium eisenackianum, in the upper Ordovician of Brittany (Deunff, 1958), and Gonisphaeridium gracilis, in the Arenig of the Montagne Noire (Rauscher 1971, 1973, 1974). G. uncinatum also ranges upward (in Brittany) from the Tremadoc into the Caradoc (Henry, 1969) and M. shinetonensis has been reported from upper Ordovician and Lower Silurian strata of the Massif Armoricain (Paris and Deunff, 1970; Moreau-Benoit, 1971). The species named above are all long ranging species that make their first appearance in Upper Cambrian strata on Random Island.

14.3 ENGLAND, WALES, AND IRELAND

Acritarch studies carried out in Britain that are of concern here are those of Potter (1974a (MS.), 1974b), on some parts of the Cambrian successions of England and Wales, and Rasul (1971, 1974, 1976, 1977, 1979) on the Tremadocian Shineton Shales in the Wrekin district of Shropshire, England. In Ireland, Lower Palaeozoic acritarchs have been studied by Gardiner and Vanguestaine (1971), Brück et al. (1979), Muir et al. (1979), and Smith (1977, 1981).

Potter (1974a, MS.) erected a zonal scheme for Lower to Upper Cambrian rocks of England and Wales (incorporating one subzone from Spain) based on acritarch assemblages from Cambrian successions in four areas, namely, the St. Tudwal's Peninsula of North Wales, the Villaminin district of Northwest Spain, and the Nuneaton and Comley areas of central England. He recognized six zones; the oldest, Zone 1, includes four subzones; three based on samples from rocks of late Lower Cambrian to Middle Cambrian age in North Wales, and the fourth (the uppermost) based on a single sample from rocks of late Middle Cambrian age in Spain. Zone 1, as a whole, is characterized by the occurrence together of Granomarginata squamacea Volkova 1968 and Eliasum llansicum (Lemniscatofusus salopiensis in Potter). The second of these species occurs in assemblage RI 1, of Middle Cambrian age, on Random Island. Subzone S1A, of late Early Cambrian age, is not represented in the Elliott's Cove section. Subzone S1B (early Middle Cambrian) is distinguished by the presence of two species, Micrhystridium cilanensis sp. nov. Potter 1974 (MS.) (possibly equivalent to Celtiberium dedalinium Fombella 1978)

and Micrhystridium? triangulatum sp. nov. Potter 1974 (MS.). Neither of these species has been reported from Random Island where the oldest assemblage is from slightly younger rocks than those of Subzone S1B.

Subzone S1C (mid- to late Middle Cambrian) is characterized by the first appearances of Granomarginata desultoria sp. nov. Potter 1974 (MS.), Micrhystridium notatum Volkova 1969 and Multiplicisphaeridium vitulaminum sp. nov. Potter 1974 (MS.) (probably synonymous with M. martae in this study and M. sp. in Martin and Dean 1984). Cristallinium cambriense (as Comptofaciesphaera cf. cambriense in Potter) occurs in the upper part of the subzone. Of the species reported from this subzone, only M. martae, C. cambriense, and E. llaniscum (occurring in all subzones) are present in assemblage RI 1 on Random Island; C. cambriense ranges upward from the base of RI 1 into Upper Cambrian and Tremadoc strata. Subzone S1C is equivalent to at least the upper part of RI 1.

Subzone V1D (Spain) is characterized by the first appearances of Timofeevia phosphoritica and T. lancarae (T. katernes sp. nov. of Potter (MS.) 1974). It also includes E. llaniscum, C. cambriense and a number of other species that, unlike those already named, have not been recorded from the Middle Cambrian of the Elliott's Cove section. One of the species found only in the Spanish assemblage that Potter considered significant is Granomarginata squamacea. Despite the apparent absence of the latter in Middle Cambrian strata on Random Island, the acritarch microflora of subzone V1D is equivalent to the association of acritarchs present in the uppermost part of the Manuels River Formation (Paradoxides

davidis Zone), i.e. the lower part of Martin's A2 assemblage. However, the diversity of species in the Spanish assemblage is not matched by its counterpart on Random Island.

Zone N2 (Nuneaton) is distinguished from Zone 1 by the absence of the two species characteristic of the latter, the first appearance of Micrhystridium lanceolatum Vanguestaine 1974, which is restricted to the zone, and the presence of Dichasphaira roscida gen. et sp. nov. Potter 1974 (MS.), Lophosphaeridium? nuneatonensis sp. nov. Potter 1974 (MS.) (also restricted to the zone), C. cambriense and T. lancarae. The last named does not occur in Potter's later assemblages but on Random Island it ranges upward into assemblage RI 4 in the upper part of the Parabolina spinulosa Zone (with an isolated occurrence in RI 6). This assemblage differs in content from that part of Martin's A2 assemblage that was derived from strata of the Lejopyge laevigata Zone. Only C. cambriense and T. lancarae are present in both of them. Further sampling of the Lejopyge laevigata Zone in the Elliott's Cove section is needed to establish whether the other species named above are really unrepresented in that zone on Random Island.

Zone N3 (Nuneaton), in strata of the Olenus Zone, is characterized by the first appearance of, among others, Vulcanisphaera turbata (V.? cf. fibra of Potter) and Timofeevia pentagonalis. Veryhachium dumontii (as V. cf. dumontii) does not appear until the next highest zone, N4. The presence of V. turbata and T. pentagonalis, and the absence of V. dumontii indicate that the acritarch microflora of Zone N3 can be equated with that of all but the lower part of assemblage RI 2 on Random Island as the latter includes

strata of the Agnostus pisiformis and Olenus Zones.

Zone N4 is also from strata of the Olenus Zone. It is distinguished from N3 by the first appearance of V. dumontii (V. cf. dumontii), Impluviculus milonii, and Leiofusa stoumonensis. These three species first occur together at the base of assemblage RI 3 on Random Island. I. milonii and L. stoumonensis are also present in the upper part of RI 2. Assemblage RI 3 occurs in strata of the upper part of the Olenus Zone and much of the Parabolina spinulosa Zone. Zone N4 is equated here with the lower part of RI 3 as species characteristic of the upper part of the latter are not represented in N4.

Zone C5 (Orusia Shales at Comley), in strata of the Parabolina spinulosa Zone, is characterized by the first appearances of Cymatiogalea cylindrata Rasul 1974, Timofeevia bifurcata (T. brevibifurcata Vanguestaine (MS.) 1974), and Veryhachium asymmetricum (Leiofusa scallenbullata Potter (MS.) 1974). These species appear in the upper part of assemblage RI 3 on Random Island. The acritarch microflora of Zone C5 is, therefore, equivalent to that of the upper part of RI 3, also in strata of the Parabolina spinulosa Zone.

Zone N6 (Nuneaton) is also in strata of the Parabolina spinulosa Zone, and its acritarch microflora has also been recovered from the Orusia Shales at Comley. The species of N6 are those that characterize assemblage RI 4 on Random Island: Trunculumarium (Ooidium) revinium, Dasydiacrodium caudatum, L. stoumonensis, V. dumontii, T. phosphoritica, and Micrhystridium shinetonensis. The equivalence of Zone N6 and RI 4 is not in doubt. RI 4 is from strata of the upper part of the Parabolina spinulosa Zone, and the stratigraphic

relationship of Zones C5 and N6 in the Orusia Shales at Comley, the relative ages of which were not known to Potter, is clear, i.e. Zone C5 is older than Zone N6. No assemblages were reported by Potter from younger Upper Cambrian strata in England or Wales.

The Tremadocian succession of the Wrekin district, Shropshire, where the representative formation is the Shineton Shales, was divided by Rasul (1979) into eight acritarch zones. The lowest of these zones, Zone 1, in Dictyonema flabelliforme beds, is faulted against the Middle Cambrian Comley Sandstone, so that its base is unknown. It contains several species that range upward into higher zones: Stelliferidium cortinulum, Cymatiogalea bellicosa, C. cristata, Acanthodiacrodium ubui, and Micrhystridium shinetonensis. Those species have equally long vertical ranges on Random Island, occurring in both Upper Cambrian and Tremadoc strata (see Chart 1). Most of the species present in Zone 1 have not been recovered from any of the Tremadoc rocks cropping out in the Elliott's Cove section, and none of the species that enter higher than Zone 1 has been reported from the Tremadocian rocks of any part of Random Island. The main species characteristic of the lowest Tremadoc rocks on Random Island, Dasydiacrodium longispinatum - and Hamatodiacrodium bucerum, do not appear in any of Rasul's zones, and Acanthodiacrodium angustum, which was found (in the preliminary study for this work) in Tremadoc strata that may be younger than those of the Elliott's Cove section, was not listed by Rasul. It is evident that the Tremadocian strata on Random Island are older than those of the Wrekin district studied by Rasul.

In Ireland, acritarchs have been used as diagnostic tools for determining the approximate ages of several formations, but they have not been used to establish zones. Gardiner and Vanguestaine reported C. cambriense, from the Lower-Middle Cambrian of southeastern Ireland. They also reported M. shinetonensis and Archaeohystrichosphaeridium minor (possibly T. phosphoritica) in rocks assigned a Tremadoc to early Arenig age. In his summary of palynomorph assemblages from Ireland, Smith (1981) noted the presence of a late Middle Cambrian Eliasum/Cristallinium assemblage (comprising E. llaniscum, T. lancarae, C. cambriense, M. martae, Retisphaeridium spp., and several species not reported from Random Island) in the Booley Bay Formation, southeast Ireland. (This information was obtained from the research of Gardiner et al., in prep.) He also mentioned that distinctive acritarchs of the Tremadoc Series are widespread in Ireland but largely as reworked assemblages in younger strata. An exception is an assemblage of Acanthodiacrodium spp., Cymatiogalea cylindrata and Tectitheca sp. from the Prioryland Mudstone Formation of County Meath.

14.4 SPAIN

Acritarchs of the Oville Formation, which crops out north and south of the Cantabrian Mountains, have been extensively studied by Fombella (1977, 1978, 1979, 1982). Earlier work on the same formation by Cramer (1972), Cramer and Díez (1972), and Potter (1974a, MS.) provided descriptions of Middle Cambrian species that are now known to be widely distributed

in Middle Cambrian strata outside Spain. The assemblages described by these authors are, therefore, undoubtedly of Middle Cambrian age. Fombella, however, maintains that the age of her assemblages ranges from early Middle Cambrian to Tremadoc. Nevertheless, all ten of the assemblages distinguished by Fombella (1982) in the Oville Formation contain species that are restricted to Middle Cambrian strata at other localities, including Random Island, where the rocks can be dated by macrofossils.

The Middle Cambrian assemblages recorded from Random Island in the present study, have, with the exception of a few rare specimens that remain unidentified, all been found in the Oville Formation. The following species are common to assemblage RI 1 on Random Island and the "assemblages" of the Oville Formation: ?Timofeevia raquelinae, Multiplicisphaeridium martae, Retisphaeridium dichamerum, Cristallinium cambriense (Cymatiosphaera ovillensis), and species of the genus Eliasum. Fombella's Eliasum llaniscum (apparently the same as Leiosphaeridia sp. 2 in Cramer and Díez, 1972) is common in RI 1. The genus Adara, restricted to the lower part of the Oville Formation, was not found in RI 1 in the present study, but Martin (in Dean and Martin, 1981) recorded a new species of the genus in her A1 assemblage (essentially equivalent to the upper part of RI 1) as being very common. Timofeevia (Multiplicisphaeridium) lancarae, originally described by Cramer and Díez (1972) from the Oville Formation, makes its appearance earlier in Spain than it does on Random Island where it has only been found near the top of the Middle Cambrian succession (lower part of Martin's A2 assemblage), i.e. in the Lejopyge laevigata Zone of latest Middle Cambrian

age. Cristallinium (Zonosphaeridium) ovillense, also originally described by Cramer and Díez (1972) from the Oville Formation, may appear in Random Island near the top of assemblage RI 2, which is of early Upper Cambrian age (specimens present on Random Island are doubtfully assigned to that species); if the Random Island species is the same as that of Cramer and Díez, it would have a relatively long stratigraphic range - from upper Middle Cambrian to middle Upper Cambrian - since it is also represented in assemblage RI 3.

Potter, 1974a (MS.), in his work on the Oville Formation, Villamanin area, northwest Spain, found, with two exceptions, the same species as Cramer and Díez in their 1972 study; the exceptions were C. ovillense, unrepresented in his sample, and Granomarginata squamacea Volkova 1968, not listed by Cramer and Díez. The assemblage described by Potter (Subzone V1D of Zone 1) was considered earlier (in section 14.3), and no further comment is needed here.

Wolf (1980) described acritarch microfloras from Lower Ordovician rocks in the Celtiberia area, Eastern Sierra Morena, southern Spain. These microfloras are typical of those found in assemblages of comparable age elsewhere. Four formations are present in the Celtiberia area, youngest to oldest, the Valconchan, Borrachon, Dere, and Santed; the first, apparently devoid of acritarchs, is considered to span the Cambrian-Tremadoc boundary, the second and third are of Tremadoc age, and the fourth is of Tremadoc - Arenig age. The species listed below (by formation) are also present in shales of Upper Cambrian and Tremadoc age on Random Island. Borrachon Formation: G. uncinatum, M. shinetonensis, V.

africana, Poikilofusa (Eupoikilofusa) squama, C. cuvillieri, and S. cortinulum; Dere Formation: G. uncinatum, M. shinetonensis, A. ubui, C. cristata, and S. striatulum; Santed Formation: G. uncinatum, M. shinetonensis, P. squama, A. ubui, C. cristata, C. diversata?, S. cortinulum, and S. striatulum. A. angustum, reported by Martin (in Martin and Dean, 1981) from the Tremadoc of Random Island (assemblage A6), is present in the Borrachon, Dere, and Santed Formations; it appears to be diagnostic for the Tremadoc.

The acritarch microflora of the Borrachon Formation, made up of species with long stratigraphic ranges, does not include the species that characterize assemblage RI 9 on Random Island. It is, therefore, considered here that the Borrachon Formation is younger than that part of the Clarenville Formation represented in the Elliott's Cove section on Random Island that contains assemblage RI 9. The strata of RI 9 may be equivalent to part of the Valconchán Formation but as no acritarchs have been found in the latter, it is not possible at present to confirm the possibility.

14.5 CZECHOSLOVAKIA, TURKEY, AND ROUMANIA

Slavikova in 1968, and Vavrdová in 1966 and 1976, described Middle Cambrian acritarchs from the Jince Formation of Czechoslovakia. Cristallinium (Dictyotidium) cambriense was originally described from the Ellipsocephalus hoffi Subzone by Slaviková as was a Retisphaeridium species that is considered by Martin (in Martin and Dean, 1983) to be the same as R. howellii Martin 1983; she found R. howellii in the

Manuels River section, eastern Newfoundland, and the species is also represented in her AO-1 and AO assemblages on Random Island (in Martin and Dean, 1984). None of the Micrhystridium, Solisphaeridium, Cymatiosphaera, Lophosphaeridium, and Leiosphaeridia species mentioned by Slaviková has been found in RI 1 during the present study, but Martin (in Martin and Dean, 1984) reported Cymatiosphaera crameri Slaviková 1968 as being present in several samples from assemblage AO-1.

Vavrdová reported finding a number of species in the strata of the overlying Eccaparadoxides pusillus Zone of the Jince Formation, some of which are present in assemblage RI 1 on Random Island. An Eliasum species (designated Leiosphaeridia sp.), possibly E. llaniscum, is figured in her 1966 and 1976 papers; Cristallinium (Staplinia) cambriense, and Multiplicisphaeridium martae are also present, as well as two species that occur above this stratigraphic level (i.e. in RI 2) on Random Island, namely, Timofeevia (Multiplicisphaeridium) lancarae, Cymatiogalea (Archaeohystrichosphaeridium) minor - which is probably equivalent to Timofeevia phosphoritica - and Micrhystridium shinetonensis. Other species recorded by Vavrdová have not been found in RI 1. The Czechoslovakian assemblage resembles Middle Cambrian assemblages from other localities, but differs from the Middle Cambrian assemblages of Random Island in that E. llaniscum and T. lancarae occur together.

Ordovician strata in Czechoslovakia have yielded acritarchs that are also present on Random Island, namely, Stelliferidium striatulum and Goniosphaeridium gracilis (Vavrdová, 1966, 1976) and Acanthodiacrodium complanatum

(Vavrdová, 1965, 1972) from the Arenig, and Goniosphaeridium eisenackianum, from the Ashgillian (Vavrdová, 1965; Konzalová-Mazanková, 1969). These species first appear on Random Island in Upper Cambrian assemblage RI 5, and, they range upward into the Tremadoc (upper part RI 8, RI 9).

Erkmen and Bozdoğan, 1980, described Middle Cambrian acritarchs from the Sosink Formation, southeastern Turkey. M. martae, E. llaniscum, and C. cambriense, present in the lower part of the formation, occur in assemblage AO on Random Island, and the second and third of the species named, range upward into A1 (AO + A1 = much of RI 1). Timofeevia phosphoritica Vanguestaine 1978 and T. lancarae, found in the upper part of the Sosink Formation, do not appear until RI 2, but Martin (in Martin and Dean, 1981) reported these species from the top of the Middle Cambrian (base of her A2 assemblage) in strata that, in the present study, did not yield identifiable acritarchs. A number of species collected from the Sosink Formation were not found in assemblage RI 1.

No comparisons can be made between Random Island and Roumania on the basis of the acritarch information currently available. However, the wide geographic distribution and long stratigraphic range of M. shinetonensis is attested to by its occurrence in the Tremadoc - Arenig of Roumania (Beju, 1972). Another widely distributed species, V. minutum, occurs in Bulgaria in rocks that are probably of Llanvirn age. (Kalvacheva and Dimitrova, 1973; Kalvacheva and Chobanova, 1974).

14.6 NORTH AFRICA

Studies dealing with the acritarch microfloras of Lower Palaeozoic rocks in North Africa have been mainly concerned with those of Tremadoc age. Recently, however, Vanguestaine and Van Looy (1983) have examined acritarchs in Middle Cambrian rocks of the Tacheddirt Valley in the High Atlas Mountains, Morocco.

Two Middle Cambrian assemblages were recovered. The first of these, from the Paradoxides oelandicus Stage or the succeeding Paradoxides paradoxissimus Stage, is characterized by the presence of Eliasum llaniscum, Cristallinium cambriense, and Timofeevia lancarae. Some samples also yielded Multiplicisphaeridium martae and Retisphaeridium dichamerum, as well as other species that are not of concern here as they occur in the Middle Cambrian of Spain and other localities, but not on Random Island. The presence of E. llaniscum, C. cambriense, M. martae, and R. dichamerum in the Moroccan assemblage indicates that it is equivalent to assemblage RI 1 (AO-1 + AO + A1 of Martin) on Random Island; M. martae and R. dichamerum are, however, restricted to the lowest part of assemblage RI 1 which is of early Middle Cambrian age. As noted earlier, T. lancarae, which is associated with these two species in the Middle Cambrian strata of Morocco, Belgium, Czechoslovakia and other localities, does not appear until later on Random Island (lower part Martin's A2), in strata of latest Middle Cambrian age.

The second, and younger, assemblage from the Tacheddirt Valley of Morocco shows much less diversity, containing only sphaeromorphs and Micrhystridium species; these are not diagnostic species and thus this assemblage cannot be

correlated with any of the Random Island assemblages.

A number of Cymatiogalea and Stelliferidium species present in rocks of Tremadoc age in North Africa also occur in the Upper Cambrian - Tremadoc succession of Random Island. These are listed below, with, in each case, the country or countries in which they are found: C. bellicosa from the Sahara (Deunff, 1961, 1964; Deunff, Gorka, and Rauscher, 1974) and Libya (Deunff and Massa, 1975), S. cortinulum from the Sahara (Deunff, 1961, 1964; Deunff, Górka, and Rauscher, 1974), Algeria (Combaz, 1967), and Libya (Deunff and Massa, 1975), S. striatulum from the Sahara (Deunff, Górka, and Rauscher, 1974) and from the Llanvirn of Libya (Deunff and Massa 1975), Stelliferidium furcatum, C. membranispina and C. cuvillieri from the Sahara (Deunff, 1961, 1964; Deunff, Górka, and Rauscher, 1974) and C. membranispina from Libya (Deunff and Massa, 1975). Representatives of other genera present in North Africa and on Random Island are as follows: Impluviculus milonii and Arbusculidium destombesii from Morocco (Deunff, 1968a and b; Loeblich and Tappan, 1969), Goniosphaeridium uncinatum, G. gracilis, G. pungens, and Poikilofusa squama from Libya (Deunff and Massa, 1975), and Saharidia fragile, P. squama, Acanthodiacrodium complanatum, and Vulcanisphaera africana from Algeria (Deunff, 1961; Combaz, 1967).

Jardiné and others (1974), in their work on the acritarchs of the Ordovician and Silurian of Algeria, described four zones from the Tremadoc, three of them from the lower Tremadoc. They noted that Combaz (1967) had assigned the strata of the oldest of the zones, Zone BO, to the Obolus macrofaunal Zone. However, none of the Ooidium species

described from that zone in the U.S.S.R. appear in the Algerian section.

S. fragile, Vulcanisphaera capillata, C. bellicosa, P. squama, and Veryhachium minutum present in Zone BO, also occur in the Tremadoc on Random Island where, however, they are not restricted to that stratigraphic level, as they all, with the exception of V. minutum, appear earlier in strata of certain, or less certain, late Upper Cambrian age. Of the species named, only C. bellicosa and P. squama range upward into the next highest zone, Zone B1. The presence of Dictyonema flabelliforme in Zone B1 establishes that it is of lower Tremadoc age. A number of species make their first appearance in B1 and range upward into B2, the youngest of the lower Tremadoc zones. Several of these, including C. cambriense, V. africana, S. cortinulum, C. cuvillieri, and Acanthodiacrodium angustum, are present in the Tremadoc of Random Island. Again, with one exception, A. angustum, they are species that range upward from the Upper Cambrian into the Tremadoc. C. cambriense has an even more extended stratigraphic range as it first appears in the lower Middle Cambrian (lowest part RI 1). The absence of these species in Zone BO in Algeria is clearly anomalous. On the other hand, the absence of Ooidium species in the Algerian zones suggests the latter occur stratigraphically above the level of assemblage RI 8 (characterized by the presence of Ooidium rossicum in abundance) on Random Island. Despite the apparent absence of Dictyonema flabelliforme in assemblage RI 9, it may be equivalent to one or more of the Algerian zones. This possibility cannot be substantiated until the acritarch microfloras of the Tremadoc sections north of Elliott's Cove

on Random Island have been thoroughly investigated.

14.7 U.S.S.R.

Some of the most extensive work that has been done on acritarchs, especially those of the Precambrian and Lower Cambrian, has been carried out by micropalaeontologists in the U.S.S.R. Nevertheless, very little information is available on Middle or Upper Cambrian acritarchs from that region. A number of authors have described acritarch assemblages from the Tremadoc. Umnova and Vanderflit (1971) established zonal schemes for Lower Cambrian, Tremadocian and Arenigian acritarch microfloras.

In a number of Russian publications on acritarchs, particularly some of the earlier ones, species descriptions are often brief and illustration of type material is by drawings alone. Drawings can depict features that may not show up clearly in photographic representations but for species without particularly distinctive features (e.g. some Acanthodiacrodium species), identification is difficult without good photographs. Thus, correlation of Random Island assemblages with those of the Russian Platform, dealt with later in this section, relies heavily on species with easily recognizable characteristics.

Most of the research into Cambrian and Tremadoc acritarchs in the U.S.S.R. has been carried out on samples obtained from rocks of those ages on the Russian Platform. Brief comments on some aspects of the stratigraphy of the Russian Platform are given here as an aid to understanding the

distribution of acritarch assemblages in the region.

The Baltic Complex, which includes the Supralaminaritic Grey Sands (the Lomonosov Suite of Estonia) and the younger Blue Clays (equivalent to the Lontovas Suite in Estonia, where it is overlain by the Eophyton Sandstone, or Piritas Suite), is undoubtedly of Lower Cambrian age.

The Blue Clays are overlain by the Izhorian (Tiskresian) Sandstones. The age of the sandstones was, for a long time, the subject of controversy. Timofeev (1959) believed that they belonged to the Middle Cambrian. However, Nalivkin (1962) noted that they are gradational below with the Eophyton Sandstone, and may, in fact, belong to the Lower Cambrian. Jankauskas (1974, 1976a) questioned Timofeev's assignment of the acritarchs of the Izhor Sandstones to the Middle Cambrian because he believes that they were derived from Tremadoc strata of the Moscow Syneclise. Andreeva (1966) and Jankauskas (1974) assigned the Izhor Sandstones (hereafter called the Izhor Formation) to the Lower Cambrian.

Many authors consider that the stratigraphic gap that exists between the Izhor Formation and the overlying Pakerort Formation throughout most of the Russian Platform corresponds to the Middle and Upper Cambrian. Hence, they regard the Pakerort Formation, comprising the Obolus Beds and the Dictyonema Shales, as being of Tremadoc age; it was originally considered to be Upper Cambrian, but later, on the basis of its macrofauna, it was moved to the Tremadoc. Some researchers have suggested that the Pakerort Formation, or at least the Obolus Beds, should be returned to the Upper Cambrian. However, the Dictyonema Shales should, at least for the time being, be retained in the Tremadoc because Dictyonema

is still considered to be diagnostic for the Iower Tremadoc.

The acritarch microfloras of the Obolus Beds, described by Umnova and Vanderflit (1971), are of particular interest because they can, at least in part, be correlated with assemblages on Random Island that are probably of Upper Cambrian age.

Jankauskas and Posti (1975) described species from five acritarch assemblages in the Lower Cambrian, and two in the Middle Cambrian, of the Pribaltic. None of the species they recorded is typical of the Middle Cambrian of Random Island. (?)Lower Cambrian species described by Jankauskas (1976b) from the Vergalsky and Rauousvensky Horizons of the Pribaltic, namely, Baltisphaeridium vilnense (considered to be a junior subjective synonymn of T. lancarae by Martin, in Martin and Dean, 1981), and Cymatiosphaera lazdynica and some specimens of Cymatiosphaera favosa (listed as synonymns of C. cambriense by Martin), are characteristic of the Middle Cambrian in other areas, including Random Island, and their occurrence in Lower Cambrian sediments is puzzling. Volkova et al. (1979) described well preserved material from Precambrian, Lower Cambrian, and Middle Cambrian deposits of the East European Platform. They also reported finding C. favosa and B. vilnense in Lower Cambrian strata. The one Middle Cambrian Formation investigated by Volkova et al. appears, from its acritarch content, to be older than that part of the Middle Cambrian studied by the writer on Random Island.

Timofeev (1957, 1959, 1963, 1966), and Timofeev, German, and Michailova (1976), described acritarchs of Middle Cambrian age, from the Izhor Formation. The acritarch microflora of

that formation consists largely of species of Ooidium, Acanthodiacrodium, and Lophodiacrodium. (Timofeev (1957) also reported finding three species of Lophodiacrodium and three species of Ooidium, including Zonooidium guttiforme, which Loeblich (1970) places in synonomy with O. rossicum, in the upper part of the Lower Cambrian "Blue Clays". The presence of these species, especially those of Ooidium, at that stratigraphic level is anomalous and suggests a misinterpretation of stratigraphic information.) The assemblage of acritarchs from the Izhor Formation has no counterpart elsewhere in formations of either Lower or Middle Cambrian age. On Random Island the genus Ooidium is present only in strata of (?)late Upper Cambrian and Tremadoc age. Acanthodiacrodium species appear earlier, in the upper part of the Parabolina spinulosa Zone, and range upward into the Tremadoc.

Andreeva (1966), after describing an acritarch assemblage from the Izhor Formation, (River Tosna, near Sablino) consisting entirely of sphaeromorphs, disputed the presence of Ooidium and diacrodians in the Izhor Formation, maintaining that the acritarch microflora described by Timofeev is similar to that of the lower Ordovician Obolus Beds. Timofeev (1957, 1959, 1962) was also responsible for describing the latter and, it is, therefore, surprising that he did not recognize the similarity himself. However, it is now apparent that the acritarchs attributed to the Izhor Formation by Timofeev must have been obtained from some other source. Jankauskas (1974) believes, as noted earlier, that that source was Tremadoc rocks of some part of the Moscow Syneclise.

Umnova and Vanderflit (1971) described sixteen acritarch

assemblages from the western and northwestern parts of the Russian Platform. Assemblages I to V are from the Lower Cambrian Lontova and Piriatas Suites, and assemblages VI and VII are from the Tiskri Formation (= Izhor Formation) which Umnova, and Vanderflit assigned with doubt to the Middle Cambrian. However, Andreeva (1966) and Jankauskas (1974, 1976b) placed the latter in the Lower Cambrian. The species recorded from the Tiskri Formation are, for the most part, simple spheres with minor, or no, ornamentataion. No correlation can be made with any of the Random Island assemblages. The stratigraphic equivalence of the Tiskri Formation with the Upper Cambrian Dolgelly Beds in Wales shown in Text-fig. 3 of Downie et al. 1979 is erroneous.

The other assemblages are from the Pakerort and the Leatsky Formations, of respectively, Tremadoc and Arenig age. The Pakerort Formation is divided into two 'members', the Obolus Beds below (assemblages VII to XII) and the Dictyonema Shales above (assemblage XIII). The Leatsky Formation yielded assemblages XIV to XVI. The lower 'member' of the Pakerort Horizon, the Obolus Beds, was divided by Umnova and Vanderflit into a lower part (assemblages VIII and IX) and an upper part (assemblages X to XII), which was designated "strictly Obolus sections" by the authors. The acritarch assemblages were obtained from the Tremadocian of three regions: Estonia, the northeastern part of the Russian Platform (Leningrad region) and the northern part of the Russian Platform (Kalinin and Yaroslavl' regions).

The lower part of the Obolus Beds is described only from Estonia and the Kalinin and Yaroslavl' regions of the northern part of the Russian Platform. It includes species that may be

synonymous with species from Random Island, England, and elsewhere. The species Baltisphaerdium cristatum Downie occurs throughout the lower part of the Obolus Beds. Potter (1974a, MS.) drew attention to the fact that the species figured by Umnova and Vanderflit as B. cristatum closely resembles T. phosphoritica. Their illustration of Leiofusa tumida Downie 1959 from assemblage X (but not from assemblage VIII), somewhat resembles Leiofusa stoumonensis, and the species designated Latoporata spectatissima, appears to belong to the genus Stelliferidium. However, not enough information is provided by Umnova and Vanderflit to make positive identifications. Nevertheless, diacromorphs are apparently totally absent from the lower part of the Obolus Beds but present in abundance in the upper part of that member of the Pakerort Formation.

T. phosphoritica and Stelliferidium species are present throughout the Upper Cambrian of Random Island, and L. stoumonensis extends from the Olenus Zone into the upper part of the Parabolina spinulosa Zone; diacromorph species appear first in the uppermost part of the Parabolina spinulosa Zone. Assemblages VIII and IX, of the lower part of the Obolus Beds appear, therefore, to be equivalent to assemblages present in that part of the Upper Cambrian on Random Island between the top of the Agnostus pisiformis Zone and the upper part of the Parabolina spinulosa Zone, i.e. all but the lower part of assemblage RI 2 and much or all of RI 3. Correlation of assemblages VIII and IX on the Russian Platform with the greater part of assemblages RI 2 and RI 3 on Random Island is, however, tenuous as it is based on rather sketchy illustrations. Potter (1974a, MS.) suggested a similar

possible correlation of assemblages VIII and IX with the English zones N3, N4, and C5 from the Olenus and Parabolina spinulosa trilobite Zones.

Assemblages XI and XII from the upper part of the Obolus Beds contain the distinctive species Ooidium rossicum, which is characteristic of assemblage RI 8 on Random Island; assemblage XII from the Kalinin and Yaroslavl' regions includes Hamatodiacrodium bucerum (Umnova 1971) comb. nov., and a new variety of that species, H. bucerum var. aciferum (Umnova 1971) comb. nov., that are also present in the mid- to upper parts of assemblage RI 8. H. bucerum appears as Form A (see species description: Section 6.4) in the middle part of assemblage RI 8, and as Form B in RI 9. H. bucerum var. aciferum is present as well preserved specimens in RI 8, with rare examples showing up in RI 9. Some of the other species present in assemblages XI and XII and their probable equivalents in assemblage RI 8 are listed below. Baltisphaeridium hirtum Timofeev 1959, closely resembles short-process forms of Baltisphaeridium crinitum Downie 1958, L. spectatissima, appears to be a species of Stelliferidium or Cymatiogalea (the species as illustrated from assemblage XI is similar to specimens of Cymatiogalea bellicosa that have lost their veils), Veryhachium quadrangulum Timofeev 1959, and Acanthodiacrodium echinatum (?)Naumova, are very similar, respectively, to Acanthodiacrodium achrasi and to Acanthodiacrodium randomense, and B. cristatum Downie 1958 may be Cymatiogalea cristata or Cymatiogalea? membranula, a species that is fairly common in RI 8.

The presence of O. rossicum, H. bucerum, and H. bucerum var. aciferum in the upper part of the Obolus Beds

and in strata of ?Upper Cambrian/Tremadoc age on Random Island establishes that Assemblages XI and XII are together equivalent to assemblage RI 8.

Assemblage X, the oldest assemblage in the upper part of the Obolus Beds (described only from the Kalinin and Yaroslavl' regions), is characterized by the first appearance of diacromorphs (A. echinatum, etc.), and it differs from assemblages XI and XII in that Q. rossicum has not yet appeared; it includes species that are or may be synonymous with species from Random Island. Domasia delmeri Stockmans and Willière is undoubtedly Veryhachium dumontii and Micrhystridium stellatum Deflandre 1945 closely resemble specimens of Impluviculus circularis in which the operculum has not developed. V. dumontii and I. circularis have long vertical ranges and they are present, together with diacromorphs, in assemblages RI 5, 6, and 7. However, the beds with Assemblage X are apparently overlain conformably by those containing assemblage XI which suggests that, despite the absence of the species that characterize RI 7 on Random Island (Ooidium? clavigerum and Striathotheca sp.), Assemblage X is equivalent to RI 7. If that is the case, and assemblages VIII and IX are equivalent to assemblages RI 2 and RI 3 on Random Island, then a stratigraphic break exists between the lower and upper parts of the Obolus Beds as defined by Umnova and Vanderflit. A stratigraphic break was not referred to by Umnova and Vanderflit who considered the Obolus Beds as a whole to be of Tremadoc age. Irrespective of whether or not such a break exists, the acritarch microfloras of assemblages VIII, IX, and X, as depicted by Umnova and Vanderflit, do not provide a basis for placing the beds

containing them in the Tremadoc. Assemblages XI and much or all of assemblage XII, considered here as equivalent together to assemblage RI 8 on Random Island, may also be of Upper Cambrian age as believed originally by Timofeev (1959) (see Chapter 15).

Acritarch assemblage XIII is present in the Dictyonema Beds of Estonia and the Leningrad region. This assemblage shows very little diversity, containing mostly sphaeromorphs, several diacromorphs, and one short-spined Baltisphaeridium species (B. pateum Timofeev). None of the species that are characteristic of RI 9 are present in assemblage XIII. However, some of the non-distinctive species illustrated by Umnova and Vanderflit may be equivalent to equally non-distinctive species, present in abundance in RI 9, that have not been discussed in the present study because they cannot be assigned satisfactorily at the species level.

14.8 NORWAY

The results of recent work by Welsch (1986, in press) on the acritarch microfloras of the Kistedal and Berlogaisse Formations, Middle to Upper Cambrian and Tremadoc age, on the Digermul Peninsula, Norway, has been made available (in part) to the author. Welsch established six zones for the Digermul Peninsula section, AI to AVI, two in the Middle Cambrian, two in the Upper Cambrian, and two in the Tremadoc.

Zone AI, (greater part of Paradoxides paradoxissimus Stage), in the lower part of the Kristedal Formation, has yielded Eliasum (E. cf. llaniscum), Multiplicisphaeridium

martae, and Cristallinium cambriense. These species are common in assemblage RI 1 on Random Island. A variety of Micrhystridium species is also present in Zone A1. Their absence in RI 1 is probably due to the limited number of acritarchs so far recovered from Middle Cambrian strata on Random Island.

Zone AII, from the top of the Paradoxides paradoxissimus Stage and from the Paradoxides forchammeri Stage is dominated by Timofeevia species - T. cf. microretis, T. lancarae, and T. phosphoritica - and by C. cambriense. The stratigraphically useful genus Eliasum is present in the lowest part of the assemblage. V. turbata does not occur in this zone, but appears at the base of the next zone, AIII. From the trilobite data, this zone falls in the interval from which no stratigraphically useful material was obtained in the present study. It is equivalent to the lower part of assemblage A2 of Martin (1981), of late Middle Cambrian age, in which V. turbata is likewise unrepresented. The acritarch microfloras of Zones AIII and AIV, from the middle and uppermost parts, respectively, of the Kistedal Formation, are of Upper Cambrian age. That of Zone III is based on six samples from the Agnostus pisiformis Zone and the two samples from the Leptoplastus Zone. The acritarch microflora of the six samples from the Agnostus pisiformis Zone comprises species of Timofeevia (T. cf. microretis, T. phosphoritica, and T. lancarae range upward from Zone AII, T. pentagonalis makes its first undoubted appearance), Cristallinium cambriense, C. randomense, Vulcanisphaera turbata, Cymatiogalea sp. A, and Stelliferidium sp. A. It is equivalent to assemblage RI 2 on Random Island in strata of

comparable age.

Four of the species named above, T. cf. microretis, T. pentagonalis, V. turbata, and C. sp. A, constitute the microflora yielded by the two samples from the Leptoplastus Zone. This association is not characteristic of strata of that trilobite zone on Random Island.

Leptoplastus has not, as far as the writer is aware, been found in the upper part of Zone III, although it has been found in younger strata between Zones III and IV that did not yield acritarchs. Thus, the strata from which the four species named above were obtained are probably older than those of the Leptoplastus Zone. That probability is supported by the fact that, on Random Island, Timofeevia pentagonalis is a typical element of assemblages RI 2 and RI 3 but not of RI 5, which is present in strata of the uppermost part of the Parabolina spinulosa Zone and much of the Peltura Zone.

The acritarch microflora of Zone AIV, attributed by Welsch to strata of the Acerocare Zone, comprises Trunculumarium revinium, Cymatiogalea sp. A, C. bellicosa, Stelliferidium sp. A, Cristallinium randomense, Acanthodiacrodium cf. A. spinum, Vulcanisphaera africana, Goniosphaeridium rasulii (comb. nov. Welsch), G. cf. G. uncinatum, and Arbusculidium cf. A. mamillosum (sp. nov. Welsch). T. revinium, restricted to AIV, is characteristic of assemblage RI 4 on Random Island where it is present in the uppermost part of the Parabolina spinulosa Zone. The other acritarchs of the assemblage range upward into AV (C. sp. A is an exception); they do not form an association that is representative of RI 4 or any of the younger assemblages from the Upper Cambrian of Random Island. It is not clear why

Welsch placed the strata of Zone IV in the Acerocare Zone. Leptoplastus and associated trilobites occur in underlying strata but no trilobites have been found in the Kistedal Formation above that stratigraphic level. The presence of Leptoplastus in strata only a few metres below those containing the acritarchs of Zone IV suggests that the latter were obtained from the Peltura Zone rather than from the Acerocare Zone. However, the uncertain stratigraphic position of AIV, and lack of diagnostic acritarchs, make it impossible to correlate that zone with one or other of the Upper Cambrian assemblages on Random Island.

Regression in the late Cambrian in the Digermul Peninsula area of Norway was followed by transgression and the concomitant deposition of sediments of the Berlogaissa Formation. Zone AV, of the lower part of the Berlogaissa Formation, was divided by Welsch into two parts, AVa and AVb, corresponding respectively to the macrofaunal zones of Obolus and Rhabdinopora (Dictyonema) flabelliforme, both of which he included in the Tremadoc. Neither Obolus nor Dictyonema has been found in the section south of Elliott's Cove. The acritarchs of AVa are mainly species of Acanthodiacrodium and Goniosphaeridium, several of which are new species that have not been found in any of the Random Island assemblages. However, the presence of Cymatiogalea bellicosa, Cristallinium randomense, Arbusculidium destombesii, Acanthodiacrodium complanatum, Goniosphaeridium uncinatum, and above all, of Ooidium rossicum indicates that AVa is equivalent to at least the upper part of assemblage RI 8 on Random Island. The latter is presently assigned a ?Upper Cambrian - Tremadoc age. However, Windolph (1984) considers that the lower part of the

Berlogaissa Formation (from which the AVa samples were obtained) is most probably of latest Cambrian age (see Chapter 15).

AVb includes a smaller number of species (none of which is common) than AVa, and with one exception, Cymatiogalea cristata, they are species that first appear in the latter, or earlier in AIV. However, C. cristata is present only in the uppermost sample of AVb which is separated by about 170 m of strata from the preceding sample localities of AVb so that the acritarchs of the former sample are probably from a higher stratigraphic level in the Tremadoc than is represented in the section south of Elliott's Cove on Random Island. The acritarch microflora of the two samples of AVb from the lowest part of the Berlogaissa Formation may be equivalent to that of the lowest part of RI 9 on Random Island (despite the absence of Dictyonema in the latter). Zone AVI, from Clonograptus tenellus Zone, has no equivalent on Random Island.

14.9 CANADA, ARGENTINA, AUSTRALIA, AND CHINA

Information on Cambrian and Tremadoc acritarchs of mainland Canada is scanty. Some early work was done by Walton (1962). Staplin, Jansonius, and Pocock (1965), in their revision of acritarch genera, referred to Walton's work and also described a new species, Retisphaeridium dichamerum, from the Albertella Zone, Alberta. This is a widely distributed species, occurring in Middle Cambrian strata in several parts of the world. Martin (in Dean and Martin, 1982, and Martin, 1984) described a number of species from the Cambrian -

Ordovician boundary interval of Wilcox Pass, Alberta. None of these can be equated with Cambrian and Tremadoc species from Random Island, Europe, or North Africa.

Acritarchs from the Cambrian and Tremadoc of South America have been studied even less than those of North America. Martin (1982), reporting on her unpublished acritarch finds in the Tremadoc of northwest Argentina, listed Saharidia sp., Cymatiogalea cuvillieri, Vulcanisphaera sp., and Acanthodiacrodium angustum, forms present also in the Upper Cambrian and Tremadoc of southeastern Newfoundland.

Some information is available on Ordovician acritarchs from Australia. Combaz and Peniguel (1972) studied material from the Canning Basin, of Arenig - Llandeilo age. Most of the species do not occur in Tremadocian strata on Random Island, but similarities do exist, as Saharidia (S. downiei? Combaz 1967) and M. shinetonensis are common to the two localities. Playford and Martin (1984) studied Arenig - Llanvirn (or ?Llandeilo) acritarchs from the same region and noted that the species showed "little similarity in detail with age-equivalent assemblages from elsewhere" (p.187).

Recently, work has been completed on acritarchs from the Cambrian-Ordovician boundary interval in Jilin Province, China (Chen et al., 1985). The genera Stelliferidium (Priscogalea), Cymatiogalea, Goniosphaeridum, Micrhystridium, Veryhachium, and Vulcanisphaera are represented in the Chinese section and, although many of the species are new, some are very similar to forms reported from the West, and, occasionally, the same species are found. C. cambriense was recovered from the uppermost 'pre-Tremadoc' and Goniosphaeridium (Baltisphaeridium) pungens from a stratigraphically lower level in Upper

Cambrian strata.

It is necessary for more work to be carried out on the acritarch microfloras of the Cambrian - Tremadoc rocks of the countries named above before they can be compared satisfactorily with those of southeastern Newfoundland, Europe, and North Africa.

14.10 NEWFOUNDLAND (EXCLUDING RANDOM ISLAND)

Martin and Dean (1978, 1983) investigated the acritarchs of the Middle Cambrian Chamberlain's Brook and Manuels River Formations in the lower valley of Manuel's River, Conception Bay, and the Tremadoc-Arenig acritarchs of the Lower Ordovician rocks on Bell Island, Conception Bay. Several of the species found at these localities appear also in Random Island assemblages. C. cambriense, V. africana, A. achrasi, A. complanatum, A. destombesii, S. fragile, and S. cortinulum occur in the Tremadoc, G. uncinatum in the Tremadoc and Arenig, and S. striatulum in the Arenig of Bell Island. Cymatiogalea? membranula and Baltisphaeridium crinitum were first described by Martin from, respectively, Tremadoc and probable Arenig, and Tremadoc, rocks of the island. The species named above are of limited stratigraphic value because they have long vertical ranges. None of the species diagnostic of RI 9 appear in the Bell Island assemblages. Martin (1982) places the Tremadocian Bell Island Group stratigraphically above the Clarenville Formation of Random Island. However, studies of ichnospecies of Cruziana by Bergström (1976) and by Pickerill and Fillion (1983)

suggest that the lower part of the Bell Island Group may be Upper Cambrian.

Retisphaeridium dichamerum appears in the late Lower Cambrian Brigus Formation and is also present, together with Eliasum llaniscum, in the early Middle Cambrian Chamberlain's Brook Formation of Manuels River.

CHAPTER FIFTEEN

SUMMARY AND CONCLUSIONS

In the present study, the Middle Cambrian, Upper Cambrian, and Lower Ordovician rocks of Random Island have been divided, on the basis of the vertical ranges of the acritarchs present within them, into a succession of nine acritarch assemblages, RI 1 to RI 9. The earlier, detailed sampling of the Middle Cambrian succession by Martin (in Martin and Dean, 1981, 1984) yielded a greater diversity of acritarchs than was found by the writer in the same succession, and enabled her to distinguish three assemblages, AO-1, AO, and A1. Assemblage RI 1 is approximately equivalent to those assemblages. The latter must, therefore, still be regarded as the definitive assemblages for the Middle Cambrian part of the Lower Palaeozoic succession on Random Island. Thus, the number of assemblages that can be distinguished in that succession is actually eleven.

Three of the assemblages in the upper part of the Lower Palaeozoic succession on Random Island, in rocks of late Upper Cambrian age, represent new finds as they were not recognized by Martin (in Martin and Dean, 1981). They are of particular significance because two of them, RI 6 and RI 7, have not been reported from Upper Cambrian rocks elsewhere, and the third, RI 8, has until now been recorded only from the Obolus Beds of the northwestern part of the Russian Platform (Timofeev, 1957; Umnova and Vanderflit, 1971) and the Obolus Zone in northern Norway (Welsch, 1986: in press). In both countries the beds containing assemblage RI 8 are presently considered to be of

early Tremadoc age. (Evidence presented below establishes that they are of Upper Cambrian age.) In this study, it has been shown that assemblage RI 8 is represented as well in the Upper Cambrian of the Ardennes region in Belgium, i.e. the microflora of Zone 6 (Vanguestaine, 1974) is equivalent to assemblage RI 8 on Random Island, and not to Martin's A5 assemblage as believed by Vanguestaine and Van Looy (1983).

On Random Island, the Middle Cambrian to Tremadoc succession, despite the presence of minor faults and of complex folding at some stratigraphic levels, is virtually continuous apart from a stratigraphic break, representing a relatively short period of non-deposition, within the upper part of the Middle Cambrian sequence (marked by the conglomerate at the base of the Elliott Cove Formation). The strata that are missing are believed to be those of the Goniagnostus nathorsti and Solenopleura brachymetopa trilobite faunal zones (Poulsen and Anderson, 1975). The Cambrian continues, without interruption, into the Tremadoc. Thus, the acritarch microfloras of the Middle Cambrian, Upper Cambrian, and Tremadoc rocks that have been divided into assemblages represent an almost unbroken evolutionary succession.

In Europe, Middle Cambrian to Tremadoc successions that have been sampled for acritarchs are, to a greater or lesser extent, incomplete due to the presence of depositional hiatuses. Hence, the acritarch zonal schemes that have been erected for Belgium, northern Norway, the Russian Platform, and elsewhere are likewise incomplete. In northern Norway, barren intervals have added to the incompleteness. The zonal scheme for the Cambrian rocks of England and Wales (Potter, 1974a, MS.) is a composite one based on samples from several

successions, including one from Spain; and, therefore, inherently incomplete; it is also incomplete because the upper part of the Upper Cambrian was not included in the scheme. Furthermore, the ages of many of the zones (particularly for the Ardennes region of Belgium, Spain, and the Russian Platform) have not been determined directly from established trilobite zones because the sedimentary rocks of those zones either lack such fossils, or such fossils are present but not suitable for dating, or they have not been studied. On Random Island, all but two of the eleven acritarch assemblages have been directly related to established trilobite zones; the exceptions are assemblages RI 7 and RI 8. (Assemblage RI 8 is shown below to be in strata of the Acerocare Zone). It is now apparent that, outside Random Island, none of the sequences of acritarch assemblages (or zones) established for Middle Cambrian to Tremadoc rocks is as complete, or has as many of its assemblages accurately dated, as that on the island. The succession of acritarch assemblages on Random Island should, therefore, become the standard for purposes of correlation. It can also be used to recognize the extent of stratigraphic gaps that occur in the Middle Cambrian to Tremadoc successions of other regions that have yielded acritarch microfloras.

In previous studies, the position of the Cambrian-Ordovician boundary on Random Island has not been determined. As noted earlier, the Cambrian is continuous with the Ordovician, and the shales of the upper part of the Elliott Cove Formation are similar to those of the lower part of the Clarenville Formation. Thus, the two formations can only be distinguished from one another by fossils. Traditionally, in European sections, the lower boundary of the

Tremadoc has been taken as the base of the beds in which Dictyonema flabelliforme makes its first appearance. However, in the western U.S.S.R. (Russian Platform), the Obolus Beds, that underlie shales containing D. flabelliforme, are included in the Tremadoc by Umnova and Vanderflit (1971); and Welsch (1985: in press), in his work on acritarchs of the Cambrian - Lower Ordovician of the Digermul Peninsula, northern Norway, shows an Obolus Zone, overlain by a Rhabdinopora (Dictyonema) flabelliformis Zone, as forming the basal part of the Tremadoc. Welsch almost certainly included the Obolus Zone in the Tremadoc because it contains an acritarch microflora that, at the time of his study, was known to occur only in the upper part of the Obolus Beds on the Russian Platform. Timofeev (1957), who originally described that microflora, placed the Obolus Beds in the Upper Cambrian.

Isolated occurrences of Dictyonema have been reported from Random Island (in strata not sampled in the present work) but no finds of Obolus have been made in rocks of late Upper Cambrian or early Tremadoc age; Obolids are, however, not restricted to the Tremadoc, and their presence (or absence) is therefore immaterial as far as establishing the position of the Cambrian-Ordovician boundary is concerned. In recent years, repeated attempts to find Dictyonema have failed. It has, therefore, been necessary to use trilobites for defining the local base of the Tremadoc. In this study, as in the earlier studies of Dean and Martin (1981, 1984), the Clarenville Formation, containing the Parabolina argentina Zone as identified by Dean (1976, p.243, in Martin and Dean, 1981), has been considered as belonging to the lower Tremadoc by comparison with the succession established in Argentina by

Harrington and Leanza (1957); other elements of the Parabolina argentina Zone are Araiopleura boethuk and Niobella. However, P. argentina and Niobella are now known to occur in the uppermost part of the Cambrian as well as in the lowest part of the Tremadoc.

Parabolina argentina is the index fossil for the lowest trilobite zone of the Tremadoc in Argentina. In that country, the Cambrian-Ordovician boundary is taken as the first appearance of Dictyonema flabelliforme and D. flabelliforme flabelliforme. These dictyonemids occur there in the same beds as P. argentina. Nevertheless, the latter is also present, at least locally, in beds well below the level at which D. flabelliforme makes its first appearance (Harrington and Leanza, 1957, fig.2, p.10). Thus, in Argentina, P. argentina ranges upward from the Upper Cambrian into the Tremadoc.

Rushton (1982) examined the trilobites of an Upper Cambrian - Tremadoc section at Bryn-llin-fawr on the east side of the Harlech Dome in North Wales. In that section, fossiliferous beds of the Acerocare Zone are overlain conformably by beds containing Dictyonema flabelliforme. Rushton found two species restricted to the Acerocare Zone that are of concern here, namely Parabolina frequens and Araiopleura stephani, the former equivalent to P. argentina and the latter closely resembling A. beothuk. He also noted that the Acerocare Zone contains species of the genera Niobella and Shumardia that are generally considered typical of the Tremadoc. Niobella and Shumardia occur in the Clarenville Formation but only the former has been found in the Elliott's Cove section.

It is now evident that the presence of Parabolina argentina, Niobella, and, less certainly, Araiopleura boethuk in the upper part of the Elliott's Cove section does not necessarily establish the age of the beds containing them as those trilobites may be of Upper Cambrian age (Acerocare Zone) or of Tremadoc age. Acritarch assemblage RI 8, largely undated by macrofossils, and previously referred to as being of ?Upper Cambrian/Tremadoc age, as well as assemblage RI 9, may likewise be of Upper Cambrian or Tremadoc age. Nevertheless, the combined thickness of the beds containing assemblages RI 8 and RI 9 is considerable which makes it unlikely that the whole of that part of the Clarenville Formation which is represented in the Elliott's Cove section is of Upper Cambrian age. There is, however, indirect evidence that assemblage RI 8 belongs to the Acerocare Zone, and that assemblage RI 9 is of Tremadoc age.

Assemblage RI 8, characterized by an abundance of Ooidium rossicum, has been correlated in this study with the acritarch microflora of subzone AVa (Obolus Zone) of Zone AV in northern Norway, assemblages XI and XII (together) in the uppermost part of the Obolus Beds on the Russian Platform, and the acritarch microflora of Zone 6 in the Ardennes region of Belgium. In northern Norway, and on the Russian Platform, conformably overlying beds contain Dictyonema flabelliforme, and are of Tremadoc age. In Belgium, D. flabelliforme is present in Zone 7 which overlies Zone 6 disconformably, and the latter is, therefore, included in the Upper Cambrian. Pending international agreement on the stratigraphic level of the Cambrian-Ordovician boundary, "the widespread sudden appearance of planktic graptolites (D. flabelliforme s. l.,

D. canadense, D. scitulum, D. rossicum, etc.) is conventionally interpreted to indicate an earliest Ordovician age, and to mark the beginning of the radiation of planktic graptolites" (Erdtmann, 1982). Hence, the beds containing acritarchs of assemblage RI 8 and Obolus but lacking Dictyonema in northern Norway and on the Russian Platform, like those of Zone 6 in Belgium, are of Upper Cambrian age. There is, however, further evidence in northern Norway that shows that the Obolus Zone and the acritarchs of assemblage RI 8 are of latest Upper Cambrian age and belong to the Acerocare Zone. The following trilobites are present at the top of subzone AVa in northern Norway: Parabolina cf. angusta, P. heres lata, P. acanthura and P. frequens finmarchicha. The first three are typical of the upper part of the Acerocare Zone in Scandinavia, and the first and third named (as P. cf. acanthura) are also present in the Acerocare Zone of the Bryn-llin-fawre Upper Cambrian-Tremadoc section in North Wales (Rushton, 1982). P. heres lata has also been recorded from the Acerocare Zone in New Brunswick (Landing et al., 1978). Several important conclusions can be drawn from the preceding discussion: (1) the presence of assemblage RI 8 on Random Island indicates that the strata of that assemblage are of latest Upper Cambrian age and belong to the Acerocare Zone; (2) where assemblage RI 8 is present elsewhere in sediments lacking macrofossils, it can be used to substantiate that those sediments belong to the uppermost part of the Cambrian; (3) Parabolina argentina, present in strata of the upper part of assemblage RI 8, appears in the uppermost Cambrian on Random Island just as it does in North Wales, northern Norway, and Argentina; (4) in northern Norway and on

the Russian Platform, the beds immediately overlying strata containing acritarchs of assemblage RI 8 are conformable and of Tremadoc age, and, therefore, the Cambrian-Ordovician boundary on Random Island lies at the top, or close to the top, of the beds containing that assemblage; (5) it follows from (4) that assemblage RI 9 is of Tremadoc age; (6) unlike Parabolina argentina and Niobella, which range upward from the Upper Cambrian into the Tremadoc on Random Island, Araiopleura boethuk has not been found in strata older than those of assemblage RI 9 so that it can be used locally as an indicator for the lower part of the Tremadoc and for distinguishing the Clarenville Formation from the Elliott Cove Formation.

It is clear that although the position of the Cambrian-Ordovician boundary on Random Island lies close to or at the top of the beds containing assemblage RI 8, a further search for Dictyonema is still necessary, and should be focused on that stratigraphic level both in the Elliott's Cove section and elsewhere in the northwestern part of the island where the upper part of the Upper Cambrian is repeated either by folding or by faulting. Furthermore, a search is also necessary in the strata of assemblages RI 8 and RI 9 for, respectively, trilobites diagnostic of the Acerocare Zone, and trilobites (Boeckaspis hirsuta, Eurytreta sabrinae, Shumardia curta, etc.) that are presently known to be restricted to the lower part of the Tremadoc.

ADDENDUM

The species Acanthodiacrodium randomense sp. nov. and Multiplicisphaeridium sp. A described in this text are equivalent, respectively, to Acanthodiacrodium digermulense and Multiplicisphaeridium cervinacornua of Welsch, 1986 (in press). Welsch kindly made the descriptions and illustrations of these and other new species described in his 1986 work available to the author. As the taxonomic part of this work was already complete when this information was received, no changes were made to accommodate these new names.

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PLATES 1-37

All magnifications X 1000 unless otherwise stated.

The following slide reference system is used for the acritarchs illustrated in Plates 1-37:

(a) The number/letter designation following the figure number (e.g., 37 C, ABC 10) is the sample locality number. Only the sample locality number is given for S.E.M. specimens.

(b) The succeeding notation [e.g., >10, (P)], refers to the size fraction from which the slide was made, <10 µm, >10 µm, etc. The (P) size fraction is >5 µm.

(c) Generally several slides were made of each size fraction. The number following the size fraction designation (e.g., (2), 4) is the preparation number. No preparation number is given if only one slide was made of a given size fraction.

(d) The letter/number designation following the comma is the specimen reference number which was obtained using an England Finder grid reference slide.

PLATE 1

Figs. 1-3, 5 Baltisphaeridium crinitum MARTIN 1978

Fig. 1 37 C >10 (2), F 38: some short processes and many truncated processes

Fig. 2 E-C 7 >10 (4), T 48/1: complete processes

Fig. 3 37 C >10 (3), O 31/4: most of the processes are truncated

Fig. 5 37 C >10 (2), U 42 2/1: folded specimen with truncated processes

Fig. 4 Baltisphaeridium sp. A

Fig. 4 19 C >10 (2), NO 29 3/1: specimen showing granular central body which has cracked

Fig. 6 Micrhystridium multiangularis UMNOVA 1971

Fig. 6 37 C 10 (1), M 34 1/3: processes paired; central body folded

Figs. 7-16 Micrhystridium shinetonensis DOWNIE 1959

Fig. 7 37 C >10 (1), U 36/4

Fig. 8 24 B (P) 1, U 43/4

Fig. 9 24 B (P) 2, slide reference lost

Fig. 10 24 B <10, slide reference lost

Fig. 11 24 B (P) 2, U 50/2: some of the processes have triangular bases

Fig. 12 24 B (P), slide reference lost

Fig. 13 37 C >10 (2), slide reference lost

Fig. 14 slide reference lost

Fig. 15 24 B (P) 2, LM 43 4/2: tapering processes

Fig. 16 37 C 10 (2), Y 39/40 2/1: hair-like processes

PLATE 1

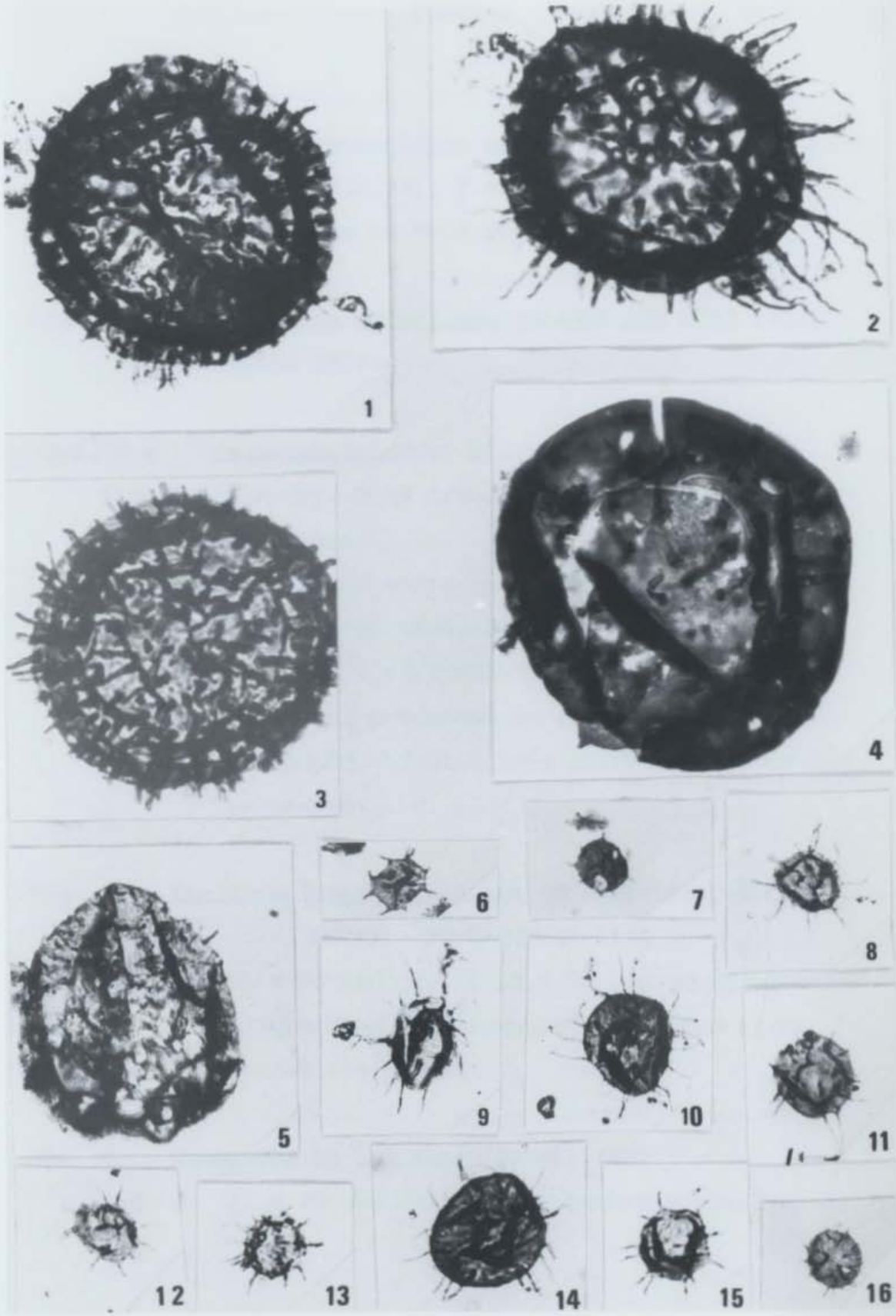

PLATE 2

Fig. 1 Multiplicisphaeridium martae CRAMER AND DÍEZ 1972

Fig. 1 12-20' >20 (4), T 43/3: mainly bifurcating processes on this specimen

Fig. 2 ?Timofeevia raquelinae (CRAMER AND DÍEZ 1972) FOMBELLA 1979

Figs. 3-6 Paliosphaeridium? clavigerum SP. NOV.

Fig. 3 6 A (P), H 43 1/3: stalked and drop-like processes

Fig. 4 6 A (P), U 45/4: process and central body cavities in communication

Fig. 5 6 A (P), F 43/3 (HOLOTYPE): hollow distal nature of processes is evident

Fig. 6 6 A 10-20, XY 32: long stalk on many of the processes

Fig. 7 Stelliferidium cortinulum (DEUNFF 1961) DEUNFF, GÓRKA, AND RAUSCHER 1974

Fig. 7 21 B 20-150 (3), L 39 1/2: up to third order bifurcation of processes; operculum lying inside the shell

Fig. 8 Cymatiogalea bellicosa DEUNFF 1961

Fig. 8 21 B 20-150 (3), V 36: membrane missing

Fig. 9 Stelliferidium furcatum? (DEUNFF 1961) DEUNFF, GÓRKA, AND RAUSCHER 1974

Fig. 9 30 B >20 (3), O 20/1: numerous short bifurcating processes, frequently with secondary bifurcation

Figs. 10, 11, 12, 13-17 Stelliferidium gautieri (MARTIN 1973) comb. nov.

Fig. 10 21 B (P), M 41: the almost linear arrangement of processes on this specimen probably does not represent a true distribution pattern, but is rather an accident of preservation

Fig. 11 21 B, slide reference lost: pattern at base of processes

Fig. 12 24 B 20-150 (1), Y 40/1: this specimen may be S. gautieri with a polygonal operculum, or a species of Timofeevia

Fig. 13 21 B 20-150 (1), S 32 2/4: pattern at base of processes

Fig. 14 slide reference lost

Fig. 15 21 B (P) 3, MN 38/39: ridges or folds connect some of the processes; operculum attached

Fig. 16 SH 13 >20 (5), GH 40/41: processes have short pinnae that form a rosette

Fig. 17 3 C (P) 1, KL 49 4/2: bases of some of the processes are interconnected

PLATE 2

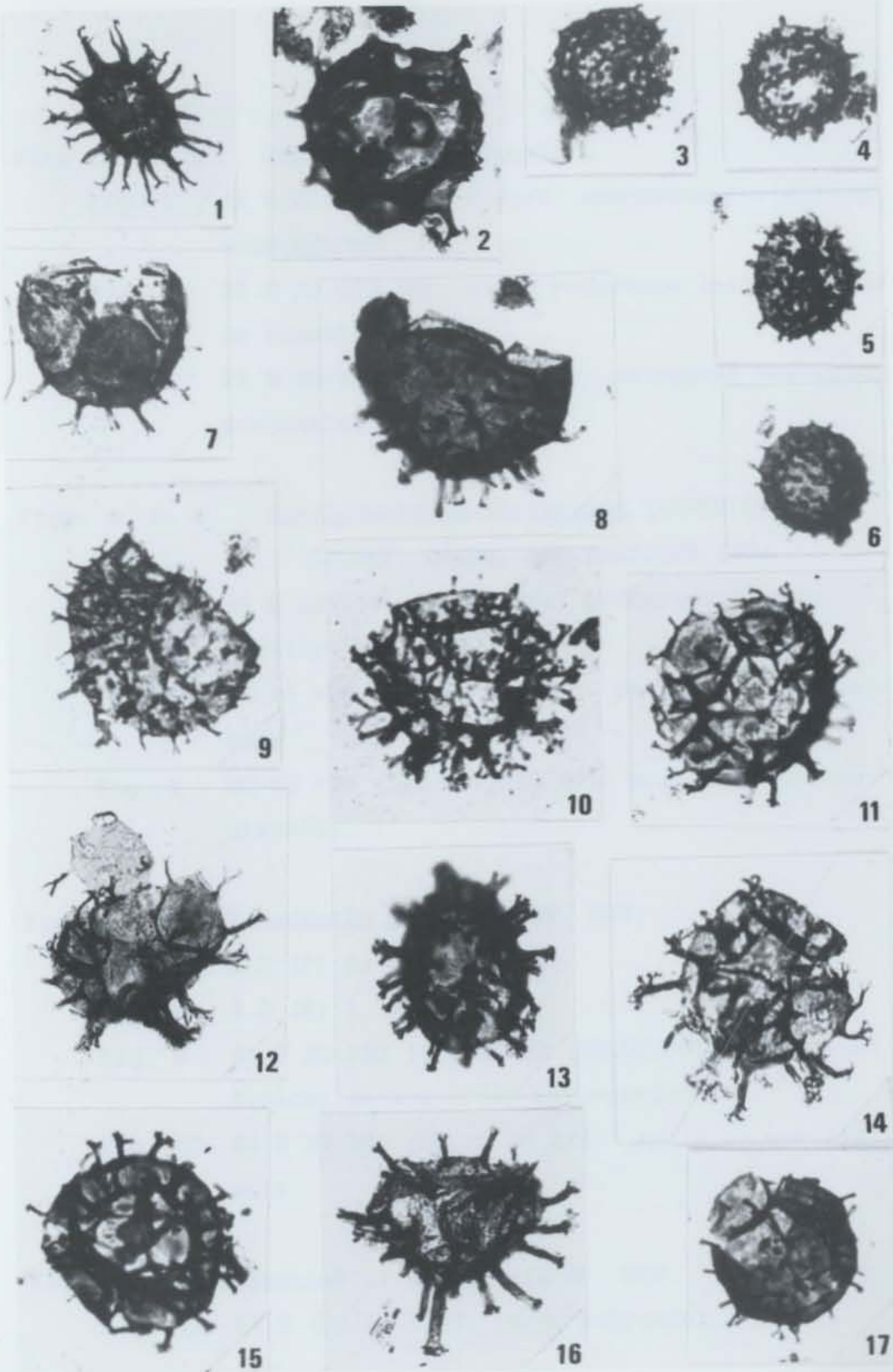

PLATE 3

Figs. 1, 2, 4 Stelliferidium gautieri

Fig. 1 21 B 20-150 (1), E 35/3: operculum projecting from pylome

Fig. 2 21 B 20-150 (3), slide reference lost: pinnae in rosettes

Fig. 4 21 B 20-150 (1), G 29/30: polygonal operculum projecting from pylome

Figs. 3, 5, 6 Stelliferidium striatulum (VAVRDOVÁ 1966) DEUNFF, GÓRKA, AND RAUSCHER 1974

Fig. 3 21 B 20-150 (3), HJ 26: processes opaque basally

Fig. 5 SH 13 >20 (5), UV 34 3/1: pattern on central body

Fig. 6 SH 13 >20 (5), L 18/19 2/1: processes hollow distally

Figs. 7-10 Timofeevia bifurcata SP. NOV.

Fig. 7 3 C (P) 3, QR 14

Fig. 8 3 C (P) 1, N 26

Fig. 9 21 B 20-150 (1), ST 43 (HOLOTYPE): polygonal fields; second order bifurcation

Fig. 10 21 B 20-150 (4), L 28 2/4: split in vesicle wall

Fig. 11 Timofeevia? cf. bifurcata SP. NOV.

Fig. 11 21 B (P) 1, L 37: large polygonal fields;

possible excystment opening present

Fig. 12 Timofeevia lancarae (CRAMER AND DÍEZ 1972) VANGUESTAINE 1978

Fig. 12 11 A 20-150 (1), FG 36 3/1: processes show delicate branching pattern

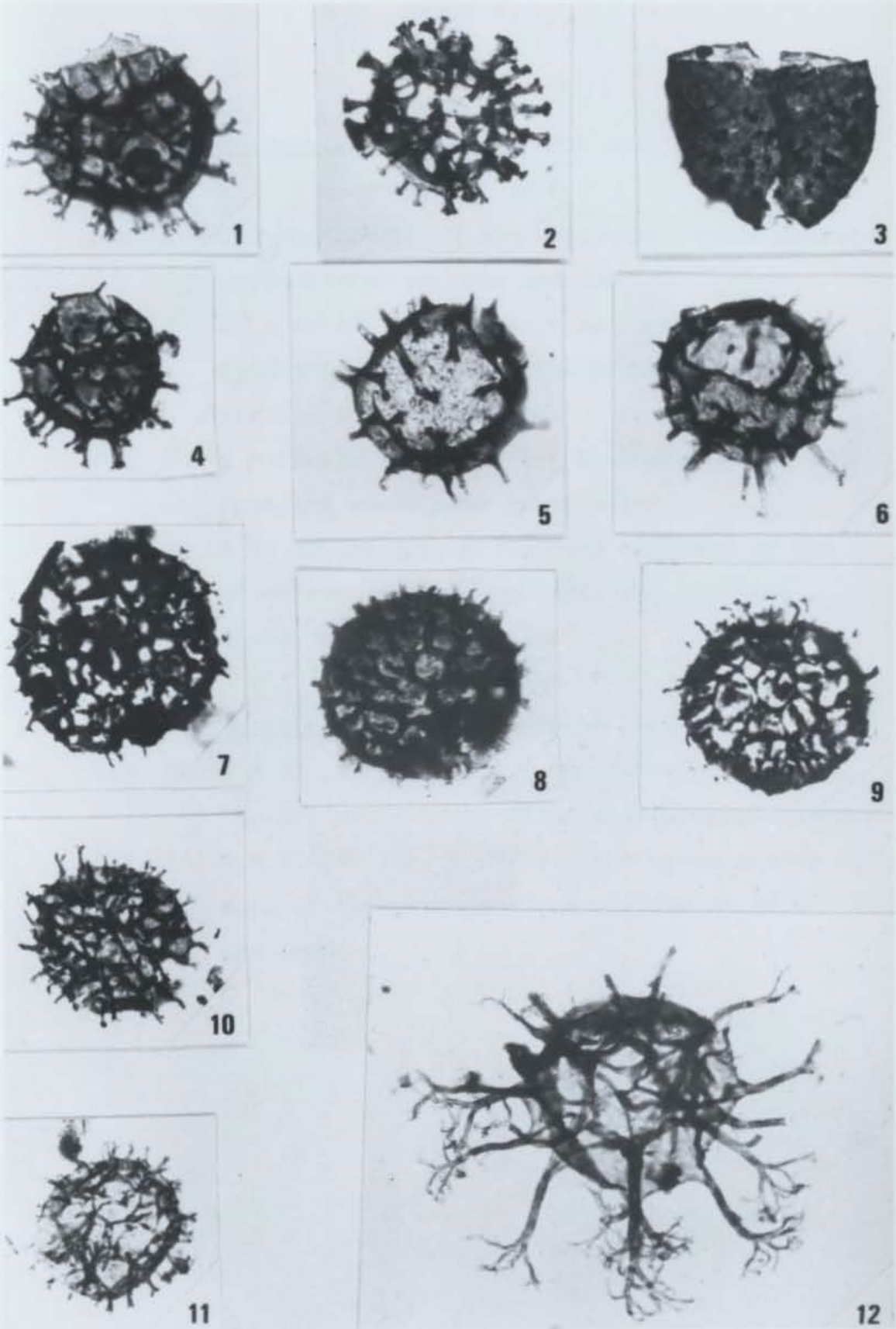
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PLATE 4

Figs. 1-4 Timofeevia lancarae (CRAMER AND DÍEZ 1972) VANGUESTAINE 1978

Fig. 1 6 A 20-150 (2), U 30: polygonal field pattern well-defined on this specimen

Fig. 2 11 A 20-150 (3), F 44: the markedly cylindrical nature of the process stems is visible on this specimen

Fig. 3 6 A 20-150 (1), X 45/1: body surface of this specimen shows some granulation

Fig. 4 6 A 20-150 (2), K 37: the entirety of the processes except, perhaps, for the most distal pinnae, is hollow

Figs. 5-6 Timofeevia microretis MARTIN 1981

Fig. 5 6 A 20-150 (2), T 37: the dense crowding of the processes masks their distribution pattern

Fig. 6 6 A 20-150 (2), U 27/28: the broad shafts of some of the processes are visible on this specimen


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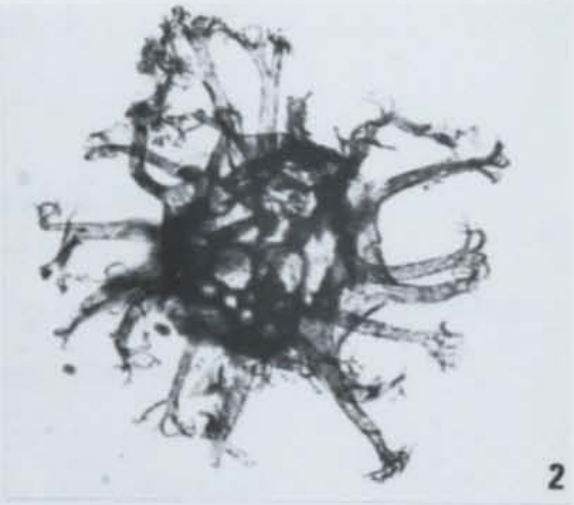
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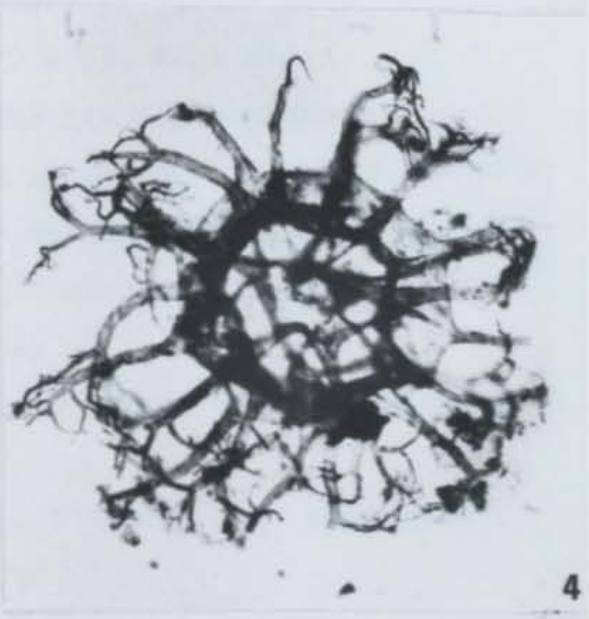
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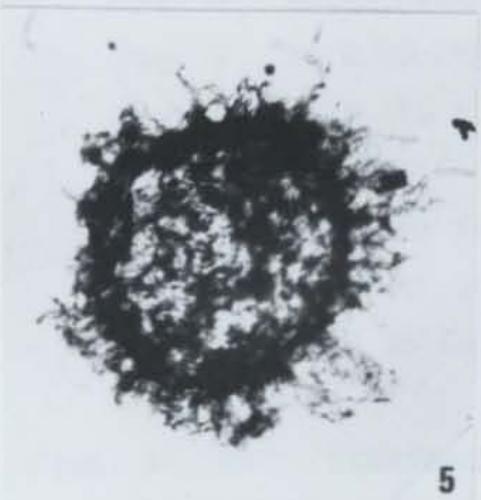
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PLATE 5

Figs. 1, 4 Timofeevia microretis MARTIN 1981

Fig. 1 6 A 20-150 (1), Y 36/1

Fig. 4 11 A 20-150 (1), Q 34: low process density; individual process shafts visible

Figs. ?2, 3, 5-13 Timofeevia pentagonalis VANGUESTAINE (1974) 1978

Fig. 2 21 B 20-150 (4), S 45: Possible T. pentagonalis. The lid may represent separation of a plate, or the operculum of a specimen of the genus Cymatiogalea.

Fig. 3 3 C (P) 3, J 36: surface of central body slightly granular

Fig. 5 3 C (P) 3, QR 9/10: central body ellipsoidal in outline

Fig. 6 21 B 20-150 (3), T 42/43 2/1: processes splayed distally

Fig. 7 21 B 20-150 (4), F 42: hexagonal central body

Fig. 8 slide reference lost

Fig. 9 21 B 20-150 (4), S 45

Fig. 10 21 B (P) 1, T 14

Fig. 11 3 C (P) 2, O 44/4

Fig. 12 21 B (P) 1, S 22/23 4/3: central body almost circular in outline

Fig. 13 21 B 20-150 (1), slide reference lost

Figs. 14, 15 Timofeevia phosphoritica VANGUESTAINE 1978

Fig. 14 SH 13 >20 (5), K 30/31 4/3: split in central body

Fig. 15 SH 13 >20 (4), OP 29 1/2

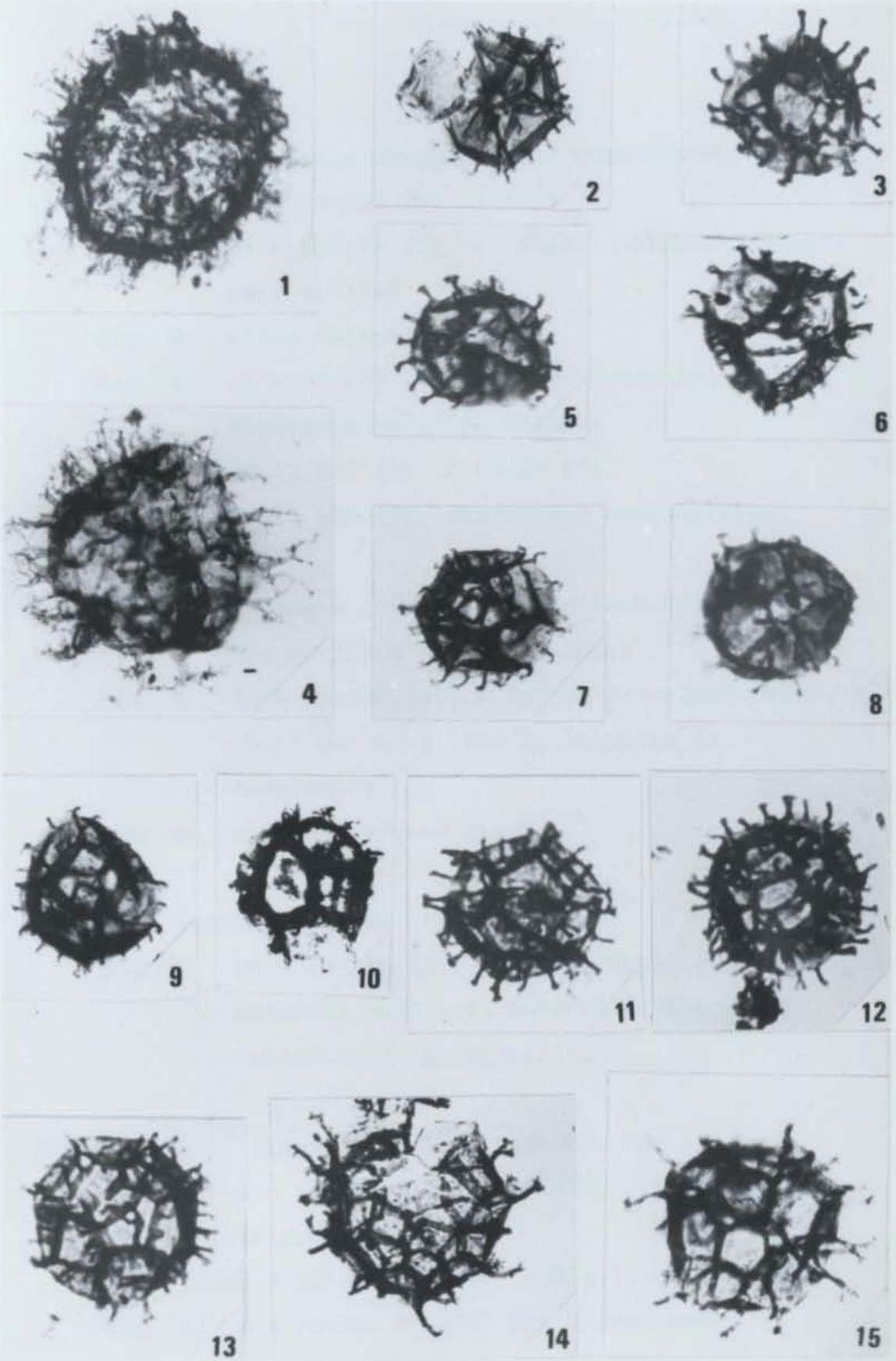
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PLATE 6

Figs. 1-6 Timofeevia phosphoritica VANGUESTAINE 1978

Fig. 1 11 A 20-150 (5), N 31/3

Fig. 2 24 B 20-150 (2), K 45/2: polygonal fields well defined

Fig. 3 slide reference lost

Fig. 4 24 B 20-150 (3), TU 27: branching pattern of processes becoming complex

Fig. 5 SH 13 >20 (5), J 28/29 4/3

Fig. 6 SH 13 >20 (3), shagrinate body surface

Figs. 7-8 Specimens intermediate in form between T. phosphoritica and T. lancarae

Fig. 7 24 B 20-150 (3), R 24 /4: processes relatively short but more like T. lancarae in complexity

Fig. 8 slide reference lost

Fig. 9 Cymatiogalea sp.

Fig. 9 24 B 20-150 (1), E 32/1: Cymatiogalea specimen with veil between processes; resembles T. phosphoritica

Figs. 10-14 Timofeevia? cuspidata SP. NOV.

Fig. 10 6 A 10-20, N 26 (HOLOTYPE): processes form triangular points

Fig. 11 6 A 10-20, U 44/3: split in central body

Fig. 12 6 A 10-20, PQ 27: small specimen

Fig. 13 6 A 10-20, S 53/3: specimen shows ridges delimiting polygonal fields

Fig. 14 6 A 20-150 (2), GH 44 3/1: cluster of eight specimens


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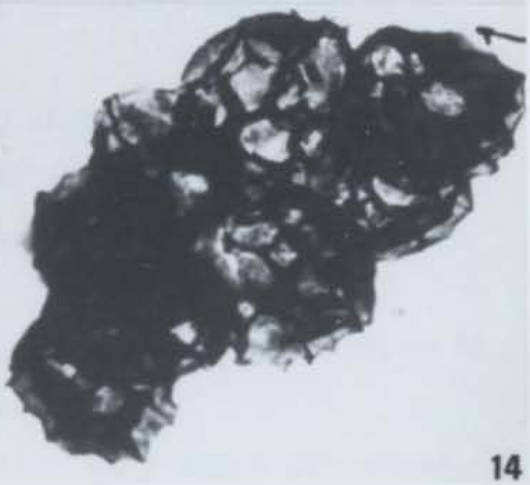
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PLATE 7

Fig. 1 Vulcanisphaera africana DEUNFF 1961

Fig. 1 E-C 7 >10 (1), F 46/3

Figs. 2, 3 Vulcanisphaera capillata JARDINÉ ET AL. 1974

Fig. 2 E-C 7 >10 (5), N 38/1: single processes at corners of polygonal fields

Fig. 3 E-C 7 >10 (3), P 28: recurved processes

Figs. 4-9 Vulcanisphaera turbata MARTIN 1981 (Form A)

Fig. 4 21 B 20-150 (2), T 24/4: heavy granulation; long processes

Fig. 5 21 B (P) 1, R 9/10 2/1: some granulation on processes

Fig. 6 21 B 20-150 (1), LM 34/35: short, well-separated processes

Fig. 7 21 B (P) 2 (1), T 49/50 4/3: filaments arise from processes

Fig. 8 6 A 20-150 (1), ST 31: extremely short processes

Fig. 9 21 B 20-150 (2), PQ 39/40: one process associated with each plate at the plate junctions; separation along plate margins

Figs. 10, 11 Vulcanisphaera turbata MARTIN 1981 (Form B)

Fig. 10 6 A, slide reference lost

Fig. 11 6 A 20-150 (1), W 31: very short processes

with medium density of spacing.

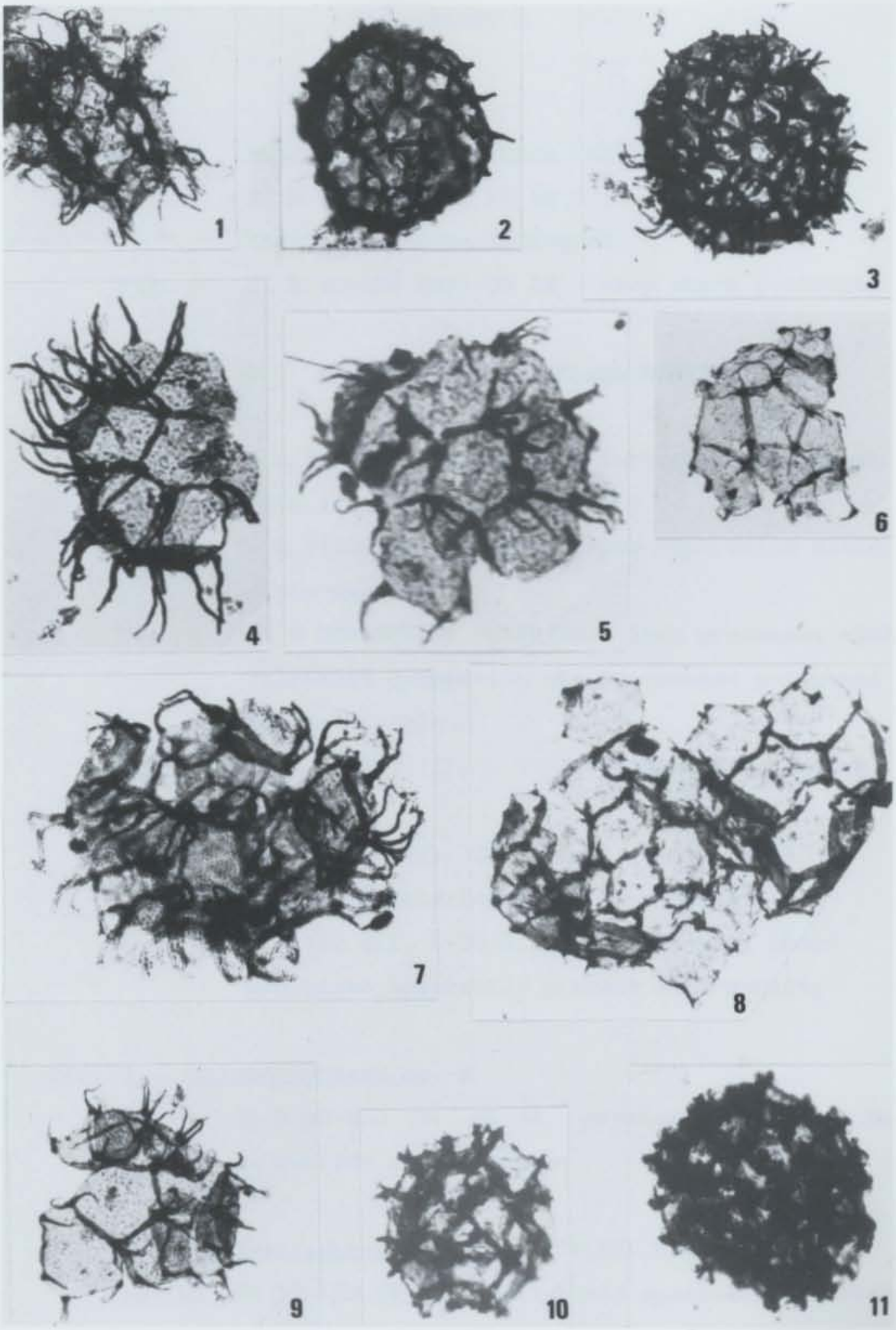
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PLATE 8

Figs. 1, 6 Vulcanisphaera turbata MARTIN 1981 (Form A)

Fig. 1 21 B 20-150 (1), DE 28 4/2: long processes that have become entangled

Fig. 6 21 B 20-150 (3), GH 39: very short processes

Figs. 2-5, 7, 8 Vulcanisphaera turbata MARTIN 1981 (Form B)

Fig. 2 6 A 20-150 (1), L 33/4: very short processes with filaments

Fig. 3 6 A 2-150 (1), P 46/4: some separation along plate margins

Fig. 4 24 B 20-150 (1), M 28/29: long processes with filaments connecting the processes; polygonal fields visible

Fig. 5 22 B 20-150 (2), J 21/2: processes of medium length

Fig. 7 6 A 20-150 (2), GH 40 1/3: very short processes interconnected by filaments

Fig. 8 8 B >10 (1), L 30/31 2/1: some very short processes apparently present intergonally

Fig. 9 Vulcanisphaera sp. B

Fig. 9 21 B 20-150 (3), QR 38: processes appear to be in contact at their tips

Fig. 10 Vulcanisphaera africana? DEUNFF 1961

Fig. 10 SH 13 >20 (5), D 37/1: this specimen resembles

V. africana in having no (obvious) polygonal field pattern, but many of the processes occur singly rather than in groups of two or three

Fig. 11 ✓ Vulcanisphaera? sp. C

Fig. 11 21 B 20-150 (3), K 35/36 4/3

Fig. 12 Vulcanisphaera sp. A

Fig. 12 21 B 20-150 (3), HJ 28: very small vulcanisphaerid

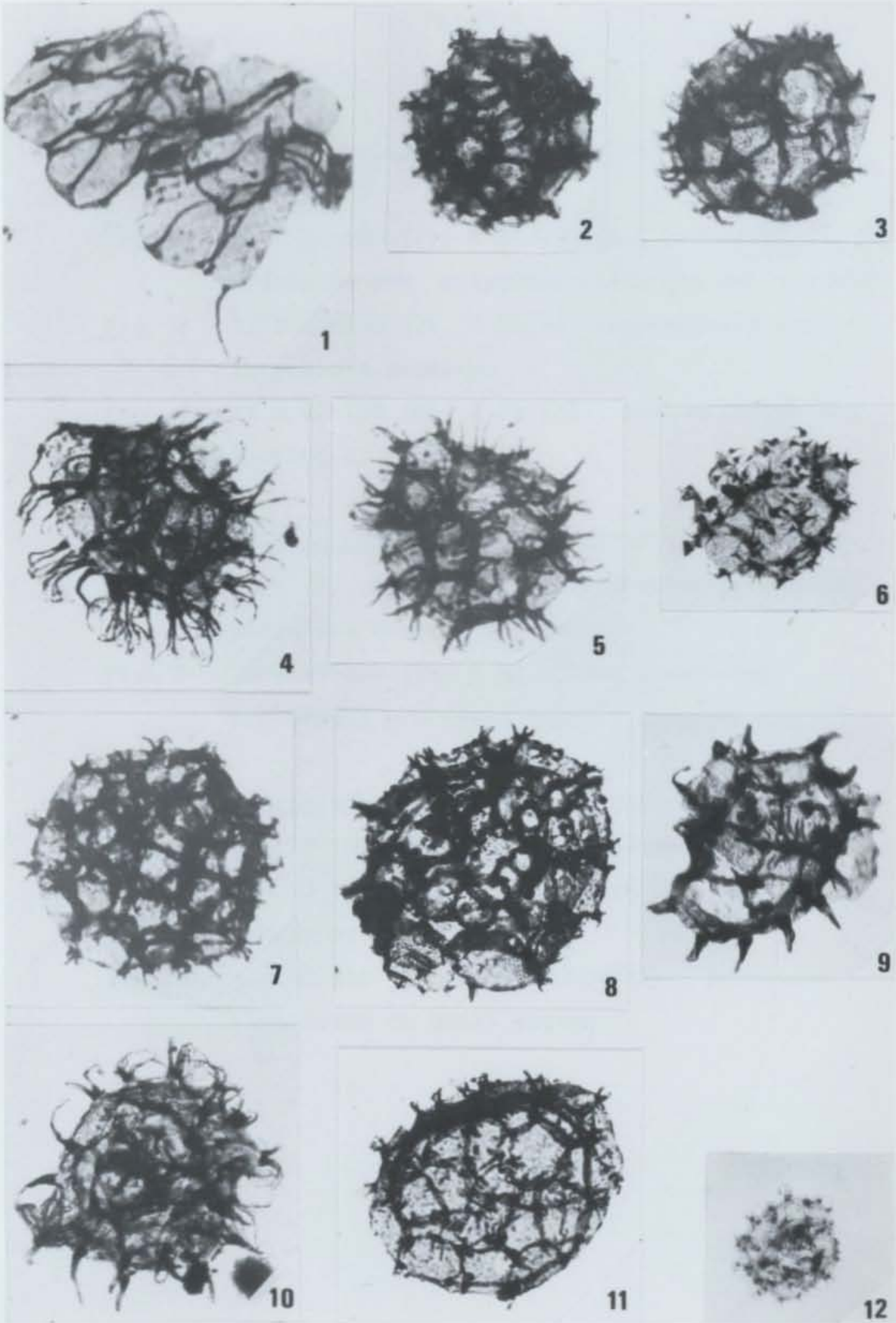
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PLATE 9

Figs. 1, 3, 4 Vulcanisphaera turbata MARTIN 1981 (Form B)

Fig. 1 11 A 20-150 (1), W 27/28 4/1: processes of medium length; polygonal field pattern visible

Fig. 3 21 B 20-150 (2), T 33/34: approaching Form A in process density

Fig. 4 21 B 20-150 (4), X 35 1/3: medium length and spacing of processes

Figs. 2, 5 Vulcanisphaera turbata MARTIN 1981 (Form C)

Fig. 2 24 B (P), T 18/2: long interwoven processes; processes densely crowded

Fig. 5 24 B 20-150 (1), E 43: long interwoven processes; processes densely crowded

Figs. 6-8 Vulcanisphaera disjunctospinata SP. NOV.

Fig. 6 6 A 20-150 (1), L 33/4: isolated processes

Fig. 7 6 A 20-150 (1), F 51/1: some granulation on processes

Fig. 8 6 A 20-150 (1), L 48 (HOLOTYPE): processes restricted to gonal angles


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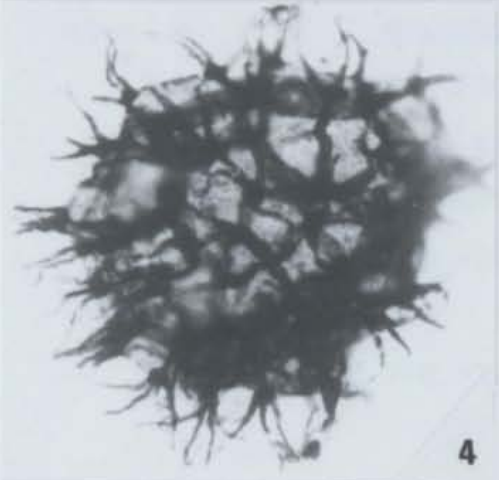
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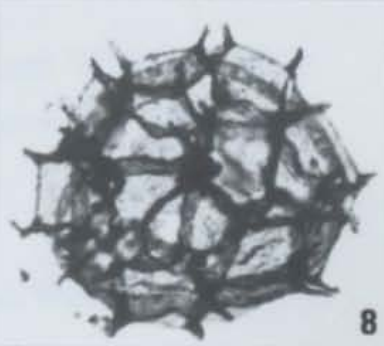
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PLATE 10

Fig. 1 Vulcanisphaera turbata MARTIN 1981 (Form C)

Fig. 1 21 B 20-150 (3), F 42: long processes; processes densely crowded (Mag. 650 X)

Figs. 4, 9 Vulcanisphaera turbata MARTIN 1981 (Form B)

Fig. 4 24 B 20-150 (1), F 46: very long processes; medium density of processes

Fig. 9 24 B 20-150 (2), L 38 4/2: long processes; medium density of processes

Figs. 2, 3 Vulcanisphaera disjunctospinata SP. NOV.

Fig. 2 6 A 20-150 (1), Q 46/4

Fig. 3 6 A 10-20, O 45/3

Figs. 5, 7, 8 Acanthodiacrodium achrasi MARTIN 1973

Fig. 5 E-C 7-8 >10 (3), C 8: central body has inflated trapezoidal shape; granulation visible on processes and central body

Fig. 7 E-C 7-8 >10 (3), O 11/2: inflated rectangular body

Fig. 8 E-C 7-8 >10 (3), L 9/4

Fig. 6 Acanthodiacrodium cf. abortivum TIMOFEEV 1959

Fig. 6 E-C 7 >10 (1), CD 44: processes curved slightly

Fig. 9 Acanthodiacrodium cf. achrasi MARTIN 1973

Fig. 9 SH 13 >10 (2), N 29/2: strong ornamentation on processes and central body

Figs. 11-16 Acanthodiacrodium randomense SP. NOV.

Fig. 11 E-C 7 >10 (1), GF 37/2: broad equatorial zone

Fig. 12 E-C 7 >10 (1), M 41: central body almost circular in outline

Fig. 13 E-C 7 >10 (1), M 45: weak ornamentation on this specimen

Fig. 14 37 C >10 (3), F 32/1 (HOLOTYPE): very pronounced ornamentation; striated equatorial zone

Fig. 15 E-C 7 >10 (3), MN 29: very short processes; split in central body

Fig. 16 37 C >10 (2), P 40/2: ornamentation visible on central body and processes


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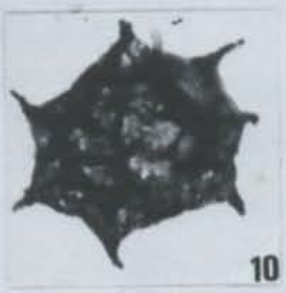
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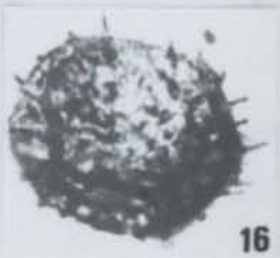
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PLATE 11

Fig. 1 Acanthodiacrodium cf. achrasi MARTIN 1973

Fig. 1 SH 13z >10 (1), G 46/1: polygonal specimen with very pronounced ornamentation on processes and central body

Figs. 2, ?3, 4-7 Acanthodiacrodium complanatum (DEUNFF 1961) VAVRDOVÁ 1965

Fig. 2 SH 13z >10 (2), ST 2: hexagonal central body with bipolar arrangement of processes; short hairs ornament both central body and processes.

Fig. 3 SH 13 >20 (1), slide reference lost: some bipolarity to the arrangement of processes; may belong to A. cf. achrasi as spines are very strongly developed

Fig. 4 SH 13 >20 (4), L 39/4: bipolar process arrangement; medium development of spinose ornamentation on processes and central body

Fig. 5 SH 13 >20 (4), J 29/4: hexagonal central body; processes concentrated at poles

Fig. 6 SH 13 >20 (3), M 42/2: no polarity to process arrangement; may represent polar view of specimen; weak spinosity

Fig. 7 SH 13 >20 (5), L 36/3: strong apical spine present; specimen resembles a member of the genus Tectitheca Burmann 1968

Figs. 8-12. Acanthodiacrodium lanatum (TIMOFEEV 1959) MARTIN 1977

Fig. 8 E-C 7 >10 (1), slide reference lost

Fig. 9 E-C 7 >10 (5), R 18/19: transverse and peripheral folding

Fig. 10 E-C 7 >10 (1), N 24: transverse folding

Fig. 11 E-C 7 >10 (1), R 31

Fig. 12 E-C 7 >10 (1), E 23/2: narrow equatorial zone with low number of processes, or none at all

Figs. 13, 15-17, 19, 20 Acanthodiacrodium andersoni SP. NOV.

Fig. 13 SH 13 (P), Q 35/1: no barren equatorial zone is evident on this specimen

Fig. 15 SH 13 (P), FG 44 3/1 (HOLOTYPE): wide equatorial zone

Fig. 16 SH 13 (P), UV 14 (PARATYPE): processes with broadly rounded apices

Fig. 17 SH 13 >20 (4), N 34: some processes slightly pointed

Fig. 19 SH 13 >20 (5), H 39/2

Fig. 20 SH 13 (P), J 44/3: processes with narrow, less rounded distal extremities

Figs. 14, 18, 21 Acanthodiacrodium sp. A

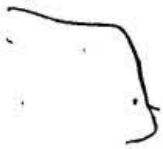
Fig. 14 E-C 7-8 >10 (1), M 7: opaque processes, some of which have a corner-like base

Fig. 18 E-C 7-8 >10 (1), ST 32

Fig. 21 E-C 7-8 >10 (2), slide refererence lost

Fig. 22 Acanthodiacrodium ubui MARTIN 1969

Fig. 22 E-C 7-8 >10 (1), P 11: strong branches on processes

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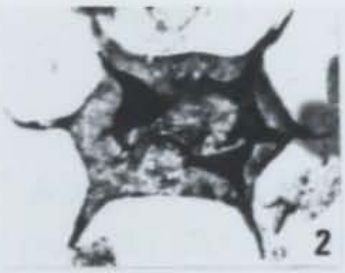
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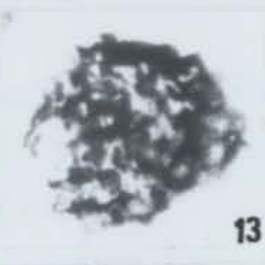
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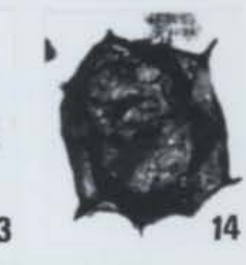
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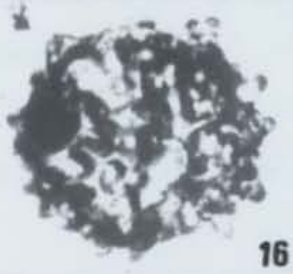
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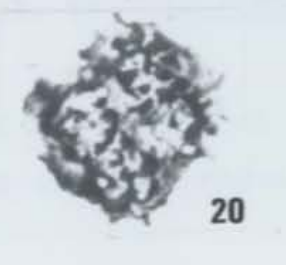
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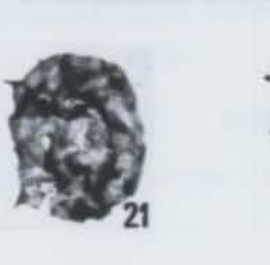
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PLATE 12

Figs. 1-3, 5, 6, 13 Acanthodiacrodium ubui MARTIN 1969

Fig. 1 24 C >10 (1a), RS 23/24: equatorial region striated

Fig. 2 E-C 7-8 >10 (3), O 11/12: knob-like ornamentation on processes

Fig. 3 19 C >10 (3), E 30/31: smooth equatorial zone

Fig. 5 24 C >10 (1), M 25: equatorial region striated

Fig. 6 19 C >10 (2), R 20: specimen resembles A. achrasi but ornamentation restricted to processes

Fig. 13 24 C >10 (3) 2, H 47/2

Fig. 4 Acanthodiacrodium sp. A

Fig. 4 E-C 7-8 >10 (2), Q 27/28: opaque processes

Figs. 7, 14, 15 Arbusculidium destombesii DEUNFF 1961

Fig. 7 E-C 7 >10 (1), M 43/3: broad shafts of processes and palmate branching visible

Fig. 14 E-C 7 >10 (4), H 16: central body somewhat convex

Fig. 15 E-C 7 >10 (1), UV 41/42: branching processes form a tangled mass

Figs. 8, 9, 11, 12, 16 Acanthodiacrodium discigerum SP. NOV.

Fig. 8 19 C >10 (1), T 41 (HOLOTYPE): each process of this specimen shows a broad dome-like base with a

slender distal extremity

Fig. 9 19 C >10 (2), OP 21 3/1: process bases, in outline, resemble very large discs

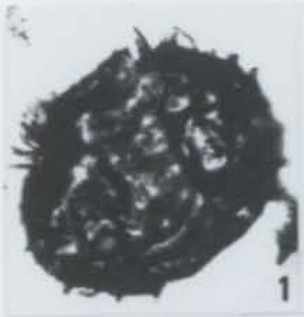
Fig. 11 19 C >10 (1), V 39/2: equatorial folding

Fig. 12 19 C >10 (2), TU 26 4/2: process-free equatorial zone visible

Fig. 16 19 C >10 (3), GH 24 3/1: barren equatorial zone not observable on this specimen

Fig. 10 Acanthodiacrodium achrasi MARTIN 1973

Fig. 10 E-C 7-8 >10 (2), L 50 1/3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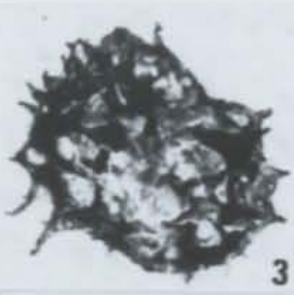
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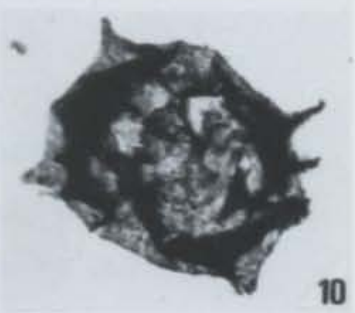
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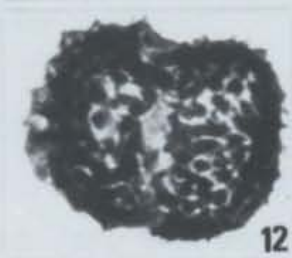
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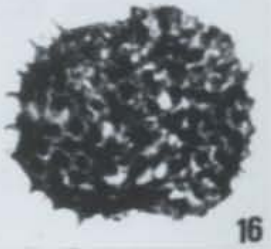
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PLATE 13

Fig. 1 Arbusculidium destombesii DEUNFF 1968

Fig. 1 E-C 7 >10 (1), X 30: broad shafts of processes give rise to palmate branches distally

Figs. 2-7 Arbusculidium rommelaeri MARTIN 1981

Fig. 2 42 C >10 (2), U 42/3

Fig. 3 E-C 7-8 >10 (3), E 10/11

Fig. 4 E-C 7 >10 (3), D 30/31 2/1

Fig. 5 E-C 7 >10 (1), G 41

Fig. 6. 42 C >10 (2), S 30/4

Fig. 7 E-C 7-8 >10 (2), O 46/47

Fig. 8 Arbusculidium aff. rommelaeri MARTIN 1981

Fig. 8 E-C 7 >10 (3), C 36/3: resembles A. rommelaeri but, the processes at both poles are longer than for that species

Figs. 9-13 Hamatodiacrodium bucerum (UMNOVA 1971) COMB. NOV.

Fig. 9 19 C >10 (2), V33/34: (Form 2) trapezoidal (almost rectangular) outline to central body; the apical processes are corner-shaped, the basal processes strongly incurved

Fig. 10 E-C 7 >10 (1), JK 24 4/2: (Form 1) some folding of central body

Fig. 11 19 C >10 (3), W 39: (Form 2) body outline coming to resemble that of Form 1; two strong

basal processes and one less developed basal process

Fig. 12 E-C 7 >10 (1), slide reference lost: (Form 1)

Fig. 13 E-C 7 >10 (1), O 31/32: (Form 1) very reduced apical process

Figs. 14-16 Hamatodiacrodium bucerum var. aciferum (UMNOVA 1971) COMB. NOV.

Fig. 14 19 C >10 (2), V 33/34: five apical processes, one of which is dominant, and four basal processes

Fig. 15 19 C >10 (2), RS 18 4/2: two apical processes and five basal processes

Fig. 16 19 C >10 (3), W 32/33 2/1: five basal processes; one apical process visible

Figs. 17-21 Dasydiacrodium longispinatum SP. NOV.

Fig. 17 E-C 7-8 >10 (2), MN 31, 3/1: resembles Alliumella baltica Umnova 1971

Fig. 18 37 C 10 (1), F 45: truncated spines

Fig. 19 E-C 7 >10 (1), P 42

Fig. 20 E-C 7-8 >10 (1), LM 16: two apical spines; several folds in central body

Fig. 21 E-C 7 >10 (1), H 24/3: undulating apical spine

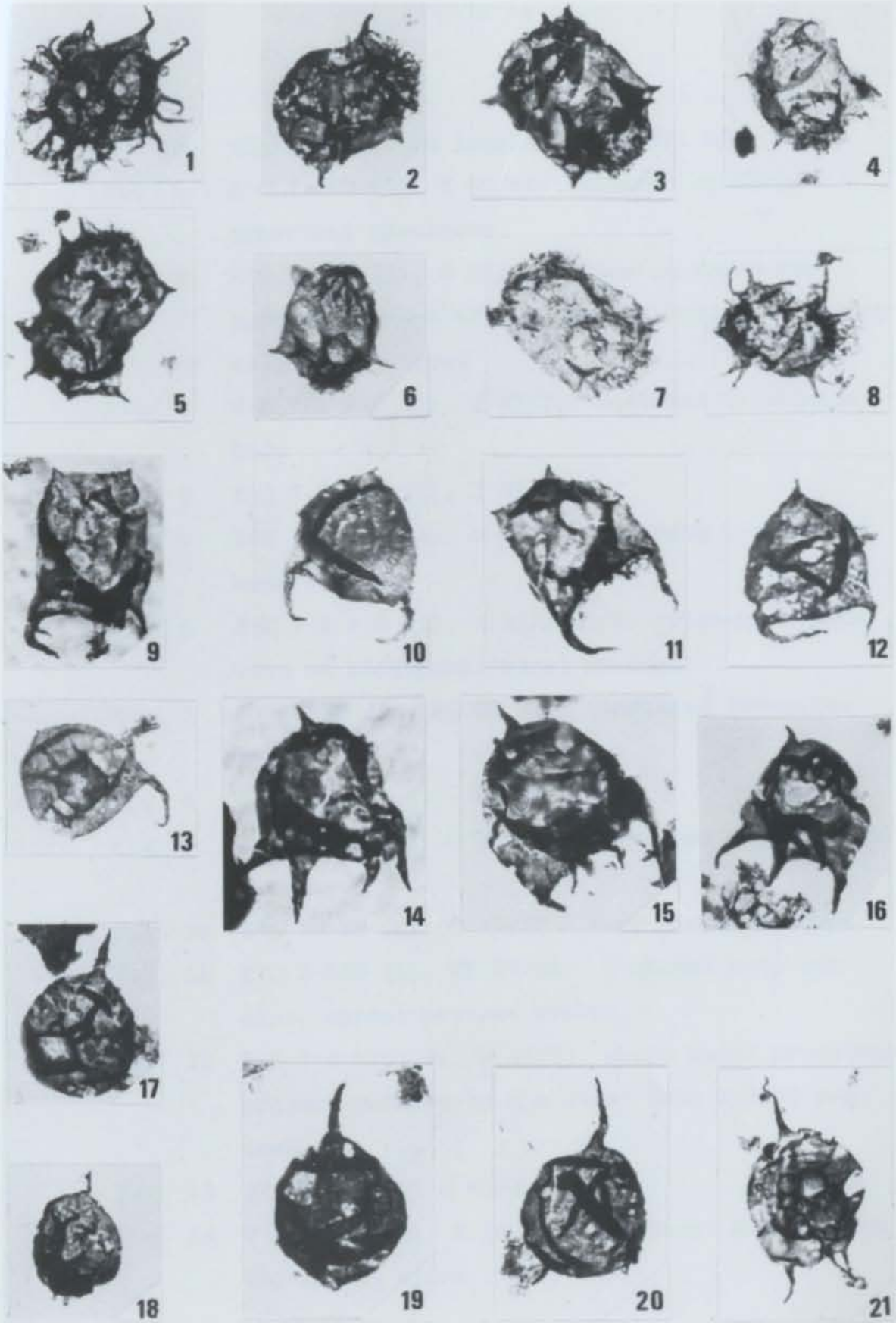
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PLATE 14

Figs. 1-16 Dasydiacrodium longispinatum SP. NOV.

Fig. 1 E-C 7 >10 (3), E 40/41: cluster of three spherical specimens

Fig. 2 E-C 7 >10 (1), O 31/32: form in which the spherical shape of the central body is becoming slightly U-shaped

Fig. 3 E-C 7-8 >10 (2), H 40/2: inflated triangular body

Fig. 4 E-C 7-8 >10 (1), T 35

Fig. 5 E-C 7-8 >10 (2), N 42/4: becoming U-shaped in body outline

Fig. 6 E-C 7-8 >10 (1), U 21/22 2/1, triangular form with an additional basal process

Fig. 7 37 C >10 (2), PQ 50 3/1: inflated isosceles shape

Fig. 8 E-C 7-8 >10 (2), MN 31 3/1

Fig. 9 E-C 7 >10 (1), H 31: an additional short apical process

Fig. 10 E-C 7 >10 (1), O 29/30: very globular shape

Fig. 11 E-C 7 >10 (1), EF 37/38: U-shaped body outline; apical process broken

Fig. 12 E-C 7-8 >10 (2), M 33/3: short basal processes project outward to the side; long apical process

Fig. 13 37 C >10 (2), W 45/3

Fig. 14 E-C 7 >10 (1), R 20/3: additional basal spine and apical spine

Fig. 15 E-C 7-8 >10 (2), D 47/4: short additional basal spine

Fig. 16 E-C 7-8 >10 (2), N 30/31: additional apical spine and basal spine

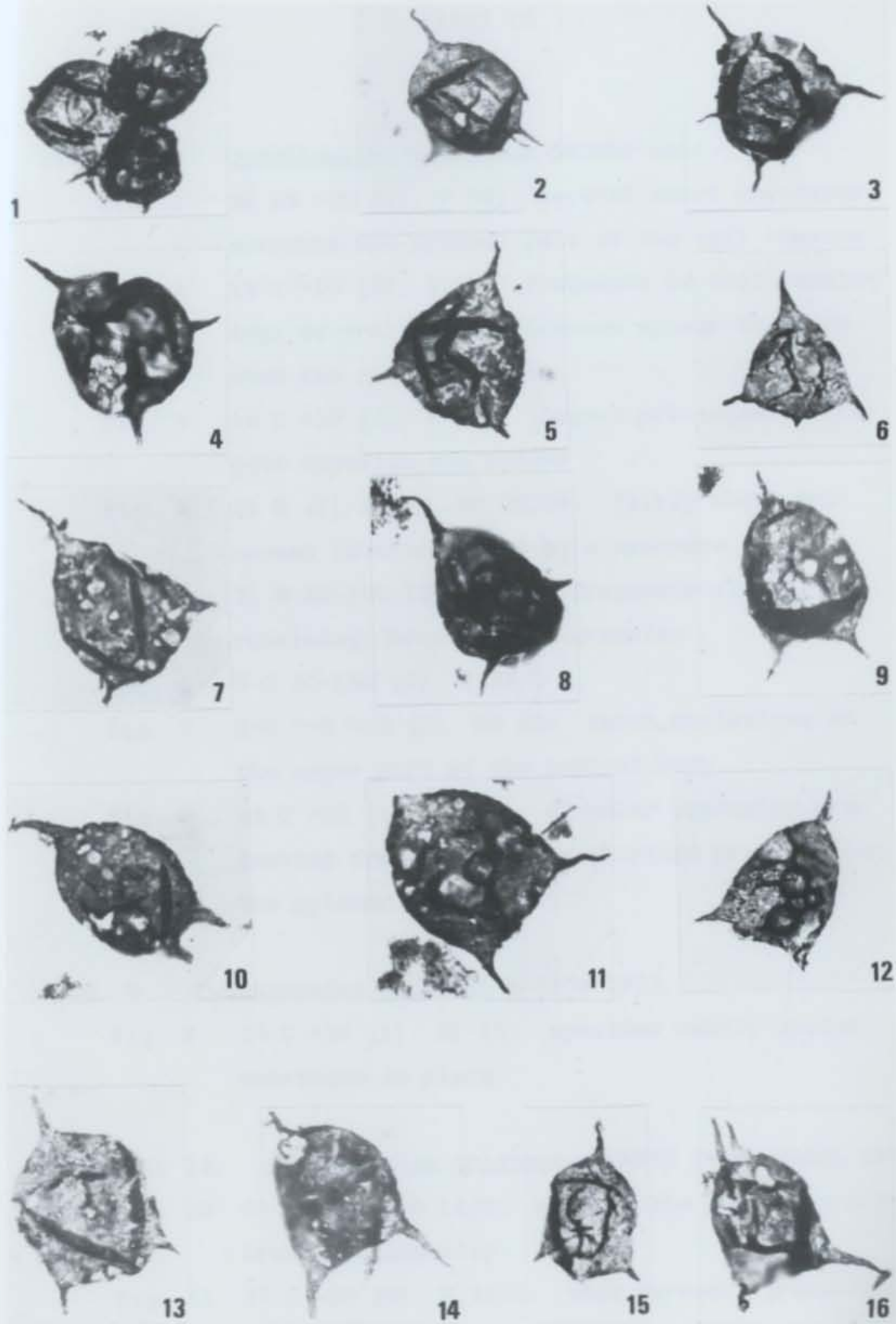
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PLATE 15

Figs. 1-8 Cymatiogalea bellicosa DEUNFF 1961

Fig. 1 SH 13 >20 (2), V 38: several short processes surround the pylome; part of the veil remains

Fig. 2 19 C >10 (3), X 19: fragments of veil remaining; several short processes appear to arise from the opercular rim

Fig. 3 19 C >10 (3), R 39: longest processes at the pole opposite the pylome

Fig. 4 21 B (P) 2 (1), MN 38/39: fairly short processes interconnected by a membrane

Fig. 5 21 B 20-150 (3), R 38: fragments of veil remaining; body surface granular

Fig. 6 3 C 20-150 (2), P 37/3

Fig. 7 E-C 7-8 >10 (2), RS 23: faint striations on the upper part of the central body

Fig. 8 24 C >10 (1a), U 38: circular operculum projecting from the pylome; shortest processes in the pylomar area

Fig. 9 Cymatiogalea bouvardi MARTIN 1973

Fig. 9 24 C >10 (1), EF 15: specimen nearly opaque; operculum in place

Figs. 10-12 Cymatiogalea cristata (DOWNIE 1958) RASUL 1974

Fig. 10 21 B (P) 3, m 11/2: most of the processes are truncated distally

Fig. 11 37 C >10 (3), H 32/3: test markedly granular

Fig. 12 37 C >10 (2), F 35/1: test markedly granular; operculum missing

Figs. 13-15 Cymatiogalea cuvillieri DEUNFF (1961) 1964

Fig. 13 37 C >10 (3), EF 23/24: tearing of central body in several places

Fig. 14 E-C 7 >10 (3), slide reference lost: operculum missing

Fig. 15 24 C >10 (1), U 42: very short denticulation of pylomar rim

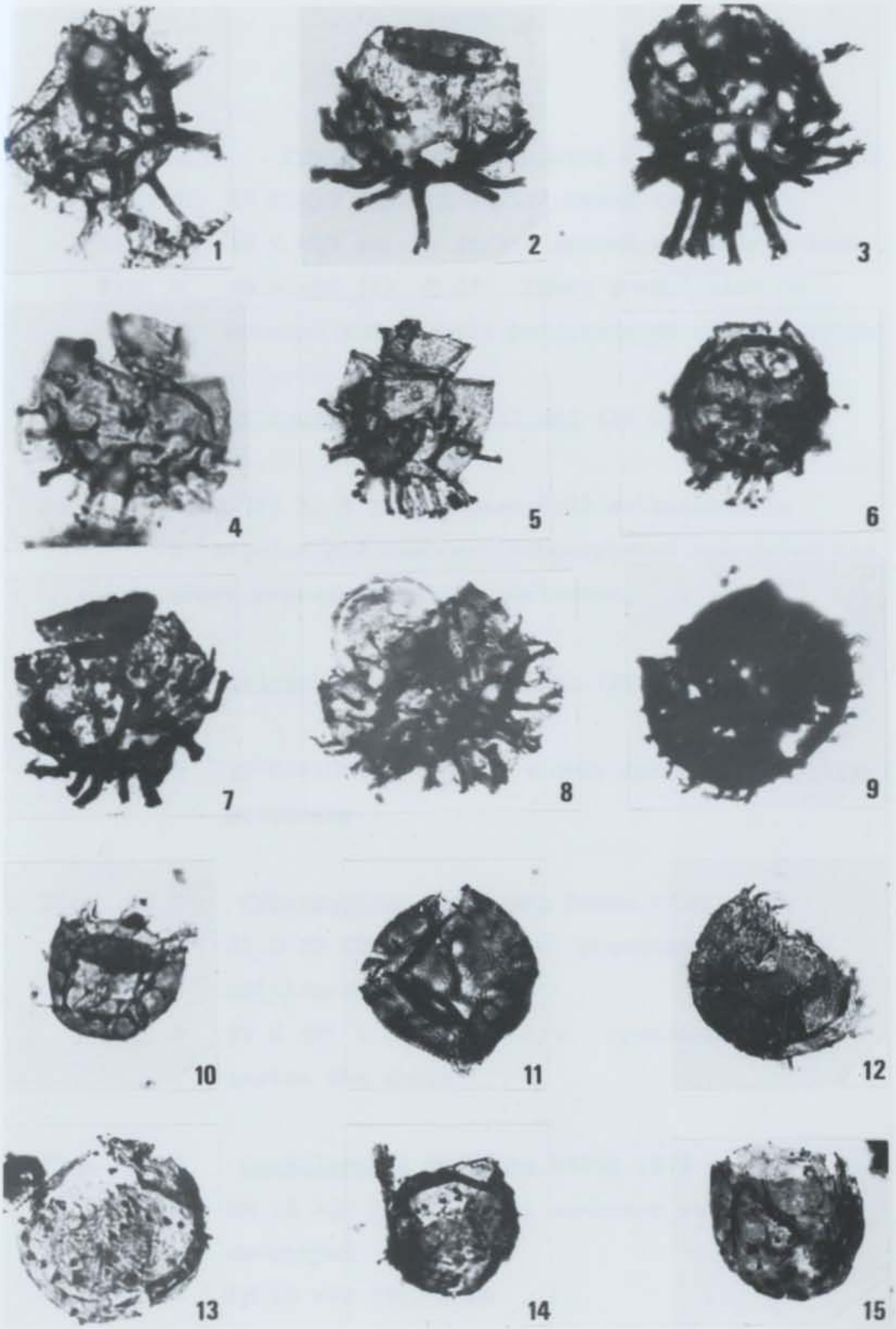
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PLATE 16

Figs. 1, 4, 5 Cymatiogalea cuvillieri DEUNFF (1961) 1964

Fig. 1 37 C >10 (30), D 39/1: small specimen

Fig. 4 19 C >10 (3), L 24/3: spines are fairly long

Fig. 5 24 C >10 (1), Q 37: heavy granulation on central body; short processes on rim of pylome

Fig. 2 Cymatiogalea aff. cuvillieri (1) DEUNFF (1961) 1964

Fig. 2 21 B (P) 1, E 13/1: hair-like extensions to triangular prominences; subpolygonal operculum has short processes on its perimeter

Fig. 3 Cymatiogalea aff. cuvillieri (2) DEUNFF (1961) 1964

Fig. 3 19 C >10 (1), L 34: widely spaced needle-like processes

Figs. 6, 7 Cymatiogalea diversata RASUL 1974

Fig. 6 21 B 20-150 (4), UV 43: processes distally multifurcate

Fig. 7 21 B (P) 2 (2), L 45 2/4: operculum fallen inside the shell

Figs. 8-12 Cymatiogalea membrana RASUL 1974

Fig. 8 SH 13 >20 (4), UV 43: membrane very strongly developed

Fig. 9 SH 13 >20 (3), K 25

Fig. 10 SH 13 >20 (5), F 18/19 4/3

Fig. 11 SH 13 >20 (5), CD 26/27

Fig. 12 SH 13 >20 (2), C 36/3

Figs. 13-15 Cymatiogalea membranispina DEUNFF 1961

Fig. 13 37 C >10 (2), L 36/2: specimen shows thick, columnar processes

Fig. 14 37 C 10 (2), Q 21: circular pylome bordered by processes

Fig. 15 37 C >10 (2), D 18/2: part of the membrane interconnecting some of the processes is intact


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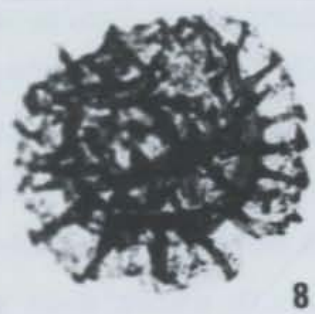
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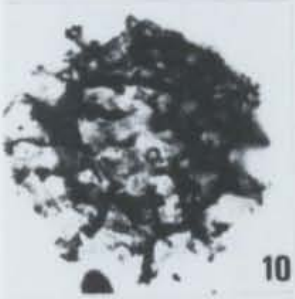
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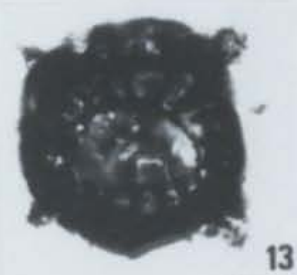
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PLATE 17

Figs. 1-3 Cymatiogalea membranispina DEUNFF 1961

Fig. 1 E-C 7 >10 (1), M 40: long processes interconnected by membranes

Fig. 2 37 C >10 (1), U 28: processes proximally opaque and distally expanded into clear, club-like terminations. (barely visible in photo)

Fig. 3 E-C 7 10-10 (1), N 43/4: short opaque processes interconnected by membranes

Figs. 4-6 Cymatiogalea? membranula MARTIN 1978

Fig. 4 19 C >10 (2), M 25 2/4: solid processes interconnected by membranes

Fig. 5 19 C >10 (3), S 27

Fig. 6 19 C >10 (1), E 33/34 2/1: some of the processes show short distal subdivisions

Figs. 7-10 Cymatiogalea velifera (Downie 1958) MARTIN 1969

Fig. 7 21 B 20-150 (3), V 38: horizontal striations can be seen on the veil

Fig. 8 21 B 20-150 (1), F 44/45: several of the processes bifurcate half-way along their length

Fig. 9 E-C 7 >10 (3), TU 43/44: infrareticulate body surface; small split in shell

Fig. 10 21 B 20-150 (1), F 34/35: most of the processes bifurcate distally

Figs. 11-13 Cymatioglea digitata SP. NOV.

Fig. 11 21 B 20-150 (3), S 21/3: ridges and veils interconnect the processes

Fig. 12 3 C 20-150 (1), HJ 42: ridges visible

Fig. 13 21 B 20-150 (1), H 41/42 (HOLOTYPE): processes have clavate or digitate terminations; subpolygonal pylome present

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Fig. 14 Cymatiogalea radiata SP. NOV.

Fig. 14 E-C 7-8 >10 (2), K 29 (HOLOTYPE): processes distally simple or expanded; veils interconnect the processes

Fig. 15 Cymatiogalea bellicosa DEUNFF 1961

Fig. 15 19 C >10 (1), E 34/1: most of the veil is intact; the area around the pylome has several short processes


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PLATE 18

Fig. 1 Cymatiogalea bellicosa DEUNFF 1961

Fig. 1 E-C 7-8, >10 (1), W 27 1/2

Fig. 2 Cymatiogalea sp. A

Fig. 2 SH 13 >20 (1), N 33: some spines on the stems of the processes

Fig. 3 Cymatiogalea? sp.

Fig. 3 21 B 2-150 (3), NO 41: strong processes interconnected by a veil; processes appear to be arranged in a polygonal pattern

Figs. 4-8 Cymatiogalea irregularis SP. NOV.

Fig. 4 21 B (P) 2 (1), O 35/3: low ridges interconnect the processes; polygonal operculum inside the shell

Fig. 5 21 B 20-150 (1), OP 40/41: processes distally multifurcate, some showing an initial bifurcation before the multifurcate subdivision

Fig. 6 21 B 20-150 (4), RS 45/46: short processes on rim of pylome

Fig. 7 21 B 20-150 (1), H 29/2: digitate nature of process terminations visible

Fig. 8 21 B (P) 2 (2), L 45 2/4 (HOLOTYPE): veil-like material partly encloses the shell (this may or or may not be a real veil); the operculum is in place

Figs. 9, 10, ?11, 15 Cymatiogalea cf. irregularis SP. NOV.

Fig. 9 21 B 20-150 (1), F 35: very short, generally simple processes

Fig. 10 21 B (P) 2 (1), LM 22/23: very short processes on rim of pylome

Fig. 11 slide reference lost: this specimen resembles C. cf. irregularis, but the opening in the shell is less regular; it may be a specimen of the genus Timofeevia.

Fig. 15 21 B 20-150 (1), F 26: the operculum has fallen inside the shell

Fig. 12 ?Timofeevia pentagonalis VANGUESTAINE (1974) 1978

Fig. 12 slide reference lost: resembles a specimen of the genus Cymatiogalea, but this is due to the loss of several plates

Figs. 13, 14 Stelliferidium cortinulum (DEUNFF 1961) DEUNFF, GÓRKA, AND RAUSCHER 1974

Fig. 13 21 B (P) 1, K 8/4

Fig. 14 21 B (P) 1, F 41/42: operculum in place; some of the processes show second order bifurcation


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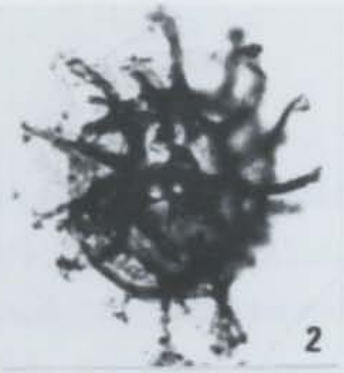
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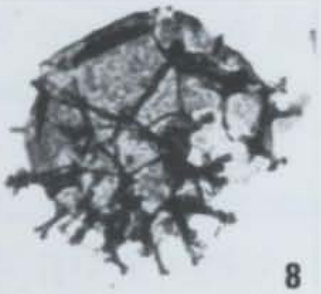
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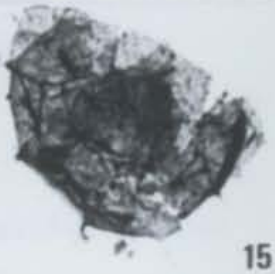
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PLATE 19

Figs. 1, 3 Eliasum pisciforme FOMBELLA 1977

Fig. 1 12-20' (1), V 22/23: split at one pole; dense granulation of the interridge areas

Fig. 3 12-20' (1), H 44/45: heavy granulation of the interridge areas

Fig. 2 Eliasum llaniscum FOMBELLA 1977

Fig. 2 12-20' (1), D 31: some splitting of shell along ridges; opening at one end

Fig. 4 Poikilofusa squama (DEUNFF 1961) MARTIN 1977

Fig. 4 E-C 7 >10 (3), S 20/21 2/1: split in central body (Mag. 300 X)

Figs. 5-10 Verybachium? asymmetricum SP. NOV.

Fig. 5 3 C 10-20 (1), Q 31/4

Fig. 6 3 C 10-20 (2), K 31: heavy granulation can be observed on this specimen

Fig. 7 3 C (P) 3, H 35

Fig. 8 3 C 10-20 (2), J 29/30: specimen view at an oblique angle

Fig. 9 3 C, slide reference lost: short processes

Fig. 10 3 C 10-20 (2), W 32/33 4/3: some folding of central body

Fig. 11 Leiofusa oculina SP. NOV.

Fig. 11 11 A 20-150 (1), UV 17: extremities almost

rounded; several folds in central body (Mag. 500 X)

Fig. 12 Leiofusa stoumonensis VANGUESTAINE 1973

Fig. 12 21 B 20-150 (1), L 28/4: several small folds in central body (Mag. 500 X)



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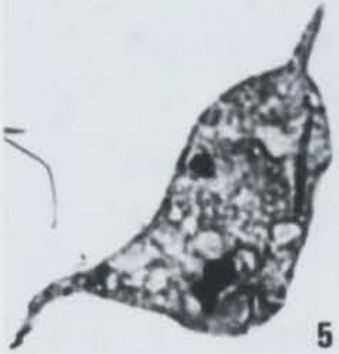

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PLATE 20

Figs. 1, 12 Leiofusa oculina SP. NOV.

Fig. 1 11 A 20-150 (2), U 29 2/4: small spine at one end; wrinkling of body surface poorly developed

Fig. 12 11 A 20-150 (2), S 42/4: (Mag. 500 X)

Figs. 2, 3, 5-8 Leiofusa stoumonensis VANGUESTAINE 1973

Fig. 2 24 B, specimen shifted: globular central body with long flagelliforme processes; specimen resembles L. flagellaris Burmann 1970 (Mag. X 500)

Fig. 3 3 C (P) 2, J 48/3: specimen with short processes (Mag. X 500)

Fig. 5 24 B 20-150 (3), G 37: longitudinal fold in central body (Mag. X 500)

Fig. 6 24 B 20-150 (2), M 47/48 3/4: long flagelliform process

Fig. 7 21 B (P) 2, T 12

Fig. 8 21 B (P) 3, OP 12/13: split in central body

Fig. 4 Pirea cf. ornata (BURMANN 1970) EISENACK 1976

Fig. 4 21 B (P) 1, T 12/1: short projection from antapical end

Fig. 10 Leiofusa sp. A

Fig. 10 21 B 20-150 (3), V 30/31: processes very short; junction of processes with central body well defined

Figs. 9, 11, 14 Poikilofusa? dubiostriata SP. NOV.

Fig. 9 21 B (P) 2 (1), R 8: longitudinal folding of the central body

Fig. 11 21 B 20-150 (1), J 25 (HOLOTYPE): prominent spinose ornamentation on processes and central body

Fig. 14 21 B 20-150 (1), LM 44

Fig. 13 Ooidium rossicum TIMOFEEV 1957

Fig. 13 24 C (P), E 49: prominent striation of equatorial zone


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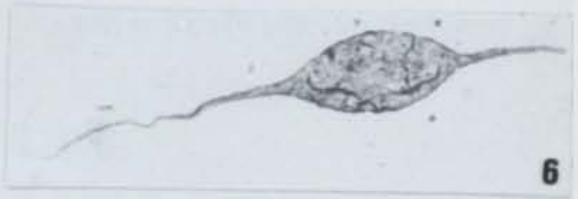
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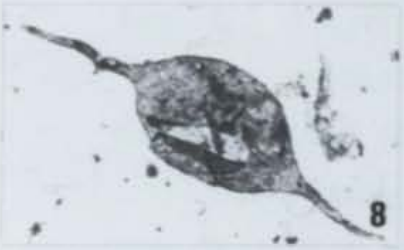
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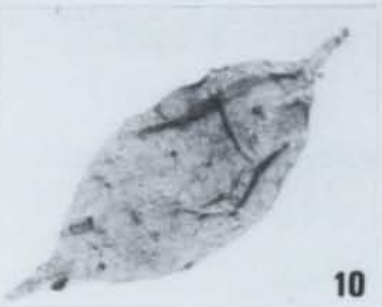
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PLATE 21

Fig. 1 Poikilofusa? dubiostriata SP. NOV.

Fig. 1 21 B (P) 2 (1), Q 8: some alignment of spinose ornamentation

Figs. 2-5 Ooidium rossicum TIMOFEEV 1957

Fig. 2 24 C (P), F 50 2/4

Fig. 3 24 C >10 (1a), Q 17/2

Fig. 4 24 C >10 (1), T 37: several folds in central body

Fig. 5 24 C >10 (1), LM 37 3/1

Figs. 6-9 Volkovia sp. A

Fig. 6 3 C (P), U 48/4: short spinose ornamentation on test

Fig. 7 24 B (P) 2, P 44: pole without process is rounded

Fig. 8 24 B (P) 2, O 47/2

Fig. 9 24 B (P) 2, L 45/3: jagged pylomar rim

Fig. 10 Coryphidium? sp.

Fig. 10 19 C >10 (1), U 35: process terminations bulbous to clavate

Figs. 11, 12 Estiastra sp. A

Fig. 11 E-C 7 >10 (1), F 24: funnel-shaped, overlapping processes with rounded terminations

Fig. 12 E-C 7 >10 (1), V 20

Figs. 13, 14 Goniosphaeridium gracilis (VAVRDOVÁ 1966) COMB. NOV.

Fig. 13 SH 13 >20 (4), D 18 1/2: hexagonal central body

Fig. 14 SH 13 >20 (5), H 37

Fig. 15 Goniosphaeridium pungens (TIMOFEEV 1959) RAUSCHER 1973.

Fig. 15 SH 13 > 20 (1), V 43/3: thin, often slightly curved processes

Figs. 16, 17 Goniosphaeridium eisenackianum? (DEUNFF 1958) COMB. NOV.

Fig. 16 SH 13 >20 (3), V 28/29 4/3: sparse spinose ornamentation on processes

Fig. 17 SH 13 >20 (4), O 23: subpolygonal central body

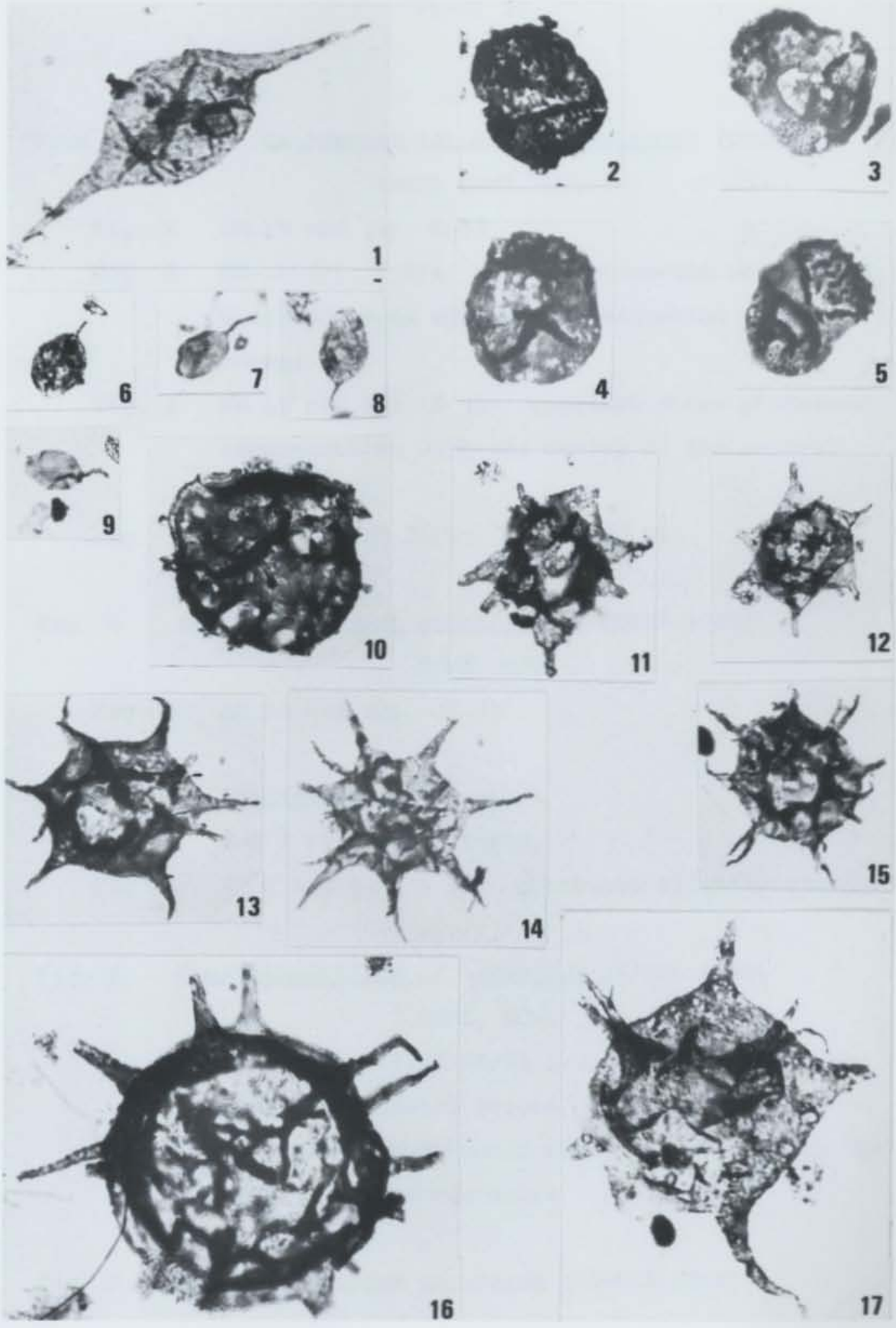
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PLATE 22

Figs. 1-3, 7 Goniosphaeridium eisenackianum? (DEUNFF 1958) COMB. NOV.

Fig. 1 SH 13 >20 (4), N 44

Fig. 2 SH 13 (P), T 8/4: narrow processes on this specimen; some spinose ornamentation of processes

Fig. 3 SH 13 >20 (1), E 43: specimen shows processes communicating with the cavity of the central body

Fig. 7 SH 13 (P), T 35/2: (Mag. 650 X)

Fig. 4 Goniosphaeridium gracilis (VAVRDOVÁ 1966) COMB. NOV.

Fig. 4 SH 13 >20 (5), JK 31

Figs. 5, 9 Goniosphaeridium sp. A

Fig. 5 E-C 7 >10 (1), M 39/40

Fig. 9 37 C >10 (1), S 51: processes slightly sinuous

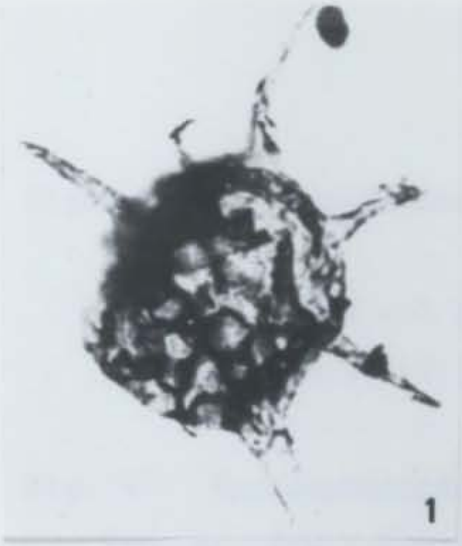
Fig. 6 Goniosphaeridium cf. symbolum (RASUL 1979) COMB. NOV.

Fig. 6 E-C 7 >10 (1), N 28/29 1/2: many of the processes are funnel-shaped, with a triangular base which makes sharp angular contact with the main stem of the process

Fig. 8 Goniosphaeridium uncinatum (DOWNIE 1958)

KJELLSTRÖM 1971

Fig. 8 E-C 7 >10 (3), J 20/21 2/1: strong lateral branches on processes .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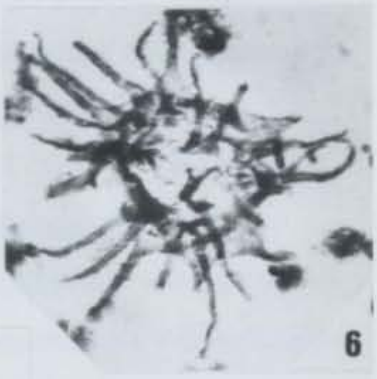
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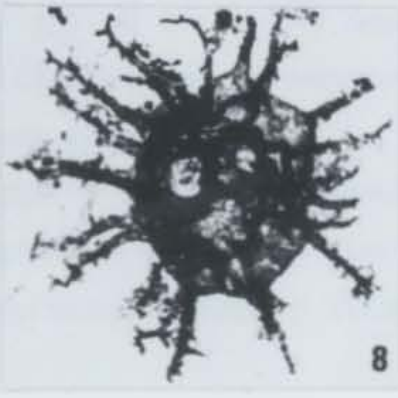
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PLATE 23

Figs. 1, 2 Goniosphaeridium uncinatum (DOWNIE 1958) KJELLSTROM 1971

Fig. 1 E-C 7 >10 (1), LM 25

Fig. 2 E-C 7 >10 (1), X 23

Fig. 4 Goniosphaeridium sp. A

Fig. 4 E-C 7 >10 (1), F 37/1: numerous slender processes

Figs. 3, 5, 6 Retisphaeridium dichamerum STAPLIN, JANSONIUS, AND POCOCK 1965

Fig. 3 12-20' >10 (3), S 13/2: polygonal network clearly defined on this specimen

Fig. 5 12-20' >10 (2), P 19: taper point folding visible on the perimeter

Fig. 6 12-20' >10 (1), WX 35 3/1: incomplete specimen with some distortion of polygonal fields

Figs. 7, 8, 26, 28 Impluviculus? bibulbulus SP. NOV.

Fig. 7 37 C 10 (1), D 42: inflated distal extremities

Fig. 8 E-C 7 >10 (5), G 29/2: no expansion of extremities; trifurcation, or second order bifurcation of one process

Fig. 26 37 C 10 (1), W 27/3: one process has a rounded base from which arise two short stalks; the other bifurcates directly without an intervening stem

Fig. 28 37 C 10 (2), HJ 39/40: no expansion of extremities

Figs. 9-12 Impluviculus milonii (DEUNFF 1968) LOEBLICH AND TAPPAN 1969

Fig. 9 3 C (P) 2, S 38/39 4/3

Fig. 10 3 C (P) 3, slide reference lost: rhombohedral operculum

Fig. 11 3 C (P) 1, S 43/4

Fig. 12 21 B (P) 3, F 14/4: fifth process present

Figs. 13, 15-21 Impluviculus circularis SP. NOV.

Fig. 13 E-C 7-8 >10 (2), PQ 19: circular body outline; eight processes present

Fig. 15 3 C 10-20 (2), K 23 1/3: body outline almost rhombohedral

Fig. 16 3 C 10-20 (2), PQ 24 3/1

Fig. 17 3 C (P) 1, F 41 1/2: all processes except one are paired

Fig. 18 24 B (P) 2, P 26

Fig. 19 3 C (P) 3, P 26/3: fifth process is not paired with any of the other four

Fig. 20 24 B (P) 2, Q 25/26 4/3 (HOLOTYPE): five slightly flexuous processes

Fig. 21 slide reference lost

Fig. 14 Specimen intermediate in shape between I. milonii and I. circularis

Fig. 14 3 C (P) 3, F 44/2: three processes arise from the same area

Figs. 23-25, 27 *Impluviculus? lacrimifer* SP. NOV.

Fig. 23 E-C 7-8 >10 (1), L 16/17 3/4

Fig. 24 24 B 10-20 (1), K 19/3

Fig. 25 24 B (P), N 50: central body slightly distorted

Fig. 27 24 B (P) 2, H 36/4 (HOLOTYPE): rhombohedral central body with irregular rhombohedral opening

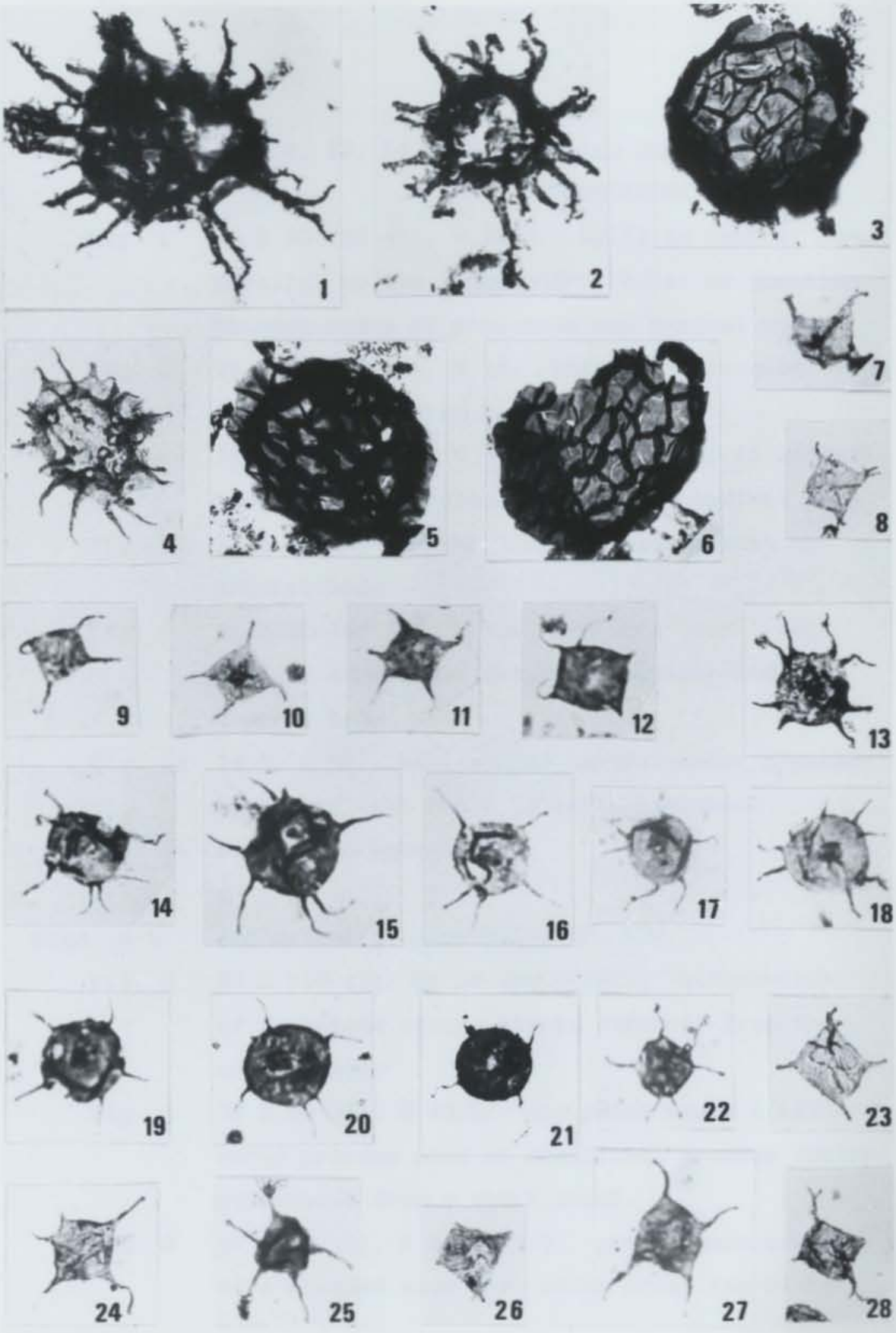
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PLATE 24

Figs. 1, 2, 6, 7, 9, 12, 14 Veryhachium dumontii VANGUESTAINE 1973

Fig. 1 24 B 20-150 (1), W 26/3: split in central body parallel to the longitudinal axis; no junction between bases of processes and central body

Fig. 2 24 B 20-150 (1), K 26: inflated triangular outline to central body

Fig. 6 24 B 20-150 (1), V 31/32 2/1: split in central body roughly parallel to the longitudinal axis

Fig. 7 24 B 20-150 (1), KL 37/38: oblique slit in central body

Fig. 9 21 B 20-150 (1), slide reference lost: well defined separation between processes and central body

Fig. 12 24 B, J 50: bell-shaped central body; ornamentation of test has a linear arrangement

Fig. 14 slide reference lost

Figs. 3-5 Impluviculus? bibulbulus SP. NOV.

Fig. 3 37 C >10 (2), DE 18 (HOLOTYPE): bifurcation of processes occurs almost directly from the central body

Fig. 4 37 C 10 (1), T 29/1: one point bears a bifurcated process plus an additional process (which bifurcates from a short stem)

Fig. 5 37 C 10 (2), E 22/23 4/3: one process consists of a rounded stub from which arise two disk-

like terminations borne on short stems

Fig. 8 . Veryhachium or Impluviculus species

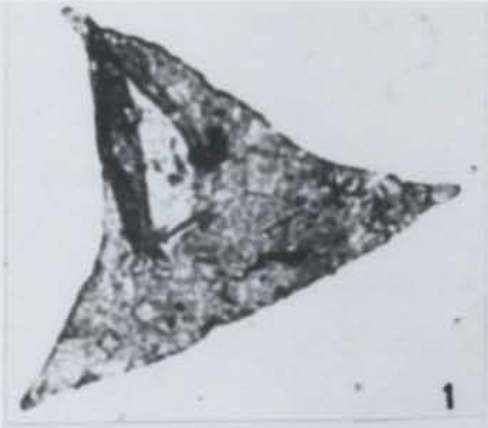
Fig. 8 24 B (P), O 43/1: there are five very long processes

Figs. 10, 11, 15 Veryhachium sp. B

Fig. 10 37 C >10 (2), C 29/4: inflated triangular central body

Fig. 11 37 C >10 (2), J 43/3: central body very globular; one process is somewhat longer than the other two

Fig. 15 37 C (2), Q 49 1/2: triangular central body is slightly inflated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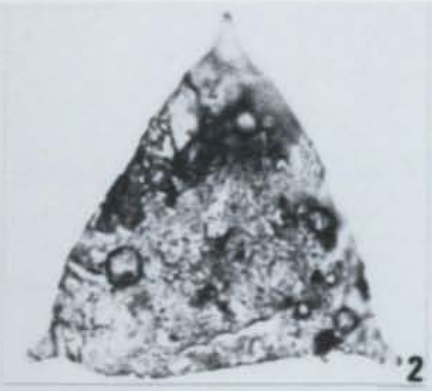
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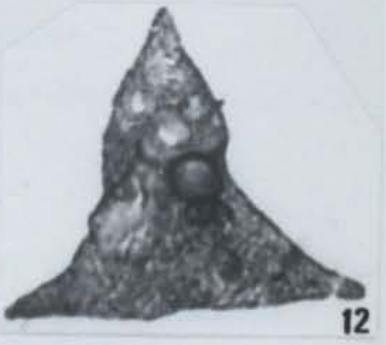
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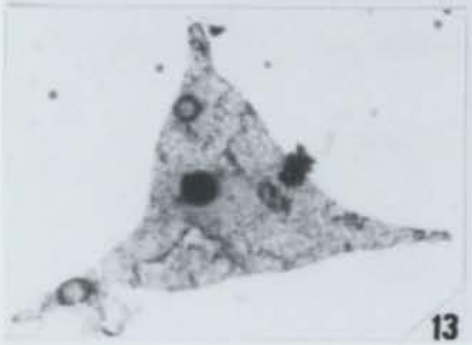
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PLATE 25

Figs. 1, 2, 5-6, ?7, 8 Veryhachium dumontii VANGUESTAINE 1973 ;

Fig. 1 21 B 20-150 (4), C 33/34.

Fig. 2 21 B 20-150 (4), O 50/51: the alignment of the granulation is clear on this specimen

Fig. 5 21 B (P) 1, M 39/4: central body has elongate, triangular outline; there is well-defined separation of the processes and central body

Fig. 6 21 B (P) 2, S 9.

Fig. 7 21 B 20-150 (3), H 23/24: two additional basal processes are present; the test shows faint granulation

Fig. 8 21 B (P) 1, T 21/22: very long processes

Figs. 3, 4 Veryhachium sp. B

Fig. 3 37 C >10 (2), D 48: inflated, subsquare central body; very short processes

Fig. 4 37 C (2), S 47/4: four processes

Fig. 9 Veryhachium sp. A

Fig. 9 24 B (P), LM 12: triangular central body; the basal processes are ~1/2 the length of the apical process

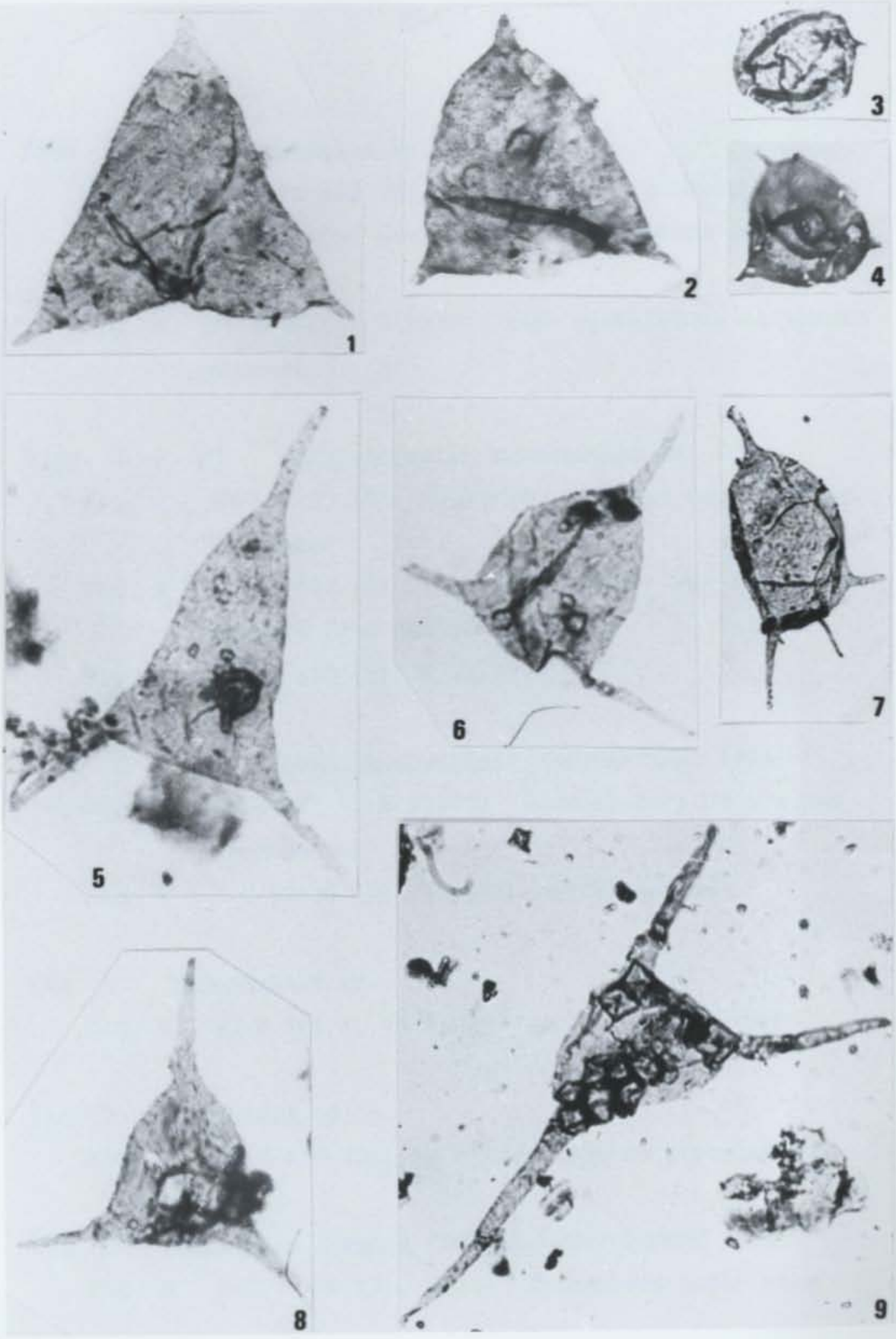
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PLATE 26

Figs. 1, 4 Veryhachium sp. A

Fig. 1 21 B 20-150 (4), Y 47/48 2/1: globular body with sparse granulation on processes and central body

Fig. 4 24 B (P) 1, T 18/1: some granulation on apical process

Figs. 2, 9, 10 Pterospermella snooksensis SP. NOV.

Fig. 2 SH 13 >20 (5), RS 25/26: central body dark at perimeter

Fig. 9 SH 13 >20 (2), V 18 (HOLOTYPE): short ribs radiate from the central body

Fig. 10 SH 13 >20 (5), K 26/27

Figs. 3, 6 Veryhachium dumontii? VANGUESTAINE 1973

Fig. 3 21 B (P) 1, R 11/12: unusual form of process arrangement

Fig. 6 3 C 10-20 (2), TU 24: small specimen

Fig. 5 Veryhachium sp.

Fig. 5 21 B (P) 1, VW 21/22

Fig. 7 Saharidia sp. A

Fig. 7 37 C >10 (2), XY 44/45: sparse granulation

Fig. 8 Saharidia fragile (DOWNIE 1958) COMBAZ 1967

Fig. 8 E-C 7 >10 (3), E 20: incomplete outer ring

(Mag. 350 X)

Fig. 11 - Nucellosphaeridium sp.

Fig. 11 E-C 7-8 >10 (1), M.14/4: small inner body shows folding


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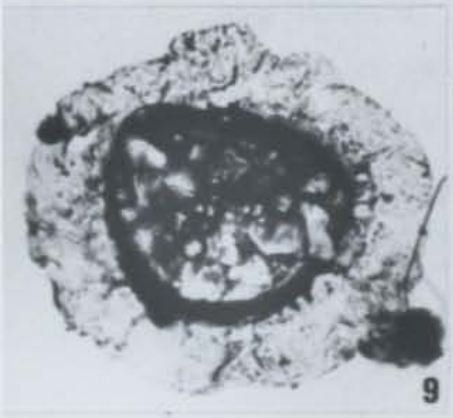
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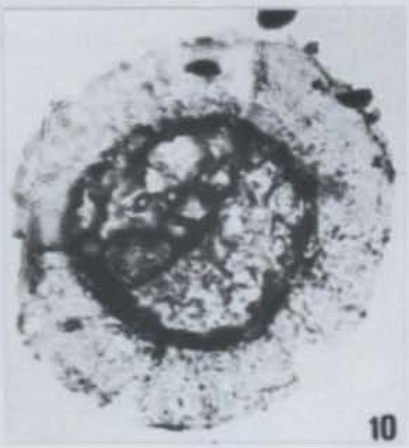
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PLATE 27

Figs. 1, 2, 4, 5, 7, 8 Cristallinium ovillense? (CRAMER AND DÍEZ 1972) MARTIN 1981

Fig. 1 21 B 20-150 (3), LM 42/3: short denticles on ridges; separation along plate margins

Fig. 2 21 B (P) 1, J 37

Fig. 4 21 B 20-150 (4), U 32: prominent denticulation

Fig. 5 21 B (P) 1, K 48/3

Fig. 7 21 B (P) 2 (1), H 10/11

Fig. 8 21 B 20-150 (2), T 30/3: separation along plate margins

Figs. 3, 6, 9, 10 Cristallinium randomense MARTIN 1981

Fig. 3 30 B >20 (2), OP 37: processes arranged in widely spaced tufts

Fig. 6 30 B >20 (3), R 46/2

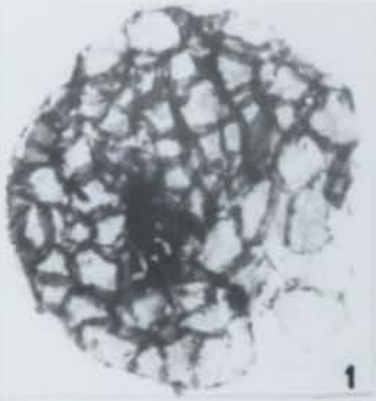
Fig. 9 22 B-2 20-150 (1), PQ 46

Fig. 10 3 C 20-150 (1), O 49/50: processes generally occur singly; they are coming to resemble those of C. cambriense

Figs. 11, 12 Trunculumarium? sp. A

Fig. 11 SH 13x >20 (1), F 52/53 2/1: tapering processes at one pole

Fig. 12 SH 13x >20 (1), E 45 1/2: filaments interconnect the processes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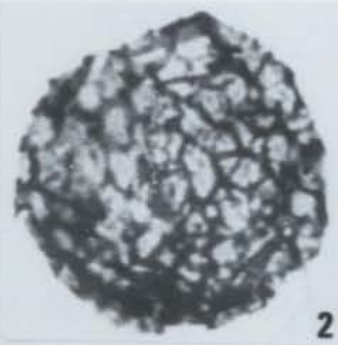
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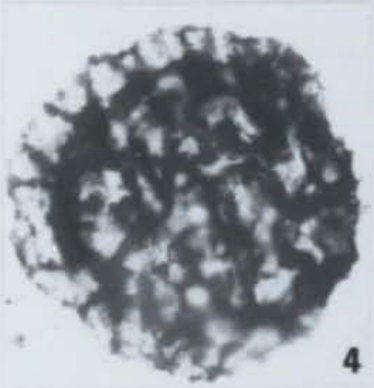
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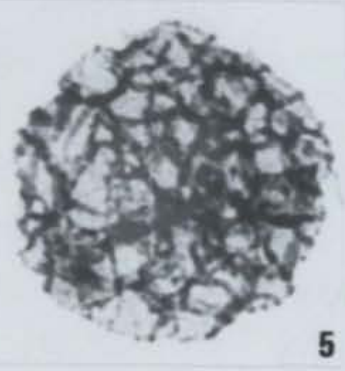
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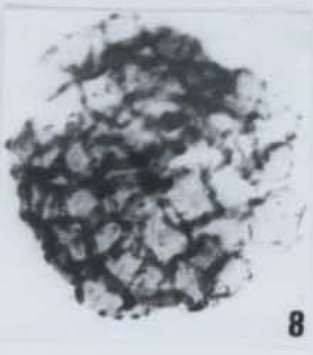
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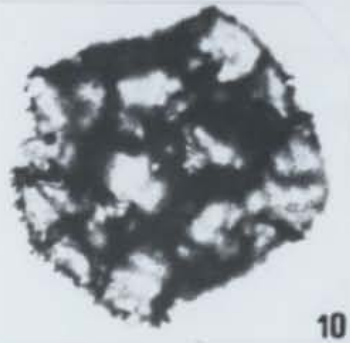
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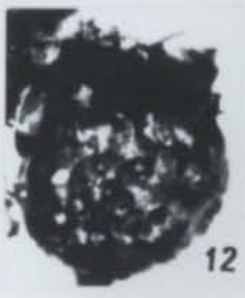
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PLATE 28

Figs. 1-8, 10, 11 Cristallinium cambriense (SLAVIKOVÁ 1968) VANGUESTAINE 1978

Fig. 1 3 C 20-150 (1), slide reference lost: broad triangular denticles on the ridges; one plate has partially separated

Fig. 2 SH 13 >20 (1), H 27

Fig. 3 21 B 20-150 (3), GH 24: very short triangular denticles

Fig. 4 24 B 20-150 (1), slide reference lost

Fig. 5 3 C, slide reference lost

Fig. 6 21 B (P) 1, NO 11: long slender denticles

Fig. 7 SH 13 >20 (4), P 22/3

Fig. 8 3 C (P) 3, U 16: separation along plate margins; broad triangular denticles

Fig. 10 SH 13 >20 (4), Q 40/1: very sparse ornamentation of ridges; denticles small

Fig. 11 SH 13 >20 (5), R 29: not much ornamentation of the ridges

Figs. 9, 12 Cristallinium randomense MARTIN 1981

Fig. 9 21 B (P) 2. (2), N 37/38 4/3: spines occur in groups; they resemble those of the short spined forms of V. turbata

Fig. 12 30 B >20 (2), O 47/48: long slender processes


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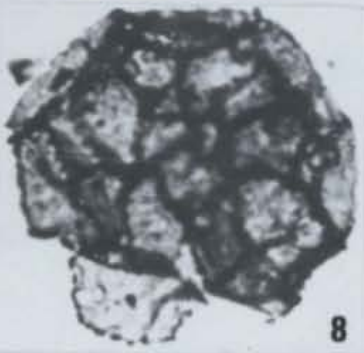
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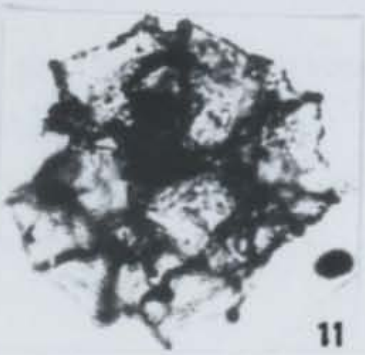
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PLATE 29

Figs. 1, 3 Citrofusa curiosa GEN. AND SP. NOV.

Fig. 1 21 B 20-150 (2), S 29/30 (HOLOTYPE): 'stick-like' projections at either pole; the upper one in the illustration is covered in a thin membrane

Fig. 3 21 B (P) 2 (1), H 10/4: smaller specimen

Figs. 5, 6, 10, 11 Leiospheres

Fig. 5 3 C 10-20 (1), slide reference lost: thin-walled sphere

Fig. 6 12-20' (1), ST 37 4/2: split in sphere; the dot-like ornamentation is randomly distributed. This specimen closely resembles Leiosphaeridia sp. 1 Cramer and Diez 1972.

Fig. 10 21 B (P), R 19/4: folded sphere with granular surface

Fig. 11 37 C (1), U 43/1: shagrinate surface; several folds present

Figs. 2, 4-7 Thick-walled sphaeromorphs

Fig. 2 24 B 20-150 (1), R 31: two thick walled spheres

Fig. 4 19 C >10 (2), slide reference lost: thick-walled sphere

Fig. 7 22 B-2 20-150 (1), R 48: thick-walled sphere with concentric folding

Fig. 8 Cymatiosphaera sp. (undescribed)

Fig. 8 SH 13 >20 (1), RS 48: subpolygonal central body with granular veil

Fig. 9 Arbusculidium rommelaeri MARTIN 1981

Fig. 9 E-C 7-8 >10 (1), H 10/11 2/1: this specimen resembles Vulcanisphaera tuberata (Downie 1958) Eisenack et al. 1973 in the nature of its simple processes

Fig. 12 Impluviculus milonii DEUNFF 1968

Fig. 12 E-C 7 >10 (5), G 20/21: no pylome present

Figs. 13, 14 Saharidia sp. A

Fig. 13 Z-2 >10 (1), H 8/4: pylome present

Fig. 14 Z-2 >10 (2), J 47/48


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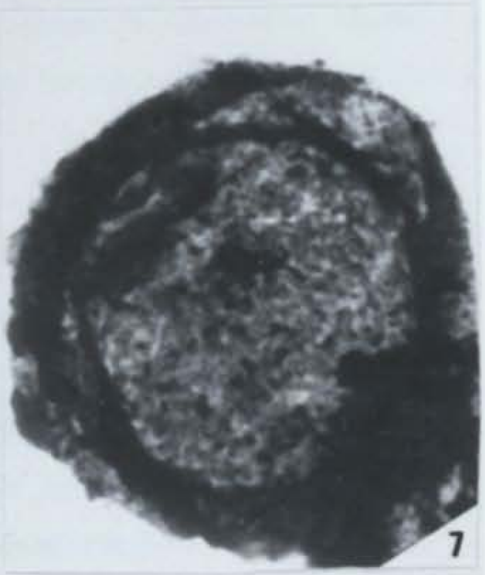
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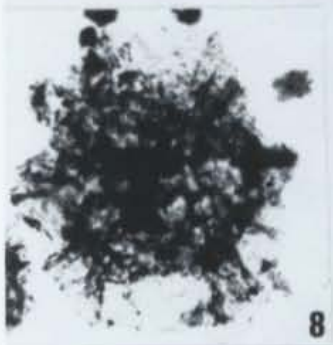
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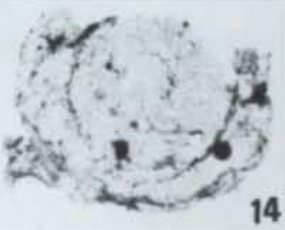
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PLATE 30

Figs. 1-3 Arbusculidium? penicillum SP. NOV.

Fig. 1 ABC 10 10-20 (1), R 31/4: three simple processes

Fig. 2 E-C 7-8 >10 (2), L 31: prominent longitudinal striation

Fig. 3 Z-5 >10 (1), B 24/2 (HOLOTYPE): five simple processes are present at one pole, and a well developed network of filaments connects those at the other pole; some longitudinal striation is evident

Fig. 4 Arbusculidium? sp.

Fig. 4 Z-5 >10 (2), T 39/40 4/3: long, slender processes occur at one pole and a fine thread-like mass surrounded by simple processes is present at the other pole; this specimen may be an extreme variant of A. rommelaeri

Figs. 5-7 Trunculumarium revinium (VANGUESTAINE 1973) LOEBLICH AND TAPPAN 1976

Fig. 5 E-C 7 >10 (1), C 40: ornamentation on the central body and processes not strongly developed

Fig. 6 Z-10 >10 (1), CD 26 4/2

Fig. 7 Z-10 >10 (1), D 13: very strongly developed ornamentation on the central body and processes

Figs. 8-12, 15, 16 Ooidium? clavigerum SP. NOV.

Fig. 8 ABC 10 10-20, FG 23 (PARATYPE): several transverse splits in the central body; processes are clasp-like in shape

Fig. 9 ABC 10 >20 (1), N 47/4: one very small process visible

Fig. 10 ABC 10 >20 (1), UV 21

Fig. 11 ABC 10 >20 (1), F 45: elongate central body

Fig. 12 ABC 10-20, U 23 3/4 (HOLOTYPE): processes are 'matchstick-like'; several transverse folds are present

Fig. 15 ABC 10 >20 (2), C 30/31: pronounced rupturing of the central body

Fig. 16 ABC 10-20, F 6/7 2/1: some, but not all, of the processes have expanded terminations

Figs. 13, 14, 17 Striatotheca sp.

Fig. 13 ABC 10 >20 (2), L 46: marked striation of the central body

Fig. 14 ABC >20 (1), E 23: processes vary greatly in size

Fig. 17 Z-5 >10 (2), C 14: processes rounded distally

Fig. 18 Multiplicisphaeridium sp. A

Fig. 18 Z-3 >10 (1), H 51: circular central body; the characteristic branching pattern of the processes is clearly visible


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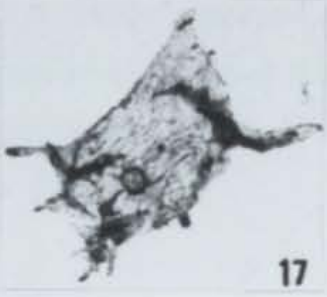
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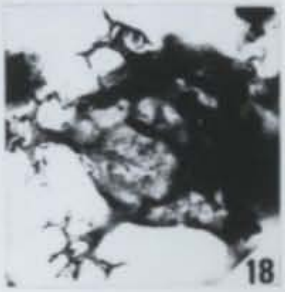
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PLATE 31

Figs. 1, 2 Baltisphaeridium crinitum MARTIN 1978

Fig. 1. Z-2 >10 (2), C 50/1: folded specimen with prominent hairs on processes

Fig. 2 Z-5 >10 (2), N 48/2: folded specimen with long, hollow, ornamented processes

Fig. 3 Vulcanisphaera capillata JARDINÉ ET AL. 1974

Fig. 3 Z-2 >10 (2), Q 53/54 2/1: numerous fine, thread-like filaments arise from the processes

Fig. 4 Goniosphaeridium pungens (Timofeev 1959) Rauscher 1973

Fig. 4 E-C 7 >10 (1), F 42: central body circular in outline

Figs. 5, 8 Goniosphaeridium gracilis VAVRDOVÁ 1966, COMB. NOV.

Fig. 5 Z-5 >10 (2), W 17/1

Fig. 8 Z-5 >10 (2), C 39/40 2/3

Figs. 6, 9, 10 Cymatiogalea bouvardi MARTIN 1973

Fig. 6 ABC 11 >10 (1), G 37 1/3: operculum in place

Fig. 9 ABC 11 >10 (2), C 16/3: pylome slightly distorted; processes hollow, and closed off from central body cavity.

Fig. 10 ABC 11 >10 (1), G 34/1

Fig. 11 Cymatiogalea cf. bouvardi MARTIN 1973

Fig. 11 30 B (P), J 16/4: processes sturdier than for typical C. bouvardi specimens

Fig. 7, 12 Goniosphaeridium species

Fig. 7 SH 13 >20 (5), L 43/1: Goniosphaeridium species with circular outline to central body and strong, tapering processes

Fig. 12 12-20', slide reference lost: unidentified species from the Middle Cambrian

Fig. 13 Veryhachium sp.

Fig. 13 21 B 20-150 (4), N 40 2/4: large species with long processes


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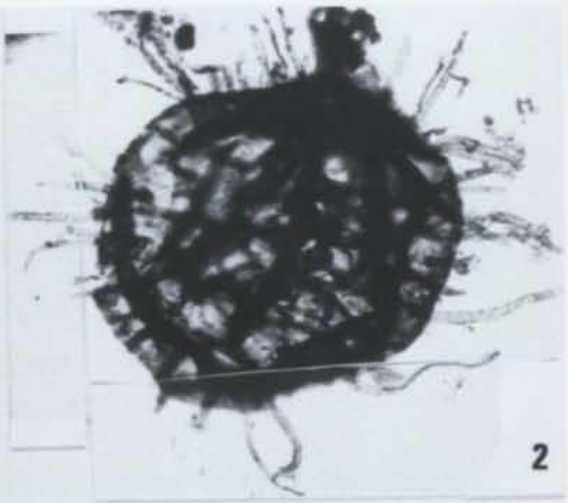
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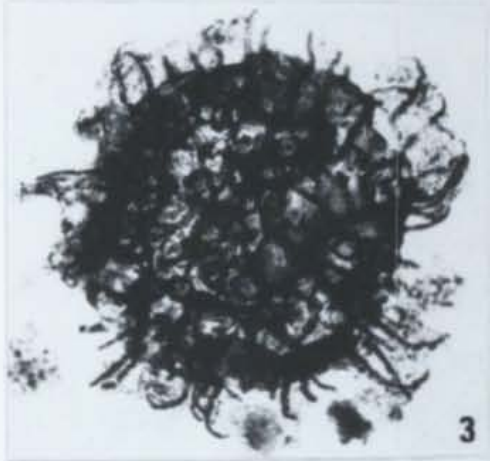
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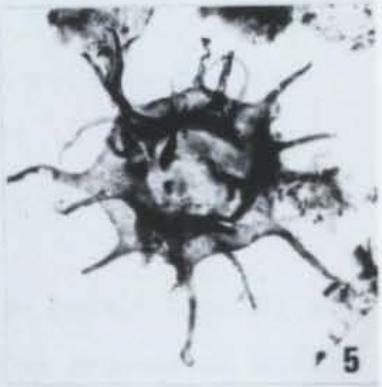
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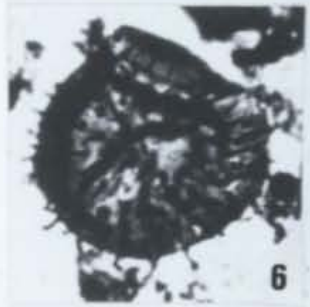
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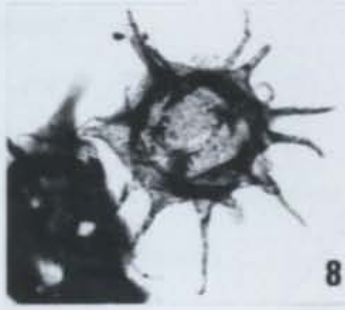
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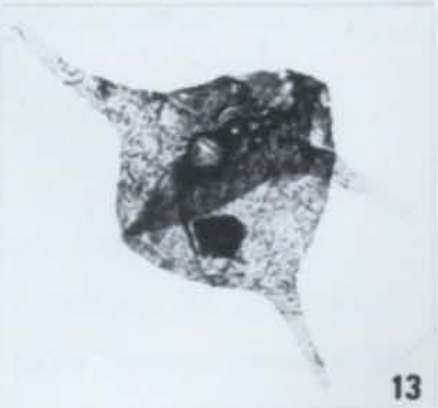
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PLATE 32

Figs. 1, (?) 2, 3-6, (?) 7-9, (?) 11 Dasydiacrodium caudatum VANGUESTAINE 1973

Fig. 1 3 C, specimen shifted

Fig. 2 30 B >20 (2), O 26/27: no antapical processes; sparse granulation

Fig. 3 3 C 10-20 (1), T 25/2: two antapical processes; heavy granulation

Fig. 4 3 C fil (1), N 46: oblique slit in central body; two antapical processes

Fig. 5 Z-10 >10 (2), D 8/2: from assemblage RI 4; seven antapical processes

Fig. 6 Z-10 >10 (2), BC 11/12: from assemblage RI 4; eight antapical processes. The processes have some polarity to their arrangement.

Fig. 7 24 B 10-20 (1), G 27/28 3/4: weak granulation; fairly irregular process arrangement

Fig. 8 24 B 20-150 (1), Y 26 1/3: process arrangement approaching that of the genus Tectitheca Burmann 1968

Fig. 9 24 B 20-150 (1), OP 24 3/1: somewhat ellipsoidal central body with one bifurcating process

Fig. 11 24 B 20-150 (1), K 28/1:

Figs. 10, 12, 13 Goniosphaeridium sp. (UNIDENTIFIED)

Fig. 10 24 B 20-150 (3), P 20/21: polygonal central body; processes and body have heavy granulation

Fig. 12 SH 13 >20 (4), W 22/1: outline of central body masked by overlapping processes; sparsely granular ornamentation

Fig. 13 SH 13 >20 (3), L 29: polygonal central body; body surface shagrinate




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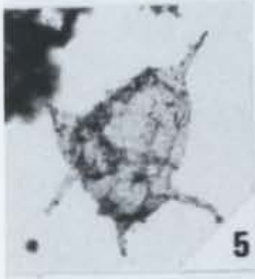
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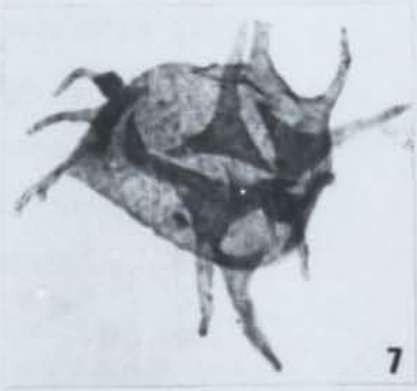
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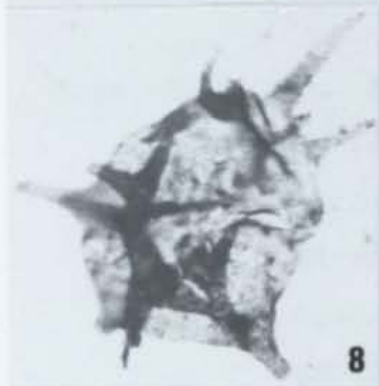
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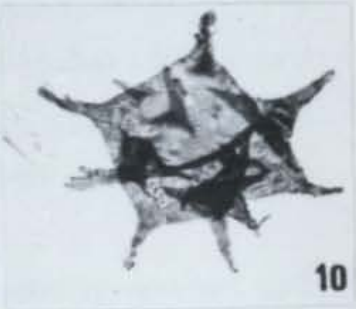
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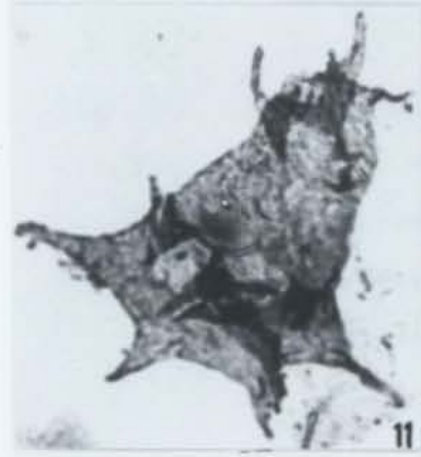
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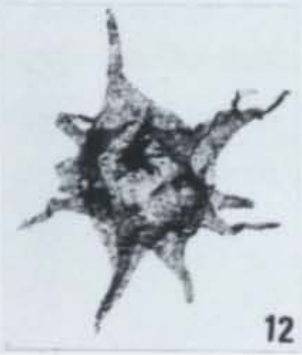
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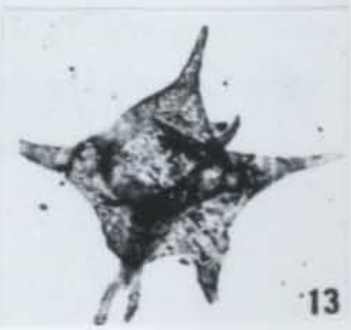
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PLATE 33

Fig. 1 Cymatiogalea? membranula MARTIN 1978

Fig. 1 ABC 11 >10 (2), T 23: veils extend part-way along the processes; this resembles the effect produced by incurving of the body wall in T. phosphoritica

Fig. 2 Timofeevia lancarae (CRAMER AND DÍEZ 1972) VANGUESTAINE 1978

Fig. 2 SH 13z >10 (2), V 34/3: hollow processes; the incurving of the body wall resembles veils interconnecting the processes

Fig. 3 Timofeevia phosphoritica VANGUESTAINE 1978

Fig. 3 SH 13z >10 (2), X 32/33

Figs. 4, 6, 7 Acanthodiacrodium cf. achrasi MARTIN 1973

Fig. 4 SH 13z >10 (1), M 30: some bipolarity to process arrangement; resembles A. complanatum

Fig. 6 SH 13 >20 (1), N 38: processes have broad bases

Fig. 7 SH 13x >20 (1), R 48 2/4: heavily-spined polygonal form

Fig. 8 Impluviculus? bibulbulus SP. NOV.

Fig. 8 E-C 7 >10 (5), DE 38 3/1: two of the processes bifurcate from a stem, a third bifurcates near the base, and the fourth appears to be truncated

Fig. 9 Unidentified Lophosphaeridium? species

Fig. 9 12-20' (1), T 37/2

Fig. 10 Acanthodiacrodium? sp.

Fig. 10 SH 13 >20 (2), M 29/30: like A. cf. achrasi but the ornamentation is weakly developed. This may be A. complanatum viewed from an angle

Figs. 11, 12 Veryhachium sp. A

Fig. 11 E-C 7-8 >10 (2), P 35/2: square, somewhat inflated, central body; very short processes, possibly truncated

Fig. 12 E-C 7-8 >10 (1), HJ 7 3/1: central body is split at one pole; opaque processes, some with slender, hair-like terminations

Fig. 13 Dasydiacrodium longispinatum SP. NOV.

Fig. 13 E-C 7-8 >10 (2), R 12/13: processes are oriented at an angle to the longitudinal axis; one additional basal process

Figs. 14-16 Lophosphaeridium sp.

Fig. 14 24 C >10 (1), V 45

Fig. 15 E-C 7-8 >10 (2), XY 1: equatorial fold present

Fig. 16 E-C 7 >10 (1), H 18/1: equatorial fold; processes have large bases, resembling those of A. discigerum sp. nov.


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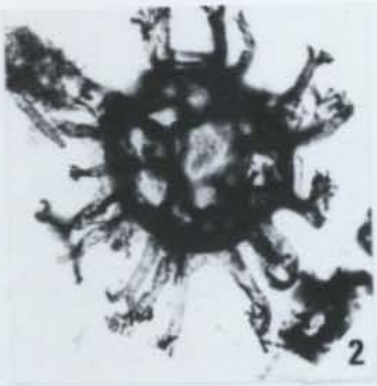
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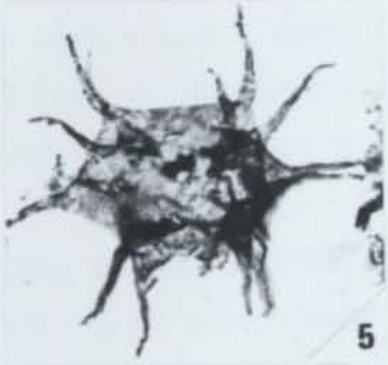
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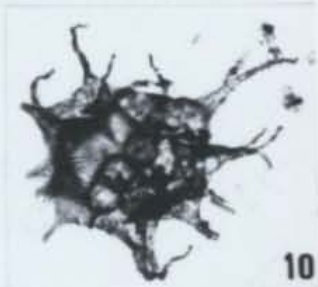
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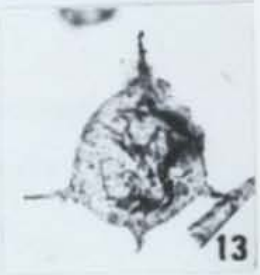
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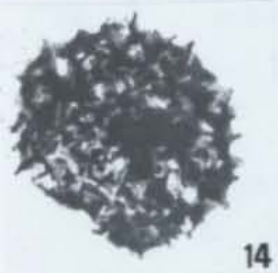
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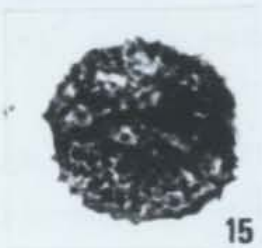
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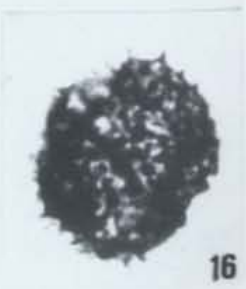
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PLATE 34

Figs. 1, 2 Leiofusa oculina SP. NOV.

Fig. 1 11 A 20-150 (2), OP 39 (HOLOTYPE): well-developed wrinkling of the body produces a scalloped effect in places; one extremity of the body is slightly pointed, the other is drawn out into a small spine (Mag. 500 X)

Fig. 2 detail of Fig. 1: large granules ornament the area around the spine and the spine itself

Figs. 3, 4 Poikilofusa squama (DEUNEF 1961) MARTIN 1977

Fig. 3 Z-4 >10 (2), Q 45 3/4: test is fairly wide

Fig. 4 Z-5 >10 (1), L 24/4

Fig. 5 Leiofusa stoumonensis VANGUESTAINE 1973

Fig. 5 3 C: smooth central body (Mag. 750 X)

Fig. 6 ?Retisphaeridium dichamerum STAPLIN, JANSONIUS, AND POCOCK 1965

Fig. 6 12-20' (1), C 25/3: distorted specimen, the surface of which is divided into polygonal fields like those of R. dichamerum

Fig. 7 Lophosphaeridium sp. (UNIDENTIFIED)

Fig. 7 12-20' (1), slide reference lost

Fig. 8 Cymatiogalea digitata SP. NOV.

Fig. 8 3 C: processes present on pylomar rim; most of

the veil has disappeared (Mag. 2000 X).

Fig. 9 Acanthodiacrodium sp. A

Fig. 9 . E-C 7: broken process reveals hollow base; the opaque, slender portion of each process extends downward into the base as a corner-shaped wedge


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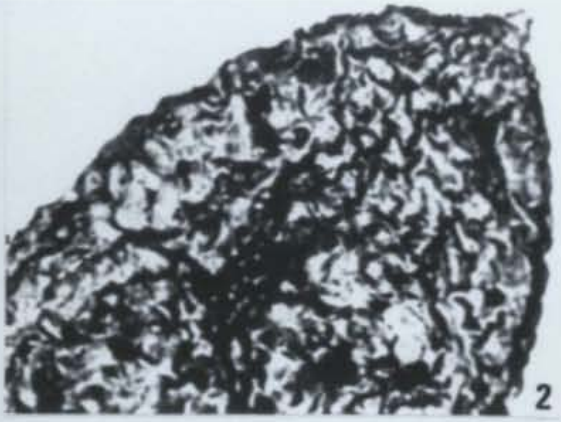
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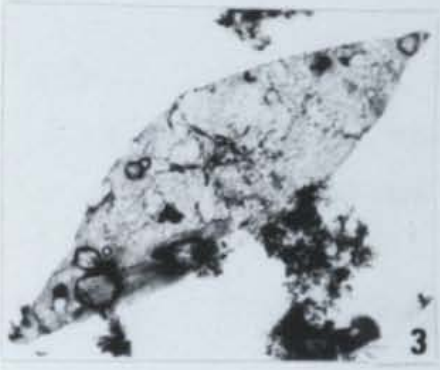
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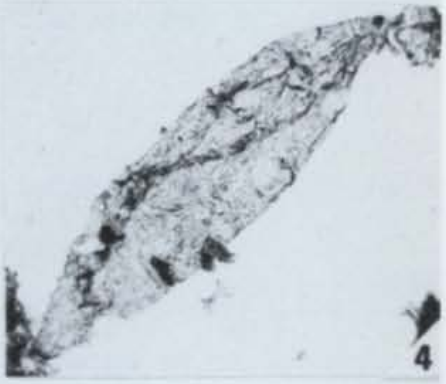
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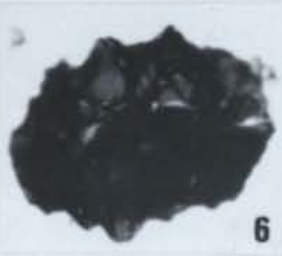
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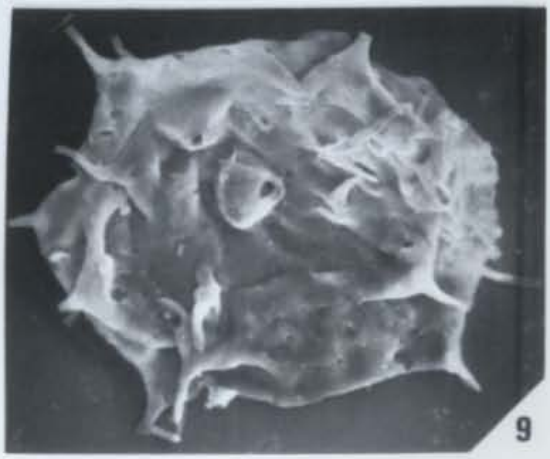
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PLATE 35

Fig. 1 Timofeevia pentagonalis VANGUESTAINE (1974) 1978

Fig. 1. 6 A: surface of central body slightly granular (Mag. 2050 X)

Fig. 2 Timofeevia? cuspidatum SP. NOV.

Fig. 2 6 A: smooth central body; processes triangular in shape (Mag. 2050 X)

Fig. 3 Cristallinium cambriense (SLAVIKOVÁ 1968) VANGUESTAINE 1978

Fig. 3 3 C: specimen shows the double row of processes on each ridge (Mag. 1000 X)

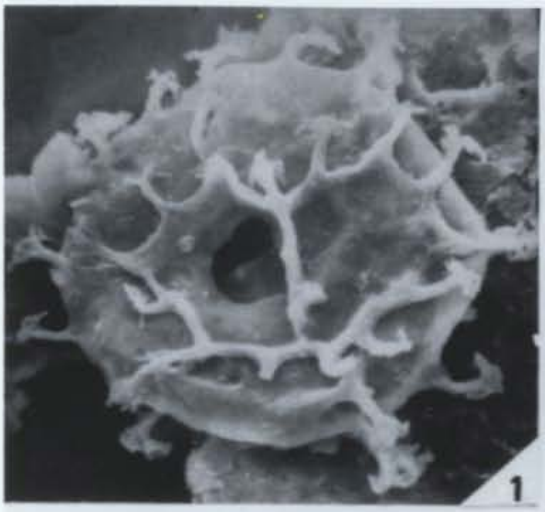
Fig. 4 Cymatiogalea sp.

Fig. 4 6 A: resembles Cymatiogalea bouvardi; faint lines radiate from the base of each process. This specimen is stratigraphically much lower than undoubted specimens of C. bouvardi. (Mag. 1750 X)

Figs. 5, 6 Paliosphaeridium? clavigerum SP. NOV.

Fig. 5 6 A: mainly stalked processes present on this specimen (Mag. 2050 X)

Fig. 6 6 A: opening present is probably a damage feature (Mag. 2050 X)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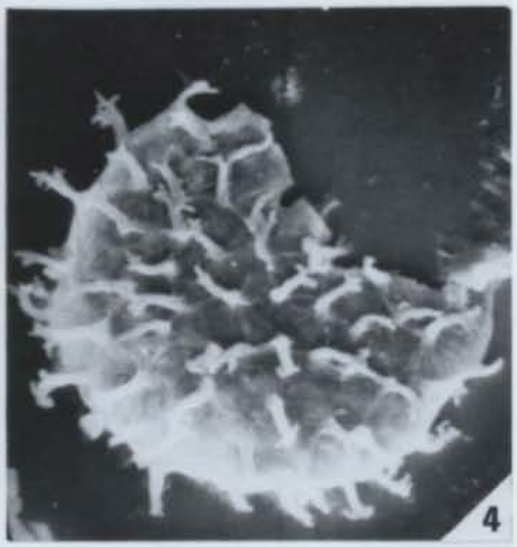
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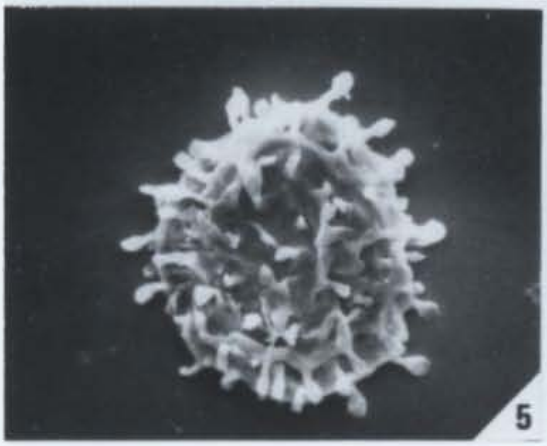
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PLATE 36

Figs. 1, 3 Acanthodiacrodium randomense SP. NOV.

Fig. 1 E-C 7-8: shows ornamentation of processes and central body (Mag. 1560 X)

Fig. 3 E-C 7-8: ornamentation generally spinose (Mag. 1640 X)

Figs. 2, 4 Lophosphaeridium? sp. A

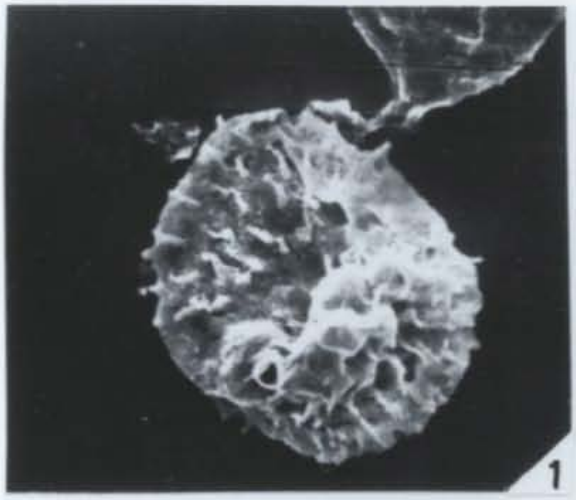
Fig. 2 E-C 7-8: equatorial fold present (Mag. 1770 X)

Fig. 4 E-C 7: most of the processes taper slightly, but some have an expanded base (Mag. 1640 X)

Figs. 5, 6 Lophosphaeridium? sp.

Fig. 5 part of Fig. 6 at higher magnification: this photograph is rotated ~90 degrees counter-clockwise with respect to Fig. 6.

Fig. 6 E-C 7-8: specimen resembles the stratigraphically lower species A. discigerum sp. nov. in the nature of its processes, but no barren equatorial zone can be detected; such a zone could, however, be masked by folding, or might not be observable due to the orientation of the specimen. This could, alternatively, be a form of Lophosphaeridium? sp. A with larger processes (Mag. 1640 X)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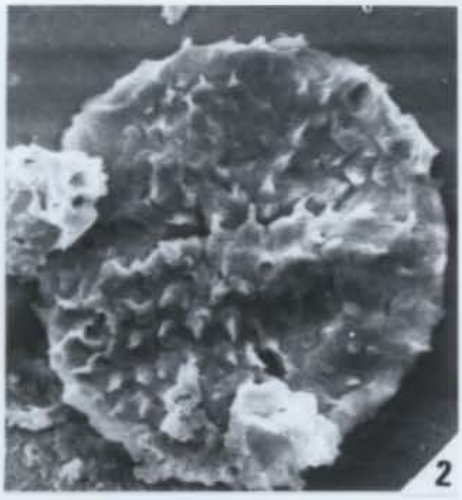
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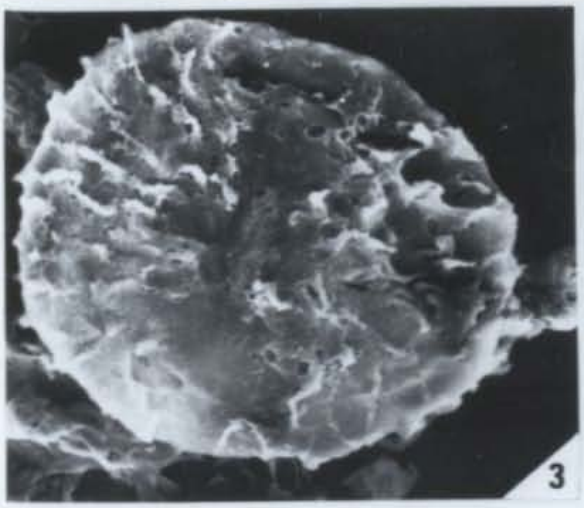
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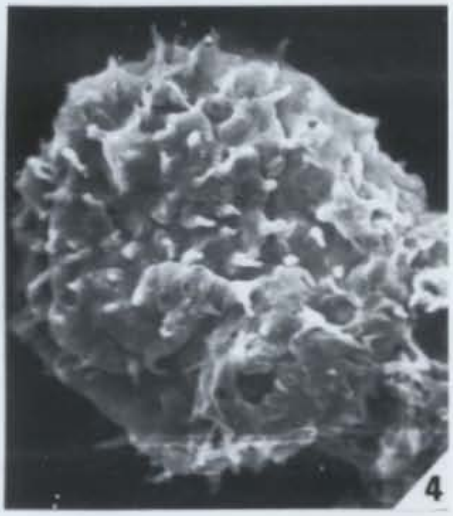
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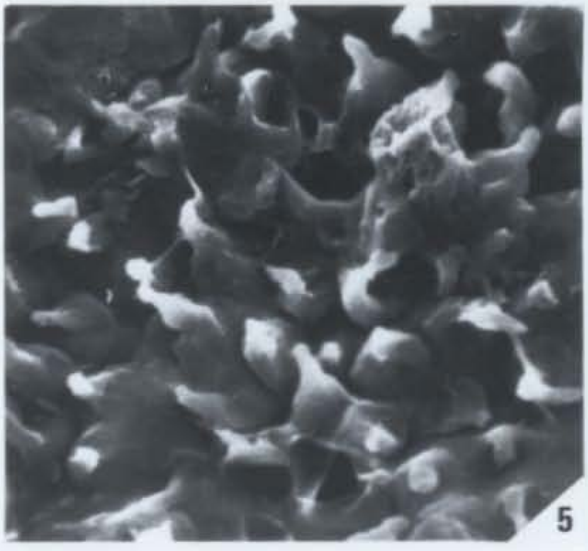
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PLATE 37

Figs. 1, 4 Dasydiacrodium longispinatum SP. NOV.

Fig. 1 E-C 7: U-shaped outline to central body; the apical process is broken (Mag. 1640 X)

Fig. 4 E-C 7-8: outline of central body intermediate between circular and U-shaped (Mag. 1560 X)

Figs. 2, 3 Hamatodiacrodium bucerum UMNOVA 1971

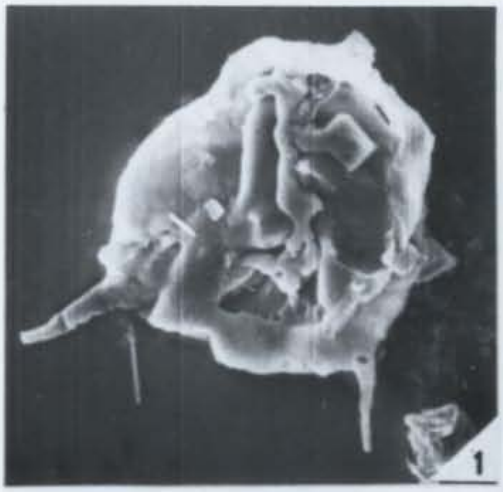
Fig. 2 E-C 7: no apical process (Mag. 1640 X)

Fig. 3 E-C 7: the short apical spine may be partly broken; several pyrite crystals lie inside the body cavity (Mag. 1640 X)

Figs. 5, 6 Acanthodiacrodium andersoni SP. NOV.

Fig. 5 SH 13: specimen shows ornamentation of the processes and central body (Mag. 1840 X)

Fig. 6 detail of Fig. 5: spinose nature of ornamentation is evident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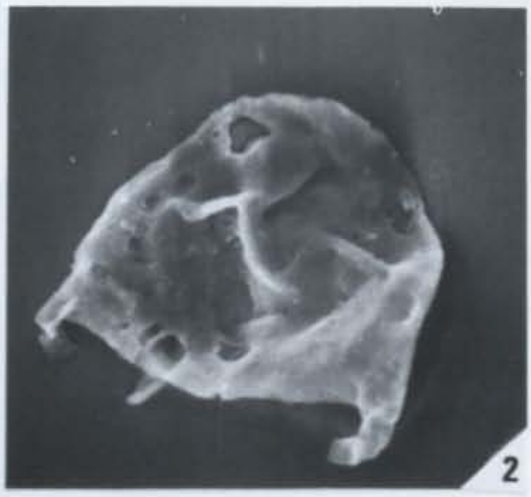
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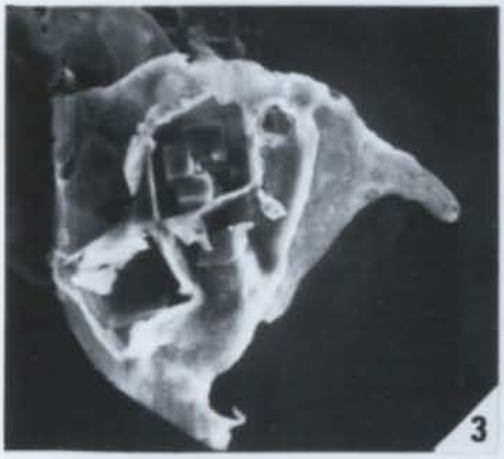
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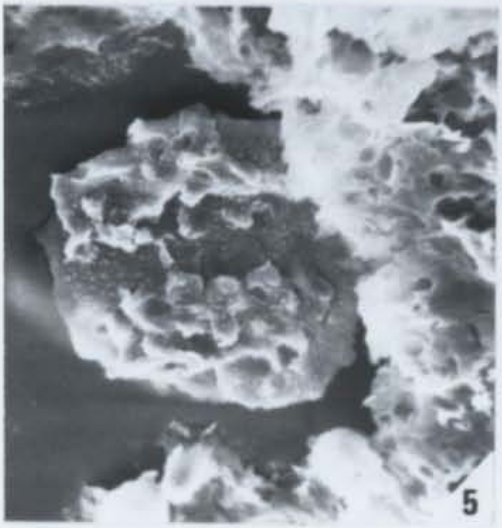
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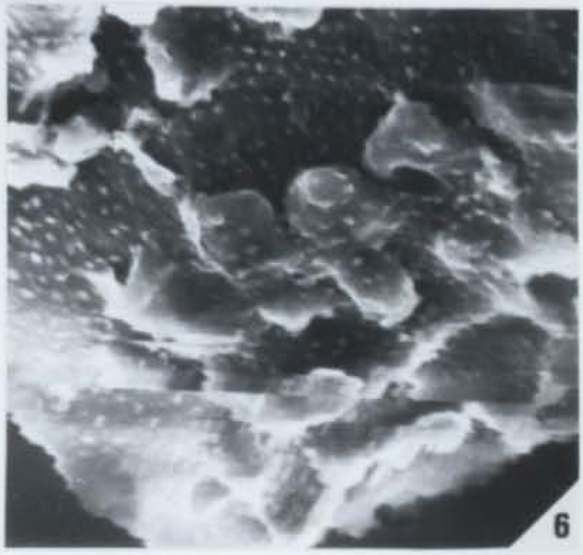
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APPENDIX ONE

SECTION DESCRIPTION AND SAMPLE LOCATIONS

The scarcity of diagnostic marker beds within the Middle Cambrian to Tremadoc succession of the Elliott's Cove section on Random Island, made it impossible to use such beds to relate sample localities to different stratigraphic levels within the section. It was, therefore, necessary to use other unnamed 'features' of the coast, readily recognizable when walking along the beach, as reference points. These 'features' are mostly small headlands or promontories that were also used by Dean and Martin (1981) for the same purpose, and their numbering system (Roman numerals) for distinguishing the headlands has been adopted here (Map 1). Other 'features' used here as additional reference points are the pebble conglomerate at the base of the Elliott Cove Formation, the bentonite layer and fault at the base of the Manuels River Formation, igneous intrusions, prominent folds, streams, and boulders imbedded in the beach. The last are glacial erratics that are too large to be moved by wave action even during storms. The more important 'features' are indicated on Map 1 which shows the position of the sample localities listed at the end of this section. Other 'features' are mentioned in the description of the section that follows which relates the sample localities to lithological units.

CHAMBERLAIN'S BROOK FORMATION

Unit Description of section

Unit 1 of the Chamberlain's Brook Formation occurs immediately north of a fault that separates it from red, green, and purple shales with intercalations of limestone of the Bonavista Formation.

1 A composite unit made up of an alternation of red and green shales. These are highly cleaved; the cleavage fragments form pencil-like splinters in the upper part of the unit. Manganese staining is ubiquitous. Unit 1 is equivalent to Beds 3-7 of Hutchinson 1962. (SAMPLES 3-4, 5)

Thickness 44 m

2 The shales of this unit undergo a gradual colour change from green at the bottom of the unit to grey-green at the top. Manganese staining further modifies the colour. The shales exhibit the same kind of cleavage as those of Unit 1. ~3.5 m below the top of the unit are three pink or green beds of limestone, one ~30 cm thick and two ~15 cm thick. (SAMPLES 9, 11)

Thickness 28.5 m

There is a small talus slope partially interrupting the sequence between Units 2 and 3, but the beds appear to be continuous in the cliff above the slope. The colour change that began in Unit 2 is most evident in Unit 3.

3 The beds of Unit 3 of the Chamberlain's Brook Formation are

separated from the overlying bentonite layer at the base of the Manuels River Formation by a fault. (The bentonite layer is hidden in an erosional recess marking the position of the fault.) Shales enclosing a limestone bed (~15 cm thick) adjacent to the fault on its southern side are tightly folded into a narrow V-shaped syncline. The grey-black shales of Unit 3 are splintery and show some distorted trilobite fragments and lingullellids. Units 2 and 3 are equivalent to Bed 8 of Hutchinson, 1962. (SAMPLE 12-20) Thickness 5.5 m

MANUELS RIVER FORMATION

Unit Description of section

4 A thin bentonite layer forms the base of this unit of black slatey shale. The shales immediately above the bentonite layer form a conspicuous ridge on the beach. The ridge is further distinguished by the presence of distorted trilobite fragments, small pyrite nodules, and brachiopods on exposed bedding surfaces. This unit is equivalent to Beds 9 and 10 of Hutchinson, 1962. (SAMPLES C-15, R+1.5, MC-6, 12) Thickness 21.8 m

5 Unit 5 is a prominent ridge composed of two ~15 cm limestone bands separated by ~30 cm of black shale. This unit is approximately equivalent to Bed 11 of Hutchinson, 1962, p.144. Thickness 0.6 m

6 Beyond the ridge are black slatey shales with limestone concretions (one reaching a metre in diameter and 15 cm in thickness). This unit is approximately equivalent to Beds 12 and 13 of Hutchinson, 1962, p.144. (SAMPLE MC-5)

Thickness 1.2 m

7 The section up to the basal conglomerate of the Elliott Cove Formation comprises thinly bedded, black shales (sometimes silty) with numerous fragments of Paradoxides and other trilobites on the bedding planes. There are also several thin (~10 cm) interbeds of grey or black limestone. This unit is approximately equivalent to Beds 14-16 of Hutchinson, 1962, p.144. (SAMPLES MC-4, C-10, MC-3, 13, MC-2, MC-1)

Thickness 13 m

ELLIOTT COVE FORMATION

Unit Description of Section

8 The base of the Elliott Cove Formation is marked by a conglomeratic layer up to 10 cm thick underlain by a conspicuous yellow-weathering band of shale. The conglomerate is made up of sub-angular to well-rounded clasts of phosphatic shale, up to 5 cm in diameter, in a silty matrix.

Thickness 0.1 m

9 Above the conglomerate are thinly-bedded soft, grey-black shales, often pyritiferous. There are also rare beds of siltstone from 2 to 5 cm thick, and, in the cliff section

beyond the conglomerate several rows of ellipsoidal limestone concretions. Just above the conglomerate some drag-folding has occurred, but the section becomes regular again further on. Estimated thickness 12 m

The section is partly concealed in the vicinity of a small waterfall at Pt. I.

10 The soft grey, micaceous shales and interbedded siltstones of this unit are iron stained, and the latter are cross-bedded and ripple-marked. Siltstone predominates in this unit. Numerous blocks of siltstone bearing ripple-marks (ranging in thickness from < 1 cm to ~15 cm) cover the beach beyond the waterfall. Some of these show load casting. Small concretions are again present. (SAMPLE 1 A)
Thickness 24.5 m

At the second small point north of the conglomerate the section is locally concealed for approximately 6 m along the beach.

11 Grey-black shales with interbeds of siltstone and sparse lenticular concretions up to 30 cm in diameter are exposed immediately beyond the second small point north of the conglomerate. (SAMPLES 3 A, 4 A, 5 A) Thickness 42 m

Section concealed for ~12 m along the beach.

12 This unit is like the underlying unit in composition but is exposed in the cliff before the overburden which obscures

the section for a short distance beyond it, are several thicker beds of siltstone or fine-grained sandstone, one ~30 cm thick, and several ~20 cm thick. (SAMPLE 6 A)

Thickness 11 m

Section concealed for ~3 m along the beach.

13 Grey-black shales with occasional thin beds of siltstone. The beds at the beginning of this part of the section are downwarped due to slumping. Agnostids are common in this unit. (SAMPLES 7 A, 8 A, 9 A-2) Thickness 38 m

14 Unit 14 is made up of 10 - 30 cm thick beds of siltstone interbedded with grey-black shale. The siltstones are cross-bedded and ripple-marked. Load casts, flute casts, and groove casts are present on the undersurfaces of the beds of siltstone. The proportion of siltstone to shale increases towards the top of this unit (from ~10 % to ~80 % or more). (SAMPLES 9 A-1, 10 A, 11 A) Thickness 27.5 m

15 A prominent sill forms Pt. III. Thickness 0.9 m

A small brook crosses the beach beyond the sill.

16 Thin beds of micaceous siltstone (generally ~1-2 cm thick), interbedded with soft grey shale. A powdering of sulphur is present on the surface of the shales. The siltstones make up as much as 50 % of the unit in places. Trace fossils are associated with the siltstones. (SAMPLE 1 B)

Thickness 7.5 m

There is only one poorly exposed outcrop of shales between Units 16 and 17. The distance from Unit 16 to Unit 17 along the beach is 21 m.

17 Interbedded shales and siltstone similar to those of Unit 16. (SAMPLES 2 B-1 and 2 B-2) Thickness 0.9 m

18 A sill intrudes the shales at this stratigraphic level. Thickness 0.9 m

Section concealed for ~10.5 m along the beach.

19 Similar lithologically to preceding unit. Thickness 2.5 m

20 At Pt. IV the sequence is intruded by a sill. Thickness 0.75 m

21 The sequence above the sill is a continuation of that present below it - siltstones and shales - the siltstones making up as much as 80 % of the sequence in places. Thickness 13 m

Overburden obscures the outcrop for 38 m along the shore.

22 Shales with intercalations of siltstone; the siltstones range from 1 to 8 cm in thickness, although there are some exceptions as much as 30 cm thick. (SAMPLE 8 B) Thickness 3.5 m

23 This part of the section, which ends at Pt. IV-a, consists,

in general, of shale interbedded with siltstone (1 to 8 cm thick, but occasionally up to 30 cm thick). However, within the unit there are shale sequences several metres thick that are virtually devoid of interbeds of siltstone. The undersurfaces of the siltstones commonly bear load casts. (SAMPLE 10 B) Thickness 26 m

Section concealed for ~36.5 m along the beach.

24 Interbedded siltstones and shales. (SAMPLE 14 B) Thickness 5.5 m

The section is interrupted for ~12 m along the shore.

25 Small, conspicuous anticlinal fold made up of grey-black shales interbedded with siltstone. The most prominent beds, (each up to a metre thick) in this structure, although resembling siltstones, were found to be basaltic sills. (SAMPLE 15 B) Thickness 12.8 m

Section concealed for ~6 m along the beach.

26 Grey-black shales with thin (~1-3 cm) intercalations of siltstone. Thickness 4 m

27 A number of massive fine-grained sandstone beds, some up to 45 cm thick, form a distinctive association. In outcrop these are badly weathered, so no sedimentary structures are observable, but several blocks on the beach exhibit lamination. Thickness 2.7 m

28 Above the sandstone unit is a series of shales with interbeds of siltstone 1-3 cm thick; the proportion of siltstone to shale is low. Rarely cone-in-cone concretions are present. A small rivulet flows through the middle of this unit. (SAMPLE 17 B) Thickness 7.5 m

Section concealed for ~12 m along the beach.

29 South of Pt. V is similar initially to Unit 28, but in this case the percentage of siltstone to shale increases from the bottom to the top of the unit; thus, the upper part of the unit consists predominantly of siltstone. Current lineation is a conspicuous feature on the surfaces of the beds of siltstone. (SAMPLES 18 B, 20 B, 21 B, 22 B-1, 22 B-2) Thickness 43 m

Overburden partly masks the section for ~7.5 m along the beach.

30 North of Pt. V almost to Pt. VI, orange weathering beds of crossbedded siltstone (1-10 cm thick) are interbedded with silty micaceous shale. Many ripple-marked bedding surfaces are exposed along this part of the section. The numerous siltstone blocks on the beach bear abundant trace fossils (burrows). (SAMPLE 24 B) Thickness 20 m

The section is obscured by overburden for ~24 m south of Pt. VI, and for ~27 m north of Pt. VI.

31 The strata north of Pt. VI comprise grey-black, pyritifer-

ous, somewhat silty shales with occasional interbeds of siltstone. Orusia lenticularis is abundant in this unit. (SAMPLE 30 B) Estimated thickness 13.5 m

Section concealed for ~24 m along the beach.

32 Pyritiferous shales interbedded with numerous thin (~5 cm thick or less) beds of siltstone, are folded into an anticline between a small promontory north of Pt. VI, and a stream that 'cuts' the anticline. Thickness 27 m

33 About 30 m north of the stream, the strata are folded into a broad flat-crested anticline. The anticline is made up largely of ripple-marked beds of siltstone (2-15 cm thick) with very little shale present between them. Thickness 20 m

34 South of Pt. VII, the section resumes its NNW dip. The unit is made up of soft, grey-black shale with thin intercalations of siltstone 1 to 2 cm thick. Rare cone-in-cone concretions are present. (SAMPLES 3 C, ABC 14) Estimated thickness 25 m

35 Just north of Pt. VII there are two small folds. The shales here are soft, grey, and pyritiferous; 1-2 cm thick beds of siltstone are present but rare in this unit. (SAMPLES 5C, ABC 13, ABC 12) Thickness 3 m

36 Unit 36 comprises near horizontal to gently dipping soft grey shales in which Orusia lenticularis is common. (SAMPLE Z-10) Thickness 5.5 m

37 Steeply dipping soft grey shales, containing ellipsoidal concretions (20-30 cm diameter). The shales often have sulphur on their surfaces. The unit ends at a possible fault (noted by Martin and Dean, 1981). (SAMPLES Z-9, 8 C, AC-H) Thickness 25.5 m

38 Above the fault there are soft grey shales (at times silty) with occasional interbeds of siltstone 1 to 5 cm thick (rarely up to 20 cm thick). This part of the section, from the fault northward to a prominent dark green, glacially-striated boulder at Pt. VIII, exhibits tight chevron folding. No thickness estimate is given for this unit. (SAMPLES Z-8, AC-G, AC-F, Z-7, AC-E, AC-D, Z-6, AC-A)

For ~85 m along the beach, north of the striated boulder at Pt. VIII, the cliffs have collapsed and there are only small isolated outcrops. About 25 m north of the striated boulder, and opposite to a large black boulder on the beach, there is a small outcrop of soft, grey, pyritiferous shale. (SAMPLES ABC 11, AC-2). ~30 m further north is a second outcrop of the same type of shales. (SAMPLE AC-1) This last sample may belong to the Clarenville Formation.

?ELLIOTT COVE/CLARENVILLE FORMATION

39 22 m north of the previous small outcrop, dark grey shales are recumbently folded. (SAMPLES ABC 10, Z-5)
Thickness 3.5 m

40 Beyond the recumbent fold, the soft grey shales and silty shales, with cone-in-cone concretions, are very much disturbed by folding. The lower part of Unit 40 is obscured by trees and shale scree. No estimate is given for the thickness of this part of the section because of its irregularity. (SAMPLES AC-W, Z-4)

41 From a small promontory south of Pt. IX, northward to a prominent white boulder at Pt. IX, the dip of the shales is steep to vertical. (SAMPLES ABC 9, 19 C, Z-3, ABC 8, 24 C)
Thickness 67 m

CLARENVILLE FORMATION

42 Between Pt. IX and Pt. X, the shales are hard, grey, micaceous, and pyritiferous. Thin beds of siltstone are rare. Cone-in-cone concretions are also present. Throughout most of the unit, the beds are steeply dipping, but midway between Pt. IX and Pt. X, there is a conspicuous anticlinal fold overturned to the northwest. (SAMPLES Z-2, AC-B, Z-1, 30 C, 32 C)
Estimated thickness 207 m

43 North of Pt. X, the shales are asymmetrically folded. No thickness estimate is given.

44 The shales are again undisturbed, except at the top of the unit where they are slightly distorted. Intercalations of siltstones are rare in this unit. Thickness 44 m

45 From Pt. XI to the stream north of Pt. XI the shales are hard, grey, and pyritiferous, with some cone-in-cone concretions. The strike of the beds is parallel to the shore. (SAMPLES 37 C, 38 C) Thickness 6 m

46 North of the stream the beds dip steeply seaward. Where the stream cut has exposed a section at right angles to the coastline, the dark grey shales are seen to be complexly folded. (SAMPLES 39 C, 40 C) Thickness 27 m

47 At Pt. XII, the section is almost completely obscured. The beds dip steeply seaward, and bedding surfaces with many cone-in-cone concretions are exposed. No estimate is made of thickness for this unit. (SAMPLE 42 C)

The shales between Pt. XII and the stream at Elliott's Cove are exposed in small outcrops, with much of the section being concealed due to collapse of the cliffs.

48 South of Pt. XIII is a short section of steeply dipping grey-black shales. Thickness 5 m

49 North of Pt. XIII to the brook at Elliott's Cove, the shales are hard, grey-black and pyritiferous, and there are occasional cone-in-cone concretions present. The beds are, for the most part, steeply dipping. (SAMPLE E2)
Estimated thickness 63 m

No estimate of the thickness of the section between the

last outcrop south of the brook at Elliott's Cove and the last outcrop just north of the community has been given because the changing dip and strike of the beds makes an accurate estimate impossible. (SAMPLES EC 5, EC 4, EC 3, EC 2, EC 1, E-C 9). The lithology of these strata is the same as that of Unit 49.

SAMPLE LOCALITIES

SAMPLES FROM THE CHAMBERLAIN'S BROOK FORMATION

Four samples were taken from the Chamberlain's Brook Formation.

Sample 3-4: from shales ~100 m north of the dyke at Gock and Hen Point. (barren)

Sample 9: from green shales ~278 m north of the prominent dyke forming Cock and Hen Point. (barren)

Sample 11: ~4.5 m below the limestone bands near the top of Unit 2 (barren)

Sample 12-20': from the uppermost part of the Chamberlains Brook Formation, 5 m below the ridge near the base of Unit 5 and ~4 m below the fault separating the Manuels River and Chamberlains Brook Formations. (well preserved but sparse acritarchs)

SAMPLES FROM THE MANUELS RIVER FORMATION

Eleven samples were taken from the Manuels River Formation.

Samples MC-6 and 12: from the ridge near the base of Unit 4. (barren)

Sample R+1.5: ~18.5 m below the conglomerate and about 2 m above the ridge near the base of Unit 4. (productive)

Sample C-15: ~16 m below the conglomerate and ~1 m below the lower limestone band of Unit 5. (productive)

Sample MC-5: ~14 m below the conglomerate. (barren)

Sample MC-4: ~11 m below the conglomerate. (barren)

Sample C-10: ~10 m below the conglomerate. (productive)

Sample MC-3: ~6 m below the conglomerate, above a group of siltstones in Unit 7. (barren)

Sample 13: ~3.5 m below the conglomerate. (barren)

Sample MC-2; ~3 m below the conglomerate, above the first siltstone below the conglomerate. (barren)

Sample MC-1: ~60 cm below the conglomerate at the base of the Elliott Cove Formation. (barren)

SAMPLES FROM THE ELLIOTT COVE FORMATION

All samples were taken from shales unless otherwise noted. Because of the extent of the Elliott Cove Formation, the sample localities are combined into geographic groups.

Eleven samples were taken between the conglomerate and the sill at Pt. III.

Sample 1 A: ~30 m north of the conglomerate. (productive)

Sample 3 A: ~97.5 m north of the conglomerate. (barren)

Sample 4 A: ~122 m north of the conglomerate. (barren)

Sample 5 A: ~152.5 m north of the conglomerate. (productive)

Sample 6 A: ~182 m north of the conglomerate. (very productive)

Sample 7 A: 213.5 m north of the conglomerate. (productive)

Sample 8 A: ~244 m north of the conglomerate. (barren)

Sample 9 A-2: ~274.5 m north of the conglomerate, from shales containing agnostids, lingulellids, and ostracodes, and in from a large white boulder on the beach. (productive)

Sample 9 A-1: ~290 m north of the conglomerate. (barren)

Sample 10 A: ~305 m north of the conglomerate. (productive)

Sample 11 A: ~335.5 m north of the conglomerate, and ~30.5 m south of the sill at Pt. III. (very productive)

Three samples were taken between the sill at Pt. III and the sill at Pt. IV.

Sample 1 B: ~30 m north of Pt. III. (productive)

Sample 2 B-1: ~61 m north of Pt. III, from a silty layer. (barren)

Sample 2 B-2: ~10 cm below sample 2 B-1, from a shaley layer with 1 mm long lingullellids. (barren)

Five samples were taken between Pt. IV and the anticline.

Sample 6 B: from a silty layer ~61 m north of Pt. IV. (productive)

Sample 8 B: ~122 m north of Pt. IV, from an outcrop by a path and small stream. (very productive)

Sample 10 B: ~185.5 m north of Pt. IV, from shales ~65 cm above a sandstone (siltstone) bed with load casts. (very productive)

Sample 14 B: from a silty band ~305 m north of Pt. IV, and

~30.5 m before the anticline. (productive)

Sample 15 B: at the anticline, from shales ~1 m above the base of the anticline. (productive)

Six samples were taken between the anticline and Pt. V.

Sample 17 B: from a 15 cm bed ~61 m beyond the core of the anticline. (productive)

Sample 18 B: ~83.5 m north of the anticline. (productive)

Sample 20 B: ~154.5 m beyond the anticline. (very productive)

Sample 21 B: ~167 m north of the anticline. (very productive)

Sample 22 B-2: from a shaley band at Pt. V, ~201.5 m north of the anticline. (very productive)

Sample 22 B-1: from a silty band ~6 m above 22 B-2. (productive)

Two samples were taken from the section between Pt. V and a prominent stream ~373 m further north (north of Pt. VI).

Sample 24 B: ~65 m north of Pt. V. (very productive)

Sample 30 B: ~242.5 m north of Pt. V and ~128 m before a prominent stream. (very productive)

Nineteen samples were taken from the section extending northward from just south of Pt. VII to Pt. VIII.

Sample 3 C: ~30.5 m north of the stream mentioned above for sample 30 B. (very productive)

Sample ABC 14: just south of Pt. VII, from shales ~1/2 m above the base of the outcrop that overlie a 4 cm siltstone band. (very productive)

Sample 5 C: from a pitching anticline just north of Pt. VII. (very productive)

Sample ABC 13: ~2 m above sample 5 C. (very productive)

Sample ABC 12: from the base of the anticline. (very productive)

Sample Z-10: ~46 m north of the pitching anticline. (very productive)

Sample Z-9: ~91.5 m north of the pitching anticline. It lies directly in from a distinctive pink and white boulder on the beach. (productive)

Sample 8 C: sample taken on a different occasion from approximately the same level as Z-9.

Sample AC-H: ~101.5 m north of the pitching anticline and ~10 m north of the crystalline boulder. This location is just below the fault noted by Martin and Dean, 1981. (very productive)

Sample Z-8: ~122 m north of the pitching anticline. (productive)

Sample AC-G: ~30 m north of sample AC-H. This location is just above the fault noted by Martin and Dean, 1981. (very productive)

Sample AC-F: ~31 m north of sample AC-G. (very productive)

Sample Z-7: sample taken on a different occasion from approximately the same level as AC-F. (very productive)

Sample AC-E: ~36.5 m north of sample AC-F and ~35 m south of a very large, striated, dark green boulder at the first promontory at Pt. VIII. (productive)

Sample AC-D: ~3 m south of the beginning of the first outcrop south of the striated green boulder. The sample was taken ~1 m above a 20 cm siltstone bed. (very productive)

Sample Z-6: from the first outcrop south of the striated boulder. (very productive)

Sample AC-A: ~1 m above Z-6, from an outcrop higher up the cliff, and partly hidden by trees. (very productive)

Sample ABC 11: from the first outcrop north of the green boulder. (very productive)

Sample AC-2: ~61 m south of a concretion which acts as a marker point in a distinctive fold structure. (very productive)

Four samples were taken on the north side of Random Island from the first outcrop north of the abandoned Snooks Harbour brick works.

Sample SH 13z: from the lowest part of the outcrop. (very productive)

Sample SH 13: ~2 m above SH 13z. (very productive)

Sample SH 13y: ~19 m above SH 13z. (very productive)

Sample SH 13x: ~4 m above SH 13y, from the highest part of the outcrop. (very productive)

SAMPLES FROM THE ?ELLIOTT COVE/CLARENVILLE FORMATION

Ten samples were taken between Pt. VIII and Pt. IX.

Sample AC-1: from a small outcrop which is the second north of the striated boulder, and ~23 m south of the concretion in the distinctive fold structure. (very productive)

Sample ABC 10: from the horizontal beds immediately preceding the fold. (very productive)

Sample Z-5: sample taken on a different occasion from approximately the same level as sample ABC 10. (very productive)

Sample AC-W: from the base of an outcrop ~27.5 m north of the concretion in the distinctive fold structure. (very productive)

Sample Z-4: ~46 m north of the concretion in the distinctive fold structure. (productive)

Sample ABC 9: ~122 m north of the concretion in the distinctive fold structure. (very productive)

Sample 19 C: sample taken on a different occasion from approximately the same level as sample ABC 9. (very productive)

Sample Z-3: ~213 m north of the concretion in the distinctive fold structure. (very productive)

Sample ABC 8: in from a very large white boulder at Pt. IX. The sample was taken from ~1.5 m below a 30 cm siltstone bed. (very productive)

Sample 24 C: just north of ABC 8. (very productive)

SAMPLES FROM THE CLARENVILLE FORMATION

Five samples were taken between Pts. IX and X.

Sample Z-2: ~78 m north of the white boulder at Pt. IX. (very productive)

Sample AC-B: ~18 m north of Z-2, from a little spur of outcrop with near vertical bedding. (very productive)

Sample Z-1: ~60 m south of Pt. X, from an outcrop which has excellent exposure to the top of the cliff. (very productive)

Sample 30 C: ~30 m south of Pt. X. (productive)

Sample 32 C: at Pt. X. (very productive)

Five samples were taken between Pt. IX and Pt. XII.

Sample 37 C: north of Pt. XI, ~20 m south of a prominent stream. (very productive)

Sample 38 C: from the outcrop on the south bank of the stream, between Pt. XI and Pt. XII. (productive)

Sample 39 C: between Pt. XI and Pt. XII, ~30 m north of the stream. (very productive)

Sample 40 C: ~61 m north of the stream. (very productive)

Sample 42 C: at Pt. XII. (very productive)

Seven samples were collected from outcrops in the immediate vicinity of Elliott's Cove.

Sample E2: from the outcrop south of the stream at Elliott's Cove. (productive)

Sample EC 5: from the first outcrop on the right side of the tra[illegible] leading to the beach at Elliott's Cove. (very productive)

Sample EC 4: sample taken on a different occasion from approximately the same level as sample EC 5. (very productive)

Sample EC 3: ~15 m south of the wharf at Elliott's Cove. (very productive)

Sample EC 2: ~61 m north of the wharf at Elliott's Cove. (very productive)

Sample EC 1: from the first outcrop beyond the shed on the beach. (very productive)

Sample E-C 9: from a small (~1 m high) outcrop ~100 m north of the wharf at Elliott's Cove. This is the northernmost outcrop of the Elliott's Cove section s.s.

Four samples were taken from coastal outcrops north of

the cable crossing and south of Pt. XV.

Sample E-C 8: from the first outcrop north of the cable crossing. (very productive)

Sample E-C 7-8: approximately halfway between E-C 8 and E-C 7. (very productive)

Sample E-C 7: at Pt. XIV. (very productive)

Sample E-C 6: north of the foot of a broad cove between Pt. XIV and Pt. XV. (very productive)

The next sample north of E-C 6, just south of Pt. XV, is from a part of the section that is repeated by folding or faulting. This marks the northern limit of the area included in the present study.

APPENDIX TWO

ACRITARCH PROCESSING TECHNIQUES

The microfossil processing techniques used in this study are based, in part, on techniques used at the University of Sheffield, England; the procedures used there were communicated to Professor M. M. Anderson and the author by K. J. Dorning and P. Shephard of that university, and this information was added to during a four month period of study by the author at the University of Sheffield under the guidance of Professor C. Downie. Additional information and clarification of certain procedural problems was provided by the following works:

(1) 'Preparation techniques for acid-insoluble microfossils' (Funkhouser and Evitt 1959)

(2) 'Palynological techniques for sediments' (Staplin, Pocock, Jansonius, and Oliphant 1960)

(3) 'Palynology and nannofossil processing techniques' (Barss and Williams 1973)

(4) 'A mounting medium for palynological residues' (Barss and Crilley 1976)

(5) 'Late Precambrian microfossils from the Visingso Beds in Southern Sweden' (Vidal 1976)

(6) 'Extraction techniques' (Gray 1965)

The following procedure was adopted in preparing the Random Island material for acritarch study.

Step 1. Mechanical cleaning prior to acid treatment.

The sample to be treated was first thoroughly washed in

tap water. The soft shales or silty shales used in the Random Island study, all with high fissility, could be extracted easily from outcrops and the least weathered and cleanest material chosen. Further cleaning with a steel brush and/or a tooth-brush was carried out on some of the less clean siltier samples. The softer shales were not given this treatment as they fall apart when scrubbed.

Step 2. Mechanical breakdown of sample.

Most of the samples were soft enough to break apart by hand. Some of the coarser material had to be broken into smaller pieces using a hammer, and a metal sheet as a crushing surface. Both the hammer head and the sheet were washed between samples. The finer dust-like material was discarded to reduce the danger of contamination. The fragments used were generally thin flakes from 2 to 4 cm in diameter. Approximately 20 gm of this material were placed in a 600 ml polymethylpentene beaker and washed several times in tap water to ensure that it was completely free of dust or clay. Distilled water was originally used at this stage, and in subsequent stages. However, on the advice of the technical personnel at the University of Sheffield, tap water was eventually substituted for the distilled water because contamination by recent organisms is easily detected when working with Cambrian - Tremadoc acritarchs.

Step 3. Nitric acid treatment to loosen recent contamination.

Concentrated nitric acid was added to a beaker to cover the sample. A plastic petri dish lid was placed over the

beaker, and the sample left overnight. The nitric acid dislodges any remaining recent contamination and probably destroys some of these recent organisms by over-oxidation. (This step must be omitted if sulphides are present in high enough concentration to cause a violent reaction with the acid. The latter can break up the rock fragments in a few seconds and expose the palynomorphs to the oxidizing action of concentrated nitic acid heated up by the energy released during the reaction.) The next day the nitric acid was poured off, and the sample washed three times, by decantation, with tap water. At that stage the rock fragments are still intact so it was not necessary to wait for a residue to settle between decantations.

Step 4. Hydrochloric acid treatment to remove carbonates.

The sample in the beaker was covered with hydrochloric acid and then left overnight. The next day the acid was decanted. Most of the samples were found to contain very little or no carbonate, and as they did not break down, they were simply washed several times with water in the usual way. In those few cases where some disaggregation was evident, the residue was allowed to settle for a minimum of one hour between decantations.

Step 5. Hydrofluoric acid treatment to remove silica.

200-300 ml of concentrated (40%) hydrofluoric acid were gradually added to the sample in ~50 ml portions. (55% hydrofluoric acid was used on some samples, but this stronger acid usually caused too violent a reaction, so its usage was discontinued.) After the first acid had been added, the sample

was left uncovered and observed for several minutes to see how strong a reaction would occur. The remainder of the acid was added in stages if no extreme reaction occurred, or after such a reaction had taken place and subsided. Once the fumes had died down, the beaker was covered. (Care must be taken not to cover the beaker too soon as the heat from the breakdown process can melt the plastic cover.) After the first day, the sample was stirred once or twice daily. No water bath was available, so the hydrofluoric treatment was carried out at room temperature over a period of one to two weeks. Fresh acid was added to any sample not almost completely broken down after the first four or five days. Occasionally, acid had to be added a third time. After the sample had been completely broken down, as much of the acid as possible was decanted. The beaker was then filled with water, the contents stirred, and the residue left to settle overnight. Thereafter, each sample was decanted daily, sometimes twice daily if settling permitted, until a pH of 6 (the normal pH of the tap water) was reached. A centrifuge was not used for settling palynomorphs because, during centrifuging, the processes and veils of the more delicate acritarchs could possibly be damaged.

Step 6. Hydrochloric acid treatment to remove fluorides.

About 200 ml of concentrated hydrochloric acid was added to the residue in a glass beaker and it was then heated to just below boiling point and maintained at that temperature for approximately 20 minutes to remove any fluorides that may have formed during the hydrofluoric acid treatment. The acid was left to cool and, after the residue had settled, decanted.

The remaining acid was entirely removed by washing the residue several times, by decantation, with water; sufficient time was allowed between decantations for the residue to settle.

Step 7. Filtering to remove fine debris.

The residues from the original suite of samples collected were filtered through a sintered glass funnel (no. 3 porosity) mounted in a suction flask. This funnel retains palynomorphs down to 5 μm in diameter. Samples collected later (for determining the extent of certain zones) were filtered only through the 10 μm and 20 μm nylon sieves, with the < 10 μm fraction of the residue being saved for future examination.

The residue was poured into the sintered glass funnel. If there was a large amount of residue, it was added in stages. After most of the liquid had passed through the filter, a jet of water from a squeeze bottle was sprayed in an irregular pattern onto the organic material left on the filter to force fine debris through the funnel. If the funnel became clogged, water was added to cover the palynomorphs and suction was reversed by means of a Higginson 'blow-suck' ball attached to the side arm of the flask. This action will blow clear any material blocking the funnel. This method was also used to free the palynomorphs from the sintered plate when removing them from the funnel.

Some samples required oxidation or the use of dispersing agents at this stage. Most of the middle Upper Cambrian to Tremadoc samples did not require oxidation either to remove unwanted organic matter or to lighten dark fossils. These samples were then separated into three size fractions - (1) 5

μm to 10 μm, (2) 10 μm to 20 μm, and (3) > 20 μm - by filtering through 10 μm and 20 μm nylon sieves respectively (the sieves being mounted in plastic holders). Palynomorphs were removed from the sieves with a pipette and placed in labelled vials. Samples that required oxidation or the action of a dispersing agent were retained in the sintered funnel for further treatment.

Step 8. Oxidation to destroy fine organic debris and/or to lighten fossils.

Samples that required bleaching were treated with dilute or concentrated nitric acid for several minutes or several hours, depending on the degree of oxidation required. Each sample was checked under the microscope at intervals to determine the progress of the bleaching. The acid was retained in the funnel by applying a clamp to the rubber hose of the suction flask. When the oxidation had reached the desired stage, the clamp was removed, allowing the acid to pass through, and the residue was washed with water several times to stop the oxidation process. The oxidized residue was then separated into size fractions as above and stored.

Concentrating the palynomorphs in many of the Middle Cambrian and lowermost Upper Cambrian samples proved to be difficult or, in some cases, impossible. The density of organic debris was so high that it masked any palynomorphs that might have been present. Thus, the degree of oxidation of acritarchs in such samples, if indeed any were present, could not be checked. As Lower Paleozoic acritarchs are generally fairly resistant to oxidation, such samples were treated with increasingly strong oxidants in an attempt to

break down the organic debris. Concentrated nitric acid, Schulze solution, and even fuming nitric acid were used on some of the samples. At intervals the residue was treated with base (5% potassium carbonate) for 2 or 2 minutes and then neutralized, and rechecked under the microscope. For some of these difficult samples, a dispersing agent, such as alconox or sodium carbonate was added to the funnel for several minutes in an effort to disaggregate some of the clumps of fine material and get them to pass through the filter. If the dispersing agent alone had no effect on the sample, the mixture was subjected to ultrasonic treatment. Even the more extreme measures were rarely successful in breaking down the debris.

Step 9. Preparation of slides.

None of the samples prepared for the present study had enough mineral debris present in the residues to warrant heavy liquid separation of the organic and inorganic fractions in zinc bromide. The next step was the preparation of permanent slides from those samples which contained observable palynomorphs. Several slides were made of each of the three size fractions, and one of the > 5 μm fraction from the first filtration. For each size fraction, several drops of residue in a vial were diluted with water to the desired concentration and two drops of 2 % cellosize (prepared according to the procedure of Barss and Williams 1973) added. The mixture was shaken and pipetted onto coverslips (no. 0) on a slide warmer set at 35 - 40 degrees Centigrade. When the water had evaporated from the residue, the slide warmer was set to 100 degrees Centigrade. A drop of light Canada balsam was then

placed on several labelled slides, and each coverslip in turn was lowered onto a slide using a disecting probe to ease it down gradually so as to trap as little air as possible. After the slide had set, it was removed from the slide warmer and cleaned with a backed razor blade, or methanol to dissolve any excess balsam.

Step 10. Cleaning of equipment.

Plastic and glass equipment was cleaned using fresh chromic acid. The nylon screens were decontaminated by gently scrubbing them with powdered alconox and placing them in an alconox solution in an ultrasonic bath for 5 to 10 minutes. The ultrasonic treatment destroys any palynomorphs present. The alconox was removed from the screens by washing them in tap water.

APPENDIX THREE

GLOSSARY OF ACRITARCH TERMINOLOGY

acuminate: "pointed distal termination of the process" (Kjellström 1971, p.12)

archaeopyle: "an excystment aperture in the wall of a dinoflagellate cyst" (Evitt 1967, p.6)

bifurcate: "process split in the distal end into two tips" (Kjellström 1971, p.14)

capitate: "applied to processes which are dilated at their distal extremities" (Lister 1970b, p.24)

central body: "the compact central portion of a test from which the projecting structures (processes, septa, etc.) extend" (Evitt 1963a, p.161)

central capsule: "that part of the cyst formed by the inner wall of the vesicle. The term is used only when the inner and outer wall are in a non-appressed condition." (Lister 1970b, p.24)

clavate: club-shaped (sculpture)

costate: "parallel, narrow elongate ridges with wide interridge areas" (Tappan and Loeblich 1971, p.387)

crest: "raised ridge (also termed "list" or "septum") following a suture in motile dinoflagellates or a field border in cysts" (Williams, Sarjeant, and Kidson 1973, p.40)

cryptosuture: "suture possessing no visible surface manifestation on the cyst. The position of a cryptosuture only becomes evident when dehiscence has commenced" (Lister 1970b, p.24)

cyst: "the spore or resting stage of a unicellular algal organism; cyst nature is indicated by the presence of an excystment suture" (Lister 1970b, p.24)

dehiscence: "used specifically to express the phenomena of 'opening' or 'parting' along a suture. When excystment is by cryptosuture, the amount of dehiscence may be expressed as a percentage of the vesicle width. " (Lister 1970b, p.24)

digitate: finger-like (processes)

echinate: "ornamentation of small hollow spines formed as outgrowths of the process or vesicle wall and not exceeding 2 um in length" (Lister 1970b, p.25)

epicyst: "that part of an acritarch cyst containing the excystment opening and anterior to the equator, corresponding to epitract of dinoflagellates" (Lister 1970b, p.25)

epityche: "an outfolded flap formed by an elongate sub-marginal slit in the vesicle wall" (Loeblich and Tappan 1969, p.45)

evexate: "non-pointed distal termination of the process" (Kjellström 1971, p.14)

excystment opening (apeture): "opening in the epicyst produced as pylome, partial rupture, median split, or epityche" (Kjellström 1971, p.14)

flagelliforme: curved, slender (process) (Kjellström 1971, p.12)

flange (same as wing): "membranous expansion of the phragma of a dinoflagellate cyst or the test of an acritarch, usually broad, flat, and of small thickness" (Williams, Sarjeant, and Kidson 1973, p.179)

furcate: forked

glabrous: "tiny granules scattered over the surface" (Tappan and Loeblich 1971, p.387)

gonal: at the point of intersection of three or more sutures

granulate: "wall with granules less than 0.5 um in diameter" (Kjellström 1971, p.14)

hemimorphic: a different type of processes and/or sculpture at each pole

heteromorphic: "describes processes that exhibit variation in a single cyst. Simple heteromorphic - all processes branching; compound heteromorphic - some processes not branching." (Lister 1970b, p.25)

holomorphic: "processes and/or sculpture of an identical type present at both poles" (Cramer 1970, p.42)

homomorphic: "the opposite condition to heteromorphic; the processes are more or less of a constant character in a single cyst" (Lister 1970b, p.25)

hypocyst: "that part of an acritarch cyst posterior to the equator and comprising the post-equatorial and antapical plates; corresponds to the hypotract of dinoflagellates" (Lister 1970b, p.25)

inner body: "in two-layered acritarchs, the inner wall plus the vesicle cavity (Lister 1970b, p.25)

intergonal: between sutural junctions

manate: "pinnae are situated principally on the distal part of the processes although some of them are also found at the levels of the morphographically lowest part of the stem. The pinnae of the distal portion of the processes have a configuration similar to the fingers of a hand when they are together." (Trans. of Cramer and Díez 1968,

p.552)

multifurcate: "having more than four branches of variable relative length arising from one node" (Sarjeant 1982, p.943)

murus: "low ridges separating the lumina of an ordinary reticulum" (Erdtman 1943, p.51)

nebula: amorphous mass of spongy, generally granular material surrounding the vesicle. It may show some irregular, radially arranged fibres

operculum: "the part of the epicyst, loss of which results in the formation of the excystment aperture. In tabulate cysts the operculum may consist of one or more plates" (Lister 1970b, p.25)

phragma: "the wall of a dinoflagellate cyst; it can be composed of one, two, or more than two layers" (Williams, Sarjeant, and Kidson 1973, p.111)

pinna: "the undivided perpendicular portion of the process is called 'stem', its first order branches are called 'pinnae' " (Cramer 1970, p.37)

pinnula: "the first branches of the pinnae are called 'pinnulae of the first order' " (Cramer 1970, p.37)

process: "excresence of the vesicle formed as an appendage" (Kjellström 1971, p.15)

psilate: "smooth wall without any structure" (Kjellström 1971, p.15)

punctate: "scattered shallow pits" (Tappan and Loeblich 1971, p.387)

pylome: "Two contrasting but not fundamentally different pylome types may be distinguished: (i) a system consisting of a (sub)circular pylome with a corresponding operculum;

(ii) a characteristic and preferential splitting of the central portion of the vesicle wall. (Cramer 1970, p.40)

ramification: branching, or, a branch

ramusculose: having many branches

regular symmetry: "symmetry in the distribution of processes and/or sculpture on an acritarch where there is no apparent topical preference for any one place of the central body, i.e., the processes or sculpture is not clearly concentrated at the poles, equator, etc." (Eisenack, Cramer, and Díez 1973, p.17).

reticulation: "usually raised surface markings, generally linear, forming a crosshatched appearance on the theca, but not permanently continuous from plate to plate." (Steidinger and Williams 1970, p.14)

rugulate: "fine, irregularly wrinkled surface" (Tappan and Loeblich 1971, p.387)

scabrate: "surface texture of outer wall resulting from the presence of numerus closely spaced linear markings about 2 um in length" (Lister 1970b, p.26)

shell: "the whole of the cyst including vesicle and processes" (Lister 1970b, p.26)

shagrinate (chagrinate): "leather-like wall ornamentation" (Kjellström 1971, p.15)

simple process: "non-furcate distal terminated process" (Kjellström 1971, p.15)

test: synonym of shell

trifurcate: "process split in the distal end into three parts" (Kjellström 1971, p.15)

tubercle: "small knob-like projection, oblate distally, rarely exceeding 3-4 um" (Lentin and Williams 1976, p.176)

veil (used in a restricted sense here to refer to): membrane oriented more or less perpendicular to the surface of the central body; often it is supported by processes or thickenings

vesicle: synonym of central body

vesicle cavity: "space enclosed by vesicle wall" (Lister 1970b, p.26)

wall: "organic layer surrounding the vesicle and process cavities and constituting in this way the skeletal material of both vesicle and process. May be divided into inner and outer walls." (Lister 1970b, p.26)

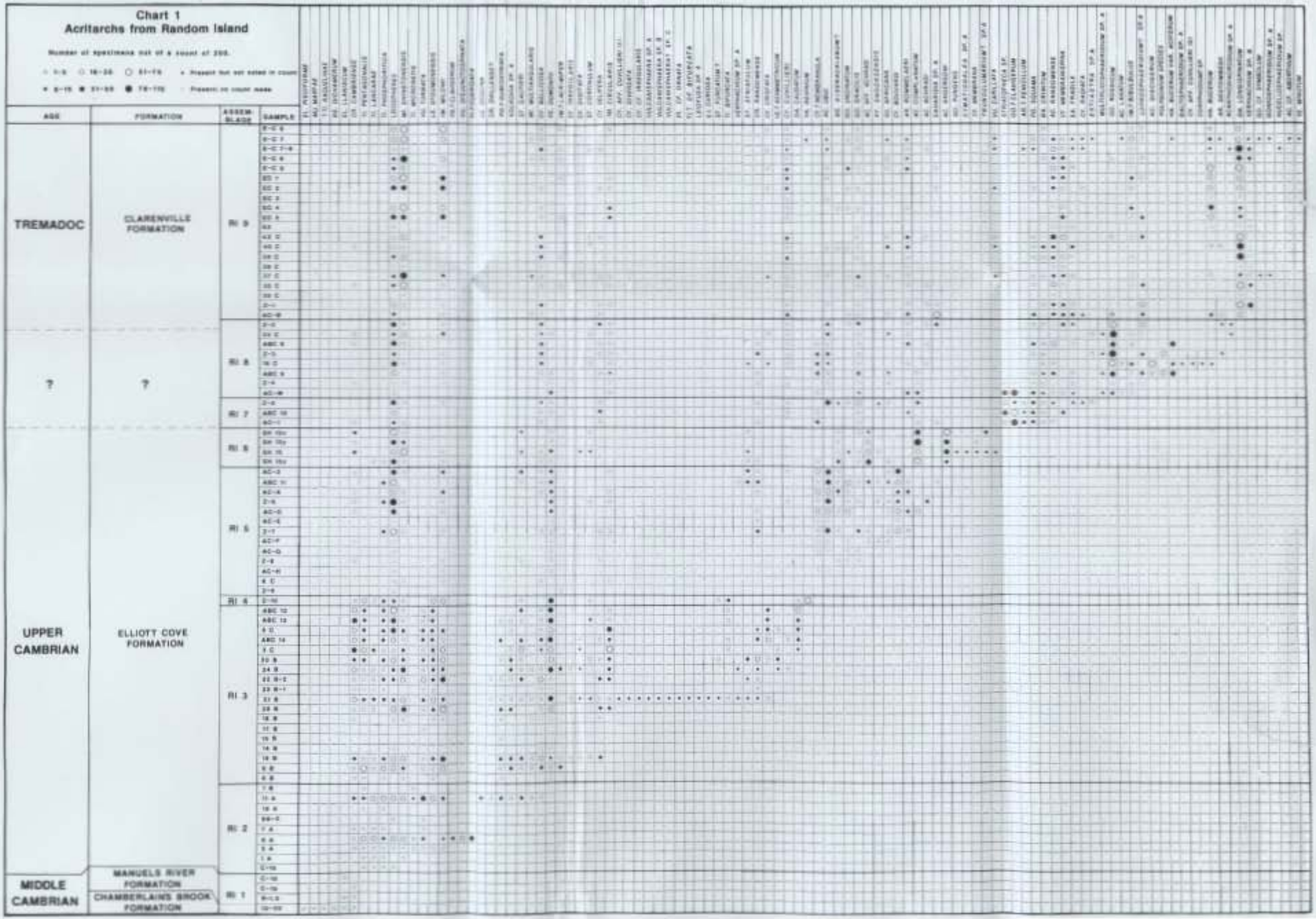
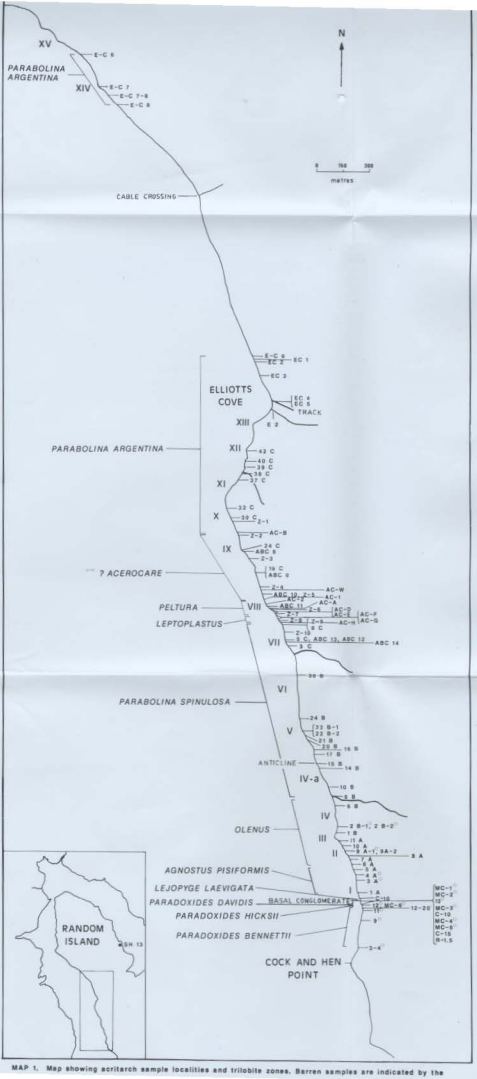


Chart 1
Acritarchs from Random Island
Number of specimens out of a count of 200.
AGE
FORMATION
ASSEMBLAGE
SAMPLE
TREMADOC
CLARENVILLE FORMATION
RI 9
?
?
RI 8
RI 7
UPPER CAMBRIAN
ELLIOTT COVE FORMATION
RI 6
RI 5
RI 4
RI 3
RI 2
MIDDLE CAMBRIAN
MANUELS RIVER FORMATION
CHAMBERLAINS BROOK FORMATION
RI 1

Chart 2.

Distribution of acritarch species present on Random Island in Middle Cambrian, Upper Cambrian, Tremadoc, and post-Tremadoc strata of other localities.

	MIDDLE CAMBRIAN													UPPER CAMBRIAN						TREMADOC										POST-TREMADOC										
+ Recovered from ?Upper Cambrian/Tremadoc strata.	RANDOM ISLAND	E. NFLD. (EXCLUDING R.I.)	CANADA (MAINLAND)	IRELAND	ENGLAND/WALES	BELGIUM	SPAIN	NORTH AFRICA	TURKEY	CZECHOSLOVAKIA	U.S.S.R	NORWAY	FRANCE	RANDOM ISLAND	CANADA (MAINLAND)	IRELAND	ENGLAND/WALES	BELGIUM	NORWAY	RANDOM ISLAND	E. NFLD. (EXCLUDING R.I.)	CANADA (MAINLAND)	IRELAND	ENGLAND/WALES	BELGIUM	SPAIN	NORTH AFRICA	U.S.S.R	POLAND	NORWAY	FRANCE	ROUMANIA	ARGENTINA	E. NFLD. (EXCLUDING R.I.	ENGLAND/WALES	BELGIUM	SPAIN	NORTH AFRICA	CZECHOSLOVAKIA	U.S.S.R.	FRANCE	ROUMANIA	BULGARIA	SWEDEN
1 (?) Present on Random Island																																								
2 Reported at this level by Martin (in Martin and Dean, 1981) only.																																								
X Present																																								
? Identification of species uncertain or age of strata questionable.																																								
EL. PISCIFORME	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MU. MARTAE	X	—	—	X	?	—	X	X	X	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TI. RAQUELINAE	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
HE. DICHAMERUM	X	X	X	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
EL. LLANISCUM	X	X	—	X	X	—	X	X	X	X	—	cf.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CR. CAMBRIENSE	X	—	—	X	X	X	X	X	X	X	—	X	—	X	—	X	—	X	X	X	X	—	—	X	X	—	X	—	—	X	—	—	—	—	—	—	—	—	—	—
TI. PENTAGONALIS	2X	—	—	—	—	X	X	—	—	X	—	—	X	X	—	X	X	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TI. LANCARAE	2X	—	—	X	—	X	X	X	X	X	X	X	—	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TI. PHOSPHORITICA	2X	—	—	—	—	X	—	—	X	X	X	X	—	X	—	—	X	X	X	—	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MI. SHINETONENSIS	—	—	—	—	—	—	—	—	—	X	—	X	—	X	—	—	X	X	—	X	—	—	X	X	X	X	—	—	—	X	X	—	—	—	X	—	X	—	X	—
TI. MICRORETIS	—	—	—	—	—	—	—	—	—	—	—	cf.	—	X	—	—	—	—	cf.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
VU. TURBATA	2X	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
LE. STOUMONENSIS	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
IM. MILONII	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	—	X	—	—	—	X	—	—	X	—	—	X	—	—	—	—	—	—	—	—	—	—
CY. BELLICOSA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	X	—	—	—	X	—	—	X	—	—	X	—	—	—	—	—	—	—	—	—	—
MI. MULTIANGULARIS	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
CY. OVILLENSE	—	—	—	—	—	—	X	—	X	—	—	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ST. GAUTIERI	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	?	—	2X	—	—	—	X	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—
VE. DUMONTII	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	—	+	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	—
CY. VELIFERA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ST. CORTINULUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	X	X	—	—	X	X	X	X	—	—	—	X	—	—	—	—	?	—	—	X	—
CY. CRISTATA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	cf.	—	—	—	—	X	—	cf.	—	X	X	X	—	—	?	X	X	—	—	—	—	?	—	—	X	—
CY. DIVERSATA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CR. RANDOMENSE	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	X	—	—	—	—	—	—	—	—	?	X	—	—	—	—	—	—	—	—	—	—
ST. STRIATULUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	+	—	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CY. CUVILLIERI	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	X	X	X	X	—	—	—	X	—	X	x	x	x	?	x	—	—
ST. FURCATUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—
DA. CAUDATUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TR. REVINIUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	X	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AC. COMPLANATUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	2X	X	—	—	X	X	—	X	—	—	X	X	—	—	—	—	—	X	—	X	—	—
1GO. EISENACKIANUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	—
GO. GRACILIS	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	?	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
CY.? MEMBRANULA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	+	X	—	—	—	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—
VU. AFRICANA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	X	X	—	—	X	—	X	X	—	X	X	X	—	—	—	—	—	—	—	—	—	—
VU. CAPILLATA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
GO. PUNGENS	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X	X	X	—	—	X	—	—	—	—	—	—	—	—	—	—	—
CY. MEMBRANA	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CY. BOUVARDI	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—
AC. UBUI	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	X	—	—	—	X	—	X	—	—	—	X	X	—	—	—	—	X	?	—	—	—	—
GO. UNCINATUM	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	X	X	—	—	X	X	X	—	—	—	X	X	—	—	X	—	X	?	—	—	X	X
AC. ACHRASI	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	X	—	X	X	—	—	—	—	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—
PO. SQUAMA	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	X	—	—	—	—	?	—	—	—	—	—
BA. CRINITUM	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CY. MEMBRANISPINA	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SA. FRAGILE	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—	X	X	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
OO. ROSSICUM	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	—	—	—	—	X	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
HA. BUCERUM VAR.ACIFERUM	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AC. LANATUM	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
AR. DESTOMBESII	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	X	—	—	X	—	X	—	—	—	X	X	—	—	—	—	—	—	—	—	—	—
HA. BUCERUM	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	X	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—
VE. MINUTUM	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X	—	—	—	—	—	X	—	—	—	—	—	—	—	—	X	—



MAP 1. Map showing acritarch sample localities and trilobite zones. Barren samples are indicated by the